

**FLUKE®**

**Calibration**

**5502A**

Multi-Product Calibrator

Operators Manual

September 2012  
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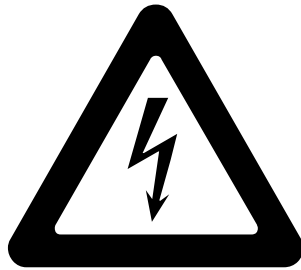
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# OPERATOR SAFETY SUMMARY

## WARNING



## HIGH VOLTAGE

is used in the operation of this equipment

## LETHAL VOLTAGE

may be present on the terminals, observe all safety precautions!

To prevent electrical shock hazard, the operator should not electrically contact the output HI or sense HI terminals or circuits connected to these terminals. During operation, lethal voltages of up to 1020 V ac or dc may be present on these terminals.

When the nature of the operation permits, keep one hand away from equipment to reduce the hazard of current flowing through vital organs of the body.



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# **Chapter 1**

## ***Introduction and Specifications***

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## Introduction

### **⚠⚠ Warning**

**To prevent possible electrical shock, fire, or personal injury, read all safety Information before you use the Product.**

The 5502A Calibrator (“the Product” or “the Calibrator”) in Figure 1-1 can be configured to source:

- DC voltage from 0 V to  $\pm 1020$  V.
- AC voltage from 1 mV to 1020 V, with output from 10 Hz to 500 kHz.
- AC current from 29  $\mu$ A to 20.5 A, with variable frequency limits.
- DC current from 0 to  $\pm 20.5$  A.
- Resistance values from a short circuit to 1100 M $\Omega$ .
- Capacitance values from 220 pF to 110 mF.
- Simulated output for eight types of Resistance Temperature Detectors (RTDs).
- Simulated output for 11 types of thermocouples.

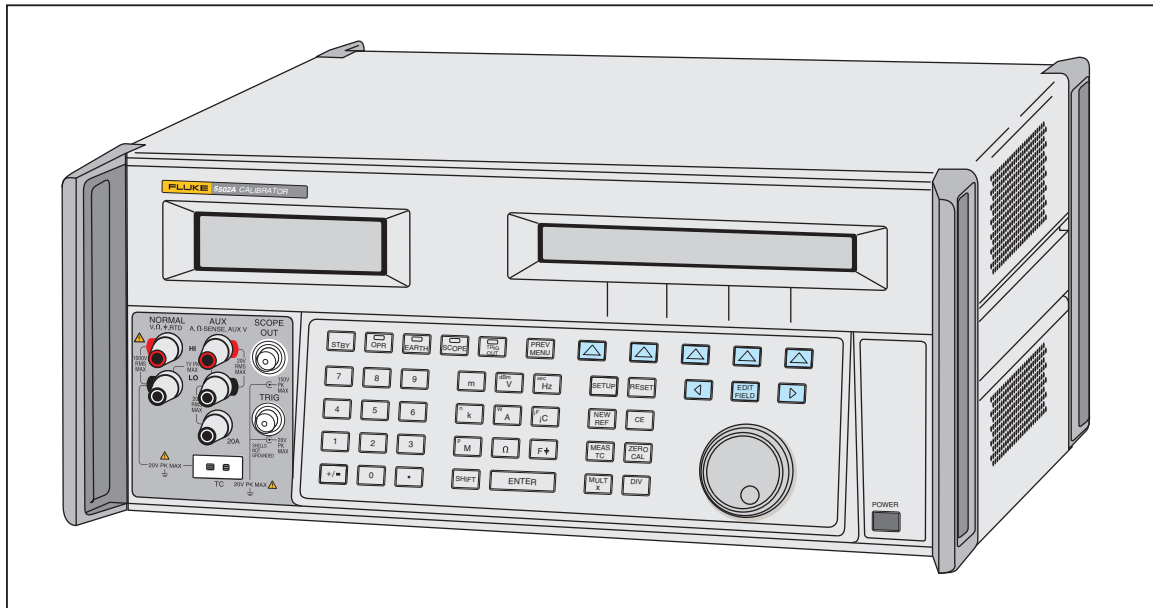


**Figure 1-1. 5502A Multi-Product Calibrator**

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Calibrator features include:

- Automatic meter error calculation, with reference values that you can select.
- **MULT** and **DIV** keys that change the output value to predetermined values for various functions.
- Programmable entry limits. These limits do not let you go above preset output limits.
- Voltage and current that can be output at the same time, to an equivalent of 20.9 kW.
- 10 MHz reference input and output. Use this to input a high-accuracy 10 MHz reference to move the frequency accuracy to the 5502A, or to put one or more Calibrators in the control of a master 5502A.
- The power to output two voltages at the same time.
- Extended bandwidth mode outputs multiple waveforms down to 0.01 Hz, and sine

waves to 2 MHz.

- A Standard IEEE-488 (GPIB) interface that complies with ANSI/IEEE Standards 488.1-1987 and 488.2-1987.
- A EIA Standard RS-232 serial data interface to print, show, or move internally stored calibration constants, and for remote control of the 5502A.
- A pass-through RS-232 serial data interface to send data to the Unit Under Test (UUT).

## Safety Information

In this manual, A **Warning** identifies conditions and procedures that are dangerous to the user. A **Caution** identifies conditions and procedures that can cause damage to the Product or the equipment under test.

### Warning

To prevent possible electrical shock, fire, or personal injury:

- Use the Product only as specified, or the protection supplied by the Product can be compromised.
- Carefully read all instructions.
- Do not use the Product around explosive gas, vapor, or in damp or wet environments.
- Use this Product indoors only.
- Do not touch voltages > 30 V ac rms, 42 V ac peak, or 60 V dc.
- Do not use the Product if it operates incorrectly.
- Do not use and disable the Product if it is damaged.
- Do not use test leads if they are damaged. Examine the test leads for damaged insulation, exposed metal, or if the wear indicator shows. Check test lead continuity.
- Use only cables with correct voltage ratings.
- Connect the common test lead before the live test lead and remove the live test lead before the common test lead.
- Use only the mains power cord and connector approved for the voltage and plug configuration in your country and rated for the Product.
- Make sure the ground conductor in the mains power cord is connected to a protective earth ground. Disruption of the protective earth could put voltage on the chassis that could cause death.

- **Replace the mains power cord if the insulation is damaged or if the insulation shows signs of wear.**
- **Do not connect directly to mains.**
- **Do not use an extension cord or adapter plug.**
- **For safe operation and maintenance of the Product, make sure that the space around the Product meets minimum requirements.**

This Calibrator complies with:

- ANSI/ISA-61010-1 (82.02.01)
- CAN/CSA C22.2 No. 61010-1-04
- ANSI/UL 61010-1:2004
- EN 61010-1:2001
- ANSI/IEEE Standards 488.1-1987 and 488.2-1987.

Symbols used in this manual and on the Product are in Table 1-1.

**Table 1-1. Symbols**

| Symbol                                                                              | Description                                                                                                                                                 | Symbol                                                                              | Description                                                                                                                |
|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| CAT I                                                                               | IEC Measurement Category I – CAT I is for measurements not directly connected to mains. Maximum transient Overvoltage is as specified by terminal markings. |  | Conforms to relevant North American Safety Standards.                                                                      |
| CE                                                                                  | Conforms to European Union directives.                                                                                                                      |  | Do not dispose of this product as unsorted municipal waste. Go to the Fluke Calibration website for recycling information. |
|  | Risk of Danger. Important information. See manual.                                                                                                          |  | Hazardous voltage                                                                                                          |
|  | Earth ground                                                                                                                                                |  | Conforms to relevant Australian EMC requirements.                                                                          |

## **Overload Protection**

The Calibrator supplies reverse-power protection, fast output disconnection, and/or fuse protection on the output terminals for all functions.

Reverse-power protection prevents damage to the calibrator from occasional, accidental, normal-mode, and common-mode overloads to a maximum of  $\pm 300$  V peak. It is not intended as protection against frequent (systematic and repeated) abuse. Such abuse will cause the Calibrator to fail.

For volts, ohms, capacitance, and thermocouple functions, there is fast output disconnection protection. This protection senses applied voltages higher than 20 volts on the output terminals. It quickly disconnects the internal circuits from the output terminals and resets the calibrator when such overloads occur.

For current and aux voltage functions, user replaceable fuses supply protection from overloads applied to the Current/Aux Voltage output terminals. The fuses are accessed by an access door on the bottom of the calibrator. You must use replacement fuses of the same rating and type specified in this manual, or the protection supplied by the Calibrator will be compromised.

## **Operation Overview**

The Calibrator can be operated at the front panel or remotely with the RS-232 or IEEE-488 ports. For remote operations, software is available to integrate 5502A operation into a wide variety of calibration requirements.

### **Local Operation**

Typical local operations include front-panel connections to the UUT, and then manual keystroke entries at the front panel to put the Calibrator in the necessary output mode.

 and  make it easy to step up or down at the push of a key. You can also examine Calibrator specifications at the push of two buttons. The backlit LCD is easy to read from many different angles and can be read in dim or bright light. The large, easy-to-read keys are color-coded and give tactile feedback.

### **Remote Operation (RS-232)**

There are two rear-panel serial data RS-232 ports: SERIAL 1 FROM HOST, and SERIAL 2 TO UUT (see Figure 1-2). Each port is dedicated to serial-data communications to operate and control the Product during calibration procedures. For complete information on remote operation, see Chapter 5.

The SERIAL 1 FROM HOST serial data port connects a host terminal or personal computer (PC) to the Calibrator. To send commands to the Calibrator: enter commands from a terminal (or a PC running a terminal program), write your own procedures with BASIC, or use optional Windows-based software such as MET/CAL Plus.

The SERIAL 2 TO UUT serial data port connects a UUT to a PC or terminal with the 5502A (see Figure 1-2). This “pass-through” configuration removes the requirement for two COM ports at the PC or terminal. A set of four commands control the operation of the SERIAL 2 TO UUT serial port. See Chapter 6 for a discussion of the UUT\_ commands.

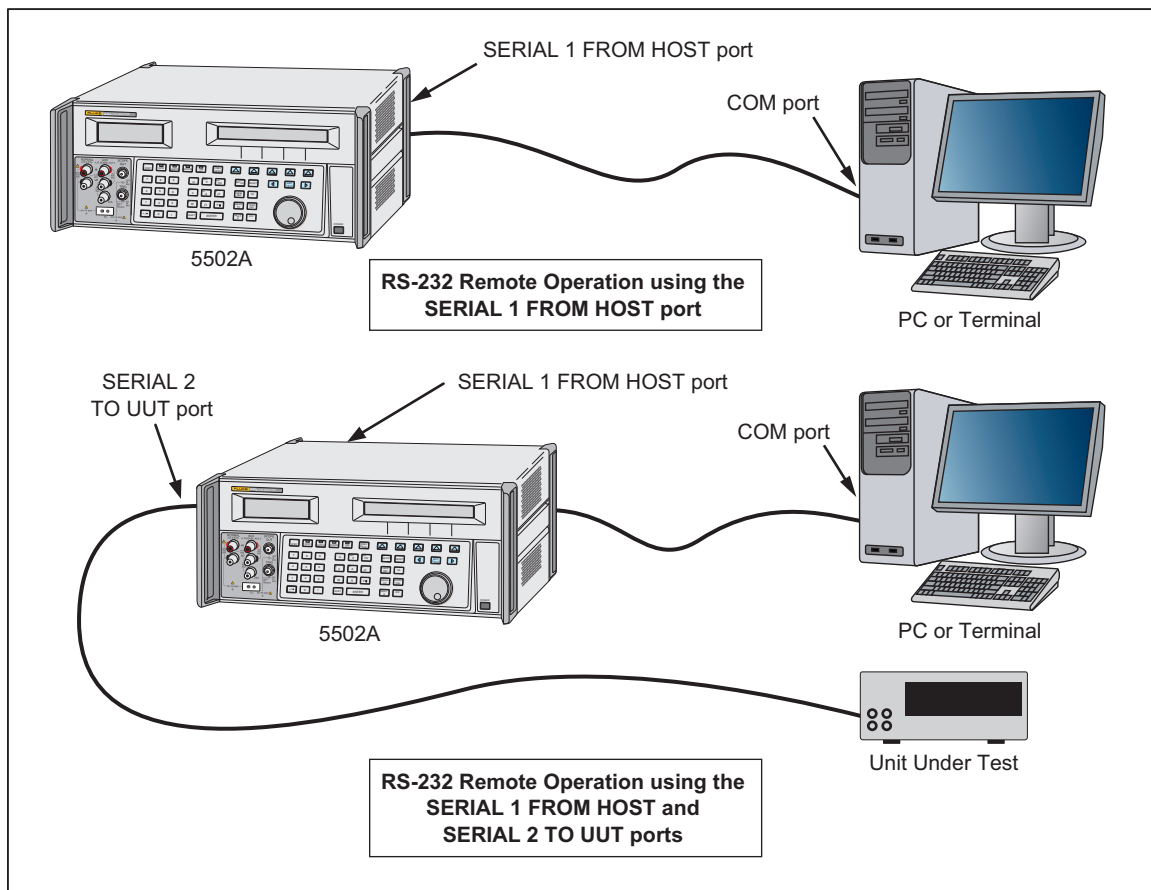


Figure 1-2. RS-232 Remote Connection

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### Remote Operation (IEEE-488)

The rear-panel IEEE-488 port is a fully programmable parallel interface bus that complies with standard IEEE-488.1 and supplemental standard IEEE-488.2. When the Calibrator is used by remote control of an instrument controller, the Calibrator operates exclusively as a “talker/listener.” You can write your own programs with the IEEE-488 command set or run the optional Windows-based MET/CAL Plus software. See Chapter 6 for a discussion of the commands available for IEEE-488 operation.

## **Instruction Manuals**

The 5502A Manual Set includes:

- *5502A Operators Manual* on included CD-ROM (PN 4155227)
- *5502A Getting Started* (PN 4155209)

One of each manual above comes with the instrument. Refer to the Fluke Calibration Catalog or speak to a Fluke Calibration sales representative (see “Contact Fluke Calibration” in this chapter) if more printed copies are necessary. The manuals are also available on the Fluke Calibration website.

### **5502A Getting Started Manual**

The *5502A Getting Started Manual* contains a brief introduction to the 5502A Manual Set, instructions on how to get your calibrator prepared for operation and a complete set of specifications.

### **5502A Operators Manual**

This *5502A Operators Manual* supplies complete information to install the Calibrator and operate it from the front-panel keys and in remote configurations. The manual also has a glossary of calibration, specifications, and error-code information. The Operators Manual includes:

- Installation
- Controls and features, front-panel operation
- Remote operation (IEEE-488 bus or serial port remote control)
- Serial port operation (print, show, or transfer data, and setup for serial port remote control)
- Operator maintenance, with verification and calibration procedures
- Accessories
- SC600 and SC300 oscilloscope calibration options

## **Contact Fluke Calibration**

To contact Fluke Calibration, call one of the following telephone numbers:

- Technical Support USA: 1-877-355-3225
- Calibration/Repair USA: 1-877-355-3225
- Canada: 1-800-36-FLUKE (1-800-363-5853)
- Europe: +31-40-2675-200
- Japan: +81-3-6714-3114
- Singapore: +65-6799-5566
- China: +86-400-810-3435
- Brazil: +55-11-3759-7600
- Anywhere in the world: +1-425-446-6110

To see product information and download the latest manual supplements, visit Fluke Calibration’s website at [www.flukecal.com](http://www.flukecal.com).

To register your product, visit <http://flukecal.com/register-product>.



## Specifications

### General Specifications

The following tables list the 5502A specifications. All specifications are valid after allowing a warm-up period of 30 minutes, or twice the time the 5502A has been turned off. (For example, if the 5502A has been turned off for 5 minutes, the warm-up period is 10 minutes.)

All specifications apply for the temperature and time period indicated. For temperatures outside of  $\pm 5^{\circ}\text{C}$  ( $t_{\text{cal}}$  is the ambient temperature when the 5502A was calibrated), the temperature coefficient as stated in the General Specifications must be applied.

The specifications also assume the Calibrator is zeroed every seven days or whenever the ambient temperature changes more than  $5^{\circ}\text{C}$ . The tightest ohms specifications are maintained with a zero cal every 12 hours within  $\pm 1^{\circ}\text{C}$  of use.

Also see additional specifications later in this chapter for information on extended specifications for ac voltage and current.

|                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Warmup Time</b> .....                                    | Twice the time since last warmed up, to a maximum of 30 minutes.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Settling Time</b> .....                                  | Less than 5 seconds for all functions and ranges except as noted.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Standard Interfaces</b> .....                            | IEEE-488 (GPIB), RS-232                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Temperature</b>                                          |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Operating .....                                             | $0^{\circ}\text{C}$ to $50^{\circ}\text{C}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Calibration ( $t_{\text{cal}}$ ) .....                      | $15^{\circ}\text{C}$ to $35^{\circ}\text{C}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Storage .....                                               | $-20^{\circ}\text{C}$ to $+70^{\circ}\text{C}$ ; The DC current ranges 0 to 1.09999 A and 1.1 A to 2.99999 A are sensitive to storage temperatures above $50^{\circ}\text{C}$ . If the 5502A is stored above $50^{\circ}\text{C}$ for greater than 30 minutes, these ranges must be re-calibrated. Otherwise, the 90 day and 1 year uncertainties of these ranges double.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Temperature Coefficient</b> .....                        | Temperature coefficient for temperatures outside of $\pm 5^{\circ}\text{C}$ is 10 % of the stated specification per $^{\circ}\text{C}$ .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Relative Humidity</b>                                    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Operating .....                                             | $<80\%$ to $30^{\circ}\text{C}$ , $<70\%$ to $40^{\circ}\text{C}$ , $<40\%$ to $50^{\circ}\text{C}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Storage .....                                               | $<95\%$ , non-condensing. After long periods of storage at high humidity, a drying-out period (with power on) of at least one week may be required.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Altitude</b>                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Operating .....                                             | 3,050 m (10,000 ft) maximum                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Non-operating .....                                         | 12,200 m (40,000 ft) maximum                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Safety</b> .....                                         | Complies with EN/IEC 61010-1:2001, CAN/CSA-C22.2 No. 61010-1-04, ANSI/UL 61010-1:2004;                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Output Terminal Electrical Overload Protection</b> ..... | Provides reverse-power protection, immediate output disconnection, and/or fuse protection on the output terminals for all functions. This protection is for applied external voltages up to $\pm 300\text{ V}$ peak.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Analog Load Isolation</b> .....                          | 20 V normal operation, 400 V peak transient                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>EMC</b> .....                                            | Complies with EN/IEC 61326-1:2006, EN/IEC 61326-2-1:2006 for controlled EM environments under the following conditions. If used in areas with Electromagnetic fields of 1 to 3 V/m from 0.08-1GHz, resistance outputs have a floor adder of $0.508\ \Omega$ Performance not specified above 3 V/m. This instrument may be susceptible to electro-static discharge (ESD) to the binding posts. Good static awareness practices should be followed when handling this and other pieces of electronic equipment. Additionally this instrument may be susceptible to electrical fast transients on the mains terminals. If any disturbances in operation are observed, it is recommended that the rear panel chassis ground terminal be connected to a known good earth ground with a low inductance ground strap. Note that a mains power outlet while providing a suitable ground for protection against electric shock hazard may not provide an adequate ground to properly drain away conducted rf disturbances and may in fact be the source of the disturbance. This instrument was certified for EMC performance with data I/O cables not in excess of 3m. |
| <b>Line Power</b> .....                                     | Line Voltage (selectable): 100 V, 120 V, 220 V, 240 V<br>Line Frequency: 47 Hz to 63 Hz<br>Line Voltage Variation: $\pm 10\%$ about line voltage setting. For optimal performance at full dual                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

outputs (e.g. 1000 V, 20 A) choose a ling voltage setting that is  $\pm 7.5\%$  from nominal.

|                                              |                                                                                                                                                                                                                                                                                                       |
|----------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Power Consumption</b> .....               | 600 VA                                                                                                                                                                                                                                                                                                |
| <b>Dimensions (HxWxL)</b> .....              | 17.8 cm x 43.2 cm x 47.3 cm (7 in x 17 in x 18.6 in) Standard rack width and rack increment, plus 1.5 cm (0.6 in) for feet on bottom of unit.                                                                                                                                                         |
| <b>Weight (without options)</b> .....        | 22 kg (49 lb)                                                                                                                                                                                                                                                                                         |
| <b>Absolute Uncertainty Definition</b> ..... | The 5502A specifications include stability, temperature coefficient, linearity, line and load regulation, and the traceability of the external standards used for calibration. You do not need to add anything to determine the total specification of the 5502A for the temperature range indicated. |
| <b>Specification Confidence Level</b> .....  | 99 %                                                                                                                                                                                                                                                                                                  |

## Detailed Specifications

### DC Voltage

| Range                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Absolute Uncertainty, tcal $\pm 5^\circ\text{C}$<br>$\pm(\%$ of output + $\mu\text{V}$ ) |               | Stability                                                                    | Resolution ( $\mu\text{V}$ ) | Max Burden <sup>[1]</sup> |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|---------------|------------------------------------------------------------------------------|------------------------------|---------------------------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 90 Day                                                                                   | 1 Year        | 24 hours, $\pm 1^\circ\text{C}$<br>$\pm(\text{ppm of output} + \mu\text{V})$ |                              |                           |
| 0 to 329.9999 mV                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0.005 + 3                                                                                | 0.006 + 3     | 5 + 1                                                                        | 0.1                          | 65 $\Omega$               |
| 0 to 3.299999 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 0.004 + 5                                                                                | 0.005 + 5     | 4 + 3                                                                        | 1                            | 10 mA                     |
| 0 to 32.99999 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 0.004 + 50                                                                               | 0.005 + 50    | 4 + 30                                                                       | 10                           | 10 mA                     |
| 30 to 329.9999 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 0.0045 + 500                                                                             | 0.0055 + 500  | 4.5 + 300                                                                    | 100                          | 5 mA                      |
| 100 to 1020.000 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 0.0045 + 1500                                                                            | 0.0055 + 1500 | 4.5 + 900                                                                    | 1000                         | 5 mA                      |
| <b>Auxiliary Output (dual output mode only) <sup>[2]</sup></b>                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                          |               |                                                                              |                              |                           |
| 0 to 329.999 mV                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 0.03 + 350                                                                               | 0.04 + 350    | 30 + 100                                                                     | 1                            | 5 mA                      |
| 0.33 to 3.29999 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 0.03 + 350                                                                               | 0.04 + 350    | 30 + 100                                                                     | 10                           | 5 mA                      |
| 3.3 to 7 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 0.03 + 350                                                                               | 0.04 + 350    | 30 + 100                                                                     | 100                          | 5 mA                      |
| <b>TC Simulate and Measure in Linear 10 <math>\mu\text{V}/^\circ\text{C}</math> and 1 <math>\text{mV}/^\circ\text{C}</math> modes <sup>[3]</sup></b>                                                                                                                                                                                                                                                                                                                                                 |                                                                                          |               |                                                                              |                              |                           |
| 0 to 329.999 mV                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 0.005 + 3                                                                                | 0.006 + 3     | 5 + 1                                                                        | 0.1                          | 10 $\Omega$               |
| <p>[1] Remote sensing is not provided. Output resistance is <math>&lt; 5\text{ m}\Omega</math> for outputs <math>\geq 0.33\text{ V}</math>. The AUX output has an output resistance of <math>&lt; 1\text{ }\Omega</math>. TC simulation has an output impedance of <math>10\text{ }\Omega \pm 1\text{ }\Omega</math>.</p> <p>[2] Two channels of dc voltage output are provided.</p> <p>[3] TC simulating and measuring are not specified for operation in electromagnetic fields above 0.4 V/m.</p> |                                                                                          |               |                                                                              |                              |                           |

| Range                                                          | Noise                                                                                       |                               |
|----------------------------------------------------------------|---------------------------------------------------------------------------------------------|-------------------------------|
|                                                                | Bandwidth 0.1 Hz to 10 Hz p-p<br>$\pm(\text{ppm of output} + \text{floor in } \mu\text{V})$ | Bandwidth 10 Hz to 10 kHz rms |
| 0 to 329.9999 mV                                               | 0 + 1                                                                                       | 6 $\mu\text{V}$               |
| 0 to 3.299999 V                                                | 0 + 10                                                                                      | 60 $\mu\text{V}$              |
| 0 to 32.99999 V                                                | 0 + 100                                                                                     | 600 $\mu\text{V}$             |
| 30 to 329.9999 V                                               | 10 + 1000                                                                                   | 20 mV                         |
| 100 to 1020.000 V                                              | 10 + 5000                                                                                   | 20 mV                         |
| <b>Auxiliary Output (dual output mode only) <sup>[1]</sup></b> |                                                                                             |                               |
| 0 to 329.999 mV                                                | 0 + 5 $\mu\text{V}$                                                                         | 20 $\mu\text{V}$              |
| 0.33 to 3.29999 V                                              | 0 + 20 $\mu\text{V}$                                                                        | 300 $\mu\text{V}$             |
| 3.3 to 7 V                                                     | 0 + 100 $\mu\text{V}$                                                                       | 1000 $\mu\text{V}$            |
| [1] Two channels of dc voltage output are provided.            |                                                                                             |                               |

## DC Current

| Range                          | Absolute Uncertainty, $\pm 5^\circ\text{C}$<br>$\pm(\% \text{ of output } + \mu\text{A})$ |                             | Resolution         | Max Compliance<br>Voltage V | Max Inductive<br>Load mH |
|--------------------------------|-------------------------------------------------------------------------------------------|-----------------------------|--------------------|-----------------------------|--------------------------|
|                                | 90 Day                                                                                    | 1 Year                      |                    |                             |                          |
| 0 to 329.999 $\mu\text{A}$     | $0.012 + 0.02$                                                                            | $0.015 + 0.02$              | 1 nA               | 10                          | 400                      |
| 0 to 3.29999 mA                | $0.010 + 0.05$                                                                            | $0.010 + 0.05$              | 0.01 $\mu\text{A}$ | 10                          |                          |
| 0 to 32.9999 mA                | $0.008 + 0.25$                                                                            | $0.010 + 0.25$              | 0.1 $\mu\text{A}$  | 7                           |                          |
| 0 to 329.999 mA                | $0.008 + 3.3$                                                                             | $0.010 + 2.5$               | 1 $\mu\text{A}$    | 7                           |                          |
| 0 to 1.09999 A                 | $0.023 + 44$                                                                              | $0.038 + 44$                | 10 $\mu\text{A}$   | 6                           |                          |
| 1.1 to 2.99999 A               | $0.030 + 44$                                                                              | $0.038 + 44$                | 10 $\mu\text{A}$   | 6                           |                          |
| 0 to 10.9999 A<br>(20 A Range) | $0.038 + 500$                                                                             | $0.060 + 500$               | 100 $\mu\text{A}$  | 4                           |                          |
| 11 to 20.5 A <sup>[1]</sup>    | $0.080 + 750$ <sup>[2]</sup>                                                              | $0.10 + 750$ <sup>[2]</sup> | 100 $\mu\text{A}$  | 4                           |                          |

[1] Duty Cycle: Currents <11 A may be provided continuously. For currents >11 A, see Figure 1-3. The current may be provided Formula  $60 - T - I$  minutes any 60 minute period where T is the temperature in  $^\circ\text{C}$  (room temperature is about  $23^\circ\text{C}$ ) and I is the output current in amperes. For example, 17 A, at  $23^\circ\text{C}$  could be provided for  $60 - 23 - 17 = 20$  minutes each hour. When the 5502A is outputting currents between 5 and 11 amps for long periods, the internal self-heating reduces the duty cycle. Under those conditions, the allowable "on" time indicated by the formula and Figure 1-3 is achieved only after the 5502A is outputting currents <5 A for the "off" period first.

[2] Floor specification is 1500  $\mu\text{A}$  within 30 seconds of selecting operate. For operating times >30 seconds, the floor specification is 750  $\mu\text{A}$ .

| Range                      | Noise                         |                               |
|----------------------------|-------------------------------|-------------------------------|
|                            | Bandwidth 0.1 Hz to 10 Hz p-p | Bandwidth 10 Hz to 10 kHz rms |
| 0 to 329.999 $\mu\text{A}$ | 2 nA                          | 20 nA                         |
| 0 to 3.29999 mA            | 20 nA                         | 200 nA                        |
| 0 to 32.9999 mA            | 200 nA                        | 2.0 $\mu\text{A}$             |
| 0 to 329.999 mA            | 2000 nA                       | 20 $\mu\text{A}$              |
| 0 to 2.99999 A             | 20 $\mu\text{A}$              | 1 mA                          |
| 0 to 20.5 A                | 200 $\mu\text{A}$             | 10 mA                         |

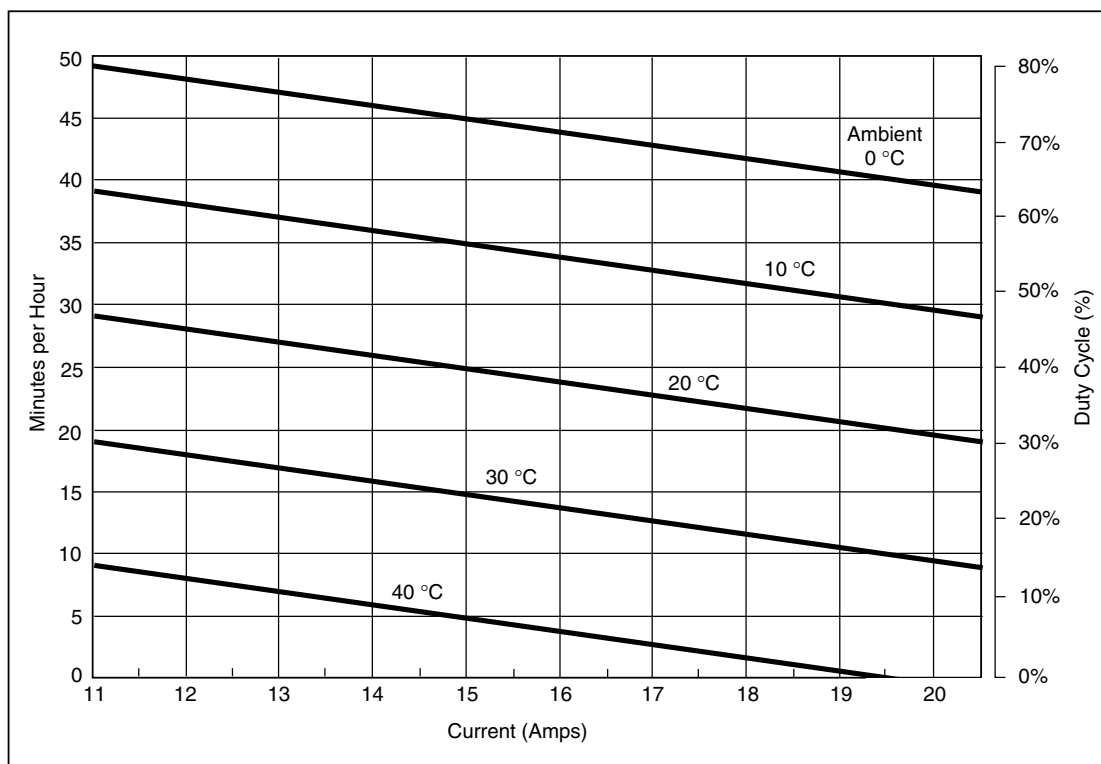


Figure 1-3. Allowable Duration of Current >11 A

**Resistance**

| Range <sup>[1]</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Absolute Uncertainty, tcal ±5 °C ±(% of output + floor) <sup>[2]</sup> |        |                                             |              | Resolution (Ω) | Allowable Current <sup>[3]</sup> (A) |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|--------|---------------------------------------------|--------------|----------------|--------------------------------------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | % of output                                                            |        | Floor (Ω) Time and temp since ohms zero cal |              |                |                                      |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 90 Day                                                                 | 1 Year | 12 hrs ±1 °C                                | 7 days ±5 °C |                |                                      |
| 0 to 10.999 Ω                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 0.009                                                                  | 0.012  | 0.001                                       | 0.01         | 0.001          | 1 mA to 125 mA                       |
| 11 to 32.999 Ω                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 0.009                                                                  | 0.012  | 0.0015                                      | 0.015        | 0.001          | 1 mA to 125 mA                       |
| 33 to 109.999 Ω                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 0.007                                                                  | 0.009  | 0.0014                                      | 0.015        | 0.001          | 1 mA to 70 mA                        |
| 110 to 329.999 Ω                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 0.007                                                                  | 0.009  | 0.002                                       | 0.02         | 0.001          | 1 mA to 40 mA                        |
| 330 to 1.09999 kΩ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 0.007                                                                  | 0.009  | 0.002                                       | 0.02         | 0.01           | 1 mA to 18 mA                        |
| 1.1 to 3.29999 kΩ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 0.007                                                                  | 0.009  | 0.02                                        | 0.2          | 0.01           | 100 μA to 5 mA                       |
| 3.3 to 10.9999 kΩ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 0.007                                                                  | 0.009  | 0.02                                        | 0.1          | 0.1            | 100 μA to 1.8 mA                     |
| 11 to 32.9999 kΩ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 0.007                                                                  | 0.009  | 0.2                                         | 1            | 0.1            | 10 μA to .5 mA                       |
| 33 to 109.999 kΩ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 0.008                                                                  | 0.011  | 0.2                                         | 1            | 1              | 10 μA to 0.18 mA                     |
| 110 to 329.999 kΩ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 0.009                                                                  | 0.012  | 2                                           | 10           | 1              | 1 μA to 50 μA                        |
| 330 kΩ to 1.09999 MΩ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 0.011                                                                  | 0.015  | 2                                           | 10           | 10             | 1 μA to 18 μA                        |
| 1.1 to 3.29999 MΩ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 0.011                                                                  | 0.015  | 30                                          | 150          | 10             | 250 nA to 5 μA                       |
| 3.3 to 10.9999 MΩ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 0.045                                                                  | 0.06   | 50                                          | 250          | 100            | 250 nA to 1.8 μA                     |
| 11 to 32.9999 MΩ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 0.075                                                                  | 0.1    | 2500                                        | 2500         | 100            | 25 nA to 500 nA                      |
| 33 to 109.999 MΩ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 0.4                                                                    | 0.5    | 3000                                        | 3000         | 1000           | 25 nA to 180 nA                      |
| 110 to 329.999 MΩ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 0.4                                                                    | 0.5    | 100000                                      | 100000       | 1000           | 2.5 nA to 50 nA                      |
| 330 to 1100.00 MΩ                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 1.2                                                                    | 1.5    | 500000                                      | 500000       | 10000          | 1 nA to 13 nA                        |
| <div>[1] Continuously variable from 0 Ω to 1.1 GΩ.</div> <div>[2] Applies for 4-WIRE compensation only. For 2-WIRE and 2-WIRE COMP, add 5 μV per amp of stimulus current to the floor specification. For example, in 2-WIRE mode, at 1 kΩ the floor specification within 12 hours of an ohms zero cal for a measurement current of 1 mA is: 0.002 Ω + 5 μV / 1 mA = (0.002 + 0.005) Ω = 0.007 Ω.</div> <div>[3] Do not exceed the largest current for each range. For currents lower than shown, the floor adder increases by Floor<sub>(new)</sub> = Floor<sub>(old)</sub> x I<sub>min</sub>/I<sub>actual</sub>. For example, a 50 μA stimulus measuring 100 Ω has a floor specification of: 0.0014 Ω x 1 mA/50 μA = 0.028 Ω, assuming an ohms zero calibration within 12 hours.</div> |                                                                        |        |                                             |              |                |                                      |

### AC Voltage (Sine Wave)

| Range                                                                                                                                                                                                                                                                                                                                                                               | Frequency          | Absolute Uncertainty, tcal<br>±5 °C ±(% of output + μV) |               | Resolution | Max Burden                            | Max Distortion and Noise 10 Hz to 5 MHz Bandwidth<br>±(% of output + floor) |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|---------------------------------------------------------|---------------|------------|---------------------------------------|-----------------------------------------------------------------------------|
|                                                                                                                                                                                                                                                                                                                                                                                     |                    | 90 Day                                                  | 1 Year        |            |                                       |                                                                             |
| 1.0 to 32.999 mV                                                                                                                                                                                                                                                                                                                                                                    | 10 Hz to 45 Hz     | 0.120 + 20                                              | 0.150 + 20    | 1 μV       | 65 Ω                                  | 0.15 + 90 μV                                                                |
|                                                                                                                                                                                                                                                                                                                                                                                     | 45 Hz to 10 kHz    | 0.080 + 20                                              | 0.100 + 20    |            |                                       | 0.035 + 90 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                                                     | 10 kHz to 20 kHz   | 0.120 + 20                                              | 0.150 + 20    |            |                                       | 0.06 + 90 μV                                                                |
|                                                                                                                                                                                                                                                                                                                                                                                     | 20 kHz to 50 kHz   | 0.160 + 20                                              | 0.200 + 20    |            |                                       | 0.15 + 90 μV                                                                |
|                                                                                                                                                                                                                                                                                                                                                                                     | 50 kHz to 100 kHz  | 0.300 + 33                                              | 0.350 + 33    |            |                                       | 0.25 + 90 μV                                                                |
|                                                                                                                                                                                                                                                                                                                                                                                     | 100 kHz to 500 kHz | 0.750 + 60                                              | 1.000 + 60    |            |                                       | 0.3 + 90 μV <sup>[1]</sup>                                                  |
| 33 mV to 329.999 mV                                                                                                                                                                                                                                                                                                                                                                 | 10 Hz to 45 Hz     | 0.042 + 20                                              | 0.050 + 20    | 1 μV       | 65 Ω                                  | 0.15 + 90 μV                                                                |
|                                                                                                                                                                                                                                                                                                                                                                                     | 45 Hz to 10 kHz    | 0.029 + 20                                              | 0.030 + 20    |            |                                       | 0.035 + 90 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                                                     | 10 kHz to 20 kHz   | 0.066 + 20                                              | 0.070 + 20    |            |                                       | 0.06 + 90 μV                                                                |
|                                                                                                                                                                                                                                                                                                                                                                                     | 20 kHz to 50 kHz   | 0.086 + 40                                              | 0.100 + 40    |            |                                       | 0.15 + 90 μV                                                                |
|                                                                                                                                                                                                                                                                                                                                                                                     | 50 kHz to 100 kHz  | 0.173 + 170                                             | 0.230 + 170   |            |                                       | 0.2 + 90 μV                                                                 |
|                                                                                                                                                                                                                                                                                                                                                                                     | 100 kHz to 500 kHz | 0.400 + 330                                             | 0.500 + 330   |            |                                       | 0.2 + 90 μV <sup>[1]</sup>                                                  |
| 0.33 V to 3.29999 V                                                                                                                                                                                                                                                                                                                                                                 | 10 Hz to 45 Hz     | 0.042 + 60                                              | 0.050 + 60    | 10 μV      | 10 mA                                 | 0.15 + 200 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                                                     | 45 Hz to 10 kHz    | 0.028 + 60                                              | 0.030 + 60    |            |                                       | 0.035 + 200 μV                                                              |
|                                                                                                                                                                                                                                                                                                                                                                                     | 10 kHz to 20 kHz   | 0.059 + 60                                              | 0.070 + 60    |            |                                       | 0.06 + 200 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                                                     | 20 kHz to 50 kHz   | 0.083 + 60                                              | 0.100 + 60    |            |                                       | 0.15 + 200 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                                                     | 50 kHz to 100 kHz  | 0.181 + 200                                             | 0.230 + 200   |            |                                       | 0.2 + 200 μV                                                                |
|                                                                                                                                                                                                                                                                                                                                                                                     | 100 kHz to 500 kHz | 0.417 + 900                                             | 0.500 + 900   |            |                                       | 0.2 + 200 μV <sup>[1]</sup>                                                 |
| 3.3 V to 32.9999 V                                                                                                                                                                                                                                                                                                                                                                  | 10 Hz to 45 Hz     | 0.042 + 800                                             | 0.050 + 800   | 100 μV     | 10 mA                                 | 0.15 + 2 mV                                                                 |
|                                                                                                                                                                                                                                                                                                                                                                                     | 45 Hz to 10 kHz    | 0.025 + 600                                             | 0.030 + 600   |            |                                       | 0.035 + 2 mV                                                                |
|                                                                                                                                                                                                                                                                                                                                                                                     | 10 kHz to 20 kHz   | 0.064 + 600                                             | 0.070 + 600   |            |                                       | 0.08 + 2 mV                                                                 |
|                                                                                                                                                                                                                                                                                                                                                                                     | 20 kHz to 50 kHz   | 0.086 + 600                                             | 0.100 + 600   |            |                                       | 0.2 + 2 mV                                                                  |
|                                                                                                                                                                                                                                                                                                                                                                                     | 50 kHz to 100 kHz  | 0.192 + 2000                                            | 0.230 + 2000  |            |                                       | 0.5 + 2 mV                                                                  |
| 33 V to 329.999 V                                                                                                                                                                                                                                                                                                                                                                   | 45 Hz to 1 kHz     | 0.039 + 3000                                            | 0.050 + 3000  | 1 mV       | 5 mA, except 20 mA for 45 Hz to 65 Hz | 0.15 + 10 mV                                                                |
|                                                                                                                                                                                                                                                                                                                                                                                     | 1 kHz to 10 kHz    | 0.064 + 9000                                            | 0.080 + 9000  |            |                                       | 0.05 + 10 mV                                                                |
|                                                                                                                                                                                                                                                                                                                                                                                     | 10 kHz to 20 kHz   | 0.079 + 9000                                            | 0.090 + 9000  |            |                                       | 0.6 + 10 mV                                                                 |
|                                                                                                                                                                                                                                                                                                                                                                                     | 20 kHz to 50 kHz   | 0.096 + 9000                                            | 0.120 + 9000  |            |                                       | 0.8 + 10 mV                                                                 |
|                                                                                                                                                                                                                                                                                                                                                                                     | 50 kHz to 100 kHz  | 0.192 + 80000                                           | 0.240 + 80000 |            |                                       | 1 + 10 mV                                                                   |
| 330 V to 1020 V                                                                                                                                                                                                                                                                                                                                                                     | 45 Hz to 1 kHz     | 0.042 + 20000                                           | 0.050 + 20000 | 10 mV      | 2 mA, except 20 mA for 45 to 65 Hz    | 0.15 + 30 mV                                                                |
|                                                                                                                                                                                                                                                                                                                                                                                     | 1 kHz to 5 kHz     | 0.064 + 20000                                           | 0.080 + 20000 |            |                                       | 0.07 + 30 mV                                                                |
|                                                                                                                                                                                                                                                                                                                                                                                     | 5 kHz to 10 kHz    | 0.075 + 20000                                           | 0.090 + 20000 |            |                                       | 0.07 + 30 mV                                                                |
| <div>[1] Max Distortion for 100 kHz to 200 kHz. For 200 kHz to 500 kHz, the maximum distortion is 0.9 % of output + floor as shown.</div> <div>Note</div> <div>Remote sensing is not provided. Output resistance is &lt;5 mΩ for outputs ≥0.33 V. The AUX output resistance is &lt;1 Ω. The maximum load capacitance is 500 pF, subject to the maximum burden current limits.</div> |                    |                                                         |               |            |                                       |                                                                             |

**AC Voltage (Sine Wave) (cont.)**

| AUX (Auxiliary Output) [dual output mode only]                                                                                                                                                                                                                                                                                                         |                          |                                                         |             |            |            |                                                                             |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|---------------------------------------------------------|-------------|------------|------------|-----------------------------------------------------------------------------|
| Range                                                                                                                                                                                                                                                                                                                                                  | Frequency <sup>[1]</sup> | Absolute Uncertainty, tcal<br>±5 °C ±(% of output + μV) |             | Resolution | Max Burden | Max Distortion and Noise 10 Hz to 5 MHz Bandwidth<br>±(% of output + floor) |
|                                                                                                                                                                                                                                                                                                                                                        |                          | 90 Day                                                  | 1 Year      |            |            |                                                                             |
| 1.0 to 329.999 mV                                                                                                                                                                                                                                                                                                                                      | 10 to 20 Hz              | 0.15 + 370                                              | 0.20 + 370  | 1 μV       | 5 mA       | 0.20 + 200 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                        | 20 to 45 Hz              | 0.08 + 370                                              | 0.10 + 370  |            |            | 0.06 + 200 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                        | 45 to 1 kHz              | 0.08 + 370                                              | 0.10 + 370  |            |            | 0.08 + 200 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                        | 1 to 5 kHz               | 0.15 + 450                                              | 0.20 + 450  |            |            | 0.30 + 200 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                        | 5 to 10 kHz              | 0.30 + 450                                              | 0.40 + 450  |            |            | 0.60 + 200 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                        | 10 to 30 kHz             | 4.00 + 900                                              | 5.00 + 900  |            |            | 1.00 + 200 μV                                                               |
| 0.33 to 3.29999 V                                                                                                                                                                                                                                                                                                                                      | 10 to 20 Hz              | 0.15 + 450                                              | 0.20 + 450  | 10 μV      | 5 mA       | 0.20 + 200 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                        | 20 to 45 Hz              | 0.08 + 450                                              | 0.10 + 450  |            |            | 0.06 + 200 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                        | 45 to 1 kHz              | 0.07 + 450                                              | 0.09 + 450  |            |            | 0.08 + 200 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                        | 1 to 5 kHz               | 0.15 + 1400                                             | 0.20 + 1400 |            |            | 0.30 + 200 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                        | 5 to 10 kHz              | 0.30 + 1400                                             | 0.40 + 1400 |            |            | 0.60 + 200 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                        | 10 to 30 kHz             | 4.00 + 2800                                             | 5.00 + 2800 |            |            | 1.00 + 200 μV                                                               |
| 3.3 to 5 V                                                                                                                                                                                                                                                                                                                                             | 10 to 20 Hz              | 0.15 + 450                                              | 0.20 + 450  | 100 μV     | 5 mA       | 0.20 + 200 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                        | 20 to 45 Hz              | 0.08 + 450                                              | 0.10 + 450  |            |            | 0.06 + 200 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                        | 45 to 1 kHz              | 0.07 + 450                                              | 0.09 + 450  |            |            | 0.08 + 200 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                        | 1 to 5 kHz               | 0.15 + 1400                                             | 0.20 + 1400 |            |            | 0.30 + 200 μV                                                               |
|                                                                                                                                                                                                                                                                                                                                                        | 5 to 10 kHz              | 0.30 + 1400                                             | 0.40 + 1400 |            |            | 0.60 + 200 μV                                                               |
| <div>[1] There are two channels of voltage output. The maximum frequency of the dual output is 30 kHz.</div> <div>Note</div> <div>Remote sensing is not provided. Output resistance is &lt;5 mΩ for outputs ≥0.33 V. The AUX output resistance is &lt;1 Ω. The maximum load capacitance is 500 pF, subject to the maximum burden current limits.</div> |                          |                                                         |             |            |            |                                                                             |

### AC Current (Sine Wave)

| Range                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Frequency       | Absolute Uncertainty, tcal ±5 °C ±(% of output + µA) |              | Compliance adder ±(µA/V) | Max Distortion and Noise 10 Hz to 100 kHz BW ±(% of output + floor) | Max Inductive Load µH |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|------------------------------------------------------|--------------|--------------------------|---------------------------------------------------------------------|-----------------------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                 | 90 Day                                               | 1 Year       |                          |                                                                     |                       |
| LCOMP Off                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                 |                                                      |              |                          |                                                                     |                       |
| 29 to 329.99 µA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 10 to 20 Hz     | 0.16 + 0.1                                           | 0.2 + 0.1    | 0.05                     | 0.15 + 0.5 µA                                                       | 200                   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 20 to 45 Hz     | 0.12 + 0.1                                           | 0.15 + 0.1   | 0.05                     | 0.10 + 0.5 µA                                                       |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 45 Hz to 1 kHz  | 0.1 + 0.1                                            | 0.125 + 0.1  | 0.05                     | 0.05 + 0.5 µA                                                       |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1 to 5 kHz      | 0.25 + 0.15                                          | 0.3 + 0.15   | 1.5                      | 0.50 + 0.5 µA                                                       |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 5 to 10 kHz     | 0.6 + 0.2                                            | 0.8 + 0.2    | 1.5                      | 1.00 + 0.5 µA                                                       |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 10 to 30 kHz    | 1.2 + 0.4                                            | 1.6 + 0.4    | 10                       | 1.20 + 0.5 µA                                                       |                       |
| 0.33 to 3.29999 mA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 10 to 20 Hz     | 0.16 + 0.15                                          | 0.2 + 0.15   | 0.05                     | 0.15 + 1.5 µA                                                       | 200                   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 20 to 45 Hz     | 0.1 + 0.15                                           | 0.125 + 0.15 | 0.05                     | 0.06 + 1.5 µA                                                       |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 45 Hz to 1 kHz  | 0.08 + 0.15                                          | 0.1 + 0.15   | 0.05                     | 0.02 + 1.5 µA                                                       |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1 to 5 kHz      | 0.16 + 0.2                                           | 0.2 + 0.2    | 1.5                      | 0.50 + 1.5 µA                                                       |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 5 to 10 kHz     | 0.4 + 0.3                                            | 0.5 + 0.3    | 1.5                      | 1.00 + 1.5 µA                                                       |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 10 to 30 kHz    | 0.8 + 0.6                                            | 1.0 + 0.6    | 10                       | 1.20 + 0.5 µA                                                       |                       |
| 3.3 to 32.9999 mA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 10 to 20 Hz     | 0.15 + 2                                             | 0.18 + 2     | 0.05                     | 0.15 + 5 µA                                                         | 50                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 20 to 45 Hz     | 0.075 + 2                                            | 0.09 + 2     | 0.05                     | 0.05 + 5 µA                                                         |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 45 Hz to 1 kHz  | 0.035 + 2                                            | 0.04 + 2     | 0.05                     | 0.07 + 5 µA                                                         |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1 to 5 kHz      | 0.065 + 2                                            | 0.08 + 2     | 1.5                      | 0.30 + 5 µA                                                         |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 5 to 10 kHz     | 0.16 + 3                                             | 0.2 + 3      | 1.5                      | 0.70 + 5 µA                                                         |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 10 to 30 kHz    | 0.32 + 4                                             | 0.4 + 4      | 10                       | 1.00 + 0.5 µA                                                       |                       |
| 33 to 329.999 mA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 10 to 20 Hz     | 0.15 + 20                                            | 0.18 + 20    | 0.05                     | 0.15 + 50 µA                                                        | 50                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 20 to 45 Hz     | 0.075 + 20                                           | 0.09 + 20    | 0.05                     | 0.05 + 50 µA                                                        |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 45 Hz to 1 kHz  | 0.035 + 20                                           | 0.04 + 20    | 0.05                     | 0.02 + 50 µA                                                        |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1 to 5 kHz      | 0.08 + 50                                            | 0.10 + 50    | 1.5                      | 0.03 + 50 µA                                                        |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 5 to 10 kHz     | 0.16 + 100                                           | 0.2 + 100    | 1.5                      | 0.10 + 50 µA                                                        |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 10 to 30 kHz    | 0.32 + 200                                           | 0.4 + 200    | 10                       | 0.60 + 50 µA                                                        |                       |
| 0.33 to 1.09999 A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 10 to 45 Hz     | 0.15 + 100                                           | 0.18 + 100   |                          | 0.20 + 500 µA                                                       | 2.5                   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 45 Hz to 1 kHz  | 0.036 + 100                                          | 0.05 + 100   |                          | 0.07 + 500 µA                                                       |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1 to 5 kHz      | 0.5 + 1000                                           | 0.6 + 1000   | [2]                      | 1.00 + 500 µA                                                       |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 5 to 10 kHz     | 2.0 + 5000                                           | 2.5 + 5000   | [3]                      | 2.00 + 500 µA                                                       |                       |
| 1.1 to 2.99999 A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 10 to 45 Hz     | 0.15 + 100                                           | 0.18 + 100   |                          | 0.20 + 500 µA                                                       | 2.5                   |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 45 Hz to 1 kHz  | 0.05 + 100                                           | 0.06 + 100   |                          | 0.07 + 500 µA                                                       |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1 to 5 kHz      | 0.5 + 1000                                           | 0.6 + 1000   | [2]                      | 1.00 + 500 µA                                                       |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 5 to 10 kHz     | 2.0 + 5000                                           | 2.5 + 5000   | [3]                      | 2.00 + 500 µA                                                       |                       |
| 3 to 10.9999 A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | 45 to 100 Hz    | 0.05 + 2000                                          | 0.06 + 2000  |                          | 0.2 + 3 mA                                                          | 1                     |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 100 Hz to 1 kHz | 0.08 + 2000                                          | 0.10 + 2000  |                          | 0.1 + 3 mA                                                          |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1 kHz to 5 kHz  | 2.5 + 2000                                           | 3.0 + 2000   |                          | 0.8 + 3 mA                                                          |                       |
| 11 to 20.5 A [1]                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 45 to 100 Hz    | 0.1 + 5000                                           | 0.12 + 5000  |                          | 0.2 + 3 mA                                                          | 1                     |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 100 Hz to 1 kHz | 0.13 + 5000                                          | 0.15 + 5000  |                          | 0.1 + 3 mA                                                          |                       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 1 to 5 kHz      | 2.5 + 5000                                           | 3.0 + 5000   |                          | 0.8 + 3 mA                                                          |                       |
| <div>[1] Duty Cycle: Currents &lt;11 A may be provided continuously. For currents &gt;11 A, see Figure 1-3. The current may be provided 60-T-I minutes any 60 minute period where T is the temperature in °C (room temperature is about 23 °C) and I is the output current in amps. For example, 17 A, at 23 °C could be provided for 60-17-23 = 20 minutes each hour. When the 5502A is outputting currents between 5 and 11 amps for long periods, the internal self-heating reduces the duty cycle. Under those conditions, the allowable "on" time indicated by the formula and Figure 1-3 is achieved only after the 5502A is outputting currents &lt;5 A for the "off" period first.</div> <div>[2] For compliance voltages greater than 1 V, add 1 mA/V to the floor specification from 1 to 5 kHz.</div> <div>[3] For compliance voltages greater than 1 V, add 5 mA/V to the floor specification from 5 to 10 kHz.</div> |                 |                                                      |              |                          |                                                                     |                       |

**AC Current (Sine Wave) (cont.)**

| Range                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Frequency       | Absolute Uncertainty, tcal<br>±5 °C ±(% of output + µA) |                 | Max Distortion and<br>Noise 10 Hz to<br>100 kHz BW ±(% of<br>output + floor) | Max Inductive Load |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|---------------------------------------------------------|-----------------|------------------------------------------------------------------------------|--------------------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                 | 90 Day                                                  | 1 Year          |                                                                              |                    |
| LCOMP On                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                 |                                                         |                 |                                                                              |                    |
| 29 to 329.99 µA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 10 to 100 Hz    | 0.20 + 0.2                                              | 0.25 + 0.2      | 0.1 + 1.0 µA                                                                 | 400 µH             |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 100 Hz to 1 kHz | 0.50 + 0.5                                              | 0.60 + 0.5      | 0.05 + 1.0 µA                                                                |                    |
| 330 µA to<br>3.29999 mA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 10 to 100 Hz    | 0.20 + 0.3                                              | 0.25 + 0.3      | 0.15 + 1.5 µA                                                                |                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 100 Hz to 1 kHz | 0.50 + 0.8                                              | 0.60 + 0.8      | 0.06 + 1.5 µA                                                                |                    |
| 3.3 to<br>32.9999 mA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 10 to 100 Hz    | 0.07 + 4                                                | 0.08 + 4        | 0.15 + 5 µA                                                                  |                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 100 Hz to 1 kHz | 0.18 + 10                                               | 0.20 + 10       | 0.05 + 5 µA                                                                  |                    |
| 33 to 329.999 mA                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | 10 to 100 Hz    | 0.07 + 40                                               | 0.08 + 40       | 0.15 + 50 µA                                                                 |                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 100 Hz to 1 kHz | 0.18 + 100                                              | 0.20 + 100      | 0.05 + 50 µA                                                                 |                    |
| 330 mA to<br>2.99999 A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 10 to 100 Hz    | 0.10 + 200                                              | 0.12 + 200      | 0.2 + 500 µA                                                                 | 400 µH [4]         |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 100 to 440 Hz   | 0.25 + 1000                                             | 0.30 + 1000     | 0.25 + 500 µA                                                                |                    |
| 3.3 A to 20.5 A [1]                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 45 to 100 Hz    | 0.10 + 2000 [2]                                         | 0.12 + 2000 [2] | 0.1 + 0 µA                                                                   |                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | 100 to 440 Hz   | 0.80 + 5000 [3]                                         | 1.00 + 5000 [3] | 0.5 + 0 µA                                                                   |                    |
| <p>[1] Duty Cycle: Currents &lt;11 A may be provided continuously. For currents &gt;11 A, see Figure 1-3. The current may be provided 60-T-I minutes any 60 minute period where T is the temperature in °C (room temperature is about 23 °C) and I is the output current in amps. For example, 17 A, at 23 °C could be provided for 60-17-23 = 20 minutes each hour. When the 5502A is outputting currents between 5 and 11 amps for long periods, the internal self-heating reduces the duty cycle. Under those conditions, the allowable "on" time indicated by the formula and Figure 1-3 is achieved only after the 5502A is outputting currents &lt;5 A for the "off" period first.</p> <p>[2] For currents &gt;11 A, Floor specification is 4000 µA within 30 seconds of selecting operate. For operating times &gt;30 seconds, the floor specification is 2000 µA.</p> <p>[3] For currents &gt;11 A, Floor specification is 1000 µA within 30 seconds of selecting operate. For operating times &gt;30 seconds, the floor specification is 5000 µA.</p> <p>[4] Subject to compliance voltages limits.</p> |                 |                                                         |                 |                                                                              |                    |

| Range                                                                            | Resolution $\mu\text{A}$ | Max Compliance Voltage V rms <sup>[1]</sup> |
|----------------------------------------------------------------------------------|--------------------------|---------------------------------------------|
| 29 to 329.99 $\mu\text{A}$                                                       | 0.01                     | 7                                           |
| 0.33 to 3.29999 mA                                                               | 0.01                     | 7                                           |
| 3.3 to 32.9999 mA                                                                | 0.1                      | 5                                           |
| 33 to 329.999 mA                                                                 | 1                        | 5                                           |
| 0.33 to 2.99999 A                                                                | 10                       | 4                                           |
| 3 to 20.5 A                                                                      | 100                      | 3                                           |
| [1] Subject to specification adder for compliance voltages greater than 1 V rms. |                          |                                             |



## Capacitance

| Range                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Absolute Uncertainty, tcal $\pm 5^{\circ}\text{C}$<br>$\pm(\% \text{ of output} + \text{floor})$ <sup>[1] [2] [3]</sup> |                         | Resolution       | Allowed Frequency or Charge-Discharge Rate |                              |                            |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|-------------------------|------------------|--------------------------------------------|------------------------------|----------------------------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 90 Day                                                                                                                  | 1 Year                  |                  | Min and Max to Meet Specification          | Typical Max for <0.5 % Error | Typical Max for <1 % Error |
| 220.0 to 399.9 pF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 0.38 + 0.01 nF                                                                                                          | 0.5 + 0.01 nF           | 0.1 pF           | 10 Hz to 10 kHz                            | 20 kHz                       | 40 kHz                     |
| 0.4 to 1.0999 nF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 0.38 + 0.01 nF                                                                                                          | 0.5 + 0.01 nF           | 0.1 pF           | 10 Hz to 10 kHz                            | 30 kHz                       | 50 kHz                     |
| 1.1 to 3.2999 nF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 0.38 + 0.01 nF                                                                                                          | 0.5 + 0.01 nF           | 0.1 pF           | 10 Hz to 3 kHz                             | 30 kHz                       | 50 kHz                     |
| 3.3 to 10.999 nF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 0.19 + 0.01 nF                                                                                                          | 0.25 + 0.01 nF          | 1 pF             | 10 Hz to 1 kHz                             | 20 kHz                       | 25 kHz                     |
| 11 to 32.999 nF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 0.19 + 0.1 nF                                                                                                           | 0.25 + 0.1 nF           | 1 pF             | 10 Hz to 1 kHz                             | 8 kHz                        | 10 kHz                     |
| 33 to 109.99 nF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 0.19 + 0.1 nF                                                                                                           | 0.25 + 0.1 nF           | 10 pF            | 10 Hz to 1 kHz                             | 4 kHz                        | 6 kHz                      |
| 110 to 329.99 nF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 0.19 + 0.3 nF                                                                                                           | 0.25 + 0.3 nF           | 10 pF            | 10 Hz to 1 kHz                             | 2.5 kHz                      | 3.5 kHz                    |
| 0.33 to 1.0999 $\mu\text{F}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 0.19 + 1 nF                                                                                                             | 0.25 + 1 nF             | 100 pF           | 10 to 600 Hz                               | 1.5 kHz                      | 2 kHz                      |
| 1.1 to 3.2999 $\mu\text{F}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 0.19 + 3 nF                                                                                                             | 0.25 + 3 nF             | 100 pF           | 10 to 300 Hz                               | 800 Hz                       | 1 kHz                      |
| 3.3 to 10.999 $\mu\text{F}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 0.19 + 10 nF                                                                                                            | 0.25 + 10 nF            | 1 nF             | 10 to 150 Hz                               | 450 Hz                       | 650 Hz                     |
| 11 to 32.999 $\mu\text{F}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 0.30 + 30 nF                                                                                                            | 0.40 + 30 nF            | 1 nF             | 10 to 120 Hz                               | 250 Hz                       | 350 Hz                     |
| 33 to 109.99 $\mu\text{F}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 0.34 + 100 nF                                                                                                           | 0.45 + 100 nF           | 10 nF            | 10 to 80 Hz                                | 150 Hz                       | 200 Hz                     |
| 110 to 329.99 $\mu\text{F}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 0.34 + 300 nF                                                                                                           | 0.45 + 300 nF           | 10 nF            | 0 to 50 Hz                                 | 80 Hz                        | 120 Hz                     |
| 0.33 to 1.0999 mF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 0.34 + 1 $\mu\text{F}$                                                                                                  | 0.45 + 1 $\mu\text{F}$  | 100 nF           | 0 to 20 Hz                                 | 45 Hz                        | 65 Hz                      |
| 1.1 to 3.2999 mF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 0.34 + 3 $\mu\text{F}$                                                                                                  | 0.45 + 3 $\mu\text{F}$  | 100 nF           | 0 to 6 Hz                                  | 30 Hz                        | 40 Hz                      |
| 3.3 to 10.999 mF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 0.34 + 10 $\mu\text{F}$                                                                                                 | 0.45 + 10 $\mu\text{F}$ | 1 $\mu\text{F}$  | 0 to 2 Hz                                  | 15 Hz                        | 20 Hz                      |
| 11 to 32.999 mF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 0.7 + 30 $\mu\text{F}$                                                                                                  | 0.75 + 30 $\mu\text{F}$ | 1 $\mu\text{F}$  | 0 to 0.6 Hz                                | 7.5 Hz                       | 10 Hz                      |
| 33 to 110.00 mF                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 1.0 + 100 $\mu\text{F}$                                                                                                 | 1.1 + 100 $\mu\text{F}$ | 10 $\mu\text{F}$ | 0 to 0.2 Hz                                | 3 Hz                         | 5 Hz                       |
| <p>[1] The output is continuously variable from 220 pF to 110 mF.</p> <p>[2] Specifications apply to both dc charge/discharge capacitance meters and ac RCL meters. The maximum allowable peak voltage is 3 V. The maximum allowable peak current is 150 mA, with an rms limitation of 30 mA below 1.1 <math>\mu\text{F}</math> and 100 mA for 1.1 <math>\mu\text{F}</math> and above.</p> <p>[3] The maximum lead resistance for no additional error in 2-wire COMP mode is 10 <math>\Omega</math>.</p> |                                                                                                                         |                         |                  |                                            |                              |                            |

**Temperature Calibration (Thermocouple)**

| TC Type<br>[1]                                                                                                                                                                                                                                                        | Range °C [2] | Absolute Uncertainty<br>Source/Measure tcal ±5 °C ±<br>°C [3] |           | TC Type<br>[1] | Range °C [2] | Absolute Uncertainty<br>Source/Measure tcal<br>±5 °C ± °C [3] |        |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|---------------------------------------------------------------|-----------|----------------|--------------|---------------------------------------------------------------|--------|
|                                                                                                                                                                                                                                                                       |              | 90 Day                                                        | 1 Year    |                |              | 90 Day                                                        | 1 Year |
| B                                                                                                                                                                                                                                                                     | 600 to 800   | 0.42                                                          | 0.44      | L              | -200 to -100 | 0.37                                                          | 0.37   |
|                                                                                                                                                                                                                                                                       | 800 to 1000  | 0.34                                                          | 0.34      |                | -100 to 800  | 0.26                                                          | 0.26   |
|                                                                                                                                                                                                                                                                       | 1000 to 1550 | 0.30                                                          | 0.30      |                | 800 to 900   | 0.17                                                          | 0.17   |
|                                                                                                                                                                                                                                                                       | 1550 to 1820 | 0.26                                                          | 0.33      |                |              |                                                               |        |
| C                                                                                                                                                                                                                                                                     | 0 to 150     | 0.23                                                          | 0.30      | N              | -200 to -100 | 0.30                                                          | 0.40   |
|                                                                                                                                                                                                                                                                       | 150 to 650   | 0.19                                                          | 0.26      |                | -100 to -25  | 0.17                                                          | 0.22   |
|                                                                                                                                                                                                                                                                       | 650 to 1000  | 0.23                                                          | 0.31      |                | -25 to 120   | 0.15                                                          | 0.19   |
|                                                                                                                                                                                                                                                                       | 1000 to 1800 | 0.38                                                          | 0.50      |                | 120 to 410   | 0.14                                                          | 0.18   |
|                                                                                                                                                                                                                                                                       | 1800 to 2316 | 0.63                                                          | 0.84      |                | 410 to 1300  | 0.21                                                          | 0.27   |
|                                                                                                                                                                                                                                                                       |              |                                                               |           |                |              |                                                               |        |
| E                                                                                                                                                                                                                                                                     | -250 to -100 | 0.38                                                          | 0.50      | R              | 0 to 250     | 0.48                                                          | 0.57   |
|                                                                                                                                                                                                                                                                       | -100 to -25  | 0.12                                                          | 0.16      |                | 250 to 400   | 0.28                                                          | 0.35   |
|                                                                                                                                                                                                                                                                       | -25 to 350   | 0.10                                                          | 0.14      |                | 400 to 1000  | 0.26                                                          | 0.33   |
|                                                                                                                                                                                                                                                                       | 350 to 650   | 0.12                                                          | 0.16      |                | 1000 to 1767 | 0.30                                                          | 0.40   |
|                                                                                                                                                                                                                                                                       | 650 to 1000  | 0.16                                                          | 0.21      |                |              |                                                               |        |
| J                                                                                                                                                                                                                                                                     | -210 to -100 | 0.20                                                          | 0.27      | S              | 0 to 250     | 0.47                                                          | 0.47   |
|                                                                                                                                                                                                                                                                       | -100 to -30  | 0.12                                                          | 0.16      |                | 250 to 1000  | 0.30                                                          | 0.36   |
|                                                                                                                                                                                                                                                                       | -30 to 150   | 0.10                                                          | 0.14      |                | 1000 to 1400 | 0.28                                                          | 0.37   |
|                                                                                                                                                                                                                                                                       | 150 to 760   | 0.13                                                          | 0.17      | T              | 1400 to 1767 | 0.34                                                          | 0.46   |
|                                                                                                                                                                                                                                                                       | 760 to 1200  | 0.18                                                          | 0.23      |                | -250 to -150 | 0.48                                                          | 0.63   |
|                                                                                                                                                                                                                                                                       |              |                                                               | -150 to 0 |                | 0.18         | 0.24                                                          |        |
|                                                                                                                                                                                                                                                                       |              |                                                               | 0 to 120  |                | 0.12         | 0.16                                                          |        |
| K                                                                                                                                                                                                                                                                     | -200 to -100 | 0.25                                                          | 0.33      | U              | 120 to 400   | 0.10                                                          | 0.14   |
|                                                                                                                                                                                                                                                                       | -100 to -25  | 0.14                                                          | 0.18      |                | -200 to 0    | 0.56                                                          | 0.56   |
|                                                                                                                                                                                                                                                                       | -25 to 120   | 0.12                                                          | 0.16      |                | 0 to 600     | 0.27                                                          | 0.27   |
|                                                                                                                                                                                                                                                                       | 120 to 1000  | 0.19                                                          | 0.26      |                |              |                                                               |        |
|                                                                                                                                                                                                                                                                       | 1000 to 1372 | 0.30                                                          | 0.40      |                |              |                                                               |        |
| <div>[1] Temperature standard ITS-90 or IPTS-68 is selectable.<br/>TC simulating and measuring are not specified for operation in electromagnetic fields above 0.4 V/m.</div> <div>[2] Resolution is 0.01 °C</div> <div>[3] Does not include thermocouple error</div> |              |                                                               |           |                |              |                                                               |        |

### Temperature Calibration (RTD)

| RTD Type                                                                                                                                                                                                                  | Range °C <sup>[1]</sup> | Absolute Uncertainty tcal<br>±5 °C ± °C <sup>[2]</sup> |        | RTD Type                      | Range °C <sup>[1]</sup>       | Absolute Uncertainty<br>tcal ±5 °C ± °C <sup>[2]</sup> |        |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|--------------------------------------------------------|--------|-------------------------------|-------------------------------|--------------------------------------------------------|--------|
|                                                                                                                                                                                                                           |                         | 90 Day                                                 | 1 Year |                               |                               | 90 Day                                                 | 1 Year |
| Pt 385,<br>100 Ω                                                                                                                                                                                                          | -200 to -80             | 0.04                                                   | 0.05   | Pt 385,<br>500 Ω              | -200 to -80                   | 0.03                                                   | 0.04   |
|                                                                                                                                                                                                                           | -80 to 0                | 0.05                                                   | 0.05   |                               | -80 to 0                      | 0.04                                                   | 0.05   |
|                                                                                                                                                                                                                           | 0 to 100                | 0.07                                                   | 0.07   |                               | 0 to 100                      | 0.05                                                   | 0.05   |
|                                                                                                                                                                                                                           | 100 to 300              | 0.08                                                   | 0.09   |                               | 100 to 260                    | 0.06                                                   | 0.06   |
|                                                                                                                                                                                                                           | 300 to 400              | 0.09                                                   | 0.10   |                               | 260 to 300                    | 0.07                                                   | 0.08   |
|                                                                                                                                                                                                                           | 400 to 630              | 0.10                                                   | 0.12   |                               | 300 to 400                    | 0.07                                                   | 0.08   |
|                                                                                                                                                                                                                           | 630 to 800              | 0.21                                                   | 0.23   |                               | 400 to 600                    | 0.08                                                   | 0.09   |
| Pt 3926,<br>100 Ω                                                                                                                                                                                                         | -200 to -80             | 0.04                                                   | 0.05   | Pt 385,<br>1000 Ω             | 600 to 630                    | 0.09                                                   | 0.11   |
|                                                                                                                                                                                                                           | -80 to 0                | 0.05                                                   | 0.05   |                               | -200 to -80                   | 0.03                                                   | 0.03   |
|                                                                                                                                                                                                                           | 0 to 100                | 0.07                                                   | 0.07   |                               | -80 to 0                      | 0.03                                                   | 0.03   |
|                                                                                                                                                                                                                           | 100 to 300              | 0.08                                                   | 0.09   |                               | 0 to 100                      | 0.03                                                   | 0.04   |
|                                                                                                                                                                                                                           | 300 to 400              | 0.09                                                   | 0.10   |                               | 100 to 260                    | 0.04                                                   | 0.05   |
|                                                                                                                                                                                                                           | 400 to 630              | 0.10                                                   | 0.12   |                               | 260 to 300                    | 0.05                                                   | 0.06   |
| Pt 3916,<br>100 Ω                                                                                                                                                                                                         | -200 to -190            | 0.25                                                   | 0.25   |                               | 300 to 400                    | 0.05                                                   | 0.07   |
|                                                                                                                                                                                                                           | -190 to -80             | 0.04                                                   | 0.04   |                               | 400 to 600                    | 0.06                                                   | 0.07   |
|                                                                                                                                                                                                                           | -80 to 0                | 0.05                                                   | 0.05   |                               | 600 to 630                    | 0.22                                                   | 0.23   |
|                                                                                                                                                                                                                           | 0 to 100                | 0.06                                                   | 0.06   |                               | PtNi 385,<br>120 Ω<br>(Ni120) | -80 to 0                                               | 0.06   |
|                                                                                                                                                                                                                           | 100 to 260              | 0.06                                                   | 0.07   | 0 to 100                      |                               | 0.07                                                   | 0.08   |
|                                                                                                                                                                                                                           | 260 to 300              | 0.07                                                   | 0.08   | 100 to 260                    |                               | 0.13                                                   | 0.14   |
|                                                                                                                                                                                                                           | 300 to 400              | 0.08                                                   | 0.09   | Cu 427<br>10 Ω <sup>[3]</sup> | -100 to 260                   | 0.3                                                    | 0.3    |
|                                                                                                                                                                                                                           | 400 to 600              | 0.08                                                   | 0.10   |                               |                               |                                                        |        |
| 600 to 630                                                                                                                                                                                                                | 0.21                    | 0.23                                                   |        |                               |                               |                                                        |        |
| Pt 385,<br>200 Ω                                                                                                                                                                                                          | -200 to -80             | 0.03                                                   | 0.04   |                               |                               |                                                        |        |
|                                                                                                                                                                                                                           | -80 to 0                | 0.03                                                   | 0.04   |                               |                               |                                                        |        |
|                                                                                                                                                                                                                           | 0 to 100                | 0.04                                                   | 0.04   |                               |                               |                                                        |        |
|                                                                                                                                                                                                                           | 100 to 260              | 0.04                                                   | 0.05   |                               |                               |                                                        |        |
|                                                                                                                                                                                                                           | 260 to 300              | 0.11                                                   | 0.12   |                               |                               |                                                        |        |
|                                                                                                                                                                                                                           | 300 to 400              | 0.12                                                   | 0.13   |                               |                               |                                                        |        |
|                                                                                                                                                                                                                           | 400 to 600              | 0.12                                                   | 0.14   |                               |                               |                                                        |        |
|                                                                                                                                                                                                                           | 600 to 630              | 0.14                                                   | 0.16   |                               |                               |                                                        |        |
| <div>[1] Resolution is 0.003 °C</div> <div>[2] Applies for COMP OFF (to the 5502A Calibrator front panel NORMAL terminals) and 2-wire and 4-wire compensation.</div> <div>[3] Based on MINCO Application Aid No. 18</div> |                         |                                                        |        |                               |                               |                                                        |        |

### Phase

| 1-Year Absolute Uncertainty, tcal ±5 °C, (Δ Φ °)                                          |              |                 |            |             |              |
|-------------------------------------------------------------------------------------------|--------------|-----------------|------------|-------------|--------------|
| Frequency (Hz)                                                                            |              |                 |            |             |              |
| 10 to 65 Hz                                                                               | 65 to 500 Hz | 500 Hz to 1 kHz | 1 to 5 kHz | 5 to 10 kHz | 10 to 30 kHz |
| 0.15 °                                                                                    | 0.9 °        | 2 °             | 6 °        | 10 °        | 15 °         |
| <p>Note</p> <p>See Power and Dual Output Limit Specifications for applicable outputs.</p> |              |                 |            |             |              |

| Phase (Φ)<br>Watts | Phase (Φ)<br>VARs | PF    | Power Uncertainty Adder due to Phase Error |              |                 |            |             |
|--------------------|-------------------|-------|--------------------------------------------|--------------|-----------------|------------|-------------|
|                    |                   |       | 10 to 65 Hz                                | 65 to 500 Hz | 500 Hz to 1 kHz | 1 to 5 kHz | 5 to 10 kHz |
|                    |                   |       | 0.00 %                                     | 0.01 %       | 0.06 %          | 0.55 %     | 1.52 %      |
| 5 °                | 85 °              | 0.996 | 0.02 %                                     | 0.15 %       | 0.37 %          | 1.46 %     | 3.04 %      |
| 10 °               | 80 °              | 0.985 | 0.05 %                                     | 0.29 %       | 0.68 %          | 2.39 %     | 4.58 %      |
| 15 °               | 75 °              | 0.966 | 0.07 %                                     | 0.43 %       | 1.00 %          | 3.35 %     | 6.17 %      |
| 20 °               | 70 °              | 0.940 | 0.10 %                                     | 0.58 %       | 1.33 %          | 4.35 %     | 7.84 %      |
| 25 °               | 65 °              | 0.906 | 0.12 %                                     | 0.74 %       | 1.69 %          | 5.42 %     | 9.62 %      |
| 30 °               | 60 °              | 0.866 | 0.15 %                                     | 0.92 %       | 2.08 %          | 6.58 %     | 11.54 %     |
| 35 °               | 55 °              | 0.819 | 0.18 %                                     | 1.11 %       | 2.50 %          | 7.87 %     | 13.68 %     |
| 40 °               | 50 °              | 0.766 | 0.22 %                                     | 1.33 %       | 2.99 %          | 9.32 %     | 16.09 %     |
| 45 °               | 45 °              | 0.707 | 0.26 %                                     | 1.58 %       | 3.55 %          | 11.00 %    | 18.88 %     |
| 50 °               | 40 °              | 0.643 | 0.31 %                                     | 1.88 %       | 4.22 %          | 13.01 %    | 22.21 %     |
| 55 °               | 35 °              | 0.574 | 0.37 %                                     | 2.26 %       | 5.05 %          | 15.48 %    | 26.32 %     |
| 60 °               | 30 °              | 0.500 | 0.45 %                                     | 2.73 %       | 6.11 %          | 18.65 %    | 31.60 %     |
| 65 °               | 25 °              | 0.423 | 0.56 %                                     | 3.38 %       | 7.55 %          | 22.96 %    | 38.76 %     |
| 70 °               | 20 °              | 0.342 | 0.72 %                                     | 4.33 %       | 9.65 %          | 29.27 %    | 49.23 %     |
| 75 °               | 15 °              | 0.259 | 0.98 %                                     | 5.87 %       | 13.09 %         | 39.56 %    | 66.33 %     |
| 80 °               | 10 °              | 0.174 | 1.49 %                                     | 8.92 %       | 19.85 %         | 59.83 %    | 100.00 %    |
| 85 °               | 5 °               | 0.087 | 2.99 %                                     | 17.97 %      | 39.95 %         |            |             |
| 90 °               | 0 °               | 0.000 | —                                          | —            |                 |            |             |

To calculate exact ac watts power adders due to phase uncertainty for values not shown, use the subsequent formula:

$$Adder(\%) = 100 \left( 1 - \frac{\cos(\Phi + \Delta\Phi)}{\cos(\Phi)} \right)$$

For example: For a PF of .9205 (Φ = 23) and a phase uncertainty of ΔΦ = 0.15, the ac watts power adder is:

$$Adder(\%) = 100 \left( 1 - \frac{\cos(23 + .15)}{\cos(23)} \right) = 0.11\%$$

### AC and DC Power Specifications

Power is simulated through the controlled simultaneous outputs of voltage and current from the Calibrator. While the amplitude and frequency ranges of the outputs are broad, there are certain combinations of voltage and current where the specifications are valid. In general these are for all dc voltages and currents, and AC voltages of 30 mV to 1020 V, ac currents from 33 mA to 20.5 A, for frequencies from 10 Hz to 30 kHz. Operation outside of these areas, within the overall calibrator capabilities, is possible, but it is not specified. The table and figure below illustrate the specified areas where power and dual output are possible.

### Specification Limits for Power and Dual Output Operation

| Frequency       | Voltages (NORMAL)  | Currents            | Voltages (AUX)   | Power Factor (PF) |
|-----------------|--------------------|---------------------|------------------|-------------------|
| dc              | 0 to ±1020 V       | 0 to ±20.5 A        | 0 to ±7 V        | —                 |
| 10 to 45 Hz     | 33 mV to 32.9999 V | 3.3 mA to 2.99999 A | 10 mV to 5 V     | 0 to 1            |
| 45 to 65 Hz     | 33 mV to 1020 V    | 3.3 mA to 20.5 A    | 10 mV to 5 V     | 0 to 1            |
| 65 to 500 Hz    | 330 mV to 1020 V   | 33 mA to 2.99999 A  | 100 mV to 5 V    | 0 to 1            |
| 65 to 500 Hz    | 3.3 to 1020 V      | 33 mA to 20.5 A     | 100 mV to 5 V    | 0 to 1            |
| 500 Hz to 1 kHz | 330 mV to 1020 V   | 33 mA to 20.5 A     | 100 mV to 5 V    | 0 to 1            |
| 1 to 5 kHz      | 3.3 to 500 V       | 33 mA to 2.99999 A  | 100 mV to 5 V    | 0 to 1            |
| 5 to 10 kHz     | 3.3 to 250 V       | 33 to 329.99 mA     | 1 to 5 V         | 0 to 1            |
| 10 to 30 kHz    | 3.3 V to 250 V     | 33 mA to 329.99 mA  | 1 V to 3.29999 V | 0 to 1            |

#### Notes

The range of voltages and currents shown in "DC Voltage Specifications," "DC Current Specifications," "AC Voltage (Sine Wave) Specifications," and "AC Current (Sine Wave) Specifications" are available in the power and dual output modes (except minimum current for ac power is 0.33 mA). Only those limits shown in this table and illustrated in the following figure are specified.

See "Calculate Power Uncertainty" to determine the uncertainty at these points.

The phase adjustment range for dual ac outputs is 0 ° to ±179.99 °. The phase resolution for dual ac outputs is 0.01 °.

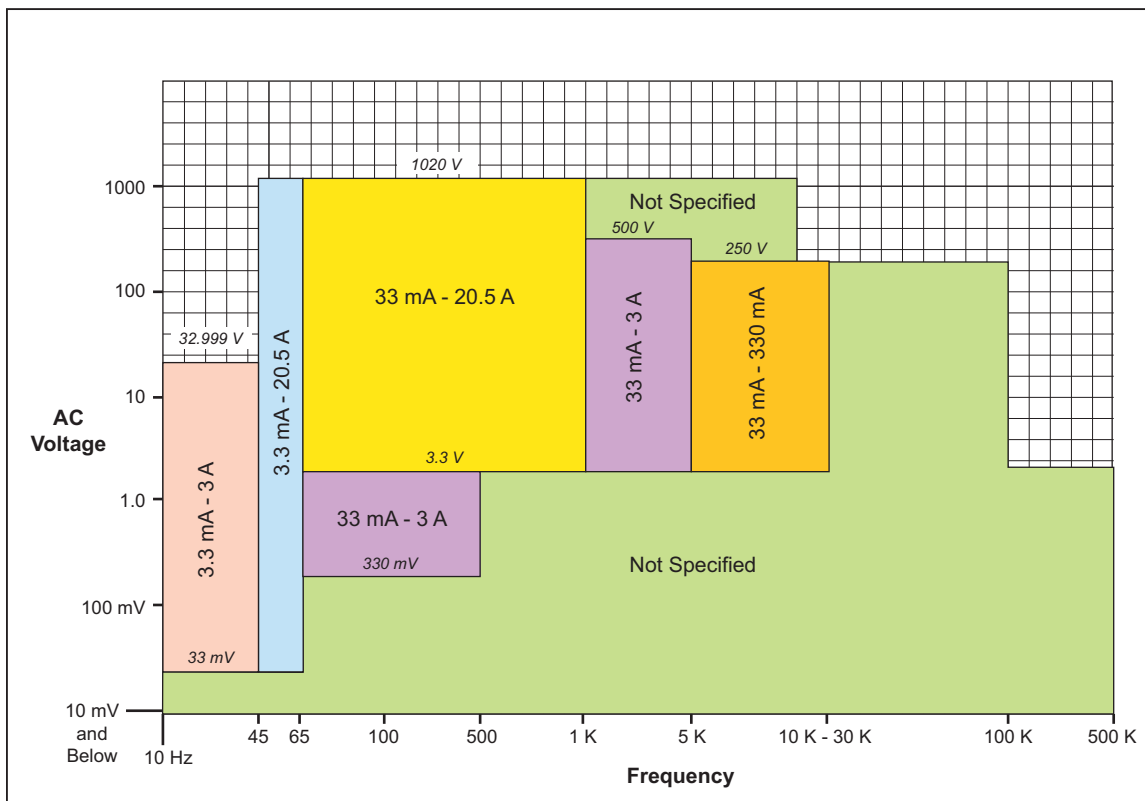


**Figure 1-4. Permissible Combinations of AC Voltage and AC Current for Power and Dual Output**

### **Calculate the Uncertainty Specifications of Power and Dual Output Settings**

Overall uncertainty for power output in watts (or VARs) is based on the root sum square (rss) of the individual uncertainties in percent for the selected voltage, current, and, if AC power, the phase parameters:

$$\text{Watts uncertainty } U_{\text{power}} = \sqrt{U^2_{\text{Voltage}} + U^2_{\text{Current}} + U^2_{\text{Phase}}}$$

$$\text{VARs uncertainty } U_{\text{VARs}} = \sqrt{U^2_{\text{Voltage}} + U^2_{\text{Current}} + U^2_{\text{Phase}}}$$

$$\text{Dual Output uncertainty } U_{\text{Dual}} = \sqrt{U^2_{\text{Voltage}} + U^2_{\text{AuxVoltage}} + U^2_{\text{Phase}}}$$

Because there are an infinite number of combinations, you must calculate the actual ac power uncertainty for your selected parameters. The results of this method of calculation are shown in the subsequent example. These examples are at various selected calibrator settings (with 1-year specifications):

**Examples of Specified Power Uncertainties at Various Output Settings:**

| Selected Output Settings |                        |              |                             |                         |                        | Absolute Uncertainty as specified for tcal ±5 °C, ±(% of output setting) |                      |                    | Power Absolute Uncertainty ±(% of Watts) <sup>[1]</sup> |
|--------------------------|------------------------|--------------|-----------------------------|-------------------------|------------------------|--------------------------------------------------------------------------|----------------------|--------------------|---------------------------------------------------------|
| Voltage Setting (Volts)  | Current Setting (Amps) | Frequency Hz | Phase Setting (units of PF) | Phase Setting (Degrees) | Selected Power (Watts) | U <sub>Voltage</sub>                                                     | U <sub>Current</sub> | U <sub>Phase</sub> | U <sub>Power</sub>                                      |
| +10.000                  | +0.500.000             | DC           |                             |                         | 5                      | 0.00550 %                                                                | 0.04680 %            |                    | 0.047 %                                                 |
| 15.000                   | +2.0000                | DC           |                             |                         | 30                     | 0.00533 %                                                                | 0.03220 %            |                    | 0.033 %                                                 |
| 100.000                  | +20.000                | DC           |                             |                         | 2000                   | 0.00600 %                                                                | 0.10375 %            |                    | 0.104 %                                                 |
| 1000.00                  | 20.000                 | DC           |                             |                         | 20000                  | 0.00565 %                                                                | 0.10375 %            |                    | 0.104 %                                                 |
| 120.000                  | 1.00000                | 60           | 1                           | 0.0                     | 120                    | 0.05250 %                                                                | 0.06000 %            | 0.000 %            | 0.080 %                                                 |
| 120.000                  | 1.00000                | 60           | 0.766                       | 40.0                    | 91.92                  | 0.05250 %                                                                | 0.06000 %            | 0.220 %            | 0.234 %                                                 |
| 240.000                  | 1.00000                | 50           | 1                           | 0.0                     | 240                    | 0.05125 %                                                                | 0.06000 %            | 0.000 %            | 0.079 %                                                 |
| 240.000                  | 1.00000                | 50           | 0.766                       | 40.0                    | 183.84                 | 0.05125 %                                                                | 0.06000 %            | 0.220 %            | 0.234 %                                                 |
| 1000.00                  | 20                     | 55           | 1                           | 0.0                     | 20000                  | 0.05200 %                                                                | 0.14500 %            | 0.000 %            | 0.154 %                                                 |
| 1000.00                  | 20                     | 55           | 0.766                       | 40.0                    | 15320                  | 0.05200 %                                                                | 0.14500 %            | 0.220 %            | 0.269 %                                                 |
| 1000.00                  | 20                     | 55           | -0.906                      | -25.0                   | 18120                  | 0.05200 %                                                                | 0.14500 %            | 0.122 %            | 0.196 %                                                 |
| 100                      | 0.30                   | 30000        | 1                           | 0.0                     | 30.0                   | 0.12900 %                                                                | 0.4667 %             | 3.407 %            | 3.442 %                                                 |
| 100                      | 0.30                   | 30000        | 0.766                       | 40.0                    | 22.98                  | 0.12900 %                                                                | 0.4667 %             | 25.128 %           | 25.133 %                                                |

[1] Add 0.02 % unless a settling time of 30 seconds is allowed for output currents >10 A or for currents on the highest two current ranges within 30 seconds of an output current >10 A.

**Calculate Power Uncertainty**

Overall uncertainty for power output in watts (or VARs) is based on the root sum square (RSS) of the individual uncertainties in percent for the selected voltage, current, and phase parameters:

$$\text{Watts uncertainty } U_{\text{Power}} = \sqrt{U_{\text{Voltage}}^2 + U_{\text{Current}}^2 + U_{\text{Phase}}^2}$$

$$\text{VARs uncertainty } U_{\text{VARs}} = \sqrt{U_{\text{Voltage}}^2 + U_{\text{Current}}^2 + U_{\text{Phase}}^2}$$

Because there are an infinite number of combinations, you must calculate the actual ac power uncertainty for your selected parameters. The method of calculation is best shown in the subsequent examples (with 1-year specifications):

**Example 1** Output: 100 V, 1 A, 60 Hz, Power Factor = 1.0 (Φ=0).

**Voltage Uncertainty** Uncertainty for 100 V at 60 Hz is 0.050 % + 3 mV, totaling: 100 V x .00005 = 50 mV added to 3 mV = 53 mV. Expressed in percent: 53 mV/100 V x 100 = 0.053 % (see "AC Voltage (Sine Wave) Specifications").

**Current Uncertainty** Uncertainty for 1 A at 60 Hz is 0.05 % +100 μA, totaling: 1 A x 0.0005 = 500 μA added to 100 μA = 0.6 mA. Expressed in percent: 0.6 mA/1 A x 100 = 0.06 % (see "AC Current (Sine Waves) Specifications").

**Phase Uncertainty** (Watts) Adder for PF = 1 (Φ=0) at 60 Hz is 0 % (see "Phase Specifications").

$$\text{Total Power Uncertainty} = U_{\text{power}} = \sqrt{0.053^2 + 0.06^2 + 0^2} = 0.080\%$$

**Example 2** Output: 100 V, 1 A, 400 Hz, Power Factor = 0.5 (Φ=60)

**Voltage Uncertainty** Uncertainty for 100 V at 400 Hz is 0.050% + 3 mV, totaling: 100 V x .00005 = 50 mV added to 3 mV = 53 mV. Expressed in percent: 53 mV/100 V x 100 = 0.053 % (see "AC Voltage (Sine Wave) Specifications").

**Current Uncertainty** Uncertainty for 1 A at 400 Hz is 0.05 % +100 μA, totaling: 1 A x 0.0005 = 500 μA added to 100 μA = 0.6 mA. Expressed in percent: 0.6 mA/1 A x 100 = 0.06 % (see "AC Current (Sine Waves) Specifications").

**Phase Uncertainty** (Watts) Adder for PF = 0.5 (Φ=60) at 400 Hz is 2.73 % (see "Phase Specifications").

$$\text{Total Power Uncertainty} = U_{\text{power}} = \sqrt{0.021^2 + 0.06^2 + 2.73^2} = 2.73\%$$

**VARs** When the Power Factor approaches 0.0, the Watts output uncertainty becomes unrealistic because the dominant characteristic is the VARs (volts-amps-reactive) output. In these cases, calculate the Total VARs Output Uncertainty, as shown in example 3:

**Example 3** Output: 100 V, 1 A, 60 Hz, Power Factor = 0.174 (Φ=80)

**Voltage Uncertainty** Uncertainty for 100 V at 60 Hz is 0.050% + 3 mV, totaling: 100 V x .00005 = 50 mV added to 3 mV = 53 mV. Expressed in percent: 53 mV/100 V x 100 = 0.053 % (see "AC Voltage (Sine Wave) Specifications").

**Current Uncertainty** Uncertainty for 1 A at 60 Hz is 0.05 % +100 μA, totaling: 1 A x 0.0005 = 500 μA added to 100 μA = 0.6 mA. Expressed in percent: 0.6 mA/1 A x 100 = 0.06 % (see "AC Current (Sine Waves) Specifications").

**Phase Uncertainty (VARs)** Adder for  $\Phi=80$  at 60 Hz is 0.05 % (see “Phase Specifications”).

$$\text{Total VARS Uncertainty} = U_{\text{VARs}} = \sqrt{0.053^2 + 0.06^2 + 0.05^2} = 0.094 \%$$

## Additional Specifications

The subsequent paragraphs provide additional specifications for the 5502A Calibrator ac voltage and ac current functions. These specifications are valid after allowing a warm-up period of 30 minutes, or twice the time the 5502A has been turned off. All extended range specifications are based on performing the internal zero-cal function at weekly intervals, or when the ambient temperature changes by more than 5 °C.

### Frequency

| Frequency Range     | Resolution | 1-Year Absolute Uncertainty, tcal<br>±5 °C ±(ppm + mHz) | Jitter |
|---------------------|------------|---------------------------------------------------------|--------|
| 0.01 to 119.99 Hz   | 0.01 Hz    | 25 + 1                                                  | 2 μs   |
| 120.0 to 1199.9 Hz  | 0.1 Hz     | 25 + 1                                                  | 2 μs   |
| 1.2 to 11.999 kHz   | 1 Hz       | 25 + 1                                                  | 2 μs   |
| 12 to 119.99 kHz    | 10 Hz      | 25 + 15                                                 | 140 ns |
| 120.0 to 1199.9 kHz | 100 Hz     | 25 + 15                                                 | 140 ns |
| 1.2 to 2.000 MHz    | 1 kHz      | 25 + 15                                                 | 140 ns |

### Harmonics (2<sup>nd</sup> to 50<sup>th</sup>)

| Fundamental Frequency <sup>[1]</sup>                                                                                                                                                                                                                                                                                                                              | Voltages NORMAL Terminals | Currents            | Voltages AUX Terminals | Amplitude Uncertainty                                                        |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|---------------------|------------------------|------------------------------------------------------------------------------|
| 10 to 45 Hz                                                                                                                                                                                                                                                                                                                                                       | 33 mV to 32.9999 V        | 3.3 mA to 2.99999 A | 10 mV to 5 V           | Same % of output as the equivalent single output, but twice the floor adder. |
| 45 to 65 Hz                                                                                                                                                                                                                                                                                                                                                       | 33 mV to 1020 V           | 3.3 mA to 20.5 A    | 10 mV to 5 V           |                                                                              |
| 65 to 500 Hz                                                                                                                                                                                                                                                                                                                                                      | 33 mV to 1020 V           | 33 mA to 20.5 A     | 100 mV to 5 V          |                                                                              |
| 500 Hz to 5 kHz                                                                                                                                                                                                                                                                                                                                                   | 330 mV to 1020 V          | 33 mA to 20.5 A     | 100 mV to 5 V          |                                                                              |
| 5 to 10 kHz                                                                                                                                                                                                                                                                                                                                                       | 3.3 to 1020 V             | 33 to 329.9999 mA   | 100 mV to 5 V          |                                                                              |
| 10 to 30 kHz                                                                                                                                                                                                                                                                                                                                                      | 3.3 to 1020 V             | 33 to 329.9999 mA   | 100 mV to 3.29999 V    |                                                                              |
| [1] The maximum frequency of the harmonic output is 30 kHz (10 kHz for 3.3 to 5 V on the Aux terminals). For example, if the fundamental output is 5 kHz, the maximum selection is the 6th harmonic (30 kHz). All harmonic frequencies (2nd to 50th) are available for fundamental outputs between 10 Hz and 600 Hz (200 Hz for 3.3 to 5 V on the Aux terminals). |                           |                     |                        |                                                                              |

**Phase Uncertainty**..... Phase uncertainty for harmonic outputs is 1 degree or the phase uncertainty shown in “Phase Specifications” for the particular output, whichever is greater. For example, the phase uncertainty of a 400 Hz fundamental output and 10 kHz harmonic output is 10 ° (from “Phase Specifications”). Another example, the phase uncertainty of a 50 Hz fundamental output and a 400 Hz harmonic output is 1 degree.

#### Example of determining Amplitude Uncertainty in a Dual Output Harmonic Mode

What are the amplitude uncertainties for the following dual outputs?

NORMAL (Fundamental) Output:

100 V, 100 Hz ..... From “AC Voltage (Sine Wave) 90 Day Specifications” the single output specification for 100 V, 100 Hz, is 0.039 % + 3 mV. For the dual output in this example, the specification is 0.039 % + 6 mV as the 0.039 % is the same, and the floor is twice the value (2 x 3 mV).

AUX (50th Harmonic) Output:

100 mV, 5 kHz ..... From “AC Voltage (Sine Wave) 90 Day Specifications” the auxiliary output specification for 100 mV, 5 kHz, is 0.15 % + 450 μV. For the dual output in this example, the specification is 0.15 % + 900 μV as the 0.15 % is the same, and the floor is twice the value (2 x 450 μV).

**AC Voltage (Sine Wave) Extended Bandwidth**

| Range                               | Frequency          | 1-Year Absolute Uncertainty<br>tcal ±5 °C | Max Voltage Resolution  |
|-------------------------------------|--------------------|-------------------------------------------|-------------------------|
| Normal Channel (Single Output Mode) |                    |                                           |                         |
| 1.0 to 33 mV                        | 0.01 to 9.99 Hz    | ±(5.0 % of output<br>+0.5 % of range)     | Two digits, e.g., 25 mV |
| 34 to 330 mV                        |                    |                                           | Three digits            |
| 0.4 to 33 V                         |                    |                                           | Two digits              |
| 0.3 to 3.3 V                        | 500.1 kHz to 1 MHz | -10 dB at 1 MHz, typical                  | Two digits              |
|                                     | 1.001 to 2 MHz     | -31 dB at 2 MHz, typical                  |                         |
| Auxiliary Output (Dual Output Mode) |                    |                                           |                         |
| 10 to 330 mV                        | 0.01 to 9.99 Hz    | ±(5.0 % of output<br>+0.5 % of range)     | Three digits            |
| 0.4 to 5 V                          |                    |                                           | Two digits              |

**AC Voltage (Non-Sine Wave)**

| Triangle Wave & Truncated Sine Range, p-p <sup>[1]</sup>                                                                                                                                                                                                                                                                                                                    | Frequency                    | 1-Year Absolute Uncertainty, tcal ±5 °C, ±(% of output + % of range) <sup>[2]</sup> | Max Voltage Resolution   |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|-------------------------------------------------------------------------------------|--------------------------|
| Normal Channel (Single Output Mode)                                                                                                                                                                                                                                                                                                                                         |                              |                                                                                     |                          |
| 2.9 to 92.999 mV                                                                                                                                                                                                                                                                                                                                                            | 0.01 to 10 Hz                | 5.0 + 0.5                                                                           | Two digits on each range |
|                                                                                                                                                                                                                                                                                                                                                                             | 10 to 45 Hz                  | 0.25 + 0.5                                                                          | Six digits on each range |
|                                                                                                                                                                                                                                                                                                                                                                             | 45 Hz to 1 kHz               | 0.25 + 0.25                                                                         |                          |
|                                                                                                                                                                                                                                                                                                                                                                             | 1 to 20 kHz                  | 0.5 + 0.25                                                                          |                          |
|                                                                                                                                                                                                                                                                                                                                                                             | 20 to 100 kHz <sup>[3]</sup> | 5.0 + 0.5                                                                           |                          |
| 93 to 929.999 mV                                                                                                                                                                                                                                                                                                                                                            | 0.01 to 10 Hz                | 5.0 + 0.5                                                                           | Two digits on each range |
|                                                                                                                                                                                                                                                                                                                                                                             | 10 to 45 Hz                  | 0.25 + 0.5                                                                          | Six digits on each range |
|                                                                                                                                                                                                                                                                                                                                                                             | 45 Hz to 1 kHz               | 0.25 + 0.25                                                                         |                          |
|                                                                                                                                                                                                                                                                                                                                                                             | 1 to 20 kHz                  | 0.5 + 0.25                                                                          |                          |
|                                                                                                                                                                                                                                                                                                                                                                             | 20 to 100 kHz <sup>[3]</sup> | 5.0 + 0.5                                                                           |                          |
| 0.93 to 9.29999 V                                                                                                                                                                                                                                                                                                                                                           | 0.01 to 10 Hz                | 5.0 + 0.5                                                                           | Two digits on each range |
|                                                                                                                                                                                                                                                                                                                                                                             | 10 to 45 Hz                  | 0.25 + 0.5                                                                          | Six digits on each range |
|                                                                                                                                                                                                                                                                                                                                                                             | 45 Hz to 1 kHz               | 0.25 + 0.25                                                                         |                          |
|                                                                                                                                                                                                                                                                                                                                                                             | 1 to 20 kHz                  | 0.5 + 0.25                                                                          |                          |
|                                                                                                                                                                                                                                                                                                                                                                             | 20 to 100 kHz <sup>[3]</sup> | 5.0 + 0.5                                                                           |                          |
| 9.3 to 93 V                                                                                                                                                                                                                                                                                                                                                                 | 0.01 to 10 Hz                | 5.0 + 0.5                                                                           | Two digits on each range |
|                                                                                                                                                                                                                                                                                                                                                                             | 10 to 45 Hz                  | 0.25 + 0.5                                                                          | Six digits on each range |
|                                                                                                                                                                                                                                                                                                                                                                             | 45 Hz to 1 kHz               | 0.25 + 0.25                                                                         |                          |
|                                                                                                                                                                                                                                                                                                                                                                             | 1 to 20 kHz                  | 0.5 + 0.25                                                                          |                          |
|                                                                                                                                                                                                                                                                                                                                                                             | 20 to 100 kHz <sup>[3]</sup> | 5.0 + 0.5                                                                           |                          |
| Auxiliary Output (Dual Output Mode)                                                                                                                                                                                                                                                                                                                                         |                              |                                                                                     |                          |
| 29 to 929.999 mV                                                                                                                                                                                                                                                                                                                                                            | 0.01 to 10 Hz                | 5.0 + 0.5                                                                           | Two digits on each range |
|                                                                                                                                                                                                                                                                                                                                                                             | 10 to 45 Hz                  | 0.25 + 0.5                                                                          | Six digits on each range |
|                                                                                                                                                                                                                                                                                                                                                                             | 45 Hz to 1 kHz               | 0.25 + 0.25                                                                         |                          |
|                                                                                                                                                                                                                                                                                                                                                                             | 1 to 10 kHz                  | 5.0 + 0.5                                                                           |                          |
| 0.93 to 9.29999 V                                                                                                                                                                                                                                                                                                                                                           | 0.01 to 10 Hz                | 5.0 + 0.5                                                                           | Two digits on each range |
|                                                                                                                                                                                                                                                                                                                                                                             | 10 to 45 Hz                  | 0.25 + 0.5                                                                          | Six digits on each range |
|                                                                                                                                                                                                                                                                                                                                                                             | 45 Hz to 1 kHz               | 0.25 + 0.25                                                                         |                          |
|                                                                                                                                                                                                                                                                                                                                                                             | 1 to 10 kHz                  | 5.0 + 0.5                                                                           |                          |
| 9.3 to 14.0000 V                                                                                                                                                                                                                                                                                                                                                            | 0.01 to 10 Hz                | 5.0 + 0.5                                                                           | Two digits on each range |
|                                                                                                                                                                                                                                                                                                                                                                             | 10 to 45 Hz                  | 0.25 + 0.5                                                                          | Six digits on each range |
|                                                                                                                                                                                                                                                                                                                                                                             | 45 Hz to 1 kHz               | 0.25 + 0.25                                                                         |                          |
|                                                                                                                                                                                                                                                                                                                                                                             | 1 to 10 kHz                  | 5.0 + 0.5                                                                           |                          |
| <div>[1] To convert p-p to rms for triangle wave, multiply the p-p value by 0.2886751. To convert p-p to rms for truncated sine wave, multiply the p-p value by 0.2165063.</div> <div>[2] Uncertainty is stated in p-p. Amplitude is verified using an rms-responding DMM.</div> <div>[3] Uncertainty for Truncated Sine outputs is typical over this frequency band.</div> |                              |                                                                                     |                          |



**AC Voltage (Non-Sine Wave) (cont.)**

| Square Wave Range (p-p) <sup>[1]</sup>                                                                                                                                                                                                                 | Frequency                  | 1-Year Absolute Uncertainty, tcal<br>±5 °C, ±(% of output + % of range) <sup>[2]</sup> | Max Voltage Resolution   |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|----------------------------------------------------------------------------------------|--------------------------|
| Normal Channel (Single Output Mode)                                                                                                                                                                                                                    |                            |                                                                                        |                          |
| 2.9 to 65.999 mV                                                                                                                                                                                                                                       | 0.01 to 10 Hz              | 5.0 + 0.5                                                                              | Two digits on each range |
|                                                                                                                                                                                                                                                        | 10 to 45 Hz                | 0.25 + 0.5                                                                             | Six digits on each range |
|                                                                                                                                                                                                                                                        | 45 Hz to 1 kHz             | 0.25 + 0.25                                                                            |                          |
|                                                                                                                                                                                                                                                        | 1 to 20 kHz                | 0.5 + 0.25                                                                             |                          |
|                                                                                                                                                                                                                                                        | 20 to 100 kHz              | 5.0 + 0.5                                                                              |                          |
| 66 to 659.999 mV                                                                                                                                                                                                                                       | 0.01 to 10 Hz              | 5.0 + 0.5                                                                              | Two digits on each range |
|                                                                                                                                                                                                                                                        | 10 to 45 Hz                | 0.25 + 0.5                                                                             | Six digits on each range |
|                                                                                                                                                                                                                                                        | 45 Hz to 1 kHz             | 0.25 + 0.25                                                                            |                          |
|                                                                                                                                                                                                                                                        | 1 to 20 kHz                | 0.5 + 0.25                                                                             |                          |
|                                                                                                                                                                                                                                                        | 20 to 100 kHz              | 5.0 + 0.5                                                                              |                          |
| 0.66 to 6.59999 V                                                                                                                                                                                                                                      | 0.01 to 10 Hz              | 5.0 + 0.5                                                                              | Two digits on each range |
|                                                                                                                                                                                                                                                        | 10 to 45 Hz                | 0.25 + 0.5                                                                             | Six digits on each range |
|                                                                                                                                                                                                                                                        | 45 Hz to 1 kHz             | 0.25 + 0.25                                                                            |                          |
|                                                                                                                                                                                                                                                        | 1 to 20 kHz                | 0.5 + 0.25                                                                             |                          |
|                                                                                                                                                                                                                                                        | 20 to 100 kHz              | 5.0 + 0.5                                                                              |                          |
| 6.6 to 66.0000 V                                                                                                                                                                                                                                       | 0.01 to 10 Hz              | 5.0 + 0.5                                                                              | Two digits on each range |
|                                                                                                                                                                                                                                                        | 10 to 45 Hz                | 0.25 + 0.5                                                                             | Six digits on each range |
|                                                                                                                                                                                                                                                        | 45 Hz to 1 kHz             | 0.25 + 0.25                                                                            |                          |
|                                                                                                                                                                                                                                                        | 1 to 20 kHz                | 0.5 + 0.25                                                                             |                          |
|                                                                                                                                                                                                                                                        | 20 to 100 kHz              | 5.0 + 0.5                                                                              |                          |
| Auxiliary Output (Dual Output Mode)                                                                                                                                                                                                                    |                            |                                                                                        |                          |
| 29 to 659.999 mV                                                                                                                                                                                                                                       | 0.01 to 10 Hz              | 5.0 + 0.5                                                                              | Two digits on each range |
|                                                                                                                                                                                                                                                        | 10 to 45 Hz                | 0.25 + 0.5                                                                             | Six digits on each range |
|                                                                                                                                                                                                                                                        | 45 Hz to 1 kHz             | 0.25 + 0.25                                                                            |                          |
|                                                                                                                                                                                                                                                        | 1 to 10 kHz <sup>[3]</sup> | 5.0 + 0.5                                                                              |                          |
| 0.66 to 6.59999 V                                                                                                                                                                                                                                      | 0.01 to 10 Hz              | 5.0 + 0.5                                                                              | Two digits on each range |
|                                                                                                                                                                                                                                                        | 10 to 45 Hz                | 0.25 + 0.5                                                                             | Six digits on each range |
|                                                                                                                                                                                                                                                        | 45 Hz to 1 kHz             | 0.25 + 0.25                                                                            |                          |
|                                                                                                                                                                                                                                                        | 1 to 10 kHz <sup>[3]</sup> | 5.0 + 0.5                                                                              |                          |
| 6.6 to 14.0000 V                                                                                                                                                                                                                                       | 0.01 to 10 Hz              | 5.0 + 0.5                                                                              | Two digits on each range |
|                                                                                                                                                                                                                                                        | 10 to 45 Hz                | 0.25 + 0.5                                                                             | Six digits on each range |
|                                                                                                                                                                                                                                                        | 45 Hz to 1 kHz             | 0.25 + 0.25                                                                            |                          |
|                                                                                                                                                                                                                                                        | 1 to 10 kHz <sup>[3]</sup> | 5.0 + 0.5                                                                              |                          |
| <div>[1] To convert p-p to rms for square wave, multiply the p-p value by 0.5.</div> <div>[2] Uncertainty is stated in p-p. Amplitude is verified using an rms-responding DMM.</div> <div>[3] Limited to 1 kHz for Auxiliary outputs ≥6.6 V p-p.</div> |                            |                                                                                        |                          |

**AC Voltage, DC Offset**

| Range <sup>[1]</sup> (Normal Channel)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Offset Range <sup>[2]</sup> | Max Peak Signal | 1-Year Absolute Uncertainty, tcal<br>$\pm 5^\circ\text{C}$ <sup>[3]</sup> $\pm(\%$ of dc output + floor) |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|-----------------|----------------------------------------------------------------------------------------------------------|
| <b>Sine Waves (rms)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                             |                 |                                                                                                          |
| 3.3 to 32.999 mV                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 0 to 50 mV                  | 80 mV           | 0.1 + 33 $\mu\text{V}$                                                                                   |
| 33 to 329.999 mV                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 0 to 500 mV                 | 800 mV          | 0.1 + 330 $\mu\text{V}$                                                                                  |
| 0.33 to 3.29999 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 0 to 5 V                    | 8 V             | 0.1 + 3300 $\mu\text{V}$                                                                                 |
| 3.3 to 32.9999 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 0 to 50 V                   | 55 V            | 0.1 + 33 mV                                                                                              |
| <b>Triangle Waves and Truncated Sine Waves (p-p)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                             |                 |                                                                                                          |
| 9.3 to 92.999 mV                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 0 to 50 mV                  | 80 mV           | 0.1 + 93 $\mu\text{V}$                                                                                   |
| 93 to 929.999 mV                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 0 to 500 mV                 | 800 mV          | 0.1 + 930 $\mu\text{V}$                                                                                  |
| 0.93 to 9.29999 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 0 to 5 V                    | 8 V             | 0.1 + 9300 $\mu\text{V}$                                                                                 |
| 9.3 to 93.0000 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 0 to 50 V                   | 55 V            | 0.1 + 93 mV                                                                                              |
| <b>Square Waves (p-p)</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                             |                 |                                                                                                          |
| 6.6 to 65.999 mV                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 0 to 50 mV                  | 80 mV           | 0.1 + 66 $\mu\text{V}$                                                                                   |
| 66 to 659.999 mV                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 0 to 500 mV                 | 800 mV          | 0.1 + 660 $\mu\text{V}$                                                                                  |
| 0.66 to 6.59999 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 0 to 5 V                    | 8 V             | 0.1 + 6600 $\mu\text{V}$                                                                                 |
| 6.6 to 66.0000 V                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | 0 to 50 V                   | 55 V            | 0.1 + 66 mV                                                                                              |
| <p>[1] Offsets are not allowed on ranges above the highest range shown above.</p> <p>[2] The maximum offset value is determined by the difference between the peak value of the selected voltage output and the allowable maximum peak signal. For example, a 10 V p-p square wave output has a peak value of 5 V, allowing a maximum offset up to <math>\pm 50</math> V to not exceed the 55 V maximum peak signal. The maximum offset values shown above are for the minimum outputs in each range.</p> <p>[3] For frequencies 0.01 to 10 Hz, and 500 kHz to 2 MHz, the offset uncertainty is 5 % of output, <math>\pm 1</math> % of the offset range.</p> |                             |                 |                                                                                                          |

**AC Voltage, Square Wave Characteristics**

| Risetime @<br>1 kHz<br>Typical | Settling Time @<br>1 kHz Typical           | Overshoot<br>@ 1 kHz<br>Typical | Duty Cycle Range                              | Duty Cycle Uncertainty                                                                                                        |
|--------------------------------|--------------------------------------------|---------------------------------|-----------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|
| <1 $\mu\text{s}$               | <10 $\mu\text{s}$ to 1 % of<br>final value | <2 %                            | 1 % to 99 % <3.3 V p-p.<br>0.01 Hz to 100 kHz | $\pm(0.02$ % of period + 100 ns), 50 % duty cycle<br>$\pm(0.05$ % of period + 100 ns), other duty cycles<br>from 10 % to 90 % |

**AC Voltage, Triangle Wave Characteristics (typical)**

| Linearity to 1 kHz                          | Aberrations                                      |
|---------------------------------------------|--------------------------------------------------|
| 0.3 % of p-p value, from 10 % to 90 % point | <1 % of p-p value, with amplitude >50 % of range |

### AC Current (Non-Sine Wave)

| Triangle Wave & Truncated Sine Wave Range p-p                                                                      | Frequency       | 1-Year Absolute Uncertainty tcal $\pm 5^{\circ}\text{C}$<br>$\pm(\% \text{ of output} + \% \text{ of range})$ | Max Current Resolution |
|--------------------------------------------------------------------------------------------------------------------|-----------------|---------------------------------------------------------------------------------------------------------------|------------------------|
| 0.047 to 0.92999 mA <sup>[1]</sup>                                                                                 | 10 to 45 Hz     | 0.25 + 0.5                                                                                                    | Six digits             |
|                                                                                                                    | 45 Hz to 1 kHz  | 0.25 + 0.25                                                                                                   |                        |
|                                                                                                                    | 1 to 10 kHz     | 10 + 2                                                                                                        |                        |
| 0.93 to 9.29999 mA <sup>[1]</sup>                                                                                  | 10 to 45 Hz     | 0.25 + 0.5                                                                                                    | Six digits             |
|                                                                                                                    | 45 Hz to 1 kHz  | 0.25 + 0.25                                                                                                   |                        |
|                                                                                                                    | 1 to 10 kHz     | 10 + 2                                                                                                        |                        |
| 9.3 to 92.9999 mA <sup>[1]</sup>                                                                                   | 10 to 45 Hz     | 0.25 + 0.5                                                                                                    | Six digits             |
|                                                                                                                    | 45 Hz to 1 kHz  | 0.25 + 0.25                                                                                                   |                        |
|                                                                                                                    | 1 to 10 kHz     | 10 + 2                                                                                                        |                        |
| 93 to 929.999 mA <sup>[1]</sup>                                                                                    | 10 to 45 Hz     | 0.25 + 0.5                                                                                                    | Six digits             |
|                                                                                                                    | 45 Hz to 1 kHz  | 0.25 + 0.5                                                                                                    |                        |
|                                                                                                                    | 1 to 10 kHz     | 10 + 2                                                                                                        |                        |
| 0.93 to 8.49999 A <sup>[2]</sup>                                                                                   | 10 to 45 Hz     | 0.5 + 1.0                                                                                                     | Six digits             |
|                                                                                                                    | 45 Hz to 1 kHz  | 0.5 + 0.5                                                                                                     |                        |
|                                                                                                                    | 1 to 10 kHz     | 10 + 2                                                                                                        |                        |
| 8.5 to 57 A <sup>[2]</sup>                                                                                         | 45 to 500 Hz    | 0.5 + 0.5                                                                                                     | Six digits             |
|                                                                                                                    | 500 Hz to 1 kHz | 1.0 + 1.0                                                                                                     |                        |
| <div>[1] Frequency limited to 1 kHz with LCOMP on.</div> <div>[2] Frequency limited to 440 Hz with LCOMP on.</div> |                 |                                                                                                               |                        |

**AC Current (Non-Sine Wave) (cont.)**

| Square Wave Range p-p                                                                                              | Frequency       | 1-Year Absolute Uncertainty tcal $\pm 5^{\circ}\text{C}$<br>$\pm(\% \text{ of output} + \% \text{ of range})$ | Max Current Resolution |
|--------------------------------------------------------------------------------------------------------------------|-----------------|---------------------------------------------------------------------------------------------------------------|------------------------|
| 0.047 to 0.65999 mA <sup>[1]</sup>                                                                                 | 10 to 45 Hz     | 0.25 + 0.5                                                                                                    | Six digits             |
|                                                                                                                    | 45 Hz to 1 kHz  | 0.25 + 0.25                                                                                                   |                        |
|                                                                                                                    | 1 to 10 kHz     | 10 + 2                                                                                                        |                        |
| 0.66 to 6.59999 mA <sup>[1]</sup>                                                                                  | 10 to 45 Hz     | 0.25 + 0.5                                                                                                    | Six digits             |
|                                                                                                                    | 45 Hz to 1 kHz  | 0.25 + 0.25                                                                                                   |                        |
|                                                                                                                    | 1 to 10 kHz     | 10 + 2                                                                                                        |                        |
| 6.6 to 65.9999 mA <sup>[1]</sup>                                                                                   | 10 to 45 Hz     | 0.25 + 0.5                                                                                                    | Six digits             |
|                                                                                                                    | 45 Hz to 1 kHz  | 0.25 + 0.25                                                                                                   |                        |
|                                                                                                                    | 1 to 10 kHz     | 10 + 2                                                                                                        |                        |
| 66 to 659.999 mA <sup>[1]</sup>                                                                                    | 10 to 45 Hz     | 0.25 + 0.5                                                                                                    | Six digits             |
|                                                                                                                    | 45 Hz to 1 kHz  | 0.25 + 0.5                                                                                                    |                        |
|                                                                                                                    | 1 to 10 kHz     | 10 + 2                                                                                                        |                        |
| 0.66 to 5.99999 A <sup>[2]</sup>                                                                                   | 10 to 45 Hz     | 0.5 + 1.0                                                                                                     |                        |
|                                                                                                                    | 45 Hz to 1 kHz  | 0.5 + 0.5                                                                                                     |                        |
|                                                                                                                    | 1 to 10 kHz     | 10 + 2                                                                                                        |                        |
| 6 to 41 A <sup>[2]</sup>                                                                                           | 45 to 500 Hz    | 0.5 + 0.5                                                                                                     |                        |
|                                                                                                                    | 500 Hz to 1 kHz | 1.0 + 1.0                                                                                                     |                        |
| <div>[1] Frequency limited to 1 kHz with LCOMP on.</div> <div>[2] Frequency limited to 440 Hz with LCOMP on.</div> |                 |                                                                                                               |                        |

**AC Current, Square Wave Characteristics (typical)**

| Range             | LCOMP | Risetime          | Settling Time                           | Overshoot                 |
|-------------------|-------|-------------------|-----------------------------------------|---------------------------|
| I < 6 A @ 400 Hz  | off   | 25 $\mu\text{s}$  | 40 $\mu\text{s}$ to 1 % of final value  | <10 % for <1 V Compliance |
| 3 A & 20 A Ranges | on    | 100 $\mu\text{s}$ | 200 $\mu\text{s}$ to 1 % of final value | <10 % for <1 V Compliance |

**AC Current, Triangle Wave Characteristics (typical)**

| Linearity to 400 Hz                         | Aberrations                                      |
|---------------------------------------------|--------------------------------------------------|
| 0.3 % of p-p value, from 10 % to 90 % point | <1 % of p-p value, with amplitude >50 % of range |

## ***Chapter 2***

# ***Prepare for Operation***

| <b>Title</b>                | <b>Page</b> |
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| Unpack and Inspection.....  | 2-3         |
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## Introduction

This chapter has instructions to unpack and install the Calibrator, select the line voltage, replace the fuse, and connect to line power. Instructions for cable connections other than line power are in these chapters:

- UUT (Unit Under Test) connections: Chapter 4, “Front Panel Operation”
- IEEE-488 parallel interface connection: Chapter 5, “Remote Operation”
- RS-232 serial interface connection: Chapter 5, “Remote Operation”

### Warning

**To prevent possible electrical shock, fire, or personal injury:**

- **Properly terminate the sense leads to prevent exposure to hazardous voltages on the sense terminals. The voltage sense terminals are at output voltage when the two-wire function is set.**
- **Do not touch exposed metal on banana plugs, they can have voltages that could cause death.**
- **Do not use a two-conductor mains power cord unless you install a protective ground wire to the Product ground terminal before you operate the Product.**
- **Make sure that the Product is grounded before use.**

## Unpack and Inspection

The calibrator is shipped in a container to prevent damage. Examine the calibrator carefully for damage and immediately report damage to the shipper. Instructions for inspection and claims are included in the shipping container.

When you unpack the calibrator, make sure that you have all the standard equipment in Table 2-1. Examine the shipping list to make sure other items that you purchased are included. Refer to the “Accessories” section in Chapter 8 for more information. Report missing items to the point of purchase or to the nearest Fluke Calibration Service Center (see “Contact Fluke Calibration” in Chapter 1). A performance test is in the “Maintenance” section of Chapter 7.

If you ship the calibrator to Fluke Calibration, use the initial container. If it is not available, you can get a new container from Fluke Calibration with the Calibrator model and serial number.

**Table 2-1. Standard Equipment**

| Item                                    | Model or Part Number         |
|-----------------------------------------|------------------------------|
| Calibrator                              | 5502A                        |
| Mains Power Cord                        | See Table 2-2 and Figure 2-2 |
| <i>5502A Getting Started Manual</i>     | 4155209                      |
| <i>5502A Operators Manual</i> on CD-ROM | 4155227                      |

## Select Line Voltage

The calibrator comes from the factory configured for the line voltage typically applicable for the country of purchase, or as specified at the time of your purchase order. You can operate the Calibrator from one of four line-voltage settings: 100 V, 120 V, 200 V, and 240 V (47 Hz to 63 Hz). To verify the line-voltage setting, note the voltage setting that you can see through the window in the power-line fuse compartment cover (Figure 2-1). The permitted line-voltage variation is 10 % above or below the line-voltage setting.

To change the line-voltage setting, complete the following procedure:

1. **Disconnect line power.**
2. To open the fuse compartment, put a screwdriver blade in the tab on the left side of the compartment and pry until it can be removed.
3. To remove the line-voltage selector assembly, hold the line-voltage indicator tab with pliers and pull it straight out of its connector.
4. Turn the line-voltage selector assembly to the necessary voltage and reinsert.
5. Make sure to use the correct fuse for the selected line voltage (100 V/120 V, use 5 A/250 V slow blow, 220 V/240 V, use 2.5 A/250 V slow blow). To install the fuse compartment, push it into position until the tab locks.

## Connect to Line Power

### Warning

**To prevent possible electrical shock, fire, or personal injury:**

- **Do not use a two-conductor mains power cord unless you install a protective ground wire to the Product ground terminal before you operate the Product.**
- **Do not use an extension cord or adapter plug.**

Make sure that the Product is grounded before use. The calibrator is shipped with the correct line-power plug for the country of purchase. If it is necessary to use a different type, refer to Table 2-2 and Figure 2-2 for a list and illustration of the line-power plug types available from Fluke Calibration.

After you make sure that the line voltage selection is set correctly and that the correct fuse for that line voltage is installed, connect the calibrator to a correctly-grounded three-prong outlet.



## Select Line Frequency

The calibrator is shipped from the factory for nominal operation at 60 Hz line frequency. If you use 50 Hz line voltage, re-configure the Calibrator for optimal performance at 50 Hz. To do this:

1. From the front panel, go into SETUP, INSTMT SETUP, OTHER SETUP.
2. Push the softkey below MAINS to change the selection to 50 Hz.
3. Store the change.

After a correct instrument warmup (on for 30 minutes or longer), you must zero the complete instrument again. See the section on “Zero the Calibrator” in Chapter 4.

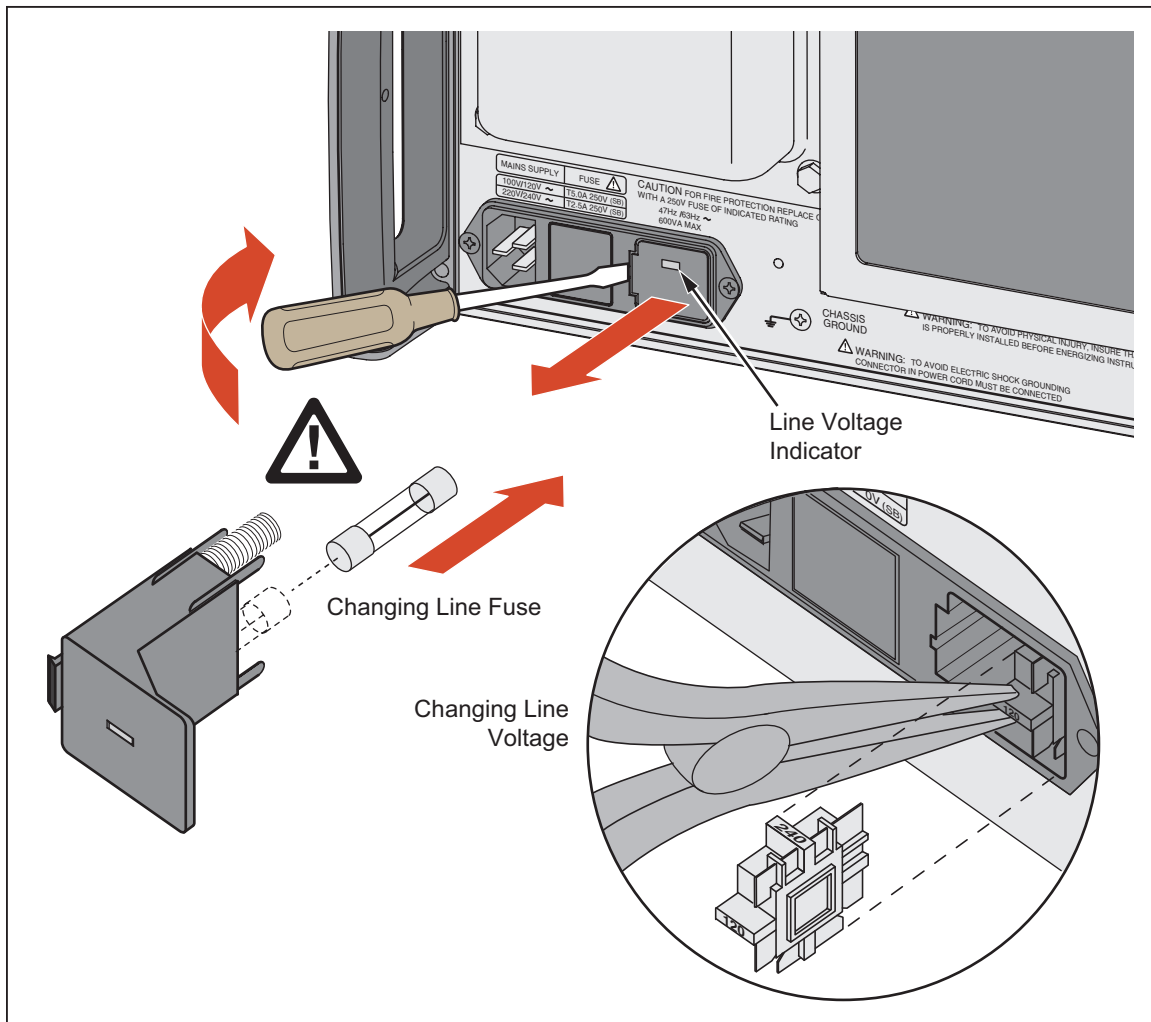
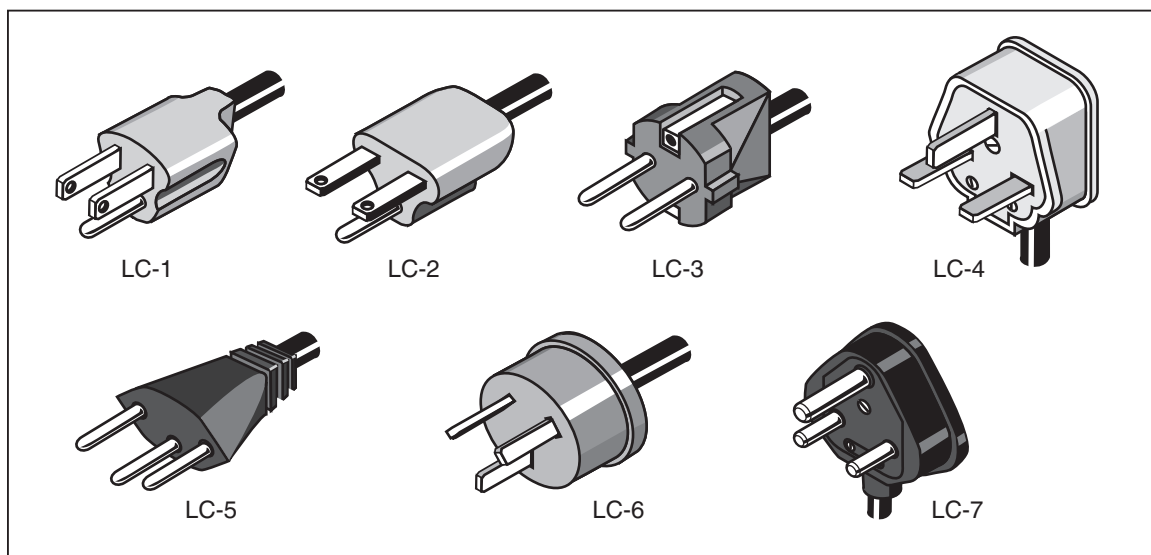


Figure 2-1. Access the Fuse and Select Line Voltage

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Table 2-2. Mains-Power Cord Types Available from Fluke Calibration

| Type           | Voltage/Current | Fluke Calibration Option Number |
|----------------|-----------------|---------------------------------|
| North America  | 120 V/15 A      | LC-1                            |
| North America  | 240 V/15 A      | LC-2                            |
| Universal Euro | 220 V/15 A      | LC-3                            |
| United Kingdom | 240 V/13 A      | LC-4                            |
| Switzerland    | 220 V/10 A      | LC-5                            |
| Australia      | 240 V/10 A      | LC-6                            |
| South Africa   | 240 V/5 A       | LC-7                            |



nn008f.eps

Figure 2-2. Mains-Power Cord Types Available from Fluke Calibration

## Placement

You can put the Product on a bench top or install it in a standard-width 24 inch (61 cm) depth equipment rack. For bench-top use, the Calibrator has a non-slip feet. To install the Calibrator in an equipment rack, use the 5502A Rack-Mount Kit, Model Y5537. Instructions to install the Calibrator into a rack come with the kit.

## **Airflow Considerations**

### **Warning**

**For safe operation and maintenance of the Product, make sure that the space around the Product meets minimum requirements.**

Baffles put cool air from the fan into the chassis to internally dissipate heat when the Calibrator is in operation. The accuracy and dependability of all internal parts of the calibrator are enhanced by a cool internal temperature. You can increase the life of the Calibrator and enhance its performance by these rules:

- The area around the air filter must be a minimum 3 inches from close walls or rack enclosures.
- The exhaust perforations on the sides of the Calibrator must be clear of blockage.
- The air that gets to the Calibrator must be at room temperature. Make sure the exhaust air from other instruments does not enter into the fan inlet.
- Clean the air filter after 30 days or more frequently if the calibrator is operated in a dusty environment. (See the “Maintenance” chapter for instructions to clean the air filter.)



## ***Chapter 3***

### ***Features***

| <b>Title</b>               | <b>Page</b> |
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| Front-Panel Features ..... | 3-3         |
| Rear-Panel Features .....  | 3-3         |
| Softkey Menu Trees.....    | 3-3         |



## Introduction

Refer to this chapter for the functions and locations of the 5502A Calibrator front and rear-panel features. Please read this information before you use the Calibrator. See the “Front-Panel Operation” section of Chapter 4 for front-panel operation instructions. For remote-operation instructions, see the “Remote Operation” section of Chapter 5.

## Front-Panel Features

Front-panel features (including all controls, displays, indicators, and terminals) are shown in Figure 3-1. Each front-panel feature is given in Table 3-1.

## Rear-Panel Features

Rear-panel features (including all terminals, sockets, and connectors) are shown in Figure 3-2. Each rear-panel feature is given in Table 3-2.

## Softkey Menu Trees

The Setup softkeys are identified in Figures 3-3 and 3-4. The Setup softkeys go with the Calibrator front-panel **SETUP** key. The functions of the five softkeys are identified by name information shown directly above each key. The softkey names change during operation so you can quickly access many different functions.

A group of softkey names is a menu. A group of connected menus is a menu tree. Figure 3-3 shows the SETUP menu tree structure. Figure 3-4 tells you about each SETUP menu tree display. Table 3-3 shows the factory-default parameters for the SETUP menu tree. To change the SETUP menus to their default values, use the softkey SETUP in the Format NV Memory menu (see Figure 3-4, menu F).

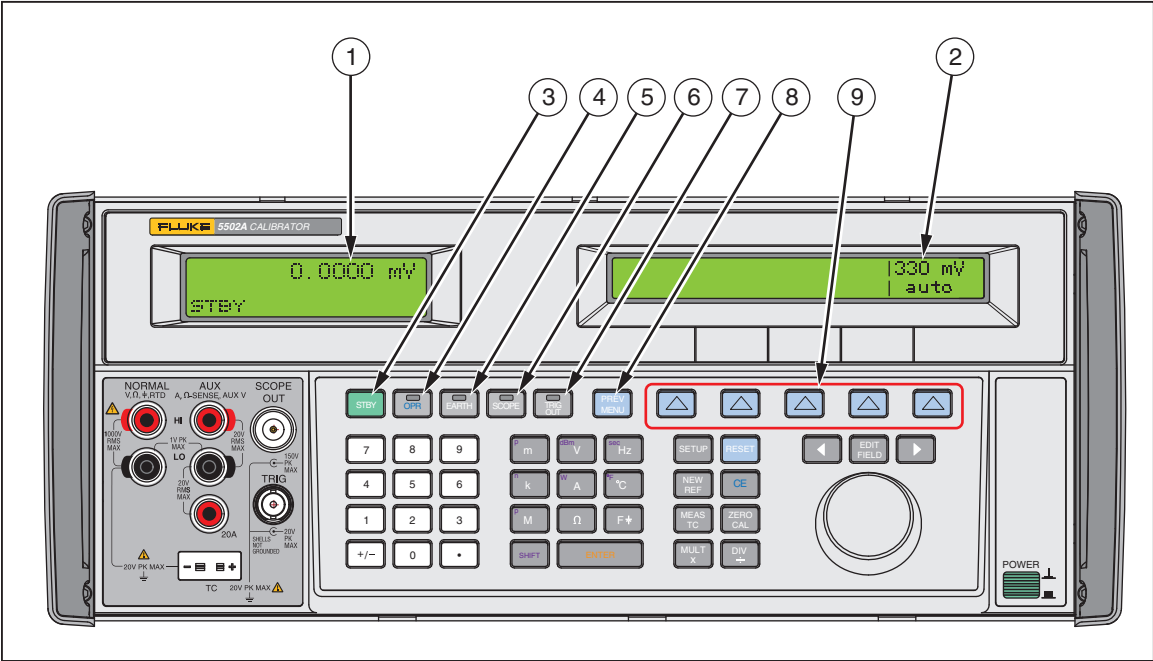


Figure 3-1. Front-Panel Features

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Table 3-1. Front-Panel Features

|   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|---|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 | <p><b>Output Display</b></p> <p>The <b>Output Display</b> is a two-line backlit LCD that shows output amplitudes, frequency, and calibrator status. Output values (or potential output values if in standby) are shown with a maximum of seven digits plus a polarity sign. Output frequencies (or potential output frequencies if the Calibrator is in standby) are shown with four digits. Calibrator status is shown by these abbreviations:</p> <p>OPR      Shown when an output is active at the front panel terminals.</p> <p>STBY      Shown when the Calibrator is in standby.</p> <p>u          When you change the output, “u” (unsettled) is shown until the output moves in to the specified accuracy.</p> <p>m          Shown while the Calibrator measures. (Thermocouple and impedance measurement only.)</p> <p>?          Shown when the amplitude is specified as typical only, and/or decreased resolution. This occurs when you operate the Calibrator in extended-bandwidth mode.</p> <p>C          Shown when the amplitude is specified as typical only, and/or decreased resolution. This occurs when you operate the Calibrator in extended-bandwidth mode.</p> |
| 2 | <p><b>Control Display</b></p> <p>The <b>Control Display</b> is a multipurpose backlit LCD used to show data entries, UUT error adjustments, softkey names, phase angles, watts, power factors, and other prompts and messages. When there is not room on the Output Display, output frequency is shown on the Control Display. Softkey names tell you the function of the softkey directly below them. Groups of softkey names together make a menu. The menus give access to many different functions with the five softkeys plus the PREV MENU key. (See Figure3-3, Softkey Menu Tree.)</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |



- ③ **STBY**

The **STBY** (Standby) key puts the Calibrator in standby mode. Standby mode is shown by “STBY” in the lower left corner of the Output Display. In standby mode, the **NORMAL**, **AUX** and **20A** output terminals are internally disconnected from the Calibrator. The Calibrator starts in standby mode. The Calibrator automatically changes to standby if:

  - **RESET** is pushed.
  - A voltage  $\geq 33$  V is selected when the previous output voltage was  $< 33$  V.
  - The output function changes. When you change from ac or dc voltage  $< 33$  V, the Calibrator does not change to STBY.
  - A current output more than 3 A is selected. This is when the output location changes to the **20A** terminal.
  - An overload condition is sensed.
- ④ **OPR**

The **OPR** (Operate) key puts the Calibrator in operate mode. Operate mode is shown by “OPR” in the lower left corner of the Output Display and the illuminated indicator on **OPR**.
- ⑤ **EARTH**

The **EARTH** (Earth Ground) key opens and closes an internal connection from the NORMAL LO terminal to earth ground. An indicator on the key shows when this connection is made. The power-up default condition is earth disabled (indicator off).
- ⑥ **SCOPE**

The **SCOPE** (Oscilloscope) key starts or stops an oscilloscope calibration option (if it is installed). An indicator on the key shows when the option is active. If an oscilloscope calibration option is not installed in the Calibrator and the **SCOPE** key is pushed, the calibrator shows an error message.
- ⑦ **TRIG OUT**

The **TRIG OUT** (Trigger Out) key sets the external trigger when in the scope mode. An indicator on the key shows when external trigger output is active. If the Calibrator is not in scope mode when **TRIG OUT** is pushed, the beeper will sound.
- ⑧ **PREV MENU**

The **PREV MENU** (Previous Menu) key recalls the previous set of menu selections. Each push of this key retreats up one level of the menu tree until the display shows the top-level menu selection of the function selected.
- ⑨ **Softkeys**

The functions of the five unlabeled blue softkeys are shown by names on the Control Display above each key. The functions change when in operation so that many different functions can be accessed with these keys. A group of softkey names is a menu. A group of connected menus is called a menu tree.

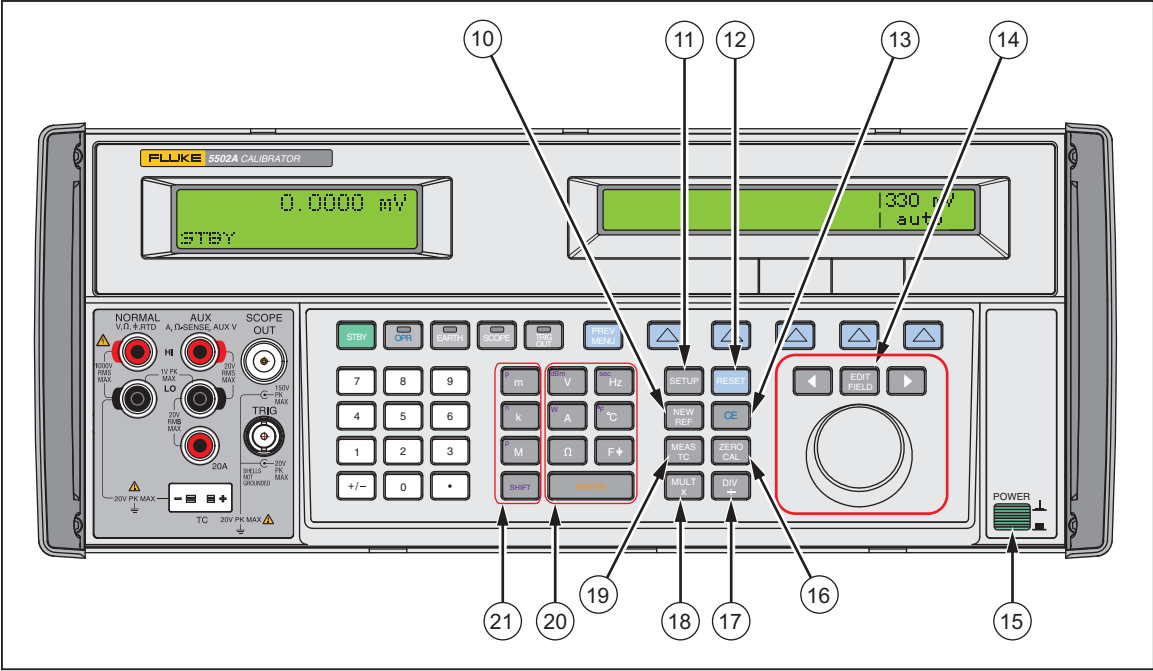


Figure 3-1. Front-Panel Features (cont.)

gvx009.eps

Table 3-1. Front-Panel Features (cont.)

|    |  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----|--|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 10 |  | The <b>NEW REF</b> (New Reference) key is active when error mode is in operation, and sets the current output value as a new reference for meter error computation.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 11 |  | The <b>SETUP</b> (Setup Menu) key puts the Calibrator into setup mode. The setup menu is shown in the Control Display. Choose Setup options with the softkeys below the Control Display.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 12 |  | The <b>RESET</b> (Reset Calibrator) key aborts the Calibrators current operation and changes it to the power-up default condition, except when it is used by remote control.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 13 |  | The <b>CE</b> (Clear Entry) key clears a partially-completed keypad entry from the Control Display. If there is a partially-completed entry when <b>CE</b> is pushed, the output is unaffected.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 14 |  | <p>The <b>EDIT FIELD</b> (Edit Output Display Field) key and its left/right arrow keys provide step adjustment of the output signals. If any of these keys are pushed or the knob is rotated, a digit on the Output Display is highlighted and the output increments or decrements as the knob is rotated. If a digit goes past 0 or 9, the digit to its left or right is carried. An error shows on the Control Display. The difference between the original (reference) output and the new output is shown.</p> <p>The  and  keys adjust the magnitude of changes by moving the highlighted digit.  lets you move from voltage or current to frequency and back. In practice, for voltage and current outputs, the knob and arrow keys are used to adjust output until the UUT reads correctly. The error display then shows the UUT deviation from the reference.</p> |

- 15 The power switch turns on and off Calibrator power. The switch is a latching push-push type. When the switch is latched in, Calibrator power is on.
- 16  The **ZERO CAL** key lets you do an ohms zero or a full-zero calibration.
- 17  The **DIV** (Divide) key immediately changes the output to 1/10th reference value (not necessarily the present output value) if the value is in performance limits. In the SCOPE mode,  changes the output to the next lower range.
- 18  The **MULT** (Multiply) key immediately changes the output to 10X the reference value (not necessarily the present output value) if the value is in performance limits. This key sets the Calibrator to standby if this change is from <33 V. In the SCOPE mode,  changes the output to the next higher range.
- 19  The **MEAS TC** (Measure Thermocouple) key starts the TC (Thermocouple) input connection and makes the Calibrator calculate a temperature derived from the voltage that is at the input.
- 20 **Output Units Keys**  
The output units keys choose the function of the Calibrator. Some keys have a secondary unit if  is pushed just before the units key. The output units are:
-  Voltage or Decibels relative to 1 mW into 600  $\Omega$  (impedance changeable).
  -  Watts or Current
  -  Resistance
  -  Frequency or Seconds (seconds applies to the SCOPE functions only)
  -  Capacitance
  -  Temperature in Fahrenheit or Celsius
- 21 **Multiplier Keys**  
Select output value multipliers. Some keys have a secondary function if  is pushed just before the multiplier key. For example, if you record 33, then push , then , then , and then , the Calibrator output value is 33  $\mu$ F. The multiplier keys are:
-  milli ( $10^{-3}$  or 0.001) or micro ( $10^{-6}$  or 0.000001)
  -  kilo ( $10^3$  or 1,000) or nano ( $10^{-9}$  or 0.000000001)
  -  mega ( $10^6$  or 1,000,000) or pico ( $10^{-12}$  or 0.000000000001)

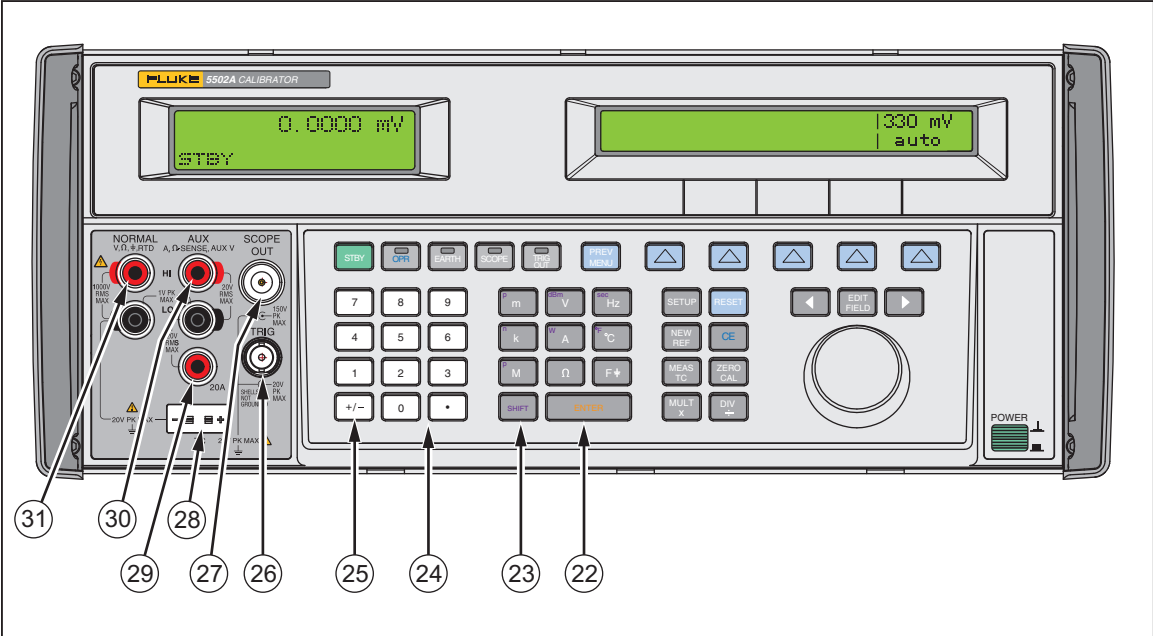


Figure 3-1. Front-Panel Features (cont.)

gvx010.eps

Table 3-1. Front-Panel Features (cont.)

|    |                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|----|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 22 | <b>ENTER</b>          | The <b>ENTER</b> key loads a newly-entered output value, shown on the Control Display, into the Calibrator, which shows on the Output Display. The new value can come from the numeric keypad. If you push <b>ENTER</b> without identifying the units for the entry, in most cases the Calibrator keeps the units that were last used. This lets you, for example, enter 1 mV, and then later enter 10 to get 10 V. (The "V" units were saved from the last entry, but not the multiplier, "m".) In the error (edit) mode, <b>ENTER</b> with no value puts the output to the value of the reference. |
| 23 | <b>SHIFT</b>          | The <b>SHIFT</b> key selects an alternative function of the units key and alternative multipliers of the multiplier keys. These alternative selections are named with small letters in the upper-left hand corner of the keys.                                                                                                                                                                                                                                                                                                                                                                       |
| 24 | <b>Numeric Keypad</b> | Use to record the digits of the output amplitude and frequency. The correct sequence to record a value is to push the digits of the output value, a multiplier key (if necessary), an output units key, and then <b>ENTER</b> . For example, to obtain an output of 20 mV, you would push this sequence of keys: <b>2</b> <b>0</b> <b>μ</b> <b>m</b> <b>V</b> . Push <b>OPR</b> to enable the output. If you push a digit key once the entry field is full, or push the decimal point key more than once in a single number, the beeper will sound.                                                  |
| 25 | <b>+/-</b>            | The <b>+/-</b> (Polarity) key changes the polarity of the output for dc voltage or dc current functions. Push the <b>+/-</b> key and then <b>ENTER</b> to toggle the output polarity.                                                                                                                                                                                                                                                                                                                                                                                                                |
| 26 | <b>SCOPE TRIG</b>     | The <b>SCOPE TRIG</b> (Scope Trigger) BNC connector is used to trigger the oscilloscope during oscilloscope calibration. This is active only when an oscilloscope option is installed.                                                                                                                                                                                                                                                                                                                                                                                                               |
| 27 | <b>SCOPE OUT</b>      | The <b>SCOPE OUT</b> (Oscilloscope) A BNC connector is used for outputs during oscilloscope calibration. This is active only when an oscilloscope calibration option is installed.                                                                                                                                                                                                                                                                                                                                                                                                                   |

**Table 3-1. Front-Panel Features (cont.)**

|    |                                                                                                                                                                                                                                                                                                                                                      |
|----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 28 | The <b>TC</b> (Thermocouple) minijack is used for thermocouple simulation during thermometer calibration, and thermocouple measurements. You must use the correct thermocouple wire and plug when you use this connector. For example, if you will simulate a type-K thermocouple, use type-K thermocouple wire and type-K plug to make connections. |
| 29 | The <b>20A</b> terminal is the source of current output when the 20 A range is selected (3 A to 20 A).                                                                                                                                                                                                                                               |
| 30 | The <b>AUX (Auxiliary Output)</b> terminals are used for ac and dc current outputs, the second voltage output in dual-voltage modes, and ohms sense for 2-wire and 4-wire compensated resistance and capacitance measurements, and RTD simulation.                                                                                                   |
| 31 | The <b>NORMAL</b> (Normal Output) terminals are used to source ac and dc voltage, ohms, and capacitance. The terminals are also used for Resistance Temperature Detector (RTD) simulation.                                                                                                                                                           |

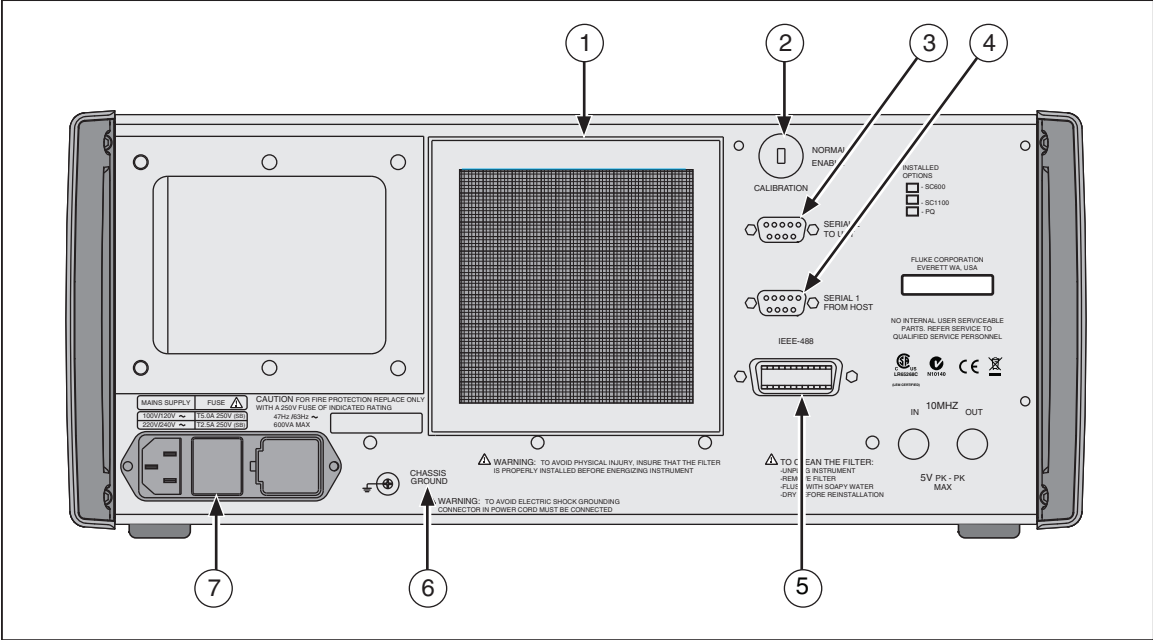


Figure 3-2. Rear-Panel Features

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Table 3-2. Rear-Panel Features

|   |                                                                                                                                                                                                                                                                                                                                                                                              |
|---|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 | The <b>Fan Filter</b> covers the air intake to keep dust and contamination out of the chassis air baffles. The fan supplies a constant cool air flow to the inner chassis. Instructions for fan filter maintenance are in Chapter 7.                                                                                                                                                         |
| 2 | The <b>CALIBRATION NORMAL/ENABLE</b> slide switch is used to write enable and disable the nonvolatile memory that stores calibration constants. Change to ENABLE to let changes be written into memory, and change to NORMAL to protect data in memory from being overwritten. The switch is recessed to let it to be covered with a calibration sticker to guarantee calibration integrity. |
| 3 | The <b>SERIAL 2 TO UUT</b> connector is used to transmit and receive RS-232 serial data between the Calibrator and a UUT. Chapter 6, "Remote Commands" tells you how to use the RS-232 serial interface for UUT communications.                                                                                                                                                              |
| 4 | The <b>SERIAL 1 FROM HOST</b> connector is for remote control of the Calibrator and for transmitting internal-constant RS-232 serial data to a printer, monitor, or host computer. Chapter 5, "Remote Operation" tells you how to use the RS-232 serial interface for remote control.                                                                                                        |
| 5 | The <b>IEEE-488</b> connector is a standard parallel interface for operating the Calibrator in remote control as a Talker/Listener on the IEEE-488 bus. Refer to Chapter 5, "Remote Operation" for bus connection and remote programming instructions.                                                                                                                                       |

Table 3-2. Rear-Panel Features (cont.)

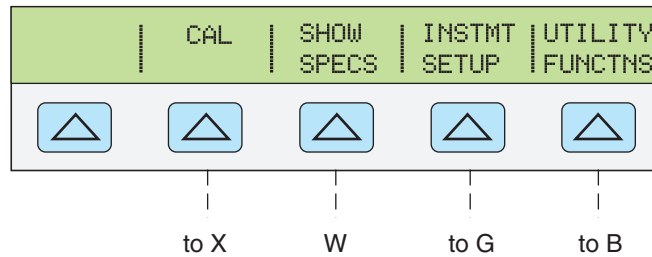
|   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|---|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 6 | <p style="text-align: center;"><b>⚠⚠ Warning</b></p> <p><b>To prevent possible electrical shock, fire, or personal injury:</b></p> <ul style="list-style-type: none"> <li>• <b>Do not use a two-conductor mains power cord unless you install a protective ground wire to the Product ground terminal before you operate the Product.</b></li> <li>• <b>Make sure that the Product is grounded before use.</b></li> </ul> <p>The <b>CHASSIS GROUND</b> terminal is internally grounded to the chassis. If the Calibrator is the location of the ground reference point in a system, this binding post can be used to connect other instruments to earth ground. Refer to the “Connect the Calibrator to a UUT” section in Chapter 4.</p> |
| 7 | <p>The <b>AC Power Input Module</b> gives you a grounded three-prong connector that takes the line power cord, a switch mechanism to select the line voltage, and a line power fuse. See the “Prepare for Operation” section in Chapter 2 for information on selecting the operating line voltage, and fuse rating and replacement information.</p>                                                                                                                                                                                                                                                                                                                                                                                      |



### Figure 3-3. Setup Softkey Menu Tree

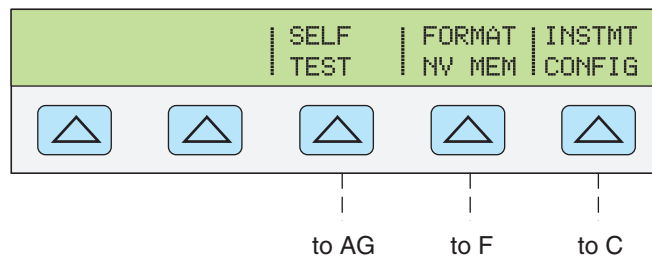


**A**



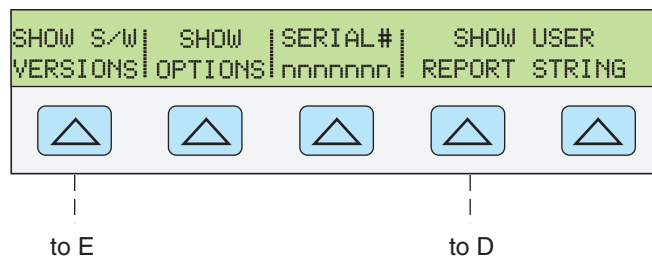
SHOW SPECS is an online summary of the programmed output specifications.

**B**



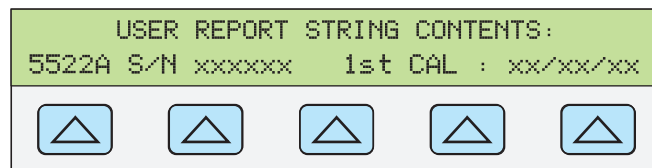
If self test does not pass, error codes are displayed. (See chapter 7, "Maintenance")

**C**



SERIAL # displays the serial number of the instrument. When corresponding with the factory, always include the serial number of the instrument.

**D**



USER REPORT STRING CONTENTS refer to a string of characters entered by the user for reporting purposes.

Figure 3-4. SETUP Softkey Menu Displays

gjh007.eps

E

|                                                                                   |                                                                                   |                                                                                   |                                                                                   |                                                                                     |
|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| SOFTWARE                                                                          | Main: 1.0                                                                         | Inguard: 1.8                                                                      |                                                                                   |                                                                                     |
| REVISIONS                                                                         | Encoder: 1.3                                                                      |                                                                                   |                                                                                   |                                                                                     |
|  |  |  |  |  |

Actual revision numbers replace the numbers in each of the above.

F

|                                                                                   |                                                                                   |                                                                                   |                                                                                   |                                                                                     |
|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Format NV Memory                                                                  |                                                                                   |                                                                                   |                                                                                   |                                                                                     |
| ALL                                                                               | CAL                                                                               | SETUP                                                                             |                                                                                   |                                                                                     |
|  |  |  |  |  |

Format NV (non-volatile) Memory should be used with **caution**. Changes are non reversible. The softkeys function only when the rear-panel CALIBRATION switch is set to ENABLE, except for the softkey SETUP, which is not dependent on the CALIBRATION switch position.

**ALL** sets all calibration and setup constants to factory setting. **CAL** set only calibration constants to factory settings. **SETUP** resets instrument setup to factory default settings (see Table 3-3).

G

| OTHER SETUP                                                                         |  |  |  |  | OUTPUT SETUP                                                                        |  |  |  |  | DISPLAY SETUP                                                                       |  |  |  |  | REMOTE SETUP                                                                        |  |  |  |  |                                                                                       |  |  |  |  |
|-------------------------------------------------------------------------------------|--|--|--|--|-------------------------------------------------------------------------------------|--|--|--|--|-------------------------------------------------------------------------------------|--|--|--|--|-------------------------------------------------------------------------------------|--|--|--|--|---------------------------------------------------------------------------------------|--|--|--|--|
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|                                                                                     |  |  |  |  | to G1                                                                               |  |  |  |  | to S                                                                                |  |  |  |  | to P                                                                                |  |  |  |  | to H                                                                                  |  |  |  |  |

G1

|                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                       |
|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| MAINS<br>60Hz                                                                       | SET<br>CLOCK                                                                        | OULD T<br>10s                                                                       | ERR UNI<br>SETUP                                                                    | TMP STD<br>its-90                                                                     |
|  |  |  |  |  |
| 50 Hz                                                                               |                                                                                     |                                                                                     | >100PPM<br>>10PPM<br>PPM<br>%                                                       | its-90                                                                                |

G2

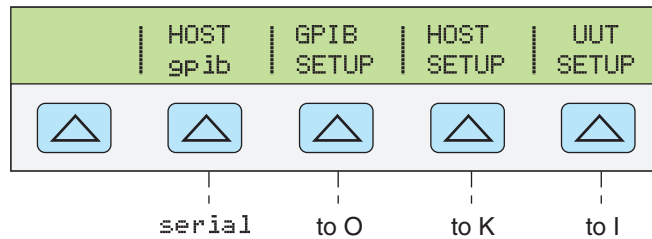
|                                                                                     |                                                                                     |                                                                                     |                                                                                     |                                                                                       |
|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
|                                                                                     |                                                                                     |                                                                                     | ERR UNI<br>>0.1%                                                                    | ERR REF<br>nominal                                                                    |
|  |  |  |  |  |
|                                                                                     |                                                                                     |                                                                                     |                                                                                     | tru val                                                                               |

TMP STD (temperature degree standard) refers to ITS-90 (1990 International Temperature Standard) (factory default) and IPTS-68 (1968 International Provisional Temperature Standard).

Figure 3-4. SETUP Softkey Menu Displays (cont.)

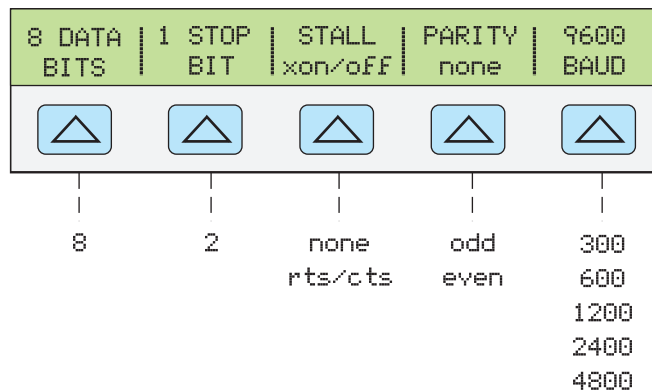
gjh008.eps

H



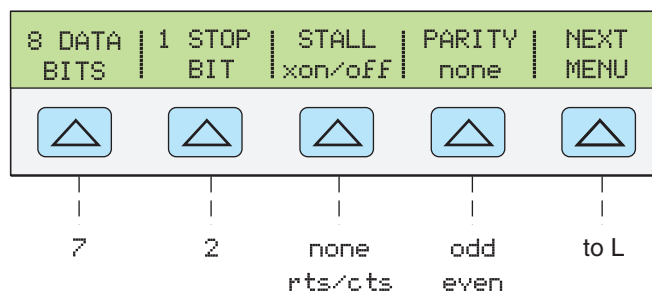
HOST selects the IEEE-488 (GPIB) (factory default) parallel port or RS-232 (serial) port. You cannot operate both IEEE-488 and RS-232 simultaneously.

I



STALL refers to the method of controlling data flow: software control (xon/off), hardware control (rts/cts) or none.

K

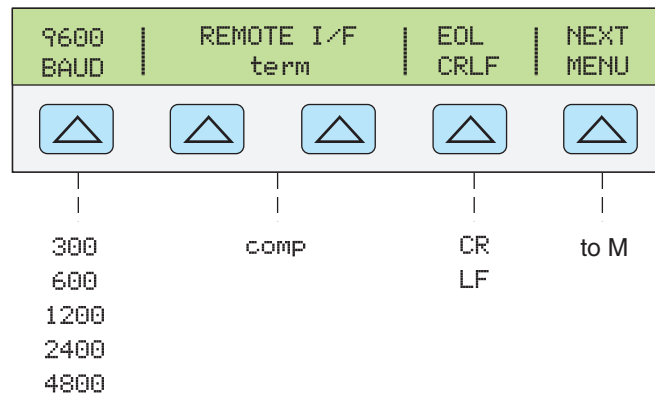


STALL refers to the method of controlling data flow: software control (xon/off), hardware control (rts/cts) or none.

Figure 3-4. SETUP Softkey Menu Displays (cont.)

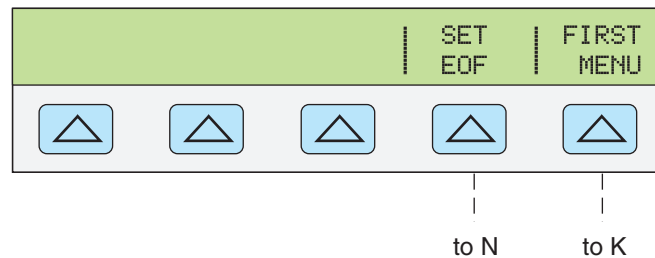
gjh030.eps

**L**



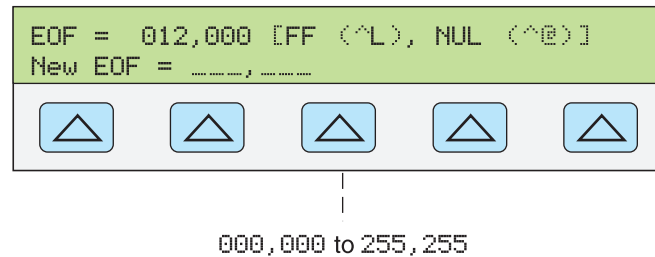
REMOTE I/F (Interface) has selections term (terminal) (factory default) and comp (computer). EOL (End of Line character) is either Carriage Return/Line Feed (CRLF), CR (Carriage Return) or LF (Line Feed).

**M**



EOF (End of File) indicates the action taken at the end of a file by entering one or two ASCII characters.

**N**

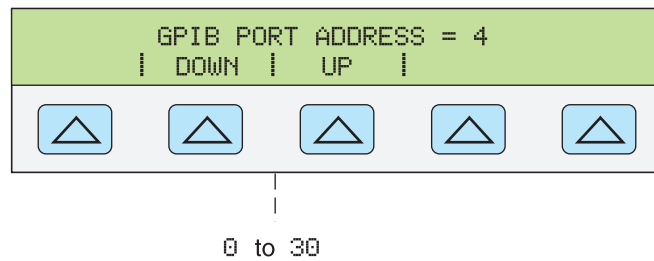


EOF (End of File) ASCII characters are entered with a range of 000 to 255 (first character) and 000 to 255 (second character). The factory defaults are 012,000, where the FF (form feed) character signals an advance to the next page, and the NULL (ignore) character holds position. When the NULL character is 000 (^@), then effectively the EOF is only the FF character, or ^L for the factory.

Figure 3-4. SETUP Softkey Menu Displays (cont.)

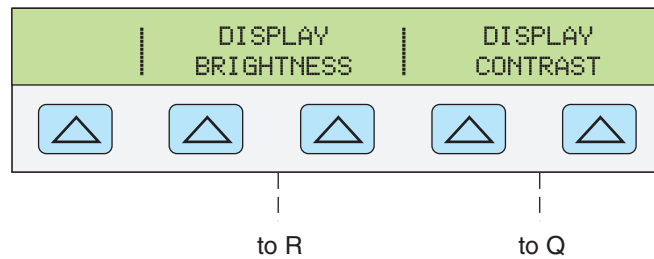
gjh003.eps

O



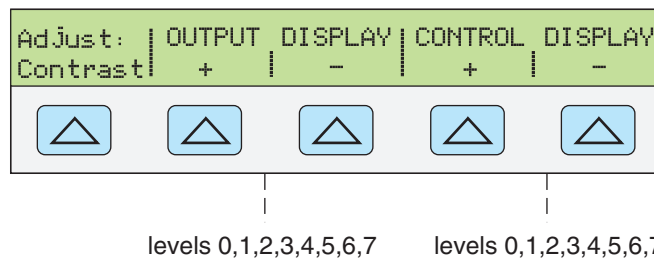
GPIB (General Purpose Interface Bus) selects the port address when using the IEEE-488 bus. The factory default is 4.

P



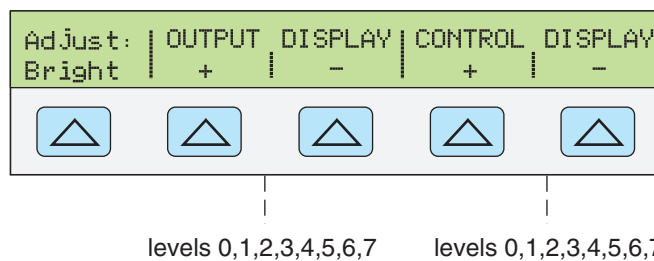
DISPLAY BRIGHTNESS and DISPLAY CONTRAST apply to both the Output Display and Control Display.

Q



There are eight levels of contrast, 0 to 7, for the Output Display and Control Display. Each may have its own level of contrast. The factory defaults are 7 and 7.

R



There are eight levels of brightness, 0 to 7, for the Output Display and Control Display. Each may have its own level of contrast. The factory defaults are 1 and 0.

Figure 3-4. SETUP Softkey Menu Displays (cont.)

gjh031.eps

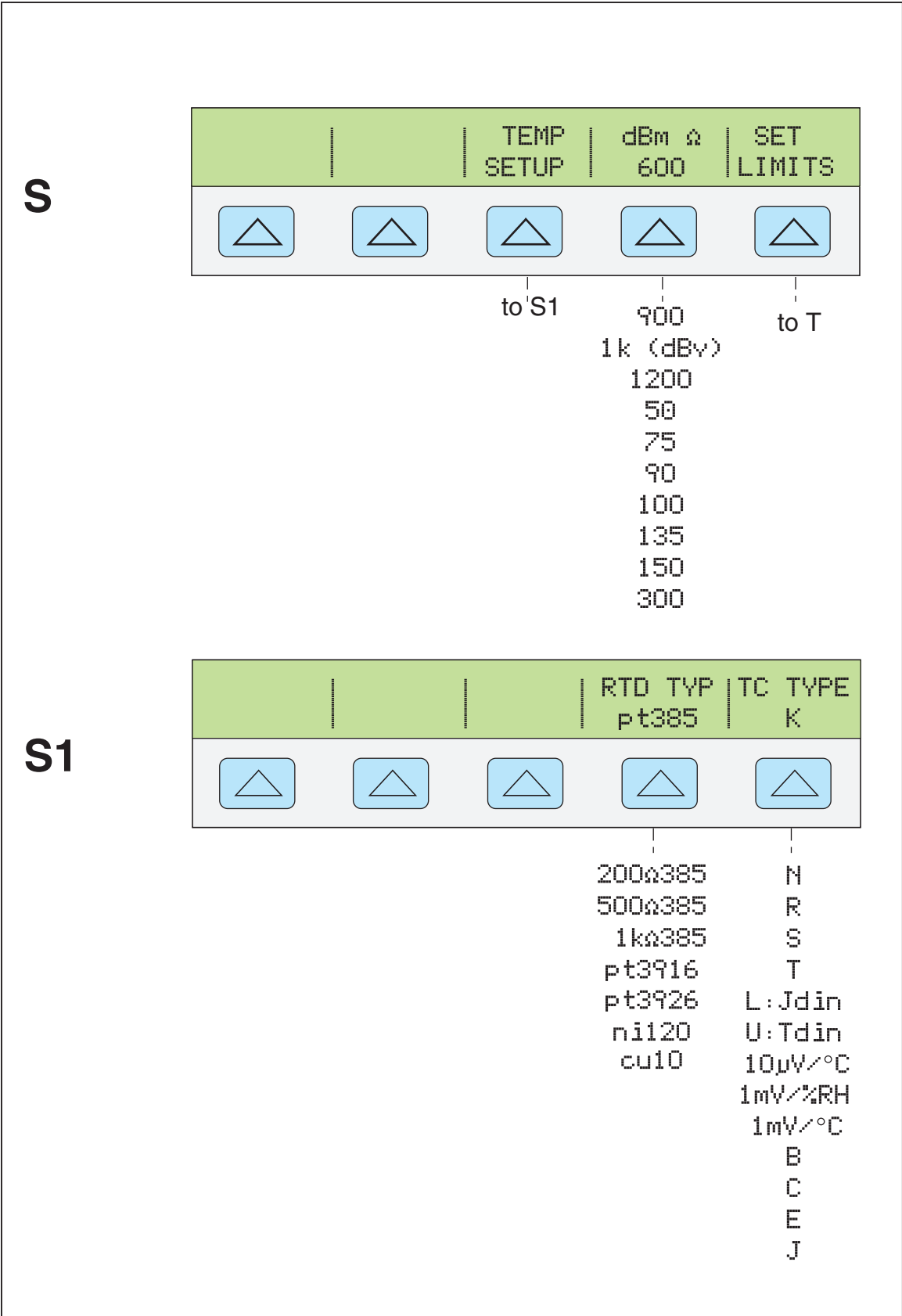


Figure 3-4. SETUP Softkey Menu Displays (cont.)

gvx032.eps

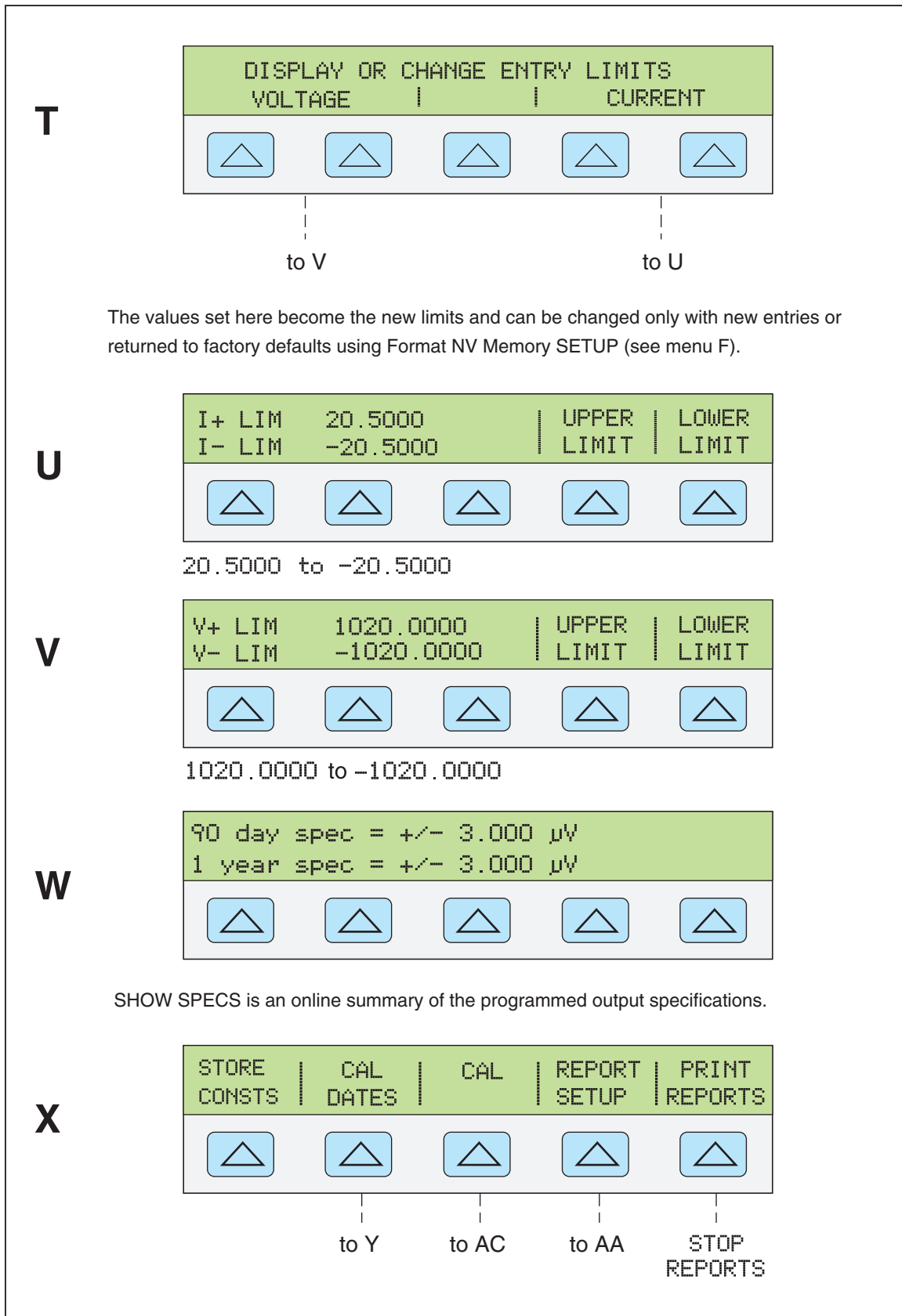


Figure 3-4. SETUP Softkey Menu Displays (cont.)

gvx012.eps

Select the desired CAL (Calibration) feature: CAL to calibrate the 5502A. CAL DATES to review when the 5502A Calibrator was last calibrated. CAL REPORTS to printout the calibration data.

**Y**

|           |                       |       |
|-----------|-----------------------|-------|
| Zero      | :1997-09-05: 08:27:13 | MORE  |
| Ohms Zero | :1997-09-05: 08:27:13 | DATES |

▲

▲

▲

▲

▲

to Z

**Z**

|      |                       |       |
|------|-----------------------|-------|
| MAIN | :1997-09-05: 08:27:13 | MORE  |
|      |                       | DATES |

▲

▲

▲

▲

▲

to Y

**AA**

|         |         |        |        |      |
|---------|---------|--------|--------|------|
| 68 LNS/ | INTERVL | TYPE   | FORMAT | DEST |
| PAGE    | 1 Year  | stored | print  | host |

▲

▲

▲

▲

▲

to AB

90 day  
1 year

active  
consts  
stored

spread

uut

**AB**

|                     |  |      |
|---------------------|--|------|
| LINES PER PAGE = 68 |  |      |
| INCR                |  | DECR |

▲

▲

▲

▲

▲

**AC**

(Only if scope  
option installed)

|       |       |      |      |         |
|-------|-------|------|------|---------|
| SCOPE | 5522A | OHMS | ZERO | ERR ACT |
| CAL   | CAL   | ZERO |      | backup  |

▲

▲

▲

▲

▲

to AE

to AD

abort  
cont  
sstep

5502A CAL opens the calibration menu. ZERO zeros the 5502A Calibrator. OHMS ZERO zeros the ohms portion of the 5502A Calibrator; ERR ACT (Error Action) set backup, abort, or cont (continue).

**Figure 3-4. SETUP Softkey Menu Displays (cont.)**

gjh013eps



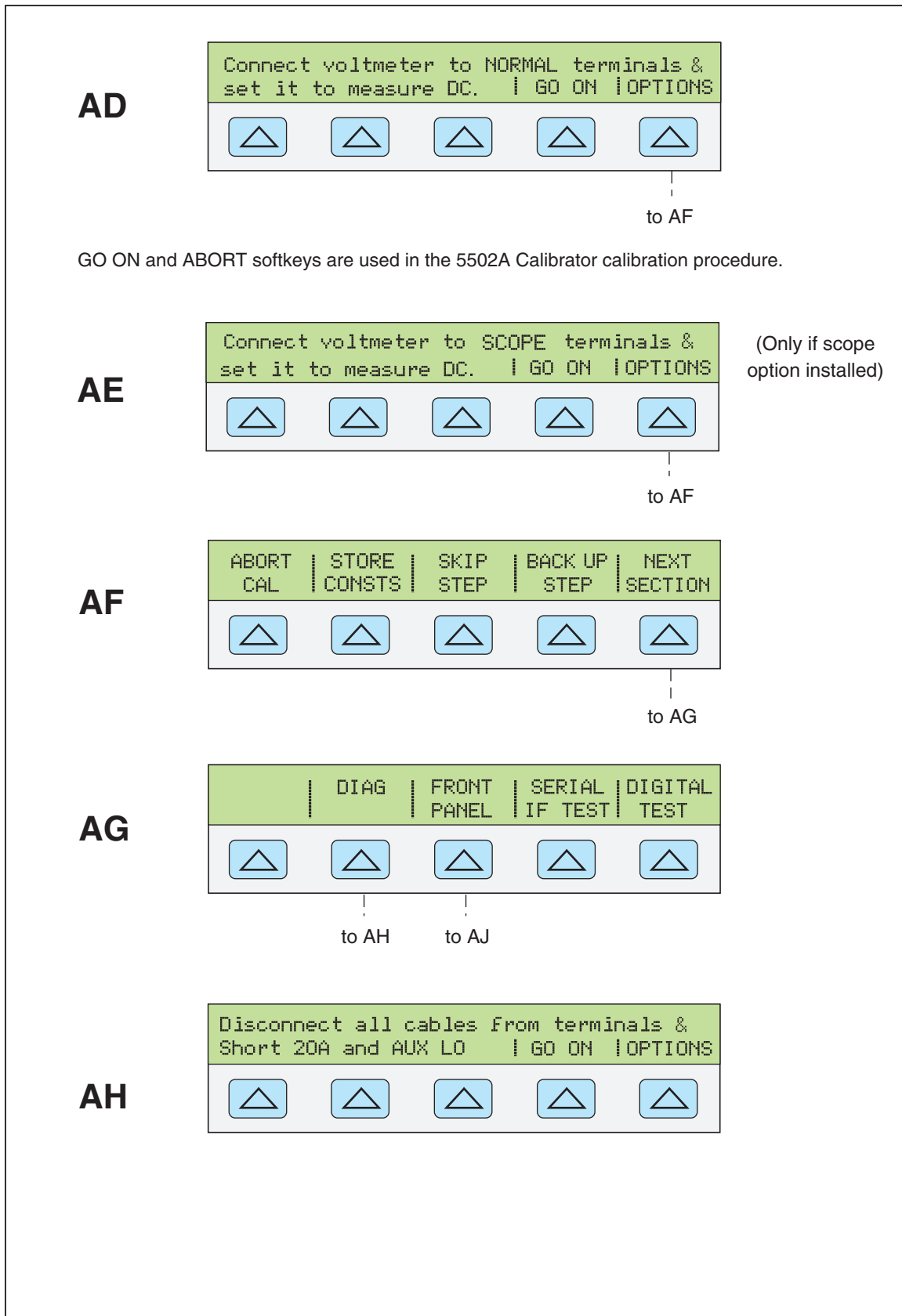


Figure 3-4. SETUP Softkey Menu Displays (cont.)

gjh033.eps

Table 3-3. Factory Defaults for SETUP Menus Power-Up Defaults

| Parameter                                                                                           | Setting                                                                   | SETUP Menu<br>(Figure 3-4) |
|-----------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|----------------------------|
| User report string (*PUD string)                                                                    | Cleared                                                                   | D                          |
| Error units                                                                                         | > 0.1%                                                                    | G1                         |
| SC-600 option overload test safety timeout                                                          | 10 s                                                                      | G1                         |
| Temperature standard                                                                                | its-90                                                                    | G1                         |
| Host interface                                                                                      | gpib (IEEE-488)                                                           | G1                         |
| UUT serial interface                                                                                | 8 bits, 1 stop bit, xon/xoff, parity none, 9600 baud                      | I                          |
| Host serial interface                                                                               | term, 8 bits, 1 stop bit, xon/xoff, parity none, 9600 baud, CRLF, 012,000 | K, L, M, N                 |
| GPIB Port Address                                                                                   | 4                                                                         | O                          |
| Display brightness (Note)                                                                           | level 1,0                                                                 | P                          |
| Display contrast (Note)                                                                             | level 7,7                                                                 | P                          |
| dBm impedance                                                                                       | 600 $\Omega$                                                              | S                          |
| RTD type                                                                                            | pt385                                                                     | S1                         |
| Thermocouple type                                                                                   | K                                                                         | S1                         |
| Current limits                                                                                      | $\pm 20.5$ A                                                              | U                          |
| Voltage limits                                                                                      | $\pm 1020$ V                                                              | V                          |
| Note:<br>Output Display and Control Display, respectively. There are 8 levels: 0,1,2,3,4,5,6, and 7 |                                                                           |                            |

# Chapter 4

## Front-Panel Operation

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## Introduction

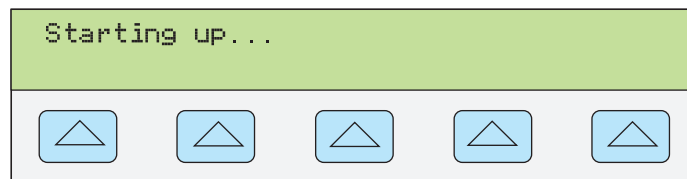
### Warning

To prevent possible electrical shock, fire, or personal injury, do not make connections to the output terminals when voltage is present. Standby mode is not sufficient to prevent shock hazard because **OPR** could be pushed accidentally. Push **RESET** and make sure that the Calibrator is in standby before you make connections to the output terminals.

This chapter gives instructions to operate the Calibrator from the front panel. For a description of front-panel controls, displays, and terminals, see Chapter 3, “Features”.

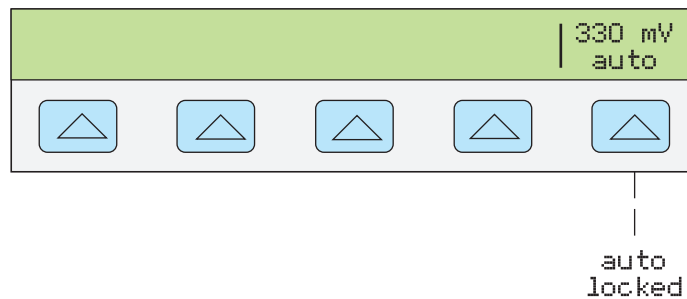
## Turn on the Calibrator

When the Calibrator is on, the initial display is “Starting Up...” (see below) and it completes a self-test routine. If a self-test fails, the Control Display shows an error code. For a description of error codes, see Chapter 7, “Maintenance.”



nn062f.eps

After self-test, the control display shows the reset condition (see below).



nn063f.eps

For a discussion of the softkey selection shown above (auto/locked), see “Auto Range Versus Locked Range” in this chapter.

## Warm up the Calibrator

When you turn on the Calibrator, let it warm up for 30 minutes to let the internal components become stable. Specifications given in Chapter 1 apply to a Calibrator that has completed its warm-up procedure.

If you turn off the Calibrator after warm up and then on again, give it a warm-up period of no less than two times the length of time it was turned off (maximum of 30 minutes). For example, if the Calibrator is turned off for 10 minutes and then on again, give it a warm-up period of no less than 20 minutes.

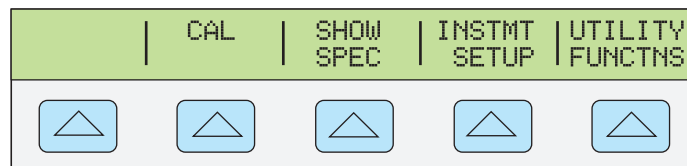
## Use the Softkeys

The five keys to the right of  are called softkeys. Softkey functions come from the name that shows directly above the key in the Control Display. Push a softkey to change a value or cause a submenu with new selections to be shown on the Control Display. Softkey menus are put in different levels, as given in the “Softkey Menu Tree” section in Chapter 3. You can move back through the menu selections with . Although  will return you to the top-level menu, it will also reset all volatile settings and return the Calibrator to 0 V dc in the standby mode. Use  as your main navigation tool to move through the menu levels.

## Use the Setup Menu

Push the front-panel  key to access various operations and changeable parameters. Most parameters are nonvolatile. This means they will be stored during reset or when you turn off the power. Chapter 3 shows a map of the menu tree, the parameters, and has a table of factory-default values.

When you push  from power-up, the display changes to:



nn064f.eps

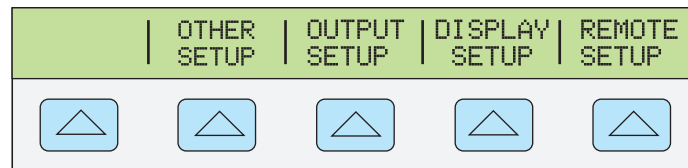
This is the primary instrument setup menu. The list below tells you about the submenus that available through each softkey and tells you where you can find more information in the manuals.

- **CAL** (Calibration)  
Opens the calibration menu. You use softkeys in this menu to see the calibration dates, print a calibration report, calibrate, and to do the Zero calibration routine. Zero calibration is given in this chapter.
- **SHOW SPECS** (Show Specifications)  
Shows published Calibrator specifications for the output value that is currently selected.

- **INSTMT SETUP** (Instrument Setup)  
Lets you change the power-up or reset default setting for different instrument parameters. Many of the same parameters in this menu can be changed during operation, but the changes you make during operation are volatile. Change them here to makes them nonvolatile. To set the Calibrator to its factory defaults, use the Format NV Memory menu in the UTILITY FUNCTNS menu.
- **UTILITY FUNCTNS** (Utility Functions)  
Lets you to start self-tests, format the nonvolatile memory (set the factory defaults), and examine the instrument configuration software versions and user report string. These features are given in the “Utilities Function Menu” section of this chapter.

### Use the Instrument Setup Menu

The softkeys in the instrument setup menu (accessed by pressing INSTMT SETUP softkey in the Setup Menu) are shown below.



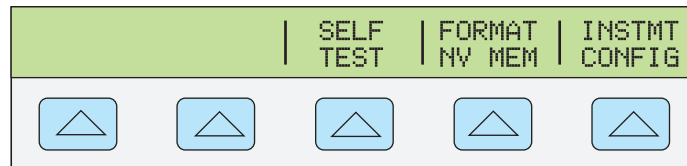
nn065f.eps

The list below gives submenus accessed by each softkey.

- **OTHER SETUP**  
Opens a menu that lets you toggle the degree reference between the 1968 International Provisional Temperature Standard (IPTS-68) and the 1990 International Temperature Standard (ITS-90) (factory default). This is also where you set the clock, and set the power-up and reset defaults for the SC-600 Oscilloscope Calibration Option Overload test safety timeout function (OVLDT), and shown error units. You can also configure the Calibrator for best operation with a 50 Hz line frequency.
- **OUTPUT SETUP**  
Opens a menu to change the power-up and reset defaults for current and voltage output limits, default thermocouple and RTD types, set the phase reference, internal or external phase reference source, and impedance for dBm display.
- **DISPLAY SETUP**  
Opens submenus to set the intensity and contrast of the Control and Output Displays.
- **REMOTE SETUP**  
Lets you change the configuration of the two RS-232 ports, SERIAL 1 FROM HOST and SERIAL 2 TO UUT, and IEEE-488 General Purpose Interface Bus (GPIB). (See Chapter 5, “Remote Operation”.)

### Utility Functions Menu

The Setup Menu softkey UTILITY FUNCTNS (Utility Functions) gives access to Self Test, Format Nonvolatile Memory, and Instrument Configuration.



nn066f.eps

- **SELF TEST**  
This softkey opens a menu with Calibrator self-test selections.
- **FORMAT NV MEM** (Format Nonvolatile Memory)  
Opens a menu to put all or part of the data in the nonvolatile memory (EEPROM) to factory defaults.
- **INSTMT CONFIG** (Instrument Configuration)  
Lets you see the versions of software installed in the Calibrator as well as the user-entered report string.

### Use the NV Memory Menu

#### Caution

**The Format Nonvolatile Memory menu softkeys permanently erase calibration constants. If you push ALL or CAL, this will invalidate the condition of calibration of the 5502A.**

Push FORMAT NV MEM in the utility functions menu to open:



nn067f.eps

It is necessary that the rear-panel CALIBRATION switch to be in the ENABLE position for the ALL and CAL softkeys in this menu. The nonvolatile memory has calibration constants and dates, setup parameters, and the user report string. With calibration constants, factory defaults are the same for all calibrators. They are not the calibration constants received when the Calibrator was calibrated by the factory before shipment.



The softkeys are:

- **ALL**  
replaces all contents of the EEPROM with factory defaults. This is used by service personnel after they replace the EEPROM, for example. It is not typically necessary.
- **CAL**  
replaces all calibration constants with factory defaults but keeps the setup parameters unchanged. This is also not typically necessary.
- **SETUP**  
replaces the setup parameters with factory defaults (Table 3-3) but keeps the calibration unchanged. You do not have to break the calibration seal for this operation. Remote commands can also change the setup parameters. (See these commands in Chapter 6: SRQSTR, SPLSTR, \*PUD, SP\_SET, UUT\_SET, TEMP\_STD, DATEFMT, RTD\_TYPE\_D, TC\_TYPE\_D, LIMIT.)

## Reset the Calibrator

When you use front panel-operation (not remote operation), you can put the Calibrator to the power-up condition with **RESET**, except after an error message, which is cleared by a push of the blue softkey.

Push **RESET** to:

- Put the Calibrator into the power-up condition: 0 V dc, standby, 330 mV range and all OUTPUT SETUP menus set to their most recent default values.
- Erases the stored values for limits and error mode reference.

## Zero the Calibrator

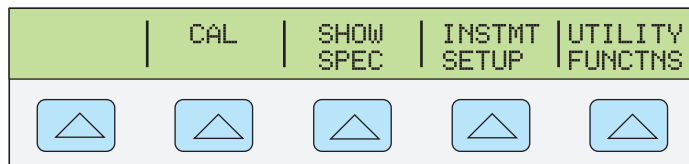
When you zero the Calibrator, the Calibrator recalibrates internal circuitry, most notably dc offsets in all ranges of operation. Zero the Calibrator each seven days to make sure the Calibrator outputs are not more or less than the limits of its specification, or when the Calibrator ambient temperature changes by more than 5 °C. The tightest ohms specifications are kept by a zero calibration each 12 hours within  $\pm 1$  °C of use. The Calibrator shows a message when it is necessary to zero the Calibrator. To zero the Calibrator is very important when your calibration workload has 1 m $\Omega$  or 1  $\mu$ V resolution, and when there has been a significant temperature change in the Calibrator work environment. There are two functions that zero the Calibrator: total instrument zero (ZERO) and ohms-only zero (OHMS ZERO).

Complete these procedures to zero the Calibrator.

*Note*

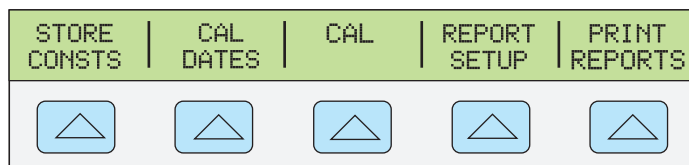
*The Calibrator rear-panel CALIBRATION switch does not have to be enabled for this procedure.*

1. Turn on the Calibrator and let it warm-up for no less than 30 minutes.
2. Push **RESET**.
3. Push **SETUP**. This opens the setup menu (see below).



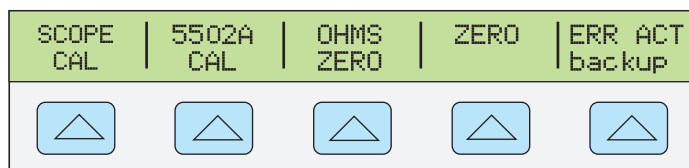
nn068f.eps

4. Push the CAL softkey. This opens the calibration information menu (see below).



nn069f.eps

5. Push the CAL softkey. This opens the calibration activity menu (see below). SCOPE CAL is shown as an option if it is installed:



gvx034.eps

6. Push the ZERO softkey to zero the Calibrator. Push the OHMS ZERO softkey to zero only the ohms function. After the zero routine is complete (several minutes), push **RESET** to reset the Calibrator. For a complete zero calibration, a short circuit that can pass 20 A must be applied between the 20A and AUX LO terminals.

## Operate and Standby Modes

When the OPERATE annunciator is illuminated and OPR is shown, the output value and function shown on the Output Display is live at the selected terminals. When STBY is shown in the Output Display, most of the Calibrator outputs are open-circuited. The front-panel thermocouple (TC) terminals are not open-circuited. To start the operate mode, push **OPR**. To put the Calibrator in standby, push **SETUP**.

If the Calibrator operates and these things occur, the Calibrator automatically goes to the standby mode:

- **RESET** is pushed.
- A voltage  $\geq 33$  V is selected when the previous output voltage was less than 33 V.
- Output function is changed between ac or dc voltage when the output voltage is  $\geq 33$  V, ac or dc current, temperature and any other function; resistance and any other function; capacitance and any other function.

- A p-p voltage output (square wave, triangle wave, or truncated sine wave) changes to rms voltage output  $\geq 33$  V (sine wave). For example, if a p-p output of 40 V is changed to rms output of 40 V by a change to the wave form with the WAVE softkey, the Calibrator goes to the standby mode.
- The output location for current is changed from AUX to 20 A, or from 20 A to AUX.
- An overload condition occurs.

## Connect the Calibrator to a UUT

### **Warning**

**To prevent possible electrical shock, fire, or personal injury, do not make connections to the output terminals when voltage is present. Standby mode is not sufficient to prevent shock hazard because OPR could be pushed accidentally. Push RESET and make sure that the Calibrator is in standby before you make connections to the output terminals.**

The NORMAL (HI and LO) outputs are used to source voltages, resistances, capacitance, and simulate resistance temperature detector (RTD) outputs. The LO terminal connects to the analog signal ground in the guard shield. This signal line can or cannot be connected to the chassis ground. This depends on how EARTH is set. See “When to Use EARTH” in this chapter for more about these internal connections.

The AUX (HI and LO) outputs source current and low voltages in the dual voltage function. These outputs are also used for four-wire or remote sensing in the resistance, capacitance, and RTD functions.

When an oscilloscope calibration option is installed, the SCOPE OUT BNC connectors and TRIG give signals for oscilloscope calibration.

Use the TC socket to measure thermocouples and to supply simulated thermocouple outputs.

## Recommended Cable and Connector Types

### **Warning**

**To prevent possible electrical shock, fire, or personal injury:**

- **Do not use test leads if they are damaged. Examine the test leads for damaged insulation, exposed metal, or if the wear indicator shows. Check test lead continuity.**
- **Use only cables with correct voltage ratings.**
- **Connect the common test lead before the live test lead and remove the live test lead before the common test lead.**
- **Use only the mains power cord and connector approved for the voltage and plug configuration in your country and rated for the Product.**

- Properly terminate the sense leads to prevent exposure to hazardous voltages on the sense terminals. The voltage sense terminals are at output voltage when the two-wire function is set.
- Do not touch exposed metal on banana plugs, they can have voltages that could cause death.
- Do not use a two-conductor mains power cord unless you install a protective ground wire to the Product ground terminal before you operate the Product.
- Make sure that the Product is grounded before use.

Cables to the Calibrator are connected to the NORMAL and AUX terminals. To prevent errors caused by thermal voltages (thermal emfs), use connectors and conductors made of copper or materials that supply small thermal emfs when connected to copper. Do not use nickel-plated connectors. For best results use the Fluke Model 5440A-7002 Low Thermal EMF Test Leads, which are made of well-insulated copper wire and tellurium copper connectors. See Chapter 8, "Accessories."

### When to Use **EARTH**

Figure 4-1 shows the internal connections made by **EARTH**.

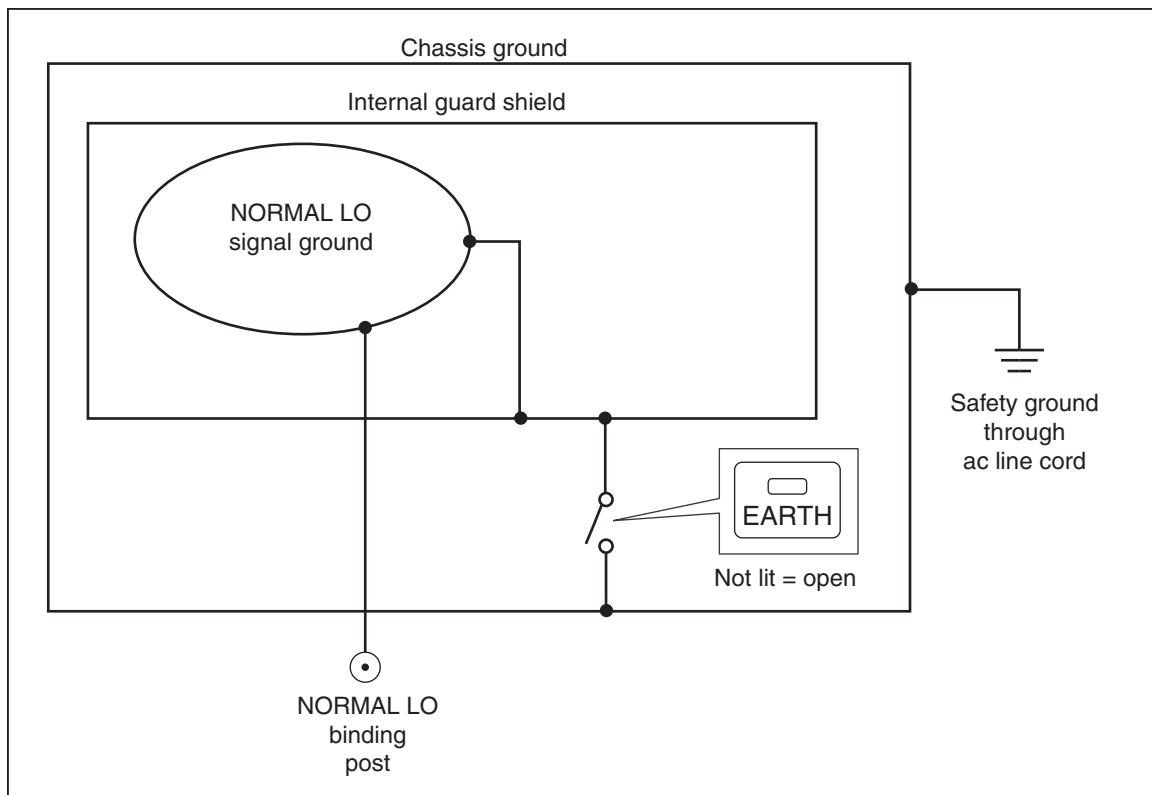


Figure 4-1. EARTH Internal Connections

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The Calibrator front panel NORMAL LO terminal is typically isolated from earth (chassis) ground. When it is necessary to make a connection from the NORMAL LO terminal and earth ground, push the **[EARTH]** key, this lights the key annunciator. When the earth key is pushed, the NORMAL LO terminal is connected to earth ground through approximately 30  $\Omega$ .

To prevent ground loops and noise you must have only one earth ground-to-LO terminal connection in the system. Typically you make all signal ground connections at the UUT and make sure that the **[EARTH]** annunciator is off. In most cases, **[EARTH]** is on only for ac and dc volts where the UUT is isolated from earth ground. There must be a safety ground for the Calibrator. See “Connect to Line Power” in Chapter 2. When the sourced output is live, a softkey LO is shown, which lets you tie or open an internal connection from the NORMAL LO terminal to the AUX LO terminal. When tied and **[EARTH]** is on, then both LO terminals are tied to chassis ground.

### **Four-Wire versus Two-Wire Connections**

Four-wire and two-wire connections are methods to connect the Calibrator to the UUT to cancel out test lead resistance to make sure the highest precision of the calibration output. Figures 4-2 through 4-4 show the connection configurations for resistance. Figures 4-5 and 4-6 show connection configurations for capacitance. The external-sensing function of the four- and two-wire compensated connections gives increased precision for resistance values less than 110 k $\Omega$  and capacitance values 110 nF and above. A part of the Calibrator output setup for resistance and capacitance includes selections for four-wire compensation (COMP 4-wire), two-wire compensation (COMP 2-wire) and two-wire no compensation (COMP off). (See “Set Resistance Output” and “Set Capacitance Output” in this chapter.) Note that compensated connections for capacitance are to compensate for lead and internal resistances, not for lead and internal capacitances.

### **Four-Wire Connection**

The four-wire connection is typical for calibration of laboratory measurement equipment. Increased precision is supplied for resistance values less than 110 k $\Omega$ . For other values, the lead resistances do not degrade the calibration and the Calibrator changes the compensation to off (COMP off).

### **Two-Wire Compensation**

The two-wire connection is typical for calibration of precision handheld Digital Multimeters (DMMs) with a two-wire input. Increased precision is supplied for resistance values less than 110 k $\Omega$  and capacitance values 110 nF and above. For other values, the Calibrator changes the compensation to off (COMP off).

### **Compensation Off**

Compensation off is a typical connection for calibration of handheld analog meters or DMMs with a two-wire input. This connection is used for all values of resistance and capacitance and is typically selected when more precision is not necessary for the analog meter or DMM level of accuracy. This is the default condition when an ohms or capacitance output is made after an output that was not ohms or capacitance.

### Cable Connections Instructions

Table 4-1 shows the figure names for each type of connection from a UUT to the Calibrator.

When you calibrate Resistance Temperature Detectors (RTDs) with the three-terminal connection shown in Figure 4-9, make sure the test leads have with resistances to cancel errors from lead resistance. This can be done, for example, with three test leads of the same length and with the same connector styles.

When you calibrate thermocouples, it is especially important to use the correct hookup wire and miniconnector between the Calibrator front panel TC terminal and the UUT. You must use the correct thermocouple wire and miniconnectors for the type of thermocouple. For example, if you simulate a temperature output for a type K thermocouple, use type K thermocouple wire and type K miniplugs for the hookup.

To connect the Calibrator to a UUT:

1. If the Calibrator is turned on, push **RESET** to remove the output from the Calibrator terminals.
2. Select the correct figure from Table 4-1 to make the connections to the UUT.
3. For capacitance outputs, connect the test leads to the UUT to null out stray capacitance. Put the cables (but do not connect them) to the Calibrator on a non-conductive surface. Null out the indication on the UUT with “rel,” “offset,” or “null,” (use the necessary method), and then connect the test leads to the Calibrator.

**Table 4-1. UUT Connections**

| 5502A Output                                                                     | Figure Reference                                                                                                       |
|----------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|
| Resistance                                                                       | 4-2 Resistance - four-wire compensation<br>4-3 Resistance - two-wire compensation<br>4-4 Resistance - compensation off |
| Capacitance                                                                      | 4-5 Capacitance - two-wire compensation<br>4-6 Capacitance - compensation off                                          |
| DC Voltage                                                                       | 4-7 DC Voltage/AC Voltage                                                                                              |
| AC Voltage                                                                       | 4-7 DC Voltage/AC Voltage                                                                                              |
| DC Current                                                                       | 4-8 DC Current/AC Current                                                                                              |
| AC Current                                                                       | 4-8 DC Current/AC Current                                                                                              |
| RTD Simulation                                                                   | 4-9 Temperature (RTD)                                                                                                  |
| Thermocouple Simulation                                                          | 4-10 Temperature (Thermocouple)                                                                                        |
| Note:<br>See the discussion under “Four-Wire versus Two-Wire Connections” above. |                                                                                                                        |

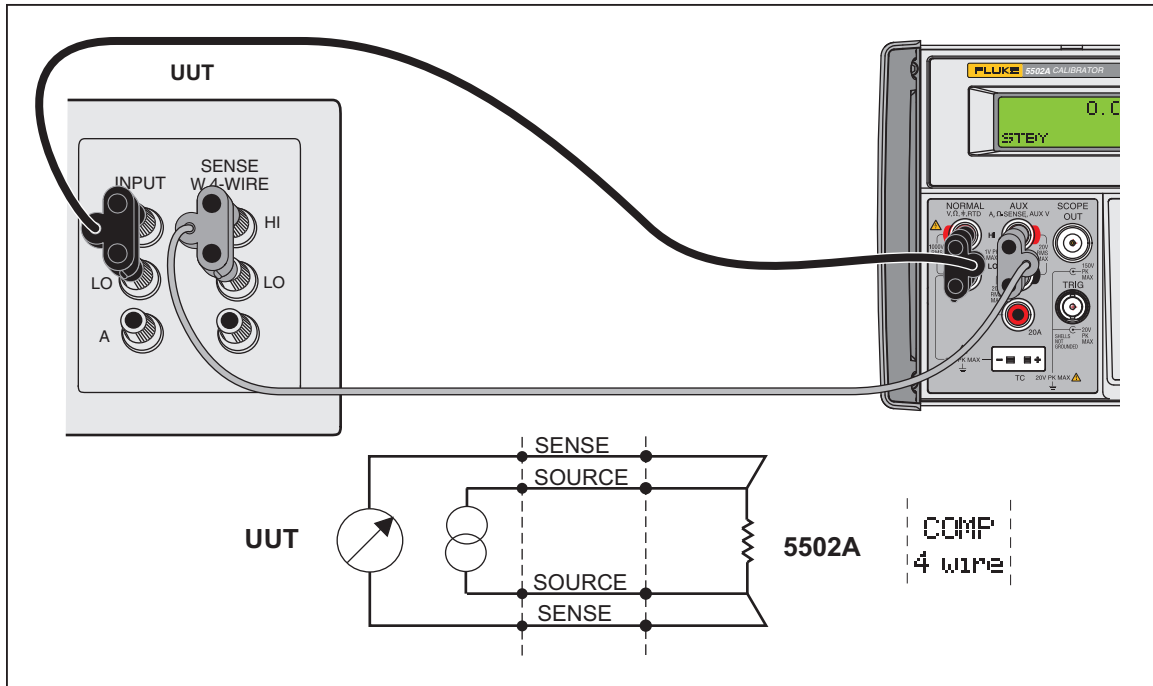


Figure 4-2. UUT Connection: Resistance (Four-Wire Compensation)

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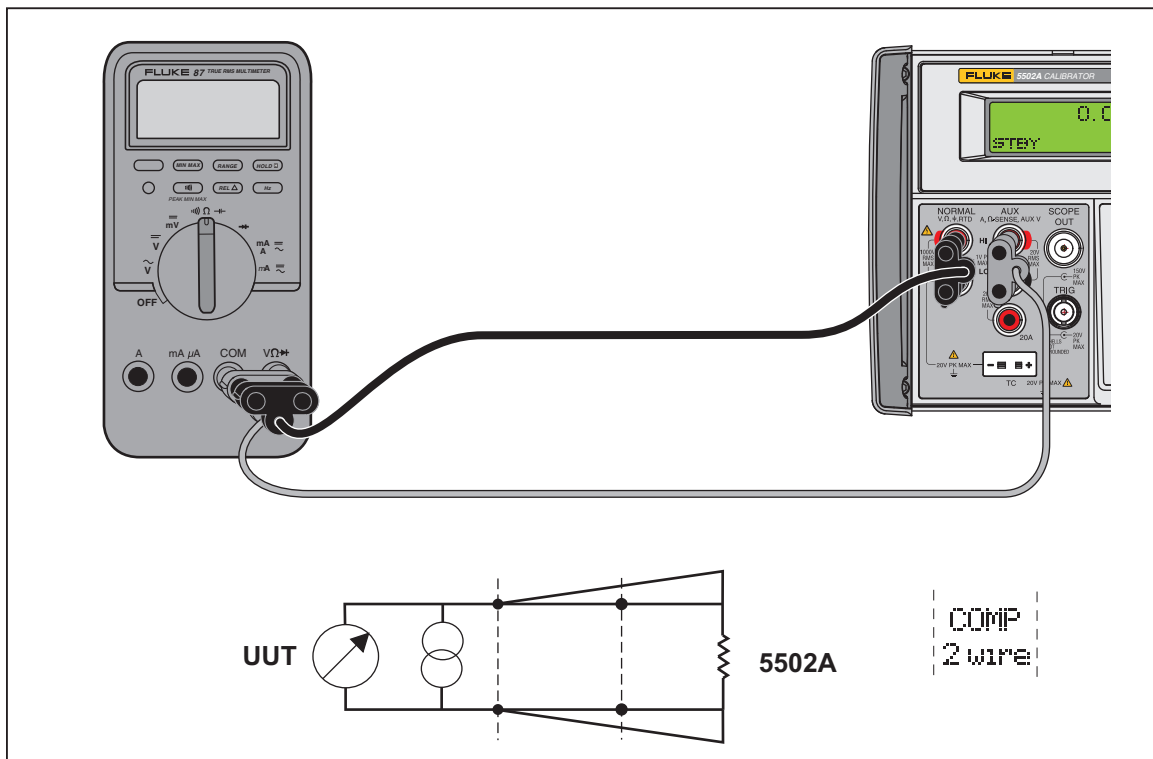


Figure 4-3. UUT Connection: Resistance (Two-Wire Compensation)

gvx015.eps

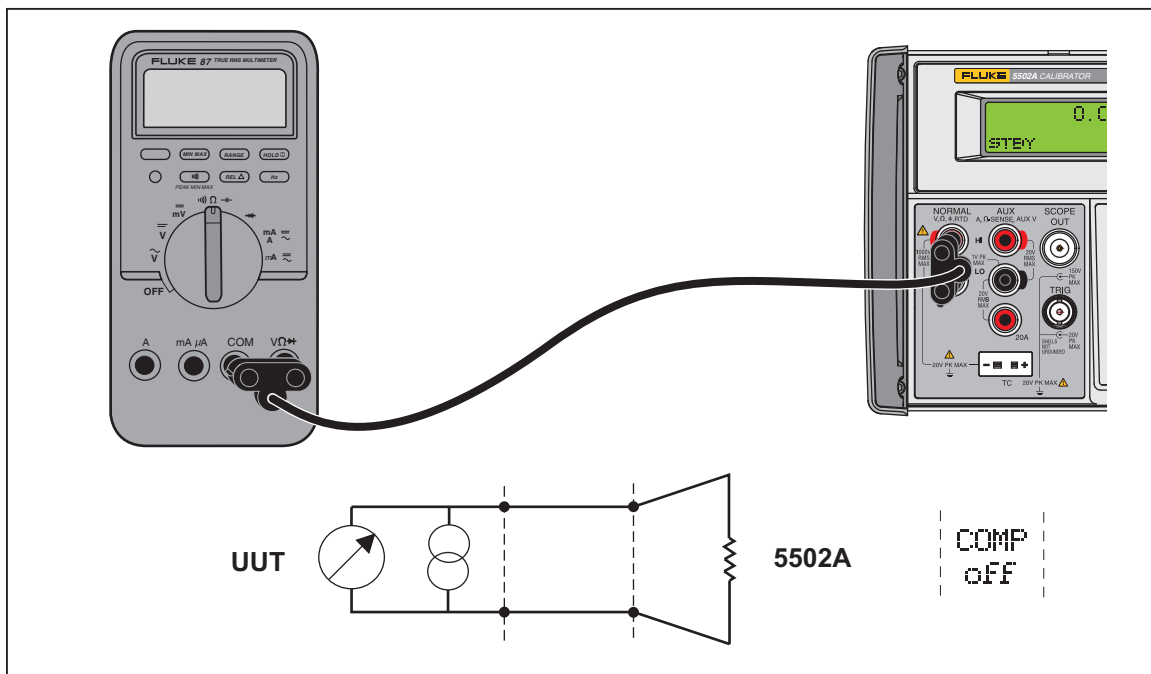


**Figure 4-4. UUT Connection: Resistance (Compensation Off)**

gvx016.eps

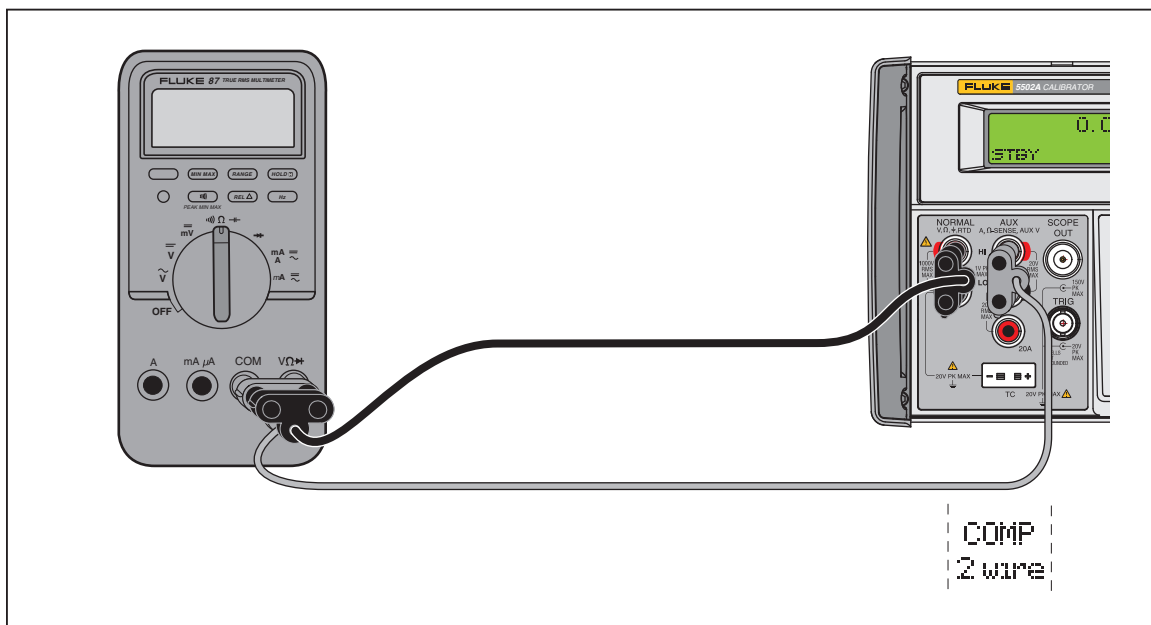
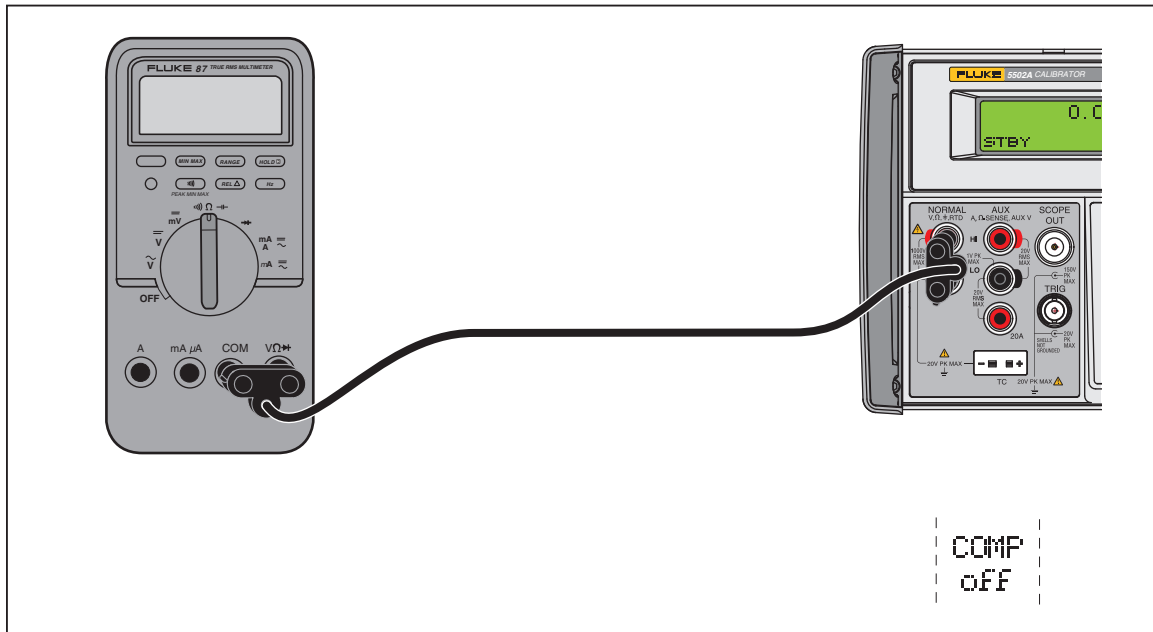


**Figure 4-5. UUT Connection: Capacitance (Two-Wire Compensation)**

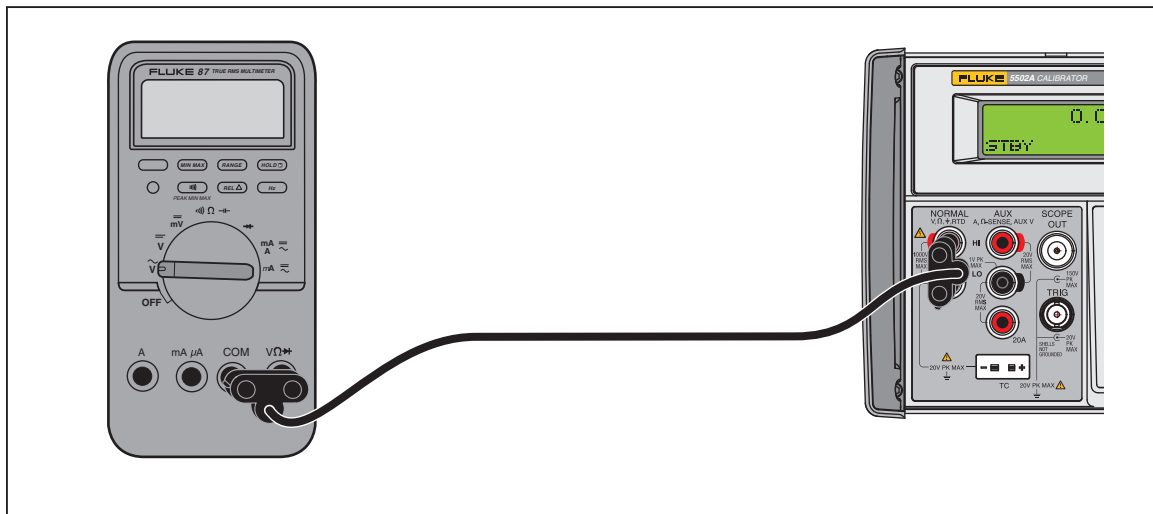
gvx017.eps





gvx018.eps

Figure 4-6. UUT Connection: Capacitance (Compensation Off)



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Figure 4-7. UUT Connection: DC Voltage/AC Voltage



**Figure 4-8. UUT Connection: DC Current/AC Current**

gvx020.eps

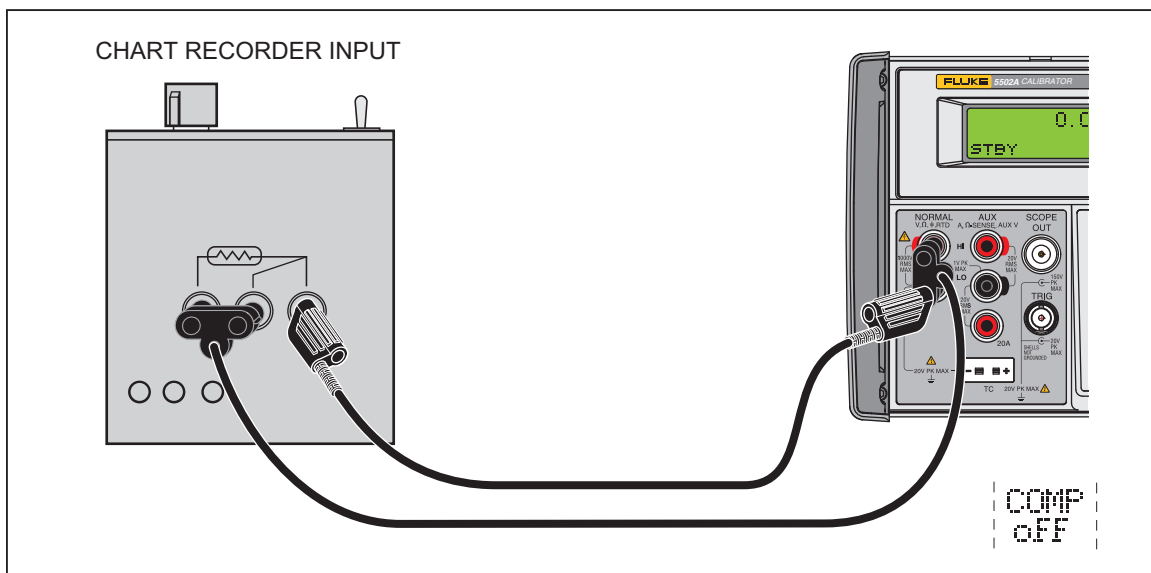


**Figure 4-9. UUT Connection: Temperature (RTD)**

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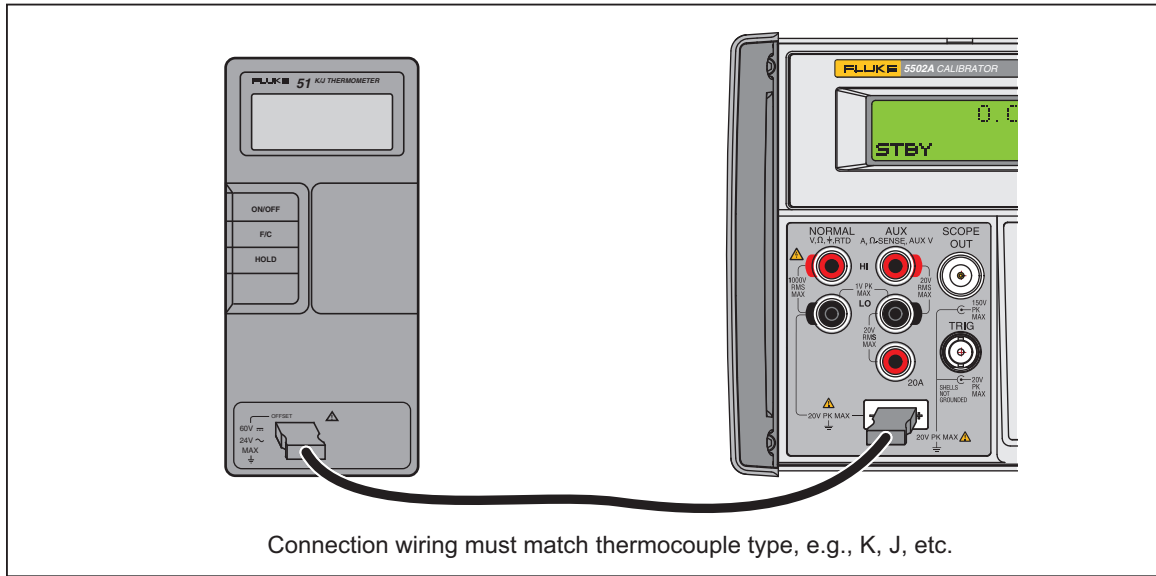


**Figure 4-10. UUT Connection: Temperature (Thermocouple)**

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## RMS Versus p-p Amplitude

The Calibrator ranges for sinusoidal ac functions are specified in rms (root-mean-square, the effective value of the wave form). For example, 1.0 to 32.999 mV, 33 to 329.999 mV, 0.33 to 3.29999 V, etc. The sine wave outputs are in rms, while the triangle wave, square wave, and truncated sine wave outputs are in p-p. The relationship between p-p and rms for the non-sine wave types are:

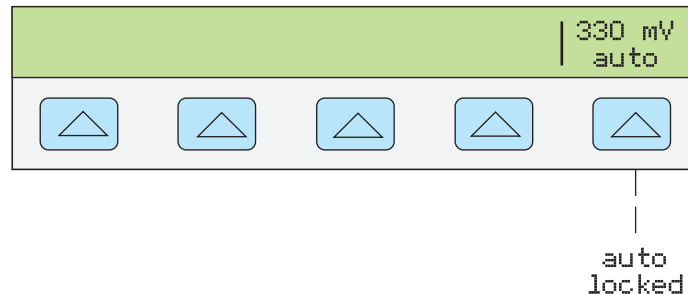
- Square wave  $\text{p-p} \times 0.5000000 = \text{rms}$
- Triangle wave  $\text{p-p} \times 0.2886751 = \text{rms}$
- Truncated Sine wave  $\text{p-p} \times 0.2165063 = \text{rms}$

While the ac function ranges are compatible for sine waves, the rms content of the other waveforms is less apparent. This quality leads to subtle Calibrator range changes. For example, if you record a sine wave voltage of 6 V (rms assumed), the selected range is 3.3 to 32.9999 V. If you then use the softkeys to change from a sine wave to a triangle wave, for example, the display changes from 6 V rms to 6 V p-p. This translates to  $6 \text{ V p-p} \times 0.2886751 = 1.73205 \text{ V rms}$ , and the range switches to 0.33 to 3.29999 V. The Output Display shows the range change because the sine wave voltage is shown as 6.0000, the resolution for the 3.3 to 32.9999 V range, while the triangle wave is shown as 6.00000, the resolution for the 0.33 to 3.29999 V range.

You must know the range in operation to record the correct values for voltage offset because the maximum offsets are specified to the range. For example, the maximum peak signal for the 3.3 to 32.9999 V range is 55 V while the maximum peak signal for the 0.33 to 3.29999 V range is 8 V. This means in the example above, the 6 V rms sine wave could have offsets applied to a maximum peak signal of 55 V because the current range is 3.3 to 32.9999 V, while the 6 V p-p triangle wave could have offsets applied to a maximum peak signal of 8 V because the current range is 0.93 to 9.29999 V. See “Specifications” in Chapter 1 and “Record a DC Offset” in this chapter for more about dc offset voltages.

## Auto Range Versus Locked Range

A softkey is supplied to toggle between the ranging methods auto or locked. This feature is available only for single-output dc volts and dc current outputs.



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When you select auto (the default), the Calibrator automatically selects the range that gives the best output resolution. When you select locked, the Calibrator locks the selected range and will not change ranges when you edit the output, or record new outputs. Values lower or higher than the locked range are not permitted. The locked selection is typically made to prevent range changes that can cause a small perturbation in the output, for example, when you measure the linearity of a given multimeter range.

## Set Output

To set the Calibrator output, push the keys for the necessary values and then push a units key to identify which of the volts, amps, hertz, etc., that the values are for. The control display shows the value and units you select as you type them into the Calibrator. When you are satisfied with the value and units, push **ENTER**. If the output display shows STBY, push **OPR** to output the selection. A small “u” (unsettled) in the Output Display shows that the Calibrators internal circuitry must become stable.

For example, to set the output to 10 V dc, push:

**1** → **0** → **dBmV** → **ENTER** → **OPR**

To set the output to 20 V ac at 60 Hz push:

**2** → **0** → **dBmV** → **6** → **0** → **Hz** → **ENTER** → **OPR**

To change the output to dc, push:

**0** → **Hz** → **ENTER** or **+/-** → **ENTER**

Step-by-step procedures are given for each output function:

- DC voltage
- AC voltage
- DC current
- AC current
- DC power
- AC power
- Dual DC voltage
- Dual AC voltage
- Capacitance
- Temperature - RTD
- Temperature - Thermocouple
- Resistance

### Set DC Voltage Output

Do these procedures to set a dc voltage output from the front-panel NORMAL terminals. If you make an entry error, push **CE** to clear the display, then record the value again.

#### **⚠ Caution**

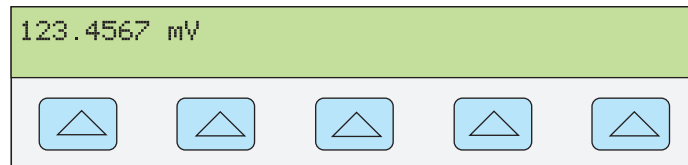
**To prevent damage to the UUT, make sure the applied voltage to the UUT is not larger than the rating of the UUT insulation and the connection wires.**

1. Push **RESET** to clear outputs from the Calibrator.
2. Connect the UUT as in the “Connect the Calibrator to a UUT” section of this chapter.
3. Set the UUT to measure dc voltage on the necessary range.
4. Push the numeric keys and decimal point key to record the necessary voltage output (maximum seven numeric keys). For example, 123.4567.

#### *Note*

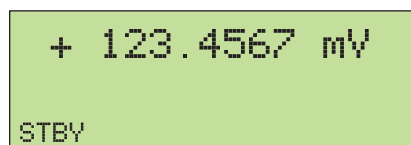
*At voltage outputs of 100 V and above (nominal), the Calibrator usually makes a small high-pitched sound.*

5. Push **+/-** to select the polarity of the voltage (default is +)
6. Push a multiplier key, if necessary. For example, push  **$\mu$  m**.
7. Push  **$\text{dBm}$  V**.
8. The Control Display shows the amplitude of your entry. For example, 123.4567 mV (see below).



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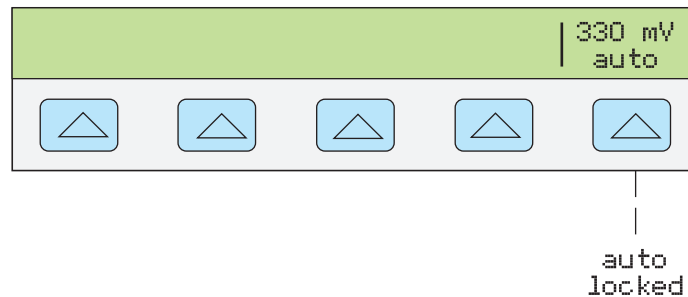
9. Push **ENTER**. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



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10. Push **OPR** to turn on the Calibrator output.

A softkey name for range is shown on the Control Display in the dc voltage function:



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**Range** (Operating Range) selects autorange (auto) or lock (locked) for the current range. When auto (the default) is selected, the Calibrator automatically selects the range that gives the best output resolution. When locked is selected, the Calibrator will not change ranges when you edit the output. The locked selection is typically made to prevent range changes that can cause a small agitation in the output, for example, when you measure the linearity of a given multimeter range.

### Set AC Voltage Output

You can select an ac voltage output in volts or as a power output in dBm, where dBm is  $10 \log (P_{out}/.001)$ , where  $P_{out}$  is shown in watts. The output range is 1 mV to 1000 V. When you select dBm outputs, the Calibrator calculates dBm at a selected impedance level. For this instance, the formula is:

$$20 \log(V) - 10 \log(\text{Impedance} * .001) = \text{dBm}.$$

Do this procedure to set an ac voltage output at the front panel NORMAL terminals. If you make an entry error, push **CE** to erase the display, then record the value again.

### **⚠ Caution**

**To prevent damage to the UUT, makes sure the applied voltage to the UUT is not larger than the rating of the UUT insulation and the connection wires.**

1. Push **RESET** to clear output from the Calibrator.
1. Connect the UUT as in the “Connect the Calibrator to a UUT” section of this chapter.
2. Set the UUT to measure ac voltage on the necessary range.

Output in volts:

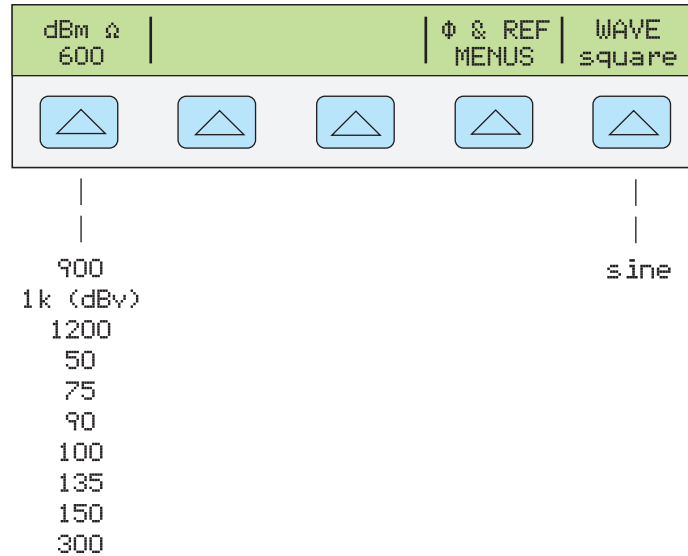
Push the numeric keys and decimal point key to record the necessary voltage output (maximum six numeric keys). For example, 2.44949.

### Output in dBm:

Push the numeric keys and decimal point key to record the necessary power output (maximum six numeric keys). For example, 10.0000. For a power output less than 1 mW (negative dBm values), push **[+/-]** to append the numeric entry with the negative (–) symbol.

When you push the dBm key, the right-most softkey turns on. This lets the dBm value and output impedance to be recorded as a unit.

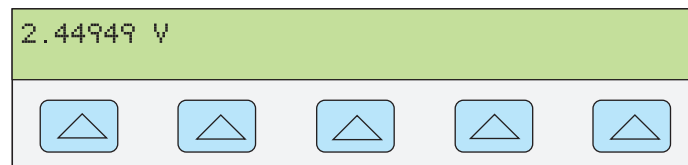
When output is recorded in dBm, the Control Display changes to:



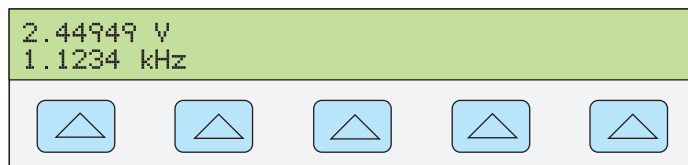
### Note

*At voltage outputs of 100 V and above (nominal), the Calibrator usually makes a small high-pitched sound.*

1. Push a multiplier key, if necessary. For example, push **[μ m]**.
2. Output in volts. Push **[dBm V]**.  
Output in dBm. Push **[SHIFT] [dBm V]**. Select an impedance for dBm from a list on the Control Display with the right-most softkey.
3. The Control Display shows the amplitude of your entry. For example, 2.44949 V (see below).

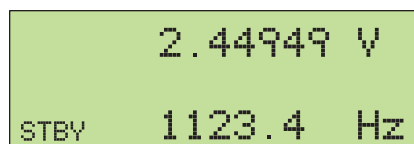


4. Push the numeric keys and decimal point key to record the necessary frequency output (maximum five numeric keys). Push a multiplier key, if necessary. For example, push the kilo multiplier key  $\text{^n k}$ . Then push the  $\text{^sec Hz}$  key. For example, 1.1234 kHz (see below).



nn074f.eps

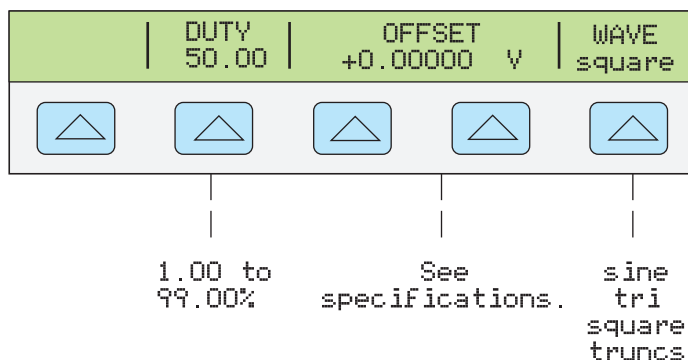
5. Push  $\text{ENTER}$ . The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



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6. Push  $\text{OPR}$  to start the Calibrator output.

Software names are shown on the Control Display in the ac voltage function, in reference to which waveform is selected: DUTY, OFFSET and WAVE.



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- **DUTY** (Duty Cycle) When the square wave is selected, DUTY shows and lets you change the duty cycle of the square wave. The range is 1.00 % to 99.00 %. The default is 50.00 %. The duty cycle must be 50.00 % if it is necessary to record an OFFSET (see below).
- **OFFSET** (Voltage Offset) shows when the necessary output is less than 33 V (sine waves), 65 V (square waves) or 93 V (triangle waves and truncated sine waves). This softkey lets you to add a positive or negative dc offset voltage to the ac output signal. See “Record a DC Offset” in this chapter for more information. When a voltage output is shown in dBm, voltage offset is not available. You can record an offset for a square wave output only when the duty cycle is 50.00 % (see DUTY above).
- **WAVE** (Waveform) lets you select one of four different types of waveforms: sine wave, triangle wave, square wave, and truncated sine wave. (See “Waveform Types” in this chapter). When a non-sinusoidal waveform is selected, the Output Display shows Pp (p-p). Output in dBm is sine wave only.



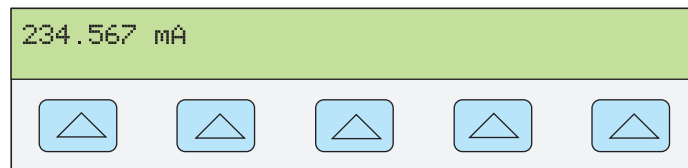
### Set DC Current Output

Do the subsequent procedure to set a dc current output between AUX HI and LO or AUX 20A and LO. Choose the inputs for the current level selected. Current larger than  $\pm 3$  A is sourced between the AUX 20A and LO terminals. If you make an entry error, push **CE** to clear the display, and then record the value again.

#### Note

See the “Specifications” section in Chapter 1 for a chart that shows duration or duty-cycle limits for current larger than 11 A. If the Calibrator goes above the duration or duty cycle, the Calibrator will turn off. After a cool-off period, the Calibrator changes to usual operation.

1. Push **RESET** to clear output from the Calibrator.
2. Connect the UUT as in the “Connect the Calibrator to a UUT” section of this chapter.
3. Set the UUT to measure dc current on the necessary range.
4. Push the numeric keys and decimal point key to record the necessary current output (maximum six numeric keys). For example, 234.567.
5. Push **+/-** to select the polarity of the current (default is +).
6. Push a multiplier key, if necessary. For example,  **$\mu$  m**.
7. Push  **$\mu$  A**.
8. The Control Display shows the amplitude of the entry. For example, 234.567 mA.



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9. Push **ENTER**. The Calibrator removes the entry from the Control Display and copies it into the Output Display (below is typical).



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10. Push **OPR** to start the Calibrator output.

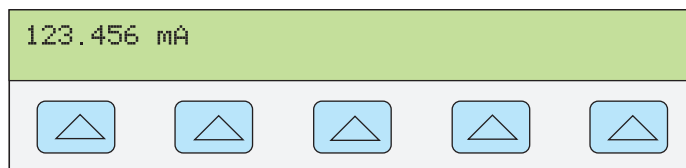
A range softkey is shown on the Control Display in the dc current function (operating range). This selects autorange (auto) or lock (locked) for the given range. When auto (the default) is selected, the Calibrator automatically selects the range that gives the best output resolution. When locked is selected, the Calibrator will not change ranges when you edit the output. The locked selection is typically made to prevent range changes that can cause a small agitation in the output, for example, when you measure the linearity of a given multimeter range.

A different softkey shows: OUTPUT. When you select 20 A for this parameter, or you select a current more than 3 A, the Calibrator switches to standby, and you must change the test lead to the 20A terminal and push **OPR** to activate the output.

### Set AC Current Output

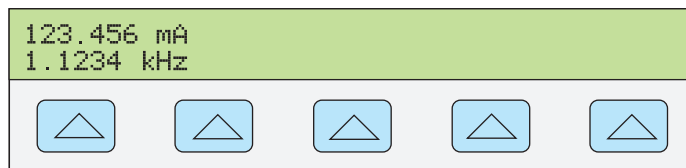
Do the subsequent procedure to set an ac current output at the AUX or 20A terminals. If you make an entry error, push **CE** to clear the display, then reenter the value.

1. Push **RESET** to clear any output from the Calibrator,
2. Connect the UUT as in the “Connect the Calibrator to a UUT” section of this chapter.
3. Set the UUT to measure ac current on the necessary range.
4. Push the numeric keys and decimal point key to record the necessary current output (maximum six numeric keys). For example, 123.456.
5. Push a multiplier key, if necessary. For example, push  **$\mu$  m**.
6. Push  **$\omega$  A**.
7. The Control Display shows the amplitude of your entry. For example, 123.456 mA (see below).



nn079f.eps

8. Push the numeric keys and decimal point key to record the necessary frequency output (maximum five numeric keys). Push a multiplier key, if necessary. For example, push the kilo multiplier key  **$^n$  k**. Then push the  **$^{Hz}$  Hz** key. For example, 1.1234 kHz (see below).



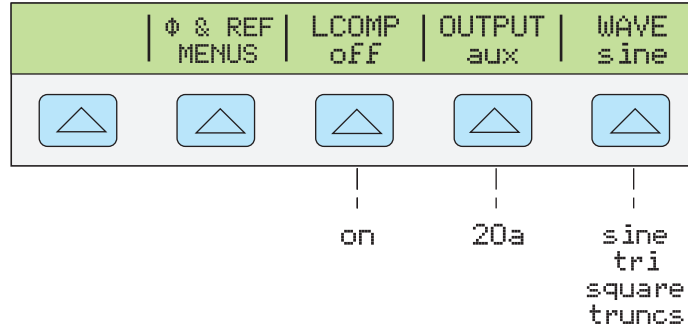
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9. Push **ENTER**. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).

+ 123.456 mA  
STBY + 1123.4 Hz

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10. Push **OPR** to activate the Calibrator output.



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- **LCOMP** turns inductive compensation on and off. Inductive compensation is available for frequencies to a maximum of 1 kHz at outputs to a maximum of 239.999 mA, and for frequencies to a maximum of 440 Hz more than 239.999 mA.
- **OUTPUT** shows if the output is on the AUX or 20A terminals. Outputs 3 A or above are always on the 20A terminals.
- **WAVE** (waveform) selects one of four different types of waveforms: sine wave, triangle wave, square wave, and truncated sine wave. (See “Waveform Types” later in this chapter for more information). When a non-sinusoidal waveform is selected, the Output Display changes the RMS indication to p-p (P<sub>P</sub>).

### Set DC Power Output

#### Note

*Tie the terminals NORMAL LO and AUX LO together at the UUT or at the Calibrator, with the “LO”s softkey selection “tied.”*

The Calibrator makes a dc power output by sourcing a dc voltage on the NORMAL outputs and a dc current on the AUX outputs. Complete the subsequent procedure to set a dc power output. If you make an entry error, push **CE** one or more times to clear the display, then reenter the value.

**⚠ Caution**

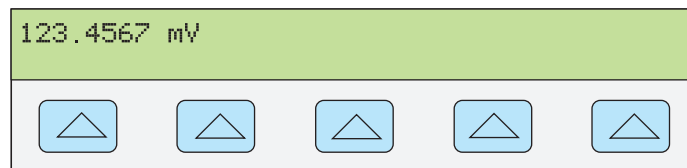
**To prevent damage to the UUT, make sure the applied voltage to the UUT is not larger than the rating of the UUT insulation and the connection wires.**

1. Push **RESET** to clear any output from the Calibrator.
2. Connect the UUT as in the “Connect the Calibrator to a UUT” section of this chapter. Change the voltage and current connections to this procedure.
3. Set the UUT to measure dc power on the necessary range.
4. Push the numeric keys and decimal point key to record the necessary voltage output (maximum seven numeric keys). For example, 123.4567.

*Note*

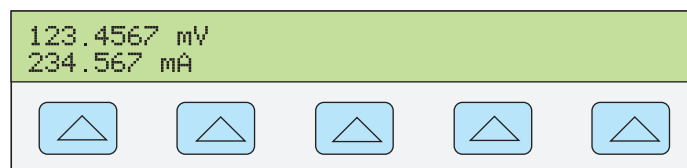
*At voltage outputs of 100 V and above (nominal), the Calibrator usually makes a small high-pitched sound.*

5. Push **+/-** to select the polarity of the voltage (default is +).
6. Push a multiplier key, if necessary. For example, push **μ m**.
7. Push **dBm V**.
8. The Control Display shows the amplitude of your entry. For example, 123.4567 mV (see below).



nn071f.eps

9. Push the numeric keys and decimal point key to record the necessary current output (maximum six numeric keys). For example, 234.567.
10. Push **+/-** to select the polarity of the current (default is +).
11. Push a multiplier key, if necessary. For example, push **μ m**.
12. Push **W A**.
13. The Control Display shows the amplitude of your entries. For example, 123.4567 mV and 234.567 mA (see below).



nn082f.eps

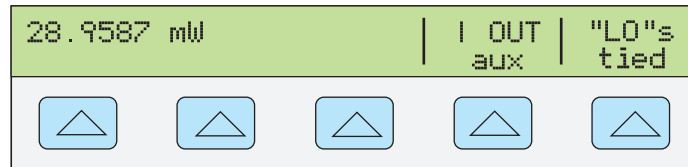
14. Push **ENTER**. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



nn083f.eps

15. Push **OPR** to activate the Calibrator output. When you change the power output levels, you must reenter voltage and current (in either order).

(Record voltage or current and then a watts entry value with **SHIFT** **W** **A**. The remaining volts or current value is calculated and displayed.)



nn322f.eps

- **I OUT** selects AUX or 20A terminals. Current outputs 3 A or above are always on the 20A terminals.
- **"LO"s** ties or opens a connection between front panel NORMAL LO and AUX LO terminals. The front panel NORMAL LO and AUX LO terminals must be tied together at the UUT or at the Calibrator. The default is tied.

### Set AC Power Output

#### Note

*Tie the terminals NORMAL LO and AUX LO together at the UUT, or at the Calibrator with the "LO"s softkey selection "tied." For optimum phase performance, tie the LO terminals at the UUT. At current levels >2.2 A, tie the terminals at the UUT. Use heavy gauge wire >10 mΩ resistance.*

The Calibrator makes an ac power output by sourcing an ac voltage on the NORMAL outputs and an ac current on the AUX outputs.

See "Set AC Voltage Output" in this chapter for information about ac voltage output in dBm. This procedure that the ac voltage output is in volts.

Complete the subsequent procedure to set an ac power output. If you make an entry error, push **CE** one or more times to clear the display, then reenter the value.

#### **⚠ Caution**

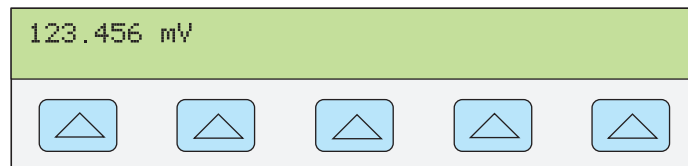
**To prevent damage to the UUT, make sure the applied voltage to the UUT is not larger than the rating of the UUT insulation and the connection wires.**

1. Push **RESET** to erase output from the Calibrator.
2. Connect the UUT as in the "Connect the Calibrator to a UUT" section of this chapter. (Change the voltage and current connections to suit your application.)
3. Set the UUT to measure ac power on the necessary range.
4. Push the numeric keys and decimal point key to record the necessary voltage output (maximum six numeric keys). For example, 123.456.

*Note*

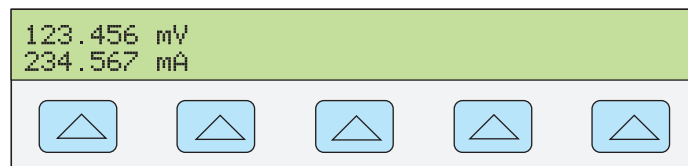
*At voltage outputs of 100 V and above (nominal), the Calibrator usually makes a small high-pitched sound.*

5. Push a multiplier key, if necessary. For example, push  $\mu$  m.
6. Push  $\text{dBm V}$ .
7. The Control Display shows the amplitude of your voltage entry. For example, 123.456 mV (see below).



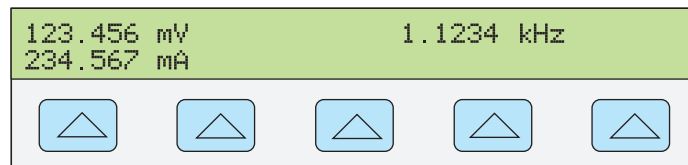
nn084f.eps

8. Push the numeric keys and decimal point key to record the necessary current output (maximum six numeric keys). For example, 234.567.
9. Push a multiplier key, if necessary. For example, push  $\mu$  m.
10. Push  $\text{W A}$ .
11. The Control Display shows the amplitude of your voltage and current entries. For example, 123.456 mV and 234.567 mA (see below).



nn085f.eps

12. Push the numeric keys and decimal point key to record the necessary frequency output (maximum five numeric keys). Push a multiplier key, if necessary. For example, push the kilo multiplier key  $\text{k}$ . Then push the  $\text{Hz}$  key. For example, 1.1234 kHz.
13. The Control Display shows your entries. For example, 123.456 mV and 234.567 mA at 1.1234 kHz (see below).



nn086f.eps

14. Push **ENTER**. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).

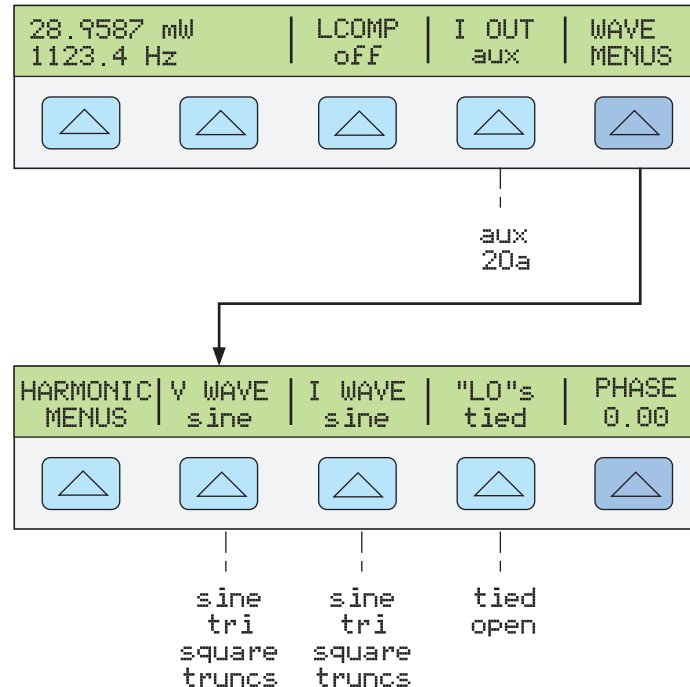


nn087f.eps

15. Push **OPR** to activate the Calibrator output. When you change power output levels, you must reenter voltage and current (in either order).

(Record voltage or current and then a watts entry value with **ENTER** **W A**. The remaining volts or current value is calculated and shown.)

Three softkey names show on the Control Display: WAVE MENUS, I OUT (AUX or 20A terminals), and LCOMP (off or on). The Control Display also shows the actual power output for sine waves. Power out is calculated as  $\text{Power} = \text{Cosine } \Phi \text{ (Volts} \times \text{Current)}$  where  $\Phi$  is the phase difference between the volts and current waveforms. Cosine  $\Phi$  is also known as the Power Factor (PF) (see below)



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- **WAVE MENUS** (Waveform Menus) Opens submenus to select the type of harmonic, waveform, front panel LO terminal condition, and phase.
- **HARMONIC MENUS** (Harmonic Frequency Menus) Opens submenus to select harmonic outputs. See "Setting Harmonics" in this chapter.
- **V WAVE** (Voltage Waveform) Selects the waveform for the voltage output at the NORMAL terminals. See "Waveform Types" in this chapter.

- **I WAVE** (Current Waveform) Selects the waveform for the current output at the front panel AUX terminals. See “Waveform Types” in this chapter.
- **“LO”s** (Low Potential Output Terminals) The front panel NORMAL LO and AUX LO terminals must be tied together either at the UUT or at the Calibrator. When tied at the UUT, select “open.” The default is tied.
- **PHASE** Sets the phase difference between the NORMAL and AUX outputs. See “Adjusting the Phase” in this chapter.

### Set a Dual DC Voltage Output

#### Note

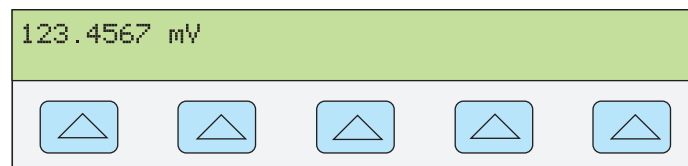
*Tie the terminals NORMAL LO and AUX LO together at the UUT or at the Calibrator, with the “LO”s softkey selection “tied.”*

The Calibrator makes a dual dc voltage output by sourcing one dc voltage on the NORMAL outputs and a second on the AUX terminals. Complete the subsequent procedure to set a dual dc voltage output. If you make an entry error, push **CE** one or more times to clear the display, then enter the value again.

#### Caution

**To prevent damage to the UUT, make sure the applied voltage to the UUT is not larger than the rating of the UUT insulation and the connection wires.**

1. Push **RESET** to clear any output from the Calibrator.
2. Connect the UUT as in the “Connect the Calibrator to a UUT” section of this chapter.
3. Set the UUT to measure dual dc voltage on the necessary range.
4. Push the numeric keys and decimal point key to record the necessary voltage output at the NORMAL terminals (maximum seven numeric keys). For example, 123.4567.
5. Push **+/-** to select the polarity of the voltage (default is +).
6. Push a multiplier key, if necessary. For example, push **μ m**.
7. Push **dBm V**.
8. The Control Display shows the amplitude of your entry for the NORMAL terminals. For example, 123.4567 mV (see below).



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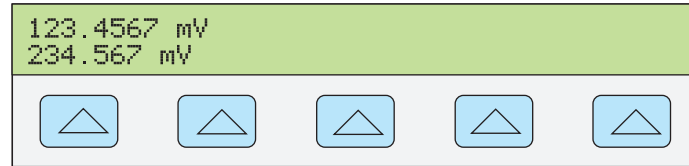
#### Note

*Voltage on the AUX output is a maximum of 3.3 V.*

9. Push the numeric keys and decimal point key to record the necessary voltage output at the AUX terminals (maximum six numeric keys). For example, 234.567.
10. Push **+/-** to select the polarity of the voltage (default is +).
11. Push a multiplier key, if necessary. For example, push **μ m**.
12. Push **dBm V**.
13. The Control Display shows the amplitude of your entries for the NORMAL terminals

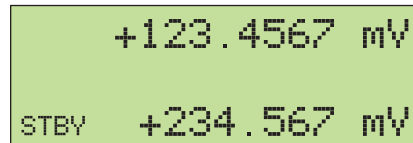


(upper reading) and AUX terminals (lower reading) (see below).



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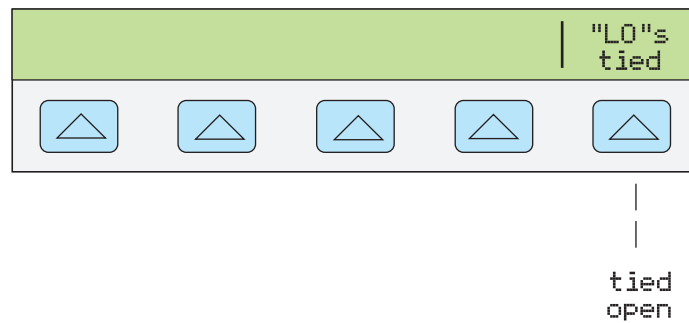
14. Push **ENTER**. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



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15. Push **OPR** to activate the Calibrator output.

A softkey named “LO”s shows on the Control Display (see below).



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- **“LO”s** (Low Potential Output Terminals) The front panel NORMAL LO and AUX LO terminals must be tied together either at the UUT or at the Calibrator. When the front panel NORMAL LO and AUX LO terminals are tied at the UUT, select “open” with the “LO”s softkey. If the NORMAL LO and AUX LO terminals are not tied at the UUT, select “tied” with the “LO”s softkey. The default is tied.

### Set a Dual AC Voltage Output

#### Note

*Tie the terminals NORMAL LO and AUX LO together at the UUT or at the Calibrator, with the “LO”s softkey selection “tied.”*

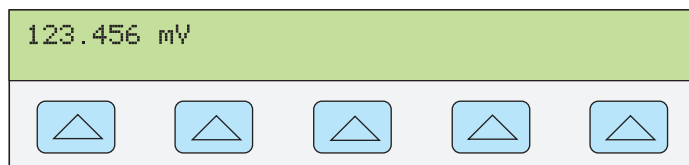
The Calibrator makes a dual ac voltage output by sourcing one ac voltage on the NORMAL outputs and a second on the AUX terminals.

Do the subsequent procedure to set a dual ac voltage output. If you make an entry error, push **CE** one or more times to clear the display, then enter the value again.

**⚠ Caution**

**To prevent damage to the UUT, make sure the applied voltage to the UUT is not larger than the rating of the UUT insulation and the connection wires.**

2. Push **RESET** to clear any output from the Calibrator.
3. Connect the UUT as in the “Connect the Calibrator to a UUT” section of this chapter.
4. Set the UUT to measure dual ac voltage on the necessary range.
5. Push the numeric keys and decimal point key to record the necessary voltage output at the NORMAL terminals (maximum six numeric keys). For example, 123.456.
6. Push a multiplier key, if necessary. For example, push **μ m**.
7. Push **dBm V**.
8. The Control Display shows the amplitude of your voltage entry. For example, 123.456 mV (see below).

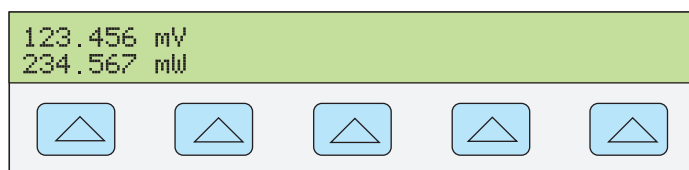


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*Note*

*The AUX output is 3.3 V rms maximum for sine waves, 6.6 V p-p for square waves, 9.3 V p-p for triangle and truncated sine waves.*

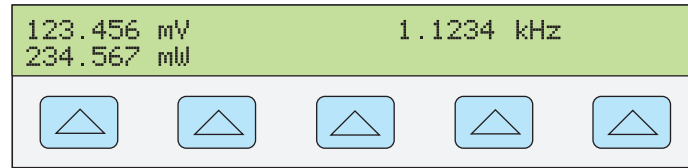
9. Push the numeric keys and decimal point key to record the necessary voltage output at the AUX terminals (maximum six numeric keys). For example, 234.567.
10. Push a multiplier key, if necessary. For example, push **μ m**.
11. Push **dBm V**.
12. The Control Display shows the amplitude of your entries for the NORMAL terminals (upper reading) and AUX terminals (lower reading) (below is typical).



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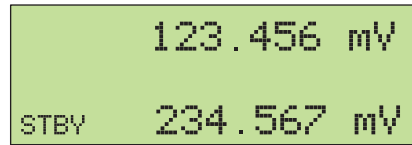
13. Push the numeric keys and decimal point key to record the necessary frequency output (maximum five numeric keys). Push a multiplier key, if necessary. For example, push the kilo multiplier key **μ k**. Then push the **Hz** key. For example, 1.1234 kHz.

14. The Control Display shows your voltage and frequency entries. For example, 123.456 mV and 234.567 mV at 1.1234 kHz (see below).



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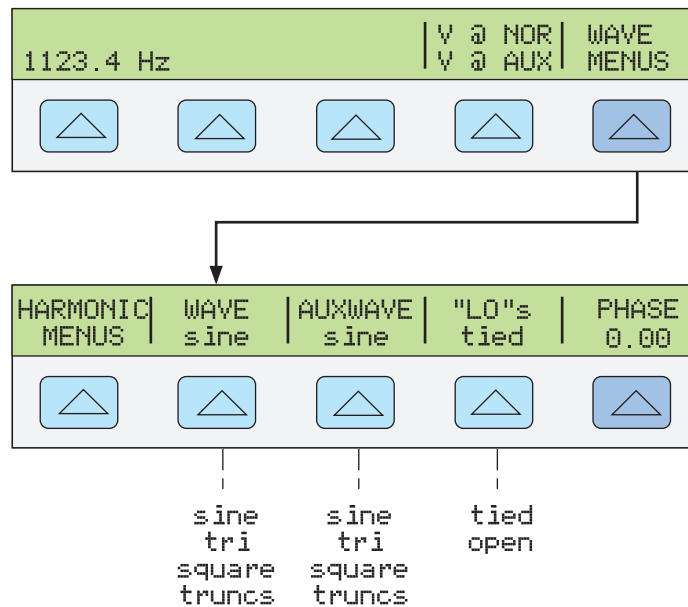
15. Push **ENTER**. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



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16. Push **OPR** to activate the Calibrator output.

Two softkey names show on the Control Display: V@NOR/V@AUX and WAVE MENUS (see below).



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- **V @ NOR** (Voltage at NORMAL Terminals) **V @ AUX** (Voltage at AUX Terminals) This is an information-only softkey position and does not have an related function. It shows the output function is dual ac voltage.

- **WAVE MENUS** (Waveform Menus) Opens submenus to select the type of harmonic, waveform, front panel LO terminal condition, and phase.
  - **HARMONIC MENUS** (Harmonic Frequency Menus) Opens submenus to select harmonic outputs. See “Set Harmonics” in this chapter.
  - **WAVE** (Normal Waveform) Selects the waveform for the voltage at the front panel NORMAL terminals. See “Waveform Types” in this chapter.
  - **AUXWAVE** (Auxiliary Waveform) Selects the waveform for the voltage at the front panel AUX terminals. See “Waveform Types” in this chapter.
  - **“LO”s** (Low Potential Output Terminals) The front panel NORMAL LO and AUX LO terminals must be tied together either at the UUT or at the Calibrator. When the front panel NORMAL LO and AUX LO terminals are tied at the UUT, select “open” with the “LO”s softkey. If the NORMAL LO and AUX LO terminals are not tied at the UUT, select “tied” with the “LO”s softkey. The default is tied.
  - **Φ & REF MENUS** (Phase Difference and 10 MHz reference source.) Selects the phase difference between the NORMAL and AUX outputs, selects internal or external 10 MHz reference, and sets the phase difference between an external master 5502A (using 10 MHz IN/OUT) and the NORMAL output. See “Adjusting the Phase” and “Synchronizing the Calibrator using 10 MHz IN/OUT” in this chapter.

### Set Resistance Output

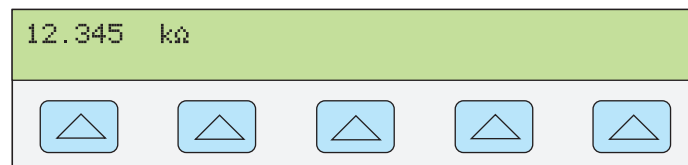
Complete the subsequent procedure to set a synthesized resistance output at the Calibrator front panel NORMAL terminals. If you make an entry error, push **CE** to clear the display, then enter the value again.

1. Push **RESET** to clear any output from the Calibrator.
2. Connect the UUT as in the “Connect the Calibrator to a UUT” section of this chapter.

#### Note

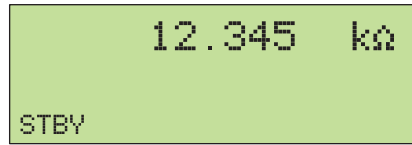
*Since this is a synthesized output, be sure the terminal connections from the Calibrator to the UUT are LO to LO and HI to HI.*

3. Set the UUT to measure resistance on the necessary range.
4. Push the numeric keys and decimal point key to record the necessary resistance output (maximum six numeric keys). For example, 12.345.
5. Push a multiplier key, if necessary. For example, push **k**.
6. Push **Ω**.
7. The Control Display shows the amplitude of your resistance entry. For example, 12.345 kΩ (see below).



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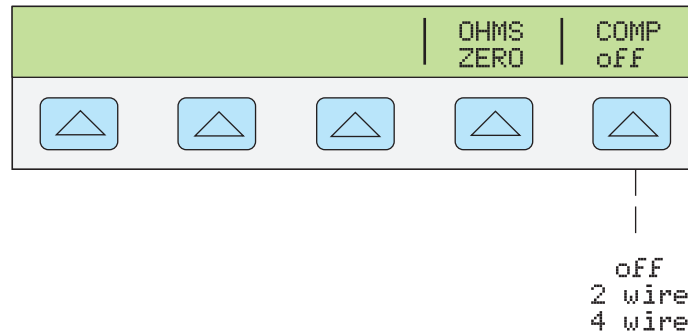
- Push **ENTER**. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



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- Push **OPR** to start the Calibrator output.

The softkeys let you select three lead-compensation settings and ohms zero (see below).



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- **OHMS ZERO** Push to recalibrate internal circuitry for the ohms function (allow several minutes).
- **COMP** (Compensation) Applies 4-wire compensation, 2-wire compensation or turns compensation off. Compensation is available for resistances to (but not including) 110 kΩ. See “Four-Wire versus Two-Wire Connections” in this chapter.

### Set Capacitance Output

Complete the subsequent procedure to set a synthesized capacitance output at the front panel NORMAL terminals. If you make an entry error, push **CE** to clear the display, then reenter the value.

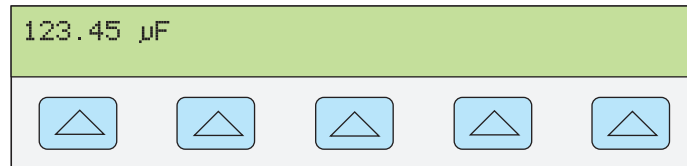
- Push **RESET** to clear any output from the Calibrator.
- Connect the UUT as in the “Connect the Calibrator to a UUT” section of this chapter. Also see “Cable Connection Instructions” for a procedure to null out stray capacitances due to the test cable connections.

#### Note

*Since this is a synthesized output, be sure the terminal connections from the Calibrator to the UUT are LO to LO and HI to HI.*

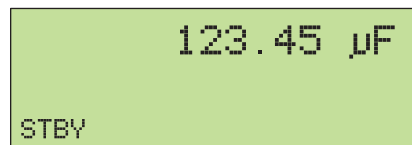
- Set the UUT to measure capacitance on the necessary range.
- Push the numeric keys and decimal point key to record the necessary capacitance output (maximum five numeric keys). For example, 123.45.

5. Push a multiplier key (preceded with the **SHIFT** key) for the necessary output. For example, push **SHIFT** then **μm** for  $\mu\text{F}$ . The other multiplier keys include **PM** for pF and **nk** for nF.
6. Push **F  $\frac{\Delta}{\Delta}$** .
7. The Control Display shows the amplitude of your capacitance entry. For example, 123.45  $\mu\text{F}$  (see below).



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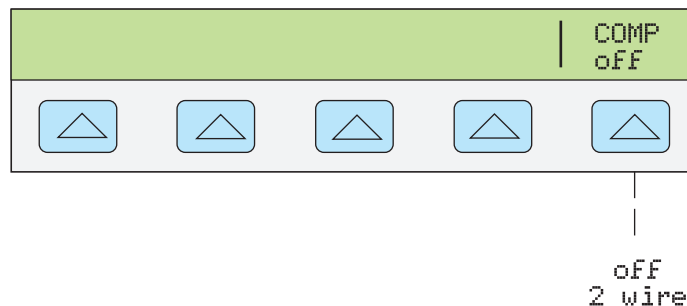
8. Push **ENTER**. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



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9. Push **OPR** to activate the Calibrator output.

The softkey in the Control Display named COMP lets you select one of three lead-compensation settings (see below).



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- **COMP** (Compensation). Applies 2-wire compensation or turns compensation off. Compensation refers to methods of connection the Calibrator to the UUT to cancel out test lead resistance (NOT capacitance). Compensation is available for capacitances of 110 nF and above. This softkey does not function in less than 110 nF. See “Four-Wire versus Two-Wire Connections” in this chapter.

## Set Temperature Simulation (Thermocouple)

### Note

*Thermocouples have no electrical isolation. Make sure the thermocouple wire and plug are not changed by extraneous temperature sources. For example, do not put your fingers on the thermocouple plug or wire when you simulate a temperature.*

Thermocouples generate a small dc voltage at specific temperatures. The simulated output is a small dc voltage that comes from the selected temperature and type of thermocouple that is simulated. To toggle the temperature reference between the 1968 International Provisional Temperature Standard (ipts-68) and the 1990 International Temperature Standard (its-90), see “Use the Instrument Setup Menu.”

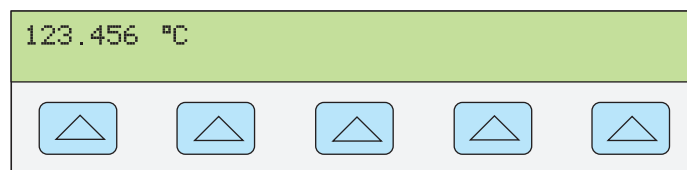
Complete the subsequent procedure to set a simulated thermocouple temperature output at the Calibrator front panel TC connector. If you make an entry error, push **CE** to clear the display, then enter the value again.

1. Push **RESET** to clear any output from the Calibrator.
2. Connect the UUT as in the “Connect the Calibrator to a UUT” section of this chapter.

### Note

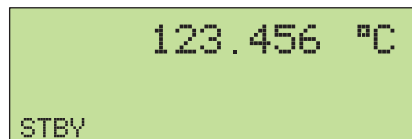
*You must use thermocouple wire and miniconnectors that agree with the type of thermocouple. For example, if you simulate a temperature output for a type-K thermocouple, use type-K thermocouple wire and type-K miniconnectors.*

3. Set the UUT to measure temperature on the necessary range.
4. Push the numeric keys and decimal point key to record the necessary temperature output (maximum six numeric keys). For example, 123.456.
5. For an output in °C, push **°C**. For an output in °F, push and then **°F**.
6. The Control Display shows the amplitude of your temperature output. For example, 123.456 °C (see below).



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7. Push **ENTER**. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).

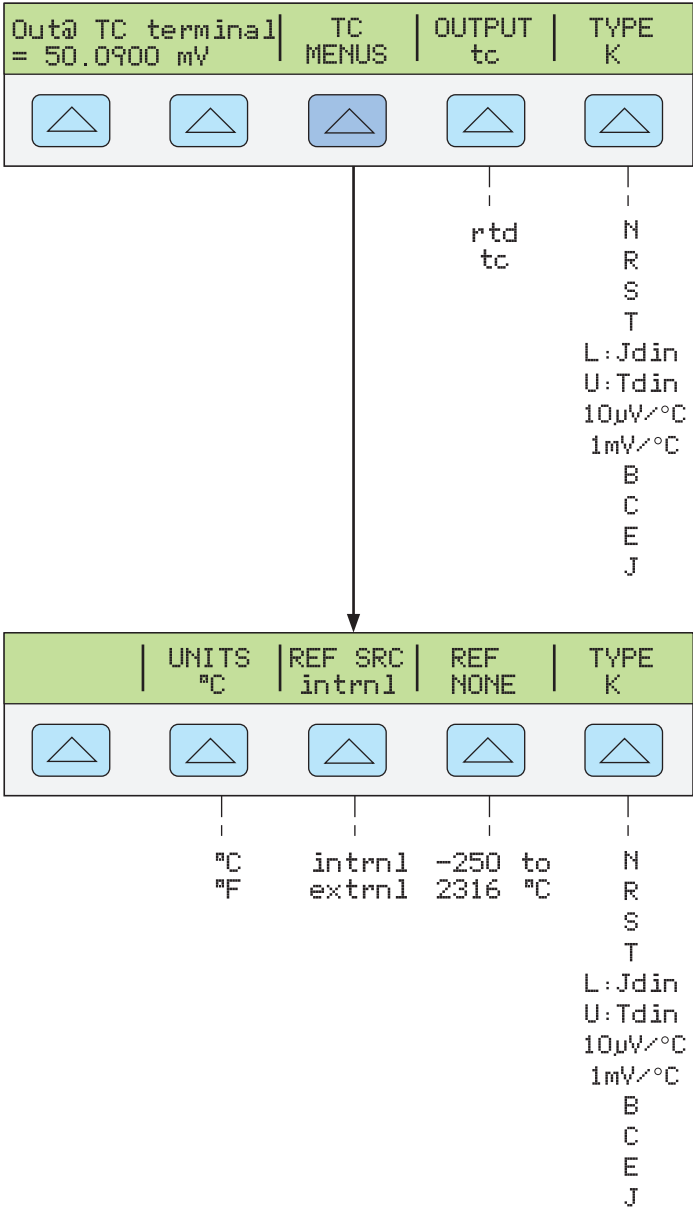


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8. Push **OPR** to activate the Calibrator output. Four softkey names show on the Control Display (see below).

*Note*

*The recorded temperature will be changed to 0 °C (32 °F) if you change between tc and rtd, or change the type of thermocouple (except for a type B thermocouple, which clears to 600 °C). If this occurs, select OUTPUT tc, the necessary thermocouple TYPE, and then reenter the temperature.*



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- **Out@TC** terminal (Output at the front panel TC terminals) Shows the actual dc voltage at the front panel TC terminals. This is a display only, not a softkey function.
- **TC MENUS** (Thermocouple Menu) Shows submenus for thermocouple outputs.
  - **UNITS** (Temperature Units) Selects °C or °F as the temperature unit.
  - **REF SRC** (Reference Source) Selects intrnl (Internal) or extrnl (External) temperature reference source. Select intrnl when the selected thermocouple has alloy wires and you use the isothermal block internal to the Calibrator. Select extrnl when you use an external isothermal block, and when the selected thermocouple has copper wires. Push the REF softkey to record the value of the external temperature reference. The best accuracy is when you use extrnl and the external isothermal block is kept at 0 °C.
  - **REF** (Temperature Reference) Shows the value of the temperature reference. When the Reference Source is Internal, the display shows the internal reference, or NONE if the Calibrator is in Standby. When the Reference Source is External, the display shows the value you recorded for external reference.
  - **OUTPUT** (Temperature Output Device) Selects the temperature device: thermocouple (tc) or resistance temperature detector (rtd). Select tc.
  - **TYPE** (Thermocouple Type) Selects the thermocouple type simulated by the Calibrator. The default is type K. (The 10 µV/°C and 1 mV/°C settings are used as an accurate output voltage source for user-supplied linearizations.)

*Note*

*The “u” indicator that occasionally shows in the Output Display shows an internal adjustment to the measured isothermal block temperature and is usual. If it shows for more than 10 seconds (nominal), or if it flashes continuously, make sure that you do not externally heat the thermocouple miniconnector or wires.*

### Set Temperature Simulation (RTD)

RTDs have a resistance quality at specified temperatures. The simulated output is a resistance value that comes from the selected temperature and type of RTD simulated. To toggle the degree reference between the 1968 International Provisional Temperature Standard (IPTS-68) and the 1990 International Temperature Standard (ITS-90), see “Use the Instrument Setup Menu” in this chapter.

Complete the subsequent procedure to set a simulated RTD temperature output at the front panel NORMAL terminals. If you make an entry error, push **CE** to clear the display, then enter the value again.

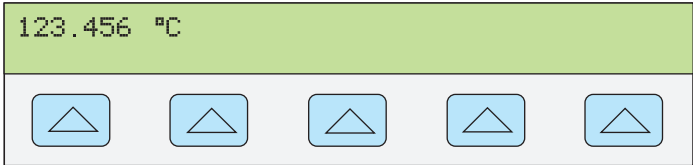
1. Push **RESET** to clear any output from the Calibrator.
2. Connect the UUT as in the “Connect the Calibrator to a UUT” section of this chapter.

*Note*

*When you calibrate Resistance Temperature Detectors (RTDs) with the three-terminal connection shown in Figure 4-9, make sure the test leads have the same resistances to cancel errors caused by lead resistance. This can be done, for example, with three of the same test lead lengths and the same connector styles.*

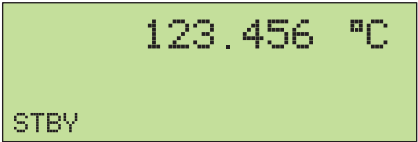
3. Set the UUT to measure temperature in the necessary range.

- 4. Push the numeric keys and decimal point key to record the necessary temperature output (maximum six numeric keys). For example, 123.456.
- 5. For an output in °C, push  $\text{°C}$ . For °F, push **SHIFT** and then  $\text{°C}$ .
- 6. The Control Display shows the amplitude of your temperature output. For example, 123.456 °C (see below).



nn102f.eps

- 7. Push **ENTER**. The Calibrator erases your entry from the Control Display and copies it into the Output Display (below is typical).



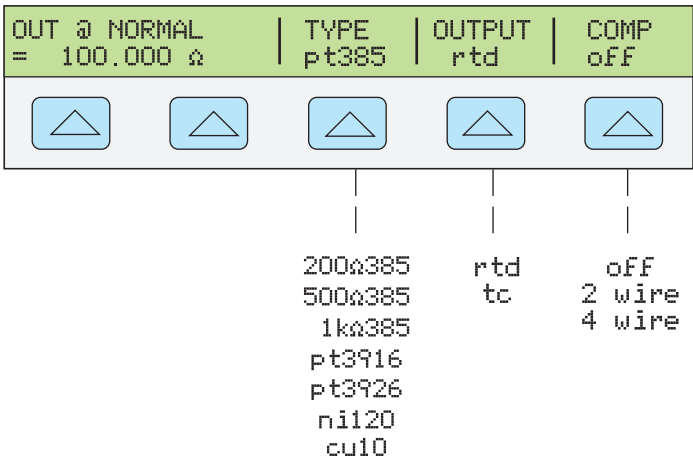
nn103f.eps

- 8. Push **OPR** to activate the Calibrator output.

Four softkey names show on the Control Display. Push the OUTPUT softkey to toggle the rtd selection, this shows the rtd setup menu and four softkey positions.

*Note*

*The temperature you recorded above will be changed to 0 °C (32 °F) if you change between tc (thermocouple) and rtd (resistance temperature detector), or change the type of rtd. If this occurs, select OUTPUT rtd, the necessary rtd TYPE, and then record the temperature again. Follow steps 4 to 8.*



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- **Out @ NORMAL** displays the location of the output terminals (always NORMAL) for rtd connections.
- **TYPE** (RTD Type) - Selects the rtd curve from a list.
- **OUTPUT** (Temperature Output Device) - Selects the temperature device: thermocouple (tc) or resistance temperature detector (rtd). Select rtd.
- **COMP** (Compensation) - Applies 4-wire compensation, 2-wire compensation or turns compensation off. Compensation refers to methods to connect the Calibrator to the UUT to cancel out test lead resistance. See “Four-Wire versus Two-wire Connections” in this chapter. For the 3-lead connection (Figure 4-9) select COMP off.

### Measure Thermocouple Temperatures

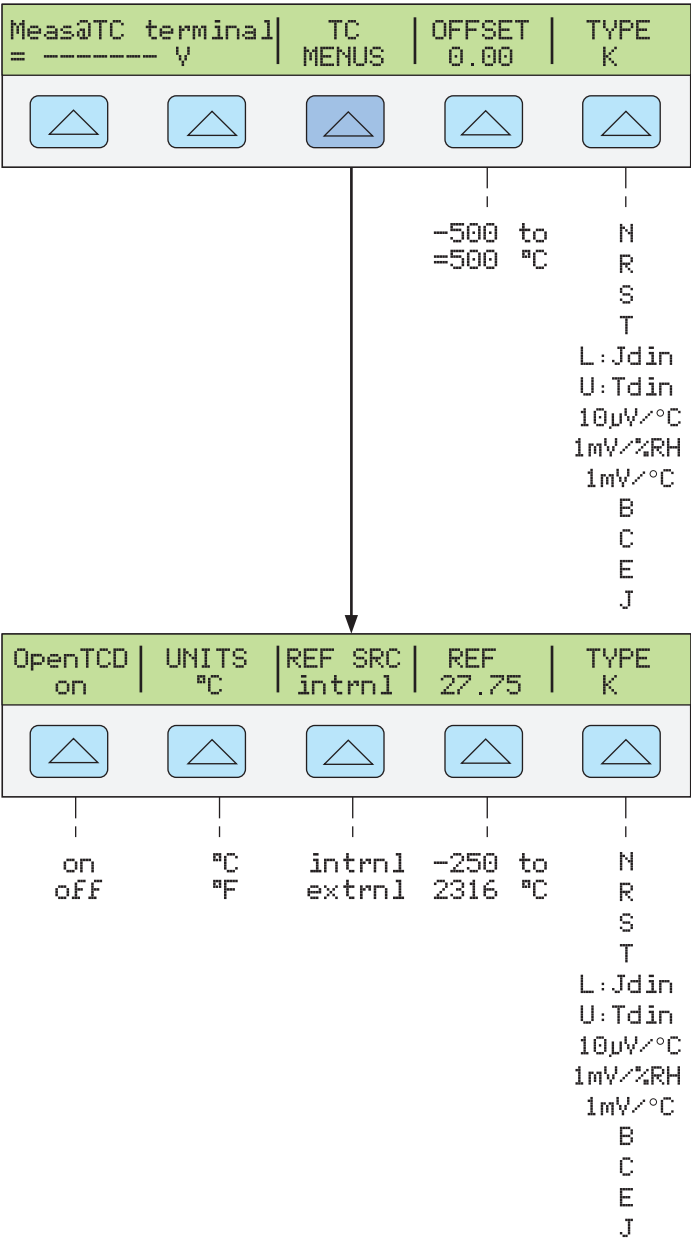
Complete the subsequent procedure to measure the output of a thermocouple connected to the TC input. If you make an entry error, push **CE** to clear the display, then reenter.

1. Push **RESET** to clear any output from the Calibrator.
2. Connect the thermocouple to the front panel TC connector.

#### Note

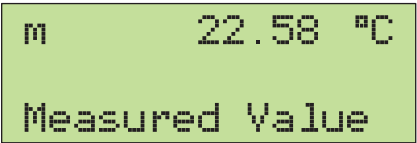
*You must use thermocouple wire and miniconnectors that agree with the type of thermocouple. For example, if you simulate a temperature output for a type-K thermocouple, use type-K thermocouple wire and type-K miniconnectors.*

3. Push **MEAS TC** to display the TC menus (see below).



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4. The measured temperature shows in the Output Display (below is typical). (The lower-case m blinks on when a measurement is being taken.)



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- **Meas@TC** terminal (Measurement at the front panel TC terminals) Shows the actual dc voltage at the front panel TC terminals. This is a display only, not a softkey function.
- **TC MENUS** (Thermocouple Menus) Opens the thermocouple output submenus.
  - **Open TCD** (Open Thermocouple Detect) Selects on or off for the Open TCD feature. When Open TCD is on, a small electrical pulse checks for thermocouple continuity that, in most cases, will have no effect on the measurement. If you measure the thermocouple with the Calibrator in parallel with a different temperature-measure device, select off for Open TCD. When an open thermocouple is found, “Open TC” is shown in the TC menu as a positive identification of the fault.
  - **UNITS** (Temperature Units) Selects °C or °F as the temperature unit.
  - **REF SRC** (Reference Source) Selects intrnl (Internal) or extrnl (External) temperature reference source. The reference source shows the ambient temperature contribution to the thermocouple output, this is necessary to remember when you simulate an accurate temperature output. Select intrnl when the selected thermocouple has alloy wires and you use the isothermal block internal to the Calibrator. Select extrnl when you use an external isothermal block, and when the selected thermocouple has copper wires. Push the REF softkey to record the value of the external temperature reference.
  - **REF** (Temperature Reference) Shows the value of the temperature reference. When the Reference Source is Internal, the display shows the internal reference. When the Reference Source is External, the display shows the value you recorded for external reference.
  - **OFFSET** (Measurement Display Offset) Selects an offset value to be added or subtracted from the actual measurement. This is useful for differential measurements (temperatures above and below a necessary temperature).
  - **TYPE** (Thermocouple Type) Selects the thermocouple type used for measurement. The default is K. (The 10µV/°C setting is used for customer-supplied linearizations. 1 mV/%RH and 1 mV/°C settings are used for the Vaisala humidity/temperature probes.)

## Waveform Types

AC voltage, ac current, dual ac voltage, and ac power functions supply a softkey to select between four different waveform types: sine wave (sine), triangle wave (tri), square wave (square), and truncated sine wave (truncs). When the Calibrator output is sine wave ac power or dual ac voltage, the Control Display shows more softkeys for harmonics and fundamental frequencies.

### Sine Wave

When the wave selection is sine, a sine wave current or voltage signal is at the Calibrator outputs (Figure 4-11). The variables for the sine wave are **amplitude**, frequency, and dc offset voltage.

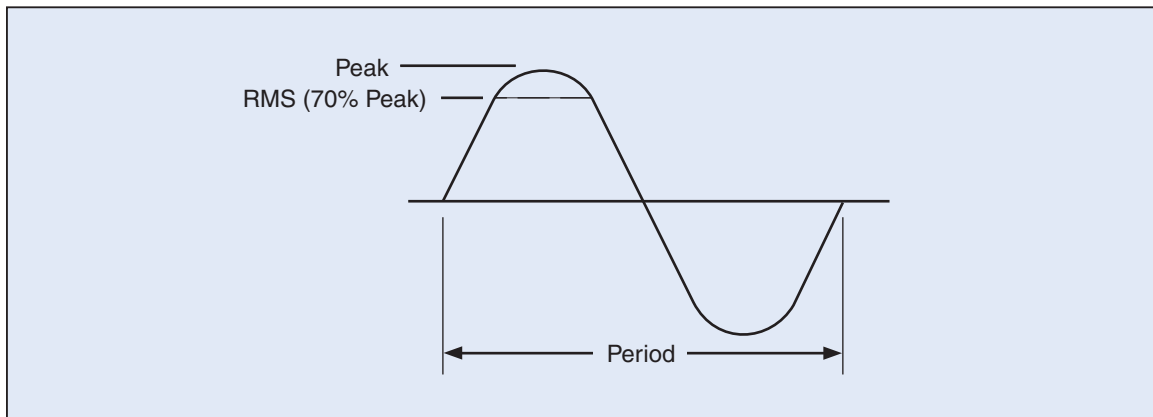


Figure 4-11. Sine Wave

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### Triangle Waves

When the wave selection is tri, the triangle wave is at the Calibrator outputs (Figure 4-12). The variables for the triangle wave are amplitude, frequency, and dc offset voltage. When a triangle wave is selected, the Output Display shows amplitudes in p-p units.

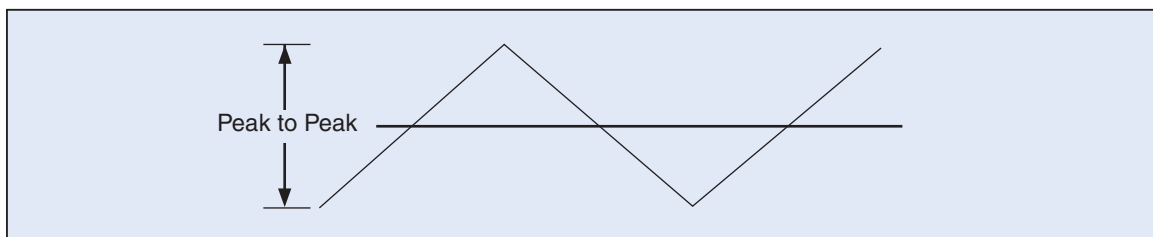


Figure 4-12. Triangle Wave

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### Square Wave

When the wave selection is square, a square wave current or voltage signal is at the Calibrator outputs (Figure 4-13). The variables for the square wave are duty cycle, amplitude, frequency, and dc offset voltage. When a square wave is selected, the Output Display shows amplitude in p-p units. If the Calibrator is set for one voltage or current output, the duty cycle of the signal can be set with the keypad. To record a new duty cycle, push the DUTY CYCLE softkey and a maximum of five numeric keys, then push **ENTER**. The negative-going edge of the square wave moves in relation to how the duty cycle is set.

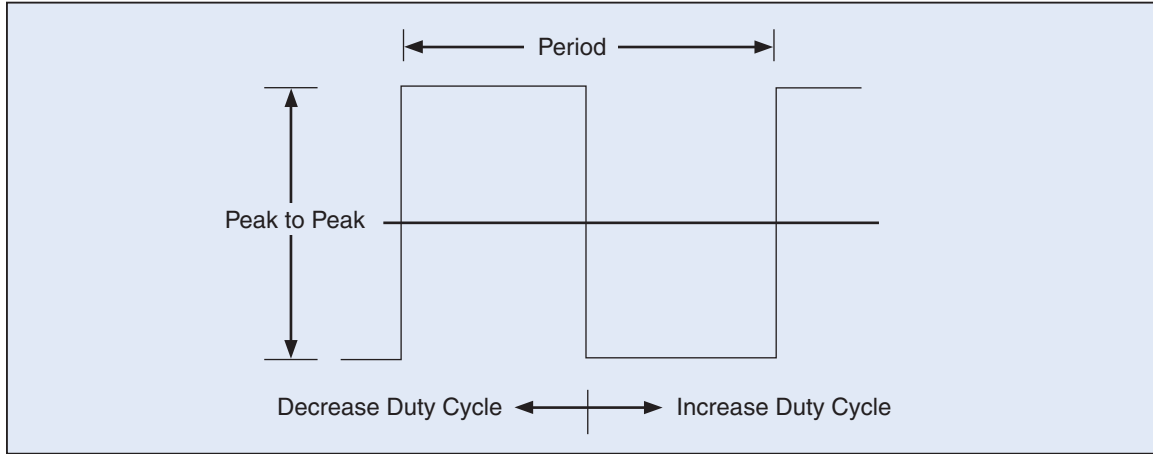


Figure 4-13. Square Wave and Duty Cycle

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### Truncated Sine Wave

When the wave selection is trunks, a truncated sine wave current or voltage signal is at the Calibrator outputs (Figure 4-14). The variables for the truncated sine wave are amplitude and frequency. When a truncated sine wave is selected, the Output Display shows amplitudes in p-p units.

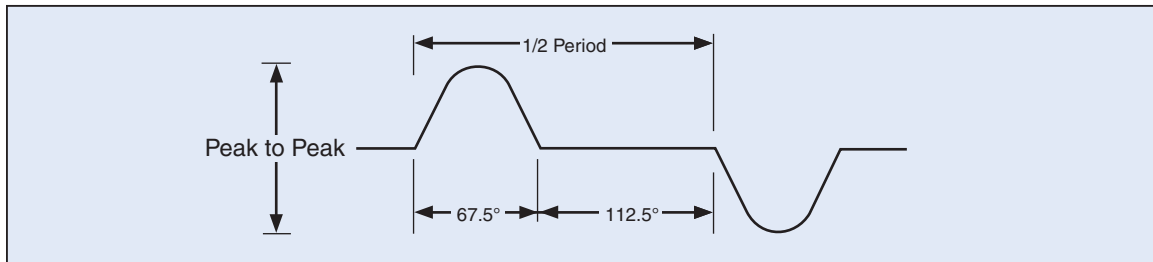


Figure 4-14. Truncated Sine Wave

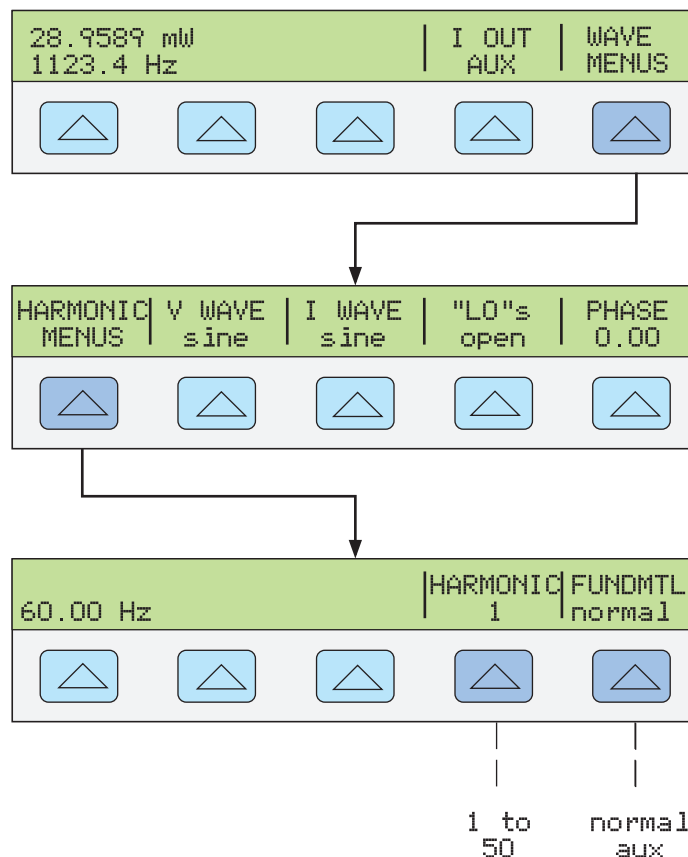
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## Set Harmonics

When the Calibrator outputs dual ac voltages or ac power (sine waves only), the Calibrator sources two signals with adjustable harmonic difference, with a maximum harmonic frequency output of 10 kHz. For example, a 120 V, 60 Hz signal can be set on the front-panel NORMAL terminals, and a 1 V, 300 Hz (5th harmonic) output on the AUX terminals. The fundamental can be configured on the NORMAL or the AUX terminals, with the harmonic output on the opposite terminals. Note that the maximum AUX output is 3.3 V, while the maximum NORMAL output is 1000 V. Unless the fundamental and harmonic frequencies are permitted for the given amplitude, the output is not permitted.

Complete the subsequent procedure to record a harmonic output. For this procedure, you will have already sourced a dual ac voltage or ac power output.

1. Push the softkey WAVE MENUS to open the waveform menu.
2. Push the softkey HARMONIC MENUS to open the harmonic submenu (below is typical).

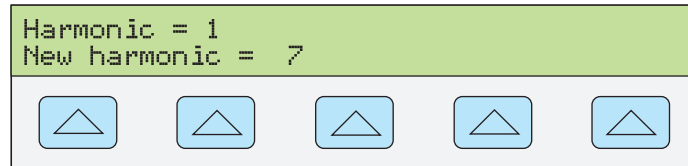


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3. Push the softkey FUNDMTL to select the Calibrator front-panel terminals for the fundamental output (NORMAL or AUX). The harmonic shows on the AUX terminals.



4. Push the softkey HARMNIC to record the necessary harmonic (1 to 50), with a maximum frequency output of 10 kHz. For example, record the 7th harmonic (see below). When the control display shows the necessary value, push **ENTER**.



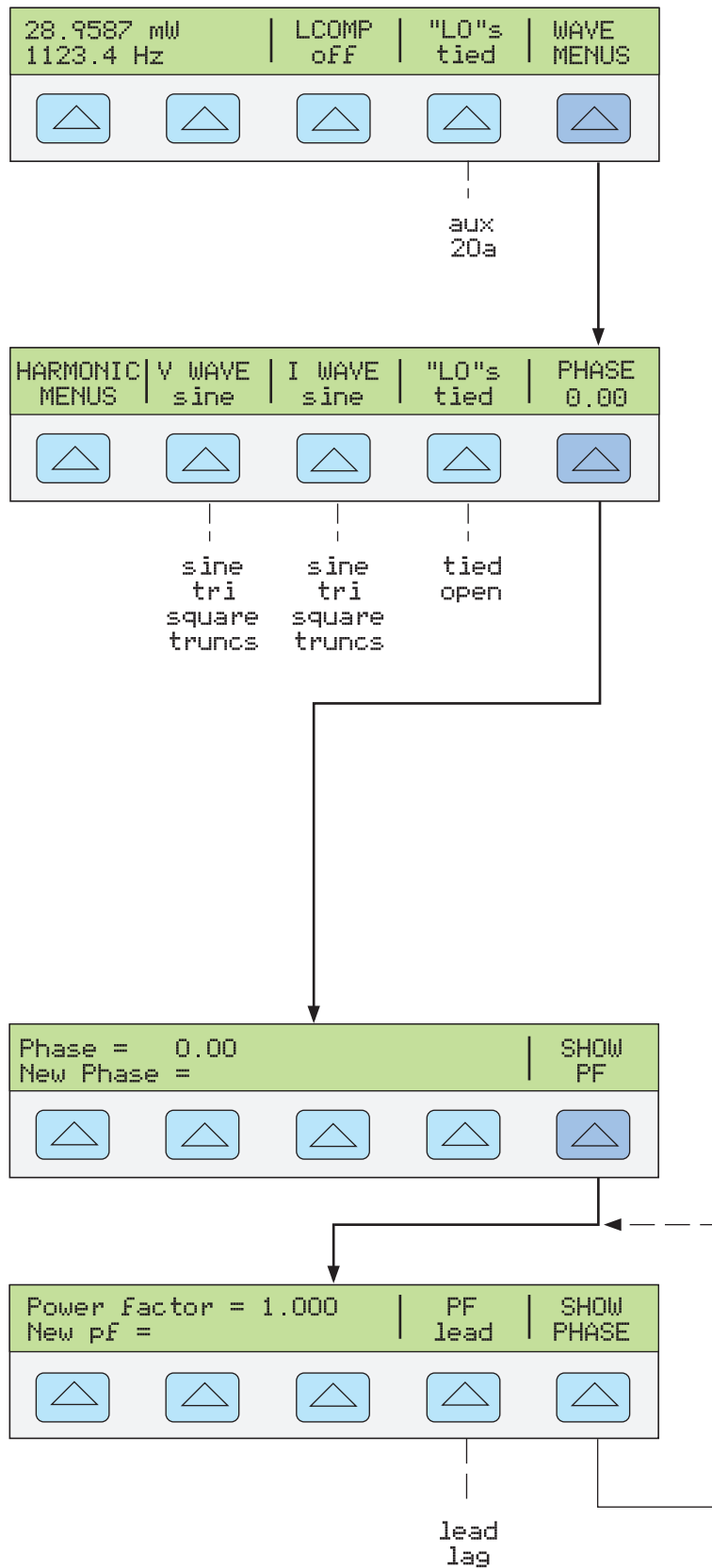
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5. Push **PREV MENU** one or more times to return to previous menus.

## Adjust the Phase

When in the dual ac voltage and ac power output modes, you can set the Calibrator to source two signals with adjustable phase difference. All phase adjustments move the AUX waveform in relation to the NORMAL waveform. Phase shift adjustments are recorded as degrees (0 to  $\pm 180.00$ ) or as a power factor (PF). A leading or positive phase shift causes the AUX waveform to lead the NORMAL waveform. A lagging or negative phase shift causes the AUX waveform to lag the NORMAL waveform.

The softkey PHASE is available after you push the WAVE MENUS softkey that shows when outputting dual ac voltages or ac power (shown below for ac power output).

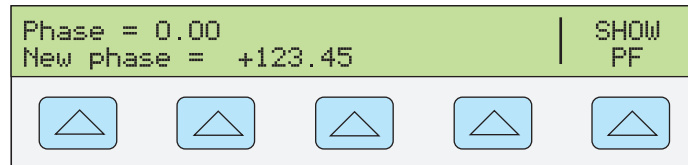


When one output is a harmonic of the other, the phase shift comes from the phase angle or power factor (cosine) of the harmonic signal. For example, when the AUX output is a 60-Hz signal, and the NORMAL output is a 120 Hz (2nd Harmonic) signal, a phase shift of 60 ° (PF of .5) moves the AUX signal 60 ° of 120 Hz (30 ° of 60 Hz).

### Record a Phase Angle

If you have already sourced a dual ac voltage or ac power output, complete the subsequent procedure to record a phase shift in degrees.

1. Push the softkey WAVE MENUS to open the harmonic menu.
2. Push the softkey PHASE to open the phase entry menu.
3. Push the numeric keys and decimal point key to record the necessary phase angle (maximum five numeric keys). For example, 123.45.
4. Push **+/-** to select leading (+) or lagging (–) phase shift (default is +).
5. The Control Display shows the value of your entry. For example, a leading phase angle of 123.45 degrees (see below). (SHOW PF shows only for sine waves.)



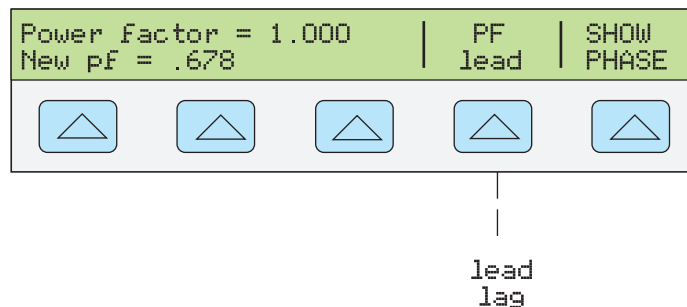
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6. Push **ENTER**. The Calibrator erases your entry from the “New phase =” line and copies it to the “Phase =” line of the Control Display.
7. Push **CE** one or more times to return to previous menus.

### Record a Power Factor

If you have already sourced a dual ac voltage or ac power output with sine waves as the waveform, complete the subsequent procedure to record a phase shift as a power factor (PF).  $PF = \cos \Phi$ , where  $\Phi$  is the phase shift.

1. Push the softkey WAVE MENUS to open the waveform menu.
2. Push the softkey PHASE to open the phase entry menu.
3. Push the softkey SHOW PF to open the power factor entry menu.
4. Push the decimal point key and numeric keys to record the necessary power factor (maximum three numeric keys). For example, .678.
5. Push the softkey PF to toggle between a leading (lead) or lagging (lag) power factor (default is lead).
6. The Control Display shows the value of your entry. For example, a leading power factor of .678 (see below).



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7. Push **ENTER**. The Calibrator clears your entry from the “New pf=” line and copies it to the “Power Factor =” line of the Control Display.
8. Push **PREV MENU** one or more times to return to previous menus.

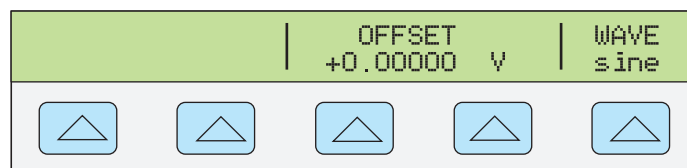
## Record a DC Offset

When the Calibrator single output is an ac voltage of sine waves, triangle waves, square waves, or truncated sine waves, you can apply a +dc offset. When you apply an offset to square wave outputs, the duty cycle must be 50.00 % (default). The offset selection is recorded with the softkey **OFFSET**, which shows when the ac voltage output is less than 33 V (sine waves), 66 V p-p (square waves) or 93 V p-p (triangle waves and truncated sine waves). The softkey **OFFSET** will not show and offsets cannot be recorded when the output is a voltage sine wave measured in dBm.

The maximum offset value permitted is in relation to the maximum offset and maximum peak signal for each range. For example, a square wave output of 10 V p-p is in the range 6.6 V p-p to 65.9999 V p-p, a range with a maximum peak signal of 55 V. For this example, the square wave peak value is 5 V, this lets a maximum  $\pm$ offset of 50 V for a maximum peak signal of 55 V.

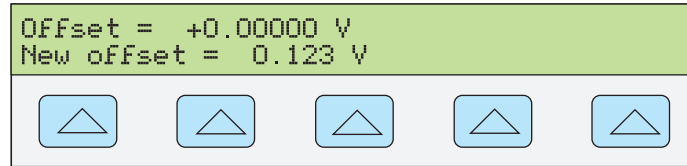
Read the specifications in Chapter 1 for offset limits. If you use an offset voltage and you make the output move into a range where offset is not permitted (for example, above 33 V for a sine wave output), the Calibrator goes into the standby mode and the offset function will be disabled.

Complete the subsequent procedure to record a dc voltage offset. If you make an entry error, push **CE** to clear the display, then reenter the value. This procedure works if you have already sourced a single ac voltage output of a maximum of 33 V (sine waves), 65 V p-p (square waves) or 93 V p-p (triangle waves and truncated sine waves), this will show the softkey **OFFSET** (see below).



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1. Push the softkey WAVE to select the necessary waveform: sine waves (sine), triangle waves (tri), square waves (square), or truncated sine wave (truncs).
2. Push the softkey OFFSET, opening the offset entry display. Record the necessary offset with the numeric keys and decimal point key. For example, 0.123 V (see below).



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3. Push the **ENTER** key to record the offset and then **PREV MENU**.

## Edit and Error Output Settings

You can edit all Calibrator outputs with the front-panel Edit Field knob and **◀**, **▶**, and **EDIT FIELD**. Also, **MULT X** and **DIV ÷** edit the output by decades. The difference in the initial output (reference) and edited output is shown as an “error” between the two positions. This lets you edit a value to get a correct measurement at the UUT and calculate an error in  $\pm\%$  or ppm (parts per million) if it is less than  $\pm 1000$  ppm. Table 4-2 shows the actions that make the Calibrator exit the error mode and go to the initial reference output, or to output a new reference, as selected.

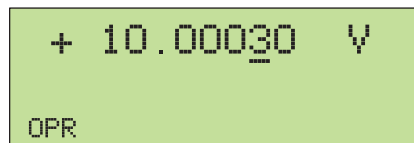
**Table 4-2. Keys That Exit Error Mode**

| Keys                              | Action                                                                                |
|-----------------------------------|---------------------------------------------------------------------------------------|
| <b>ENTER</b>                      | Shows to the reference value from before the current value.                           |
| <b>+/-</b> or <b>ENTER</b>        | Establishes a new reference.                                                          |
| A new keypad entry + <b>ENTER</b> | Establishes a new reference.                                                          |
| <b>NEW REF</b>                    | Establishes the present output as a new reference.                                    |
| <b>MULT X</b>                     | Sets the Calibrator to ten times the reference value and establishes a new reference. |
| <b>DIV ÷</b>                      | Sets the Calibrator to one-tenth the reference value and establishes a new reference. |
| <b>RESET</b>                      | Shows to the power-up condition.                                                      |

### Edit the Output Setting

When you initially source an output from the Calibrator, you record a value, for example, 10.00000 V dc. To edit the output value for your operation, turn the front-panel Edit Field knob clockwise to increase the value or counter-clockwise to decrease the value. (The Edit Field controls will not operate if you are in a setup function. Push **PREV MENU** one or more times to exit a setup function.)

To select a higher-order digit, use an Edit Field cursor key ◀ or ▶. The output digit in edit is always underlined (see below).

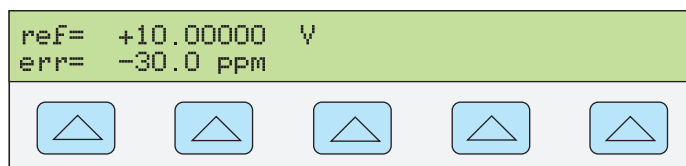


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The short indication of the letter “u” on the Output Display when you edit during OPR (Operate) means “unsettled”. The Calibrator output must become stable to a new value.

### Show the UUT Error

When you edit the output value, the Control Display shows the difference in the reference value (the value you initially recorded) and the edit value (the value shown in the Output Display), shows the error difference in parts per million (ppm) or percent (%). For example, if ERR UNI is set to > 100 ppm, the error will be shown in ppm to a maximum of 99 and then the error will change to 0.0100 % at 100 ppm. This lets you edit the output so that the UUT shows the anticipated value and so give an indication of the UUT accuracy.



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For example, an edited difference of .00030 V for an output of 10.00000 V shows  $0.00030/10.00000=0.000030$ , or 30 parts per million. The sign is negative (-30.0 ppm) because the output necessary to show 10.00000 at the UUT shows the UUT measurement is below the output value. When the reference is negative, the error sign is in relation to the magnitude. For example, if the reference is -10.00000 V and the output shown is -10.00030, the error is -30 ppm.

The Calibrator has two methods to show the UUT error. The first method is the “nominal” method that is used in the Fluke Calibration 5700A, 5720A, 5500A, 5520A, 5522A, and 5502A Calibrators. The second method is the “true value” method. Each method is used in this Calibrator.

The nominal method of error calculation uses the formula:

$$\frac{\text{reference value} - \text{edit value}}{\text{reference value}}$$

The nominal method is useful for measure the error of the Calibrator, when you verify its performance against a more accurate device.

The true-value method of error calculation uses the formula:

$$\frac{\text{Reference value} - \text{edit value}}{\text{edit value}}$$

With the nominal or true-value method, small changes in output value give you a calculated error that is the same. In the example above, the Control display will show the error as -30.0 ppm.

The true-value method is useful for large changes in output value. For example, if you apply 10.0000 V to an analog meter, and then adjust the Calibrator output to 11.0000 V so that the analog meter reads exactly 10 V, the true-value method will show

$$\begin{aligned}\text{nominal} &= +10.0000 \text{ V} \\ \text{rel err} &= -9.0909 \%\end{aligned}$$

The -9.0909 % is the relative error of the analog meter when compared to the true value (11.0000 V in this case).

To select the UUT error calculation method:

1. Push **SETUP**.
2. Push the softkey INSTMT SETUP.
3. Push the softkey OTHER SETUP.
4. Push the softkey ERROR SETUP
5. Push the softkey ERR REF to toggle between “nominal” and “tru val”.

### Use Multiply and Divide

The Calibrator output value (or reference value if you have edited the output) can be multiplied by a factor of 10 by the **MULT** key. Similarly, the output value (or reference value if you have edited the output) can be divided a factor of 10 by the **DIV** key. The output is put in STBY (Standby) if the multiplied value is more than 33 V. Push **OPR** to continue if necessary. This feature is useful for UUTs with ranges organized in decades.

### Set Output Limits

An output-limit feature is available to help prevent accidental damage to a UUT from overcurrent or overvoltage conditions. This feature lets you preset the maximum positive and negative voltage or current output. These entry limits prevent higher outputs entries from the front-panel keys or the output-adjustment controls. Positive limits for voltage and current set the limits for ac voltage and current. Your limit selections are kept in the nonvolatile memory. Voltage limits are shown as rms values, and voltage offsets are ignored.

To set voltage and current entry limits:

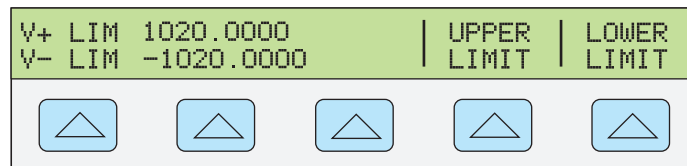
1. Push **RESET** to clear output from the Calibrator.
2. Push **SETUP**.
3. Push the softkey INSTMT SETUP to open the setup submenus.

4. Push the softkey OUTPUT SETUP to open the output setup submenus.
5. Push the softkey SET LIMITS to open the set limits menu (see below).



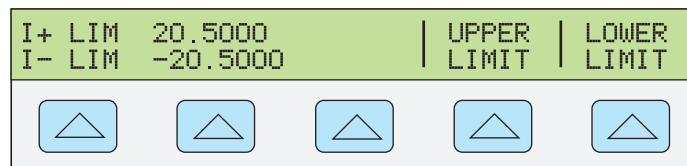
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6. To Limit Voltage (applies to both dc and ac voltages), push a softkey below VOLTAGE to open the voltage limits menu (see below).



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- a. Push the “Upper Limit” or the “Lower Limit” softkey, as necessary, and record the new limit.
- b. Push **ENTER** then **PREV MENU** one or more times to return to a previous menu.
7. To Limit Current (applies to both dc and ac currents). Push a softkey below CURRENT to open the current limits menu (see below).



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- a. Push the “Upper Limit” or the “Lower Limit” softkey, as necessary, and record the new limit.
- b. Push **ENTER** then **PREV MENU** one or more times to return to a previous menu.

## Sample Applications

- Calibrate a Fluke 80 Series Digital Multimeter (DMM)
- Calibrate a Fluke Model 41 Power Harmonics Analyzer for Power and Harmonics
- Calibrate a Fluke Model 51 Digital Thermometer



### How Calibrate an 80 Series Digital Multimeter

This example shows the steps necessary to calibrate a Fluke 80 Series DMM.

#### Note

*These procedures are included here as an example. The 80 Series Service Manual contains the authoritative test and calibration procedures for 80 Series DMMs.*

Two procedures are given. The first procedure tests each function and range for compliance to specifications. The second is the calibration procedure for the 80 Series meters. The 80 Series Service Manual gives instructions for disassembly and access to the pca (printed circuit assembly). It will be necessary to access the pca for the calibration procedure.

Before you connect the Calibrator to the 80 Series DMM, you must know what type of cables to use and if **EARTH** should be used. This is given in the “Cables” and “EARTH Connection” sections of this chapter.

#### Cables

Fluke 5440A-7002 Low-Thermal Cables are recommended for many calibrations connections, but they are not necessary for 80 Series calibration. Thermal emf errors that the Low-Thermal cables will prevent are not important when you calibrate a 3-1/2 digit meter. The cables work for the subsequent measurements:

- AC and dc voltages
- All resistances
- AC and dc currents to a maximum of 20 A

#### EARTH Connection

Because the 80 Series DMMs are battery operated, their inputs have no connection to earth ground. It will be necessary to start with the earth (chassis) ground of the Calibrator to LO. (Push **EARTH** so that the indicator is illuminates.)

#### Verify the Meter

You can use the error mode feature of the Calibrator of the meter (DMM) to make sure that all ranges of all functions are in specification limits:

1. Turn on the Calibrator and let it warm up.

#### Warning

**To prevent electrical shock, fire, or personal injury, make sure the Product is in standby mode before you make connections between the product and tester.**

2. Make sure that the Calibrator is in standby and connect the DMM as shown in Figure 4-15.

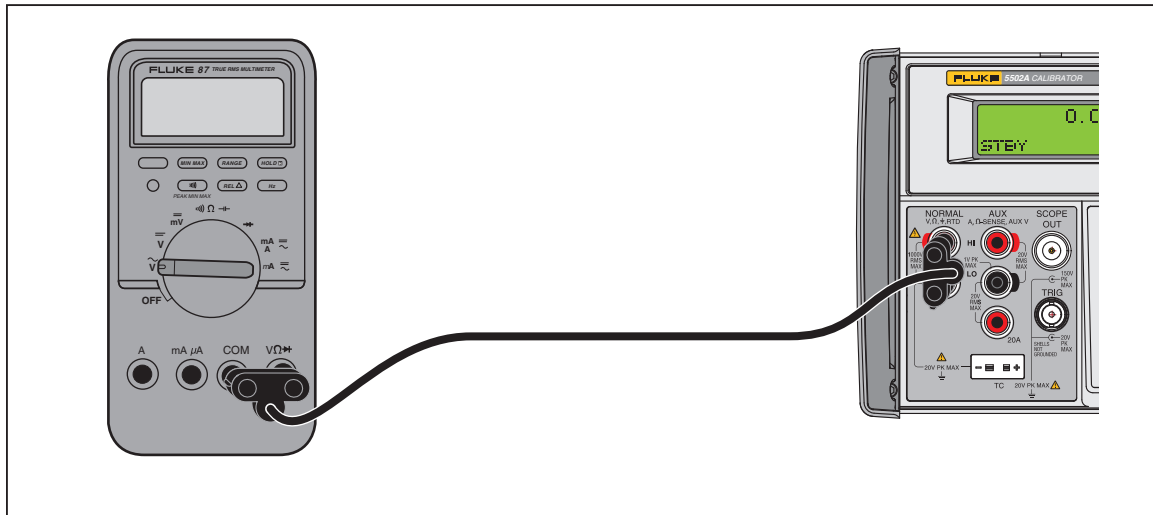


**Figure 4-15. Cable Connections to Verify 80 Series General Functions**

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3. Verify the dc voltage function:
  - a. Turn on the DMM and set the function switch to  $\overline{V}$ .
  - b. Set the warmed-up Calibrator to 3.5 V dc.
  - c. Push **OPR**.
  - d. Use the output-adjustment controls to adjust the Calibrator output to measure +3.5000 on the DMM display.
  - e. Make sure that the error shown on the control display is below the specification that is in the DMM Users Manual.
  - f. Verify the DMM error at 35.0 V, -35.0 V, 350.0 V (use **MULT**). Make sure the errors are in specification limits. When **MULT** makes the output to go over 33 V, the Calibrator goes into standby. When this occurs, push **OPR** to operate.
  - g. Verify the DMM error at 1000 V to make sure it is in specification limits.
  - h. Set the output of the Calibrator to 350 mV and push **OPR**. Make sure that the errors are in specification limits.
4. Verify the ac voltage function:
  - a. Push **RESET** on the Calibrator and set the DMM function switch to  $\tilde{V}$ .
  - b. Set the output of the Calibrator to 350 mV at 60 Hz and push **OPR**. Make sure the errors are in specification limits.

- c. Verify the error against specifications at the subsequent voltages and frequencies in Table 4-3.

**Table 4-3. Verification Voltages and Frequencies**

| Voltage | Frequency                |
|---------|--------------------------|
| 350 mV  | 60 Hz, 5 kHz, and 20 kHz |
| 3.500 V | 60 Hz, 5 kHz, and 20 kHz |
| 35.00 V | 60 Hz, 5 kHz, and 20 kHz |
| 329.0 V | 60 Hz, 5 kHz, and 20 kHz |
| 100.0 V | 20 kHz                   |
| 200.0 V | 20 kHz                   |
| 300.0 V | 20 kHz                   |
| 1000 V  | 60 Hz and 5 kHz          |

5. Verify the frequency function:
  - a. Push **RESET** on the Calibrator, set the DMM function switch to  $\tilde{V}$ , and push Hz on the DMM.
  - b. Set the Calibrator to 150 mV at 19.0 kHz and push **OPR**. Make sure the error is in specification limits.
  - c. Set the Calibrator to 150 mV at 190 kHz, push **EDIT FIELD** twice to move the cursor to the frequency measurement in the output display and push **MULT X**. Make sure the error is in specification limits.
6. Verify frequency sensitivity and trigger levels:
  - a. Push **RESET** on the Calibrator.
  - b. Set the DMM function switch to  $\tilde{V}$  and push Hz on the DMM to choose the frequency mode.
  - c. Set the Calibrator to 300 mV at 1 kHz and push **OPR**. Make sure the frequency error is in specification.
  - d. Change the Calibrator output to 1.7 V. Make sure the frequency error is in specification.
  - e. Change the Calibrator output to 1.0 V. Make sure that the DMM displays 000.0 frequency.
  - f. Push RANGE to change the DMM range to 40 V. Change the Calibrator output to 6.0 V. Make sure the frequency error is in specification limits.
  - g. Change the Calibrator output to 2.0 V. Verify that the DMM shows 000.0 frequency.

7. Verify the ohms function:
  - a. Push **RESET** on the Calibrator and set the DMM function switch to  $\Omega \rightarrow \rightarrow$ .
  - b. Set the Calibrator to 190.0  $\Omega$  with 2-wire compensation (see Figure 4-3).
  - c. Push **OPR**. Make sure the error is in specifications limits.
  - d. Do the last step for 19.00 k $\Omega$ , 1.900 M $\Omega$ , and 19.00 M $\Omega$ . Make sure the errors are in specifications limits.
  - e. Push RANGE on the DMM to record the 40 nS range. This range is for conductance tests of high resistances.
  - f. Set the Calibrator output to 100 M $\Omega$ . Make sure the error is in specification limits.
8. Verify the capacitance function (use the REL feature of the 80 Series to subtract cable capacitance):
  - a. Push **RESET** on the Calibrator and set the DMM function switch to  $\Omega \rightarrow \rightarrow$ .
  - b. Set the Calibrator output to 1.0  $\mu$ F with compensation off.
  - c. Push **OPR**. Make sure the error is in specification limits.
  - d. Do this again with 0.470  $\mu$ F, 0.047  $\mu$ F, and 4.70 nF. Make sure the errors are in specification limits.
9. Verify the diode test function:
  - a. Push **RESET** on the Calibrator and set the DMM function switch to  $\rightarrow \rightarrow$ .
  - b. Set the Calibrator to 3.0 V dc and push **OPR**. Make sure the error is in specification limits.
10. Verify the ac and dc current function:
  - a. Push **RESET** on the Calibrator and set the DMM function switch to mA $\rightarrow \rightarrow$ .
  - b. Make sure that the Calibrator is in standby and connect the DMM as shown in Figure 4-16.

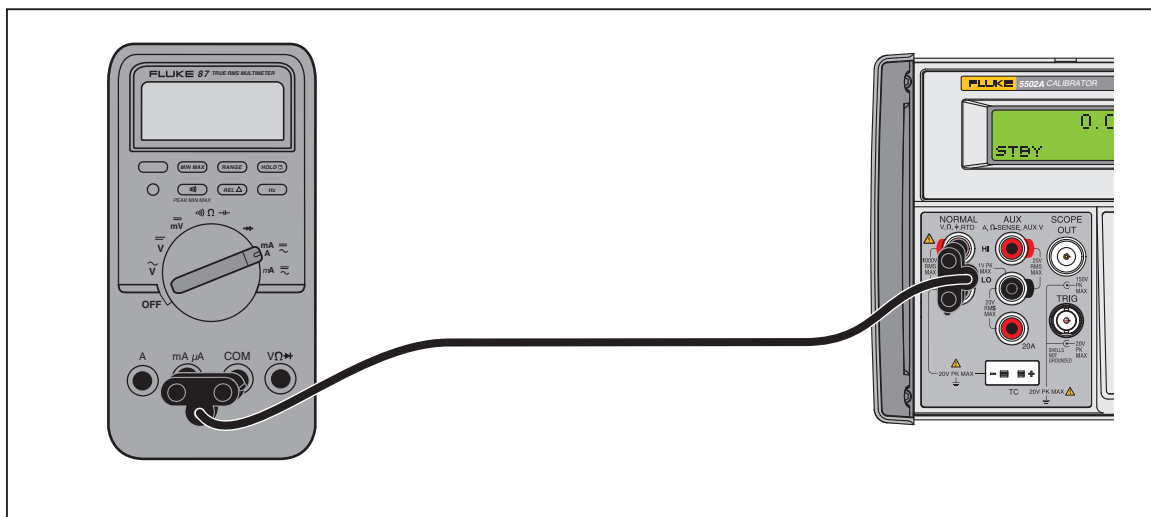


**Figure 4-16. Cable Connections to Verify an 80 Series Current Function**

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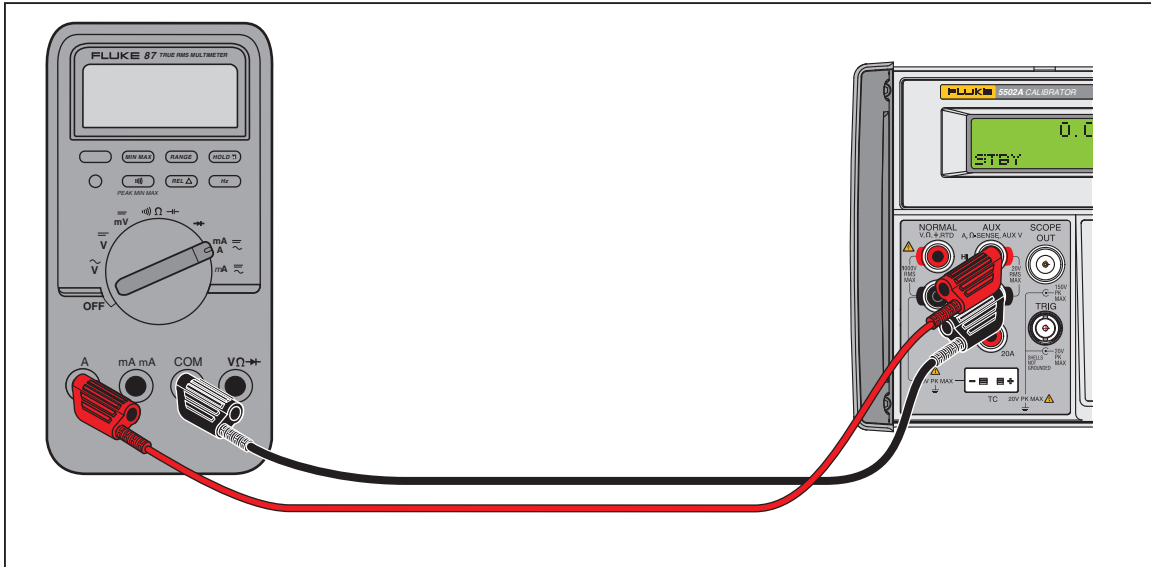
- c. Set the Calibrator to 35.0 mA and push **OPR**.
- d. Use the output adjustment controls to adjust the Calibrator output for a measurement of +35.00 mA on the DMM. Make sure that the error shown on the control display is in specification limits.
- e. Do this step again with 350.0 mA. Make sure the error is in specification limits.
- f. Push the blue key on the DMM to change to ac current measurement.
- g. Set the Calibrator output to 35.0 mA at 60 Hz. Make sure the error is in specification limits.
- h. Do this step again with the Calibrator set to:

| AC Current | Frequency |
|------------|-----------|
| 35.0 mA    | 1.0 kHz   |
| 350.0 mA   | 60 Hz     |
| 350.0 mA   | 1.0 kHz   |

- i. Push **STBY** on the Calibrator and switch the DMM function switch to  $\mu A \sim$ .
- j. Set the Calibrator output to 350  $\mu A$  at 0 Hz and push **OPR**. Make sure the error is in specification limits.
- k. Do this again with 3500  $\mu A$  at 0 Hz.
- l. Push **STBY** on the Calibrator and push the blue key on the DMM to switch to ac measurements.
- m. Change the Calibrator output to 350.0  $\mu A$  at 60 Hz and push **OPR**. Make sure the error is in specification limits.
- n. Do this step again with the Calibrator set to:

| AC Current     | Frequency |
|----------------|-----------|
| 350.0 $\mu A$  | 1.0 kHz   |
| 3500.0 $\mu A$ | 60 Hz     |
| 3500.0 $\mu A$ | 1.0 kHz   |

11. Verify the high current function.
  - a. Push **RESET** on the Calibrator.
  - b. Make sure that the Calibrator is in standby and connect the DMM as shown in Figure 4-17.



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**Figure 4-17. Cable Connections to Verify an 80 Series High Amps Function**

- c. Set the Calibrator output to 3.5 A at 0 Hz and push **OPR**. Make sure the error is in specification limits.
- d. Do this step again with 0 A at 0 Hz. Make sure the error is in specification limits.
- e. Push **STBY** on the Calibrator and push the blue key on the DMM to change to ac measurements.
- f. Set the Calibrator output to 3.5 A at 60 Hz and push **OPR**. Make sure the error is in specification limits.
- g. Do this step again with the Calibrator set to:

| AC Current | Frequency |
|------------|-----------|
| 3.5 A      | 1.0 kHz   |
| 10.0 mA    | 60 Hz     |
| 10.0 mA    | 1.0 kHz   |

### Calibrate the Meter

Continue with calibration if there was a range that was out of tolerance in the verification procedure.

#### Note

*To do the adjustment to calibrate the meter, it is necessary to disassemble the meter. Refer to the diagrams and access procedures in the 80 Series Service Manual.*

1. Make sure that the Calibrator is set to 0 V dc in standby. Push **RESET** if necessary.
2. Turn on the 80 Series DMM, and set its function switch to  $\bar{V}$ .
3. Connect a set of test leads to the DMM as shown in Figure 4-16.
4. Set the Calibrator to 3.5 V dc and push **OPR**.
5. The DMM shows  $3.500 \pm 0.001$ . If necessary, adjust R21 to get the correct measurement.
6. Set the DMM function switch to  $\tilde{V}$  and set the Calibrator output to 3.500 V at 100 Hz.
7. The DMM shows  $3.500 \pm 0.002$ . If necessary, adjust R34 to get the correct measurement.
8. Change the Calibrator output to 10 kHz.
9. The DMM shows  $3.500 \pm 0.004$ . If necessary, adjust C2 to get the correct measurement.
10. Change the Calibrator output to 35.00 V at 10 kHz.
11. The DMM shows  $35.00 \pm 0.04$ . If necessary, adjust C3 to get the correct measurement.

### Verify a Model 41 Power Harmonics Analyzer

For the Model 41 Power Harmonics Analyzer, hereafter referred to as the Tester, two voltages with different phase relationships are necessary to verify the functionality of the power and harmonics features. The procedure included here is to demonstrate the operation of the dual-voltage function of the Calibrator.

#### Note

*These procedures are included here as an example. The Model 41 Service Manual has the complete authoritative test and calibration procedures*

### Verify Watts, VA, VAR Performance

Do the subsequent procedure to verify the watts, VA, and VAR functions of the Tester. Refer to Table 4-4.

#### Warning

**To prevent electrical shock, fire, or personal injury, make sure the Product is in standby mode before you make connections between the product and Tester.**

Table 4-4. Watts Performance, Text Screen

| Calibrator Outputs        |                  |                         | Performance Limits |        |        |       |                              |      |                              |     |
|---------------------------|------------------|-------------------------|--------------------|--------|--------|-------|------------------------------|------|------------------------------|-----|
| Normal<br>V ac @<br>60 Hz | Phase<br>in DEG. | AUX<br>mV ac @<br>60 Hz | W/KW               |        | VA/KVA |       | VAR/KVAR<br>Model 41<br>Only |      | Phase<br>Harmonics<br>Screen |     |
|                           |                  |                         | MIN                | MAX    | MIN    | MAX   | MIN                          | MAX  | MIN                          | MAX |
| 5.0 V                     | 0.0              | 30.0 mV                 | 145                | 156    | 145    | 156   | 0                            | 4    | -2                           | 2   |
| 8.0 V                     | 0.0              | 30.0 mV                 | 234                | 246    | 234    | 246   | 0                            | 4    | -2                           | 2   |
| 100.0 V                   | 157.0            | 150.0 mV                | -14.3k             | -13.3k | 14.5k  | 15.6k | 5.4k                         | 6.3k | 155                          | 159 |
| 100.0 V                   | 157.0            | 360.0 mV                | -37k               | -29k   | 32k    | 40k   | 10k                          | 18k  | 155                          | 159 |
| 10.0 V                    | 46.0             | 1.40 V                  | 9.2                | 10.2   | 13.5   | 14.5  | 9.6                          | 10.6 | 44                           | 48  |
| 100.0 V                   | 46.0             | 1.40 V                  | 92                 | 102    | 135    | 145   | 96                           | 106  | 44                           | 48  |

1. Connect the Calibrator to the Model 41 as shown in Figure 4-18.

*Note*

*Voltage is connected to the Model 41 amps input to simulate current clamp operation (1 mV = 1 A).*

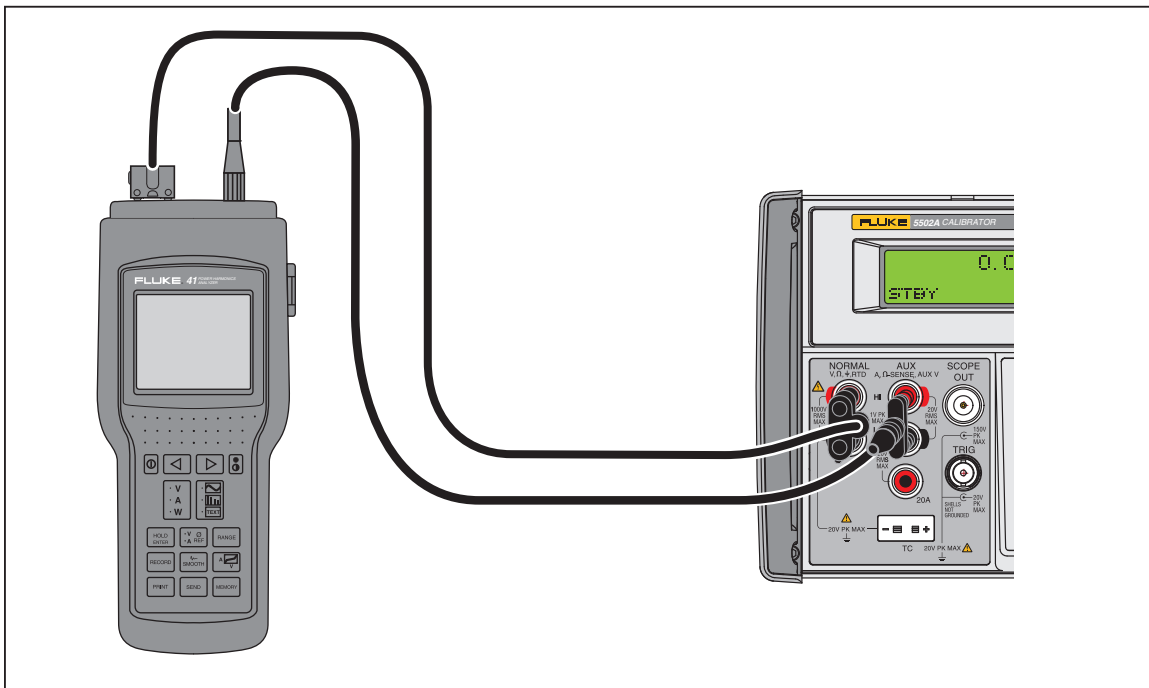


Figure 4-18. Cable Connections to Verify a 40 Series Watts Function

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2. Make sure that the EARTH indicator is illuminated. If not, push **[EARTH]**.
3. Set the Calibrator output to 5.0 V at 60 Hz on the NORMAL output and 30 mV at 60 Hz on the AUX output.
4. Push the WAVE MENUS, then the  $\phi$  & REF MENUS softkey on the Calibrator. Make sure the AUX  $\phi$  NRM angle is 0.00 degrees. Push **[OPR]**.
5. Select W from VAW on the Tester.
6. Push the mode button on the Tester for the text screen mode. Verify that the W/KW, VA/KVA, and VAR/KVAR indications are in the minimum and maximum limits specified in Table 4-4.
7. Push the mode button on the Tester for the harmonics screen mode. Verify that the fundamental frequency phase angle indications are between the minimum and maximum indications given in Table 4-4.
8. Do step 5, 6, and 7 again and use the Calibrator outputs and performance limits shown in Table 4-4.
9. Push **[STBY]** on the Calibrator to remove the voltage from the Tester.

#### Verify Harmonics Volts Performance

1. Push the mode button on the Tester for the harmonics screen.
2. Push the VAW button on the Tester until V is shown above the upper-right corner of the harmonics screen.
3. Push the VA $\phi$  REF button on the Tester until A $\Phi$  is shown in the top status line.
4. Push the SMOOTH button on the Tester until ~20s is shown in the top status line.
5. Connect the Calibrator NORMAL output to the V and COM connectors on the Tester.
6. Connect the Calibrator AUX output to the Current Probe connector on the Tester.
7. Set the Calibrator output to 7.0 V at 60 Hz on the NORMAL output and 700 mV at 60 Hz on the AUX output. Push the WAVE MENUS, then the  $\Phi$  & REF MENUS softkey and make sure the phase angle is -10.0 degrees. Push the HARMONIC MENU softkey and make sure the HARMONIC selection is set to "1" and the FUNDMTL selection is set to "aux." Push **[OPR]**.
8. Move the Tester cursor to the necessary harmonic number.
9. Make sure that the harmonic amplitude and phase angle indications shown by the Tester are in the minimum and maximum limits shown in Table 4-5.

#### Note

*The Tester will read a positive phase when the Calibrator output is a negative phase because, on the Calibrator, the polarity of the phase is relative to the NORMAL channel output.*

10. Do steps 7, 8, and 9 again and use the values and limits in Table 4-5.

Table 4-5. Harmonics Performance for Volts, Harmonics Screen

| 5502A<br>Normal Output |          |        | Fluke<br>Tester    | Performance Limits |     |       |     |
|------------------------|----------|--------|--------------------|--------------------|-----|-------|-----|
| Amplitude              | Harmonic | Phase  | Harmonic<br>cursor | Amplitude          |     | Phase |     |
| (V)                    | No.      | (deg.) | No.                | MIN                | MAX | MIN   | MAX |
| 7.00                   | 1        | -10    | 1                  | 6.7                | 7.3 | 8     | 12  |
| 7.00                   | 3        | -20    | 3                  | 6.7                | 7.3 | 14    | 26  |
| 7.00                   | 9        | -30    | 9                  | 6.7                | 7.3 | 21    | 39  |
| 7.00                   | 13       | -40    | 13                 | 6.7                | 7.3 | 29    | 51  |
| 7.00                   | 21       | -50    | 21                 | 6.5                | 7.5 | 35    | 65  |
| 7.00                   | 31       | -60    | 31                 | 6.2                | 7.8 | 40    | 80  |

11. Push **STBY** to remove the voltage from the Tester.

#### Verify Harmonics Amps Performance

1. Push the VAW button on the Tester until A is shown above the top right corner of the harmonics display.
2. Push the VA $\phi$  REF button on the Tester until V $\phi$  is shown in the top status line.
3. Push the SMOOTH button on the Tester until ~20s is shown in the top status line of the Tester.
4. Connect the Calibrator NORMAL output to the V and COM connectors on the Tester.
5. Connect the Calibrator AUX output to the Current Probe connector on the Tester.
6. Set the Calibrator output to 7.0 V at 60 Hz on the NORMAL output and 20 mV at 60 Hz on the AUX output. Push the WAVE MENUS, then the  $\phi$  & REF MENUS softkey and make sure the phase angle is 10.00 degrees. Push the HARMONIC MENU softkey and make sure the HARMONIC selection is set to "1" and the FUNDMTL selection is set to "normal." Push **OPR**.
7. See that the harmonic amplitude and phase angle indications shown by the Tester are in the minimum and maximum limits shown in Table 4-6.

Table 4-6. Harmonics Performance for Amps, Harmonics Screen

| 5502A<br>AUX Output |          |        | Fluke<br>Tester    | Performance Limits |      |       |     |
|---------------------|----------|--------|--------------------|--------------------|------|-------|-----|
| Amplitude           | Harmonic | Phase  | Harmonic<br>cursor | Amplitude          |      | Phase |     |
| (mV)                | No.      | (deg.) | No.                | MIN                | MAX  | MIN   | MAX |
| 20.0                | 1        | 10     | 1                  | 19.1               | 20.9 | 8     | 12  |
| 20.0                | 3        | 20     | 3                  | 19.1               | 20.9 | 14    | 26  |
| 20.0                | 9        | 30     | 9                  | 19.1               | 20.9 | 21    | 39  |
| 20.0                | 13       | 40     | 13                 | 19.1               | 20.9 | 29    | 51  |
| 20.0                | 21       | 50     | 21                 | 18.7               | 21.3 | 35    | 65  |
| 20.0                | 31       | 60     | 31                 | 18.1               | 21.9 | 40    | 80  |

### Calibrate a Fluke 51 Thermometer

The Fluke 51 Thermometer measures temperature with a type J or K thermocouple. The Calibrator simulates the two thermocouples. This simplifies the test and calibration. The subsequent section shows how the Calibrator is used to calibrate this thermometer.

#### Note

*These procedures are included here as an example. The Model 51 Service Manual has the authoritative test and calibration procedures.*

### Verify the Thermometer

The subsequent test is to be done only after the thermometer has had time to become stable to an ambient temperature of 23 °C ±5 °C (73 °F ±9 °F).

1. Connect the Fluke 51 Thermometer to the Calibrator with the correct connection cable (Figure 4-19). The connection cable and miniconnector material must be the same as the thermocouple type. For example, if you verify a K thermocouple, the cable and miniconnector are for a type-K thermocouple.

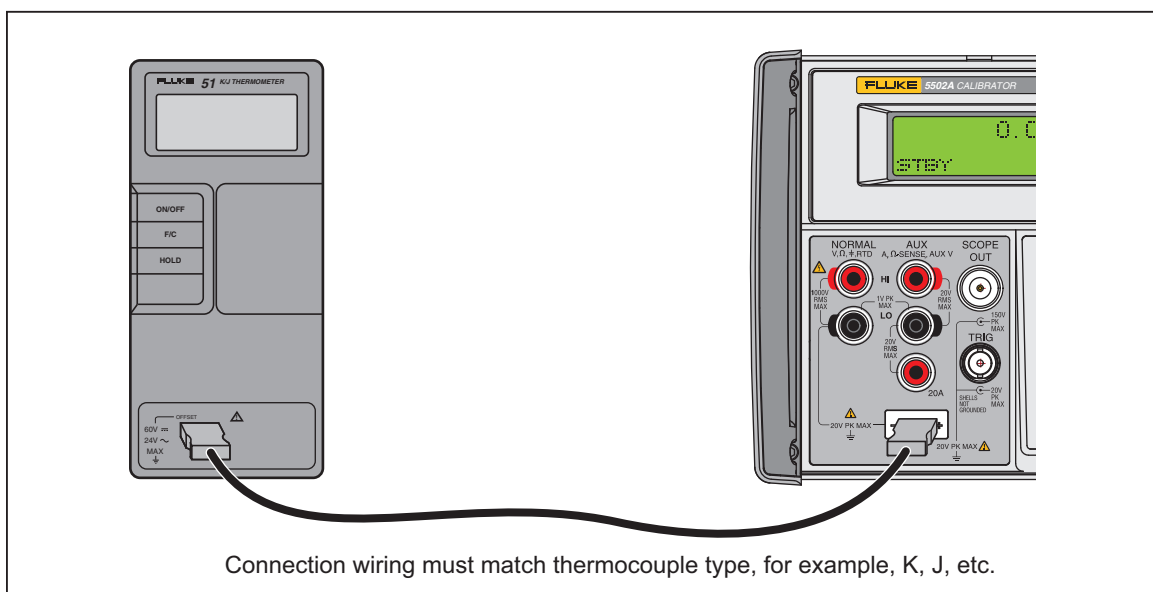


Figure 4-19. Cable Connections to Verify a 50 Series Thermometer

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2. Make sure that the EARTH indicator is on. If not, push **EARTH**.
3. Push **0** **°C** **ENTER** to set up the Calibrator. Make sure the softkey named OUTPUT shows “tc”. If not, push the OUTPUT softkey until it does.
4. Select the thermocouple type and reference source with the TC MENUS softkey. Make sure the REF SRC softkey selection shows “intrnl.” If not, push the REF SRC softkey. Make sure the TYPE softkey shows J or K. This will be the one that the 51 is set to. Continue to push the TYPE softkey until the selected thermocouple type is shown.
5. Record the Calibrator values shown in Table 4-7 and verify performance is not more or less than its specifications (see Chapter 1).

**Table 4-7. Thermocouple Performance**

| Thermocouple Type <sup>[1]</sup> | 5502A Setting | Display Readings |               |
|----------------------------------|---------------|------------------|---------------|
|                                  |               | Degrees C        | Degrees F     |
| K                                | -182.0 °C     | -182.0 ±(0.9)    | -295.6 ±(1.6) |
| K                                | -80.0 °C      | -80.0±(0.8)      | -112.0 ±(1.4) |
| K                                | 530.0 °C      | 530.0 ±(1.2)     | 986.0 ±(2.3)  |
| K                                | 1355.0 °C     | 1355.0 ±(2.1)    | 2471.0 ±(3.8) |
| J                                | -197.0 °C     | -197.0 ±(1.0)    | -322.6 ±(1.7) |
| J                                | 258.0 °C      | 258.0 ±(1.1)     | 496.4 ±(1.9)  |
| J                                | 705.0 °C      | 705.0 ±(1.5)     | 1301.0 ±(2.7) |

[1] When you change thermocouple types, be sure to also change the hookup wire that goes with the thermocouple. For example, K-type thermocouple wire changes to J-type thermocouple wire.

### Calibrate the Thermometer

The subsequent procedure uses “UUT” (Unit Under Test) in place of “Fluke 51”. Use copper hookup wire for all connections other than steps 17 to 20.

### Caution

**To prevent damage to the Fluke 51 Thermometer, use only the elastomeric switch pad supplied when you short the switch grid on the circuit board.**

1. Turn off the UUT and remove the top case. Keep the PCA in the bottom case.
2. Make sure the Calibrator is in standby and connect the UUT to the Calibrator as shown in Figure 4-19. When you make this connection with the UUT case top removed, make sure that the wide blade is on the same side as the wide case top hole.
3. At the same time, short the TP1 grid and short the ON/OFF switch grid to turn on the UUT. Hold the elastomeric switch pad on TP1 for a minimum of 3 seconds after turn on. This puts the UUT into the Thermocouple Calibration mode.
4. Select °C mode and T1 on the UUT.

*Note*

*Specified voltages are necessary for the subsequent steps to be at the inputs of the Thermometer. With the 10  $\mu\text{V}/^\circ\text{C}$  type thermocouple selection of the Calibrator, you can choose the output voltage on the TC terminals.*

5. Push **0**, **°C**, and **ENTER**. Make sure the softkey named OUTPUT shows “tc”. If not, push the OUTPUT softkey until it does.
6. Push the TYPE softkey until 10 $\mu\text{V}/^\circ\text{C}$  is shown. This selection lets you choose the voltage on the TC terminal.
7. Push the TC MENU softkey.
8. Push REF SRC softkey until “external” is shown.
9. Push the REF softkey to record an external reference value.
10. Push **0** and **ENTER** to set the external reference to 0  $^\circ\text{C}$ .
11. Push **PREV MENU** to move to the last menu level.
12. Push **OPR**.
13. Let the UUT indication become stable and then adjust the T1 offset adjustment (R7) for in indication of 25.2  $^\circ\text{C} \pm 0.1^\circ\text{C}$ .
14. Change the Calibrator output to 5380.7  $^\circ\text{C}$ . This puts 53.807 mV on the tc terminals.
15. Let the UUT indication become stable and adjust R21 for a display indication of +1370.0  $^\circ\text{C} \pm 0.4^\circ\text{C}$ .
16. Push **STBY** on the Calibrator to remove voltage from the UUT. Disconnect the UUT from the Calibrator. Short the ON/OFF switch grid to turn off the UUT.
17. With an elastomeric switch pad in your left and right hands, use the left one to short out the TP2 grid, and use the right one to first turn on the instrument and then quickly short out the VIEW switch grid. Hold this position until the display is held in self-test. This puts the UUT into the Reference Junction Sensor calibration mode, and the VIEW procedure turns off a filter so that the indication was stable immediately.
18. With a type K thermocouple bead (supplied with the 5520A-525/LEADS test lead kit) and the Calibrator MEAS TC mode (push **MEAS TC**), measure the reference junction transistor temperature. To do this, put the K-bead into the middle hole of the isothermal block. The bead tip must be put into the well, against the body of Q1. To do this, cover the well and set the bead with a piece of tissue to help the bead stay in position. Do not hold the bead in position with your hands as this can introduce a measurement error. Let the temperature indication become stable.
19. Adjust R16 for a temperature indication on the UUT that is the same as shown on the Calibrator.
20. Power down the UUT and assemble it.



# Chapter 5

## Remote Operation

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## Introduction

This chapter gives methods to operate the Calibrator by remote control.

### Warning

**The 5502A Calibrator can output voltages to a maximum of 1020 V rms and must be programmed with caution to prevent hazardous voltage production without sufficient warning to the operator.**

**Write programs carefully and test them extensively to make sure of safe operation of the Calibrator. Fluke Calibration recommends that you include error-catching routines in your programs. These error-catching routines will help you find programming errors that can cause the Calibrator to act other than intended. You can program the Calibrator to cause an SRQ when an error is found by setting the Service Request Enable (SRQ) register. The subsequent skeleton program has error-catching code:**

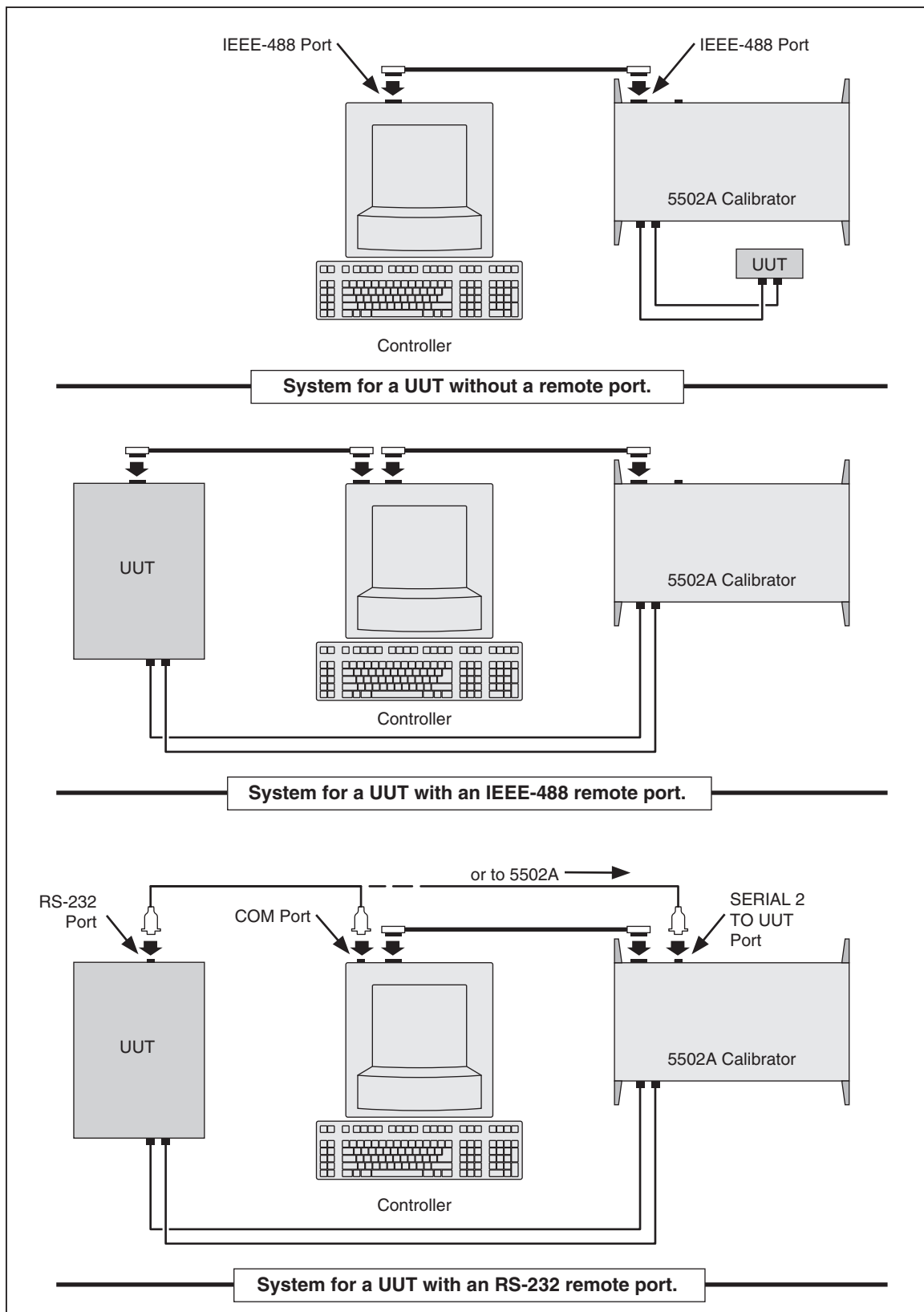
```
10   PRINT @4, "*CLS"           ! Clear status
20   PRINT @4, "*SRE 8"        ! Set SRE Error Available
30   ON SRQ GOTO 1000          ! Enable SRQ Function
100                                ! Place body of program here

900   STOP                     ! End of program

1000  REM Start of SRQ Handler   ! Start routine
1010  PRINT @4, "FAULT?"        ! Request fault code
1020  INPUT @4, A%              ! Input fault code
1030  PRINT @4, "EXPLAIN? ";A%  ! Request fault text
1040  INPUT @4, A$              ! Input fault text
1050  PRINT "Fault ";A$ detected" ! Print message
1060  PRINT @4, "STBY"         ! Place 5502A in standby
1070  STOP
```

Remote control can be interactive and you can control each step from a terminal, or with the control of a computer sequence that operates the Calibrator in an automated system. The Calibrator rear panel has three ports for remote operations: IEEE-488 parallel port (also known as a General Purpose Interface Bus, or GPIB port), and two RS-232 serial ports, SERIAL 1 FROM HOST and SERIAL 2 TO UUT.

**IEEE-488** The IEEE-488 parallel port is usually used in larger control and calibration systems. An IEEE-488 system is more costly to set up, but can control multiple Calibrators and multiple UUTs. Also, parallel system throughput is faster than serial system throughput. The controller in an IEEE-488 system is typically a MS-DOS compatible personal computer (PC) that has one or more IEEE-488 ports. You can write your own computer sequences for system operation with the command set, or you can purchase optional Fluke Calibration software MET/CAL Plus. Typical IEEE-488 configurations are shown in Figure 5-1. The configuration that shows the PC with two IEEE-488 ports is used with MET/CAL. For this configuration, put the Units Under Test (UUTs) on isolated IEEE-488 port. You can also "piggy-back" the connectors on one IEEE-488 port.



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**Figure 5-1. Typical IEEE-488 Remote Control Connections**

**RS-232** The SERIAL 1 FROM HOST serial port connects the PC and Calibrator, while the SERIAL 2 TO UUT serial port is used as a pass-through port for commands from the PC to UUT with the Calibrator. You can write your own computer programs with the command set, or use the PC as a terminal and enter individual commands, or you can purchase optional Fluke Calibration MET/CAL Plus software for RS-232 system operations. Typical RS-232 remote configurations are shown in Figure 5-2.

After you configure the IEEE-488 or RS-232 port for remote operation, you are prepared to start command set use. The operation of the command set is given in “Use Commands” in this chapter. A summary of remote commands is in Chapter 6, “Remote Commands.”

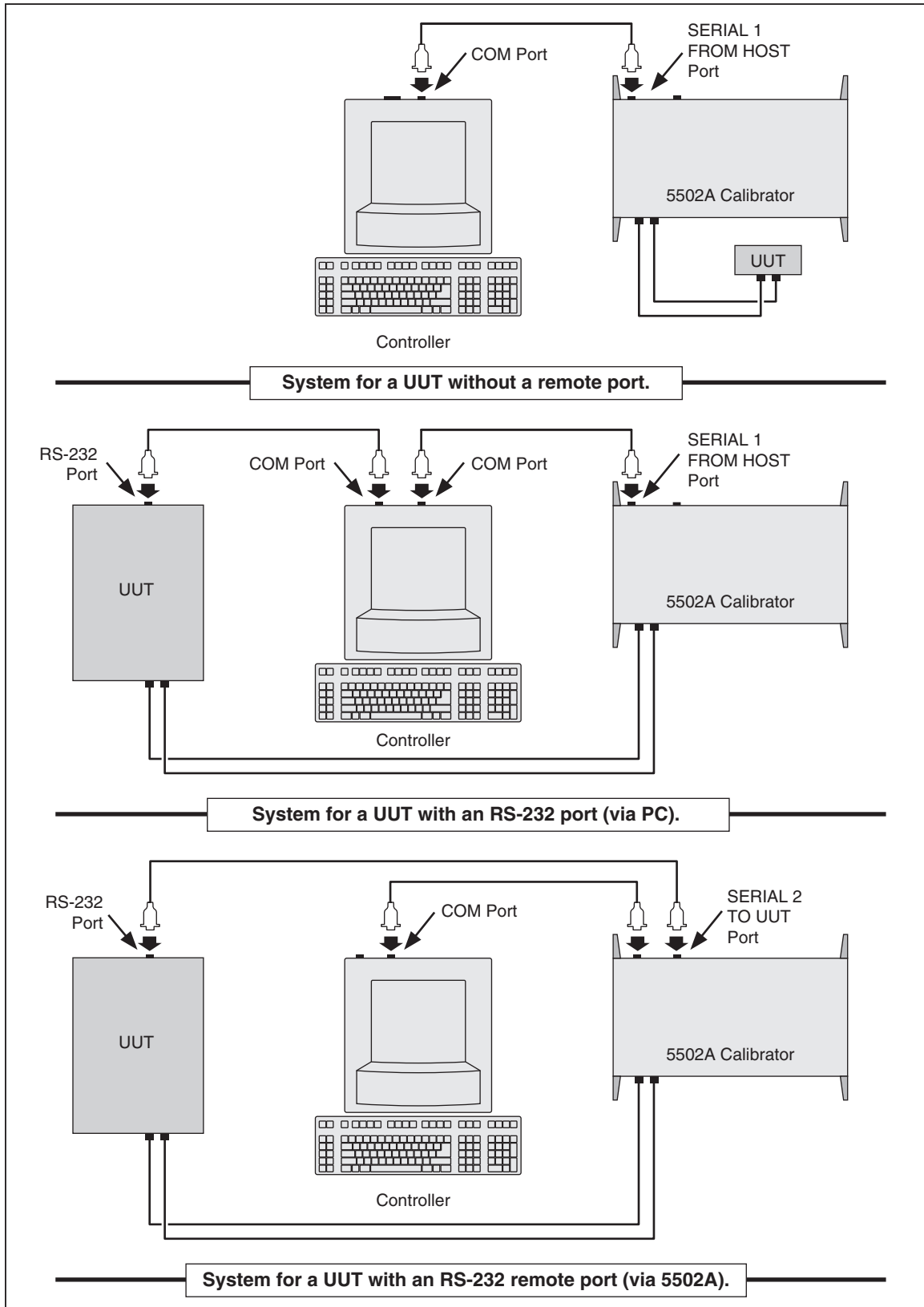
## ***Set up the IEEE-488 Port for Remote Control***

The Calibrator is fully programmable for to use on the IEEE Standard 488.1 interface bus. The IEEE-488 interface is also in compliance with supplemental standard IEEE-488.2, which gives more IEEE-488 features. Devices connected to the IEEE-488 bus are designated as talkers, listeners, talker/listeners, or controllers. The Calibrator operates as a talker/listener when it is remotely controlled by an instrument.

A PC with an IEEE-488 interface controls the Calibrator. Compatible software for IEEE-488 operation can be purchased from Fluke Calibration with MET/CAL Plus.

When you use the IEEE-488 remote control interface, there are two restrictions:

1. **Number of Devices** A maximum of 15 devices can be connected in one IEEE-488 bus system. For example, one instrument controller, one Calibrator, and thirteen UUTs.
2. **Cable Length** The total length of IEEE-488 cables used in one IEEE-488 system is 2 meters multiplied by the number of devices in the system, or 20 meters. Use that which is less. For example, if 8 devices are connected, the maximum cable length is  $2 \times 8 = 16$  meters. If 15 devices are connected, the maximum cable length is 20 meters.



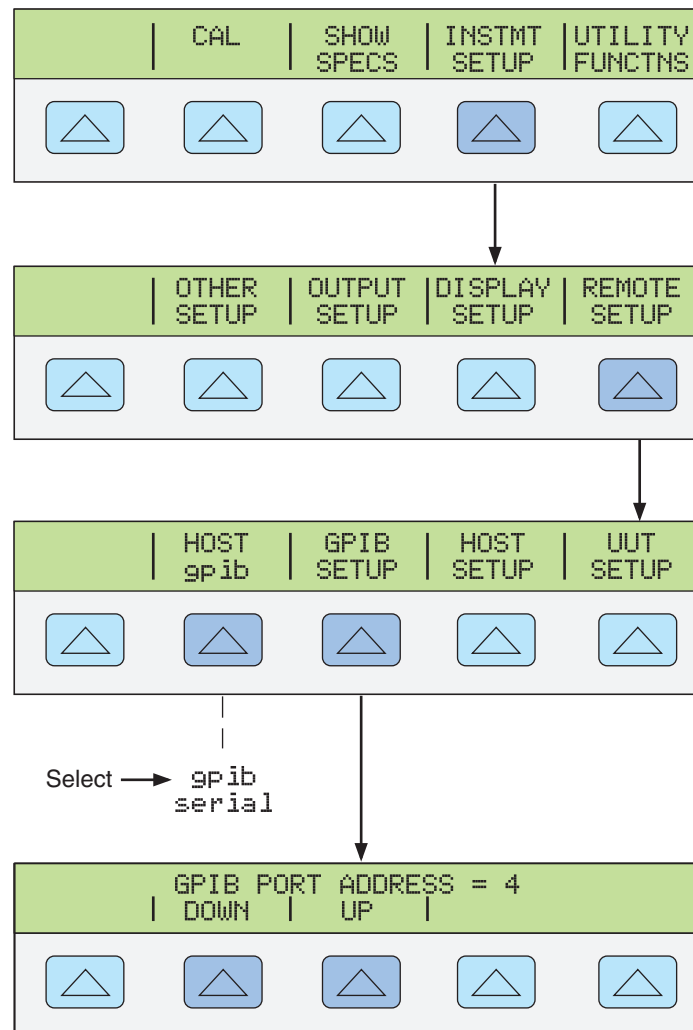
gjh042.eps

**Figure 5-2. Typical RS-232 Remote Control Connections**

### IEEE-488 Port Setup Procedure

Complete the subsequent procedure to set up the Calibrator for remote operations with the IEEE-488 remote control port. This procedure selects GPIB as the interface and to select the GPIB address for the interface.

1. Turn the Calibrator power on. You can operate the Calibrator during warmup, but specifications are not guaranteed until the warmup is complete.
2. Push **SETUP** on the Calibrator front panel.
3. Navigate the softkey selections shown below. Verify the HOST port selection is GPIB. Select the necessary GPIB port address (0 to 30) with the UP/DOWN softkeys. The factory default is 4.



nn120f.eps

4. Push **PREV** (not **ENTER**) several times until the message STORE CHANGES/DISCARD CHANGES appears or, if there were no changes, the reset display. If you select STORE CHANGES, the GPIB and host port information are kept in the instrument non-volatile memory.

### Verify the IEEE-488 Port

The subsequent procedure verifies IEEE-488 communications between the PC and the Calibrator with the Win32 Interactive Control utility. This utility is supplied with National Instruments interface cards for the PC, which are the recommended interfaces. (See Chapter 8, "Accessories.") A typical connection is shown in Figure 5-3.

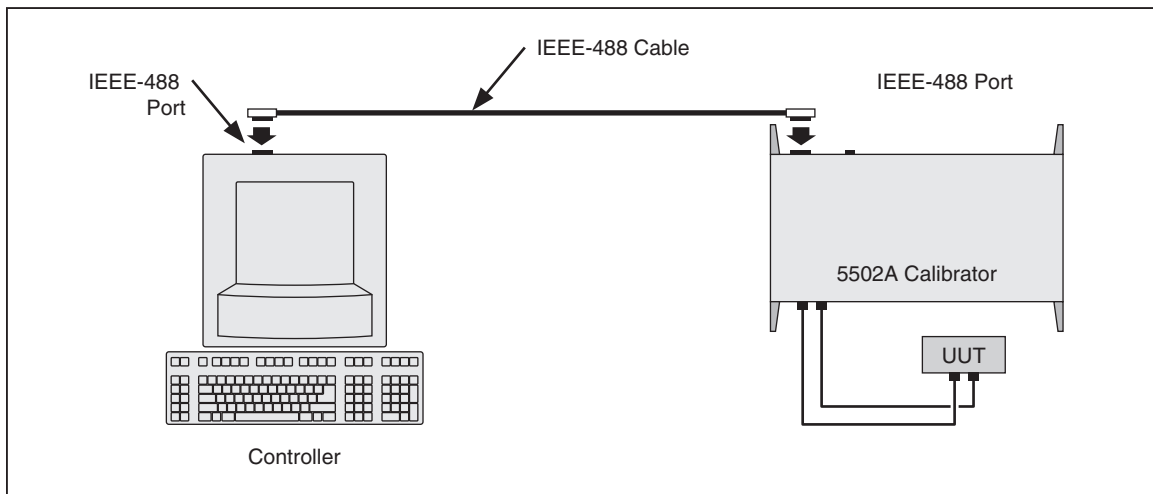
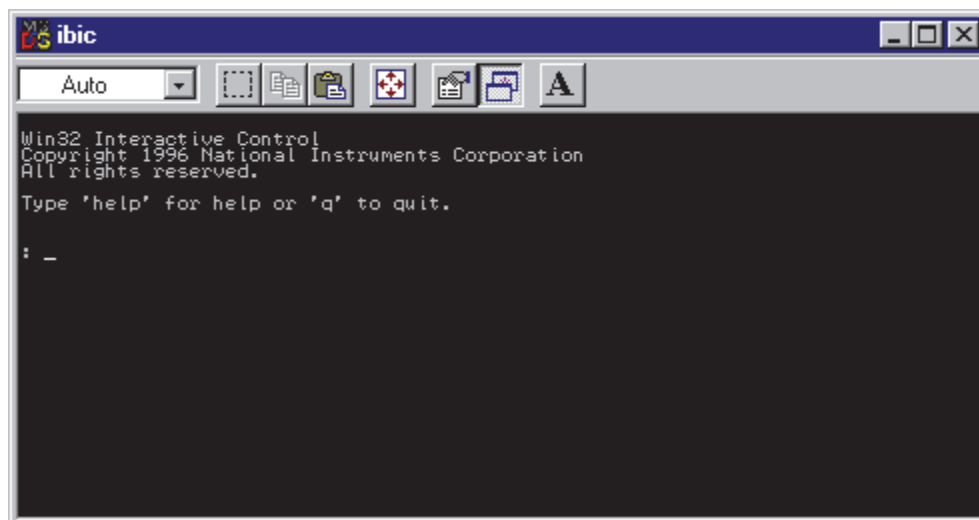


Figure 5-3. IEEE-488 Port Verification

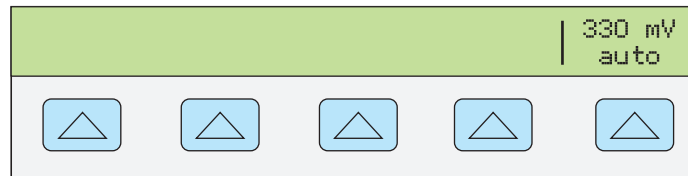
gjh043.eps

Complete the subsequent procedure to verify IEEE-488 operation with Win32 Interactive Control.

1. Complete the "IEEE-488 Port Setup Procedure" in this chapter to set up the Calibrator for GPIB operation. Note the GPIB Address Port (default is 4).
2. Connect the PC and Calibrator IEEE-488 ports with a standard IEEE-488 cable. (See Chapter 8, "Accessories," for IEEE-488 cables available from Fluke Calibration.)
3. From the programs menu, select "NI-488.2M software for...(your operating system)".
4. From the NI488.2M software menu, select "Win32 interactive control".
5. A DOS window opens with a prompt as shown here:



6. At the prompt type the subsequent line to start the IEEE interface card:  
`<ibdev 0 4 0 10 1 0>`  
 The second number in this line is the primary address of the calibrator. If the address is changed from the factory default, change this line accordingly.
7. The prompt reads `<ud0:>`. From this prompt type `<ibwrt "remote">` then push the ENTER (or RETURN) key.
8. Make sure that the calibrator is in remote control.
9. Select the Local command from the Control menu, then click OK in the Parameter Input Window. See the Calibrator Control Display changes to the reset condition (below).



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10. From the `ud0:` prompt, type `<q>` and then push the ENTER (or RETURN) key.

## Set up the RS-232 Host Port for Remote Control

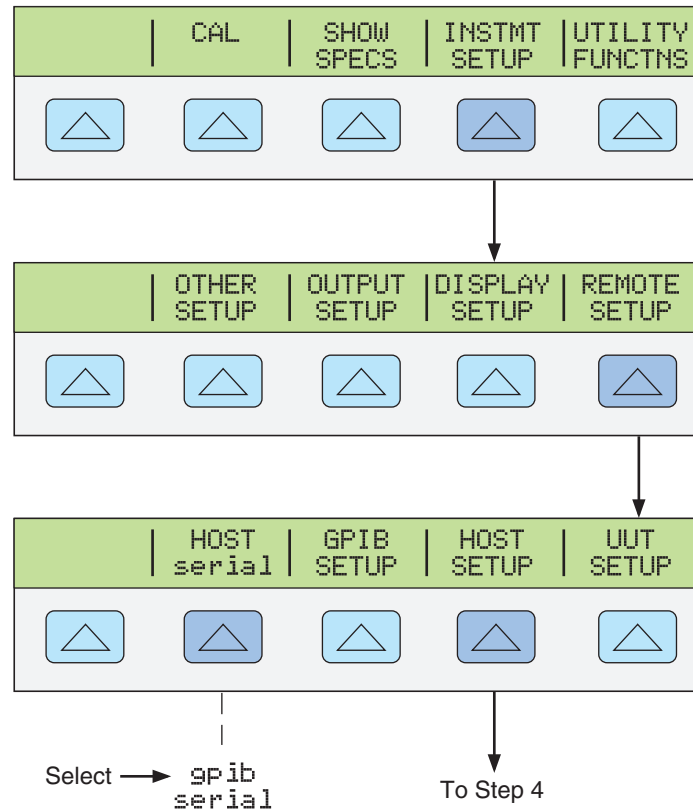
The Calibrator is fully programmable with an RS-232 connection with a PC the rear panel SERIAL 1 FROM HOST port (Figure 5-2). You can record individual commands from a terminal, write your own programs with, for example, a Windows-based language such as Visual Basic, or use optional Windows-based Fluke Calibration software such as MET/CAL Plus.

The RS-232 cable length for the port must not be more than 15 meters (50 feet), although longer cable lengths are permitted if the load capacitance measured at a connection point (including signal terminator) does not go more than 2500 pF.

### RS-232 Host Port Setup Procedure

Complete the subsequent procedure to set up the SERIAL 1 FROM HOST port. The RS-232 parameters that you select here must be the same parameters set for the PC COM port. The factory defaults (shown on the display below) are 9600 baud, 8 data bits, 1 stop bit, and no parity. Other parameters include flow control, EOL (end-of-line) character, and EOF (end-of-file) characters.

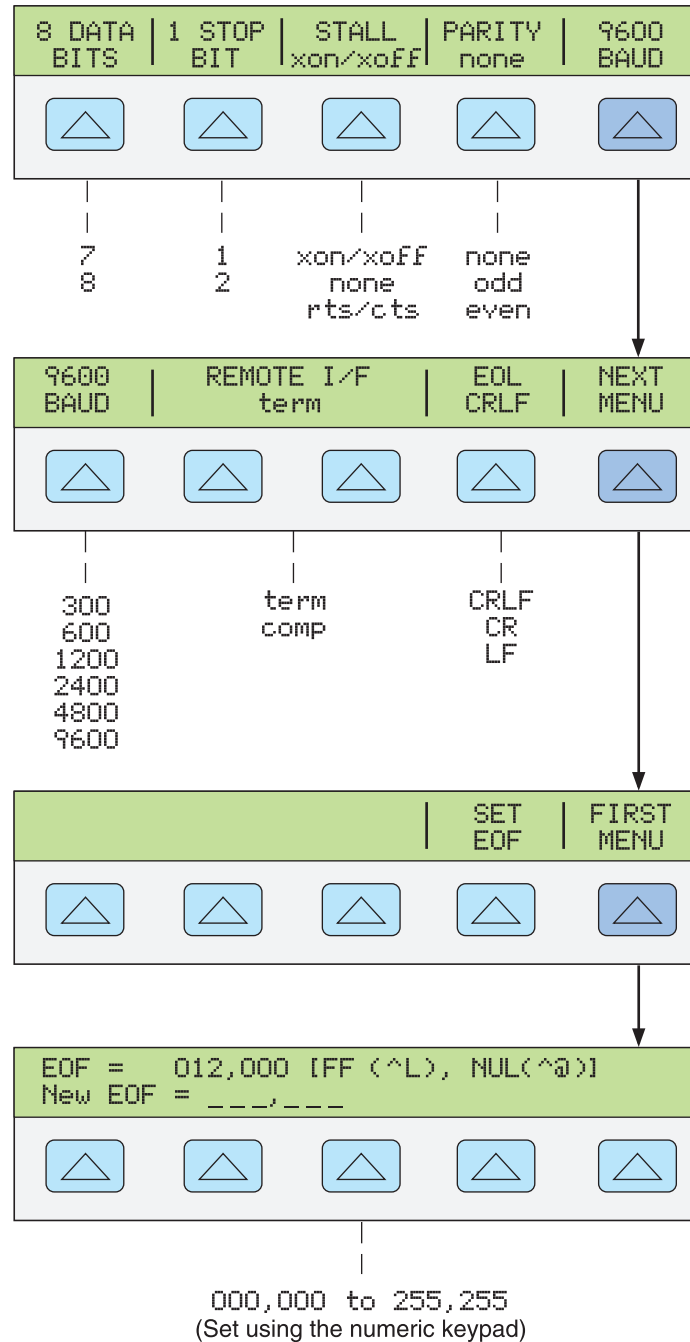
1. Turn on the Calibrator power. You can operate the Calibrator during warmup, but specifications are not guaranteed until warmup is complete.
2. Push **SETUP** on the Calibrator front panel.
3. Negotiate the softkey selections shown below to select the serial port for remote operation, then continue to Step 4.



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4. Navigate the softkey selections shown below to select the HOST serial port parameters for the PC COM parameters. (Individual softkey functions are discussed in Chapter 3, “Features.”) If operating the port with a computer program instead of individual commands from a terminal, select Remote I/F comp.





nn122f.eps

5. Push **PREV MENU** (not **ENTER**) several times until the message STORE CHANGES/DISCARD CHANGES appears or, if there were no changes, the reset display. If you select STORE CHANGES, the serial and host port information are kept in the instrument non-volatile memory.

### Verify the RS-232 Host Port

Choose or adapt one of the subsequent procedures to verify the Calibrator RS-232 Host port connected to a PC COM port. A typical connection is shown in Figure 5-4. Note that a null modem cable is used for connection. (See Appendix C for information about RS-232 cables and connectors.)

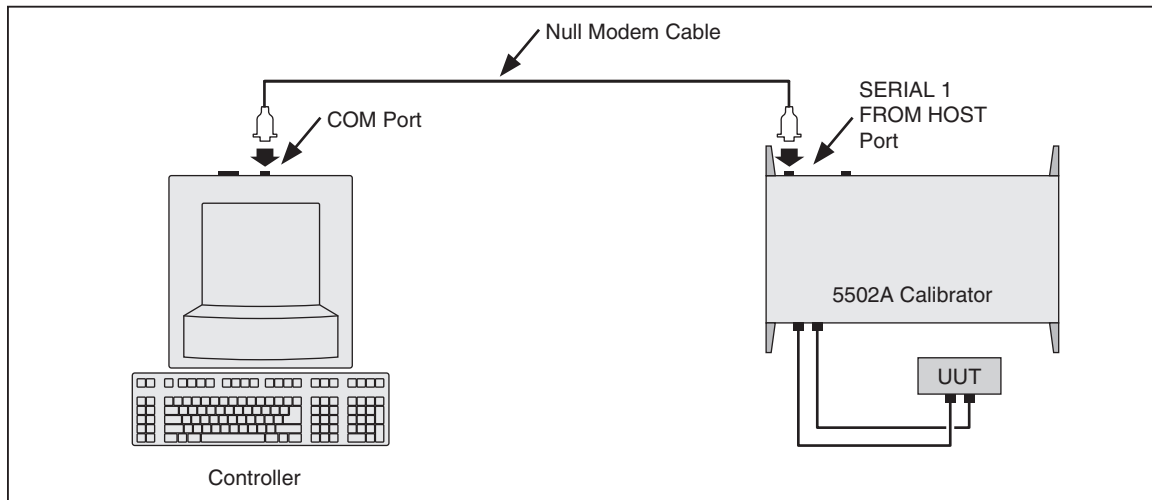


Figure 5-4. RS-232 Host Port Verification

**Terminal** This procedure uses the Terminal accessory supplied with Windows (or equal) to verify RS-232 Host port operation. To use this method, you must select term as the Remote I/F in Step 4 in the procedure “RS-232 Host Port Setup Procedure.”

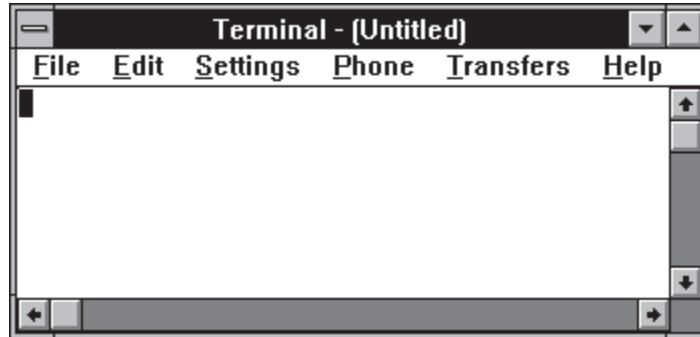
**Visual Basic** This procedure uses Visual Basic (see Appendix D) to verify RS-232 Host port and RS-232 UUT port operation.

### Verify RS-232 Host Port Operation with a Terminal

Complete the subsequent procedure to verify RS-232 Host port operation with the Windows Terminal accessory (or equal).

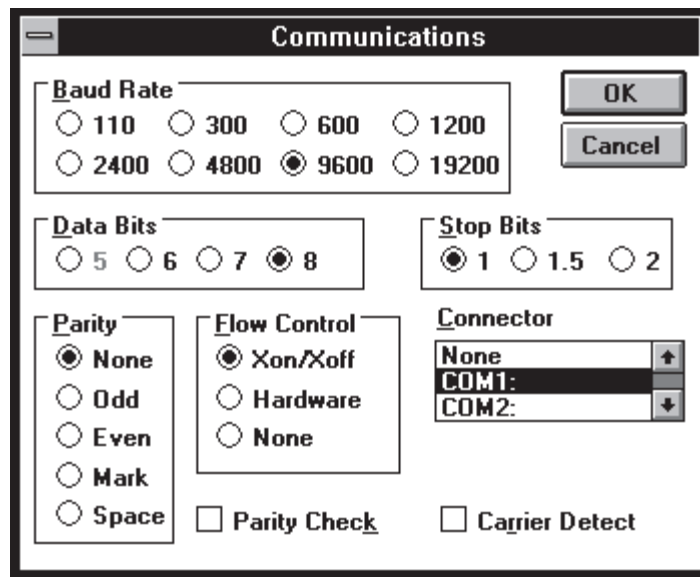
1. Complete the “RS-232 Host Port Setup Procedure” before in this chapter to set up the Calibrator for RS-232 Host port operation. Write down the RS-232 Host port parameters that you selected in this procedure.
2. Connect the selected COM port on the PC to the Calibrator SERIAL 1 FROM HOST port with a standard null-modem RS-232 cable. (See Appendix C for information on RS-232 cables and connectors.)
3. Open Windows to the Program Manager screen on your PC.

4. Open Terminal from the Accessory group of Program Manager (below). If a terminal configuration file already exists, for example, host.trm, select the necessary file with the Open command from the File menu and go to Step 7. If not, go to Step 5.



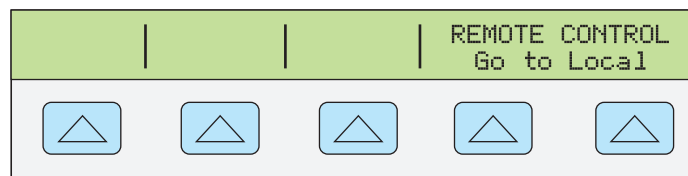
nn308f.bmp

5. Select the Communications command from the Setting menu. Record the RS-232 parameters that match those selected at the Calibrator for the Host port. If you use the Calibrator factory defaults, you will see the Communications dialog box for COM1 as shown below. Select COM as necessary. Click OK.



nn309f.bmp

6. Verify the Calibrator is powered and in the reset condition. (If in doubt, push **RESET** on the Calibrator front panel.)
7. On the Terminal screen, type the command REMOTE and push <Enter>. See that the Calibrator Control Display changes to REMOTE CONTROL (see below).



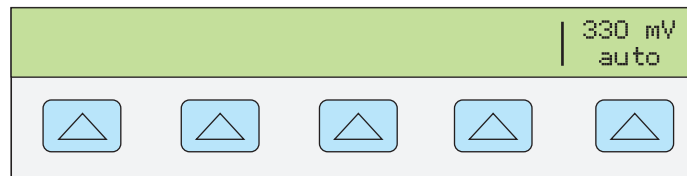
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The characters REMOTE must have shown on the terminal screen as they were recorded. If they did not show on the screen, but the Control Display changed to REMOTE CONTROL, then see step 4 of the “RS-232 Host Port Setup Procedure” and change the REMOTE I/F setting from comp to term.

If nonsense characters showed on the screen, then there is a mismatch of RS-232 parameters. See step 4 of the “RS-232 Host Port Setup Procedure” procedure for the correct RS-232 settings and then do this procedure again. Start at Step 5.

If no characters showed on the screen, then see step 3 of the “RS-232 Host Port Setup Procedure” procedure to make sure that serial was selected for the Host port. Check that you used the correct RS-232 cable. It must be in a null-modem configuration where the RX and TX lines are reversed (see Appendix C). Also make sure that you have connected to the correct COM port on the PC.

8. Type the command LOCAL and push <Enter>. See that the Calibrator Control Display changes to the reset condition (below).



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To experiment with other commands in the command set, see Chapter 6, “Remote Commands.” When finished, select the Exit command from the File menu to close the Terminal accessory.

Hint: To keep the communication parameters in Terminal for future operations, first select Save from the File menu and then give a name, for example, host.trm.

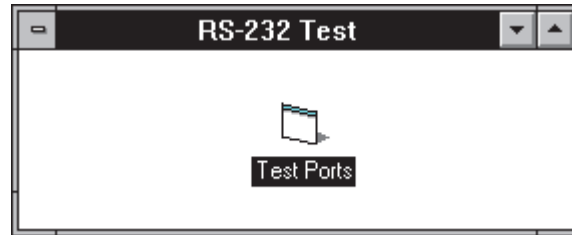
### **Verify RS-232 Host Port Operation with Visual Basic**

Complete the subsequent procedure to verify RS-232 (Host) operation with the Windows-based programming language Visual Basic. This procedure is if you have completed Appendix D, “Creating a Visual Basic Test Program” to make the group RS-232 Test.

Complete the subsequent procedure to verify RS-232 operation with Visual Basic.

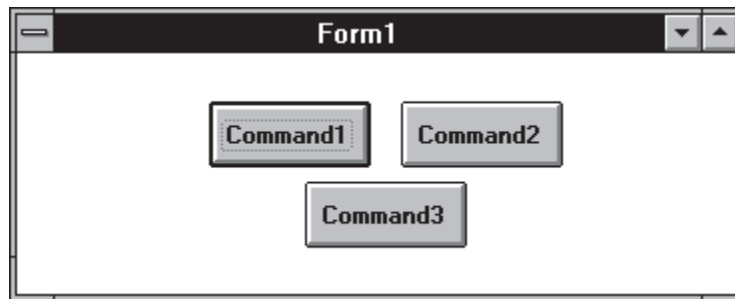
1. Complete the “RS-232 Host Port Setup Procedure” before in this chapter to set up the Calibrator for RS-232 Host port operation. Note the RS-232 Host port parameters that you selected in this procedure.

2. Connect the selected COM port on the PC to the Calibrator SERIAL 1 FROM HOST port with a standard null-modem RS-232 cable. (See Appendix C for information on RS-232 cables and connectors.)
3. To start the program, open the Test Ports icon from the RS-232 Test group ( see below).



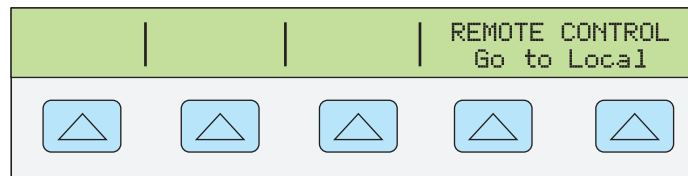
nn310f.bmp

4. Verify the Calibrator is turned on and in the reset condition (if in doubt, push **RESET**), then click the Command1 button ( see below).



nn311f.bmp

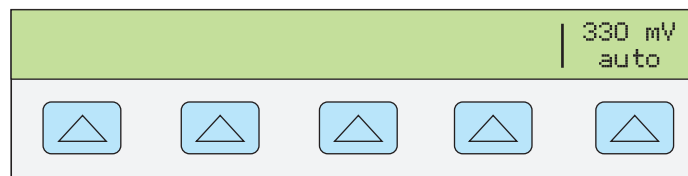
5. See that the Calibrator Control Display changes to REMOTE CONTROL (see below).



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6. Click the Command2 button. See that the Calibrator Control Display changes to the reset condition (see below).

(The Command3 button is used to verify the RS-232 UUT port later in this chapter.)



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7. Click on the top-left corner and close the program.

## **Set up the RS-232 UUT Port for Remote Control**

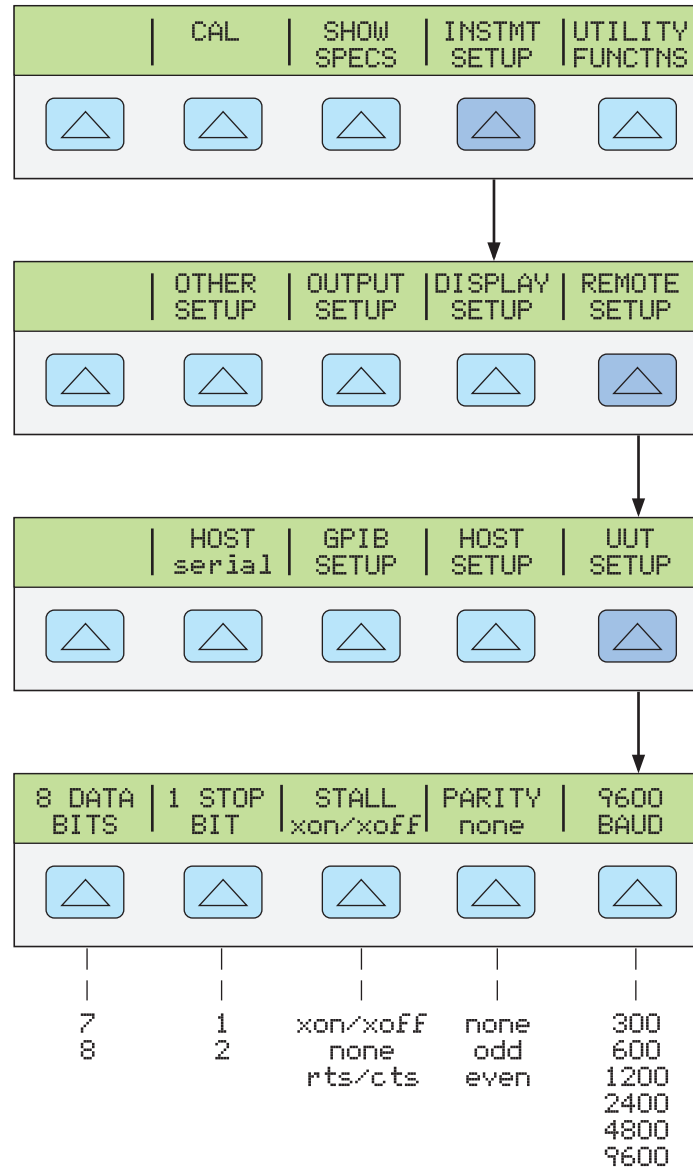
The SERIAL 2 TO UUT serial data port connects a UUT to a PC or terminal with the Calibrator (Figures 5-1 and 5-2). This “pass-through” configuration removes the requirement for two COM ports at the PC or Terminal. The UUT\_\* commands (see Chapter 6) are for the UUT port data flow.

The RS-232 cable length for each port must not be more than 15 meters, although longer cable lengths are permitted if the load capacitance measured at a connection point (including signal terminator) is not more than 2500 pF.

### **RS-232 UUT Port Setup Procedure**

Complete the subsequent procedure to set up the SERIAL 1 FROM HOST port. The RS-232 parameters you select here must be the same as the parameters set for the PC COM port. The factory defaults (shown on the display below) are 9600 baud, 8 data bits, 1 stop bit, and no parity. Other parameters include flow control, EOL (end-of-line) character, and EOF (end-of-file) characters.

1. Turn on the Calibrator power. You can operate the Calibrator during warmup, but specifications are not guaranteed until warmup is complete.
2. Push **RESET** on the Calibrator front panel.
3. Navigate the softkey selections shown below to select the serial port for remote operation, then continue to Step 4.



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### Verify the RS-232 UUT Port with RS-232 Host Port

Choose or adapt one of the subsequent test procedures to verify the Calibrator RS-232 UUT port with the RS-232 Host port. Connect the UUT and PC as shown in Figure 5-5. Note that a modem cable (NOT null modem) is used for UUT connection. (See Appendix C for information about RS-232 cables and connectors.)

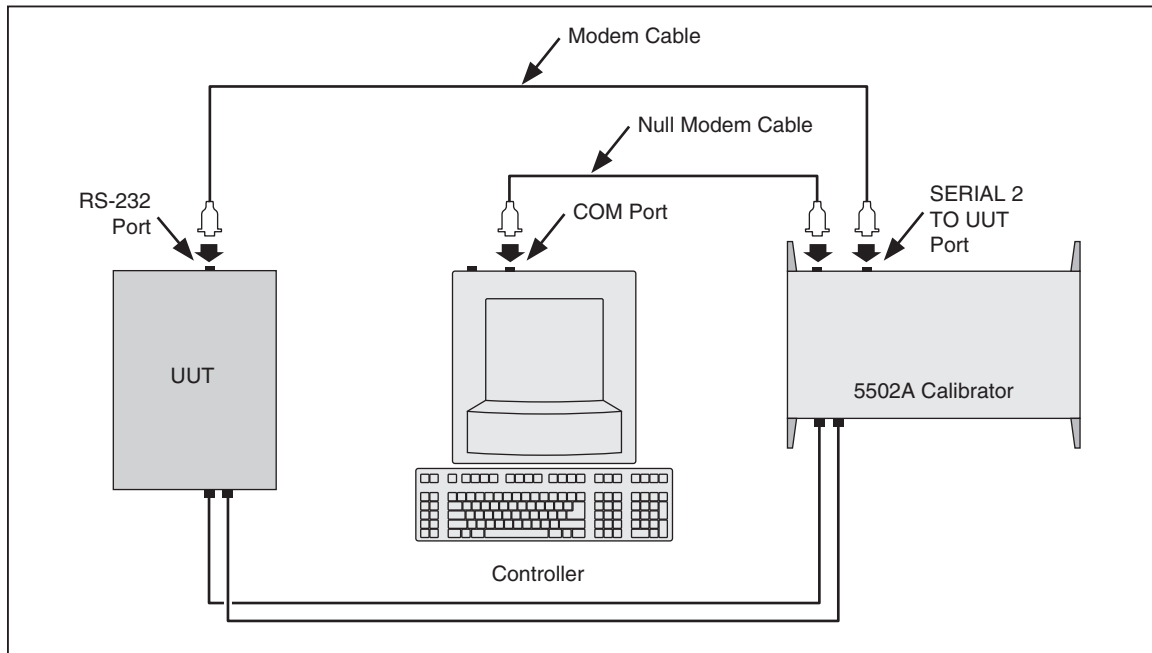


Figure 5-5. Testing the RS-232 UUT Port with RS-232 Host Port

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**Terminal** This procedure uses the Terminal accessory supplied with Windows (or equal) to verify RS-232 UUT port operation.

**Visual Basic** This procedure uses Visual Basic (see Appendix D) to verify RS-232 Host port and RS-232 UUT port operation.

### Test RS-232 UUT Port Operation with a Terminal

Complete the subsequent procedure to verify RS-232 UUT port operation with the RS-232 Host port with the Windows Terminal accessory (or equal).

1. Complete “RS-232 UUT Port Setup Procedure” to the Calibrator RS-232 UUT port to the same parameters of the UUT RS-232 port.
2. Complete “Test RS-232 Host Port Operation with a Terminal” to set up the Calibrator RS-232 Host port to the same parameters of the PC COM port. After Step 9, go to this procedure and continue to Step 3 below.
3. On the Terminal screen, type UUT\_SEND “<uut command>” where <uut command> is the command you selected for the UUT response, then push <Enter>. See the UUT result. For example, to send the command REMS to a UUT, use UUT\_SEND “REMS\n” and push <Enter>.

Note that \n is used, which shows a Carriage Return (CR) as the end-of-line character. Other characters include \r (Line Feed), \t (Tab), \b (Backspace) and \f (Form Feed). If an end-of-line character is necessary for the UUT commands, select one or more of the above.

The characters UUT\_SEND “<uut command>” show as they are recorded. If they did not show on the screen, the RS-232 interface between the PC and Calibrator Host port is not in operation. Read the “RS-232 Host Port Setup Procedure” and correct the problem.

4. If the UUT command does not do what it must, see step 3 of the “RS-232 UUT Port Setup Procedure” to verify the RS-232 UUT port parameters. Also examine the cable for UUT connection was a modem (not null modem) cable. Make sure the command was recorded correctly and had the correct end-of-line character(s), if necessary.



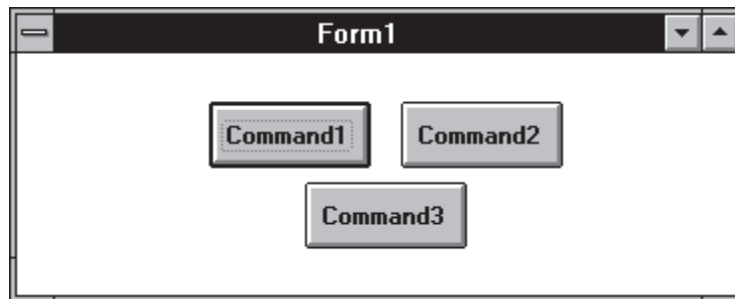
5. When you complete UUT commands tests, select the Exit command from the File menu to close the Terminal accessory.

### **Verify RS-232 UUT Port Operation with Visual Basic**

Complete the subsequent procedure to verify RS-232 UUT port operation with the RS-232 Host port with a Visual Basic test program. For this procedure, complete Appendix D, "Creating a Visual Basic Test Program" to make the program used for this test.

Complete the subsequent procedure to verify RS-232 operation with Visual Basic.

1. Complete the "RS-232 UUT Port Setup Procedure" in this chapter to set up the Calibrator RS-232 UUT port to the same parameters of the UUT RS-232 port.
2. Complete "Verify RS-232 Host Port Operation with Visual Basic" to prepare the Calibrator RS-232 Host port. After Step 6, go to this procedure and continue to Step 3.
3. Click the Command3 button (below is typical). See that the UUT reacts to the command you used when you completed Appendix D, "Make a Visual Basic Test Program."



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If the UUT did not react, make sure the RS-232 parameters are set for the Calibrator UUT port and set for the UUT port. Make sure you used a modem (not null modem) cable for the Calibrator to UUT connection. Examine the Visual Basic program to make sure the UUT command and the end-of-line character was recorded correctly.

4. To close the program, click the top-left corner and Close.

### **Verify the RS-232 UUT Port with IEEE-488 Port**

This procedure uses the Win32 Interactive Control utility supplied by National Instruments with the recommended interface cards. Connect the UUT, Calibrator, and PC as shown in Figure 5-6. Note that a modem cable (NOT null modem) is used for the UUT connection. (See Appendix C for information about RS-232 cables and connectors.)

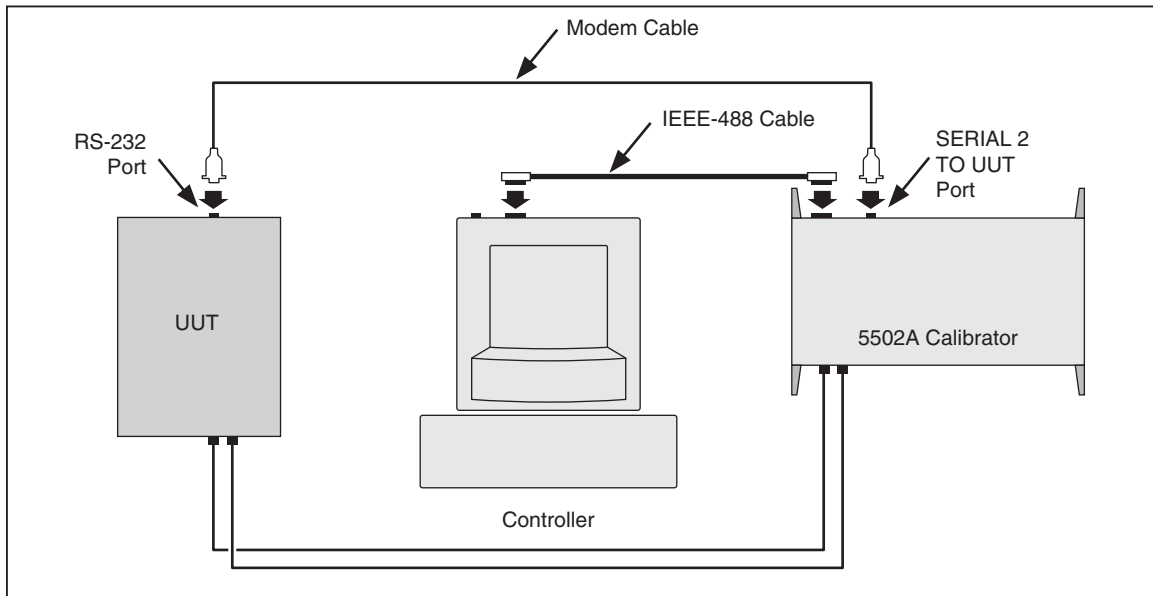
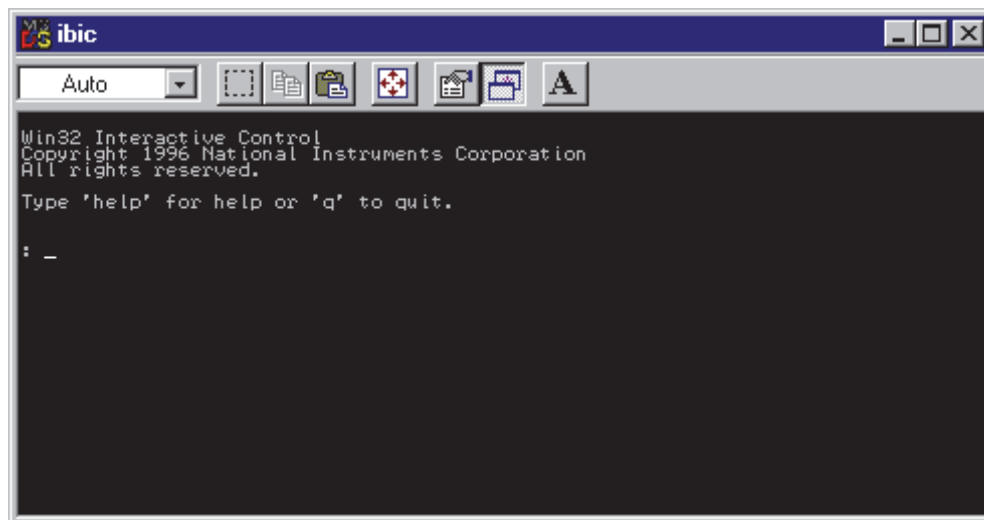


**Figure 5-6. Verify the RS-232 UUT Port with IEEE-488 Port**

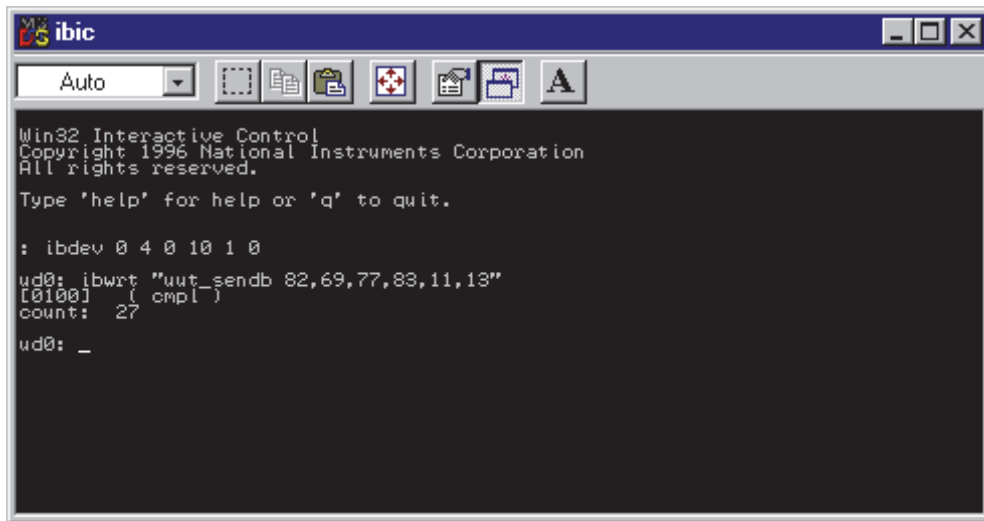
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Complete the subsequent procedure to verify RS-232 UUT port operation with the IEEE-488 port with the Win32 Interactive Control utility.

1. Complete the "IEEE-488 Port Setup Procedure" in this chapter to set up the Calibrator for GPIB operation.
2. Complete "Verify the IEEE-488 Port" to prepare the Calibrator IEEE-488 port to be verified. Before the last step, come to this procedure and continue to Step 3 below.
3. Go to Start then to the Programs menu.
4. Select "NI-488.2M software for... (your operating system)".
5. From the NI488.2M software menu, select "Win32 interactive control".
6. A DOS window opens with a prompt:



7. At the prompt, type the subsequent line to turn on the IEEE interface card:  
`<ibdev 0 4 0 10 1 0>`
8. The second number in this line is the primary address of the calibrator. If the address has changed from the factory default, change this line accordingly.
9. The prompt reads `<ud0:>`. From this prompt, type  
`<ibwrt "uut_sendb 82,69,77,83,11,13">`
10. Push the ENTER (or RETURN) key. This command will send REMS<CR><LF> to the UUT serial port. After the command is recorded, the Win32 Interactive Control shows the status of the command. If an error is found, examine the typing or consult the National Instruments manual regarding Win32 Interactive control. The count message is the quantity of characters sent through the bus (see below).



11. Verify that the UUT is in remote.
12. From the ud0: prompt type `<q>` then push the ENTER (or RETURN) key.

## Change between Remote and Local Operation

With local mode (front-panel operation) and remote, the Calibrator can also be put into a local lockout condition by command of the controller. In combination, the local, remote, and lockout conditions give four possible operation conditions given as follows.

### Local State

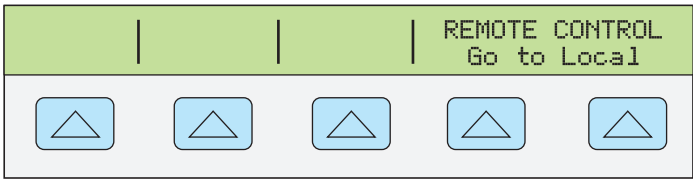
The Calibrator responds to local and remote commands. This is correct front-panel operation. All remote commands are can be used.

### Local with Lockout State

Local with lockout is the same as local, but the Calibrator will change to the remote with lockout as an alternative to the remote condition when it gets a remote command.

**Remote Condition**

When the Calibrator is put in remote, with the RS-232 REMOTE command, or with IEEE-488 asserting the REN line, it goes to the remote condition. In the remote condition, the Output Display continues to show the output conditions or measurement as in local operation. The Control Display changes to:

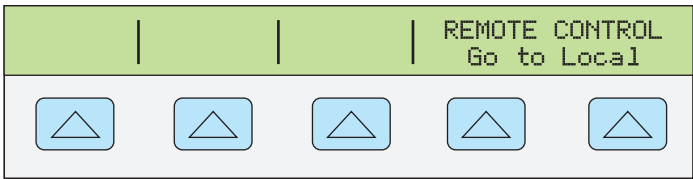


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The left side of the Control Display shows data for the given output function, but front-panel operation is only for the power switch and the "Go To Local" softkeys. Push one of these softkeys, and use RS-232 to send the command LOCAL, or IEEE-488 to send the GTL (Go To Local) message will put the Calibrator to the local condition.

**Remote with Lockout Condition**

When the Calibrator is put in lockout with the RS-232 LOCKOUT command or with the IEEE-488 message LLO, the Calibrator front panel controls are totally locked out. In remote with lockout, the Control Display changes to:



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The left side of the Control Display shows information regarding the given output function. Front-panel operation is only for the power switch. To change the Calibrator to the local with lockout condition, send the RS-232 LOCAL command or the IEEE-488 GTL (Go To Local) message.

Table 5-1 summarizes the possible Remote/Local condition changes. (For more information on IEEE-488 GPIB messages, see "IEEE-488 Overview.")

**Table 5-1. Operation State Transitions**

| From                | To                  | Front Panel         | GPIB Message     | Serial Command |
|---------------------|---------------------|---------------------|------------------|----------------|
| Local               | Remote              |                     | MLA (REN True)   | REMOTE         |
|                     | Local with Lockout  |                     | LLO              | LOCKOUT        |
| Remote              | Local               | Go to Local Softkey | GTL or REN False | LOCAL          |
|                     | Remote with Lockout |                     | LLO              | LOCKOUT        |
| Local with Lockout  | Local               |                     | REN False        | LOCAL          |
|                     | Remote with Lockout |                     | MLA (REN True)   | REMOTE         |
| Remote with Lockout | Local               |                     | REN False        | REMOTE         |
|                     | Local with Lockout  |                     | GTL              |                |

## RS-232 Interface Overview

The two Calibrator RS-232 ports are in accordance with EIA (Electronic Industries Association) standard RS-232. RS-232 is a serial binary data interchange that operates from 300 to 9600 baud (selectable), and distances to a maximum of 50 feet. The Calibrator rear panel SERIAL 1 FROM HOST port is configured as DTE (Data Terminal Equipment) while the SERIAL 2 TO UUT is configured as DCE (Data Communications Equipment). See Appendix C for RS-232 cable and connector information. For more information, see the EIA standard RS-232.

A summary of RS-232 terms, interface lines and mnemonics are shown in Table 5-2.

**Table 5-2. RS-232 Interface Wiring**

| Mnemonic | Description                   |
|----------|-------------------------------|
| CTS      | Clear to Send                 |
| DB-9     | Type DB connector, 9 pins     |
| DB-25    | Type DB connector, 25 pins    |
| DCD      | Data Carrier Detect           |
| DCE      | Data Communications Equipment |
| DSR      | Data Set Ready                |
| DTE      | Data Terminal Equipment       |
| DTR      | Data Terminal Ready           |
| GND      | Ground                        |
| RI       | Ring Indicator                |
| RLSD     | Received Line Signal Detector |
| RTD      | Request to Send               |
| RX       | Receive Line                  |
| TX       | Transmit Line                 |

## **IEEE-488 Interface Overview**

The IEEE-488 parallel interface sends commands as data and receives measurements and messages as data. The maximum data exchange rate is 1 Mbyte, with a maximum distance of 20 meters for the sum length of the connection cables. One cable must not be more than 4 meters in length. Some commands are kept for RS-232 serial operation because these functions must be implemented as IEEE messages per the IEEE Standards. For example, the command REMOTE could be sent as data with the IEEE-488 interface to put the Calibrator into remote, but it is not because the remote function to be sent to the device as the uniline message REN is necessary for the IEEE Standards. This is also correct for other commands and functions, as shown below, with their equivalent RS-232 emulation. A summary of IEEE-488 messages is shown in Table 5-3.

**Table 5-3. RS-232 Emulation of IEEE-488 Messages**

| IEEE-488 Message | RS-232 Equivalent                                      |
|------------------|--------------------------------------------------------|
| GTL              | LOCAL command                                          |
| GTR              | REMOTE command                                         |
| LLO              | LOCKOUT command                                        |
| SDC, DCL         | ^C (<Cntl> C) character [clear the device]             |
| GET              | ^T (<Cntl> T) character [execute a group trigger]      |
| SPE, SPD         | ^P (<Cntl> P) character [print the serial poll string] |
| UNL, UNT         | (not emulated on RS-232)                               |

The IEEE-488 interface comes from the IEEE Standards 488.1 and 488.2. For more information, refer to the standards IEEE-488.1 and IEEE-488.2.

**IEEE-488.1** IEEE-488.1 is the hardware piece of the interface. The parallel signal lines are divided into eight lines for the data bus, three lines for the handshake, and five lines for bus management. The handshake lines are for the timing for data interchange. The bus management lines control the operation of data interchange. The ATN line shows the operation of the DIO lines for addresses or messages (true), or for DIO data (false). The EOI line is used with the data lines to show the end of a message, and with the ATN line for polling. The SRQ line is used by the devices to show the controller that servicing is necessary. The IFC line is used by the controller to quickly get all the devices on the bus to stop talking and start listening. The REN line is used to implement the remote/local conditions.

**IEEE-488.2** IEEE-488.2 is the software piece of the interface, specifying data formats, common commands, message interchange protocol and the status register implementation.

Use the subsequent items to decode the columns in Figure 5-7. Appendix C shows a typical IEEE-488 connector and pin assignments.

|       |                                                                                                  |                                                           |
|-------|--------------------------------------------------------------------------------------------------|-----------------------------------------------------------|
| Type  | M - Multiline<br>U - Uniline                                                                     |                                                           |
| Class | AC - Addressed Command<br>AD - Address (Talk or listen)<br>UC - Universal Command<br>ST - Status | DD - Device Dependent<br>HS - Handshake<br>SE - Secondary |
| Other | B1, B2, etc. - Information Bits<br>Blanks - Doesn't Care condition                               | Logic Zero = 0 = False<br>Logic One = 1 = True            |

| MESSAGE DESCRIPTION |                           |                  |                       | DATA BUS                         |                  |                  |                  |                  |                  |                  |                  | HAND-SHAKE  |                  |                  | BUS MANAGEMENT |             |             |             |             |
|---------------------|---------------------------|------------------|-----------------------|----------------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|-------------|------------------|------------------|----------------|-------------|-------------|-------------|-------------|
| M<br>N<br>E<br>M    | MESSAGE<br>NAME           | T<br>Y<br>P<br>E | C<br>L<br>A<br>S<br>S | D<br>I<br>O<br>8                 | D<br>I<br>O<br>7 | D<br>I<br>O<br>6 | D<br>I<br>O<br>5 | D<br>I<br>O<br>4 | D<br>I<br>O<br>3 | D<br>I<br>O<br>2 | D<br>I<br>O<br>1 | D<br>A<br>V | N<br>R<br>F<br>D | N<br>D<br>A<br>C | A<br>T<br>N    | E<br>O<br>I | S<br>R<br>Q | I<br>F<br>C | R<br>E<br>N |
| ACG                 | Addressed Command Group   | M                | AC                    |                                  | 0                | 0                | 0                |                  |                  |                  |                  |             |                  |                  | 1              |             |             |             |             |
| ATN                 | Attention                 | U                | UC                    |                                  |                  |                  |                  |                  |                  |                  |                  |             |                  |                  | 1              |             |             |             |             |
| DAB                 | Data Byte                 | M                | DD                    | B8                               | B7               | B6               | B5               | B4               | B3               | B2               | B1               |             |                  |                  | 0              |             |             |             |             |
| DAC                 | Data Accepted             | U                | HS                    |                                  |                  |                  |                  |                  |                  |                  |                  |             |                  | 0                |                |             |             |             |             |
| DAV                 | Data Valid                | U                | HS                    |                                  |                  |                  |                  |                  |                  |                  |                  | 1           |                  |                  |                |             |             |             |             |
| DCL                 | Device Clear              | M                | UC                    |                                  | 0                | 0                | 1                | 0                | 1                | 0                | 0                |             |                  |                  | 1              |             |             |             |             |
| END                 | End                       | U                | ST                    |                                  |                  |                  |                  |                  |                  |                  |                  |             |                  |                  | 0              | 1           |             |             |             |
| EOS                 | End Of String             | M                | DD                    | B8                               | B7               | B6               | B5               | B4               | B3               | B2               | B1               |             |                  |                  | 0              |             |             |             |             |
| GET                 | Group Execute Trigger     | M                | AC                    |                                  | 0                | 0                | 0                | 1                | 0                | 0                | 0                |             |                  |                  | 1              |             |             |             |             |
| GTL                 | Go To Local               | M                | AC                    |                                  | 0                | 0                | 0                | 0                | 0                | 0                | 1                |             |                  |                  | 1              |             |             |             |             |
| IDY                 | Identify                  | U                | UC                    |                                  |                  |                  |                  |                  |                  |                  |                  |             |                  |                  |                | 1           |             |             |             |
| IFC                 | Interface Clear           | U                | UC                    |                                  |                  |                  |                  |                  |                  |                  |                  |             |                  |                  |                |             |             | 1           |             |
| LAG                 | Listen Address Group      | M                | AD                    |                                  | 0                | 1                |                  |                  |                  |                  |                  |             |                  |                  | 1              |             |             |             |             |
| LLO                 | Local Lock Out            | M                | UC                    |                                  | 0                | 0                | 1                | 0                | 0                | 0                | 1                |             |                  |                  | 1              |             |             |             |             |
| MLA                 | My Listen Address         | M                | AD                    |                                  | 0                | 1                | B5               | B4               | B3               | B2               | B1               |             |                  |                  | 1              |             |             |             |             |
| MTA                 | My Talk Address           | M                | AD                    |                                  | 1                | 0                | B5               | B4               | B3               | B2               | B1               |             |                  |                  | 1              |             |             |             |             |
| MSA                 | My Secondary Address      | M                | SE                    |                                  | 1                | 1                | B5               | B4               | B3               | B2               | B1               |             |                  |                  | 1              |             |             |             |             |
| NUL                 | Null Byte                 | M                | DD                    |                                  | 0                | 0                | 0                | 0                | 0                | 0                | 0                |             |                  |                  |                |             |             |             |             |
| OSA                 | Other Secondary Address   | M                | SE                    | (OSA = SCG and MSA-NOT)          |                  |                  |                  |                  |                  |                  |                  |             |                  |                  |                |             |             |             |             |
| OTA                 | Other Talk Address        | M                | AD                    | (OTA = TAG and MTA-NOT)          |                  |                  |                  |                  |                  |                  |                  |             |                  |                  |                |             |             |             |             |
| PCG                 | Primary Command Group     | M                | ----                  | (PCG = ACG or UCG or LAG or TAG) |                  |                  |                  |                  |                  |                  |                  |             |                  |                  |                |             |             |             |             |
| PPC                 | Parallel Poll Configure   | M                | AC                    |                                  | 0                | 0                | 0                | 0                | 1                | 0                | 1                |             |                  |                  | 1              |             |             |             |             |
| PPE                 | Parallel Poll Enable      | M                | SE                    |                                  | 1                | 1                | 0                | B4               | B3               | B2               | B1               |             |                  |                  | 1              |             |             |             |             |
| PPD                 | Parallel Poll Disable     | M                | SE                    |                                  | 1                | 1                | 1                | B4               | B3               | B2               | B1               |             |                  |                  | 1              |             |             |             |             |
| PPR1                | Parallel Poll Response 1  | U                | ST                    |                                  |                  |                  |                  |                  |                  |                  | 1                |             |                  |                  | 1              | 1           |             |             |             |
| PPR2                | Parallel Poll Response 2  | U                | ST                    |                                  |                  |                  |                  |                  |                  | 1                |                  |             |                  |                  | 1              | 1           |             |             |             |
| PPR3                | Parallel Poll Response 3  | U                | ST                    |                                  |                  |                  |                  |                  | 1                |                  |                  |             |                  |                  | 1              | 1           |             |             |             |
| PPR4                | Parallel Poll Response 4  | U                | ST                    |                                  |                  |                  |                  | 1                |                  |                  |                  |             |                  |                  | 1              | 1           |             |             |             |
| PPR5                | Parallel Poll Response 5  | U                | ST                    |                                  |                  |                  | 1                |                  |                  |                  |                  |             |                  |                  | 1              | 1           |             |             |             |
| PPR6                | Parallel Poll Response 6  | U                | ST                    |                                  |                  | 1                |                  |                  |                  |                  |                  |             |                  |                  | 1              | 1           |             |             |             |
| PPR7                | Parallel Poll Response 7  | U                | ST                    |                                  | 1                |                  |                  |                  |                  |                  |                  |             |                  |                  | 1              | 1           |             |             |             |
| PPR8                | Parallel Poll Response 8  | U                | ST                    | 1                                |                  |                  |                  |                  |                  |                  |                  |             |                  |                  | 1              | 1           |             |             |             |
| PPU                 | Parallel Poll Unconfigure | M                | UC                    |                                  | 0                | 0                | 1                | 0                | 1                | 0                | 1                |             |                  |                  | 1              |             |             |             |             |
| REN                 | Remote Enable             | U                | UC                    |                                  |                  |                  |                  |                  |                  |                  |                  |             |                  |                  |                |             |             |             | 1           |
| RFD                 | Ready For Data            | U                | HS                    |                                  |                  |                  |                  |                  |                  |                  |                  |             | 0                |                  |                |             |             |             |             |
| RQS                 | Request For Service       | U                | ST                    |                                  | 1                |                  |                  |                  |                  |                  |                  |             |                  |                  | 0              |             |             |             |             |
| SCG                 | Secondary Command Group   | M                | SE                    |                                  | 1                | 1                |                  |                  |                  |                  |                  |             |                  |                  | 1              |             |             |             |             |
| SDC                 | Selected Device Clear     | M                | AC                    |                                  | 0                | 0                | 0                | 0                | 1                | 0                | 0                |             |                  |                  | 1              |             |             |             |             |
| SPD                 | Serial Poll Disable       | M                | UC                    |                                  | 0                | 0                | 1                | 1                | 0                | 0                | 1                |             |                  |                  | 1              |             |             |             |             |
| SPE                 | Serial Poll Enable        | M                | UC                    |                                  | 0                | 0                | 1                | 1                | 0                | 0                | 0                |             |                  |                  | 1              |             |             |             |             |
| SRQ                 | Service Request           | U                | ST                    |                                  |                  |                  |                  |                  |                  |                  |                  |             |                  |                  |                |             | 1           |             |             |
| STB                 | Status Byte               | M                | ST                    | B8                               |                  | B6               | B5               | B4               | B3               | B2               | B1               |             |                  |                  | 0              |             |             |             |             |
| TCT                 | Take Control              | M                | AC                    |                                  | 0                | 0                | 0                | 1                | 0                | 0                | 1                |             |                  |                  | 1              |             |             |             |             |
| TAG                 | Talk Address Group        | M                | AD                    |                                  | 1                | 0                |                  |                  |                  |                  |                  |             |                  |                  | 1              |             |             |             |             |
| UCG                 | Universal Command Group   | M                | UC                    |                                  | 0                | 0                | 1                |                  |                  |                  |                  |             |                  |                  | 1              |             |             |             |             |
| UNL                 | Unlisten                  | M                | AD                    |                                  | 0                | 1                | 1                | 1                | 1                | 1                | 1                |             |                  |                  | 1              |             |             |             |             |
| UNT                 | Untalk                    | M                | AD                    |                                  | 1                | 0                | 1                | 1                | 1                | 1                | 1                |             |                  |                  | 1              |             |             |             |             |

Figure 5-7. IEEE-488 Remote Message Coding



## Use Commands

Communications between the controller and the Calibrator is made of commands, queries, and interface messages. Although the commands come from the 488.2 standard, they can be used on the IEEE-488 or RS-232 interface, but for some specified RS-232 commands given in “Commands for RS-232 Only.” (For more about command structures, see the IEEE 488.2 standard.)

See Chapter 6, “Remote Commands” when more information about command references used this chapter are necessary.

All commands and units can be recorded in UPPER or lower case.

There are four remote control configurations that use commands, queries and interface messages: IEEE-488, RS-232 Terminal Mode, RS-232 Computer Mode, and RS-232 Pass-Through Mode. (set up and verify each mode is given in this chapter.)

**IEEE-488 Mode** The IEEE-488 mode is used when the Calibrator is operated by computer program. In this mode, necessary information is shown by query, and interface messages are queued and returned by command.

**RS-232 Terminal Mode** The RS-232 terminal mode is an interactive mode where an operator inputs commands, with immediate indications for requested information (queries) and interface messages.

**RS-232 Computer Mode** The RS-232 computer mode is used when the Calibrator is operated by computer program. In this mode, requested information is shown by query, and interface messages are queued and returned by command.

**RS-232 Pass-Through Mode** The RS-232 pass-through mode is used to move commands from the PC to a UUT, but with the Calibrator. This configuration is used when the UUT has an RS-232 port. Commands are sent to the UUT with the UUT\_SEND command, shows use the UUT\_RECV? query, and UUT\_FLUSH cleans the UUT receive buffer in the Calibrator.

## Types of Commands

The commands for the Calibrator can be grouped into one or more categories, depending on how they operate. Each category is given below.

### Device-Dependent Commands

Device-dependent commands are unique to the Calibrator. An example of a device-dependent command is,

```
OUT 100 V, 1 A, 60 HZ
```

this tells the Calibrator to source 100 watts of ac power.

### Common Commands

Common commands are specified by the IEEE 488.2 standard and are common to most bus devices. Common commands always start with an \* character. Common commands are available if you use the IEEE-488 or RS-232 interface for remote control. An example of a common command is,

```
*IDN?
```

this tells the Calibrator to give the instrument identification string.

### Query Commands

Query commands request information. That information is given as the command executes, or the information is put into a buffer until requested. An example of a query, which always completes with a question mark, is,

RANGE?

This shows the Calibrator primary and secondary outputs.

### Interface Messages (IEEE-488)

Interface messages manage traffic on the IEEE-488 interface bus. Device addressing and clearing, data handshaking, and commands to put status bytes on the bus are all directed by interface messages. Some of the interface messages occur as condition changes of dedicated control lines. The remaining interface messages are sent with the data lines with the ATN signal true.

#### *Note*

*All device-dependent and common commands are sent over the data lines with the ATN signal false.*

An important thing about interface messages is that unlike device-dependent and common commands, interface messages are not sent literally (in a direct way). For example, when you send a device-dependent query to the Calibrator, the controller automatically sends the interface message MTA (My Talk Address).

IEEE-488 standards define interface messages. Table 5-4 shows the interface messages that the Calibrator accepts. Table 5-4 also shows the BASIC statement to make the interface message. Table 5-5 shows the interface messages that the Calibrator sends. The mnemonics shown in the tables are not sent in BASIC PRINT statements as commands are; this is how they are different from device-dependent and common commands.

Interface messages are controlled automatically in most cases. For example, handshake messages DAV, DAC, and RFD automatically occur with the direction of an interface of the instrument as each byte is sent over the bus.

**Table 5-4. IEEE-488 Interface Messages (Received)**

| Mnemonic | Name                  | Function                                                                                                                                                                                                                                                             |
|----------|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ATN      | Attention             | A control line that, when asserted, tells all instruments on the bus that the subsequent data bytes are an interface message. When ATN is low, the subsequent data bytes are interpreted as device-dependent or common commands addressed to a specified instrument. |
| DAC      | Data Accepted         | Sets the handshake signal line NDAC low.                                                                                                                                                                                                                             |
| DAV      | Data Valid            | Asserts the handshake signal line DAV.                                                                                                                                                                                                                               |
| DCL      | Device Clear          | Clears the input/output buffers.                                                                                                                                                                                                                                     |
| END      | End                   | A message that occurs when the Controller asserts the EOI signal line before it sends a byte.                                                                                                                                                                        |
| GET      | Group Execute Trigger | Trigger a TC measurement and put the indication in the output buffer.                                                                                                                                                                                                |
| GTL      | Go To Local           | Transfer control of the Calibrator from one of the remote conditions to one of the local conditions, see Table 5-1.                                                                                                                                                  |
| LLO      | Local Lockout         | Transfers remote/local control of the Calibrator, see Table 5-1.                                                                                                                                                                                                     |
| IFC      | Interface Clear       | A control line that sets the interface to a quiescent condition.                                                                                                                                                                                                     |
| MLA      | My Listen Address     | Addresses a specified device on the bus as a listener. The controller sends MLA automatically when it tells a device-dependent or common command to a specified instrument.                                                                                          |
| MTA      | My Talk Address       | Addresses a specified device on the bus as a talker. The controller sends MTA automatically whenever it directs a device-dependent or common query to a specified instrument.                                                                                        |
| REN      | Remote Enable         | Transfer remote/local control of the Calibrator, see Table 5-1.                                                                                                                                                                                                      |
| RFD      | Ready For Data        | Sets the handshake signal line NRFD low.                                                                                                                                                                                                                             |
| SDC      | Selected Device Clear | Does the same thing as DCL, but only if the Calibrator is currently addressed as a listener.                                                                                                                                                                         |
| SPD      | Serial Poll Disable   | Cancels the effect of a Serial Poll Enable.                                                                                                                                                                                                                          |
| SPE      | Serial Poll Enable    | After the Calibrator receives this message, it will show the Status Byte the next time it is addressed as a talker over the GPIB interface.                                                                                                                          |
| UNL      | Unlisten              | “Unaddresses” a specified device on the bus as a listener. The controller sends UNL automatically after the device has successfully received a device-dependent or common command.                                                                                   |
| UNT      | Untalk                | “Unaddresses” a specified device on the bus as a listener. The controller sends UNL automatically after the device has successfully received a device-dependent or common query.                                                                                     |

Table 5-5. IEEE-488 Interface Messages (Sent)

| Mnemonic | Name            | Function                                                                                                                                                                                 |
|----------|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| END      | End             | A message that occurs when the Calibrator asserts the EOI control line. The Calibrator asserts EOI while it transmits the ASCII character LF for its termination sequence or terminator. |
| DAC      | Data Accepted   | Set the handshake signal line NDAC low.                                                                                                                                                  |
| DAV      | Data Valid      | Asserts the handshake signal line DAV.                                                                                                                                                   |
| RFD      | Ready for Data  | Sets the handshake line NRFD low.                                                                                                                                                        |
| SRQ      | Service Request | A control line that a device on the bus can assert to show that attention is necessary. Refer to "Check Calibrator Status".                                                              |
| STB      | Status Byte     | The status byte is what the Calibrator sends when it replies to a serial poll (interface message SPE).                                                                                   |

### Compound Commands

A compound command is two or more commands in one command line. For example, the subsequent two commands could be recorded individually,

```
OUT 1 V, 60 HZ
OPER
```

where the Calibrator sources 1 V ac at 60 Hz, and then goes into operate, or they could be mixed into a compound command,

```
OUT 1 V, 60 HZ; OPER
```

with a semi-colon as a separator. Be careful when a compound command includes the coupled commands. (See "Coupled Commands.")

### Coupled Commands

A coupled command refers to two or more commands that are in a compound command (see "Compound Commands") that do things that could interfere with each other and cause a fault. Commands in a compound command are disconnected with the ; character. Compound commands with only coupled commands are not order-dependent.

In Chapter 6, the command shows a checkbox for coupled commands.

The coupled commands, but not the scope commands, are:

```
CUR_POST DBMZ DC_OFFSET HARMONIC OUT WAVE
```

An example of the coupled command interference is the command

```
*RST; OUT 100V, 1kHz; WAVE SINE
```

Followed by the commands

```
WAVE TRI
OUT 10V, 1kHz
```

The WAVE TRI causes an error. At 100 V, only sine waves are permitted. The WAVE and OUT are coupled commands. So, the compound command

```
WAVE TRI; OUT 10V, 1kHz
```

is successful. The WAVE and OUT are programmed together and at 10 V, triangle waves are permitted.

### Overlapped Commands

Commands that start execution but slightly more time to complete is necessary are overlapped commands, because they can be overlapped by the subsequent command

before they have completed execution.

In Chapter 6, the command shows a checkbox for overlapped commands.

The overlapped commands, but not the scope commands, are:

|           |           |            |
|-----------|-----------|------------|
| DBM       | OPER      | TSENS_TYPE |
| DC_OFFSET | OUT       | WAVE       |
| DPF       | PHASE     | ZCOMP      |
| DUTY      | RANGELCK  |            |
| EARTH     | *RST      |            |
| HARMONIC  | RTD_TYPE  |            |
| INCR      | STBY      |            |
| LCOMP     | TC_OFFSET |            |
| LOWS      | TC_OTCD   |            |
| MULT      | TC_REF    |            |
| OLDREF    | TC_TYPE   |            |

You can use the command \*WAI to wait until the overlapped command has completed execution before you do the subsequent command. For example,

```
OUT 1 V, 1 A, 60 HZ; *WAI
```

You can also use the status commands \*OPC and \*OPC? to find completion of overlapped commands. (See “Check 5502A Status.”)

### Sequential Commands

Commands that start immediately are sequential commands.

In Chapter 6, the command shows a checkbox for sequential commands.

Most of the commands are sequential.

### Commands where a Calibration Switch is Necessary

For the subsequent commands, the rear panel CALIBRATION switch must be in the ENABLE position:

```
CLOCK          (when setting date but not time)
FORMAT ALL
FORMAT CAL
*PUD
```

If you try to use these commands with the CALIBRATION switch in the NORMAL position, an error is logged into the error queue. (Or it returns the error message if in the RS-232 Terminal Mode.)

**Commands for RS-232 Only**

The RS-232 checkbox shows RS-232 interface commands.

The IEEE-488 and RS-232 interfaces send commands to the Calibrator as data, but not those IEEE-488 functions that must be implemented as a message as specified in the IEEE-488 standards. For example, the RS-232 interface uses the command REMOTE to put the Calibrator in the remote mode. Although the IEEE-488 interface could also send a command REMOTE as data, it does not because this is one of the functions that must be implemented with the IEEE-488 Standards. The relationship between these IEEE-488 messages and the equivalent RS-232 emulation is shown in Table 5-6.

**Table 5-6. Commands for RS-232 Only**

| IEEE-488 Message <sup>[1]</sup>                  | RS-232 Equivalent                                      |
|--------------------------------------------------|--------------------------------------------------------|
| GTL                                              | LOCAL command                                          |
| GTR                                              | REMOTE command                                         |
| LLO                                              | LOCKOUT command                                        |
| SRQ                                              | SRQSTR command                                         |
| SDC, DCL                                         | ^C (<Cntl> C) character [clear the device]             |
| GET                                              | ^T (<Cntl> T) character [execute a group trigger]      |
| SPE, SPD                                         | ^P (<Cntl> P) character [print the serial poll string] |
| [1] See "How IEEE-488 Operates" in this chapter. |                                                        |

With the commands and special characters that emulate the IEEE-488 functions shown above, there are more commands that are related to operation and control of the actual RS-232 Host port and these are unrelated to IEEE-488 operations. These include the subsequent six commands.

|         |         |         |
|---------|---------|---------|
| SP_SET  | SPLSTR  | SRQSTR  |
| SP_SET? | SPLSTR? | SRQSTR? |

### Commands for IEEE-488 Only

The IEEE-488 checkbox shows commands that are used for the IEEE-488 interface. This is all the commands but those used for RS-232 operations. (See “Commands for RS-232 Only.”) All commands are transferred over the IEEE-488 as data, except for the commands LOCAL, REMOTE, and LOCKOUT, which are implemented per IEEE Standards as messages (see Table 5-7).

**Table 5-7. Commands for IEEE-488 Only**

| IEEE-488 Message <sup>[1]</sup>                  | Command Representation       |
|--------------------------------------------------|------------------------------|
| GTL                                              | LOCAL command                |
| GTR                                              | REMOTE command               |
| LLO                                              | LOCKOUT command              |
| SRQ                                              | SRQSTR command               |
| SDC, DCL                                         | Clear the device             |
| GET                                              | Execute a group trigger      |
| SPE, SPD                                         | Print the serial poll string |
| [1] See “How IEEE-488 Operates” in this chapter. |                              |

### Command Syntax

The subsequent syntax rules apply to all the remote commands. Information about syntax of response messages is also given.

### Parameter Syntax Rules

Table 5-8 shows the units accepted in command parameters and used in responses. All commands and units can be recorded in UPPER or lower case.

**Table 5-8. Units Accepted in Parameters and Used in Responses**

| Units | Meaning                                                                     |
|-------|-----------------------------------------------------------------------------|
| HZ    | Frequency in units of hertz                                                 |
| KHZ   | Frequency in units of kilohertz                                             |
| MHZ   | Frequency in units of megahertz                                             |
| UV    | Volts in units of microvolts                                                |
| MV    | Volts in units of millivolts                                                |
| V     | Volts in units of volts                                                     |
| KV    | Volts in units of kilovolts                                                 |
| UA    | Current in units of microamperes                                            |
| MA    | Current in units of milliamps                                               |
| A     | Current in units of amps                                                    |
| PCT   | Percent                                                                     |
| PPM   | Parts-per-million                                                           |
| DBM   | Volts in units of decibels referenced to 1 milliwatt into 600 $\Omega$ load |

|      |                                     |
|------|-------------------------------------|
| OHM  | Resistance in units of ohms         |
| KOHM | Resistance in units of kilohms      |
| MOHM | Resistance in units of megohms      |
| NF   | Capacitance in units of nanofarads  |
| PF   | Capacitance in units of picofarads  |
| UF   | Capacitance in units of microfarads |
| MF   | Capacitance in units of millifarads |
| F    | Capacitance in units of farads      |
| CEL  | Temperature in degrees Celsius      |
| FAR  | Temperature in degrees Fahrenheit   |
| NS   | Period in units of nanoseconds      |
| US   | Period in units of microseconds     |
| MS   | Period in units of milliseconds     |
| S    | Period in units of seconds          |

**General Rules** The general rules for parameter use is:

1. When a command has more than one parameter, the parameters must be disconnected by commas. For example: OUT 1V, 2A.
2. Numeric parameters can have a maximum of 15 significant digits and their exponents can be in the range  $\pm 1.0E\pm 20$ .
3. If you include too many or too few parameters, this causes a command error.
4. Null parameters cause an error, for example, the adjacent commas in OUT 1V, , 2A.
5. Expressions, for example  $4+2*13$ , are not permitted as parameters.
6. Binary Block Data can be in one of two ways: Indefinite Length and Definite Length format (both IEEE-488.2 standards).

**Indefinite Length** The Indefinite Length format accepts data bytes after the #0 until the ASCII Line Feed character is received with an EOI signal (for RS-232 just a line feed or carriage return will terminate the block).

**Definite Length** The Definite Length format specifies the number of data bytes. #n and an n-digit number come before the data bytes. The n-digit number identifies how many data bytes follow. For examples, see the UUT\_SEND and \*PUD command descriptions in Chapter 6.

### *Extra Space or Tab Characters*

In the command descriptions in Chapter 6, parameters are shown disconnected by spaces. One space after a command is necessary (unless no parameters are necessary). All other spaces are optional. Spaces are put in for clarity in the manual and can be left in or ignored as necessary. You can put in more spaces or tabs between parameters as necessary. More spaces in a parameter are typically not permitted. They are permitted between a number and its related multiplier or unit. Chapter 6 has examples for commands where parameters or responses are not self-explanatory.



## Terminators

Table 5-9 summarizes the terminator characters for the IEEE-488 and RS-232 remote interfaces.

**Table 5-9. Terminator Characters**

| Terminator Function                                                                                                                                                                                                                                                                                                                                                                                          | ASCII Characters |         | Control Command Terminator | Language Command Terminator |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|---------|----------------------------|-----------------------------|
|                                                                                                                                                                                                                                                                                                                                                                                                              | Number           | Program |                            |                             |
| Carriage Return (CR)                                                                                                                                                                                                                                                                                                                                                                                         | 13               | Chr(13) | <Cntrl> M                  | \n                          |
| Line Feed (LF)                                                                                                                                                                                                                                                                                                                                                                                               | 10               | Chr(10) | <Cntrl> J                  | \r                          |
| Backspace (BS)                                                                                                                                                                                                                                                                                                                                                                                               | 8                | Chr(8)  | <Cntrl> H                  | \b                          |
| Form Feed (FF)                                                                                                                                                                                                                                                                                                                                                                                               | 12               | Chr(12) | <Cntrl> L                  | \f                          |
| Examples:<br>RS-232 Terminal Mode      OUT 1 V, 60 Hz <Enter><br>UUT_SEND "REMS/n"      <Enter><br>UUT_SEND #205REMS^M      <Enter> (^M means <cntrl>M)<br>RS-232 Computer Mode      Comm1.Output = "OUT 1 V, 60 Hz" + Chr(10)<br>(typical to Visual Basic)      Comm1.Output = "UUT_SEND ""REMS/n"" " Chr(10)<br>IEEE-488 Mode              OUT 1 V, 60 Hz<br>(command only)              UUT_SEND "REMS\n" |                  |         |                            |                             |

**IEEE-488 Interface** The Calibrator sends the ASCII character Line Feed with the EOI control line held high as the terminator for response messages. The calibrator recognizes these as terminators when found in incoming data.

- ASCII LF character
- All ASCII character sent with the EOI control line asserted

**RS-232 Interface** The Calibrator shows an EOL (End of Line) character with each response to the PC. This is selectable as Carriage Return (CR), Line Feed (LF) or CRLF. (See "RS-232 Host Port Setup Procedure" in this chapter.) Commands sent to the Calibrator must end in a CR, LF, or CRLF. (See Table 5-9.)

## Incoming Character Processing

The Calibrator works with all incoming data as follows (except Binary Block Data as described under Parameter Syntax Rules):

1. The most significant data bit (DIO8) is ignored.
2. All data is read as 7-bit ASCII.
3. Lower-case or upper-case characters are accepted.
4. ASCII characters with decimal equivalents less than 32 (Space) are discarded. Characters 10 (LF) and 13 (CR) and in the \*PUD command argument are not discarded. All characters in Binary Block Data arguments are permitted. Binary Block Data stops with a special procedure.

### Response Message Syntax

The command descriptions in Chapter 6 tell you about the indications from the Calibrator where applicable. To know what type of data to read in, see the first part of the entry in the "Response" in the tables. The response is shown as one of the data types in Table 5-10.

**Table 5-10. Response Data Types**

| Data Type                     | Description                                                                                                                                                                                                                                 |
|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Integer                       | Integers for some controllers or computers are decimal numbers in the range -32768 to 32768.<br>Responses in this range are named Integer.<br>Example:       *ESE 123; *ESE?<br>returns:       123                                          |
| Floating                      | Numbers that may have up to 15 significant figures plus an exponent that can range from $\pm E20$ .<br>Example:       DC_OFFSET?<br>returns:       1.4293E+00                                                                               |
| String                        | ASCII characters with quotation mark delimiters.<br>Example:       SRQSTR "SRQ from 5502A"; SRQSTR?<br>returns:       "SRQ from 5502A"                                                                                                      |
| Character Response Data (CRD) | This type of response is always a keyword.<br>Example:       OUT 10V, 100HZ; FUNC?<br>returns:       ACV                                                                                                                                    |
| Indefinite ASCII (IAD)        | ASCII characters followed by EOM. Queries with this type of response MUST be the last Query in a program message.<br>Example:       *OPT?<br>returns:       SC600<br>CAL reports and lists that have Line Feeds are typically of this type. |

**Table 5-10. Response Data Types (cont.)**

| Data Type         | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Binary Block Data | <p>A special data type specified by the IEEE-488.2 standard. This type is used in *PUD? query. It is specified as follows:</p> <p>#(non-zero digit) (digits) (user data)</p> <p>The non-zero digit specifies the number of characters that in the &lt;digits&gt; field. Characters permitted in the digits field are 0 through 9 (ASCII 48 through 57 decimal). The value of the number in the &lt;digits&gt; field in decimal gives the number of user data bytes that follow in the &lt;user data&gt; field. The maximum response is 64 characters.</p> <p>Example:        *PUD "test1"; *PUD?<br/> returns:        #205test1</p> |

## Check 5502A Status

The programmer has access to status registers, enable registers, and queues in the Calibrator to show various conditions in the instrument as shown in Figure 5-8. Some registers and queues are specified by the IEEE-488.2 standard. The remaining are specified to the Calibrator. In addition to the status registers, the Service Request (SRQ) control line, and a 16-element buffer named the Error Queue supply status information. Table 5-11 shows the status registers and gives the read/write commands and related mask registers.

**Table 5-11. Status Register Summary**

| Status Register                                 | Read Command | Write Command |
|-------------------------------------------------|--------------|---------------|
| Serial Poll Status Byte (STB)                   | *STB?        | —             |
| Service Request Enable Register (SRE)           | *SRE?        | *SRE          |
| Event Status Register (ESR)                     | *ESR?        | —             |
| Event Status Enable Register (ESE)              | *ESE?        | *ESE          |
| Instrument Status Register (ISR)                | ISR?         | —             |
| Instrument Status Change Register (ISCR)        | ISCR?        | —             |
| ISCR 1 to 0 transition                          | ISCR0?       | —             |
| ISCR 0 to 1 transition                          | ISCR1?       | —             |
| Instrument Status Change Enable Register (ISCE) | ISCE?        | ISCE          |
| ISCE 1 to 0 transition                          | ISCE0?       | ISCE0         |
| ISCE 0 to 1 transition                          | ISCE1?       | ISCE1         |

Each status register and queue has a summary bit in the Serial Poll Status Byte. Enable registers are used to mask various bits in the status registers and supply summary bits in the Serial Poll Status Byte. For IEEE-488 interface operation, the Service Request Enable Register is used to assert the SRQ control line on detection of status condition or conditions the programmer chooses. For RS-232 interface operation, the SRQSTR string is sent over the serial interface when the SRQ line is set. (See the SRQSTR command description in Chapter 6.)

### **Serial Poll Status Byte (STB)**

The Calibrator sends the serial poll status byte (STB) when it responds to a serial poll. This byte is set to 0 when the power is turned on. The STB byte is specified as shown in Figure 5-9. If you use the RS-232 as the remote control interface, transmitting the ^P character (in the Terminal mode, hold down the <Cntl> key and push P) gives the SPLSTR (Serial Poll String) and the status byte. Refer to the \*STB command, and for RS-232 interface operation, the SPLSTR and SPLSTR? commands, in Chapter 6 for more information.

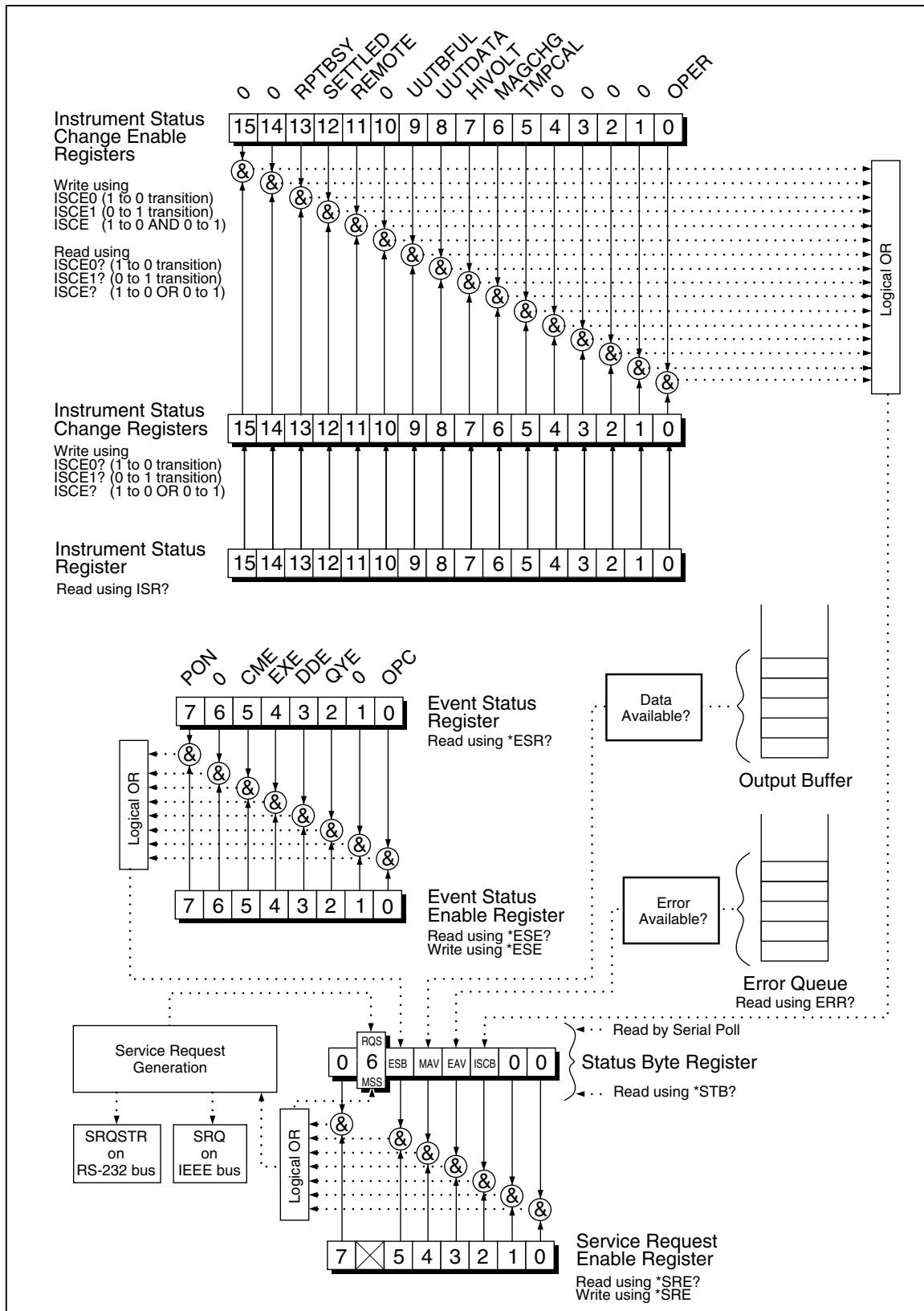


Figure 5-8. Status Register Overview

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| 7 | 6          | 5   | 4   | 3   | 2    | 1 | 0 |
|---|------------|-----|-----|-----|------|---|---|
| 0 | RQS<br>MSS | ESB | MAV | EAV | ISCB | 0 | 0 |

|      |                                                                                                                                                                                                                                                                                                             |
|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| RQS  | Requesting service. The RQS bit is set to 1 whenever bits ESB, MAV, EAV, or ISCB change from 0 to 1 and are enabled (1) in the SRE. When RQS is 1, the 5502A asserts the SRQ control line on the IEEE-488 interface. You can do a serial poll to read this bit to see if the 5502A is the source of an SRQ. |
| MSS  | Master summary status. Set to 1 whenever bits ESB, MAV, EAV, or ISCB are 1 and enabled (1) in the SRE. This bit can be read using the *STB? command in serial remote control in place of doing a serial poll.                                                                                               |
| ESB  | Set to 1 when one or more enabled ESR bits are 1.                                                                                                                                                                                                                                                           |
| MAV  | Message available. The MAV bit is set to 1 when data is available in the IEEE-488 interface output buffer of the 5502A.                                                                                                                                                                                     |
| EAV  | Error available. An error has occurred and an error is available to be read from the error queue by using the ERR? query.                                                                                                                                                                                   |
| ISCB | One or more enabled ISCR bits are 1.                                                                                                                                                                                                                                                                        |

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**Figure 5-9. Serial Poll Status Byte (STB) and Service Request Enable (SRE)**

### **Service Request (SRQ) Line**

**IEEE-488** Service Request (SRQ) is an IEEE-488.1 bus control line that the Calibrator asserts to tell the controller that some type of service is necessary. Many instruments can be on the bus, but they all share a single SRQ line. To find which instrument set SRQ, the Controller typically does a serial poll of each instrument. The calibrator asserts SRQ when the RQS bit in its Serial Poll Status Byte is 1. This bit tells the controller that the Calibrator was the source of the SRQ.

**RS-232** Remote operations with the RS-232 interface emulate the IEEE-488 SRQ line with an SRQSTR string sent with the serial interface when the SRQ line is set. (See the SRQSTR command description in Chapter 6 for more information.)

The Calibrator clears SRQ and RQS when the controller/host does a serial poll, sends \*CLS, or when the MSS bit is cleared. The MSS bit is cleared only when ESB, MAV, EAV, and ISCB are 0, or they are disabled by their associated enable bits in the SRE register being set to 0.

### **Service Request Enable Register (SRE)**

The Service Request Enable Register (SRE) enables or masks the bits of the Serial Poll Status Byte. The SRE is cleared at power up. Refer to Figure 5-9 for the bit functions.

### Programming the STB and SRE

If you reset (to 0) the bits in the SRE, you can mask (disable) associated bits in the serial poll status byte. Bits set to 1 enable the associated bit in the serial poll status byte. The subsequent sample BASIC program enables the Error Available (EAV) bit.

```

10 ! THIS PROGRAM SETS EAV IN THE SRE
20 PRINT @6, "*SRE 8"           ! LOAD THE REGISTER
30 PRINT @6, "*SRE?"           ! ASK FOR THE SRE CONTENTS
40 INPUT @6, A%                 ! RETRIEVE THE REGISTER CONTENTS
50 PRINT "SRE = ";A%
60 RETURN

```

The subsequent BASIC program gives an error and verifies the Serial Poll Status Byte. Enable the EAV bit with the example above.

```

10 ! THIS PROGRAM GENERATES AN ERROR AND CHECKS IT
20 PRINT @6, "OUT 1300V"        ! 1300V IS OUT OF 5502A RANGE
30 A% = SPL(6)                  ! DO A SERIAL POLL
40 IF ((A% AND 72%)=0%) THEN PRINT "EAV and RQS should have been set"
50 PRINT @6, "*STB?"           ! RETRIEVE BYTE
60 INPUT @6, A%
70 IF ((A% AND 8%)=0%) THEN PRINT "EAV should have been set"

```

### Event Status Register (ESR)

The Event Status Register is a two-byte register where the higher eight bits are 0 and the lower eight bits represent different conditions of the Calibrator. The ESR is cleared (set to 0) when you turn power on, and each time it is read.

Parameters are necessary for many of the remote commands. Incorrect use of parameters can make command errors. When a command error occurs, bit CME (5) in the Event Status Register (ESR) goes to 1 (if enabled in ESE register), and the error is recorded in the error queue.

### Event Status Enable (ESE) Register

A mask register called the Event Status Enable register (ESE) lets the controller enable or mask (disable) each bit in the ESR. When a bit in the ESE is 1, the related bit in the ESR is enabled. When an enabled bit in the ESR is 1, the ESB bit in the Serial Poll Status Byte also goes to 1. The ESR bit stays 1 until the controller reads the ESR or does a device clear, a selected device clear, or sends the reset or \*CLS command to the Calibrator. The ESE is cleared (set to 0) when the power is turned on.

### Bit Assignments for the ESR and ESE

The bits in the Event Status Register (ESR) and Event Status Enable register (ESE) are given as shown in Figure 5-10.

|    |    |    |    |    |    |   |   |
|----|----|----|----|----|----|---|---|
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| 0  | 0  | 0  | 0  | 0  | 0  | 0 | 0 |

|     |   |     |     |     |     |   |     |
|-----|---|-----|-----|-----|-----|---|-----|
| 7   | 6 | 5   | 4   | 3   | 2   | 1 | 0   |
| PON | 0 | CME | EXE | DDE | QYE | 0 | OPC |

PON      Power on. This bit is set to 1 if line power has been turned off and on since the last time the ESR was read.

CME      Command error. The IEEE-488 interface of the 5502A encountered an incorrectly formed command. (The command ERR? fetches the earliest error code in the error queue, which contains error codes for the first 15 errors that have occurred.)

EXE      Execution error. An error occurred while the 5502A tried to execute the last command. This could be caused, for example, by a parameter being out of range. (The command ERR? fetches the earliest error in the error queue, which contains error codes for the first 15 errors that have occurred.)

DDE      Device-dependent error. An error related to a device-dependent command has occurred.

QYE      Query error. The 5502A was addressed to talk when no response data was available or appropriate, or when the controller failed to retrieve data on the output queue.

OPC      Operation complete. All commands previous to reception of a \*OPC command have been executed, and the interface is ready to accept another message.

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Figure 5-10. Event Status Register (ESR) and Event Status Enable (ESE)

### Program the ESR and ESE

To read the contents of the ESR, send the remote command, \*ESR?. The ESR is cleared (set to 0) each time it is read. To read the contents of the ESE, send the remote command, \*ESE?. The ESE is not cleared when it is read. When you read the registers, the Calibrator answers by sending a decimal number that when change to binary shows bits 0 through 15. The subsequent sample BASIC program gets the contents of each register:

```

10 ! THIS PROGRAM READS THE ESR AND THE ESE REGISTERS
20 PRINT @6, "*ESR?" ! ASK FOR THE ESR CONTENTS
30 INPUT @6, A% ! RETRIEVE THE REGISTER CONTENTS
40 PRINT @6, "*ESE?" ! ASK FOR THE ESE CONTENTS
50 INPUT @6, B% ! RETRIEVE THE REGISTER CONTENTS
60 PRINT "ESR = ";A% ! DISPLAY THE ESR REGISTER CONTENTS VALUE
70 PRINT "ESE = ";B% ! DISPLAY THE ESE REGISTER CONTENTS VALUE
80 END

```



Change the contents of variables A and B into binary, and you can read the status of the registers. For example if A is 32, its binary equal is: 00000000 00100000. Thus, bit 5 (CME) in the ESR is set (1) and the remaining of the bits are reset (0). This means that the Calibrator tried to do an incorrectly formed command.

If you set the bits in the ESE, you can mask (disable) the related bits in the ESR. For example, to prevent the occurrence of a command error from causing bit 5 (ESB) in the serial poll status byte to go to 1, you can reset (to 0) bit 5 in the ESE register. The subsequent sample program makes sure of the status of the CME bit, then toggles it if it is 1.

```
10 ! THIS PROGRAM RESETS BIT 5 (CME) IN THE ESE
20 PRINT @6, "*ESE 33" ! INITIAL ESE IS CME + OPC
30 GOSUB 100 ! GET AND PRINT INITIAL ESE
40 IF (A% AND 32%) THEN A% = A% - 32% ! CLEAR CME (BIT 5)
50 PRINT @6, "*ESE ";A% ! LOAD ESE WITH NEW VALUE
60 GOSUB 100 ! GET AND PRINT NEW ESE
70 END
100 PRINT @6, "*ESE?" ! ASK FOR ESE CONTENTS
110 INPUT @6, A% ! RETRIEVE REGISTER CONTENTS
120 PRINT "ESE = ";A%
130 RETURN
```

### **Instrument Status Register (ISR)**

The Instrument Status Register (ISR) gives the controller access to the condition of the Calibrator, including some of the information given to the operator on the Control Display and the display annunciators during local operation.

### **Instrument Status Change Registers**

There are two registers that monitor changes in the ISR. These are the ISCR0 (Instrument Status 1-0 Change Register) and the ISCR1 (Instrument Status 0-1 Change Register). Each status change register has a related mask register. Each ISCR is cleared (set to 0) when you turn the Calibrator on, each time it is read, and at each \*CLS (Clear Status) command.

### **Instrument Status Change Enable Registers**

The Instrument Status Change Enable registers (ISCE0 and ISCE1) are mask registers for the ISCR0 and ISCR1 registers. If a bit in the ISCE is enabled (set to 1) and the related bit in the ISCR makes the correct change, the ISCB bit in the Status Byte is set to 1. If all bits in the ISCE are disabled (set to 0), the ISCB bit in the Status Byte does not go to 1. The contents of the ISCE registers are set to 0 at power-up.

### **Bit Assignments for the ISR, ISCR, and ISCE**

The bits in the Instrument Status, Instrument Status Change, and Instrument Status Change Enable registers are given in Figure 5-11.

|    |    |         |         |        |    |         |         |
|----|----|---------|---------|--------|----|---------|---------|
| 15 | 14 | 13      | 12      | 11     | 10 | 9       | 8       |
| 0  | 0  | RPTBUSY | SETTLED | REMOTE | 0  | UUTBFUL | UUTDATA |

|        |        |        |   |   |   |   |      |
|--------|--------|--------|---|---|---|---|------|
| 7      | 6      | 5      | 4 | 3 | 2 | 1 | 0    |
| HIVOLT | MAGCHG | TMPCAL | 0 | 0 | 0 | 0 | OPER |

|         |                                                                                                                                                                                              |
|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| RPTBUSY | Set to 1 when a calibration report is being printed to the serial port.                                                                                                                      |
| SETTLED | Set to 1 when the output has stabilized to within specification or the TC measurement has settled and is available.                                                                          |
| REMOTE  | Set to 1 when the 5502A is under remote control.                                                                                                                                             |
| UUTBFUL | Set to 1 when data from the UUT port has filled up the UUT buffer.                                                                                                                           |
| UUTDATA | Set to 1 when there is data available from the UUT port.                                                                                                                                     |
| HIVOLT  | Set to 1 when the 5502A is programmed to a voltage above 33 Volts.                                                                                                                           |
| MAGCHG  | Set to 1 when the output magnitude has changed as a result of another change (for example RTD_TYPE). This bit is always 0 in the ISR. It changes to 1 only in the ISCR0 and ISCR1 registers. |
| TMPCAL  | Set to 1 when the 5502A is using temporary (non-stored) calibration data.                                                                                                                    |
| OPER    | Set to 1 when the 5502A is in operate, 0 when it is in standby.                                                                                                                              |

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Figure 5-11. Bit Assignments for the ISR, ISCEs and ISCR

### Program the ISR, ISCR, and ISCE

To read the contents of the ISR, send the remote command, `ISR?`. To read the contents of the ISCR0 or 1, send the remote command, `ISCR0?`, or `ISCR1?`. To read the contents of the ISCE0 or 1, send the remote command, `ISCE0?`, or `ISCE1?`. The Calibrator sends a decimal number that represents bits 0 through 15 to answer. Each time you read the ISCR0 or 1, its contents are zeroed. The subsequent sample program reads all five registers:

```

10 ! THIS PROGRAM READS THE ISR, ISCR, AND ISCE REGISTERS
20 ! NOTE THAT THE ICSR? COMMANDS CLEAR THE ISCR CONTENTS
30 PRINT @6, "ISR?" ! ASK ISR CONTENTS
40 INPUT @6, A% ! RETRIEVE REGISTER CONTENTS FROM 5502A
50 PRINT @6, "ISCR0?" ! ASK FOR AND CLEAR ISCR0 CONTENTS
60 INPUT @6, B% ! RETRIEVE REGISTER CONTENTS FROM 5502A
70 PRINT @6, "ISCE0?" ! ASK FOR ISCE0 CONTENTS
80 INPUT @6, C% ! RETRIEVE REGISTER CONTENTS FROM 5502A
90 PRINT @6, "ISCR1?" ! ASK FOR AND CLEAR ISCR1 CONTENTS
100 INPUT @6, D% ! RETRIEVE REGISTER CONTENTS FROM 5502A
110 PRINT @6, "ISCE1?" ! ASK FOR ISCE1 CONTENTS
120 INPUT @6, E% ! RETRIEVE REGISTER CONTENTS FROM 5502A
130 PRINT "ISR = ";A% ! DISPLAY ISR
140 PRINT "ISCR0 = ";B% ! DISPLAY ISCR0
150 PRINT "ISCE0 = ";C% ! DISPLAY ISCE0
160 PRINT "ISCR1 = ";D% ! DISPLAY ISCR1
170 PRINT "ISCE1 = ";E% ! DISPLAY ISCE1
180 END

```

Change the returned variables into binary, and you can read the status of the instrument. For example if a register contains 128, its binary equivalent is: 00000000 10000000. Bit 7 (HIVOLT) is set (1) and the remaining of the bits are reset (0).

If you set the bits in an ISCE register, you can mask (disable) the related bits in the ISCR. For example, to cause an SRQ interrupt when the output has become stable, bit 12 (SETTLED) in the ISCE1 register must be 1. (The ISCB bit must also be enabled in the SRE.) The subsequent sample program loads a decimal 1024 into the ISCE, which sets bit 12 and resets the other bits:

```

10 ! THIS PROGRAM LOADS 00010000 00000000 BINARY INTO THE ISCE
20 PRINT @6, "ISCE 4096" ! LOAD DECIMAL 4096 INTO ISCE
30 PRINT @6, "ISCE?" ! READ BACK ISCE VALUE
40 INPUT @6, A% ! "
50 PRINT "ISCE = ";A% ! PRINT IT, IT SHOULD BE 4096
60 END

```

### Output Queue

The output queue is loaded when a query is done, and holds a maximum of 800 characters. The controller reads it with a statement like a BASIC INPUT statement, removes what it reads from the queue. If the queue is empty, the Calibrator does not answer to the INPUT statement from the controller. The Message Available (MAV) bit in the Serial Poll Status Byte is 1 if there is something in the output queue and 0 if the output queue is empty.

### Error Queue

When a command error, execution error, or device-dependent error occurs, its error code is put in the error queue where it can be read by the `ERR?` command. (See Appendix E for error messages.) A procedure to decode an error code is to send the command, `EXPLAIN?`, which gives a description of an error code. If you read the first error with the `ERR?` command, this removes that error from the queue. A response of 0 means the error queue is empty. The Error Available (EAV) bit in the Serial Poll Status Byte shows if the queue is empty. The error queue is cleared when you turn off the power, and when you use the `*CLS` (Clear Status) common command.

The error queue has a maximum of 16 entries. If many errors occur, only the first 15 errors are kept in the queue. A 16th entry in the queue is an "error queue overflow" error, and all later errors are discarded until the queue is at minimum partially read. The first errors are kept, because if many errors occur before the user can acknowledge and read them, the earliest errors are the most likely to point to the problem. The later errors are typically repetitions or consequences of the initial problem.

## **Remote Program Examples**

The subsequent programming examples show procedures to handle errors, to read measurements, get a number of successive indications, lock the range, and calibrate the Calibrator. These excerpts from programs are written in DOS BASIC.

### **Guidelines to Program the Calibrator**

Commands are done one at a time as they are received. For some commands, a previous condition must be set before the command will be accepted by the Calibrator. For example, the waveform must be SQUARE before the DUTY command will be accepted. Use the subsequent programming guidelines to make sure that the output is programmed to the necessary condition.

- All external connections commands must be programmed first. The calibrator will be put in standby and the output can be changed to accommodate the new external connection. The setting can be set if the given output does not use the setting (for example, setting the current post while sourcing voltage).
- The output and output mode must be programmed subsequently with the OUT command.
- All other output parameters such as impedance compensation, offset, and waveforms must be programmed subsequently. The DUTY command must follow the WAVE command.
- The error status should be checked with the ERR? command. The calibrator will not do the OPER command if an unacknowledged error exists.
- Finally, the Calibrator must be put in operate with the OPER command.

First, it is necessary for a controller program to initialize the interface and the Calibrator. Refer to subsequent sample program:

```
10 INIT PORT 0 \ REMOTE @6          ! PUT THE 5502A INTO THE REMOTE STATE
20 PRINT @6, "*RST;OUT 10V;OPER" ! RESET THE 5502A, PROGRAM IT TO
```

If necessary, use SRQs, first use the \*SRE, \*ESE, and ISCE commands to enable the necessary event. Refer to "Checking 5502A Status."

You retrieve instrument parameters with a query (a programming command that ends with a question mark):

```
200 PRINT @6, "FUNC?"                ! RETRIEVE OUTPUT FUNCTION
210 INPUT LINE @6, A$
220 PRINT "Function is: ";A$
230 PRINT @6, "ONTIME?"              ! RETRIEVE ON TIME
240 INPUT LINE @6, A$
250 PRINT "The instrument has been on for ";A$;" minutes"
```

This program gives the subsequent sample output:

```
Function is: DCV
The instrument has been on for 134 minutes
```

Make sure that there are no for programming errors as in the subsequent sample programs. Verify the Error Available (EAV) bit in the serial poll register with a serial poll.

```

300 A = SPL(6)                                ! CHECK FOR ERRORS
310 IF (A AND 8) THEN PRINT "There was an error"
320 PRINT @6, "*CLS"                          ! CLEAR ERRORS

```

Get errors and explanations as follows. Since errors are accumulated in a queue, you must read the complete queue to get and clear all the errors.

```

400 PRINT @6, "ERR?"                          ! CHECK FOR ERRORS
410 INPUT @6, A, A$                          ! READ IN THE ERROR
420 IF (A = 0) THEN GOTO 500                  ! NO MORE ERRORS
430 PRINT "Error# :"; A, A$                  ! PRINT ERROR# AND EXPLANATION
440 GOTO 400
500 END

```

### Write an SRQ and Error Handler

It is good to include fault (error) handling routines in your procedures. The subsequent sample program lines show a procedure to stop program execution on occurrence of an SRQ (Service Request) on the bus, see if the Calibrator is the source of the SRQ, get its fault messages, and act on the faults. You must change and extend this code as necessary for your procedure.

To use SRQs, first use the \*SRE, \*ESE, and ISCE commands to enable the necessary event. Refer to "Check the 5502A Status" for more information.

```

10  INIT PORT0                                ! IFC the bus
20  CLEAR PORT0                              ! DCL the bus
30  ! INITIALIZE THE 5502A SRQ HANDLER
40  PRINT @6, "*SRE 8"                       ! Enable STB.EAV (error available)
50  ON SRQ GOTO 1100                          ! Install SRQ handler
60  ! Body of the application goes here
1100 ! Bus SRQ handler
1110 CLEAR PORT0                             ! Make sure devices are not confused
1120 IF (SPL(6) AND 64) THEN GOSUB 1200      ! If (STB.RQS) call SRQ
1130 ! TEST OTHER DEVICES RQS BITS IF DESIRED
1140 RESUME
1200 ! 5502A SRQ handler
1210 IF (SPL(6) AND 8) THEN GOSUB 1300      ! If (STB.EAV) call handler
1220 ! Test other STB bits if desired here
1299 RETURN
1300 ! 5502A STB.EAV (error) handler
1320 PRINT @6, "ERR?"                       ! Read and clear error
1330 INPUT @6, E%, E$                       ! Read in error # and explanation
1340 PRINT "Error# :"; E, E$                 ! Print error # and explanation
1350 IF (E% <> 0) THEN GOTO 1320             ! Until no more errors
1360 STOP                                    ! Other commands for your app
1370 END

```

### Verify a Meter on the IEEE-488 Bus

This program selects 10 V dc output, makes sure that the Calibrator is set to 10 V, then triggers a Fluke 45 to get a reading. It shows calibrator output, Fluke 45 indication, and the meter error in ppm. For this program, the Calibrator bus address is 4 and the Fluke 45 bus address is 1.

```
10 REM THIS PROGRAM VERIFIES THE ACCURACY OF A FLUKE 45 AT 10V DC
20 INIT PORT 0 ! INITIALIZE THE INTERFACE
30 CLEAR PORT 0 ! "
40 PRINT @1, "VDC;RATE 5;AUTO;TRIGGER 2" ! SETS FLUKE 45 TO 10V DC
50 PRINT @1, "OUT 10 V; OPER;" ! SET THE 5502A TO 10V DC
60 PRINT @4, "*WAI; OUT?" ! WAIT FOR SETTLE, REQUEST THE OUTPUT VALUE
70 PRINT @4, V,U$,F,V2,U2$ ! GET THE DATA FROM THE 5502A
80 PRINT @1, "*TRG;VAL?" ! TRIGGER 45 TO TAKE READING
90 INPUT @1, VM ! GET THE DATA FROM THE 45
100 ER = ABS(V - VM)/V * 1E6 ! COMPUTE ERROR
110 PRINT "5502 OUTPUT: ";V;U$ ! PRINT THE RESULTS
120 PRINT "45 MEASURED: ";VM;"V"
130 PRINT "ERROR: ";ER;"PPM"
140 END
```

### Verify a Meter on the RS-232 UUT Serial Port

This program selects 10 V dc output, makes sure that the Calibrator is set to 10 V, then triggers a Fluke 45 to get a reading. It shows Calibrator output, the Fluke 45 indication, and the meter error in ppm. For this program, the Calibrator uses the IEEE-488 interface with bus address 4 and the Fluke 45 is on the Calibrator SERIAL 2 TO UUT port.

```
10 REM THIS PROGRAM VERIFIES THE ACCURACY OF A FLUKE 45 AT 10V DC
20 INIT PORT 0 ! INITIALIZE THE INTERFACE
30 CLEAR PORT 0 ! "
40 PRINT @4, "UUT_SEND `VDC;RATE S;AUTO;TRIGGER 2\n'" ! SET FLUKE 45
50 PRINT @4, "UUT_RECV" ! SEND THE FLUKE 45 PROMPT
60 PRINT @4, P$ ! GET THE FLUKE 45 PROMPT
70 PRINT @4, "OUT 10 V; OPER" ! SET THE 5502A TO 10 V DC
80 PRINT @4, "*WAI; OUT?" ! WAIT FOR SETTLE; GET VALUE
90 PRINT @4, "V,U$,F,V2,U2$" ! GET THE DATA FROM 5502A
100 PRINT @4, "UUT_SEND `*TRG; VAL?\n'" ! TRIGGER FLUKE 45 READING
110 PRINT @4, "UUT_RECV?" ! SEND 45 READING TO 5502A
120 INPUT @4, VM, P$ ! GET 45 READING AND PROMPT
130 ER = ABS (V - VM)/V * 1E6 ! COMPUTE ERROR
140 PRINT "5502 OUTPUT: ";V;U$ ! PRINT THE RESULTS
150 PRINT "FLUKE 45 MEASURED: ";ER;"PPM" ! PRINT THE RESULTS
160 END
```

### Use \*OPC?, \*OPC, and \*WAI

The \*OPC?, \*OPC, and \*WAI commands let you keep control of the sequence of execution of commands that could be passed up by subsequent commands.

If you had sent an OUT command, you can make sure that the output has become stable by sending the query \*OPC?. When the OUT command has completed (output settled), a "1" is shown in the output buffer. You must follow an \*OPC? command with a read command. The read command makes the program execution pause until the addressed instrument answers. The subsequent sample program shows how you can use \*OPC?.

```
10 PRINT @4, "OUT 100V,1KHZ;/;/OPER;/ / *OPC?" ! 5502A ADDRESS IS 4
20 INPUT @4, A ! READ THE "1" FROM THE 5502A
30 !PROGRAM HALTS HERE UNTIL A "1" IS PUT INTO THE OUTPUT BUFFER
40 PRINT "OUTPUT SETTLED"
```

The \*OPC command is like the \*OPC? query in operation, except that it sets bit 0 (OPC for “Operation Complete”) in the Event Status Register to 1 as an alternative to sending a 1 to the output buffer. One simple use for \*OPC is to put it in the program so that it gives an SRQ (Service Request). Then an SRQ handler written into the program can find the operation complete condition and respond correctly. You can use \*OPC like \*OPC?, except your program must read the ESR to find the finish of all operations. The subsequent sample program shows how you can use \*OPC.

```
10 REMOTE
20 PRINT @4, "OUT 100V,1KHZ//OPER//;*OPC"      ! 5502A ADDRESS IS 4
30 PRINT @4, "**ESR?"                            ! PUT THE ESR BYTE IN BUFFER
40 INPUT @4, A%                                ! READ THE ESR BYTE
50 IF (A% AND 1%) = 0% GOTO 30                  ! TRY AGAIN IF NO OPC
60 PRINT "OUTPUT SETTLED"
70 END
```

The \*WAI command makes the Calibrator stop until all commands are complete before it continues to the subsequent command, and does no more. Use \*WAI as an easy procedure to stop operation until the commands before it are complete. The subsequent sample program shows how you can use \*WAI.

```
10 REMOTE
20 PRINT @4, "OUT 100V,1KHZ//OPER//;*WAI"      ! 5502A ADDRESS IS 4
30 PRINT @4, "OUT?"                            ! READ THE OUTPUT VALUE
40 PRINT @4, A$,B$,C$                          ! A$ CONTAINS THE OUTPUT
VALUE
50 PRINT "OUTPUT SETTLED"
60 PRINT "OUTPUT IS: "/;A$//B$//;" at "/;C$
70 END
```

### Get a Thermocouple Measurement

The subsequent program measures one temperature measurement at a time.

```
10 REM Set Bus Timeout to 20 seconds, Init IEEE Bus
20 TIMEOUT 20 * 1000
30 INIT PORT 0
40 CLEAR @6
100 REM Reset 5502A, TC measurement mode
110 PRINT @6,"*RST// TC_TYPE J// TC_MEAS FAR"
200 PRINT "Hit Carriage Return to take a Reading"
210 INPUTLINE A$
220 REM Request the measurement value
230 PRINT @6, "VAL?"
240 REM Read measurement, unit
250 INPUT @6, M,U$
260 GOTO 200
```

### Use the RS-232 UUT Port to Control an Instrument

The SERIAL 2 TO UUT RS-232 port is used to send commands to a different instrument. For example, a meter that is being calibrated can have its RS-232 port connected to the Calibrator SERIAL 2 TO UUT serial port. Commands sent from a controller can go through the Calibrator’s UUT port and be received by the meter or UUT. There are seven special UUT\_\* commands that Calibrator can use to pass commands to an instrument that you connect to the UUT port. See to Chapter 6.

### **Input Buffer Operation**

As the Calibrator receives each data byte from the controller, it puts the bytes in a part of memory the input buffer. The input buffer holds a maximum of 350 data bytes and operates with first in, first out protocol.

**IEEE-488** The Calibrator sees the EOI IEEE-488 control line as an isolated data byte and puts it into the input buffer if it is met as part of a message terminator. Input buffer operation is transparent to the program on the controller. If the controller sends commands faster than the Calibrator can process them, the input buffer fills to capacity. When the input buffer is full, the Calibrator holds off the IEEE-488 bus with the NRFD (Not Ready For Data) handshake line. When the Calibrator has processed a data byte from the full input buffer, it completes the handshake, and lets the controller send a different data byte. The calibrator clears the input buffer on power-up and on receiving the DCL (Device Clear) or SDC (Selected Device Clear) messages from the controller.

**RS-232** Under RS-232-C serial port remote control with ^S (<Cntl> S) XOFF protocol, the Calibrator gives a ^S XOFF when the input buffer becomes 80 % full. The Calibrator gives a ^Q (<Cntl> Q) when it has read a sufficient amount of the input buffer so that it is less than 40 % full. When you use RTS (Request to Send) protocol (selected as part of the “RS-232 Host Port Setup Procedure”), the serial interface asserts and unasserts RTS in response to same conditions as for XON/XOFF protocol.



**Chapter 6**  
***Remote Commands***

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## Introduction

This chapter documents the IEEE-488/RS-232 remote commands for the Calibrator. Remote commands duplicate procedures that can be started from the front panel in local operation. After the summary table is a complete alphabetical listing of all commands complete with protocol information. Isolated headings in the alphabetical listing give the parameters and responses, plus an example for each command. For information on command use, see Chapter 5, "Remote Operation."

## Command Summary by Function

Tables 6-1 through 6-10 show and tell you about the command set for the Calibrator.

**Table 6-1. Common Commands**

| Command | Description                                                                                                                                                                      |
|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| *CLS    | (Clear status.) Clears the ESR, ISCR0, ISCR1, the error queue, and the RQS bit in the status byte. This command stops pending operation complete commands (*OPC or *OPC?).       |
| *ESE    | Puts a byte into the Event Status Enable register.                                                                                                                               |
| *ESE?   | Shows the contents of the Event Status Enable register.                                                                                                                          |
| *ESR?   | Shows the contents of the Event Status Register and clears the register.                                                                                                         |
| *IDN?   | Identification query. Shows instrument model number, serial number, and firmware revision levels for the main and front panel CPUs, and inguard PGA.                             |
| *OPC    | Sets bit 0 (OPC for "Operation Complete") in the Event Status Register to 1 when all pending device operations are complete.                                                     |
| *OPC?   | Shows a 1 after all pending operations are complete. This command makes program execution pause until all operations are complete. (See also *WAI.)                              |
| *OPT?   | Shows the installed hardware and software options.                                                                                                                               |
| *PUD    | Protected user data command. This command lets you keep a string of bytes in nonvolatile memory. This command works only when the CALIBRATION switch is in the ENABLE position.  |
| *PUD?   | Shows the contents of the *PUD (Protected User Data) memory.                                                                                                                     |
| *RST    | Resets the condition of the instrument to the power-up condition. This command holds off execution of subsequent commands until it is complete. (Overlapped command.)            |
| *SRE    | Puts a byte into the Service Request Enable register (SRE).                                                                                                                      |
| *SRE?   | Shows the byte from the Service Request Enable register.                                                                                                                         |
| *STB?   | Shows the status byte.                                                                                                                                                           |
| *TRG    | Changes the operation mode to thermocouple MEASURE, triggers a measurement, and shows the value of the measurement. This command is equal to sending "TC_MEAS;*OPC;VAL?".        |
| *TST?   | Starts a series of self-tests, then shows a "0" for pass or a "1" for fail. If faults are detected, they are kept into the fault queue where they can be read by the ERR? query. |
| *WAI    | Keeps further remote commands from being done until all previous remote commands have finished.                                                                                  |

**Table 6-2. Error Mode Commands**

| Command   | Description                                                                                                                                                          |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| EDIT      | Sets the edit field. PRI is specified for the output value in single output functions and the primary output value in dual output functions.                         |
| EDIT?     | Shows the edit field position.                                                                                                                                       |
| ERR_REF   | Selects the error reference source.                                                                                                                                  |
| ERR_REF?  | Shows the currently selected error reference source.                                                                                                                 |
| ERR_UNIT  | Chooses how UUT error is shown.                                                                                                                                      |
| ERR_UNIT? | Shows currently selected value of ERR_UNIT.                                                                                                                          |
| INCR      | Increments or decrements the output (as selected by the edit field) and changes to error mode, the same as if you use the output adjustment knob in local operation. |
| MULT      | Multiplies the reference magnitude (as selected by the edit field).                                                                                                  |
| NEWREF    | Sets the reference value to be the current Calibrator output value, the same as if you push the NEW REF key in local operation.                                      |
| OLDREF    | Sets the Calibrator output to the previously programmed reference value, the same as if you push the ENTER key in local operation.                                   |
| OUT_ERR?  | Shows the UUT error calculated after shifting the output with the INCR command.                                                                                      |
| REFOUT?   | Shows the value of the reference, which is the output values of the Calibrator the last time a new reference was made with an OUT, NEWREF, or MULT.                  |
| EDIT      | Sets the edit field. PRI is specified for the output value in single output functions and the primary output value in dual output functions.                         |

**Table 6-3. External Connection Commands**

| Command   | Description                                                                                     |
|-----------|-------------------------------------------------------------------------------------------------|
| CUR_POST  | Selects the live binding posts for current output. This applies to current and power outputs.   |
| CUR_POST? | Shows the live binding posts for current output.                                                |
| EARTH     | Connects or disconnects the internal guard shield from earth (chassis) ground.                  |
| EARTH?    | Shows if the internal guard shield is connected or disconnected from earth (chassis) ground.    |
| LOWS?     | Shows if or not the low terminals are internally open or connected together.                    |
| LOWS      | Selects if or not the low terminals are internally open or connected together for dual outputs. |
| RTD_TYPE  | Sets the Resistance Temperature Detector (RTD) type.                                            |

**Table 6-3. External Connection Command (cont.)**

| Command     | Description                                                                                                                    |
|-------------|--------------------------------------------------------------------------------------------------------------------------------|
| RTD_TYPE?   | Shows the Resistance Temperature Detector (RTD) type.                                                                          |
| TC_REF      | Sets if the internal temperature sensor or an external reference value is used for Thermocouple (TC) outputs and measurements. |
| TC_REF?     | Shows the source and value of the temperature that is used as a reference for thermocouple simulation and measurement.         |
| TC_TYPE     | Sets the thermocouple (TC) temperature type.                                                                                   |
| TC_TYPE?    | Shows the thermocouple (TC) type.                                                                                              |
| TSENS_TYPE  | Sets temperature sensor type when output is set to a temperature with OUT command.                                             |
| TSENS_TYPE? | Shows the temperature sensor type.                                                                                             |

**Table 6-4. Oscilloscope Commands**

| Commands  | Description                                                                                        |
|-----------|----------------------------------------------------------------------------------------------------|
| OL_TRIP?  | Shows the found condition of scope overload protection.                                            |
| OUT_IMP   | Sets the output impedance of the SCOPE BNC.                                                        |
| OUT_IMP?  | Shows the output impedance of the SCOPE BNC.                                                       |
| RANGE     | Sets the Calibrator range when in OVERLD, PULSE, or MEASZ scope modes.                             |
| SCOPE     | Sets the calibrator output to an oscilloscope mode.                                                |
| SCOPE?    | Shows the current oscilloscope mode.                                                               |
| TDPULSE   | Starts or deactivates the tunnel diode pulser drive for the –SC600 and –SC300 EDGE mode.           |
| TDPULSE?  | Shows whether the tunnel diode pulser drive for the –SC600 and –SC300 EDGE mode is active.         |
| TLIMIT    | Sets the time limit for –SC600 OVERLD mode to stay in operate.                                     |
| TLIMIT?   | Shows the time limit for –SC600 OVERLD mode to stay in operate.                                    |
| TLIMIT_D  | Sets the power-up and reset default for the time limit for –SC600 OVERLD mode to stay in operate.  |
| TLIMIT_D? | Shows the power-up and reset default for the time limit for –SC600 OVERLD mode to stay in operate. |
| TMWAVE    | Selects the waveform for MARKER mode.                                                              |
| TMWAVE?   | Shows the timemark waveform setting for MARKER mode.                                               |
| TRIG      | Sets the frequency of the signal at the TRIG BNC.                                                  |
| TRIG?     | Shows the frequency of the signal at the TRIG BNC.                                                 |
| VAL?      | Shows the last thermocouple value, or, for the –SC600, impedance measurement value.                |
| VIDEOFMT  | Selects the format for VIDEO mode.                                                                 |
| VIDEOFMT? | Shows the VIDEO mode format.                                                                       |
| VIDEOMARK | Sets the VIDEO mode line marker location.                                                          |

Table 6-4. Oscilloscope Commands (cont.)

| Commands   | Description                                                            |
|------------|------------------------------------------------------------------------|
| VIDEOMARK? | Shows the VIDEO mode line marker location.                             |
| ZERO_MEAS  | Sets the zero offset for capacitance measurement with the -SC600.      |
| ZERO_MEAS? | Shows the zero offset for the capacitance measurement with the -SC600. |

Table 6-5. Output Commands

| Command   | Description                                                                                                                         |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------|
| CFREQ?    | Shows the optimum frequency value for stimulus for capacitance modes.                                                               |
| DBMZ      | Sets the impedance used for dBm outputs (ac volts).                                                                                 |
| DBMZ?     | Shows the impedance used for dBm outputs (ac volts).                                                                                |
| DC_OFFSET | Applies a dc offset to an ac output voltage.                                                                                        |
| DPF       | Sets the displacement power factor (phase angle) between the NORMAL and AUX terminals for ac power output only.                     |
| DPF?      | Shows the displacement power factor (phase angle) between the NORMAL and AUX terminals.                                             |
| DUTY      | Sets the duty cycle of square wave outputs.                                                                                         |
| DUTY?     | Shows the duty cycle of square wave outputs.                                                                                        |
| FUNC?     | Shows the current output, measurement, or calibration function.                                                                     |
| HARMONIC  | Makes the frequency of one output be a harmonic (multiple) of the other output (named the fundamental).                             |
| HARMONIC? | Shows the current instrument harmonic and fundamental locations.                                                                    |
| LCOMP     | Starts or deactivates inductive load compensation for ac current output.                                                            |
| LCOMP?    | Shows if inductive load compensation for ac current output is active.                                                               |
| OPER      | Starts the Calibrator output if it is in standby.                                                                                   |
| OPER?     | Shows the operate/standby setting.                                                                                                  |
| OUT       | Sets the output of the Calibrator and makes a new reference point for the error mode.                                               |
| OUT?      | Shows the output amplitudes and frequency of the Calibrator.                                                                        |
| PHASE     | Sets the phase difference between the NORMAL and AUX terminals for dual outputs. The NORMAL terminal output is the phase reference. |
| PHASE?    | Shows the phase difference between the NORMAL and AUX terminals.                                                                    |
| POWER?    | Shows the equivalent power for dc and ac power output.                                                                              |
| RANGE?    | Shows the current output ranges.                                                                                                    |
| RANGELCK  | Locks in the currents range, or selects auto ranging.                                                                               |
| RANGELCK? | Shows if or not the preset output range is locked.                                                                                  |

**Table 6-5. Output Commands (cont.)**

| Command | Description                                                          |
|---------|----------------------------------------------------------------------|
| STBY    | Puts the Calibrator in standby.                                      |
| WAVE    | Sets the waveforms for ac outputs.                                   |
| WAVE?   | Shows the waveforms of the output.                                   |
| ZCOMP   | Starts (2-wire or 4-wire) or deactivates impedance compensation.     |
| ZCOMP?  | Shows if impedance compensation is active and if active, which type. |

**Table 6-6. RS-232 Host Port Commands**

| Command      | Description                                                                                                       |
|--------------|-------------------------------------------------------------------------------------------------------------------|
| LOCAL        | Puts the Calibrator into the local condition.                                                                     |
| LOCKOUT      | Puts the Calibrator into the lockout condition. This command duplicates the IEEE-488 LLO (Local Lockout) message. |
| REMOTE       | Puts the Calibrator into the remote condition. This command duplicates the IEEE-488 REN (Remote Enable) message.  |
| SPLSTR       | Sets the serial remote mode Serial Poll response string.                                                          |
| SPLSTR?      | Shows the string programmed for serial remote mode Serial Poll responses.                                         |
| SRQSTR       | Sets the serial remote mode SRQ (Service Request) response (up to 40 characters).                                 |
| SRQSTR?      | Shows the string programmed for Serial Mode SRQ response.                                                         |
| UUT_RECVB?   | Shows binary data from the UUT serial port as integers.                                                           |
| UUT_SENDB    | Sends binary data to the UUT serial port as integers.                                                             |
| ^P (<cntl>p) | Control-P character prints the serial poll string. (See SPLSTR for string format.)                                |
| ^C (<cntl>c) | Control-C character clears the device.                                                                            |
| ^T (<cntl>t) | Control-T character does a group trigger.                                                                         |

**Table 6-7. RS-232 UUT Port Commands**

| Command    | Description                                                                             |
|------------|-----------------------------------------------------------------------------------------|
| UUT_FLUSH  | Flush the UUT receive buffer.                                                           |
| UUT_RECV?  | Shows data from the UUT serial port.                                                    |
| UUT_RECVB? | Shows binary data as integers from the UUT serial port.                                 |
| UUT_SEND   | Sends a string to the UUT serial port.                                                  |
| UUT_SET    | Sets the UUT serial port communication parameters and keeps them in nonvolatile memory. |
| UUT_SET?   | Shows the UUT serial port communication parameters contained in nonvolatile memory.     |

Table 6-8. Setup and Utility Commands

| Command     | Description                                                                                                     |
|-------------|-----------------------------------------------------------------------------------------------------------------|
| CLOCK       | Sets the real-time clock.                                                                                       |
| CLOCK?      | Queries the real-time clock.                                                                                    |
| DBMZ_D      | Sets the power-up and reset default impedance used for dBm outputs (ac volts).                                  |
| DBMZ_D?     | Shows the power-up and reset default impedance used for dBm outputs (ac volts).                                 |
| FORMAT      | <b>Use with extreme care.</b> Restores the contents of the nonvolatile memory device to factory defaults.       |
| LIMIT       | Sets the maximum permitted output magnitudes, negative and positive.                                            |
| LIMIT?      | Shows the programmed output magnitude limits for voltage and current.                                           |
| PR_RPT      | Prints the Stored, Active or CAL-Constant CAL_Report through the HOST or UUT Serial Port.                       |
| RTD_TYPE_D  | Set the default Resistance Temperature Detector (RTD) sensor type.                                              |
| RTD_TYPE_D? | Shows the default Resistance Temperature Detector (RTD) sensor type.                                            |
| SP_SET      | Sets the HOST serial port communication parameters and saves them in nonvolatile memory.                        |
| SP_SET?     | Shows the HOST serial port communication parameters contained in nonvolatile memory.                            |
| TC_TYPE_D   | Sets the power-up and reset default thermocouple type.                                                          |
| TC_TYPE_D?  | Shows the power-up and reset default thermocouple type.                                                         |
| TEMP_STD    | Sets the temperature degree standard, IPTS -68 or its-90.                                                       |
| TEMP_STD?   | Shows the temperature degree standard, IPTS -68 or its-90.                                                      |
| TLIMIT_D    | Sets the power-up and reset default for the time limit for –SC600 OVERLD mode to stay in operate.               |
| TLIMIT_D?   | Shows the power-up and reset default for the time limit for –SC600 OVERLD mode to stay in operate.              |
| UNCERT?     | Shows specified uncertainties for the current output. If there are no specifications for an output, shows zero. |



**Table 6-9. Status Commands**

| Command  | Description                                                                                                                                             |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| ERR?     | Shows the first error code with an explanation in the Calibrator error queue, and then removes that error code from the queue.                          |
| EXPLAIN? | Tells you about an error code. This command shows a string that tells you about the error code given as the parameter.                                  |
| FAULT?   | Shows the first error code contained in the Calibrator error queue, and then removes that error from the queue.                                         |
| FUNC?    | Shows the current output, measurement, or calibration function.                                                                                         |
| ISCE     | Puts two bytes into both the Instrument Status 1 to 0 Change Enable register and the Instrument Status 0 to 1 Change Enable register.                   |
| ISCE?    | Shows the OR of the contents of the Instrument Status 1 to 0 Change Enable register and the Instrument Status 0 to 1 Change Enable register.            |
| ISCE0    | Puts two bytes into the Instrument Status 1 to 0 Change Enable register.                                                                                |
| ISCE0?   | Shows the contents of the Instrument Status 1 to 0 Change Enable register.                                                                              |
| ISCE1    | Puts two bytes into the Instrument Status 0 to 1 Change Enable register.                                                                                |
| ISCE1?   | Shows the contents of the Instrument Status 0 to 1 Change Enable register.                                                                              |
| ISCR?    | Shows the OR of the contents of the Instrument Status 1 to 0 Change Register and the Instrument Status 0 to 1 Change Register and clears the registers. |
| ISCR0?   | Shows and clears the contents of the Instrument Status 1 to 0 Change Register.                                                                          |
| ISCR1?   | Shows and clears the contents of the Instrument Status 0 to 1 Change Register.                                                                          |
| ISR?     | Shows the contents of the Instrument Status Register.                                                                                                   |

**Table 6-10. Thermocouple (TC) Measurement Commands**

| Command    | Description                                                                                        |
|------------|----------------------------------------------------------------------------------------------------|
| TC_MEAS    | Changes the operation mode to thermocouple measurement.                                            |
| TC_OFFSET  | Sets a temperature offset for the thermocouple measurement mode.                                   |
| TC_OFFSET? | Shows the temperature offset when in the thermocouple measurement mode.                            |
| TC_OTCD?   | Shows if the open thermocouple detection circuit is set.                                           |
| TC_OTCD    | Activates or deactivates the open thermocouple detection circuit in thermocouple measurement mode. |
| VAL?       | Shows the last thermocouple value, or, for the -SC600, impedance measurement value.                |
| VVAL?      | Shows the last value of the thermocouple measurement in volts.                                     |

## Commands

The subsequent text is an alphabetical listing of all Calibrator commands and queries. Common commands and device-dependent commands are shown as part of the listing. Each command title includes a graphic that shows remote interface applicability, IEEE-488 and RS-232, and command group: Sequential, Overlapped, and Coupled.

**IEEE-488 (GPIB) and RS-232 Applicability**    ☒ IEEE-488    ☒ RS-232    Each command and query has a check box that shows applicability to IEEE-488 (general purpose interface bus, or GPIB) and RS-232 remote operations. For sorting, this list ignores the \* character that comes before the common commands.

**Sequential Commands**    ☒ Sequential    Commands done immediately as they occur in the data stream are named sequential commands. For more, see “Sequential Commands” in Chapter 5.

**Overlapped Commands**    ☒ Overlapped    Commands where more time to execute is necessary. These commands are named overlapped commands because they can overlap the subsequent command before they complete execution. To be sure an overlapped command is not interrupted during execution, use the \*OPC, \*OPC?, and \*WAI commands to find when the command is complete. For more, see “Overlapped Commands” in Chapter 5.

**Coupled Commands**    ☒ Coupled    These are named coupled commands (examples: CUR\_POST and OUT) because they “couple” in a compound command sequence. Precautions are necessary to make sure the action of one command does not disable the action of a second command and cause a fault. For more information, see “Coupled Commands” in Chapter 5.

---

**CFREQ?**    ☒ IEEE-488    ☒ RS-232    ☒ Sequential    ☐ Overlapped    ☐ Coupled

(Capacitance Frequency query) Shows the optimal frequency for stimulus when you measure or calibrate capacitance output.

Response:    <value>    of the optimal frequency

Example:    CFREQ? shows 1.0E+2

Shows 100 Hz as the optimal frequency for the selected capacitance output (1.0  $\mu$ F for this example). The indication is 0 if not sourcing capacitance.

---

**CLOCK**    ☒ IEEE-488    ☒ RS-232    ☒ Sequential    ☐ Overlapped    ☐ Coupled

(Real-Time Clock command) Sets the real time clock, time only, or date and time. To set the date, the CALIBRATION switch must be in the ENABLE position.

Parameters:    1. (optional) year in the format YYYY  
                  2. (optional) month in the format MM  
                  3. (optional) day in the format DD  
                  4. hour in the format HH  
                  5. minute in the format MM  
                  6. second in the format SS

Examples:    CLOCK 1998,6,1,9,52,10  
                  sets clock to June 1, 1998, 9:52:10 AM

CLOCK 13,10,10 sets clock time only to 1:10:10 PM

---

**CLOCK?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Real\_Time Clock query) Shows the date and time the real time clock.

Response: (character) 1. date in the format YYYY-MM-DD  
(character) 2. time in the format HH:MM:SS

Example: CLOCK? shows 1998-12-04,13:03:50

The clock is set to December 4, 1998, 13:03:50.

---

**\*CLS** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Clear Status command) Clears the ESR, ISCR0, ISCR1, the error queue, and the RQS bit in the status byte. This command stops pending operation complete commands (\*OPC or \*OPC?).

Parameter: (None)

Example: \*CLS

Clear the ESR, ISCR0, ISCR1, the error queue, and the RQS bit in the status byte.

---

**CUR\_POST** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☒ Coupled

(Current Post command) Selects the binding posts for current output. This also applies to power outputs. The current post setting is kept until the power is turned off or the **RESET** button is pressed.

Parameters: AUX (selects the AUX terminals)  
A20 (selects the 20A terminals)

Example: CUR\_POST AUX

Selects the Calibrator front panel AUX terminals for the output current.

---

**CUR\_POST?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Current Post query) Shows the active front panel binding post terminals used for current output: AUX or 20A.

Responses: AUX (AUX terminals are selected)  
A20 (20A terminals are selected)

Example: CUR\_POST? shows AUX

Shows AUX when the AUX terminals are selected for output current.

---

**DBMZ** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☒ Coupled

(dBm Impedance command) Sets the impedance used for dBm outputs (ac volts).

Parameters: Z50 (50 ohms)  
Z75 (75 ohms)  
Z90 (90 ohms)  
Z100 (100 ohms)  
Z135 (135 ohms)  
Z150 (150 ohms)  
Z300 (300 ohms)  
Z600 (600 ohms)  
Z900 (900 ohms)

Z1000 (1000 ohms = dBv)

Z1200 (1200 ohms)

Example: DBMZ Z600

---

**DBMZ?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(dBm Impedance query) Shows the impedance used for dBm outputs (ac volts).

Response: (character) Impedance keyword

Example: DBMZ? shows Z600

---

**DBMZ\_D** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(dBm Impedance Default command) Sets the power-up and reset default impedance used for dBm outputs (ac volts).

Parameters: Z50 (50 ohms)  
 Z75 (75 ohms)  
 Z90 (90 ohms)  
 Z100 (100 ohms)  
 Z135 (135 ohms)  
 Z150 (150 ohms)  
 Z300 (300 ohms)  
 Z600 (600 ohms)  
 Z900 (900 ohms)  
 Z1000 (1000 ohms = dBv)  
 Z1200 (1200 ohms)

Example: DBMZ\_D Z600

This setting only applies when single output AC voltages that are sourced. The dBm impedance is set to the default at power on, reset, and when you go into single output AC mode.

---

**DBMZ\_D?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(dBm Impedance Default query) Shows the power-up and reset default impedance used for dBm outputs (ac volts).

Response: (character) Impedance keyword

Example: DBMZ\_D? shows Z600

---

**DC\_OFFSET** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☒ Coupled

(DC Voltage Offset command) Applies a dc offset to an ac output voltage (maximum six digits). This command applies only to single ac voltage outputs. If the selected offset is too large for the active ac voltage range, an error message is shown.

Parameter: <value> signed offset amplitude

Example: DC\_OFFSET +123.45 MV

Install a dc offset of +123.45 mV to the ac output signal.

---

**DC\_OFFSET?**

☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(DC Voltage Offset query) shows the value of the dc offset voltage.

Response: <value> signed offset amplitude

Example: DC\_OFFSET? shows +1.44E-03

Shows 1.44 mV as the value of the applied dc offset. If +0.00000E+00 is shown, the dc offset is zero.

---

**DPF** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Displacement Power Factor command) Sets the displacement power factor (phase angle) between the Calibrator front panel terminals NORMAL and AUX (for sine waves output only). The NORMAL terminal output is the phase reference. The phase offset is expressed as the cosine of the phase offset (0.000 to 1.000) and a LEAD (default) or LAG term, which tells if the AUX output leads or lags the NORMAL output.

Parameters: <value>, LEAD  
<value>, LAG

Example: DPF .123, LEAD

Set the current output on the Calibrator AUX terminals to lead the voltage output on the NORMAL terminals by 82.93 degrees. (Cosine of 82.93 degrees is 0.123, nominal.)

---

**DPF?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Displacement Power Factor query) Shows the displacement power factor (cosine of the phase angle) between the Calibrator front panel NORMAL and AUX terminals for sine wave outputs.

Responses: <value>, LEAD  
<value>, LAG

Example: DPF? shows 5.00E-01, LEAD

Shows a leading power factor of .5 when the current output on the Calibrator AUX terminals leads the voltage output on the NORMAL terminals by 60 degrees. (Cosine of 60 degrees is 0.5.) 0 shows if power factor does not apply to the output.

---

**DUTY** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Duty Cycle command) Sets the duty cycle of the square wave output. The duty cycle is the percentage of time the waveform is in the positive part of its cycle (1.00 to 99.00 percent). Duty cycle applies only to single-output square waves.

Parameter: <value> of duty cycle with optional PCT (percent) unit

Example: DUTY 12.34 PCT

Set the square wave duty cycle to 12.34 %.

---

**DUTY?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Duty Cycle query) Shows the value of the square wave output duty cycle (1.00 to 99.00).

Response: <value> of duty cycle in percent

Example: DUTY? shows 1.234E+01

Shows 12.34 % for the value of the square wave duty cycle.

---

**EARTH** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Earth Ground command) Selects if the Calibrator front panel NORMAL LO terminal is tied to chassis (earth) ground. When set, the Calibrator keeps the earth setting until power off or reset.

Parameters: OPEN (disconnect front panel LO terminal from chassis ground)  
TIED (connect front panel LO terminal to chassis ground)

Example: EARTH TIED

Load TIED to tie the Calibrator front panel NORMAL LO terminal to earth (the front panel **EARTH** key annunciator is on).

---

**EARTH?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Earth Ground query) Shows if the Calibrator front panel NORMAL LO terminal is tied to chassis (earth) ground.

Responses: (character) OPEN (front panel LO terminal disconnected from chassis ground)

(character) TIED (front panel LO terminal connected to chassis ground)

Example: EARTH? shows OPEN

Shows OPEN when EARTH is not tied to the NORMAL LO terminal (the front panel **EARTH** key annunciator is off).

---

**EDIT** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Edit command) Sets the edit field to the primary, secondary or frequency field.

Parameters: PRI (edit the value in single output functions and the primary output value in dual output functions)

SEC (edit the secondary value in dual output functions)

FREQ (edit the frequency value in single ac output functions)

OFF (edit is off, which is the same as with the NEWREF command)

Example: EDIT FREQ

Load FREQ into the edit field to edit frequency.

---

**EDIT?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Edit query) Shows the edit field setting.

Responses: (character) PRI (value in single output functions, and the primary output value in dual output functions is in edit)

(character) SEC (secondary value in dual output functions is in edit)

(character) FREQ (frequency value in single ac output functions is in edit)

(character) OFF (no value is in edit.)

Example: EDIT? shows OFF

Shows OFF when no value is in edit.

---

**ERR?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Error query) Shows the first error code contained in the Calibrator error queue, and then removes that error code from the queue. After the error code is an explanation of the error code, like, but sometimes has more specified information, than the EXPLAIN? command. The explanation sent in response to this query can contain variables specified to a particular error event. See Appendix D for a list of error codes and error messages.

A zero value is shown when the error queue is empty. To read the full contents of the error queue, do ERR? until the response 0, "No Error" is shown. For terminal users, the error queue Shows for ERR? is always 0, "No Error" because error messages are shown as an alternative to queued.

Response:    <value>, (error code value)  
                  <string>    (text string explaining the error)

Example:    ERR? shows 0, "No Error"

Shows 0, "No Error" when the error queue is empty.

**ERR\_REF** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

Chooses the error reference for error calculations.

|            |         |                                         |
|------------|---------|-----------------------------------------|
| Parameter: | NOMINAL | Sets the reference to the nominal value |
|            | TRUVAL  | Sets the reference to the output value  |

**ERR\_REF?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

Shows the error reference for error calculations.

|           |         |                                                  |
|-----------|---------|--------------------------------------------------|
| Response: | NOMINAL | The nominal value is used as the error reference |
|           | TRUVAL  | The output value is used as the error reference  |

**ERR\_UNIT** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(UUT Error Unit Thresh Hold command) Chooses how UUT error is shown (this is nonvolatile).

|            |        |                                                       |
|------------|--------|-------------------------------------------------------|
| Parameter: | GT1000 | UUT error is shown in % more than 1000 ppm, ppm below |
|            | GT100  | UUT error is shown in % more than 100 ppm, ppm below  |
|            | GT10   | UUT error is shown in % more than 10 ppm, ppm below   |
|            | PPM    | UUT error is shown in ppm always                      |
|            | PCT    | UUT error is shown in % always                        |

**ERR\_UNIT?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(UUT Error Unit Thresh Hold query) Shows currently selected values of ERR\_UNIT.

|            |        |                                                       |
|------------|--------|-------------------------------------------------------|
| Responses: | GT1000 | UUT error is shown in % more than 1000 ppm, ppm below |
|            | GT100  | UUT error is shown in % more than 100 ppm, ppm below  |
|            | GT10   | UUT error is shown in % more than 10 ppm, ppm below   |
|            | PPM    | UUT error is shown in ppm always                      |
|            | PCT    | UUT error is shown in % always                        |

**\*ESE** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled **Error!**  
Bookmark not defined.

(Event Status Enable command) Puts a byte into the Event Status Enable (ESE) register. (See "Event Status Enable Register (ESE)" in Chapter 5)

Parameter: <value> (decimal equivalent of the ESE byte, 0 to 255)

Example: \*ESE 140

Load decimal 140 (binary 10001100) to enable bits 7 (PON), 3 (DDE) and 2 (QYE).

---

**\*ESE?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Event Status Enable query) Shows the contents of the Event Status Enable (ESE) register. (See “Event Status Enable Register (ESE)” in Chapter 5)

Response: <value> (decimal equivalent of the ESE byte, 0 to 255)

Example: \*ESE? shows 133

Shows decimal 133 (binary 10000101) when bits 7 (PON), 2 (QYE), 1 (OPC) are enabled.

---

**\*ESR?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Event Status Register query) Shows the contents of the Event Status Register (ESR) and clears the register. (See Event Status Register (ESR)” in Chapter 5)

Response: <value> (decimal equivalent of the ESR byte, 0 to 255)

Example: \*ESR? shows 189

Shows decimal 189 (binary 10111101) when bits 7 (PON), 5 (CME), 4 (EXE), 3 (DDE), 2 (QYE) and 0 (OPC) are enabled.

---

**EXPLAIN?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Explain Error query) Tells you about an error code. This command shows a string that tells you about the error code given as the parameter. The error code (same as the parameter) originally comes from sending the FAULT? query. (See the ERR? command, which shows both the error code and the explanation string.) See Appendix E for a list of error codes and error messages.

Parameter: <value> if the error code (an integer)

Response: <string> that tells you about the error code, with the parameter (if there is one) as a percent sign followed by d (integer parameter), f (floating point parameter), or s (string parameter)

Example: EXPLAIN? 539 shows “Can’t change compensation now.”

Shows the explanation of error 539: “Can’t change compensation now.”

---

**FAULT?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Fault query) Shows the first error code contained in the Calibrator error queue, then remove that error from the queue. After you get the error code, use the EXPLAIN? command to see an explanation. A zero value is shown when the error queue is empty. To read the complete contents of the error queue, do FAULT? until the response is 0. (Only system errors appear in the error queue.)

Response: <value> of the error code

Example: FAULT? shows 539

Shows the first error code in the error queue, number 539. To see an explanation of the error, record the command EXPLAIN? 539.

---



**FORMAT** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Format command) **Use with extreme care.** Restores the contents of the nonvolatile memory device to factory defaults. The memory holds calibration constants and setup parameters. You lose all calibration data permanently. The CALIBRATION switch on the rear panel of the Calibrator must be set in the ENABLE position or an execution error occurs, except for FORMAT SETUP.

Parameter: ALL (replaces the whole contents with factory defaults)  
CAL (replaces all cal constants with factory defaults)  
SETUP (replaces setup parameters with factory defaults)

Example: FORMAT SETUP

Replace the setup parameters with the default setup values (below). (The FORMAT ALL command is the same as FORMAT CAL and then FORMAT SETUP.) The FORMAT SETUP command also clears the \*PUD string (see the \*PUD command) and SRQSTR is set to "SRQ: %02x %02x %04x %04x" (see the SRQSTR command) and SPLSTR is set to "SPL: %02x %02x %04x %04x" (see the SPLSTR command).

| Features                                                                                 |                                                      |                                    |           |
|------------------------------------------------------------------------------------------|------------------------------------------------------|------------------------------------|-----------|
| Temperature Standard                                                                     | ITS-90                                               | Display Contrast*                  | level 7,7 |
| Host Connection                                                                          | GPIO (IEEE-488)                                      | Display Brightness*                | level 1,0 |
| GPIO Port Address                                                                        | 4                                                    | RTD Power Up Default Type          | pt385     |
| Serial Ports                                                                             | 8 bits, 1 stop bit, xon/xoff, parity none, 9600 baud | Thermocouple Power Up Default Type | K         |
| EOL (end of line)                                                                        | CRLF                                                 | Current Limits                     | ±20.5 A   |
| EOF (end of file)                                                                        | 012,000                                              | Voltage Limits                     | ±1020 V   |
| Remote I/F                                                                               | term                                                 |                                    |           |
| Remote Commands                                                                          |                                                      |                                    |           |
| SRQSTR                                                                                   | SRQ: %02x %02x %04x %04x                             | *PUD string                        | cleared   |
| * Output Display and Control Display, respectively. There are 8 levels: 0,1,2,3,4,5,6,7. |                                                      |                                    |           |
| Defaults                                                                                 |                                                      |                                    |           |
| dBm Impedance                                                                            | 600 Ω                                                |                                    |           |

**FUNC?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Function query) Shows the current output, measurement, or calibration function. See the response below for output and measurement modes.

Responses: DCV (dc volts function)  
ACV (ac volts function)  
DCI (dc current function)  
ACI (ac current function)  
RES (ohms function)

|          |                                            |
|----------|--------------------------------------------|
| CAP      | (capacitance function)                     |
| RTD      | (temperature with an rtd function)         |
| TC_OUT   | (temperature with a thermocouple function) |
| DC_POWER | (dc power function)                        |
| AC_POWER | (ac power function)                        |
| DCV_DCV  | (dual dc volts function)                   |
| ACV_ACV  | (dual ac volts function)                   |
| TC_MEAS  | (measure temperature with a thermocouple)  |
| SACV     | (oscilloscope ac volts function)           |
| SDCV     | (oscilloscope dc volts function)           |
| MARKER   | (oscilloscope marker function)             |
| LEVSINE  | (oscilloscope leveled sine function)       |
| EDGE     | (oscilloscope edge function)               |
| VIDEO    | (-SC600 video trigger function)            |
| PULSE    | (-SC600 pulse output function)             |
| MEAS_Z   | (-SC600 impedance measurement function)    |
| OVERLD   | (-SC600 overload test function)            |

Example: FUNC? shows DCV\_DCV

Shows DCV\_DCV when the Calibrator output function dual dc volts.

---

**HARMONIC** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☒ Coupled

(Harmonic command) Makes the frequency of one output a multiple of a different output for the ac voltage or ac power functions (sine waves only). For example, in dual ac voltage, have the frequency of the voltage output on the Calibrator front panel NORMAL terminals at 60 Hz and the frequency of the voltage output on the AUX terminals at the 7th harmonic (420 Hz). The range for the harmonics is 1 to 50.

Parameters: <value>, PRI (fundamental at 5502A NORMAL terminals)  
<value>, SEC (fundamental at 5502A AUX terminals)

Example: HARMONIC 5, PRI

Put the fundamental frequency at the primary (PRI) output (NORMAL terminals), and the 5th harmonic frequency is at the secondary output (AUX terminals). For example, if the fundamental frequency output is 60 Hz, the harmonic frequency output is 300 Hz.

---

**HARMONIC?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Harmonic query) Shows the current instrument harmonic property and location of the fundamental output PRI (primary, the NORMAL terminals) or SEC (secondary, the AUX terminals).

Response: <value>, PRI (harmonic value, fundamental at primary output)  
<value>, SEC (harmonic value, fundamental at secondary output)

Example: HARMONIC? shows 5, SEC

Shows that the 5th harmonic frequency is selected, and the fundamental is at the secondary output (AUX terminals). This means that the harmonic frequency is at the primary, or NORMAL terminals.

---

**\*IDN?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Identification query) Shows instrument model number, serial number, and firmware revision levels for the primary, encoder, and inguard CPUs.

Responses: (Indefinite ASCII) A message that has four fields separated by commas as follows:

1. Manufacturer
2. Model number
3. Serial number
4. Firmware revision levels for the Main CPU+Front Panel CPU+Ingard PGA

Example: \*IDN? shows FLUKE,5502A,5248000,1.0+1.3+1.8

Shows Fluke manufacturer, model 5502A, serial number 5248000, main firmware version 1.0, encoder firmware 1.3, and inguard PGA 1.8.

---

**INCR** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Increment command) Increments or decrements the output (as selected if you use the EDIT command, or defaults to the primary output) and records error mode; the same as if you use the Calibrator output adjustment knob in local operation.

Parameters: <+ value> (increment value) (optional unit matching edit field)  
<-value> (decrement value)

Example: INCR +.00001 mV

Load the error mode and increment the selected edit field by .00001 mV.

---

**ISCE** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Instrument Status Change Enable command) Puts two bytes into the two 16-bit ISCE mask registers (ISCE1 and ISCE0). (See “Instrument Status Change Enable Registers” in Chapter 5 for more information.)

Parameter: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: ISCE 6272

Load decimal 6272 (binary 0001010001000000) to enable bits 12 (SETTLED), 10 (REMOTE) and 6 (HIVOLT). This is equivalent to sending the commands ISCE0 6272 and ISCE1 6272 (see below).

---

**ISCE?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Instrument Status Change Enable query) Shows the two bytes from the two 16-bit ISCE mask registers (ISCE1 and ISCE0). (See “Instrument Status Change Enable Registers” in Chapter 5 for more information.)

Response: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: ISCE? shows 6272

Shows decimal 6272 (binary 0001010001000000) if bits 12 (SETTLED), 10 (REMOTE), and 6 (HIVOLT) are set to 1.

---

**ISCE0** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Instrument Status 1 to 0 Change Enable command) Puts the two bytes into the 16-bit ISCE0 register. (See “Instrument Status Change Enable Registers” in Chapter 5 for more information.)

Parameter: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: ISCE0 6272

Load decimal 6272 (binary 0001010001000000) to enable bits 12 (SETTLED), 10 (REMOTE) and 6 (HIVOLT).

---

**ISCE0?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Instrument Status 1 to 0 Change Enable query) Shows the two bytes from the 16-bit ISCE0 register. (See “Instrument Status Change Enable Registers” in Chapter 5 for more information.)

Response: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: ISCE0? shows 6272

Shows decimal 6272 (binary 0001010001000000) if bits 12 (SETTLED), 10 (REMOTE), and 6 (HIVOLT) are set to 1.

---

**ISCE1** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled **Error!**  
Bookmark not defined.

(Instrument Status 0 to 1 Change Enable command) Puts the two bytes into the 16-bit ISCE1 register. (See “Instrument Status Change Enable Registers” in Chapter 5 for more information.)

Parameter: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: ISCE1 6272

Load decimal 6272 (binary 0001010001000000) to enable bits 12 (SETTLED), 10 (REMOTE) and 6 (HIVOLT).

---

**ISCE1?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled **Error!**  
Bookmark not defined.

(Instrument Status 0 to 1 Change Enable query) Shows the two bytes from the 16-bit ISCE1 register. (See “Instrument Status Change Enable Registers” in Chapter 5 for more information.)

Response: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: ISCE1? shows 6272

Shows decimal 6272 (binary 0001010001000000) if bits 12 (SETTLED), 10 (REMOTE), and 6 (HIVOLT) are set to 1.

---

**ISCR?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled **Error!**  
Bookmark not defined.

(Instrument Status Change Register query) Shows and clears the contents of the Instrument Status 1 to 0 Change Register (ISCR0) and Instrument Status 0 to 1 Change Register (ISCR1). (See “Instrument Status Change Register” in Chapter 5 for more information.)

Response: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: ISCR? shows 6272

Shows decimal 6272 (binary 0001010001000000) if bits 12 (SETTLED), 10 (REMOTE), and 6 (HIVOLT) are set to 1.

---

**ISCR0?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled Error!  
Bookmark not defined.

(Instrument Status 1 to 0 Change Register query) Shows and clears the contents of the Instrument Status 1 to 0 Change Register.

Response: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: ISCR0? shows 6272

Shows decimal 6272 (binary 0001010001000000) if bits 12 (SETTLED), 10 (REMOTE), and 6 (HIVOLT) are set to 1.

---

**ISCR1?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled Error!  
Bookmark not defined.

(Instrument Status 0 to 1 Change Register query) Shows and clears the contents of the Instrument Status 0 to 1 Change Register.

Response: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: ISCR1? shows 6272

Shows decimal 6272 (binary 0001010001000000) if bits 12 (SETTLED), 10 (REMOTE), and 6 (HIVOLT) are set to 1.

---

**ISR?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled Error!  
Bookmark not defined.

(Instrument Status Register query) Shows contents of the Instrument Status Register.

Response: <value> (decimal equivalent of the 16 bits, 0 to 32767)

Example: ISR? shows 6272

Shows decimal 6272 (binary 0001010001000000) if bits 12 (SETTLED), 10 (REMOTE), and 6 (HIVOLT) are set to 1.

---

**LCOMP** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled Error!  
Bookmark not defined.

(Inductive compensation command) Activates or deactivates inductive load compensation for ac current output. For current output, compensation is permitted when the frequency is less than 440 Hz and the amplitude is less than 0.33 A. Compensation is also permitted when the frequency is less than 1 kHz and the amplitude is larger than or equal to 0.33 A.

Parameters: OFF (turns off the inductive load compensation circuitry)  
ON (turns on the inductive load compensation circuitry)

Example: LCOMP ON

---

**LCOMP?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled Error!  
Bookmark not defined.

(Inductive compensation query) Shows if inductive load compensation for ac current output is active.

Responses: (character) OFF (Inductive load compensation circuitry is off)  
(character) ON (Inductive load compensation circuitry is on)

Example: LCOMP? shows ON

---

**LIMIT** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Limit command) Sets the maximum permitted output magnitude, negative and positive, for voltage and current, which is kept in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to remote commands.) Negative and positive values must be recorded. When set, the Calibrator keeps the limit settings until another limit is recorded, or the **FORMAT SETUP** command resets the limits (and all other defaults) to the factory settings ( $\pm 1020$  V,  $\pm 20.5$  A). See the **FORMAT** command.

The magnitude of the limit has this effect on different waveforms:

|                     |                                                       |
|---------------------|-------------------------------------------------------|
| dc                  | magnitude of limit                                    |
| ac (sine wave)      | magnitude of limit (rms)                              |
| ac (non-sine wave)  | magnitude of limit x 3 (peak-to-peak)                 |
| ac (with dc offset) | magnitude of limit x 2.4 (absolute peak) (volts only) |

Parameters: <positive value>,<negative value>

Example: **LIMIT** 100V, -100V

Limit the voltage output to  $\pm 100$  V dc, 100 V ac rms, 300 V peak-to-peak, 240 V peak.

Example: **LIMIT** 1A, -1A

Limit the current output to  $\pm 1$  A dc, 1 A ac rms, 3 A peak-to-peak.

---

**LIMIT?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Limit query) Shows the programmed output magnitude limits for voltage and current.

Response: <positive value voltage>,<negative value voltage>,  
<positive value current>,<negative value current>

Example: **LIMIT?**  
shows 1020.0000, -1020.0000, 20.5000, -20.5000

Shows the current value of the voltage and current limits (reset values shown).

---

**LOCAL** ☐ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Local command) Puts the Calibrator into the local condition, clearing the remote condition (see the **REMOTE** command) and front panel lockout (see the **LOCKOUT** command). This command duplicates the IEEE-488 GTL (Go To Local) message.

Parameter: (None)

Example: **LOCAL**

Set the instrument into the local condition, clearing the remote condition and front panel lockout (if enable).

---

**LOCKOUT** ☐ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Lockout command) Puts the Calibrator into the lockout condition when in remote control (see the **REMOTE** command). This means no local operation at the front panel is permitted during remote control. To clear the lockout condition, use the **LOCAL** command. This command duplicates the IEEE-488 LLO (Local Lockout) message.

Parameter: (None)

Example: **LOCKOUT**

Set the instrument into the front panel lockout condition. The front panel's controls cannot be used.

---

**LOWS** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Low Potential Output Terminals command) Selects if the Calibrator front panel NORMAL LO terminal and AUX LO terminal are internally tied together (default) or are open. This feature is used for ac power, dc power, dual dc volts and dual ac volts outputs. When set, the Calibrator keeps the LO setting until power off or reset.

Parameter: OPEN (disconnect NORMAL LO and AUX LO terminals)

TIED (connect NORMAL LO and AUX LO terminals)

Example: LOWS TIED

Tie the front panel NORMAL LO and AUX LO terminals together.

---

**LOWS?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Low Potential Output Terminals query) Shows if the Calibrator front panel NORMAL LO terminal and AUX LO terminal are internally tied together (default) or are open.

Response: OPEN (disconnected NORMAL LO and AUX LO terminals)

TIED (connected NORMAL LO and AUX LO terminals)

Example: LOWS? shows OPEN

Shows OPEN when the Calibrator front panel NORMAL LO and AUX LO terminals are not tied together.

---

**MULT** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Multiply command) Multiplies the reference magnitude (as selected with the EDIT command or default to the primary output). The reference magnitude is the current reference in direct mode or in error mode.

Parameter: <value> (multiplier expressed as a floating point number)

Example: MULT 2.5

Multiply the reference that exists by 2.5, creating a new reference. For example, a reference that exists of 1 V is multiplied to 2.5 V.

---

**NEWREF** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(New Reference command) Sets the new reference to the current Calibrator output value and exit the error mode (if selected). For example, you might edit the Calibrator output with the EDIT and INCR commands, and then use the NEWREF command to establish a new reference point and exit the error mode. This is the same as pressing the Calibrator front panel  key.

Parameter: (None)

Example: NEWREF

Set the reference value to the current Calibrator output value.

---

**OLDREF** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Old Reference command) Sets the Calibrator output to the reference value and exit the error mode (if selected). If editing the output with the EDIT and INCR commands and



you want to return to the reference value, use the OLDREF command. If editing the output and you want to make the edited value the new reference, use the NEWREF command.

Parameter: (None)

Example: OLDREF

Set the output to the reference value that exists, clearing editing changes.

---

**ONTIME?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Calibrator On Time query) Shows the time in minutes since the Calibrator was most recently powered up.

Response: <minutes> (24-hour clock)

Example: ONTIME? shows 47

Shows the time since the Calibrator was last powered up: 47 minutes.

---

**\*OPC** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Operations Complete command) Sets bit 0 (OPC) of the Event Status Register to 1 when all pending device operations are complete. Also see the \*ESR? command.

Parameter: (None)

Example: \*OPC

Set bit 0 of the Event Status Register to 1 when all pending device operations are done.

---

**\*OPC?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Operations Complete query) Shows a 1 after all pending operations are complete. This command causes program execution to pause until operations are complete. (See \*WAI.)

Response: 1 (all operations are complete)

Example: \*OPC? shows 1

Shows 1 when all pending operations are complete.

---

**OPER** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Operate command) Activates the Calibrator output if it is in standby. This is the same as pressing the Calibrator front panel **OPR** key. If there are errors in the error queue, the OPER command is inhibited for outputs 33 V and over. (Also see the ERR? command and STBY command.)

Parameter: (None)

Example: OPER

Connect the selected output to the Calibrator front panel terminals. Also lights the annunciator in the **OPR** key.

---

**OPER?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Operate query) Shows the operate/standby setting.

Response: 1 (Operate)

0 (Standby)



Example: OPER? shows 1

Shows 1 when the Calibrator is in operate.

**\*OPT?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Options command) Shows a list of the installed hardware and software options.

Responses: <option string>,<option string>,... (options list, separated by commas)  
0 (no options are installed)

Example: \*OPT? shows SC600

Shows SC600 when the Oscilloscope Calibration Option is installed.

**OUT** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☒ Coupled

(Output command) Sets the output of the Calibrator and establishes a new reference point for the error mode. If only one amplitude is supplied, the Calibrator sources a single output. If two amplitudes are supplied, the Calibrator sources two outputs. The second amplitude will be sourced at the AUX terminals for dual voltage outputs. If the frequency is not supplied, the Calibrator will use the frequency that is currently in use.

To source or measure a temperature, select the desired sensor and sensor parameters first. (See the TSENS\_TYPE, RTD\_\*, and TC\_\* commands.)

To source a signal with the Calibrator scope options, refer to the SCOPE command.

If you change the frequency of an ac function and the harmonic output is not explicitly set at the same time with the HARMONIC command, the harmonic will be set to 1.

Use multipliers e.g., k, M,  $\mu$  with the OUT command, as desired.

|                                  |                                                                           |
|----------------------------------|---------------------------------------------------------------------------|
| Parameters: <value> V            | Volts dc or update volts ac                                               |
| <value> DBM                      | Volts ac dBm update                                                       |
| <value> V, <value> Hz            | Volts ac or volts dc with 0 Hz                                            |
| <value> DBM, <value> Hz          | Volts ac in dBm                                                           |
| <value> A                        | Current dc or update current ac                                           |
| <value> A, <value> Hz            | Current ac                                                                |
| <value> OHM                      | Resistance                                                                |
| <value> F                        | Capacitance                                                               |
| <value> CEL                      | Temperature (Celsius)                                                     |
| <value> FAR                      | Temperature (Fahrenheit)                                                  |
| <value> HZ                       | Update frequency                                                          |
| <value> V, <value> A             | Power dc or update power ac                                               |
| <value> V, <value> A, <value> HZ | Power ac                                                                  |
| <value> V, <value> V             | Dual volts dc or update dual ac                                           |
| <value> V, <value> V, <value> HZ | Dual volts ac in volts                                                    |
| <value>                          | For single output, changes amplitude keeping unit and frequency the same. |

|                      |                                    |
|----------------------|------------------------------------|
| Examples: OUT 15.2 V | (volts; 15.2 V @ same frequency)   |
| OUT 20 DBM           | (volts; 20 dBm @ same frequency)   |
| OUT 10 V, 60 Hz      | (volts ac; 10 V @ 60 Hz)           |
| OUT 10 DBM, 50 HZ    | (volts ac; 10 dBm @ 50 Hz)         |
| OUT 1.2 MA           | (current; 1.2 mA @ same frequency) |
| OUT 1 A, 400 HZ      | (current ac; 1 A @ 400 Hz)         |

|                         |                                     |
|-------------------------|-------------------------------------|
| OUT 1 KOHM              | (ohms; 1 k $\Omega$ )               |
| OUT 1 UF                | (capacitance; 1 $\mu$ F)            |
| OUT 100 CEL             | (temperature; 100 $^{\circ}$ C)     |
| OUT 32 FAR              | (temperature; 32 $^{\circ}$ F)      |
| OUT 60 HZ               | (frequency update; 60 Hz)           |
| OUT 10 V, 1 A           | (power; 10 watts @ same frequency)  |
| OUT 1 V, 1 A, 60 HZ     | (power ac; 1 watts @ 60 Hz)         |
| OUT 1 V, 2 V            | (dual volts; 1 V, 2 V @ same freq.) |
| OUT 10 MV, 20 MV, 60 HZ | (dual volts; .01 V, .02 V @ 60 Hz)  |

Each example shows a value and unit, e.g., -15.2 V. If a value is recorded without a unit, the value of the output that exists is changed, when logically allowed.

**OUT?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Output query) Shows the output amplitudes and frequency of the Calibrator. Multipliers (e.g., K or M) are not used in the response.

Parameters: V (optional for ac voltage and TC modes)  
 DBM (optional for ac voltage modes)  
 CEL (optional for RTD and TC modes, Celsius)  
 FAR (optional for RTD and TC modes, Fahrenheit)  
 OHM (optional for RTD modes, ohms)

Response: <primary amplitude value>,<primary units>,  
 <secondary amplitude value>,<secondary units>,  
 <fundamental frequency value>

Examples: OUT? shows -1.520000E+01,V,0E+00,0,0.00E+00  
 OUT? shows 1.88300E-01,A,0E+00,0,4.420E+02  
 OUT? shows 1.23000E+00,V,2.34000E+00,V,6.000E+01  
 OUT? shows 1.92400E+06,OHM,0E+00,0,0.00E+00  
 OUT? shows 1.52000E+01,V,1.88300E-01,A,4.420E+02  
 OUT? DBM shows 2.586E+01,DBM,0E+00,A,4.420E+02  
 OUT? shows 1.0430E+02,CEL,0E+00,0,0.00E+00  
 OUT? FAR shows 2.19740000E+02,FAR,0E+00,0,0.00E+00  
 OUT? V shows 4.2740E-03,V,0E+00,0,0.00E+00  
 OUT? OHM shows 1.40135E+02,OHM,0E+00,0,0.00E+00

The respective values for the above examples are:

-15.2 V  
 188.3 mA, 442 Hz  
 1.23 V, 2.34 V, 60 Hz  
 1.924 M $\Omega$   
 15.2 V, 188.3 mA, 442 Hz  
 25.86 dBm, 442 Hz (25.86 dBm = 15.2 V at 600  $\Omega$ )  
 104.3  $^{\circ}$ C  
 219.74  $^{\circ}$ F (same value as 104.3  $^{\circ}$ C, in Fahrenheit)  
 4.274 mV (same value as 104.3  $^{\circ}$ C for a K-type thermocouple, in volts)  
 140.135  $\Omega$  (same value as 104.3  $^{\circ}$ C for a pt385 RTD, in ohms)

The primary and secondary units are: V, DBM, A, OHM, F, CEL, FAR. The units for the <frequency value> is always assumed to be Hz.

**OUT\_ERR?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Output Error query) Shows the UUT error and units computed by the Calibrator after shifting the output with the INCR command. The return units are PPM (parts per million), PCT (percent), DB (decibels) or 0 if there is no error. The UUT error is not computed when editing frequency.

Response: <value of error>, <units>

Example: OUT\_ERR? shows -1.00000E+01, PCT

Shows -10% when the UUT is reading low by 10 %.

---

**PHASE** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Phase Difference command) Sets a phase difference between the Calibrator front panel NORMAL and AUX or 20A terminals for ac power and ac dual voltage outputs. The NORMAL terminal output is the phase reference. The set range is 0.00 to  $\pm 180.00$  degrees, with + for a leading phase difference and - for a lagging phase difference.

Parameter: <phase value> DEG (DEG, for degree, is optional)

Example: PHASE -60 DEG

Set the phase difference so the frequency output at the AUX terminals lags the frequency output at the NORMAL terminals by 60 degrees.

---

**PHASE?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Phase Difference query) Shows the phase difference between the Calibrator front panel NORMAL and AUX terminals for ac power and ac dual voltage outputs.

Response: <phase value>

Example: PHASE? shows -6.000E+01

Shows -60 when the frequency output at the AUX terminals is lagging the frequency output at the NORMAL terminals by 60 degrees.

---

**POWER?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Calculate Power Output query) Shows the equivalent real power for ac and dc power outputs, based on the voltage and current settings, and power factor (ac only). If the output is not ac or dc power, the return is 0E+00 (zero) watts.

Response: <value> (in watts)

Example: POWER? shows 1.00000E+01

Shows 10 when the output voltage is 10 V dc and output current 1 A dc, for 10 watts real power.

Example: POWER? shows 1.00000E+01

Shows 10 when the output voltage is 10 V ac and output current 2 A ac and power factor is .5, for 10 watts real power.

---

**PR\_PRT** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

Description: Prints a self calibration report out the selected serial port.

Parameters: 1. Type of report to print: **STORED**, **ACTIVE**, or **CONSTS**

2. Format of report: **PRINT** (designed to be read), **SPREAD** (designed to be loaded into a spreadsheet )
3. Calibration interval to be used for instrument specifications in the report: **I90D** (90 day spec), **I1Y** (I year spec)
4. Serial port through which to print: **HOST, UUT**

Example: PR-PRT STORED, PRINT, i90D, HOST

---

**\*PUD** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Protected User Data command) Stores a string of 64 characters (maximum), which is kept in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to remote commands.) This command works only when the CALIBRATION switch on the rear panel of the Calibrator is in the ENABLE position. Include a line feed (RS-232) character to stop the block data or End or Identify (EOI) command (IEEE-488).

Parameter: #2<nn><nn characters string> (definite length)  
 #0<character string> (indefinite length)  
 "<character string>" (character string)  
 '<character string>' (character string)

Example: \*PUD #0CAL LAB NUMBER 1

Store the string CAL LAB NUMBER 1 in the protected user data area with the indefinite length format.

Example: \*PUD #216CAL LAB NUMBER 1

Store the string CAL LAB NUMBER 1 in the protected user data area with the definite length format, where #2 means two digits follow which represent the number of text characters nn in CAL LAB NUMBER 1 (including spaces=16).

Example: \*PUD "CAL LAB NUMBER 1"

Store the string CAL LAB NUMBER 1 in the protected user data area with the character string format.

---

**\*PUD?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Protected User Data query) Shows the contents of the \*PUD (Protected User Data) memory in definite length format.

Response: #2nn<nn characters>

Example: \*PUD? shows #216CAL LAB NUMBER 1

Shows #2 then 16 then 16 characters of text (with spaces) stored in the nonvolatile memory.

---

**RANGE?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Range query) Shows the current output ranges. The primary output and secondary outputs are shown. If there is no secondary output, 0 is shown. Dual outputs are shown with P for primary output (front panel NORMAL terminals) and S for secondary output (front panel AUX terminals).

Response: <primary output>,<secondary output>

Examples: DC330MV, 0 (dc volts 330 mV range)

|                     |                                      |
|---------------------|--------------------------------------|
| DC33MA_A, 0         | (dc current 33 mA range)             |
| AC3_3V, 0           | (ac volts 3.3 V range)               |
| AC330MA_A, 0        | (ac current 330 mA range)            |
| R110OHM, 0          | (ohms 110 $\Omega$ range)            |
| C1_1UF, 0           | (capacitance 1.1 $\mu$ F range)      |
| TCSRC, 0            | (temperature thermocouple source)    |
| RTD_110, 0          | (temperature RTD 110 $\Omega$ range) |
| DC3_3V_P, DC3A_AS   | (dc power 3.3 V, 3 A ranges)         |
| AC330V_P, AC20A_2S  | (ac power 330 V, 20 A ranges)        |
| DC330MV_P, DC3_3V_S | (dual dc volts 330 mV, 3.3 V ranges) |
| AC330V_P, AC3_3V_S  | (dual ac volts 330 V, 3.3 V ranges)  |

Shows the symbolic name of the single or first output, and show the symbolic name of the second output (0 if there is no second output).

**RANGELCK** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Range Lock command) Locks in the current range, or selects auto ranging for dc voltage and dc current single outputs. The range automatically unlocks if the output function changes, for example from dc volts to dc current. When RANGELCK is on, this is equivalent to the softkey range lock that shows locked. When RANGELCK is off, this is equivalent to the softkey range lock that shows auto.

Parameter: ON (Locks the dc volts or dc current range)  
OFF (Unlocks the dc volts or dc current range for autoranging)

Example: RANGELCK OFF

Set the range lock off to allow autoranging for dc volts or dc current.

**RANGELCK?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Range Lock query) Shows if the preset dc volts or dc current single output range is locked.

Response: ON (range is locked and autoranging is not allowed)  
OFF (range is not locked and autoranging is allowed)

Example: RANGELCK? shows OFF

Shows OFF when the range for dc volts or dc current is not locked (autoranging enabled).

**REFOUT?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Reference Output query) Shows the current value of the reference when editing the output (error mode). If not editing the output with the INCR command, the return is 0 (0E+00). The reference value is set with the OUT, NEWREF or MULT commands. To find which quantity is being edited, use the EDIT? and OUT? commands.

Response: <reference value>

Example: REFOUT? shows 0E+00

Shows 0 when the output is not being edited.

Example: REFOUT? shows 2.500000E-01

Shows .250 when the output is being edited and the reference is, for example, 250 mV.

**REMOTE**   ☐ IEEE-488   ☒ RS-232   ☒ Sequential   ☐ Overlapped   ☐ Coupled

(Remote command) Puts the Calibrator into the remote condition. This command duplicates the IEEE-488 REN (Remote Enable) message. When in the remote condition, the Control Display shows the softkey “REMOTE CONTROL Go to Local.” Push this softkey to change the Calibrator to local operation. If the front panel is locked out, the Control Display shows the softkey “REMOTE CONTROL LOCAL LOCK OUT.” (See the LOCKOUT command.) To unlock the front panel, use the LOCAL command, or cycle the Calibrator power switch.

Parameter:   (None)

Example:   REMOTE

Put the Calibrator in the remote condition and show this condition on the front panel Control Display with a softkey REMOTE CONTROL.

---

**RPT\_STR**   ☒ IEEE-488   ☒ RS-232   ☒ Sequential   ☐ Overlapped   ☐ Coupled

(Report String command) Loads the user report string. The user report string can be read on the Control Display in local operation, and is shown on calibration reports. The CALIBRATION switch must be set to ENABLE. (Sequential command.)

Parameter:   String of up to 40 characters

---

**RPT\_STR?**   ☒ IEEE-488   ☒ RS-232   ☒ Sequential   ☐ Overlapped   ☐ Coupled

(Report String query) Shows the user report string. The user report string can be read on the Control Display in local operation, and is shown on calibration reports. (Sequential command.)

Parameter:   None

Response:   (String) a maximum of 40 characters

---

**\*RST**   ☒ IEEE-488   ☒ RS-232   ☐ Sequential   ☒ Overlapped   ☐ Coupled

(Reset Instrument command) Resets the Calibrator to the power-up condition. \*RST holds off execution of subsequent commands until the reset operation is complete. This command is the same as if you push the front panel **RESET** key.

A reset gets the subsequent commands and values:

| Command    | Value          | Command   | Value              |
|------------|----------------|-----------|--------------------|
| CUR_POST   | AUX            | RTD_TYPE  | <RTD_TYPE_D value> |
| DBMZ       | <DBMZ_D value> | SCOPE     | OFF                |
| DC_OFFSET  | 0V             | STBY      | (No output)        |
| DUTY       | 50PCT          | TC_OFFSET | 0 CEL              |
| EARTH      | OPEN           | TC_OTCD   | ON                 |
| HARMONIC   | 1, PRI         | TC_REF    | INT                |
| LCOMP      | OFF            | TC_TYPE   | <TC_TYPE_D value>  |
| LOWS       | TIED           | TRIG      | OFF                |
| OUT        | 0V, 0HZ        |           |                    |
| Command    | Value          | Command   | Value              |
| OUT_IMP    | Z1M            | WAVE      | NONE, NONE         |
| PHASE      | 0DEG           | ZCOMP     | OFF                |
| RANGELCK   | OFF            | ZERO_MEAS | OFF                |
| TSENS_TYPE | TC             |           |                    |

Changes made to the setup menus that are not kept in memory are discarded on reset.

Response: (None)

Example: \*RST

Put the Calibrator in a reset condition, evoking the commands and values shown above.

**RTD\_TYPE** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Resistance Temperature Detector Type command) Sets the Resistance Temperature Detector (RTD) sensor type.

Before you use RTD\_TYPE, select RTD with the TSENS\_TYPE command. After you use RTD\_TYPE, select the output temperature with the OUT command. Changes in temperature sensors changes the output to 0 °C. When set, the Calibrator keeps the RTD type until power off or reset.

Parameters: PT385 (100-ohm RTD, curve  $\alpha=0.00385$  ohms/ohm/°C)  
 PT385\_200 (200-ohm RTD, curve  $\alpha=0.00385$  ohms/ohm/°C)  
 PT385\_500 (500-ohm RTD, curve  $\alpha=0.00385$  ohms/ohm/°C)  
 PT385\_1000 (1000-ohm RTD, curve  $\alpha=0.00385$  ohms/ohm/°C)  
 PT3926 (100-ohm RTD, curve  $\alpha=0.003926$  ohms/ohm/°C)  
 PT3916 (100-ohm RTD, curve  $\alpha=0.003916$  ohms/ohm/°C)  
 CU10 (10-ohm RTD, empirical curve)  
 NI120 (120-ohm RTD, empirical curve)

Example: RTD\_TYPE PT3926

Set the RTD type to a 100-ohm type, with the pt3926 curve ( $\alpha=0.003926$  ohms/ohm/°C). The resistance of 100 ohms refers to the ice point property, (the resistance of the RTD at 0 °C (32 °F)).



**RTD\_TYPE?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Resistance Temperature Detector Type query) Shows the Resistance Temperature Detector (RTD) type used for RTD temperature simulations.

Responses: PT385 (100-ohm RTD, curve  $\alpha=0.00385$  ohms/ohm/ $^{\circ}$ C)  
 PT385\_200 (200-ohm RTD, curve  $\alpha=0.00385$  ohms/ohm/ $^{\circ}$ C)  
 PT385\_500 (500-ohm RTD, curve  $\alpha=0.00385$  ohms/ohm/ $^{\circ}$ C)  
 PT385\_1000 (1000-ohm RTD, curve  $\alpha=0.00385$  ohms/ohm/ $^{\circ}$ C)  
 PT3926 (100-ohm RTD, curve  $\alpha=0.003926$  ohms/ohm/ $^{\circ}$ C)  
 PT3916 (100-ohm RTD, curve  $\alpha=0.003916$  ohms/ohm/ $^{\circ}$ C)  
 CU10 (10-ohm RTD, empirical curve)  
 NI120 (120-ohm RTD, empirical curve)

Example: RTD\_TYPE? shows PT3926

Shows PT3926 when a 100-ohm RTD with curve  $\alpha=0.003926$  ohms/ohm/ $^{\circ}$ C is set as the RTD type.

**RTD\_TYPE\_D** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Resistance Temperature Detector Type Default command) Sets the default Resistance Temperature Detector (RTD) at power on and reset, which is kept in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to remote commands.)

Parameters: PT385 (100-ohm RTD, curve  $\alpha=0.00385$  ohms/ohm/ $^{\circ}$ C)  
 PT385\_200 (200-ohm RTD, curve  $\alpha=0.00385$  ohms/ohm/ $^{\circ}$ C)  
 PT385\_500 (500-ohm RTD, curve  $\alpha=0.00385$  ohms/ohm/ $^{\circ}$ C)  
 PT385\_1000 (1000-ohm RTD, curve  $\alpha=0.00385$  ohms/ohm/ $^{\circ}$ C)  
 PT3926 (100-ohm RTD, curve  $\alpha=0.003926$  ohms/ohm/ $^{\circ}$ C)  
 PT3916 (100-ohm RTD, curve  $\alpha=0.003916$  ohms/ohm/ $^{\circ}$ C)  
 CU10 (10-ohm RTD, empirical curve)  
 NI120 (120-ohm RTD, empirical curve)

Example: RTD\_TYPE\_D PT3926

Set the RTD default type to a 100-ohm RTD with curve  $\alpha=0.003926$  ohms/ohm/ $^{\circ}$ C.

**RTD\_TYPE\_D?**

☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Resistance Temperature Detector Type Default query) Shows the default Resistance Temperature Detector (RTD) used at power on and reset.

Responses: PT385 (100-ohm RTD, curve  $\alpha=0.00385$  ohms/ohm/ $^{\circ}$ C)  
 PT385\_200 (200-ohm RTD, curve  $\alpha=0.00385$  ohms/ohm/ $^{\circ}$ C)  
 PT385\_500 (500-ohm RTD, curve  $\alpha=0.00385$  ohms/ohm/ $^{\circ}$ C)  
 PT385\_1000 (1000-ohm RTD, curve  $\alpha=0.00385$  ohms/ohm/ $^{\circ}$ C)  
 PT3926 (100-ohm RTD, curve  $\alpha=0.003926$  ohms/ohm/ $^{\circ}$ C)  
 PT3916 (100-ohm RTD, curve  $\alpha=0.003916$  ohms/ohm/ $^{\circ}$ C)  
 CU10 (10-ohm RTD, empirical curve)  
 NI120 (120-ohm RTD, empirical curve)

Example: RTD\_TYPE\_D? shows PT3926



Shows PT3926 when the RTD default type is a 100-ohm RTD with curve  $\alpha=0.003926$  ohms/ohm/°C.

---

**SP\_SET** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Host Serial Port Set command) Sets the RS-232-C settings for the Calibrator rear panel SERIAL 1 FROM HOST serial port, which is kept in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to remote commands.) (To set the parameters for the rear panel SERIAL 2 TO UUT serial port, see the UUT\_SET command.) The factory default values are shown below in **BOLD** type. (To return to the factory defaults, see the FORMAT SETUP command.)

The interface selection sets the command response, with command echo back for commands and error messages with TERM (terminal) or no echo back with COMP (computer).

|             |                     |                                                                                  |
|-------------|---------------------|----------------------------------------------------------------------------------|
| Parameters: | <baud rate value>,  | 300, 600, 1200, 2400, 4800, <b>9600</b>                                          |
|             | <interface>,        | <b>TERM</b> (terminal), COMP (computer)                                          |
|             | <flow control>,     | <b>XON</b> (xon/xoff), NOSTALL (none), RTS (rts/cts)                             |
|             | <number data bits>, | DBIT7 (7 bits) or <b>DBIT8</b> (8 bits)                                          |
|             | <number stop bits>, | <b>SBIT1</b> (1 bit) or SBIT2 (2 bits)                                           |
|             | <parity>,           | <b>PNONE</b> (none), PODD (odd), PEVEN (even)                                    |
|             | <end of line char.> | CR (carriage return), LF (line feed),<br><b>CRLF</b> (carriage return/line feed) |

Example: SP\_SET 9600,TERM,XON,DBIT8,SBIT1,PNONE,CRLF

Set the parameters for the rear panel SERIAL 1 FROM HOST serial port to the factory default values.

---

**SP\_SET?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Host Serial Port Set query) Shows the RS-232-C settings for the Calibrator rear panel SERIAL 1 FROM HOST serial port. (To return the parameters for the rear panel SERIAL 2 TO UUT serial port, see the UUT\_SET? command.) The factory default values are shown below in **BOLD** type. (To return to the factory defaults, see the FORMAT SETUP command.)

|            |                     |                                                                                  |
|------------|---------------------|----------------------------------------------------------------------------------|
| Responses: | <baud rate value>,  | 300, 600, 1200, 2400, 4800, <b>9600</b>                                          |
|            | <interface>,        | <b>TERM</b> (terminal), COMP (computer)                                          |
|            | <flow control>,     | <b>XON</b> (xon/xoff), NOSTALL (none), RTS (rts/cts)                             |
|            | <number data bits>, | DBIT7 (7 bits) or <b>DBIT8</b> (8 bits)                                          |
|            | <number stop bits>, | <b>SBIT1</b> (1 bit) or SBIT2 (2 bits)                                           |
|            | <parity>,           | <b>PNONE</b> (none), PODD (odd), PEVEN (even)                                    |
|            | <end of line char.> | CR (carriage return), LF (line feed),<br><b>CRLF</b> (carriage return/line feed) |

Example: SP\_SET? shows 9600,TERM,XON,DBIT8,SBIT1,PNONE,CRLF

Shows the parameters for the rear panel SERIAL 1 FROM HOST serial port, as shown, when set to the factory default values.

---

**SPLSTR** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Serial Poll String command) Sets the Serial Poll String (string up to 40 characters) which is kept in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to

remote commands.) The SPLSTR is sent to the host over the serial interface when a ^P (<cntl> P) character is sent. The default format is:

SPL: %02x %02x %04x %04x

where the term %02x (8 bits) means print the value in hexadecimal with 2 hex digits, and %04x (16 bits) means print the value in hexadecimal with 4 hex digits. The string representations are:

SPL: (STB) (ESR) (ISCR0) (ISCR1)

See the commands \*STB?, \*ESR?, ISCR0?, and ISCR1?. A typical string in the default format sent to the host is: SPL: 44 00 0000 1000. This command is for format. For values instead of format, record a ^P (<cntl> p) character. Also see the SRQSTR command.

Parameter: "<string>\n" (\n represents the NEWLINE character, hex 0A)

Example: SPLSTR "SPL: %02x %02x %04x %04x\n"

Set the SPLSTR to the default values SPL: %02x %02x %04x %04x\n.

---

**SPLSTR?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Serial Poll Response String query) Shows the string programmed for Serial Poll response. For values, record a ^P (<cntl> p) character. Also see the SRQSTR command.

Response: <string>

Example: SRQSTR shows SRQ: %02x %02x %04x %04x\n

Shows the SPLSTR string format (default settings in this example).

---

**\*SRE** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Service Request Enable command) Puts a byte into the Service Request Enable (SRE) register. (See "Service Request Enable Register (SRE)" in Chapter 5. Since bit 6 is not used (decimal value 64), the maximum entry is 255 – 64 = 191.

Parameter: <value> (the decimal equivalent of the SRE byte, 0 to 191)

Example: \*SRE 56

Enable bits 3 (EAV), 4 (MAV), and 5 (ESR).

---

**\*SRE?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Service Request Enable query) Shows the byte in the Service Request Enable (SRE).

Response: <value> (the decimal equivalent of the SRE byte, 0 to 191)

Example: \*SRE? shows 56

Shows 56 when bits 3 (EAV), 4 (MAV), and 5 (ESR) are enabled.

---

**SRQSTR** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Service Request String command) Sets the Serial Mode SRQ (Service Request) response (up to 40 characters) in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to remote commands.) The SRQSTR is sent to the host over the serial interface when the SRQ line is asserted (terminal mode only). Default format is:

SRQ: %02x %02x %04x %04x

where the term %02x (8 bits) means print the value in hexadecimal with 2 hex digits, and %04x (16 bits) means print the value in hexadecimal with 4 hex digits. The string representations are:

SRQ: (STB) (ESR) (ISCR0) (ISCR1)

See the commands \*STB?, \*ESR?, ISCR0?, and ISCR1? A typical string in the default format sent to the host is: SRQ: 44 00 0000 1000. This command is for format. See the SPLSTR command for the serial poll response.

Parameter: "<string>\n" (\n represents the Line Feed character, hex 0A)

Example: SRQSTR "SRQ: %02x %02x %04x %04x\n"

Set the SRQSTR to the default values SRQ: %02x %02x %04x %04x\n.

---

**SRQSTR?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Service Request String query) Shows the string programmed for Serial Mode SRQ response. This is the format of the Service Request String; actual values come from the registers. Also see the SPLSTR command.

Response: <string>

Example: SRQSTR shows SRQ: %02x %02x %04x %04x\n

Shows the SRQSTR string format (default settings in this example).

---

**\*STB?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Status Byte Register query) Shows the byte for the Status Byte Register. (See "Status Byte Register (STB)" in Chapter 5.)

Response: <value> (the decimal equivalent of the STB byte, 0 to 255)

Example: \*STB? shows 72

Shows 72 if bits 3 (EAV) and 6 (MSS) are set.

---

**STBY** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Standby command) Deactivates the Calibrator output if it is in operate. This is the same as if you push the Calibrator front panel **STBY** key.

Parameter: (None)

Example: STBY

Disconnect the selected output from the Calibrator front panel terminals.

---

**TC\_MEAS** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Thermocouple Measure command) Selects the measure thermocouple mode.

Parameters: CEL (Celsius) (optional)  
FAR (Fahrenheit) (optional)

Example: TC\_MEAS CEL

Measure the thermocouple temperature that is attached to the Calibrator TC terminals, in Celsius.

---

**TC\_OFFSET** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Thermocouple Temperature Measurement Offset command) Adds a temperature offset to thermocouple measurements ( $\pm 500$  °C). This command does not apply to thermocouple sourcing.

Parameters: <value> CEL (offset in Celsius) (optional)  
<value> FAR (offset in Fahrenheit) (optional)

Example: TC\_OFFSET +10 CEL

Add a temperature offset of +10 °C to the thermocouple measurements.

---

**TC\_OFFSET?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Thermocouple Temperature Measurement Offset query) Shows the temperature offset used for thermocouple measurements ( $\pm 500$  °C).

Responses: <value> CEL (offset in Celsius) (optional)  
<value> FAR (offset in Fahrenheit) (optional)

Example: TC\_OFFSET? shows 1.000E+01, CEL

Shows 10 Celsius when a temperature offset of +10 °C has been added to the thermocouple measurements.

---

**TC\_OTCD** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Thermocouple Open Detection command) Activates or deactivates the open thermocouple detection circuit in thermocouple measurement mode. When set, the Calibrator keeps open thermocouple detection circuit setting until power off or reset.

Parameters: ON (turn on thermocouple detection circuit) (default)  
OFF (turn off thermocouple detection circuit)

Example: TC\_OTCD ON

Activate the open thermocouple detection circuit. If an open thermocouple is detected, this condition is shown on the front panel.

---

**TC\_OTCD?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Thermocouple Open Detection query) Shows the status of the open thermocouple detection circuit in thermocouple measurement mode.

Responses: ON (thermocouple detection circuit is on)  
OFF (thermocouple detection circuit is off)

Example: TC\_OTCD? shows ON

Shows ON when the open thermocouple detection circuit is activated.

---

**TC\_REF** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Thermocouple Reference command) Sets if the internal temperature sensor (INT) or an external reference value (EXT) is used for Thermocouple (TC) outputs and measurements. If the first parameter is EXT, the second parameter must be the temperature value to use as the reference for the thermocouple reference junction temperature. When set, the Calibrator keeps reference setting until power off or reset.

Parameters: INT  
EXT, <value of external reference> CEL (or FAR)

Example: TC\_REF EXT, 25.6 CEL

Set the thermocouple reference to external, with a value of 25.6 °C.

---

**TC\_REF?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Thermocouple Reference query) Shows the source and value of the temperature being used as a reference for thermocouple simulation and measurement (in Celsius, CEL, or Fahrenheit, FAR, depending on active units). The options are Internal reference (INT) or External reference (EXT).

If INT is shown, the reference temperature return is 0 unless you are in a thermocouple mode of operation and the Calibrator is in Operate.

Responses: INT, <value of reference temperature>,CEL (or FAR)  
EXT, <value of reference temperature>,CEL (or FAR)

Example: TC\_REF? shows INT, 2.988E+01, CEL

Shows Internal, 29.88, Celsius, when the thermocouple reference is internal and at 29.88 °C. (If the temperature return for the internal reference is 0 (0.00E+00), the Calibrator is not in Operate, and/or the Calibrator is not in a thermocouple mode.)

---

**TC\_TYPE** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Thermocouple Type command) Sets the Thermocouple (TC) temperature sensor type. The TC type is used when the output is set to a temperature value with the OUT command and the temperature sensor type is set to TC with the TSENS\_TYPE command. When the thermocouple type is changed while you simulate a temperature output, the temperature is changed to 0 °C. When set, the Calibrator keeps the TC type until power off or reset.

Parameters: B (B-type thermocouple)  
C (C-type thermocouple)  
E (E-type thermocouple)  
J (J-type thermocouple)  
K (K-type thermocouple) (default)  
N (N-type thermocouple)  
R (R-type thermocouple)  
S (S-type thermocouple)  
T (T-type thermocouple)  
X (10 µV/°C linear output)  
Y (% relative humidity)  
Z (1 mV/°C linear output)

Example: TC\_TYPE J

Set the thermocouple type to simulate a temperature output to a J-type thermocouple.

---

**TC\_TYPE?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Thermocouple Type query) Shows the Thermocouple (TC) temperature sensor type. When the thermocouple type is changed while you simulate a temperature output, the temperature is changed to 0 °C.

Responses:

|   |                                 |
|---|---------------------------------|
| B | (B-type thermocouple)           |
| C | (C-type thermocouple)           |
| E | (E-type thermocouple)           |
| J | (J-type thermocouple)           |
| K | (K-type thermocouple) (default) |
| N | (N-type thermocouple)           |
| R | (R-type thermocouple)           |
| S | (S-type thermocouple)           |
| T | (T-type thermocouple)           |
| X | (10 $\mu$ V/°C linear output)   |
| Y | (% relative humidity)           |
| Z | (1 mV/°C linear output)         |

Example: TC\_TYPE? shows K

Shows K when the thermocouple type to simulate a temperature output is a K-type thermocouple.

---

**TC\_TYPE\_D** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Thermocouple Type Default command) Sets the default thermocouple (TC) sensor type, which is kept in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to remote commands.) The TC type is set to the default at power on and reset.

Responses:

|   |                                 |
|---|---------------------------------|
| B | (B-type thermocouple)           |
| C | (C-type thermocouple)           |
| E | (E-type thermocouple)           |
| J | (J-type thermocouple)           |
| K | (K-type thermocouple) (default) |
| N | (N-type thermocouple)           |
| R | (R-type thermocouple)           |
| S | (S-type thermocouple)           |
| T | (T-type thermocouple)           |
| X | (10 $\mu$ V/°C linear output)   |
| Y | (% relative humidity)           |
| Z | (1 mV/°C linear output)         |

Example: TC\_TYPE\_D J

Set the thermocouple type default to a type-J thermocouple.

---

**TC\_TYPE\_D?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Thermocouple Type Default query) Shows the default thermocouple (TC) sensor type.

Responses: B (B-type thermocouple)  
C (C-type thermocouple)  
E (E-type thermocouple)  
J (J-type thermocouple)  
K (K-type thermocouple) (default)  
N (N-type thermocouple)  
R (R-type thermocouple)  
S (S-type thermocouple)  
T (T-type thermocouple)  
X (10  $\mu$ V/ $^{\circ}$ C linear output)  
Y (% relative humidity)  
Z (1 mV/ $^{\circ}$ C linear output)

Example: TC\_TYPE\_D? shows K

Shows K when the thermocouple type default is a type-K thermocouple.

---

**TEMP\_STD** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Temperature Degree Standard command) Selects the temperature standard IPTS -68 (1968 International Provisional Temperature Standard) or its-90 (1990 International Temperature Standard), which is kept in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to remote commands.) The default is its-90.

Parameters: IPTS\_68  
ITS\_90

Example: TEMP\_STD ITS\_90

See the temperature standard to ITS-90.

---

**TEMP\_STD?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Temperature Degree Standard command) Shows the temperature standard IPTS-68 (1968 International Provisional Temperature Standard) or ITS-90 (1990 International Temperature Standard).

Parameters: IPTS\_68  
ITS\_90

Example: TEMP\_STD? shows ITS\_90

Shows ITS\_90 when the temperature degree standard is the 1990 International Temperature Standard.

---

**\*TRG**   ☒ IEEE-488   ☒ RS-232   ☒ Sequential   ☐ Overlapped   ☐ Coupled

(Trigger Thermocouple Measurement command) Triggers a thermocouple temperature measurement and shows the value of the measurement. Also changes the operating mode to thermocouple measurement if this is not already the operating mode. (This command is equivalent to sending TC\_MEAS ; \*WAI ; VAL?)

Responses:   <measurement value>,CEL   (value is in Celsius)  
                   <measurement value>,FAR   (value is in Fahrenheit)  
                   0.00E+00, OVER   (value is over or under capability)  
                   0.00E+00, OPENTC   (open thermocouple)  
                   0.00E+00, NONE   (wrong mode or no measurement)

Example:   \*TRG shows +2.500E+01, CEL

Trigger a thermocouple measurement and return 25.00 Celsius when the thermocouple temperature measurement is 25 °C.

---

### **TSENS\_TYPE**

☒ IEEE-488   ☒ RS-232   ☐ Sequential   ☒ Overlapped   ☐ Coupled

(Temperature Sensor Type command) Sets the temperature sensor type to thermocouple (TC) or Resistance Temperature Detector (RTD) for temperature measurements. The Calibrator simulates the RTD temperature as a resistance output on the NORMAL terminals, and simulates the thermocouple temperature as a dc voltage output on the TC terminals. If the temperature sensor type is changed, the temperature output is reset to 0 degrees C. When set, the Calibrator keeps the temperature sensor type until power off or reset.

Parameters:   TC   (Thermocouple)  
                   RTD   (Resistance Temperature Detector)

Example:   TSENS\_TYPE RTD

Set the temperature sensor type to an RTD.

---

### **TSENS\_TYPE?**

☒ IEEE-488   ☒ RS-232   ☒ Sequential   ☐ Overlapped   ☐ Coupled

(Temperature Sensor Type query) Shows the temperature sensor type thermocouple (TC) or Resistance Temperature Detector (RTD) for temperature measurements.

Responses:   TC   (Thermocouple)  
                   RTD   (Resistance Temperature Detector)

Example:   TSENS\_TYPE? shows TC

Shows TC when the temperature sensor type is a thermocouple.

---

**\*TST?**   ☒ IEEE-488   ☒ RS-232   ☒ Sequential   ☐ Overlapped   ☐ Coupled

(Self Test command) Start self-test and shows a 0 for pass or a 1 for fail. If faults are found, they are shown on screen (terminal mode) or are logged into the fault queue where they can be read by the ERR? query (computer mode).

Response:   0 (pass self test)  
                   1 (fail self test)

Example:   \*TST? shows 1

Shows 0 when self test is successful.

---



**UNCERT?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Uncertainties command) Shows specified uncertainties for the current output. If there are no specifications for an output, shows zero.

Parameter: 1. (optional) Preferred unit of primary output uncertainty or PCT (default)  
2. (optional) Preferred unit of secondary output uncertainty or PCT (default)

Response: 1. (float) 90-day specified uncertainty of primary unit  
2. (float) 1-year specified uncertainty of primary output  
3. (character) Unit of primary output uncertainty  
4. (float) 90-day specified uncertainty of secondary unit  
5. (float) 1-year specified uncertainty of secondary output  
6. (character) Unit of secondary output uncertainty.

Example: UNCERT? shows 6.120E-01, 6.150E-01, PCT, 9.50E-02, 1.150E-01, PCT

---

**UUT\_FLUSH** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Flush UUT Receive Buffer command) Flushes the UUT receive buffer for data received from the UUT over the Calibrator rear panel SERIAL 2 TO UUT serial port. The command can be sent over GPIB or RS-232 ports, but applies to SERIAL 2 TO UUT serial port operation.

Parameter: (None)

Example: UUT\_FLUSH

Flush the Calibrator receive data buffer for the UUT.

---

**UUT\_RECV?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(UUT Receive Data query) Shows data from the UUT in IEEE-488.2 Standard format over the Calibrator rear panel SERIAL 2 TO UUT serial port. The command can be sent over GPIB or RS-232 ports, but applies to SERIAL 2 TO UUT serial port operation.

Response: <data> (binary block data in definite length format from UUT)

Example: UUT\_RECV? shows #211+1.99975E+0

Shows (for example) a measurement from the UUT. The format is #2 (two numbers follow) 11 (characters follow) +1.99975E+0 (11 characters).

---

**UUT\_RECVB?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(UUT Receive Binary Data query) Shows binary data as integers from the UUT serial port. Use the UUT\_RECV? command instead if receiving ASCII data.

Parameter: (Optional) Maximum number of integers per line

Response: (Indefinite ASCII) Comma separated integers as follows:

1. (integer) Number of data bytes shown that do not include the count
2. (integer) Data from the UUT serial port as series of comma separated integers

Example:    "=>" followed by a carriage return and a line feed shows 4,61,62,13,10

---

**UUT\_SEND**   ☒ IEEE-488   ☒ RS-232   ☒ Sequential   ☐ Overlapped   ☐ Coupled

(Send UUT Data command) Sends data to the UUT serial port in binary block or string data format over the Calibrator rear panel SERIAL 2 TO UUT serial port. The command can be sent over GPIB or RS-232 ports, but applies to SERIAL 2 TO UUT serial port operation. Include a line feed (RS-232) character to stop the block data or End or Identify (EOI) command (IEEE-488).

Parameter:    #2<nn><nn characters string>    (definite length)  
                   #0<character string>        (indefinite length)  
                   "<character string>"        (character string)

Examples:

UUT\_SEND #206F1S2R0            (definite length format)

Sends the data F1S2R0 to the UUT in definite length format. The format is #2 (two numbers follow) 06 (characters follow) F1S2R0 (6 characters).

UUT\_SEND #0F1S2R0 (indefinite length format)

Sends the data F1S2R0 to the UUT in indefinite length format. The format is #0 then the characters.

UUT\_SEND "F1S2R0" (character string)

Sends the data F1S2R0 to the UUT as a character string.

Special Case When the character string sent to a UUT must complete in a carriage return (CR) command or line feed (LF) command or both, you must use:

**Definite Length Format** Follow the instructions above and after the character string add a command ^J for CR or ^M for LF or both, where ^J means hold down the <Cntl> key and type the letter J. For example, if you send the string REMS in this format with both CR and LF, you can count 4 characters for REMS and 1 character each for ^J and ^M for a total of 6 characters. The command will be UUT\_SEND #206REMS^J^M then <enter>. (The ^J and ^M "characters" actually perform the CR and LF functions.)

**Indefinite Length Format** This format cannot be used when CR and LF commands are necessary for the character string.

**Character String** Follow the instructions above and after the character string, add a \n for CR or \r for LF or both, where the alpha character is recorded in lower case. For example, in the terminal mode to send the string REMS in this format with CR and LF, the command will be UUT\_SEND "REMS\n\r". In the computer mode where commands are recorded as part of a command string, use double quotes to show embedded quotes. For example, "uut\_send "REMS\n\r" " ".

The subsequent characters and commands can be implemented as described above:

|                 |     |    |
|-----------------|-----|----|
| Carriage Return | ^J  | \n |
| Line Feed       | ^M  | \r |
| Tab             | Tab | \t |
| Backspace       | ^H  | \b |
| Form Feed       | ^L  | \f |

---

---

**UUT\_SENDB** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Send UUT Binary Data command) Send binary data to the UUT serial port (Calibrator rear panel SERIAL 2 to UUT serial port). Use the UUT\_SEND command instead of sending ASCII data. The command can be sent over GPIB or RS-232 ports, but applies to SERIAL 2 TO UUT serial port operation.

Parameter: Comma separated integers to send (maximum of 10)

Example: UUT\_SENDB 42,73,68,78,63,10

Send the ASCII characters "\*IDN?" followed by a new line (ASCII 10) to the UUT serial port.

---

**UUT\_SET** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(UUT Serial Port Set command) Sets the RS-232-C settings for the Calibrator rear panel SERIAL 2 TO UUT serial port, which is kept in the Calibrator non-volatile memory. (While saving configuration data in the non-volatile memory, a period of about 2 seconds, the Calibrator does not respond to remote commands.) (To set the parameters for the rear panel SERIAL 1 FROM HOST serial port, see the SP\_SET command.) The factory default values are shown below in **BOLD** type. (To return to the factory defaults, see the FORMAT SETUP command.)

The interface selection sets the command response, with command echo back with TERM (terminal) and no echo back with COMP (computer).

Parameters:     <baud rate value>,     300, 600, 1200, 2400, 4800, **9600**  
                  <flow control>,     **XON** (xon/xoff), NOSTALL (none), RTS (rts/cts)  
                  <number data bits>,     DBIT7 (7 bits) or **DBIT8** (8 bits)  
                  <number stop bits>,     **SBIT1** (1 bit) or SBIT2 (2 bits)  
                  <parity>             **PNONE** (none), PODD (odd), PEVEN (even)

Example: UUT\_SET 9600,XON,DBIT8,SBIT1,PNONE

Set the parameters for the rear panel SERIAL 2 TO UUT serial port to the factory default values.

---

**UUT\_SET?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(UUT Serial Port Set query) Shows the RS-232-C settings for the Calibrator rear panel SERIAL 2 TO UUT serial port. (To return the parameters for the rear panel SERIAL 1 FROM HOST serial port, see the SP\_SET? command.) The factory default values are shown below in **BOLD** type. (To return to the factory defaults, see the FORMAT SETUP command.)

Responses:     <baud rate value>,     300, 600, 1200, 2400, 4800, **9600**  
                  <flow control>,     **XON** (xon/xoff), NOSTALL (none), RTS (rts/cts)  
                  <number data bits>,     DBIT7 (7 bits) or **DBIT8** (8 bits)  
                  <number stop bits>,     **SBIT1** (1 bit) or SBIT2 (2 bits)  
                  <parity>             **PNONE** (none), PODD (odd), PEVEN (even)

Example: UUT\_SET? shows 9600,XON,DBIT8,SBIT1,PNONE

Shows the parameters for the rear panel SERIAL 2 TO UUT serial port, as shown, when set to the factory default values.

---

**VAL?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Measurement Value command) Shows the last value of the thermocouple temperature or scope impedance measurement. The unit shows the status of the indication.

Parameter: (Optional) Units to return

Responses: 1. (Float) Measured temperature  
2. (Character) CEL, FAR, OHM, F,  
OVER (value is over or under capability),  
OPENTC (open thermocouple),  
or NONE (wrong mode or no measurement)

Example: VAL? shows 0.00E+00, NONE

Shows 0 and NONE when there is no recent measurement because the Calibrator is not in a measurement mode, or because no measurement was made.

---

**VVAL?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Thermocouple Measurement Voltage command) Shows the last value of the thermocouple temperature measurement in volts. If the last measurement was an overload or open thermocouple condition, or there is no measurement, shows 0E+00.

Responses: <measurement value in volts> (valid measurement)  
0E+00 (overload, open TC, or no measurement)

Example: VVAL? shows 1.1047E-03 (1.1047 mV, equivalent to 50 °C with type K thermocouple and TC reference = 23.0 °C)

---

**\*WAI** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Wait-to-Continue command) Prevents more remote commands from being done until all previous remote commands have been done. For example, if you send an OUT command, you can cause the Calibrator to pause until the output has become stable before you continue on to the subsequent command if you follow OUT with a \*WAI command. The \*WAI command is useful with overlapped command. This prevents the Calibrator from processing other commands until the overlapped command is processed.

Example: \*WAI

Process all commands that exist before you continue.

---

**WAVE** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☒ Coupled

(Waveform command) Sets the waveforms for ac outputs. If the Calibrator is sourcing one output, one parameter is necessary. If the Calibrator is sourcing two outputs, two parameters are necessary or one parameter to set the waveform to the two outputs. Waveform selections are SINE (sine wave), TRI (triangle wave), SQUARE (square wave), TRUNCS (truncated sine wave), or NONE (waveform does not apply).

Parameter: <1st waveform> , (SINE, TRI, SQUARE, TRUNCS, NONE)  
<2nd waveform> (SINE, TRI, SQUARE, TRUNCS, NONE)

Example: WAVE SINE, SQUARE

Set the waveforms for a dual output to Sine wave on the primary output (Calibrator front panel NORMAL terminals) and Square wave on the secondary output (front panel AUX or 20A terminals).

---

**WAVE?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Waveform query) Shows the waveform types for ac outputs. Waveform selections are SINE (sine wave), TRI (triangle wave), SQUARE (square wave), TRUNCS (truncated sine wave), or NONE (waveform does not apply).

Responses: <1st waveform> , (SINE, TRI, SQUARE, TRUNCS, NONE)  
<2nd waveform> (SINE, TRI, SQUARE, TRUNCS, NONE)

Example: WAVE? shows SQUARE, NONE

Shows SQUARE when the ac primary output (Calibrator front panel NORMAL terminals) is a square wave and NONE when there is no secondary output on the front panel AUX terminals.

---

**ZCOMP** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

(Impedance Compensation command) Activates or deactivates 2-wire or 4-wire impedance compensation. For resistance output, compensation is permitted when the resistance is less than 110 k $\Omega$ . For capacitance output, compensation is permitted when the capacitance is equal to or larger than 110 nF. For all other resistances and capacitances, the compensation is NONE and tries to use other parameters results in the error message "Can't change compensation now." For RTD temperature simulation, compensation is permitted for all temperatures.

Parameter: NONE (Turns off impedance compensation circuitry)  
WIRE2 (Turns on the 2-wire impedance compensation circuitry)  
WIRE4 (Turns on the 4-wire impedance compensation circuitry)

Example: ZCOMP WIRE2

Set 2-wire impedance compensation for the Calibrator UUT connection. (Resistance if the ohms value is less than 110 k $\Omega$ , capacitance if the farads value is 110 nF or more, or RTD temperature simulation, any value.)

---

**ZCOMP?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

(Impedance Compensation query) Shows status of 2-wire or 4-wire impedance compensation.

Responses: NONE (impedance compensation is turns off)  
WIRE2 (2-wire impedance compensation is on)  
WIRE4 (4-wire impedance compensation is off)

Example: ZCOMP? shows NONE

Shows NONE when no impedance compensation is applied to the resistance, capacitance or RTD output.

---

**ZERO\_MEAS** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

Sets the zero offset for capacitance measurement with the -SC600.

Parameter: 1. (boolean) ON  
(boolean) OFF

Example: ZERO\_MEAS ON

Sets the zero offset to the current measurement value.

---

**ZERO\_MEAS?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

Shows the zero offset for capacitance measurements with the -SC600.

Parameter: (None)

Responses: 1. (character) OFF (no zero in effect)  
(character) ON (zero in effect)  
2. (float) offset value  
3. (character) units (F)

Example: ZERO\_MEAS? shows ON, -3.66E-02, F

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## **Chapter 7**

# ***Maintenance***

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## Introduction

This chapter tells you how to do the usual maintenance and calibration tasks necessary to keep the 5502A Calibrator in service.

See the Service Manual for intensive maintenance tasks like troubleshooting, calibration or repair, and all procedures where it is necessary to open the Calibrator cover. The Service Manual also has complete verification and calibration procedures.

### **Warning**

**To prevent possible electrical shock, fire, or personal injury:**

- **Turn the Product off and remove the mains power cord. Stop for two minutes to let the power assemblies discharge before you open the fuse door.**
- **Replace a blown fuse with exact replacement only for continued protection against arc flash.**
- **Disconnect the mains power cord before you remove the Product covers.**
- **Use only specified replacement parts.**
- **Use only specified replacement fuses.**
- **Have an approved technician repair the Product.**

## Replace the Mains Power Fuse

### **Warning**

**To prevent possible electrical shock, fire, or personal injury, replace a blown fuse with exact replacement only for continued protection against arc flash.**

Access the line-power fuse on the rear panel. The fuse rating is 5 A/250 V slow blow fuse when the Calibrator is set to 100 V/120 V line voltage, 2.5 A/250 V slow blow when the Calibrator is set to 220 V/240 V line voltage. Fuses that are not user replaceable are shown in the “Maintenance” section of Chapter 7.

To examine or replace the fuse, see Figure 7-1 and continue as follows:

1. **Disconnect line power.**
2. Open the fuse compartment. Put a screwdriver blade into tab on the left side of the compartment and carefully pry until it can be removed with the fingers.
3. Remove the fuse from the compartment for replacement or verification. Be sure the correct fuse is installed.
4. Put the fuse compartment into the Calibrator. Push it into position until the tab locks.

## Replace the Line Fuse

Access the line power fuse from the rear panel. The fuse rating information above the ac power input module shows the correct replacement fuse for each line voltage setting. Table 7-1 shows the fuse part numbers for each line voltage setting.

To verify or replace the fuse, refer to Figure 7-1 and do the subsequent steps:

1. **Disconnect line power.**
2. The line power fuse and line voltage switch are in a compartment on the right end of the ac input module. To open the compartment and remove the fuse, put the blade of a standard screwdriver to the left of the tab at the left side of the compartment cover.
3. Pull the tab out of the slot and the compartment cover will come part way out.
4. Remove the compartment cover.
5. The fuse comes out with the compartment cover and can be easily replaced.

To install the fuse, push the compartment cover back into the compartment until the tab locks with the ac input module.

**Table 7-1. Replacement Line Fuses**

| Part Number                                                                                                                       | Fuse Description      | Line Voltage Setting |
|-----------------------------------------------------------------------------------------------------------------------------------|-----------------------|----------------------|
|  109215                                          | 5A/250 V Time Delay   | 100 V or 120 V       |
|  851931                                         | 2.5A/250 V Time Delay | 200 V or 240 V       |
|  To ensure safety, use exact replacement only. |                       |                      |

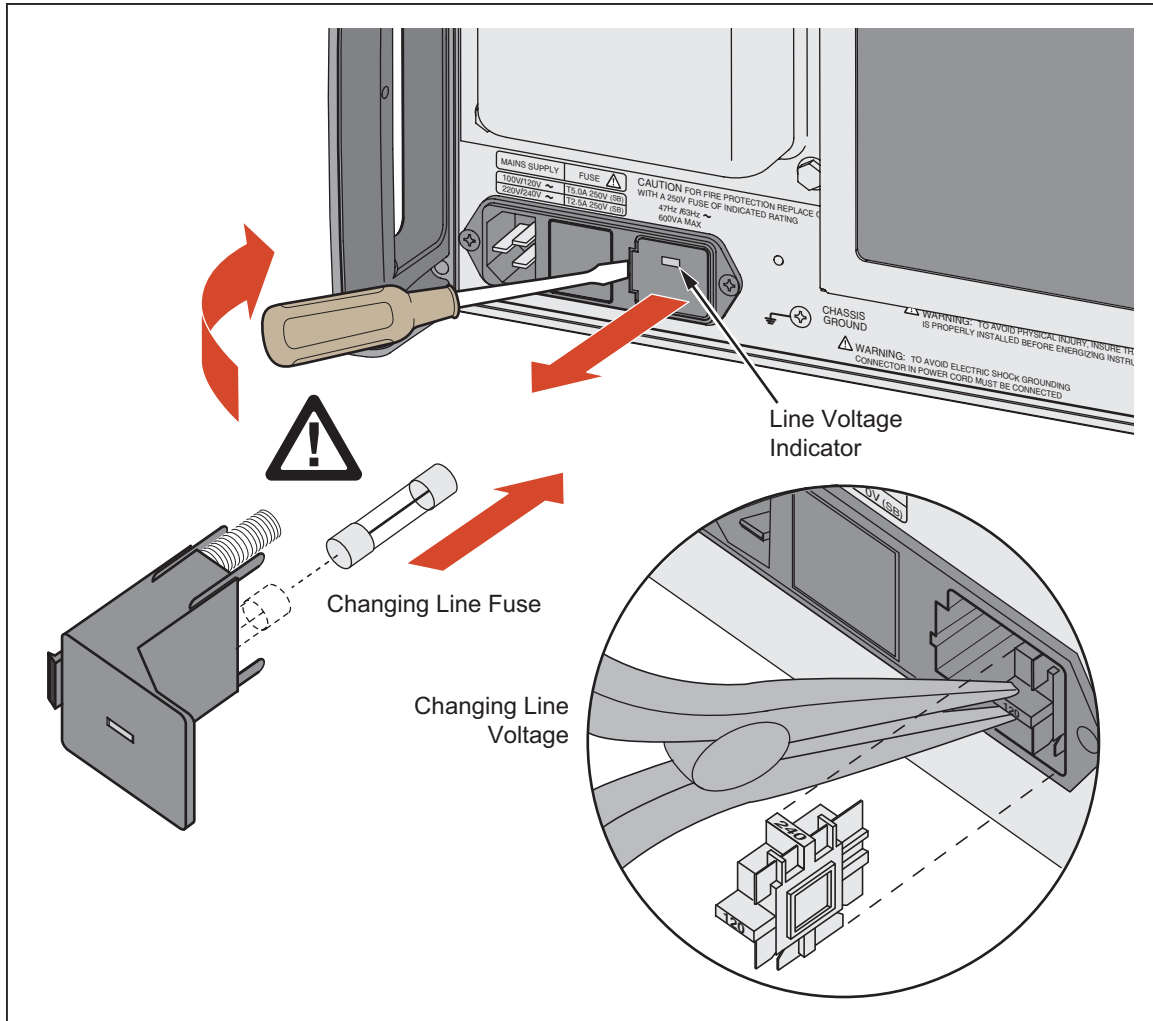


Figure 7-1. Accessing the Fuse

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Replace the Current Fuses

⚠⚠ Warning

To prevent possible electrical shock, fire, or personal injury:

- Replace a blown fuse with exact replacement only for continued protection against arc flash.
- Disconnect the mains power cord before you remove the bottom fuse cover.
- Use only specified replacement fuses.
- Have an approved technician repair the Product.

Access the current fuses from the bottom of the Calibrator. These fuses are the 3A and 20A outputs protection from over-current. Table 7-2 shows the fuse part numbers for the two current fuses. To replace a current fuse:

1. Turn the Calibrator over on its top.
2. Remove the two screws with a Phillips head screwdriver as shown in Figure 7-2.

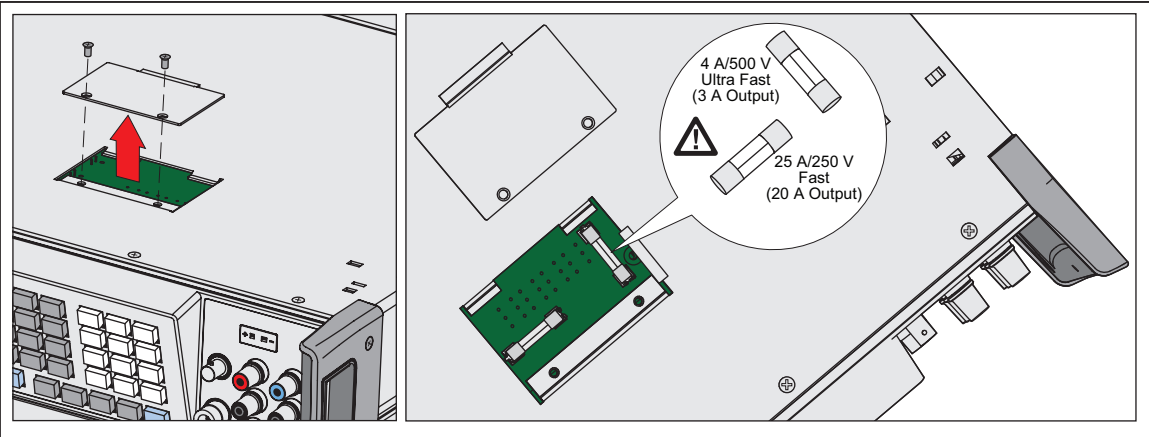


Figure 7-2. Current Fuse Replacement

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3. Lift off the fuse door.
4. Remove the fuse and replace it with a new fuse of the same rating.

Table 7-2. Replacement Current Fuses

| Part Number | Fuse Description    |
|-------------|---------------------|
| 3674001     | 4A/500 V Ultra Fast |
| 3470596     | 25A/250 V Fast      |

⚠ To ensure safety, use exact replacement only.

5. Replace the fuse door over the fuse compartment.
6. Install the two screws to hold the fuse door in position.

## Clean the Air Filter

The air filter must be removed and cleaned each 30 days or more frequently if the calibrator is operated in a dusty environment. The air filter is accessed from the rear panel of the calibrator.

To clean the air filter, refer to Figure 7-3 and continue as follows:

1. Turn off the power, let the fan stop, and disconnect the ac line cord.
2. Remove the filter element.
  - a. Hold the top and bottom of the air filter frame.
  - b. Squeeze the edges of the frame to the middle to disengage the filter tabs from the slots in the calibrator.
  - c. Pull the filter frame straight out from the calibrator.
3. Clean the filter element.
  - a. Clean the filter element in soapy water.
  - b. Flush the filter element.
  - c. Shake out the unwanted water, and then let the filter element to dry before you install it.
4. Install the filter element. Do the filter removal steps in reverse.

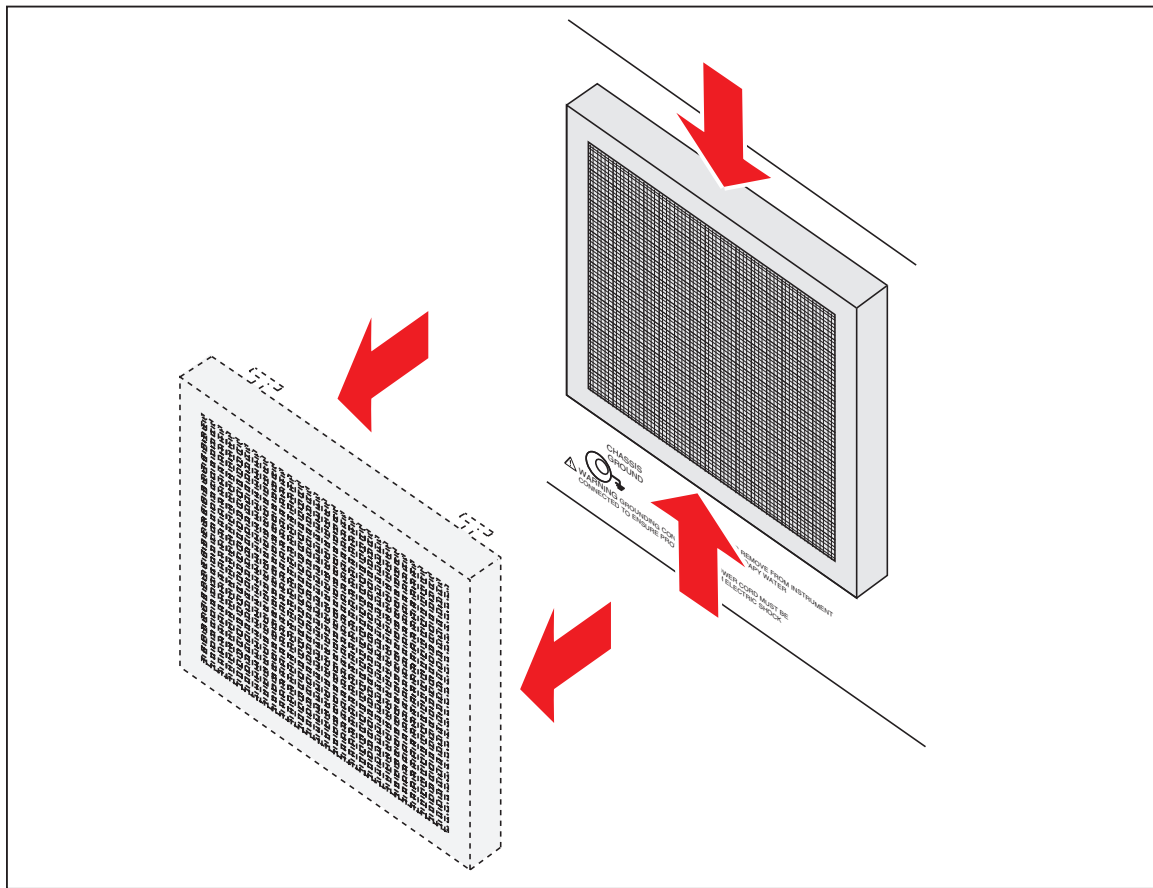


**Figure 7-3. Access the Air Filter**

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## Clean the Calibrator

Clean the case, front panel keys, and display with a soft cloth dampened with water or a non-abrasive weak cleaning solution that will not harm plastics.

### Caution

**Do not use aromatic hydrocarbons or chlorinated solvents for cleaning. They can damage the plastic materials used in the calibrator.**

## Performance Tests

To make sure that the Product is in specification, use Tables 7-3 through 7-15. The tables are for approved metrology personnel who have access to a standards laboratory that has the correct equipment to test calibration equipment of this level of accuracy. The tables show the recommended test points and the permitted maximum and lower limits for each point. The limits were calculated by adding or subtracting the 90-day specification from the output value. There is no built-in factor for measurement uncertainty.

**Table 7-3. Verification Tests for DC Voltage (Normal)**

| Range       | Output       | Lower Limit  | Upper Limit  |
|-------------|--------------|--------------|--------------|
| 329.9999 mV | 0.0000 mV    | -0.0030 mV   | 0.0030 mV    |
| 329.9999 mV | 329.0000 mV  | 328.9805 mV  | 329.0194 mV  |
| 329.9999 mV | -329.0000 mV | -329.0194 mV | -328.9805 mV |
| 3.299999 V  | 0.000000 V   | -0.000005 V  | 0.000005 V   |
| 3.299999 V  | 1.000000 V   | 0.9999855 V  | 1.000045 V   |
| 3.299999 V  | -1.000000 V  | -1.000045 V  | -0.999955 V  |
| 3.299999 V  | 3.290000 V   | 3.2899863 V  | 3.290136 V   |
| 3.299999 V  | -3.290000 V  | -3.290136 V  | -3.2898638 V |
| 32.99999 V  | 0.00000 V    | -0.00005 V   | 0.00005 V    |
| 32.99999 V  | 10.00000 V   | 9.99955 V    | 10.00045 V   |
| 32.99999 V  | -10.00000 V  | -10.00045 V  | -9.99955 V   |
| 32.99999 V  | 32.90000 V   | 32.89863 V   | -32.90136 V  |
| 32.99999 V  | -32.90000 V  | 32.90136 V   | -32.89863 V  |
| 329.9999 V  | 50.0000 V    | 49.9972 V    | 50.0027 V    |
| 329.9999 V  | 329.0000 V   | 328.9846 V   | 329.0153 V   |
| 329.9999 V  | -50.0000 V   | -50.0027 V   | -49.9972 V   |
| 329.9999 V  | -329.0000 V  | -329.0153 V  | -328.9846 V  |
| 1000.000 V  | 334.000 V    | 333.983 V    | 334.016 V    |
| 1000.000 V  | 900.000 V    | 899.958 V    | 900.042 V    |
| 1000.000 V  | 1020.000 V   | 1019.952 V   | 1020.047 V   |
| 1000.000 V  | -334.000 V   | -334.016V    | -333.983 V   |
| 1000.000 V  | -900.000 V   | -900.042 V   | -899.958 V   |
| 1000.000 V  | -1020.000 V  | -1020.047 V  | -1019.952 V  |

**Table 7-4. Verification Tests for DC Voltage (AUX)**

| Range      | Output      | Lower Limit | Upper Limit |
|------------|-------------|-------------|-------------|
| 329.999 mV | 0.000 mV    | -0.350 mV   | 0.350 mV    |
| 329.999 mV | 329.000 mV  | 328.551 mV  | 329.449 mV  |
| 329.999 mV | -329.000 mV | -329.449 mV | -328.551 mV |
| 3.29999 V  | 0.33000 V   | 0.32955 V   | 0.33045 V   |
| 3.29999 V  | 3.29000 V   | 3.28866 V   | 3.29134 V   |
| 3.29999 V  | -3.29000 V  | -3.29134 V  | -3.28866 V  |
| 7.0000 V   | 7.0000 V    | 6.9976 V    | 7.0025 V    |
| 7.0000 V   | -7.0000 V   | -7.0025 V   | -6.9976 V   |

**Table 7-5. Verification Tests for DC Current (AUX)**

| Range           | Output           | Lower Limit      | Upper Limit      |
|-----------------|------------------|------------------|------------------|
| 329.999 $\mu$ A | 0.000 $\mu$ A    | -0.020 $\mu$ A   | 0.020 $\mu$ A    |
| 329.999 $\mu$ A | 190.000 $\mu$ A  | 189.957 $\mu$ A  | 190.043 $\mu$ A  |
| 329.999 $\mu$ A | -190.000 $\mu$ A | -190.043 $\mu$ A | -189.957 $\mu$ A |
| 329.999 $\mu$ A | 329.000 $\mu$ A  | 328.941 $\mu$ A  | 329.059 $\mu$ A  |
| 329.999 $\mu$ A | -329.000 $\mu$ A | -329.059 $\mu$ A | -328.941 $\mu$ A |
| 3.29999 mA      | 0.00000 mA       | -0.00005 mA      | 0.00005 mA       |
| 3.29999 mA      | 1.90000 mA       | 1.89976 mA       | 1.90024 mA       |
| 3.29999 mA      | -1.90000 mA      | -1.90020 mA      | -1.89980 mA      |
| 3.29999 mA      | 3.29000 mA       | 3.28969 mA       | 3.29031 mA       |
| 3.29999 mA      | -3.29000 mA      | -3.29031 mA      | -3.28969 mA      |
| 32.9999 mA      | 0.0000 mA        | -0.00025 mA      | 0.00025 mA       |
| 32.9999 mA      | 19.0000 mA       | 18.9982 mA       | 19.0018 mA       |
| 32.9999 mA      | -19.0000 mA      | -19.0018 mA      | -18.9982 mA      |
| 32.9999 mA      | 32.9000 mA       | 32.8971 mA       | 32.9029 mA       |
| 32.9999 mA      | -32.9000 mA      | -32.9029 mA      | -32.8971 mA      |
| 329.999 mA      | 0.000 mA         | -0.0033 mA       | 0.0033 mA        |
| 329.999 mA      | 190.000 mA       | 189.982 mA       | 190.018 mA       |
| 329.999 mA      | -190.000 mA      | -190.018 mA      | -189.982 mA      |
| 329.999 mA      | 329.000 mA       | 328.971 mA       | 329.029 mA       |
| 329.999 mA      | -329.000 mA      | -329.029 mA      | -328.971 mA      |
| 2.99999 A       | 0.00000 A        | -0.00004 A       | 0.00004 A        |

Table 7-5. Verification Tests for DC Current (AUX) (cont.)

| Range     | Output     | Lower Limit | Upper Limit |
|-----------|------------|-------------|-------------|
| 2.99999 A | 1.09000 A  | 1.08979 A   | 1.09021 A   |
| 2.99999 A | -1.09000 A | -1.09021 A  | -1.08962 A  |
| 2.99999 A | 2.99000 A  | 2.98906 A   | 2.99094 A   |
| 2.99999 A | -2.99000 A | -2.99094 A  | -2.98906 A  |
| 20.5000 A | 0.0000 A   | -0.0005 A   | 0.0005 A    |
| 20.5000 A | 11.0000 A  | 10.9953 A   | 11.0046 A   |
| 20.5000 A | -11.0000 A | -11.0046 A  | 10.9953 A   |
| 20.5000 A | 20.0000 A  | 19.9833 A   | 20.0168 A   |
| 20.5000 A | -20.0000 A | -20.0168 A  | -19.9833 A  |

Table 7-6. Verification Tests for Resistance

| Range              | Output             | Lower Limit         | Upper Limit         |
|--------------------|--------------------|---------------------|---------------------|
| 10.999 $\Omega$    | 0.000 $\Omega$     | -0.0010 $\Omega$    | 0.0010 $\Omega$     |
| 10.999 $\Omega$    | 2.000 $\Omega$     | 1.9989 $\Omega$     | 2.0011 $\Omega$     |
| 10.999 $\Omega$    | 10.900 $\Omega$    | 10.8980 $\Omega$    | 10.9019 $\Omega$    |
| 32.999 $\Omega$    | 11.900 $\Omega$    | 11.8974 $\Omega$    | 11.9025 $\Omega$    |
| 32.999 $\Omega$    | 19.000 $\Omega$    | 18.9967 $\Omega$    | 19.0032 $\Omega$    |
| 32.999 $\Omega$    | 30.000 $\Omega$    | 29.9958 $\Omega$    | 30.0042 $\Omega$    |
| 109.999 $\Omega$   | 33.000 $\Omega$    | 32.9962 $\Omega$    | 33.0037 $\Omega$    |
| 109.999 $\Omega$   | 109.000 $\Omega$   | 108.9909 $\Omega$   | 109.0090 $\Omega$   |
| 329.999 $\Omega$   | 119.000 $\Omega$   | 118.9896 $\Omega$   | 119.0103 $\Omega$   |
| 329.999 $\Omega$   | 190.000 $\Omega$   | 189.9847 $\Omega$   | 190.0153 $\Omega$   |
| 329.999 $\Omega$   | 300.000 $\Omega$   | 299.9770 $\Omega$   | 300.0230 $\Omega$   |
| 1.09999 k $\Omega$ | 0.33000 k $\Omega$ | 0.329749 k $\Omega$ | 0.330251 k $\Omega$ |
| 1.09999 k $\Omega$ | 1.09000 k $\Omega$ | 1.089921 k $\Omega$ | 1.090078 k $\Omega$ |
| 3.29999 k $\Omega$ | 1.19000 k $\Omega$ | 1.189896 k $\Omega$ | 1.190103 k $\Omega$ |
| 3.29999 k $\Omega$ | 1.9000 k $\Omega$  | 1.899847 k $\Omega$ | 1.900153 k $\Omega$ |
| 3.29999 k $\Omega$ | 3.00000 k $\Omega$ | 2.999770 k $\Omega$ | 3.000230 k $\Omega$ |
| 10.9999 k $\Omega$ | 3.3000 k $\Omega$  | 3.29974 k $\Omega$  | 3.30025 k $\Omega$  |
| 10.9999 k $\Omega$ | 10.9000 k $\Omega$ | 10.89921 k $\Omega$ | 10.90078 k $\Omega$ |
| 32.9999 k $\Omega$ | 11.9000 k $\Omega$ | 11.89896 k $\Omega$ | 11.90103 k $\Omega$ |
| 32.9999 k $\Omega$ | 19.0000 k $\Omega$ | 18.99847 k $\Omega$ | 19.00153 k $\Omega$ |
| 32.9999 k $\Omega$ | 30.0000 k $\Omega$ | 29.99977 k $\Omega$ | 30.00230 k $\Omega$ |



**Table 7-6. Verification Tests for Resistance (cont.)**

| Range              | Output             | Lower Limit         | Upper Limit         |
|--------------------|--------------------|---------------------|---------------------|
| 109.999 k $\Omega$ | 33.000 k $\Omega$  | 32.9971 k $\Omega$  | 33.0028 k $\Omega$  |
| 109.999 k $\Omega$ | 109.000 k $\Omega$ | 108.9910 k $\Omega$ | 109.0089 k $\Omega$ |
| 329.999 k $\Omega$ | 119.000 k $\Omega$ | 118.9872 k $\Omega$ | 119.0127 k $\Omega$ |
| 329.999 k $\Omega$ | 190.000 k $\Omega$ | 189.9809 k $\Omega$ | 190.0191 k $\Omega$ |
| 329.999 k $\Omega$ | 300.000 k $\Omega$ | 299.9710 k $\Omega$ | 300.0290 k $\Omega$ |
| 1.09999 M $\Omega$ | 0.33000 M $\Omega$ | 0.329961 M $\Omega$ | 0.330038 M $\Omega$ |
| 1.09999 M $\Omega$ | 1.09000 M $\Omega$ | 1.089878 M $\Omega$ | 1.090121 M $\Omega$ |
| 3.29999 M $\Omega$ | 1.19000 M $\Omega$ | 1.189839 M $\Omega$ | 1.190160 M $\Omega$ |
| 3.29999 M $\Omega$ | 1.90000 M $\Omega$ | 1.899761 M $\Omega$ | 1.900239 M $\Omega$ |
| 3.29999 M $\Omega$ | 3.00000 M $\Omega$ | 2.999640 M $\Omega$ | 3.000360 M $\Omega$ |
| 10.9999 M $\Omega$ | 3.3000 M $\Omega$  | 3.29846 M $\Omega$  | 3.30153 M $\Omega$  |
| 10.9999 M $\Omega$ | 10.9000 M $\Omega$ | 10.89504 M $\Omega$ | 10.90495 M $\Omega$ |
| 32.9999 M $\Omega$ | 11.9000 M $\Omega$ | 11.88857 M $\Omega$ | 11.91142 M $\Omega$ |
| 32.9999 M $\Omega$ | 19.0000 M $\Omega$ | 18.98325 M $\Omega$ | 19.01675 M $\Omega$ |
| 32.9999 M $\Omega$ | 30.0000 M $\Omega$ | 29.99750 M $\Omega$ | 30.02500 M $\Omega$ |
| 109.999 M $\Omega$ | 33.000 M $\Omega$  | 32.8650 M $\Omega$  | 33.1350 M $\Omega$  |
| 109.999 M $\Omega$ | 109.000 M $\Omega$ | 108.5610 M $\Omega$ | 109.4390 M $\Omega$ |
| 329.999 M $\Omega$ | 119.000 M $\Omega$ | 118.4240 M $\Omega$ | 119.5760 M $\Omega$ |
| 329.999 M $\Omega$ | 290.000 M $\Omega$ | 288.7400 M $\Omega$ | 291.2600 M $\Omega$ |
| 1100.00 M $\Omega$ | 400.00 M $\Omega$  | 394.700 M $\Omega$  | 405.300 M $\Omega$  |
| 1100.00 M $\Omega$ | 640.00 M $\Omega$  | 631.820 M $\Omega$  | 648.180 M $\Omega$  |
| 1100.00 M $\Omega$ | 1090.00 M $\Omega$ | 1076.420 M $\Omega$ | 1103.580 M $\Omega$ |

**Table 7-7. Verification Tests for AC Voltage (Normal)**

| Range     | Output    | Frequency | Lower Limit | Upper Limit |
|-----------|-----------|-----------|-------------|-------------|
| 32.999 mV | 3.000 mV  | 45 Hz     | 2.977 mV    | 3.022 mV    |
| 32.999 mV | 3.000 mV  | 10 kHz    | 2.977 mV    | 3.022 mV    |
| 32.999 mV | 30.000 mV | 9.5 Hz    | 28.350 mV   | 31.650 mV,  |
| 32.999 mV | 30.000 mV | 10 Hz     | 29.944 mV   | 30.056 mV   |
| 32.999 mV | 30.000 mV | 45 Hz     | 29.956 mV   | 30.044 mV   |
| 32.999 mV | 30.000 mV | 1 kHz     | 29.956 mV   | 30.044 mV   |
| 32.999 mV | 30.000 mV | 10 kHz    | 29.956 mV   | 30.044 mV   |
| 32.999 mV | 30.000 mV | 20 kHz    | 29.944 mV   | 30.056 mV   |

Table 7-7. Verification Tests for AC Voltage (Normal) (cont.)

| Range      | Output     | Frequency | Lower Limit            | Upper Limit |
|------------|------------|-----------|------------------------|-------------|
| 32.999 mV  | 30.000 mV  | 50 kHz    | 29.932 mV              | 30.068 mV   |
| 32.999 mV  | 30.000 mV  | 100 kHz   | 29.877 mV              | 30.123 mV   |
| 32.999 mV  | 30.000 mV  | 450 kHz   | 29.715 mV              | 30.285 mV   |
| 329.999 mV | 33.000 mV  | 45 Hz     | 32.970 mV              | 33.029 mV   |
| 329.999 mV | 33.000 mV  | 10 kHz    | 32.970 mV              | 33.029 mV   |
| 329.999 mV | 300.000 mV | 9.5 Hz    | 283.350 mV             | 316.650 mV  |
| 329.999 mV | 300.000 mV | 10 Hz     | 299.917 mV             | 300.083 mV  |
| 329.999 mV | 300.000 mV | 45 Hz     | 299.893 mV             | 300.107 mV  |
| 329.999 mV | 300.000 mV | 1 kHz     | 299.983 mV             | 300.107 mV  |
| 329.999 mV | 300.000 mV | 10 kHz    | 299.983 mV             | 300.107 mV  |
| 329.999 mV | 300.000 mV | 20 kHz    | 299.782 mV             | 300.218 mV  |
| 329.999 mV | 300.000 mV | 50 kHz    | 299.702 mV             | 300.298 mV  |
| 329.999 mV | 300.000 mV | 100 kHz   | 299.311 mV             | 300.689 mV  |
| 329.999 mV | 300.000 mV | 500 kHz   | 298.470 mV             | 301.530 mV  |
| 3.29999 V  | 0.33000 V  | 45 Hz     | 0.32984 V              | 0.33015 V   |
| 3.29999 V  | 0.33000 V  | 10 kHz    | 0.32984 V              | 0.33015V    |
| 3.29999 V  | 3.00000 V  | 9.5 Hz    | 2.83500 V              | 3.16500 V   |
| 3.29999 V  | 3.00000 V  | 10 Hz     | 2.99868 V              | 3.00132 V   |
| 3.29999 V  | 3.00000 V  | 45 Hz     | 2.99910 V              | 3.00090 V   |
| 3.29999 V  | 3.00000 V  | 1 kHz     | 2.99910V               | 3.00090 V   |
| 3.29999 V  | 3.00000 V  | 10 kHz    | 2.99910 V              | 3.00090 V   |
| 3.29999 V  | 3.00000 V  | 20 kHz    | 2.99817 V              | 3.00183 V   |
| 3.29999 V  | 3.00000 V  | 50 kHz    | 2.99745 V              | 3.00255 V   |
| 3.29999 V  | 3.00000 V  | 100 kHz   | 2.99437 V              | 3.00563V    |
| 3.29999 V  | 3.00000 V  | 450 kHz   | 2.98659 V              | 3.01340 V   |
| 3.29999 V  | 3.29000 V  | 1 MHz     | 2.250 V <sup>[1]</sup> |             |
| 32.9999 V  | 3.3000 V   | 45 Hz     | 3.2985 V               | 3.3014 V    |
| 32.9999 V  | 3.3000 V   | 10 kHz    | 3.2985 V               | 3.3014 V    |
| 32.9999 V  | 30.0000 V  | 9.5 Hz    | 28.3500 V              | 31.6500 V   |
| 32.9999 V  | 30.0000 V  | 10 Hz     | 29.9866 V              | 30.0134V    |
| 32.9999 V  | 30.0000 V  | 45 Hz     | 29.9919 V              | 30.0081 V   |
| 32.9999 V  | 30.0000 V  | 1 kHz     | 29.9919 V              | 30.0081 V   |
| 32.9999 V  | 30.0000 V  | 10 kHz    | 29.9919 V              | 30.0081 V   |

**Table 7-7. Verification Tests for AC Voltage (Normal) (cont.)**

| Range                                        | Output    | Frequency | Lower Limit | Upper Limit |
|----------------------------------------------|-----------|-----------|-------------|-------------|
| 32.9999 V                                    | 30.0000 V | 20 kHz    | 29.9802 V   | 30.0198 V   |
| 32.9999 V                                    | 30.0000 V | 50 kHz    | 29.9736 V   | 30.0264 V   |
| 32.9999 V                                    | 30.0000 V | 90 kHz    | 29.9404 V   | 30.0596 V   |
| 329.999 V                                    | 33.000 V  | 45 Hz     | 32.984 V    | 33.015 V    |
| 329.999 V                                    | 33.000 V  | 10 kHz    | 32.969 V    | 33.030V     |
| 329.999 V                                    | 300.000 V | 45 Hz     | 299.880 V   | 300.120 V   |
| 329.999 V                                    | 300.000 V | 1 kHz     | 299.880 V   | 300.120 V   |
| 329.999 V                                    | 300.000 V | 10 kHz    | 299.799 V   | 300.201 V   |
| 329.999 V                                    | 300.000 V | 18 kHz    | 299.754 V   | 300.246 V   |
| 329.999 V                                    | 300.000 V | 50 kHz    | 299.703 V   | 300.297 V   |
| 329.999 V                                    | 200.000 V | 100 kHz   | 199.536 V   | 200.464 V   |
| 1020.00 V                                    | 330.00 V  | 45 Hz     | 329.84 V    | 330.15 V    |
| 1020.00 V                                    | 330.00 V  | 10 kHz    | 329.73 V    | 330.26 V    |
| 1020.00 V                                    | 1000.00V  | 45 Hz     | 999.56 V    | 1000.44 V   |
| 1020.00 V                                    | 1000.00 V | 1 kHz     | 999.56 V    | 1000.44 V   |
| 1020.00 V                                    | 1000.00 V | 5 kHz     | 999.349 V   | 1000.66 V   |
| 1020.00 V                                    | 1000.00 V | 8 kHz     | 999.23 V    | 1000.77 V   |
| 1020.00 V                                    | 1020.00 V | 1 kHz     | 1019.55 V   | 1020.44 V   |
| 1020.00 V                                    | 1020.00 V | 8 kHz     | 1019.21 V   | 1020.78 V   |
| [1] Typical specification is -24 dB at 2 MHz |           |           |             |             |

**Table 7-8. Verification Tests for AC Voltage (AUX)**

| Range      | Output, AUX <sup>[1]</sup> | Frequency | Lower Limit | Upper Limit |
|------------|----------------------------|-----------|-------------|-------------|
| 329.999 mV | 10.000 mV                  | 45 Hz     | 9.622 mV    | 10.378 mV   |
| 329.999 mV | 10.000 mV                  | 1 kHz     | 9.622 mV    | 10.378 mV   |
| 329.999 mV | 10.000 mV                  | 5 kHz     | 9.535 mV    | 10.465 mV   |
| 329.999 mV | 10.000 mV                  | 10 kHz    | 9.520 mV    | 10.480 mV   |
| 329.999 mV | 10.000 mV                  | 30 kHz    | 8.700 mV    | 11.300 mV   |
| 329.999 mV | 300.000 mV                 | 9.5 Hz    | 283.500 mV  | 316.500 mV  |
| 329.999 mV | 300.000 mV                 | 10 Hz     | 299.180 mV  | 300.820 mV  |
| 329.999 mV | 300.000 mV                 | 45 Hz     | 299.390 mV  | 300.610 mV  |
| 329.999 mV | 300.000 mV                 | 1 kHz     | 299.390 mV  | 300.610 mV  |
| 329.999 mV | 300.000 mV                 | 5 kHz     | 299.100 mV  | 300.900 mV  |
| 329.999 mV | 300.000 mV                 | 10 kHz    | 298.650 mV  | 301.350 mV  |

Table 7-8. Verification Tests for AC Voltage (AUX) (cont.)

| Range                                | Output, AUX <sup>[1]</sup> | Frequency | Lower Limit | Upper Limit |
|--------------------------------------|----------------------------|-----------|-------------|-------------|
| 329.999 mV                           | 300.000 mV                 | 30 kHz    | 287.100 mV  | 312.900 mV  |
| 3.29999 V                            | 3.00000 V                  | 9.5 Hz    | 2.835 V     | 3.165V      |
| 3.29999 V                            | 3.00000 V                  | 10 Hz     | 2.99505 V   | 3.00495 V   |
| 3.29999 V                            | 3.00000 V                  | 45 Hz     | 2.99745 V   | 3.00255 V   |
| 3.29999 V                            | 3.00000 V                  | 1 kHz     | 2.99745 V   | 3.00255 V   |
| 3.29999 V                            | 3.00000 V                  | 5 kHz     | 2.99410 V   | 3.00590 V   |
| 3.29999 V                            | 3.00000 V                  | 10 kHz    | 2.98960 V   | 3.01040 V   |
| 3.29999 V                            | 3.00000 V                  | 30 kHz    | 2,87720 V   | 3.12280 V   |
| 5.00000 V                            | 5.00000 V                  | 9.5 Hz    | 4.72500 V   | 5.27500 V   |
| 5.00000 V                            | 5.00000 V                  | 10 Hz     | 4.99205 V   | 5.00795 V   |
| 5.00000 V                            | 5.00000 V                  | 45 Hz     | 4.99605 V   | 5.00395 V   |
| 5.00000 V                            | 5.00000 V                  | 1 kHz     | 4.99605 V   | 5.00395 V   |
| 5.00000 V                            | 5.00000 V                  | 5 kHz     | 4.99110 V   | 5.00890 V   |
| 5.00000 V                            | 5.00000 V                  | 10 kHz    | 4.98360 V   | 5.01640 V   |
| [1] Set the NORMAL output to 300 mV. |                            |           |             |             |

Table 7-9. Verification Tests for AC Current

| Range          | Output         | Frequency | Lower Limit    | Upper Limit    |
|----------------|----------------|-----------|----------------|----------------|
| 329.99 $\mu$ A | 33.00 $\mu$ A  | 1 kHz     | 32.87 $\mu$ A  | 33.13 $\mu$ A  |
| 329.99 $\mu$ A | 33.00 $\mu$ A  | 10 kHz    | 32.60 $\mu$ A  | 33.40 $\mu$ A  |
| 329.99 $\mu$ A | 33.00 $\mu$ A  | 30 kHz    | 32.20 $\mu$ A  | 33.80 $\mu$ A  |
| 329.99 $\mu$ A | 190.00 $\mu$ A | 45 Hz     | 189.71 $\mu$ A | 190.29 $\mu$ A |
| 329.99 $\mu$ A | 190.00 $\mu$ A | 1 kHz     | 189.71 $\mu$ A | 190.29 $\mu$ A |
| 329.99 $\mu$ A | 190.00 $\mu$ A | 10 kHz    | 188.66 $\mu$ A | 191.34 $\mu$ A |
| 329.99 $\mu$ A | 190.00 $\mu$ A | 30 kHz    | 187.32 $\mu$ A | 192.68 $\mu$ A |
| 329.99 $\mu$ A | 329.00 $\mu$ A | 10 Hz     | 328.37 $\mu$ A | 329.63 $\mu$ A |
| 329.99 $\mu$ A | 329.00 $\mu$ A | 45 Hz     | 328.57 $\mu$ A | 329.43 $\mu$ A |
| 329.99 $\mu$ A | 329.00 $\mu$ A | 1 kHz     | 328.57 $\mu$ A | 329.43 $\mu$ A |
| 329.99 $\mu$ A | 329.00 $\mu$ A | 5 kHz     | 328.03 $\mu$ A | 329.97 $\mu$ A |
| 329.99 $\mu$ A | 329.00 $\mu$ A | 10 kHz    | 326.83 $\mu$ A | 331.17 $\mu$ A |
| 329.99 $\mu$ A | 329.00 $\mu$ A | 30 kHz    | 324.65 $\mu$ A | 333.35 $\mu$ A |
| 3.2999 mA      | 0.3300 mA      | 1 kHz     | 0.3296 mA      | 0.3304 mA      |
| 3.2999 mA      | 0.3300 mA      | 5 kHz     | 0.3293 mA      | 0.3307 mA      |
| 3.2999 mA      | 0.3300 mA      | 30 kHz    | 0.3268 mA      | 0.3332 mA      |

**Table 7-9. Verification Tests for AC Current (cont.)**

| Range     | Output      | Frequency | Lower Limit | Upper Limit |
|-----------|-------------|-----------|-------------|-------------|
| 3.2999 mA | 1.9000 mA   | 1 kHz     | 1.8983 mA   | 1.9017 mA   |
| 3.2999 mA | 1.9000 mA   | 10 kHz    | 1.8921 mA   | 1.9079 mA   |
| 3.2999 mA | 1.9000 mA   | 30 kHz    | 1.8842 mA   | 1.9158 mA   |
| 3.2999 mA | 3.2900 mA   | 10 Hz     | 3.2846 mA   | 3.2954 mA   |
| 3.2999 mA | 3.2900 mA   | 45 Hz     | 3.2872 mA   | 3.2928 mA   |
| 3.2999 mA | 3.2900 mA   | 1 kHz     | 3.2872 mA   | 3.2928 mA   |
| 3.2999 mA | 3.2900 mA   | 5 kHz     | 3.2845 mA   | 3.2955 mA   |
| 3.2999 mA | 3.2900 mA   | 10 kHz    | 3.2765 mA   | 3.3035 mA   |
| 3.2999 mA | 3.2900 mA   | 30 kHz    | 3.2631 mA   | 3.3169 mA   |
| 32.999 mA | 3.3000 mA   | 1 kHz     | 3.297 mA    | 3.303 mA    |
| 32.999 mA | 3.3000 mA   | 5 kHz     | 3.296 mA    | 3.304 mA    |
| 32.999 mA | 3.3000 mA   | 30 kHz    | 3.285 mA    | 3.315 mA    |
| 32.999 mA | 19.0000 mA  | 1 kHz     | 18.991 mA   | 19.009 mA   |
| 32.999 mA | 19.0000 mA  | 10 kHz    | 18.967 mA   | 19.033 mA   |
| 32.999 mA | 19.0000 mA  | 30 kHz    | 18.935 mA   | 19.065 mA   |
| 32.999 mA | 32.9000 mA  | 10 Hz     | 32.849 mA   | 32.951 mA   |
| 32.999 mA | 32.9000 mA  | 1 kHz     | 32.886 mA   | 32.914 mA   |
| 32.999 mA | 32.9000 mA  | 5 kHz     | 32.877 mA   | 32.923 mA   |
| 32.999 mA | 32.9000 mA  | 10 kHz    | 32.844 mA   | 32.956 mA   |
| 32.999 mA | 32.9000 mA  | 30 kHz    | 32.791 mA   | 33.009 mA   |
| 329.99 mA | 33.0000 mA  | 1 kHz     | 32.97 mA    | 33.03 mA    |
| 329.99 mA | 33.0000 mA  | 5 kHz     | 32.92 mA    | 33.08 mA    |
| 329.99 mA | 33.0000 mA  | 30 kHz    | 32.69 mA    | 33.31 mA    |
| 329.99 mA | 190.0000 mA | 1 kHz     | 189.91 mA   | 190.09 mA   |
| 329.99 mA | 190.0000 mA | 10 kHz    | 189.60 mA   | 190.40 mA   |
| 329.99 mA | 190.0000 mA | 30 kHz    | 189.19 mA   | 190.81 mA   |
| 329.99 mA | 329.0000 mA | 10 Hz     | 328.49 mA   | 329.51 mA   |
| 329.99 mA | 329.0000 mA | 45 Hz     | 328.86 mA   | 329.14 mA   |
| 329.99 mA | 329.0000 mA | 1 kHz     | 328.86 mA   | 329.14 mA   |
| 329.99 mA | 329.0000 mA | 5 kHz     | 328.69 mA   | 329.31 mA   |
| 329.99 mA | 329.0000 mA | 10 kHz    | 328.37 mA   | 329.63 mA   |
| 329.99 mA | 329.0000 mA | 30 kHz    | 327.75 mA   | 330.25 mA   |
| 2.99999 A | 0.33000 A   | 1 kHz     | 0.32978 A   | 0.33022 A   |

Table 7-9. Verification Tests for AC Current (cont.)

| Range     | Output    | Frequency | Lower Limit | Upper Limit |
|-----------|-----------|-----------|-------------|-------------|
| 2.99999 A | 0.33000 A | 5 kHz     | 0.32735 A   | 0.33265 A   |
| 2.99999 A | 0.33000 A | 10 kHz    | 0.31840 A   | 0.34160 A   |
| 2.99999 A | 1.09000 A | 10 Hz     | 1.08827 A   | 1.09174 A   |
| 2.99999 A | 1.09000 A | 45 Hz     | 1.08951 A   | 1.09049 A   |
| 2.99999 A | 1.09000 A | 1 kHz     | 1.08951 A   | 1.09049 A   |
| 2.99999 A | 1.09000 A | 5 kHz     | 1.08355 A   | 1.09645 A   |
| 2.99999 A | 1.09000 A | 10 kHz    | 1.06320 A   | 1.11680A    |
| 2.99999 A | 2.99000 A | 10 Hz     | 2.98542 A   | 2.99459 A   |
| 2.99999 A | 2.99000 A | 45 Hz     | 2.98840 A   | 2.99160 A   |
| 2.99999 A | 2.99000 A | 1 kHz     | 2.98840 A   | 2.99160 A   |
| 2.99999 A | 2.99000 A | 5 kHz     | 2.97405 A   | 3.00595 A   |
| 2.99999 A | 2.99000 A | 10 kHz    | 2.92520 A   | 3.05480 A   |
| 20.5000 A | 3.3000 A  | 500 Hz    | 3.2954 A    | 3.3046 A    |
| 20.5000 A | 3.3000 A  | 1 kHz     | 3.2954 A    | 3.3046 A    |
| 20.5000 A | 3.3000 A  | 5 kHz     | 3.2155 A    | 3.3845 A    |
| 20.5000 A | 11.0000 A | 45 Hz     | 10.9840A    | 11.0160 A   |
| 20.5000 A | 11.0000 A | 65 Hz     | 10.9840 A   | 11.0160A    |
| 20.5000 A | 11.0000 A | 500 Hz    | 10.9807 A   | 11.0193 A   |
| 20.5000 A | 11.0000 A | 1 kHz     | 10.9807 A   | 11.0193 A   |
| 20.5000 A | 11.0000 A | 5 kHz     | 10.7200 A   | 11.2800A    |
| 20.5000 A | 20.0000 A | 45 Hz     | 19.9750 A   | 20.0250 A   |
| 20.5000 A | 20.0000 A | 65 Hz     | 19.9750 A   | 20.0250 A   |
| 20.5000 A | 20.0000 A | 500 Hz    | 19.9690 A   | 20.0310 A   |
| 20.5000 A | 20.0000 A | 1 kHz     | 19.9690 A   | 20.0310 A   |
| 20.5000 A | 20.0000 A | 5 kHz     | 19.4950 A   | 20.5050 A   |

Table 7-10. Verification Tests for Capacitance

| Range     | Output    | Test Frequency<br>or Current | Lower Limit | Upper Limit |
|-----------|-----------|------------------------------|-------------|-------------|
| 0.3999 nF | 0.2200 nF | 5 kHz                        | 0.2192 nF   | 0.2308 nF   |
| 0.3999 nF | 0.3500 nF | 1 kHz                        | 0.3387 nF   | 0.3613 nF   |
| 1.0999 nF | 0.4800 nF | 1 kHz                        | 0.4682 nF   | 0.4918 nF   |
| 1.0999 nF | 0.6000 nF | 1 kHz                        | 0.5877 nF   | 0.6123 nF   |
| 1.0999 nF | 1.0000 nF | 1 kHz                        | 0.9862 nF   | 1.0138 nF   |

**Table 7-10. Verification Tests for Capacitance (cont.)**

| Range          | Output         | Test Frequency<br>or Current | Lower Limit     | Upper Limit     |
|----------------|----------------|------------------------------|-----------------|-----------------|
| 3.299 nF       | 2.0000 nF      | 1 kHz                        | 1.9824 nF       | 2.0176 nF       |
| 10.999 nF      | 7.0000 nF      | 1 kHz                        | 6.9767 nF       | 7.0233 nF       |
| 10.999 nF      | 10.9000 nF     | 1 kHz                        | 10.8693 nF      | 10.9307 nF      |
| 32.999 nF      | 20.000 nF      | 1 kHz                        | 19.8620 nF      | 20.1380 nF      |
| 109.99 nF      | 70.00 nF       | 1 kHz                        | 69.767 nF       | 70.233 nF       |
| 109.99 nF      | 109.00 nF      | 1 kHz                        | 108.693 nF      | 109.307 nF      |
| 329.99 nF      | 200.00 nF      | 1 kHz                        | 199.320 nF      | 200.680 nF      |
| 329.99 nF      | 300.00 nF      | 1 kHz                        | 299.130 nF      | 300.870 nF      |
| 1.0999 $\mu$ F | 0.7000 $\mu$ F | 100 Hz                       | 0.69767 $\mu$ F | 0.70233 $\mu$ F |
| 1.0999 $\mu$ F | 1.0900 $\mu$ F | 100 Hz                       | 1.05929 $\mu$ F | 1.12071 $\mu$ F |
| 3.2999 $\mu$ F | 2.0000 $\mu$ F | 100 Hz                       | 1.99320 $\mu$ F | 2.00680 $\mu$ F |
| 3.2999 $\mu$ F | 3.0000 $\mu$ F | 100 Hz                       | 2.99130 $\mu$ F | 3.00870 $\mu$ F |
| 10.999 $\mu$ F | 7.000 $\mu$ F  | 100 Hz                       | 6.9767 $\mu$ F  | 7.0233 $\mu$ F  |
| 10.999 $\mu$ F | 10.900 $\mu$ F | 100 Hz                       | 10.8693 $\mu$ F | 10.9307 $\mu$ F |
| 32.999 $\mu$ F | 20.000 $\mu$ F | 100 Hz                       | 19.9100 $\mu$ F | 20.0900 $\mu$ F |
| 32.999 $\mu$ F | 30.000 $\mu$ F | 100 Hz                       | 29.8800 $\mu$ F | 30.1200 $\mu$ F |
| 109.99 $\mu$ F | 70.00 $\mu$ F  | 50 Hz                        | 69.662 $\mu$ F  | 70.338 $\mu$ F  |
| 109.99 $\mu$ F | 109.00 $\mu$ F | 50 Hz                        | 108.529 $\mu$ F | 109.471 $\mu$ F |
| 329.99 $\mu$ F | 200.00 $\mu$ F | 54 $\mu$ A dc                | 199.020 $\mu$ F | 200.980 $\mu$ F |
| 329.99 $\mu$ F | 300.00 $\mu$ F | 80 $\mu$ A dc                | 298.680 $\mu$ F | 301.320 $\mu$ F |
| 1.0999 mF      | 0.3300 mF      | 90 $\mu$ A dc                | 0.32788 mF      | 0.33212 mF      |
| 1.0999 mF      | 0.7000 mF      | 180 $\mu$ A dc               | 0.69662 mF      | 0.70338 mF      |
| 1.0999 mF      | 1.0900 mF      | 270 $\mu$ A dc               | 1.08529 mF      | 1.09471 mF      |
| 3.299 mF       | 1.100 mF       | 270 $\mu$ A dc               | 1.0933 mF       | 1.1067 mF       |
| 3.299 mF       | 2.000 mF       | 540 $\mu$ A dc               | 1.9902 mF       | 2.0098 mF       |
| 3.299 mF       | 3.000 mF       | 800 $\mu$ A dc               | 2.9868 mF       | 3.0132 mF       |
| 10.999 mF      | 3.300 mF       | 900 $\mu$ A dc               | 3.2788 mF       | 3.3212 mF       |
| 10.999 mF      | 10.900 mF      | 2.7 mA dc                    | 10.8529 mF      | 10.9471 mF      |
| 32.999 mF      | 20.000 mF      | 5.4 mA dc                    | 19.8300 mF      | 20.1700 mF      |
| 32.999 mF      | 30.000 mF      | 8.0 mA dc                    | 29.7600 mF      | 30.2400 mF      |
| 110.00 mF      | 33.00 mF       | 9.0 mA dc                    | 32.570 mF       | 33.430 mF       |
| 110.00 mF      | 110.00 mF      | 27.0 mA dc                   | 108.800 mF      | 111.200 mF      |

Table 7-11. Verification Tests for Thermocouple Simulation

| TC Type       | Output, °C                  | Lower Limit, mV | Upper Limit, mV |
|---------------|-----------------------------|-----------------|-----------------|
| 10 $\mu$ V/°C | 0.00 °C (0.0000 mV)         | -0.0030         | 0.0030          |
|               | 100.00 °C (1.0000 mV)       | 0.99696         | 1.00304         |
|               | -100.00 °C (-1.0000 mV)     | -1.00304        | -0.99696        |
|               | 1000.00 °C (10.0000 mV)     | 9.99660         | 10.00340        |
|               | -1000.00 °C (10.0000 mV)    | -10.0034        | -9.9966         |
|               | 10000.00 °C (100.0000 mV)   | 99.9930         | 100.0070        |
|               | -10000.00 °C (-100.0000 mV) | -100.0070       | -99.9930        |

Table 7-12. Verification Tests for Thermocouple Measurement

| TC Type       | Input, mV                   | Lower Limit, °C | Upper Limit, °C |
|---------------|-----------------------------|-----------------|-----------------|
| 10 $\mu$ V/°C | 0.00 °C (0.0000 mV)         | -0.30           | -0.30           |
|               | 10000.00 °C (100.0000 mV)   | 9999.30         | 10000.70        |
|               | -10000.00 °C (-100.0000 mV) | -10000.70       | -9999.30        |
|               | 30000.00 °C (300.0000 mV)   | 29998.50        | 30001.50        |
|               | -30000.00 °C (-300.0000 mV) | -30001.50       | -29998.50       |



Table 7-13. Verification Tests for Phase Accuracy, V and V

| Range,<br>Normal<br>Output, V | Output,<br>Normal V | Frequency | Range,<br>AUX<br>Output | Output,<br>AUX | Phase ° | Lower<br>Limit° | Upper<br>Limit ° |
|-------------------------------|---------------------|-----------|-------------------------|----------------|---------|-----------------|------------------|
| 3.29999                       | 3.00000             | 65 Hz     | 3.29999 V               | 3.00000 V      | 0       | -0.150          | 0.150            |
|                               |                     | 400 Hz    |                         |                |         | -0.900          | 0.900            |
|                               |                     | 1 kHz     |                         |                |         | -2.000          | 2.000            |
|                               |                     | 5 kHz     |                         |                |         | -6.000          | 6.000            |
|                               |                     | 10 kHz    |                         |                |         | -10.000         | 10.000           |
|                               |                     | 30 kHz    |                         |                |         | -15.000         | 15.000           |
|                               |                     | 65 Hz     |                         |                | 60      | 59.850          | 60.150           |
|                               |                     | 400 Hz    |                         |                |         | 59.100          | 60.900           |
|                               |                     | 1 kHz     |                         |                |         | 58.000          | 62.000           |
|                               |                     | 5 kHz     |                         |                |         | 54.000          | 66.000           |
|                               |                     | 10 kHz    |                         |                |         | 50.000          | 70.000           |
|                               |                     | 30 kHz    |                         |                |         | 45.000          | 75.000           |
|                               |                     | 65 Hz     |                         |                | 90      | 89.850          | 90.150           |
|                               |                     | 400 Hz    |                         |                |         | 89.100          | 90.900           |
|                               |                     | 1 kHz     |                         |                |         | 88.000          | 92.000           |
|                               |                     | 5 kHz     |                         |                |         | 84.000          | 96.000           |
|                               |                     | 10 kHz    |                         |                |         | 80.000          | 100.000          |
|                               |                     | 30 kHz    |                         |                |         | 75.000          | 105.000          |
|                               | 32.9999             | 65 Hz     |                         |                |         | 89.85           | 90.15            |
|                               | 329.999             | 65 Hz     |                         |                |         | 89.85           | 90.15            |

Table 7-14. Verification Tests for Phase Accuracy, V and I

| Range,<br>Normal<br>Output, V | Output,<br>Normal V | Frequency | Range,<br>AUX<br>Output | Output,<br>AUX | Phase ° | Lower<br>Limit ° | Upper<br>Limit ° |
|-------------------------------|---------------------|-----------|-------------------------|----------------|---------|------------------|------------------|
| 329.999 mV                    | 30.000 mV           | 65 Hz     | 329.99 mA               | 300.00 mA      | 0       | -0.15            | 0.15             |
|                               |                     | 1 kHz     | 329.99 mA               | 300.00 mA      |         | -2.00            | 2.00             |
|                               |                     | 30 kHz    | 329.99 mA               | 300.00 mA      |         | -15.00           | 15.00            |
|                               | 200.000 mV          | 65 Hz     | 2099999 A               | 2.00000 A      |         | -0.15            | 0.15             |
|                               | 50.000 mV           | 65 Hz     | 20.5000 A               | 5.0000 A       |         | -0.15            | 0.15             |
|                               |                     | 400 Hz    | 20.5000 A               | 5.0000 A       |         | -0.90            | 0.90             |
|                               | 30.000 mV           | 65 Hz     | 329.99 mA               | 300.00 mA      | 60      | 59.85            | 60.15            |
|                               | 200.000 mV          | 65 Hz     | 2.99999 A               | 2.00000 A      |         | 59.85            | 60.15            |
|                               |                     | 65 Hz     | 20.5000 A               | 20.0000 A      |         | 59.85            | 60.15            |
|                               |                     | 400 Hz    | 20.5000 A               | 20.0000 A      |         | 59.10            | 60.90            |
| 32.999 mV                     | 3.3000 V            | 65 Hz     | 329.99 mA               | 300.00 mA      | 0       | -0.15            | 0.15             |
|                               |                     | 65 Hz     | 2.99999 A               | 2.00000 A      |         | -0.15            | 0.15             |
|                               |                     | 65 Hz     | 20.5000 A               | 5.0000 A       |         | -0.15            | 0.15             |
|                               |                     | 400 Hz    | 20.5000 A               | 5.0000 A       |         | -0.90            | 0.90             |
|                               |                     | 65 Hz     | 329.99 mA               | 300.00 mA      | 90      | 89.85            | 90.15            |
|                               |                     | 65 Hz     | 2.99999 A               | 2.00000 A      |         | 89.85            | 90.15            |
|                               |                     | 65 Hz     | 20.5000 A               | 20.0000 A      |         | 89.85            | 90.15            |
|                               |                     | 400 Hz    | 20.5000 A               | 20.0000 A      |         | 89.10            | 90.90            |
| 329.999 V                     | 33.000 V            | 65 Hz     | 329.99 mA               | 300.00 mA      | 0       | -0.15            | 0.15             |
|                               |                     | 65 Hz     | 2.99999 A               | 2.00000 A      |         | -0.15            | 0.15             |
|                               |                     | 65 Hz     | 20.5000 A               | 5.0000 A       |         | -0.15            | 0.15             |
|                               |                     | 400 Hz    | 20.5000 A               | 5.0000 A       |         | -0.90            | 0.90             |
|                               |                     | 65 Hz     | 329.99 mA               | 300.00 mA      | 90      | 89.85            | 90.15            |
|                               |                     | 65 Hz     | 2.99999 A               | 2.00000 A      |         | 89.85            | 90.15            |
|                               |                     | 65 Hz     | 20.5000 A               | 20.0000 A      |         | 89.85            | 90.15            |
|                               |                     | 400 Hz    | 20.5000 A               | 20.0000 A      |         | 89.10            | 90.90            |

**Table 7-15. Verification Tests for Frequency**

| Range, Normal Output, V                         | Output, Normal, V | Frequency  | Lower Limit <sup>[1]</sup> | Upper Limit <sup>[1]</sup> |
|-------------------------------------------------|-------------------|------------|----------------------------|----------------------------|
| 3.29999                                         | 3.00000           | 119.00 Hz  | 118.99602 Hz               | 119.00398 Hz               |
|                                                 |                   | 120.0 Hz   | 119.99600 Hz               | 120.00400 Hz               |
|                                                 |                   | 1000.0 Hz  | 999.974000 Hz              | 1000.026000 Hz             |
|                                                 |                   | 100.00 kHz | 99.99750000 Hz             | 100.00250000 Hz            |
| [1] Frequency accuracy is specified for 1 year. |                   |            |                            |                            |



## ***Chapter 8***

# ***Accessories***

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## Introduction

Table 8-1 summarizes the available models, options, accessories, cables, and components.

**Table 8-1. Options and Accessories**

| Model                                                                                                                             | Description                                                            |
|-----------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| SC300                                                                                                                             | Oscilloscope Calibration Option                                        |
| SC600                                                                                                                             | Oscilloscope Calibration Option                                        |
| 55XX/CASE                                                                                                                         | Transit Case                                                           |
| 5522A/CARRYCASE                                                                                                                   | Carry Case with front/rear panels that you can remove.                 |
| 5500A/HNDL                                                                                                                        | Side Handle                                                            |
| 5500A/LEADS                                                                                                                       | Comprehensive Lead Set                                                 |
| 109215                                                                                                                            | Replacement fuse; 5 A/250 V Time Delay (100 V or 120 V line voltage)   |
| 851931                                                                                                                            | Replacement fuse; 2.5 A/250 V Time Delay (200 V or 240 V line voltage) |
| 3674001                                                                                                                           | Replacement fuse; 4 A/500 V, Ultra fast, 0.25 x 1.25, ceramic body     |
| 3470596                                                                                                                           | Replacement fuse; 25 A/250 V, Fast, 6.3 X 32 mm                        |
| MET/CAL Plus                                                                                                                      | Fluke Calibration Metrology Software                                   |
| MET/CAL-IEEE USB                                                                                                                  | IEEE Interface Option.                                                 |
| 884X-USB                                                                                                                          | USB to RS-232 Cable Adapter                                            |
|  To ensure safety, use exact replacement only. |                                                                        |

**Table 8-1. Options and Accessories (cont.)**

| <b>Model</b> | <b>Description</b>                      |
|--------------|-----------------------------------------|
| Y5537        | 24 in. (61 cm) Rack Mount Kit for 5502A |
| Y8021        | Shielded IEEE-488 Cable 0.5 m (1.64 ft) |
| Y8022        | Shielded IEEE-488 Cable 2 m (6.56 ft)   |
| Y8023        | Shielded IEEE-488 Cable 4 m (13 ft)     |

### ***Rack Mount Kit***

The Y5537 rack mount kit supplies all the hardware necessary to install the 5502A on slides in a 24-inch (61 cm) equipment rack. Instructions are supplied in the kit. (To rack mount the 5725A Amplifier, order kit Y5735.)

### ***IEEE-488 Interface Cable***

Shielded IEEE-488 cables are available in three lengths (See Table 8-1). The cables attach to the 5502A to other IEEE-488 devices. Each cable has double 24-pin connectors at each end for stacking. Metric threaded installation screws are supplied with connectors. Appendix D shows the pinout for the IEEE-488 connector.

### ***5500A/LEADS***

The optional test lead kit, 5500A/LEADS, is a kit of test leads for voltage and current, thermocouple extension wires, thermocouple miniconnectors, and thermocouple measuring “beads.”



# Chapter 9

## SC600 Oscilloscope Calibration Option

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## Introduction

The SC600 Oscilloscope Calibration Option (the SC600 Option) has functions that help you keep your oscilloscope's accuracy by verifying and calibrating the subsequent oscilloscope qualities:

- Vertical deflection qualities are calibrated and verified. The VOLT function lets you compare the voltage gain to the graticule lines on the oscilloscope.
- Pulse transient response is examined and calibrated, verifying the accuracy of the measurement of pulse transitions of the oscilloscope with the EDGE function. Also, the Calibrator lets you do faster pulse response checks with an external tunnel diode pulser.
- Frequency response is examined by verifying the bandwidth with the leveled sine wave (LEVSINE) function. Vertical deflection is monitored until the -3 dB point is seen on the oscilloscope.
- Horizontal (time base) deflection qualities are calibrated and verified with the time MARKER function. This calibration procedure is like the one for verifying the vertical deflection qualities, but it examines the horizontal axis.
- The oscilloscope can show, hold, and measure pulse width. This is examined with the PULSE function. This function lets you to change the pulse width and the period.
- The oscilloscope can trigger on different waveforms. This is done with the wave generator (WAVEGEN) function.
- The oscilloscope can trigger on and capture complex TV trigger signals. This is done with the VIDEO function.
- The input qualities of the oscilloscope can be measured with the Input resistance and capacitance (MEAS Z) function.
- You can verify the oscilloscope input protection circuit with the overload (OVERLD) function.

The menus that implement these functions also include parameters to change how the output signal reacts to voltage, frequency, and time settings. This gives you control of the signal when you calibrate, and gives more methods to see signal qualities.

## SC600 Oscilloscope Calibration Option Specifications

These specifications apply only to the SC600 Oscilloscope Calibration Option. General specifications that apply to the 5502A Calibrator can be found in Chapter 1. The specifications are correct given the 5502A is operated with the conditions specified in Chapter 1, and has completed a warm-up period of no less than two times the length of time the Calibrator was powered off, to a maximum of 30 minutes.

### Voltage Function Specifications

| Voltage Function                                                           | DC Signal                                                                                          |                             | Square Wave Signal <sup>[1]</sup>                      |                                           |
|----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|-----------------------------|--------------------------------------------------------|-------------------------------------------|
|                                                                            | 50 Ω Load                                                                                          | 1 MΩ Load                   | 50 Ω Load                                              | 1 MΩ Load                                 |
| Amplitude Qualities                                                        |                                                                                                    |                             |                                                        |                                           |
| Range                                                                      | 0 to ±6.599 V                                                                                      | 0 to ±130 V                 | ±1 mV to ±6.599 V p-p                                  | ±1 mV to ±130 V p-p                       |
| Resolution                                                                 | Range<br>1 to 24.999 mV<br>25 to 109.99 mV<br>110 mV to 2.1999 V<br>2.2 to 10.999 V<br>11 to 130 V |                             | Resolution<br>1 μV<br>10 μV<br>100 μV<br>1 mV<br>10 mV |                                           |
| Adjustment Range                                                           | Continuously adjustable                                                                            |                             |                                                        |                                           |
| 1-Year Absolute Uncertainty, tcal ±5 °C                                    | ±(0.25 % of output + 40 μV)                                                                        | ± 0.05 % of output + 40 μV) | ±(0.25 % of output + 40 μV)                            | ±(0.1 % of output + 40 μV) <sup>[2]</sup> |
| Sequence                                                                   | 1-2-5 (e.g., 10 mV, 20 mV, 50 mV)                                                                  |                             |                                                        |                                           |
| Square Wave Frequency Qualities                                            |                                                                                                    |                             |                                                        |                                           |
| Range                                                                      | 10 Hz to 10 kHz                                                                                    |                             |                                                        |                                           |
| 1-Year Absolute Uncertainty, tcal ±5 °C                                    | ±(2.5 ppm of setting)                                                                              |                             |                                                        |                                           |
| Typical aberration within 4 μs from 50 % of leading/trailing edge          | <(0.5 % of output + 100 μV)                                                                        |                             |                                                        |                                           |
| [1] Selectable positive or negative, zero referenced square wave.          |                                                                                                    |                             |                                                        |                                           |
| [2] For square wave frequencies above 1 kHz, ± (0.25 % of output + 40 μV). |                                                                                                    |                             |                                                        |                                           |

### Edge Specifications

| Edge Qualities into 50 Ω Load                                                                    |                                                                                                     | 1-Year Absolute Uncertainty,<br>tcal ± 5 °C |
|--------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|---------------------------------------------|
| Rise Time                                                                                        | ≤300 ps                                                                                             | (+0 ps / -100 ps)                           |
| Amplitude Range (p-p)                                                                            | 4.5 mV to 2.75 V                                                                                    | ±(2 % of output + 200 μV)                   |
| Resolution                                                                                       | 4 digits                                                                                            |                                             |
| Adjustment Range                                                                                 | ±10 % around each sequence value<br>(indicated below)                                               |                                             |
| Sequence Values                                                                                  | 5 mV, 10 mV, 25 mV, 50 mV, 60 mV, 80 mV, 100 mV, 200 mV, 250 mV, 300 mV, 500 mV, 600 mV, 1 V, 2.5 V |                                             |
| Frequency Range <sup>[1]</sup>                                                                   | 900 Hz to 11 MHz                                                                                    | ±(2.5 ppm of setting)                       |
| Typical Jitter, edge to trigger                                                                  | <5 ps (p-p)                                                                                         |                                             |
| Leading Edge Aberrations <sup>[2]</sup>                                                          | within 2 ns from 50 % of rising edge                                                                | <(3 % of output + 2 mV)                     |
|                                                                                                  | 2 to 5 ns                                                                                           | <(2 % of output + 2 mV)                     |
|                                                                                                  | 5 to 15 ns                                                                                          | <(1 % of output + 2 mV)                     |
|                                                                                                  | after 15 ns                                                                                         | <(0.5 % of output + 2 mV)                   |
| Typical Duty Cycle                                                                               | 45 % to 55 %                                                                                        |                                             |
| Tunnel Diode Pulse Drive                                                                         | Square wave at 100 Hz to 100 kHz, with variable amplitude of 60 to 100 V p-p.                       |                                             |
| [1] Above 2 MHz rise time specification <350 ps                                                  |                                                                                                     |                                             |
| [2] All edge aberration measurements made with Tektronix 11801 mainframe with SD26 input module. |                                                                                                     |                                             |

### Leveled Sine Wave Specifications

| Leveled Sine Wave Qualities into 50 Ω                                                                                                                                                                                                                                         | Frequency Range                        |                             |                           |                           |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|-----------------------------|---------------------------|---------------------------|
|                                                                                                                                                                                                                                                                               | 50 kHz (reference)                     | 50 kHz to 100 MHz           | 100 to 300 MHz            | 300 to 600 MHz            |
| Amplitude Qualities (for measuring oscilloscope bandwidth)                                                                                                                                                                                                                    |                                        |                             |                           |                           |
| Range (p-p)                                                                                                                                                                                                                                                                   | 5 mV to 5.5 V                          |                             |                           |                           |
| Resolution                                                                                                                                                                                                                                                                    | <100 mV: 3 digits<br>≥100 mV: 4 digits |                             |                           |                           |
| Adjustment Range                                                                                                                                                                                                                                                              | continuously adjustable                |                             |                           |                           |
| 1-Year Absolute Uncertainty, tcal ±5 °C                                                                                                                                                                                                                                       | ±(2 % of output + 300 μV)              | ±(3.5 % of output + 300 μV) | ±(4 % of output + 300 μV) | ±(6 % of output + 300 μV) |
| Flatness (relative to 50 kHz)                                                                                                                                                                                                                                                 | not applicable                         | ±(1.5 % of output + 100 μV) | ±(2 % of output + 100 μV) | ±(4 % of output + 100 μV) |
| Short-Term Amplitude Stability                                                                                                                                                                                                                                                | ≤ 1 % <sup>[1]</sup>                   |                             |                           |                           |
| Frequency Qualities                                                                                                                                                                                                                                                           |                                        |                             |                           |                           |
| Resolution                                                                                                                                                                                                                                                                    | 1 kHz                                  |                             | 10 kHz                    |                           |
| 1-Year Absolute Uncertainty, tcal ±5 °C                                                                                                                                                                                                                                       | ±2.5 ppm <sup>[2]</sup>                |                             |                           |                           |
| Distortion Qualities                                                                                                                                                                                                                                                          |                                        |                             |                           |                           |
| 2nd Harmonic                                                                                                                                                                                                                                                                  | ≤ -33 dBc                              |                             |                           |                           |
| 3rd and Higher Harmonics                                                                                                                                                                                                                                                      | ≤ -38 dBc                              |                             |                           |                           |
| <div>[1] Within 1 hour after reference amplitude setting, provided temperature varies no more than ±5 °C.</div> <div>[2] With REF CLK set to ext, the frequency uncertainty of the Leveled Sine Wave is the uncertainty of the external 10 MHz clock ±0.3 Hz/gate time.</div> |                                        |                             |                           |                           |

### Time Marker Specifications

| Time Marker into 50 Ω                                                                                                                                                                                                            | 5 s to 50 ms                                               | 20 ms to 100 ns              | 50 to 20 ns             | 10 ns                   | 5 to 2 ns |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|------------------------------|-------------------------|-------------------------|-----------|
| 1-Year Absolute Uncertainty at Cardinal Points, tcal ±5 °C                                                                                                                                                                       | ±(25 + t *1000) ppm <sup>[1]</sup>                         | ±2.5 ppm                     | ±2.5 ppm                | ±2.5 ppm                | ±2.5 ppm  |
| Wave Shape                                                                                                                                                                                                                       | spike or square                                            | spike, square, or 20 %-pulse | spike or square         | square or sine          | sine      |
| Typical Output Level                                                                                                                                                                                                             | >1 V p-p <sup>[2]</sup>                                    | >1 V p-p <sup>[2]</sup>      | >1 V p-p <sup>[2]</sup> | >1 V p-p <sup>[2]</sup> | >1 V p-p  |
| Typical Jitter (rms)                                                                                                                                                                                                             | <10 ppm                                                    | <1 ppm                       | <1 ppm                  | <1 ppm                  | <1 ppm    |
| Sequence                                                                                                                                                                                                                         | 5-2-1 from 5 s to 2 ns (e.g., 500 ms, 200 ms, 100 ms)      |                              |                         |                         |           |
| Adjustment Range <sup>[3]</sup>                                                                                                                                                                                                  | At least ±10 % around each sequence value indicated above. |                              |                         |                         |           |
| Amplitude Resolution                                                                                                                                                                                                             | 4 digits                                                   |                              |                         |                         |           |
| <div>[1] t is the time in seconds.</div> <div>[2] Typical rise time of square wave and 20 %-pulse (20 % duty cycle pulse) is &lt; 1.5 ns.</div> <div>[3] Time marker uncertainty is ±50 ppm away from the cardinal points.</div> |                                                            |                              |                         |                         |           |

### Wave Generator Specifications

| Wave Generator Qualities                                                    | Square Wave, Sine Wave, and Triangle Wave into 50 $\Omega$ or 1 M $\Omega$       |
|-----------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| <b>Amplitude</b>                                                            |                                                                                  |
| Range                                                                       | into 1 M $\Omega$ : 1.8 mV to 55 V p-p<br>into 50 $\Omega$ : 1.8 mV to 2.5 V p-p |
| 1-Year Absolute Uncertainty, tcal $\pm 5^{\circ}\text{C}$ , 10 Hz to 10 kHz | $\pm(3\% \text{ of p-p output} + 100 \mu\text{V})$                               |
| Sequence                                                                    | 1-2-5 (e.g., 10 mV, 20 mV, 50 mV)                                                |
| Typical DC Offset Range                                                     | 0 to $\pm (\geq 40\% \text{ of p-p amplitude})$ <sup>[1]</sup>                   |
| <b>Frequency</b>                                                            |                                                                                  |
| Range                                                                       | 10 Hz to 100 kHz                                                                 |
| Resolution                                                                  | 4 or 5 digits depending upon frequency                                           |
| 1-Year Absolute Uncertainty, tcal $\pm 5^{\circ}\text{C}$                   | $\pm(25 \text{ ppm} + 15 \text{ mHz})$                                           |
| [1] The DC offset plus the wave signal must not exceed 30 V rms.            |                                                                                  |

**Pulse Generator Specifications**

| Pulse Generator Qualities                                                    | Positive pulse into 50 $\Omega$                  |
|------------------------------------------------------------------------------|--------------------------------------------------|
| Typical rise/fall times                                                      | <2 ns                                            |
| Available Amplitudes                                                         | 2.5 V, 1 V, 250 mV, 100 mV, 25 mV, 10 mV         |
| <b>Pulse Width</b>                                                           |                                                  |
| Range                                                                        | 4 ns to 500 ns <sup>[1]</sup>                    |
| Uncertainty <sup>[2]</sup>                                                   | 5 % of pulse width $\pm 2$ ns                    |
| <b>Pulse Period</b>                                                          |                                                  |
| Range                                                                        | 22 ms to 200 ns (45.5 Hz to 5 MHz)               |
| Resolution                                                                   | 4 or 5 digits depending upon frequency and width |
| 1-Year Absolute Uncertainty at Cardinal Points, tcal $\pm 5$ °C              | $\pm 2.5$ ppm                                    |
| [1] Pulse width not to exceed 40 % of period.                                |                                                  |
| [2] Pulse width uncertainties for periods below 2 $\mu$ s are not specified. |                                                  |

**Trigger Signal Specifications (Pulse Function)**

| Pulse Period    | Division Ratio | Amplitude into 50 $\Omega$ (p-p) | Typical Rise Time |
|-----------------|----------------|----------------------------------|-------------------|
| 22 ms to 200 ns | off/1/10/100   | $\geq 1$ V                       | $\leq 2$ ns       |

**Trigger Signal Specifications (Time Marker Function)**

| Time Marker Period | Division Ratio | Amplitude into 50 $\Omega$ (p-p) | Typical Rise Time |
|--------------------|----------------|----------------------------------|-------------------|
| 2 to 9 ns          | off/100        | $\geq 1$ V                       | $\leq 2$ ns       |
| 10 to 749 ns       | off/10/100     | $\geq 1$ V                       | $\leq 2$ ns       |
| 750 ns to 34.9 ms  | off/1/10/100   | $\geq 1$ V                       | $\leq 2$ ns       |
| 35 ms to 5 s       | off/1          | $\geq 1$ V                       | $\leq 2$ ns       |

**Trigger Signal Specifications (Edge Function)**

| Edge Signal Frequency | Division Ratio | Typical Amplitude into 50 $\Omega$ (p-p) | Typical Rise Time | Typical Lead Time |
|-----------------------|----------------|------------------------------------------|-------------------|-------------------|
| 900 Hz to 11 MHz      | off/1          | $\geq 1$ V                               | $\leq 2$ ns       | 40 ns             |

**Trigger Signal Specifications (Square Wave Voltage Function)**

| Voltage Function Frequency | Division Ratio | Typical Amplitude into 50 $\Omega$ (p-p) | Typical Rise Time | Typical Lead Time |
|----------------------------|----------------|------------------------------------------|-------------------|-------------------|
| 10 Hz to 10 kHz            | off/1          | $\geq 1$ V                               | $\leq 2$ ns       | 1 $\mu$ s         |

**Trigger Signal Specifications**

| Trigger Signal Type             | Parameters                                                 |
|---------------------------------|------------------------------------------------------------|
| Field Formats                   | Selectable NTSC, SECAM, PAL, PAL-M                         |
| Polarity                        | Selectable inverted or uninverted video                    |
| Amplitude into 50 $\Omega$ load | Adjustable 0 to 1.5 V p-p $\Omega$ , ( $\pm 7$ % accuracy) |
| Line Marker                     | Selectable Line Video Marker                               |

**Oscilloscope Input Resistance Measurement Specifications**

| Scope Input Selected | 50 $\Omega$       | 1 M $\Omega$                     |
|----------------------|-------------------|----------------------------------|
| Measurement Range    | 40 to 60 $\Omega$ | 500 k $\Omega$ to 1.5 M $\Omega$ |
| Uncertainty          | 0.1 %             | 0.1 %                            |

**Oscilloscope Input Capacitance Measurement Specifications**

| Scope Input selected                                                                                                                                                                        | 1 M $\Omega$                                                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|
| Measurement Range                                                                                                                                                                           | 5 to 50 pF                                                   |
| Uncertainty                                                                                                                                                                                 | $\pm (5 \text{ % of input} + 0.5 \text{ pF})$ <sup>[1]</sup> |
| [1] Measurement made within 30 minutes of capacitance zero reference. SC600 option must be selected for at least five minutes prior to capacitance measurement, including the zero process. |                                                              |

### Overload Measurement Specifications

| Source Voltage | Typical 'On' Current Indication | Typical 'Off' Current Indication | Maximum Time Limit DC or AC (1 kHz) |
|----------------|---------------------------------|----------------------------------|-------------------------------------|
| 5 to 9 V       | 100 to 180 mA                   | 10 mA                            | Settable 1 s to 60 s                |

### Oscilloscope Connections

With the cable supplied with the SC600 Option, connect the SCOPE output on the Calibrator to one of the channel connectors on your oscilloscope (see Figure 9-1).

To use the external trigger, connect the TRIG output on the Calibrator to the external trigger connection on your oscilloscope. To use the external trigger and see its signal with the calibration signal, connect the TRIG output to A different channel. See your oscilloscope manual for instructions to connect and see an external trigger.

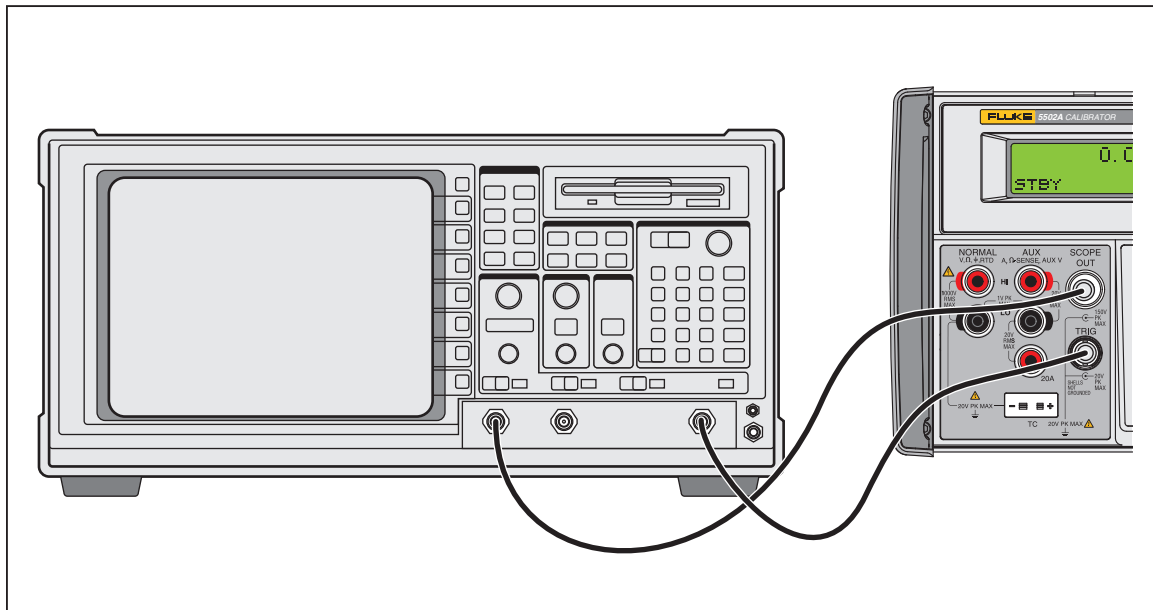
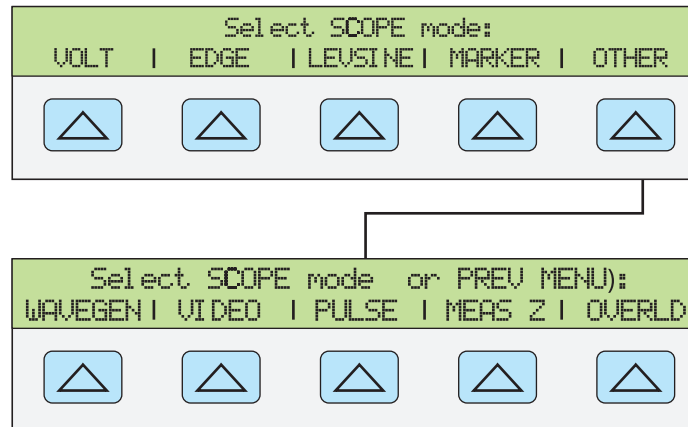


Figure 9-1. Oscilloscope Connection: Channel and External Trigger

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### Start the SC600 Option

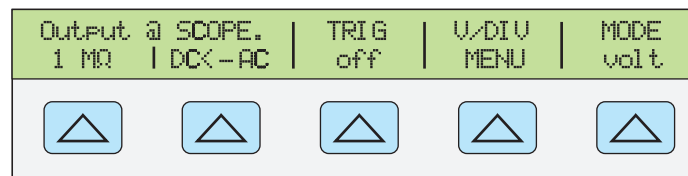
Push **SCOPE** (LED on) to select the SC600 Option. The SCOPE menu, shown below, shows in the Control Display. You can push the first four softkeys to go directly to the VOLT, EDGE, LEVSINE, and MARKER calibration menus. Push the last softkey to go to the OTHER menu (also shown below), this lets you access to WAVEGEN, VIDEO, PULSE, Impedance/Capacitance measurement (MEAS Z), and Overload (OVERLD) menus. Push **PREV MENU** to return to the SCOPE menu from the OTHER menu. This chapter tells you about each of these menus.



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### The Output Signal

If you have selected VOLT mode from the SCOPE menu, see the subsequent description. The Control Displays shows as follows with VOLT mode selected:



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The location of the output signal is shown on the Control Display (the display on the right side). If your Calibrator is connected, but the output does not show on the oscilloscope, you can have the Calibrator in standby mode. The settings for the output signal are indicated in the Output Display (the display on the left side).

If STBY is shown, push the **OPR** key. The Output Display will show OPR and the output should show on the oscilloscope.

### Adjust the Output Signal

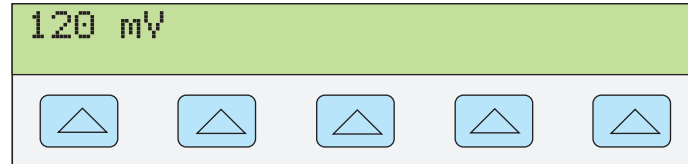
The Calibrator has several ways to change the settings for the output signal during calibration. Since oscilloscope calibration requires many adjustments of the output signal, the three available methods for changing these settings for oscilloscope calibration are summarized below. These methods provide the means of jumping to a new value or sweeping through a range of values.



### Key in a Value

The subsequent example is for use in the LEVSINE mode. To key a specific value directly into the Calibrator from its front panel:

1. Key in the value you want to record, including the units and prefixes. For example, to record 120 mV push **1** **2** **0** **μ** **m** **V**. The control display shows:



gj002i.eps

#### Note

Units and prefixes printed in red in the upper-left corner of the keys are accessed through the **SHIFT** key. For example, to record 200  $\mu$ s, push **2** **0** **0** **SHIFT** **μ** **m** **SHIFT** **Hz**.

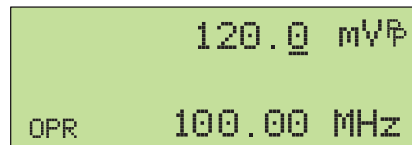
If you make an error, push **CE** to clear the Control Display and return to the menu.

2. Push **ENTER** to activate the value and move it to the Output Display.  
Other settings in the display will remain unaltered unless you key in an entry and specify the units for that setting.

### Adjust Values with the Rotary Knob

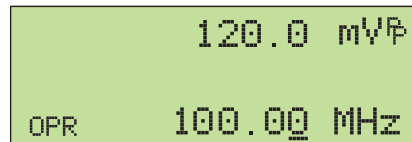
To adjust values in the Output Display with the rotary knob:

1. Turn the rotary knob. A cursor shows in the output display under the lowest digit and begins changing that digit. If you wish to place the cursor in the field without changing the digit, push **EDIT FIELD**, see below.



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2. To move the cursor between the voltage and frequency fields, push **EDIT FIELD**, see below.

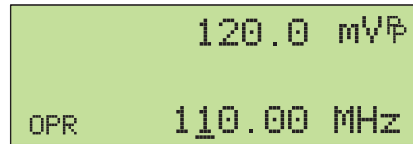


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3. Use **▶** and **◀** to move the cursor to the digit you want to change.

4. Turn the rotary knob to change the value.

When you use the rotary knob in Volt mode or Marker mode, the Control Display shows the new value's percent change from the reference value. This is useful for determining the percentage of error on the oscilloscope. You can set the reference value to the new value with **NEW REF**, see below.



gjh047.eps

5. Push **ENTER** to remove the cursor from the Output Display and save the new value as the reference value.

*Note*

*If you attempt to use the rotary knob to adjust a value to an amount that is invalid for the function you will use, or is outside the value's range limits, the value will not change and the 5502A will beep. If you need to reach a different range of values, turn the knob quickly to jump to the new range.*

Use **MULT** and **DIV**

The **MULT** and **DIV** keys cause the current value of the signal to jump to a predetermined cardinal value, whose amount is determined by the current function. These keys are given in more detail under the descriptions for each function.

**Reset the Oscilloscope Option**

You can reset all parameters in the 5502A to their default settings during front-panel operations. Push the **RESET** key on the front panel.

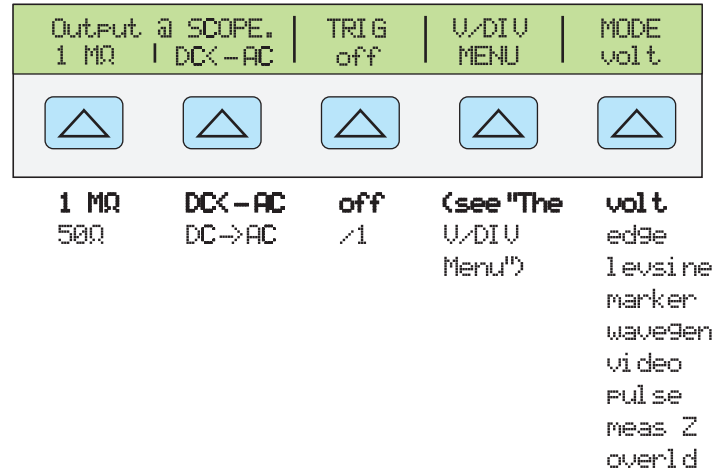
After resetting the 5502A, push **SCOPE** to return to the Oscilloscope Calibration Option (the Volt menu shows). Push **OPR** to connect the signal output.

**Calibrate the Voltage Amplitude on an Oscilloscope**

The oscilloscope voltage (vertical) gain is calibrated by applying a dc or low frequency square wave signal and adjusting its gain to meet the height specified for different voltage levels, designated by the graticule line divisions on the oscilloscope. The signal is applied from the 5502A in Volt mode. The specific voltages that you should use for calibration, and the graticule line divisions that need to be matched, vary for different oscilloscopes. See your oscilloscope's service manual.

**The Volt Function**

The Voltage gain is calibrated with the Volt function. This function is accessed through the Volt menu, which shows when you start the SCOPE option, or when you push the softkey below MODE to scroll through the oscilloscope calibration menus, see below.



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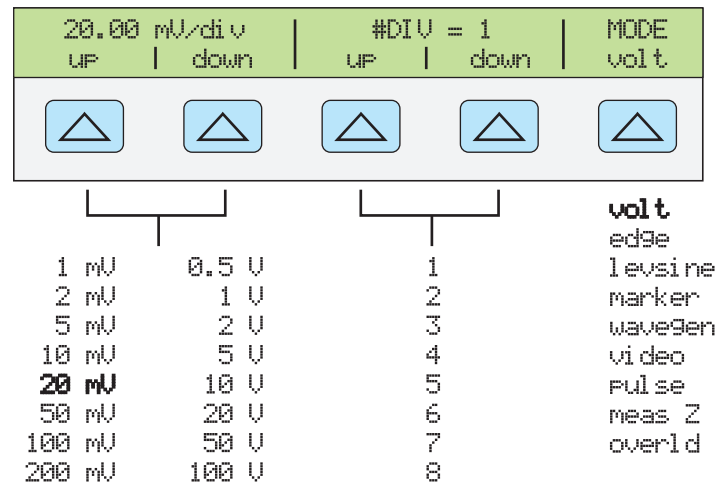
You can push the MODE softkey to move through the functions in the sequence shown, or you can push **PREV MENU** to return directly to the SCOPE menu.

Each menu item is given below:

- **OUTPUT @ SCOPE** Shows the location of the signal output. If the signal does not show on the oscilloscope, push **OPR**. To disconnect the signal, push **STBY**.
- **DC <-> AC** Toggles between a dc or ac signal. Push the softkey from the ac signal, to get the dc equivalent output.
- **1 MΩ** Toggles the output impedance setting of the Calibrator between 1 MΩ and 50 Ω.
- **TRIG** If you use a square wave to calibrate the external trigger, use this key to toggle the trigger off and on. When on, the reading will show “/1”, which indicated that the external trigger is at the same frequency as the volt output. The external trigger can be useful for many oscilloscopes that have difficulty triggering on low amplitude signals. You can also toggle the trigger off and on. Push **TRIG OUT**.
- **V/DIV MENU** Opens the voltage scaling menu, which lets you select the scale of the signal in volts per division. This menu is given below in detail, under “The V/DIV Menu.”
- **MODE** Shows you are in Volt mode. Use the softkey to change modes and open the corresponding menus for the other four oscilloscope calibration modes

### The V/DIV Menu

The V/DIV menu, shown below, sets the number of volts denoted by each division on the oscilloscope. This menu gives alternative methods for changing the output amplitude that can be more convenient for certain oscilloscope applications. To access the V/DIV menu, push V/DIV from the Volt menu.



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Each item in the V/DIV menu is given below.

- **V/div** Changes the scale of the output display by changing the number of volts that are represented by each division. The available settings, shown in the figure above, are provided in 1-2-5 step increments. Push the softkey below **UP** to increase the volts per division. Push the softkey below **DOWN** to decrease the volts per division.
- **# DIV** Specifies the number of divisions that establish the peak-to-peak value of the waveform. The value can be adjusted from one to eight divisions. The amount denoted by each division is shown in the V/div field. Push the softkey below UP to increase the signal's height, and push the softkey below DOWN to decrease it.

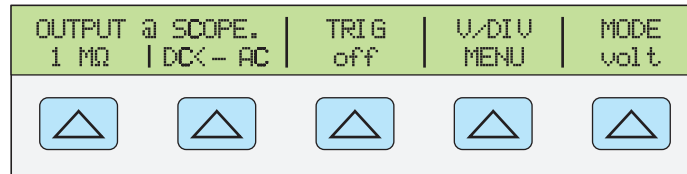
### Shortcuts to Set the Voltage Amplitude

The **MULT** and **DIV** keys step the voltages through cardinal point values of an oscilloscope in a 1-2-5 step sequence. For example, if the voltage is 40 mV, then push **MULT** to increase the voltage to the nearest cardinal point, which is 50 mV. Push **DIV** to decrease the voltage to the nearest cardinal point, which is 20 mV.

### Amplitude Calibration Procedure for an Oscilloscope

This example procedure tells you how to use the Volt menu to calibrate the oscilloscope's amplitude gain. During calibration, you will need to set different voltages and verify that the gain matches the graticule lines on the oscilloscope according to the specifications for your particular oscilloscope. See your oscilloscope manual for the recommended calibration settings and appropriate gain values.

Before you start this procedure, verify that you are running the oscilloscope option in Volt mode. If you are, the Control Display shows the subsequent menu.

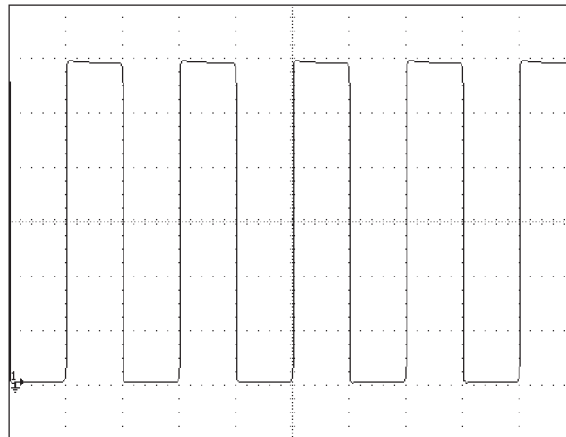


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Do the subsequent sample procedure to calibrate the vertical gain.

1. Connect the Calibrator to Channel 1 on the oscilloscope, making sure the oscilloscope is terminated at the proper impedance (1 MΩ for this example). Verify that the **OPR** key on the 5502A is illuminated, indicating that the signal is connected.
2. Key in the voltage level that is recommended for your oscilloscope. For example to record 30 mV, push **3** **0** **μm** **dBmV**, then push **ENTER**. See "Keying in a Value" earlier in this chapter.
3. Adjust the oscilloscope as necessary. The waveform should be similar to the one shown below, with the gain at exactly the amount specified for the calibration settings for your oscilloscope.

This example shows the gain at 30 mV to be 6 divisions, at 5 mV per division.



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4. Change the voltage to the next value recommended for calibrating your oscilloscope model, and repeat this procedure at the new voltage level, verifying the gain is correct according to the specifications in your manual.
5. Repeat the procedure for each channel.

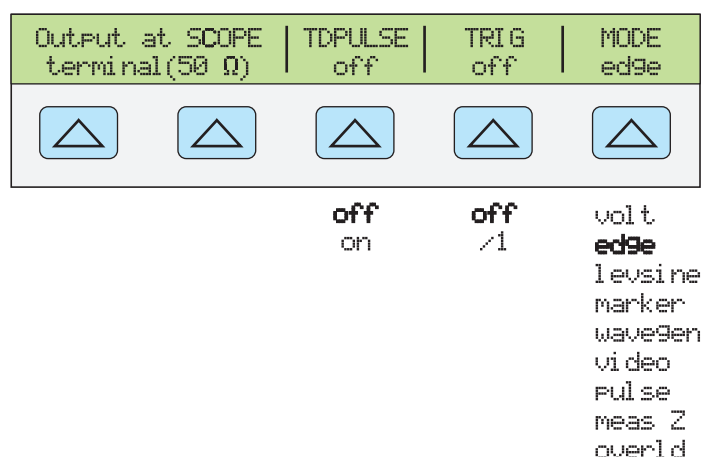
## Calibrate the Pulse and Frequency Response on an Oscilloscope

The pulse response is calibrated with a square-wave signal that has a fast leading edge rise-time. With this signal, you adjust the oscilloscope as necessary until it meets its particular specifications for rise time and pulse aberrations.

Subsequent pulse verification, the frequency response is examined by applying a leveled sine wave and acquiring a frequency reading at the -3 dB point, when the amplitude drops approximately 30 %.

### The Edge Function

The Edge function is used for calibrating the pulse response for your oscilloscope. To reach the Edge menu, push the softkey below MODE until “edge” shows.



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You can push the MODE softkey to move through the functions in the sequence shown, or you can push **PREV MENU** to return directly to the SCOPE menu.

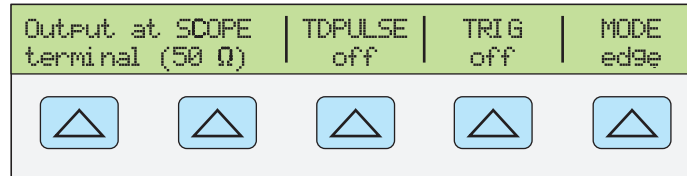
Each option in the Edge menus is given below.

- **OUTPUT @ SCOPE terminal (50Ω)** Shows the location and impedance of the signal output. If the signal does not show on the oscilloscope, push **OPR**. To disconnect the signal, push **STBY**.  
You cannot change the output impedance in Edge mode.
- **TD PULSE** Push once to turn the Tunnel Diode Pulser drive signal on, again to turn the Pulser drive off. This signal sources up to 100 V p-p to drive a Tunnel Diode Pulser (Fluke Part Number 606522, Tektronix 067-0681-01, or equivalent).
- **TRIG** If you use the external trigger, use this key to toggle the trigger off and on. When on, the reading will show “/1” which shows that the external trigger is at the same frequency as the edge output. The external trigger can be useful for many digital storage oscilloscopes that have difficulty triggering on fast rise time signals. You can also toggle the trigger off and on by pushing the TRIG OUT key.
- **MODE** Shows you are in Edge mode. Use the softkey to change modes and open the corresponding menus for the other four oscilloscope calibration modes.

### **Pulse Response Calibration Procedure for an Oscilloscope**

This sample procedure shows how to examine the oscilloscope's pulse response. Before you examine your oscilloscope, see your oscilloscope's manual for the recommended calibration settings.

Before you start this procedure, verify that you are running the oscilloscope option in Edge mode. If you are, the Control Display shows the subsequent menu.



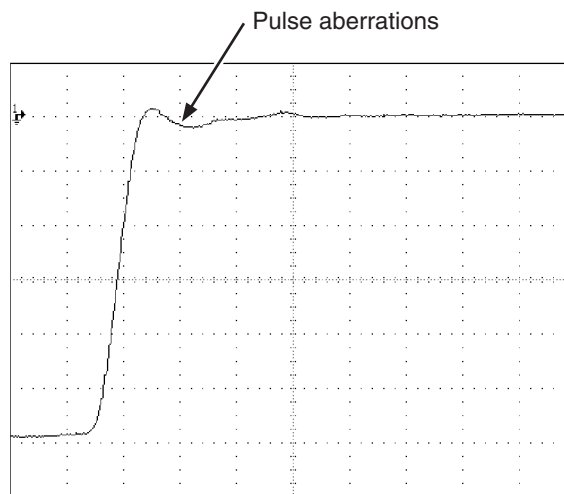
gjh067.eps

Do the subsequent sample procedure to calibrate the pulse response.

1. Connect the 5502A to Channel 1 on the oscilloscope. Select 50Ω impedance or use a 50Ω termination directly at the oscilloscope input. Verify that the **OPR** key is illuminated, indicating that the signal is connected.
2. Alter the voltage setting for the signal so it matches the amplitude value recommended by your oscilloscope manufacturer for calibrating the edge response. The default setting is 25 mV @ 1 MHz.

For example, on a Fluke PM3392A oscilloscope, start with a signal of 1 V @ 1 MHz.

3. Adjust the scale on your oscilloscope to achieve a good picture of the edge. For example, on a Fluke PM3392A oscilloscope with a 1 V @ 1 MHz signal, use 200 mV/div.
4. Adjust the time base on your oscilloscope to the fastest position available (20.0 or 50.0 ns/div).



gl007i.eps

5. Verify that your oscilloscope exhibits the proper rise time and pulse aberration qualities.
6. Push **STBY** to remove the input signal.

### Pulse Response Calibration with a Tunnel Diode Pulser

You can use the Calibrator to drive a tunnel diode pulser. This lets you see pulse edge rise times as fast as 125 ps.

The Calibrator sources a maximum pulser drive signal of 100 V p-p at 100 kHz. The recommended (and default) output setting is 80 V p-p at 100 kHz.

Do the subsequent procedure to use a tunnel diode pulser:

1. Connect the Calibrator, tunnel diode pulser, and oscilloscope as shown in Figure 9-2.
2. With the SC600 Option in EDGE mode, push the TDPULSE softkey to “on”.
3. Push **OPR**.
4. Rotate the control on the pulser box to the minimum setting necessary to trigger a reading.

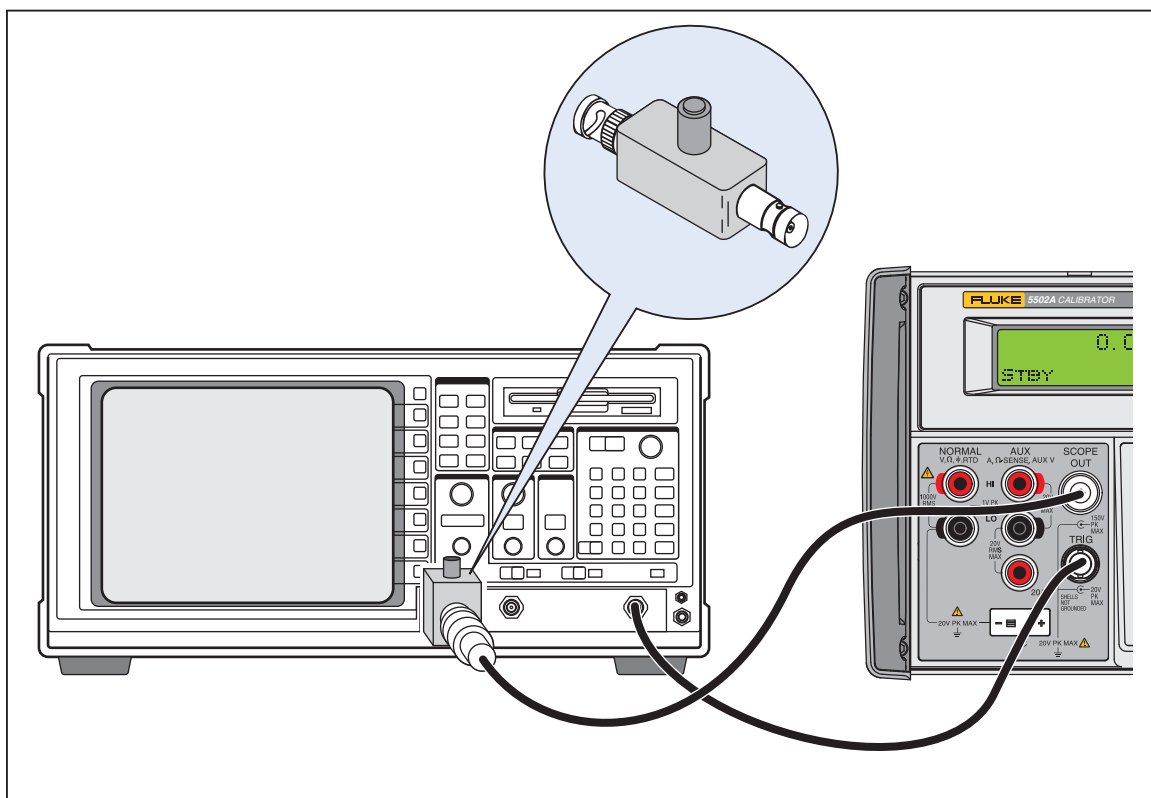


Figure 9-2. Tunnel Diode Pulser Connections

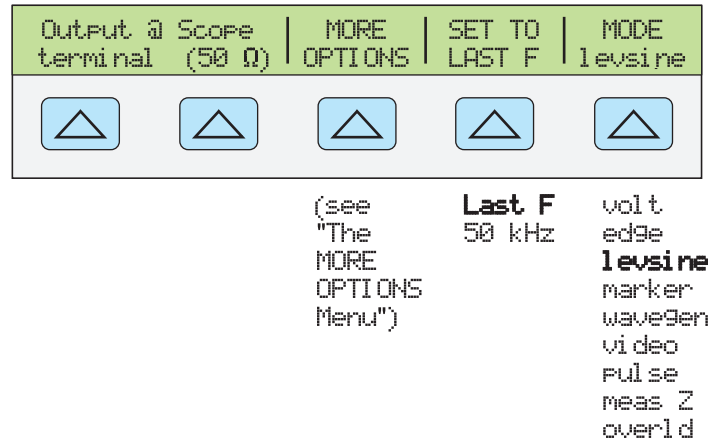
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### The Leveled Sine Wave Function

The Leveled Sine Wave (Levsine) function uses a leveled sine wave, whose amplitude remains relatively constant over a range of frequencies, to examine the bandwidth of the oscilloscope. When you examine your oscilloscope, you change the wave's frequency until the amplitude shown on the oscilloscope drops 30 %, which is the amplitude that corresponds to the -3 dB point.

To access the Levsine menu, push the softkey below MODE until “levsine” shows.





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You can push the MODE softkey to move through the functions in the sequence shown, or you can push **PREV MENU** to return directly to the SCOPE menu.

- **OUTPUT @ SCOPE terminal (50Ω)** Shows the location and impedance of the signal output. If the signal does not show on the oscilloscope, push **OPR**. To disconnect the signal, push **STBY**. You cannot change the impedance while you are in Levsine mode.
- **MORE OPTIONS** Opens more menu items, which are given in “The MORE OPTIONS Menu” section.
- **SET TO LAST F** Toggles between the current frequency setting and the reference value of 50 kHz. This option is useful for reverting to the reference to examine the output after you make adjustments at a different frequency.
- **MODE** Shows you are in Levsine mode. Use the softkey to change modes and open the related menus for the other four calibration modes.

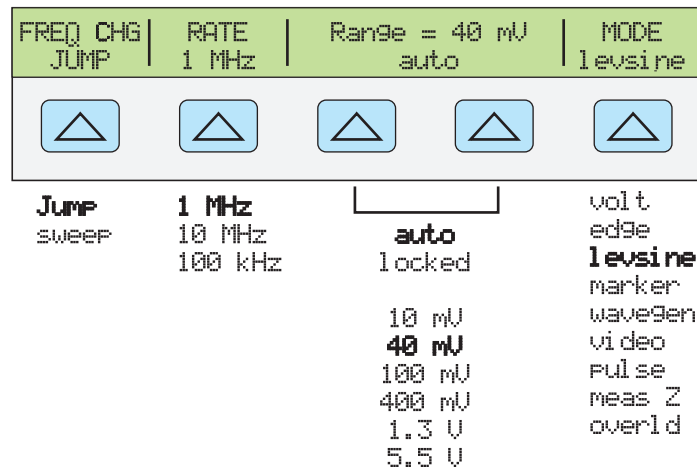
### Shortcuts to Set the Frequency and Voltage

Three options are available to control the sine wave settings.

- **SET TO LAST F** toggles between the last frequency used and the reference frequency of 50 kHz, this lets you examine the output at the reference after you make adjustments at a different frequency.
- **MORE OPTIONS** lets you use an automatic frequency sweep and lock the voltage range, if necessary. The subsequent section gives more information on this menu.
- The **MULT X** and **DIV ÷** keys step frequencies up or down in amounts that let you quickly access a new set of frequencies. For example, if the value is 250 kHz, **MULT X** changes it to 300 kHz, and **DIV ÷** changes it to 200 kHz. For voltage values, **MULT X** and **DIV ÷** step through cardinal point values in a 1.2-3-6 sequence.

## The MORE OPTIONS Menu

When you select MORE OPTIONS, you open options that give you more control of the frequency and voltage. To access the MORE OPTIONS menu, push the softkey below MORE OPTIONS in the Levsine menu.



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Each option in the MORE OPTIONS menu is given below.

- FREQ CHANGE** Toggles between two settings that control how the output signal adjusts to a new frequency. This is the default setting.
 

“Jump” causes the output signal to jump immediately to a new frequency setting. “Sweep” causes the signal to sweep through a series of frequency values, over a range you set. Use the sweep function to see the signal gradually change over a given bandwidth and see the point at which its amplitude changes. Sweep function instructions are given in the “Sweep Through a Frequency Range” section.
- RATE** Used when FREQ CHANGE is set to “sweep” to select a sweep speed of 100 kHz, 1 MHz, or 10 MHz.
 

A slower sweep rate lets you see the frequency change very slowly. After a faster sweep, you can pinpoint a specified frequency with a slower sweep over a subset of your previous frequency range.
- Range** The softkeys toggle between two settings. The first setting (“auto”) changes the range limit automatically in accordance with the voltage level. The second setting (“locked”) freezes the current range limit. Subsequent changes in voltage level are then measured with this range limit.

There are six range limits in levsine mode: 10 mV, 40 mV, 100 mV, 400 mV, 1.3 V, and 5.5 V. When set to “auto” the Calibrator uses your voltage setting to automatically set the range limit that gives the most accurate output. When set to “locked” the range limit stays set and you can decrease the voltage down to the bottom of the range.

For example, if the range limit is 40 mV and you record 5 mV with “auto” selected, the Calibrator automatically changes the range limit to 10 mV and output 5 mV from the 10 mV range. If you start with the 40 mV range “locked” and then record 5 mV, the Calibrator outputs 5 mV from the 40 mV range.

The default range setting is “auto” which must always be used unless you are troubleshooting discontinuities in your oscilloscope’s vertical gain. The range setting will go to “auto” after you are out of levsine mode.

- **MODE** Shows that you are in levsine mode. Use the softkey to change modes and open the related menus for the other four calibration modes.

### Sweep Through a Frequency Range

When you change frequencies with the sweep method, the output sine wave sweeps through a specified range of frequencies. This feature lets you identify the frequency at which the oscilloscope’s signal shows special behavior. You can quickly see the frequency response of the oscilloscope. Before you start this procedure, make sure you are in the MORE OPTIONS menu and the sine wave is shown on the oscilloscope.

Do the subsequent procedure to sweep through frequencies:

1. Make sure the output signal shows the frequency you will start with. If not, key in that frequency and push **ENTER**.
2. Toggle **FREQ CHANGE** to “sweep.” Toggle the **RATE** to “100 kHz” if you want to observe a very slow sweep over a small range.
3. Key in the end frequency; then push **ENTER**. After you push **ENTER**, the signal sweeps through frequencies between the two values you recorded, and the Sweep menu shows on the Control Display as shown below.
4. You can let the signal sweep through the full range, or you can stop the sweep if necessary to record the frequency at a specified point.

To interrupt the sweep, push the softkey below **HALT SWEEP**. The current frequency will show on the Output Display and the MORE OPTIONS menu will show again on the Control Display.

#### Note

*When you push **HALT SWEEP** and interrupt the frequency sweep, the **FREQ CHANGE** method changes to “jump.”*

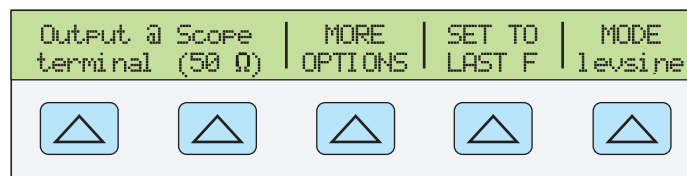
5. Do the procedure again if necessary. For example, if you did a fast sweep, you can pinpoint a specified frequency with a slow sweep over a subset of your previous frequency range.

### Frequency Response Calibration Procedure for an Oscilloscope

This sample procedure, which verifies the frequency response on your oscilloscope, is usually done after the pulse response is verified.

This procedure examines the bandwidth by finding the frequency at the -3 dB point for your oscilloscope. The reference sine wave in this procedure has an amplitude of 6 divisions, so that the -3 dB point can be found when the amplitude drops to 4.2 divisions.

Before you start this example procedure, verify that you have the oscilloscope option in Levsine mode. If you are, the Control Display shows the subsequent menu, see below.

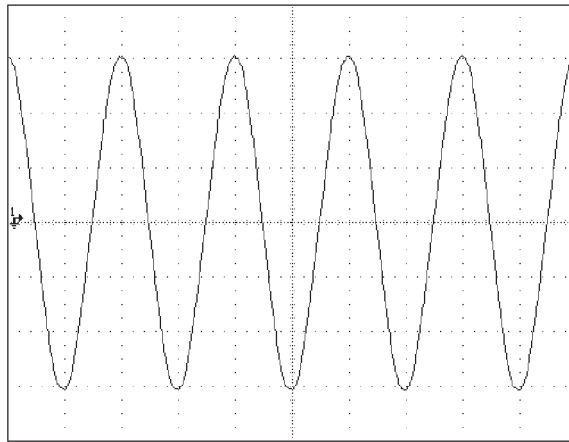


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Do the subsequent sample procedure to calibrate the frequency response.

1. Push the **OPR** key on the 5502A to reconnect the signal. Select 50  $\Omega$  impedance or use a 50  $\Omega$  external termination directly at the oscilloscope input.
2. Adjust the sine wave settings in the Output Display. Refer to the calibration recommendations in your oscilloscope manual. For example, for the HP 54522C oscilloscope, start at 600 mV @ 1 MHz. To record 600 mV, push **6** **0** **0**  **$\mu$  m** **dBm V**; then push **ENTER**.
3. Adjust the oscilloscope as necessary. The sine wave must show at six divisions, peak-to-peak, as shown below.

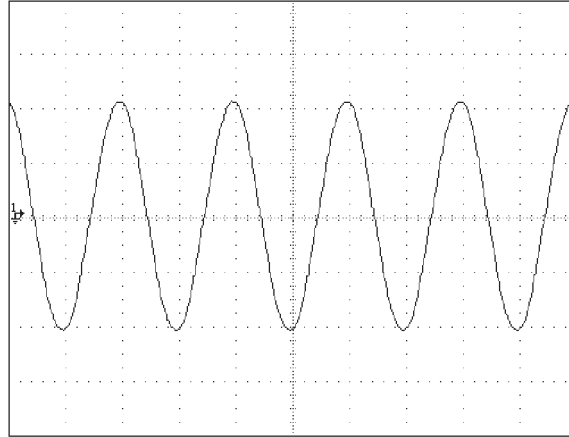
If necessary, make small adjustments to the voltage amplitude until the wave gets to six divisions. To fine-tune the voltage, push **EDIT FIELD** to bring a cursor into the Output Display, move the cursor with the **◀** key, and turn the rotary knob to adjust the value.



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4. Increase the frequency to 400 MHz (for 500 MHz instruments), or 500 MHz (for 600 MHz instruments). To record 400 MHz, push **4** **0** **0** **P M** **Hz** then push **ENTER**.
5. Continue to increase the frequency slowly until the waveform decreases to 4.2 divisions, as shown below.

To increase the frequency slowly, fine-tune it with the rotary knob. To do this, push **EDIT FIELD** to place a cursor in the Output Display, push **EDIT FIELD** again to place it in the frequency field, and use the **◀** and **▶** keys to move it to the digit you want to change. Then turn the rotary knob to change the value. Continue with small increments in the frequency until the signal drops to 4.2 divisions. At 4.2 divisions, the signal is at the frequency that agrees to the -3 dB point, see below.



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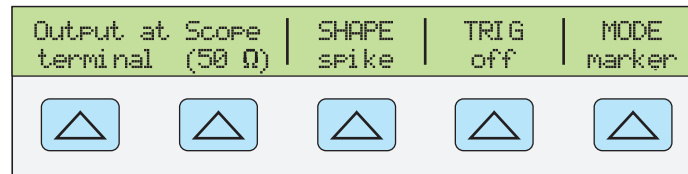
6. Push **STBY** to remove the input signal.
7. Do this procedure again for the remaining channels on your oscilloscope.

## Calibrate the Time Base of an Oscilloscope

The horizontal deflection (time base) of an oscilloscope is calibrated with a method equivalent to the vertical gain calibration. A time marker signal is made from the Calibrator and the signal's peaks are aligned to the graticule line divisions on the oscilloscope.

### The Time Marker Function

The Time MARKER function, which is available through the MARKER menu, lets you calibrate the timing response of your oscilloscope. To access the MARKER menu, push the softkey below MODE until "marker" shows.



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You can push the MODE softkey to move through the functions as shown, or you can push **PREV MENU** to go directly to the SCOPE menu.

Each option in the Marker menu is given below.

- **OUTPUT @ SCOPE terminal (50Ω)** Shows the location of the signal output. If the signal does not show on the oscilloscope, push **OPR**. To disconnect the signal, push **STBY**.
- **SHAPE** Shows the type of waveform. With reference to the frequency setting, possible selections are sine, spike, square (50 % duty cycle square wave), and sq20% (20 % duty cycle square wave.) Note that selections available under SHAPE refer to the selected marker period (frequency) as follows:

| Selection | Period (Frequency)               |
|-----------|----------------------------------|
| Sine      | 10 ns – 2 ns (100 MHz – 500 MHz) |
| Spike     | 5 s – 20 ns (0.2 Hz – 50 MHz)    |
| Square    | 5 s – 10 ns (0.2 Hz – 100 MHz)   |
| Sq20%     | 20 ms – 100 ns (50 kHz – 10 MHz) |

- **TRIG** If you use the external trigger, use this key to move through the trigger settings. The available trigger settings are: off, /1 (trigger signal shows on each marker), /10 (trigger signal shows on every tenth marker), and /100 (trigger signal shows on each 100 markers). You can also toggle the trigger off and on. Push the TRIG OUT key.
- **MODE** Shows you are in Marker mode. Use the softkey to change modes and open the related menus for the other four oscilloscope calibration modes.

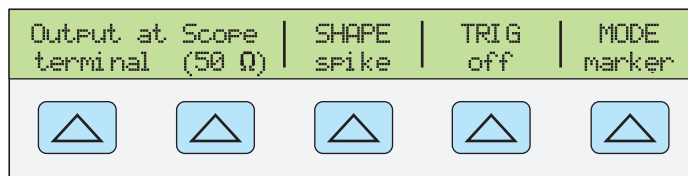
Default marker values are 1.000 ms, SHAPE = spike.

The **MULT** and **DIV** keys step the voltages through cardinal point values of an oscilloscope in a 1-2-5 step sequence. For example, if the period is 1.000 ms, push **MULT** to increase the period to the nearest cardinal point, which is 2.000 ms. Push **DIV** to decrease the voltage to the nearest cardinal point, which is 500 μs.

### Time Base Marker Calibration Procedure for an Oscilloscope

This sample procedure uses the Time Marker function to examine the horizontal deflection (time base) of your oscilloscope. See the manual for your oscilloscope for the time base values recommended for calibration.

Before you start this procedure, verify that you are in Marker mode. If you are, the Control Display shows the subsequent menu, see below.



gj060.eps

Do the subsequent sample procedure to calibrate the time base.

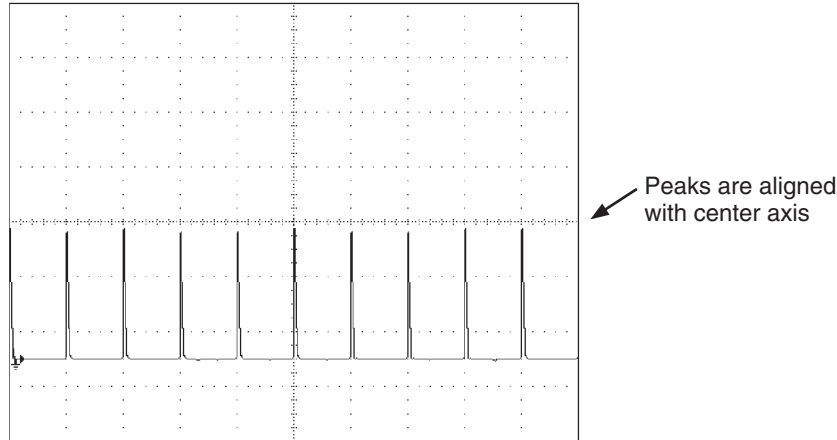
1. Connect the Calibrator to Channel 1 on the oscilloscope. Select 50 Ω impedance or use an external 50 Ω termination. Make sure the oscilloscope is dc-coupled.
2. Apply a time marker value. Refer to the recommended calibration settings in your oscilloscope manual. For example, to record 200 ns, push **2** **0** **0** **SHIFT** **k** **SHIFT** **Hz**, then push **ENTER**.

*Note*

*You can record the equivalent frequency as an alternative to the time marker value. For example, you can record 5 MHz for 200 ns.*

3. Set the time base of your oscilloscope to show 10 time markers. The time markers must align with the oscilloscope divisions, as shown in the example below.

For an accurate indication, align the peaks of the signal with the horizontal center axis.



gl011i.eps

4. Do this procedure again for all time marker values recommended for your oscilloscope. Do this procedure again for digital and analog mode as necessary. It can be necessary, for some oscilloscopes, to change the magnification while you calibrate in analog mode.
5. Push **STBY** to remove the input signal.

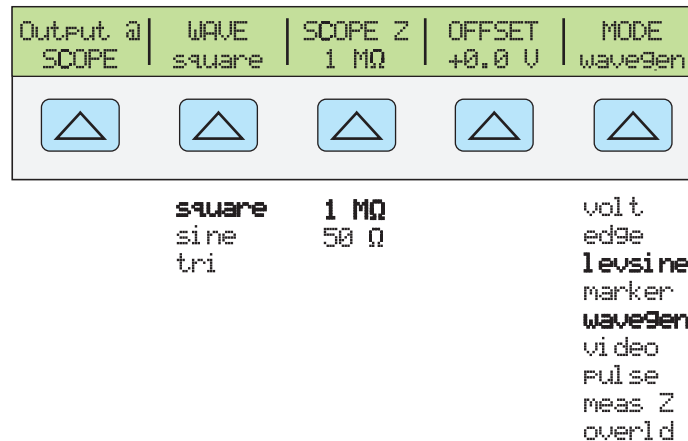
## Test the Trigger SC600 Option

The oscilloscope can trigger on different waveforms. This can be tested with the wave generator. When the wave generator is used, a square, sine, or triangle wave is transmitted and the wave output impedance, offset, and voltage can be changed to test the trigger function at different levels.

*Note*

*The wave generator must not be used to verify the accuracy of your oscilloscope.*

The wave generator is available through the Wavegen menu, shown below. To access this menu, push the softkey below MODE until “wavegen” shows, see below.



gjh061.eps

You can push the MODE softkey to go through the functions in the sequence shown, or you can push **PREV MENU** to return directly to the OTHER modes menu.

Each option in the Wavegen menu is given below.

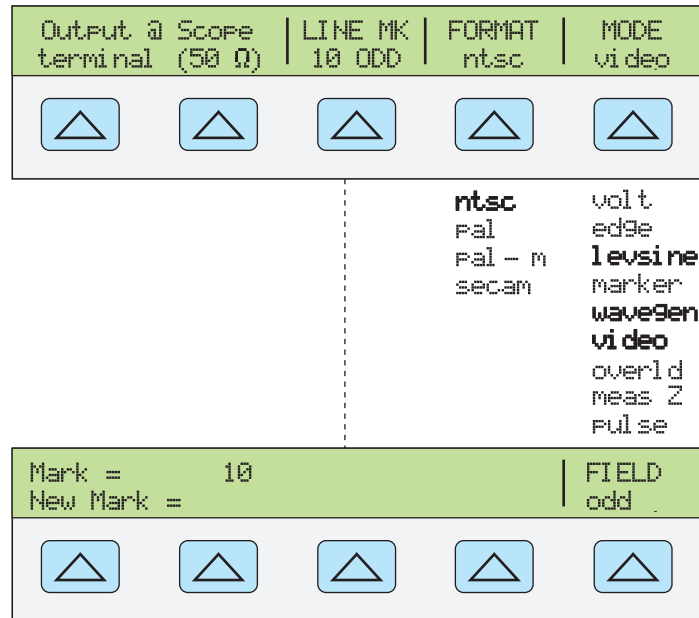
- **OUTPUT @ SCOPE** Shows the location of the signal output. If the signal does not show on the oscilloscope, push **OPR**. To disconnect the signal, push **STBY**.
- **WAVE** Scrolls through the three types of waveforms that are available. You can select a square, sine, or triangle wave as the output.
- **SCOPE Z** Toggles the output impedance setting of the Calibrator between 50  $\Omega$  and 1 M $\Omega$ .
- **OFFSET** Shows the offset of the given wave. To change the offset, record the new value, and push **ENTER**. The rotary knob does not change the offset. The rotary knob changes the voltage output.

When you change the offset, you must stay in specified limits to prevent clipping the peaks. The limit comes from the peak-to-peak value of the wave. The maximum peak excursion is equal to the offset plus half of the wave's peak-to-peak value. See “Wave Generator Specifications” at the start of this chapter.

- **MODE** Shows you are in Wavegen mode. Use the softkey to change modes and open the related menus for the other four oscilloscope calibration modes.



## Test Video Triggers



gjh062.eps

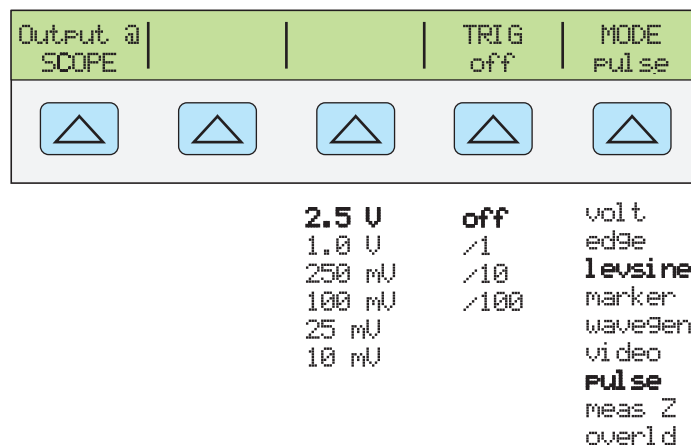
You can push the MODE softkey to move through the functions in the sequence shown, or you can push **PREV MENU** to return directly to the OTHER modes menu.

Each option in the Video menu is given below.

- **OUTPUT @ SCOPE terminal (50Ω)** Shows the location of the signal output. If the signal does not show on the oscilloscope, push **OPR**. To disconnect the signal, push **STBY**.
- **LINE MK** Lets you to select the marker line number. For ntsc and pal-m formats, you can also select field (“odd” or “even”). For pal and secam formats, the field (“ODD” or “EVEN”) is selected automatically in reference to the marker line number.
- **FORMAT** Scrolls through the available formats. You can select ntsc, pal, pal-m, and secam.
- **MODE** Shows you are in VIDEO mode. Use the softkey to change modes and open the related menus for the other four oscilloscope calibration modes.

Default video settings are +100 %, format = NTSC, and videomark = 10.

## Verify Pulse Capture



gjh063.eps

You can push the MODE softkey to move through the functions in the sequence shown, or you can push **PREV MENU** to return directly to the OTHER modes menu.

Each option in the PULSE menu is given below.

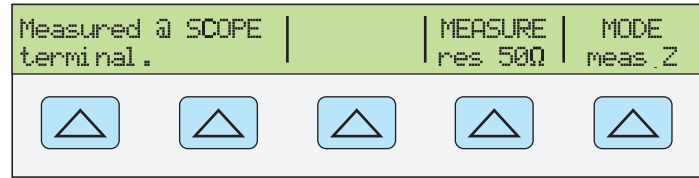
- **OUTPUT @ SCOPE** Shows the location of the signal output. If the signal does not show on the oscilloscope, push **OPR**. To disconnect the signal, push **STBY**.
- **AMPL** Shows the output level. You can select 2.5 V, 1.0 V, 250 mV, 100 mV, 25 mV, or 10 mV.
- **TRIG** If you use the external trigger, use this key to move through the trigger settings. The available trigger settings are: off, /1 (trigger signal shows on each marker), /10 (trigger signal shows on every tenth marker), and /100 (trigger signal shows on each 100 markers). You can also toggle the trigger off and on. Push **TRIG OUT**.
- **MODE** Shows you are in PULSE mode. Use the softkey to change modes and open the menus for the other oscilloscope calibration modes.

Default Pulse settings are 100.0 ns width and 1.000 ms period. To change these values, you have some options. Usually, you will record values for pulse width and period. To do this, record the pulse width value with units first, followed immediately by the period value and units, followed by **ENTER**. For example, you could record a pulse width of 50 ns and a period of 200 ns with the subsequent sequence:

**5 0 SHIFT<sup>n</sup> k SHIFT<sup>sec</sup> Hz 2 0 0 SHIFT<sup>n</sup> k SHIFT<sup>sec</sup> Hz ENTER**.

To change only the pulse width, record a value in seconds. You can record this value with units (for example, 200 ns) or without units (for example, 0.0000002). To change only the period, record a frequency with units (for example, 20 MHz, this changes the period to 50 ns).

## Measure Input Resistance and Capacitance



res 50Ω  
res 1MΩ  
cap  
volt  
edge  
levsine  
marker  
wavegen  
video  
Pulse  
meas\_Z  
overld

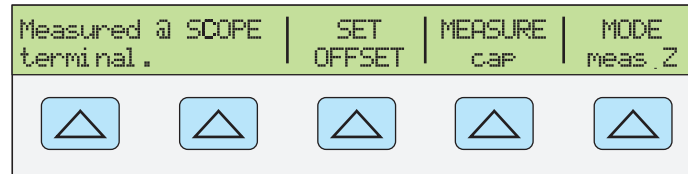
gjh064.eps

You can push the MODE softkey to move through the functions in the sequence shown, or you can push **PREV MENU** to return directly to the OTHER modes menu.

Each option in the Impedance/Capacitance (MEAS Z) menu is given below.

- **Measured @ SCOPE terminal** Shows the location of the measured input.
- **MEASURE** Shows the type of test. You can select res 50 Ω or res 1 MΩ termination (for impedance) or cap (capacitance).
- **MODE** Shows the Calibrator is in MEAS Z mode. Use the softkey to change modes and open the menus for the other oscilloscope calibration modes.

If you have selected Capacitance measurement, the menu shows as follow:



CLEAR  
OFFSET

gjh065.eps

- **SET OFFSET** With the cable disconnected at the oscilloscope but still connected at the Calibrator, push **SET OFFSET** to cancel the capacitance of the Calibrator and cable. Push again (**CLEAR OFFSET**) to cancel the offset.

### Input Impedance Measurement

With MEAS Z mode selected, do the subsequent procedure to measure the input impedance of an oscilloscope:

1. Use the MEASURE softkey to select “res 50Ω” or “res 1 MΩ” termination.
2. Connect the SCOPE terminal on the Calibrator to Channel 1 on the oscilloscope.
3. Push **OPR** to initiate the measurement.

### Input Capacitance Measurement

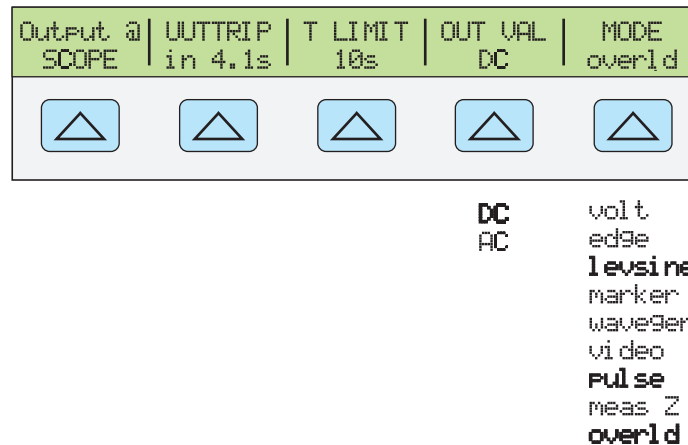
With MEAS Z mode selected, do the subsequent procedure to measure the input capacitance of an oscilloscope:

1. Set the oscilloscope for 1 M $\Omega$  input impedance. Note that input capacitance tests cannot be done with 50  $\Omega$  input impedance.
2. Use the MEASURE softkey to select “cap”.
3. With the output cable connected to the Calibrator but not connected to the oscilloscope, push the SET OFFSET softkey to cancel stray capacitances.
4. Connect the output cable to Channel 1 on the oscilloscope.
5. Push **OPR** to initiate the measurement.

## Test Overload Protection

### ⚠ Caution

This test examines the power handling capability of the 50  $\Omega$  input of your oscilloscope. Before proceeding, ensure that the power rating of your oscilloscope can handle the voltages and currents that this test can output. Failing to do so could damage your oscilloscope.



gjh066.eps

You can push the **MODE** softkey to move through the functions in the sequence shown, or you can push **PREV MENU** to return directly to the OTHER modes menu.

Each option in the OVERLD menu is given below.

- **OUTPUT @ SCOPE** Shows the location of the signal output.
- **UUTTRIP** Shows test results. “NO” shows if the overload protection did not trip during the selected time limit. A value in seconds shows (for example, “4.1s”) if the overload protection has tripped during the time limit.
- **T LIMIT** Shows the selected time limit to apply the output value. Push this softkey to key in or edit a different time limit (1s to 60s.)
- **OUT VAL** Shows the output voltage type. You can select DC or AC and a value ranging from 5 V to 9 V (shown in Output Display). Key in or edit this value.
- **MODE** Shows you are in OVERLD (Overload) mode. Use the softkey to change modes and open menus for other oscilloscope calibration modes.

Default overload settings are +5.000 V and DC.

You can also set the overload time limit with **SETUP**, **INSTMT SETUP** softkey, **OTHER SETUP** softkey, **TLIMDEF** softkey, then choose 1s to 60s.

Do the subsequent procedure to verify the overload protection of an oscilloscope:

1. Connect the Calibrator to Channel 1 on the oscilloscope.
2. Select the voltage type (DC or AC) with the OUT VAL softkey.
3. Key in the voltage level. (The default value is 5 V.)
4. If necessary, change the time. (Refer to the procedure given above.) The default time is 10s.
5. Look for test results shown with the UUTTRIP softkey.

## Remote Commands and Queries

This section tells you commands and queries that are exclusive to the SC600 Option. Each command description shows if it can be used with IEEE-488 and RS-232 remote interfaces and identifies it as a Sequential, Overlapped, or Coupled command.

**IEEE-488 (GPIB) and RS-232 Applicability** Each command and query has a check box that shows applicability to IEEE-488 (general purpose interface bus, or GPIB) and RS-232 remote operations.

**Sequential Commands** Commands done immediately as they are found in the data stream are referred to as sequential commands. For more information, see “Sequential Commands” in Chapter 5.

**Overlapped Commands** Commands SCOPE, TRIG, and OUT\_IMP are designated as overlapped commands because they can be overlapped (interrupted) by the subsequent command before they have completed execution. When an overlapped command is interrupted, it can take longer to do while it stops for other commands to be completed. To prevent an overlapped command interruption during execution, use \*OPC, \*OPC?, or \*WAI, which prevent interruptions until they sense command completion. For more information, see “Overlapped Commands” in Chapter 5.

**Coupled Commands** SCOPE and OUT\_IMP are coupled commands because they can be coupled (combined) with other commands to make a compound command sequence. Precautions are necessary to make sure that commands are not coupled so that they disable each other, since a fault can be the result. For more information, see “Coupled Commands” in Chapter 5.

## General Commands

Table 9-1 is a list of Scope command parameters.

Table 9-1. SCOPE Command Parameters

| Parameter | Description/Example                                                                                                                                                                                              |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| OFF       | Turns the oscilloscope hardware off. Programs 0 V, 0 Hz, output at the NORMAL terminals, standby.                                                                                                                |
| VOLT      | Oscilloscope ac and dc VOLT mode. Programs 20 mV peak-to-peak, 1 kHz, output at the SCOPE BNC, output impedance 1 M $\Omega$ , standby if from OFF or if in standby. FUNC? Shows SACV (for ac) or SDCV (for dc). |
|           | Example: SCOPE VOLT; OUT 4 V, 1 kHz<br>(ac voltage, 4 V peak-to-peak, 1 kHz.)                                                                                                                                    |

Table 9-1. SCOPE Command Parameters (cont.)

| Parameter | Description/Example                                                                                                                                                                       |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| EDGE      | Oscilloscope EDGE mode. Programs 25 mV peak-to-peak, 1 MHz, output at the SCOPE BNC, standby if from OFF or previously in standby. FUNC? shows EDGE.                                      |
|           | Example: SCOPE EDGE; OUT 0.5 V, 5 kHz<br>(Edge, 0.5 V peak-to-peak, 5 kHz.)                                                                                                               |
| LEVSINE   | Oscilloscope LEVSINE mode. Programs 30 mV peak-to-peak, 50 kHz, output at the SCOPE BNC, standby if from OFF or previously in standby. FUNC? shows LEVSINE.                               |
|           | Example: SCOPE LEVSINE; OUT 1 V, 50 kHz<br>(Leveled sine wave, 1 V peak-to-peak, 50 kHz.)                                                                                                 |
| MARKER    | Oscilloscope MARKER mode. Programs the period to 1 ms, output at the SCOPE BNC, standby if from OFF or previously in standby. FUNC? shows MARKER.                                         |
|           | Example: SCOPE MARKER; OUT 2 MS<br>(Marker, period of 2 ms.)                                                                                                                              |
| WAVEGEN   | Oscilloscope WAVEGEN mode. Programs 20 mV peak-to-peak, square wave, 1 kHz, no offset, output impedance 1 M $\Omega$ , standby if from OFF or previously in standby. FUNC? shows WAVEGEN. |
|           | Example: SCOPE WAVEGEN; OUT 1 V, 1 kHz<br>(Wave Generator, 1 V peak-to-peak, 1 kHz.)                                                                                                      |
| VIDEO     | Oscilloscope VIDEO mode. Programs 100% output (1 V p-p), line marker 10, format NTSC. FUNC? shows VIDEO.                                                                                  |
|           | Examples: SCOPE VIDEO; OUT 90<br>(Video, 90% output)<br>SCOPE VIDEO; OUT -70<br>(Video, -70% output, inverse video)                                                                       |
| PULSE     | Oscilloscope PULSE mode. Programs 100 ns pulse width, 1.000 $\mu$ s period, 2.5 V range. FUNC? shows PULSE.                                                                               |
|           | Example: SCOPE PULSE; OUT 50 ns, 500 ns; RANGE TP8DB<br>(Pulse, 50 ns pulse width, 500 ns period, 1.5 V range)                                                                            |
| MEASZ     | Oscilloscope Impedance/Capacitance measurement (MEAS Z) mode. Programs 50 $\Omega$ range. FUNC? shows MEASZ.                                                                              |
|           | Example: SCOPE MEASZ; RANGE TZCAP<br>(MEAS Z mode, capacitance range)                                                                                                                     |
| OVERLD    | Oscilloscope Overload mode. Programs 5 V dc range. FUNC? shows OVERLD.                                                                                                                    |
|           | Example: SCOPE OVERLD; OUT 7 V; RANGE TOLAC<br>(Overload, 7 V output, ac range)                                                                                                           |

## SCOPE

(IEEE-488, RS-232, Sequential)

Programs the SC600 oscilloscope calibration option hardware, if installed. The instrument settings are determined by this command's parameter. Once in SCOPE mode, use the OUT command to program new output.

OPER, STBY, \*OPC, \*OPC?, and \*WAI all operate as given in Chapter 6. The state of the oscilloscope's output while in SCOPE mode is reflected by the bit in the ISR that is assigned to SETTLED.

The FUNC? query shows SDCV, SACV, LEVSINE, MARKER, EDGE, and WAVEGEN for the corresponding oscilloscope modes.

|             |         |                                                                                                                                                                               |
|-------------|---------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Parameters: | OFF     | Turns the oscilloscope hardware off. Programs 0V, 0 Hz, output at the NORMAL terminals, standby.                                                                              |
|             | VOLT    | AC and dc voltage mode of the oscilloscope. Programs 20 mV peak-to-peak, 1 kHz, output at the SCOPE BNC, output impedance 1 MΩ, standby if from OFF or previously in standby. |
|             | EDGE    | Oscilloscope Edge mode. Programs 25 mV peak-to-peak, 1 MHz, output at the SCOPE BNC, standby if from OFF or previously in standby.                                            |
|             | LEVSINE | Oscilloscope-leveled sine mode. Programs 30 mV peak-to-peak, 50 kHz, output at the SCOPE BNC, standby if from OFF or previously in standby.                                   |
|             | MARKER  | Oscilloscope Marker mode. Programs the period to 1 ms, output at the SCOPE BNC, standby if from OFF or previously in standby.                                                 |
|             | WAVEGEN | Oscilloscope Wavegen mode. Programs 20 mV peak-to-peak, square wave, 1 kHz, no offset, output impedance 1 MΩ, standby if from OFF or previously in standby.                   |
|             | VIDEO   | Oscilloscope video trigger mode. Programs 100 % output; ntsc format, mark line 10, odd field.                                                                                 |
|             | PULSE   | Oscilloscope pulse mode. Programs 100 nanosecond width pulses every 1 microsecond.                                                                                            |
|             | MEASZ   | Oscilloscope impedance measurement mode.                                                                                                                                      |
|             | OVERLD  | Oscilloscope overload test mode. Programs a 5 V dc output with a 10 second time limit.                                                                                        |

|          |                |                 |                                                |
|----------|----------------|-----------------|------------------------------------------------|
| Example: | SCOPE VOLT;    | OUT -2V, 0 Hz   | (dc voltage, -2 V)                             |
|          | SCOPE VOLT;    | OUT 4V, 1 kHz   | (ac voltage, 4 V peak-to-peak, 1 kHz.)         |
|          | SCOPE EDGE;    | OUT 0.5V, 5 kHz | (Edge, 0.5 V peak to peak, 5 kHz.)             |
|          | SCOPE LEVSINE; | OUT 1V, 20 kHz  | (Leveled sine wave, 2 V peak-to-peak, 20 kHz.) |
|          | SCOPE MARKER;  | OUT 2 MS        | (Marker, period of 2 ms.)                      |

|                              |                                                        |
|------------------------------|--------------------------------------------------------|
| SCOPE WAVEGEN; OUT 1V, 1 kHz | (Wave Generator, 1 V peak-to-peak, 1 kHz.)             |
| SCOPE VIDEO; OUT 100PCT      | (Video trigger; 100% amplitude)                        |
| SCOPE PULSE; OUT 100NS, 1US  | (Pulse output, 100ns width pulses every 1 microsecond) |
| SCOPE MEASZ                  | (Impedance measurement mode)                           |
| SCOPE OVERLD; OUT 5V         | (Overload test mode; output 5V)                        |

**SCOPE?**

(IEEE-488, RS-232, Sequential)

Shows the oscilloscope's current mode of operation. Shows OFF if the oscilloscope is off.

Parameters: None

Response: <character> (Shows OFF, VOLT, EDGE, LEVSINE, MARKER, WAVEGEN, VIDEO, PULSE, MEASZ, or OVERLD)

**TRIG**

(IEEE-488, RS-232, Sequential)

Programs the oscilloscope's trigger output BNC.

Parameters: OFF (Turns the trigger output off.)

DIV1 (Turns the trigger output on. Frequency is the same as the signal at SCOPE output.)

DIV10 (Turns the trigger output on. Frequency is 1/10 of the signal at SCOPE output.)

DIV100 (Turns the trigger output on. Frequency is 1/100 of the signal at SCOPE output.)

**TRIG?**

(IEEE-488, RS-232, Sequential)

Shows the output setting of the oscilloscope's trigger.

Parameters: (None)

Response: <character> (Shows OFF, DIV1, DIV10, or DIV100.)

**OUT\_IMP**

(IEEE-488, RS-232, Sequential)

Programs the oscilloscope's output impedance.

Parameters: Z50 (Programs the oscilloscope output impedance to 50  $\Omega$ .)

Z1M (Programs the oscilloscope output impedance to 1 M $\Omega$ .)

**OUT\_IMP?**

(IEEE-488, RS-232, Sequential)

Shows the impedance setting of the oscilloscope's output.



Parameters: (None)

### **RANGE**

Programs the instrument range in PULSE, MEAS Z, and OVERLD modes.

|             |         |                                                    |
|-------------|---------|----------------------------------------------------|
| Parameters: | TP0DB   | Sets the range to 2.5 V in pulse mode.             |
|             | TP8DB   | Sets the range to 1.0 V in pulse mode.             |
|             | TP20DB  | Sets the range to 250 mV in pulse mode.            |
|             | TP28DB  | Sets the range to 100 mV in pulse mode.            |
|             | TZ50OHM | Sets the impedance to 50 $\Omega$ in Meas Z mode.  |
|             | TZ1MOHM | Sets the impedance to 1 M $\Omega$ in Meas Z mode. |
|             | TZCAP   | Sets the impedance to cap in Meas Z mode.          |
|             | TOLDC   | Sets the instrument to DC in Overload mode.        |
|             | TOLAC   | Sets the impedance to AC in Overload mode.         |

Example: RANGE TP20DB

### **Edge Function Commands**

#### **TDPULSE**

(IEEE-488, RS-232, Sequential)

Turns tunnel diode pulse drive on/off in EDGE mode.

Parameters: ON (or non-zero) or OFF (or zero)

Example: TDPULSE ON

Shows the tunnel diode pulse drive setting in EDGE mode.

Parameters: None

Response: 1 if ON, 0 if OFF.

### **Marker Function Commands**

#### **TMWAVE**

(IEEE-488, RS-232, Sequential)

Selects the waveform for MARKER mode.

|             |         |                                            |
|-------------|---------|--------------------------------------------|
| Parameters: | SINE    | Sine wave (2 ns to 15 ns)                  |
|             | SPIKE   | Triangular/sawtooth pulse (15 ns to 5s)    |
|             | SQUARE  | Square wave (50% duty cycle) (4 ns to 5s)  |
|             | SQ20PCT | Square wave (20% duty cycle) (85 ns to 5s) |

Example: TMWAVE SPIKE

#### **TMWAVE?**

(IEEE-488, RS-232, Sequential)

Shows the MARKER mode waveform setting.

Parameters: None

Response: <character> (Shows SINE, SPIKE, SQUARE, or SQ20PCT.)

## **Video Function Commands**

### **VIDEOFMT**

(IEEE-488, RS-232, Sequential)

Selects the format for VIDEO mode.

Parameters: NTSC, PAL, PALM (for PAL-M), or SECAM

Example: VIDEOFMT SECAM

### **VIDEOFMT?**

(IEEE-488, RS-232, Sequential)

Shows the VIDEO mode format.

Parameters: None

Response: NTSC, PAL, PALM (for PAL-M), or SECAM

### **VIDEOMARK**

(IEEE-488, RS-232, Sequential)

Programs the VIDEO mode line marker location.

Parameters: Line marker number.

Example: VIDEOMARK 10

### **VIDEOMARK?**

(IEEE-488, RS-232, Sequential)

Shows the VIDEO mode line marker setting.

Parameters: None.

Response: <character> SINE, SPIKE, SQUARE or SQ20PCT

## **Overload Function Commands**

### **OL\_TRIP?**

(IEEE-488, RS-232, Sequential)

Shows the found state of scope overload protection.

Parameters: None

Response: Shows the number of seconds before protection was tripped. Shows 0 if protection has not tripped or if OVERLD mode not active.

### **TLIMIT**

(IEEE-488, RS-232, Sequential)

Sets the OPERATE time limit for the OVERLD mode signal. The Calibrator automatically goes to STANDBY if the UUT protection trips during this interval or at the end of this interval if the protection has not tripped.

Parameters: 1 to 60 (seconds)

Example: TLIMIT 30

### **TLIMIT?**

(IEEE-488, RS-232, Sequential)

Shows the programmed OPERATE time limit for the OVERLD mode signal.

Response: <Integer> Time limit in seconds.

### **TLIMIT\_D**

(IEEE-488, RS-232, Sequential)

Sets the default OPERATE time limit for the OVERLD mode signal.

Parameters: 1 to 60 (seconds)

Example: TLIMIT\_D 15

### **TLIMIT\_D?**

(IEEE-488, RS-232, Sequential)

Shows the default overload time limit.

Response: <Integer> Default time limit in seconds.

## **Impedance/Capacitance Function Commands**

### **ZERO\_MEAS**

(IEEE-488, RS-232, Sequential)

Sets the measurement offset to the capacitance value.

Parameters: (boolean) ON or OFF.

### **\*TRG**

(IEEE-488, RS-232, Sequential)

Triggers and shows a new impedance measurement value when used with the SC600 option in MEAS Z mode. (See Chapter 6 for \*TRG use in all cases except MEAS Z mode with the SC600 option.)

Responses: <measurement value>, OHM (input impedance value in ohms)  
<measurement value>, F (input capacitance value in farads)  
<measurement value>, NONE (no measurement is available)

Example: \*TRG shows 1.00E+03, OHM (1 kΩ input impedance).

#### *Note*

*You can also use the VAL? query to show an impedance measurement value with the SC600 option. VAL? shows the last measurement, whereas \*TRG gets a new measurement. Responses are the same as shown above for the \*TRG command. (See Chapter 6 for VAL? use with thermocouple measurements.)*

## Verification Tables

The verification test points are supplied here as a guide when verification to 1-year specifications is necessary.

**Table 9-2. SC600 Option DC Voltage Verification**

| (1 M $\Omega$ output impedance unless noted) |                       |                  |                     |
|----------------------------------------------|-----------------------|------------------|---------------------|
| Nominal Value (V dc)                         | Measured Value (V dc) | Deviation (V dc) | 1-Year Spec. (V dc) |
| 0                                            |                       |                  | 0.00004             |
| 0.00125                                      |                       |                  | 0.000040625         |
| -0.00125                                     |                       |                  | 0.000040625         |
| 0.00249                                      |                       |                  | 0.000041245         |
| -0.00249                                     |                       |                  | 0.000041245         |
| 0.0025                                       |                       |                  | 0.00004125          |
| -0.0025                                      |                       |                  | 0.00004125          |
| 0.00625                                      |                       |                  | 0.000043125         |
| -0.00625                                     |                       |                  | 0.000043125         |
| 0.0099                                       |                       |                  | 0.00004495          |
| -0.0099                                      |                       |                  | 0.00004495          |
| 0.01                                         |                       |                  | 0.000045            |
| -0.01                                        |                       |                  | 0.000045            |
| 0.0175                                       |                       |                  | 0.00004875          |
| -0.0175                                      |                       |                  | 0.00004875          |
| 0.0249                                       |                       |                  | 0.00005245          |
| -0.0249                                      |                       |                  | 0.00005245          |
| 0.025                                        |                       |                  | 0.0000525           |
| -0.025                                       |                       |                  | 0.0000525           |
| 0.0675                                       |                       |                  | 0.00007375          |
| -0.0675                                      |                       |                  | 0.00007375          |
| 0.1099                                       |                       |                  | 0.00009495          |
| -0.1099                                      |                       |                  | 0.00009495          |
| 0.11                                         |                       |                  | 0.000095            |
| -0.11                                        |                       |                  | 0.000095            |
| 0.305                                        |                       |                  | 0.0001925           |
| -0.305                                       |                       |                  | 0.0001925           |
| 0.499                                        |                       |                  | 0.0002895           |

Table 9-2. SC600 Option DC Voltage Verification (cont.)

| (1 M $\Omega$ output impedance unless noted) |                       |                  |                     |
|----------------------------------------------|-----------------------|------------------|---------------------|
| Nominal Value (V dc)                         | Measured Value (V dc) | Deviation (V dc) | 1-Year Spec. (V dc) |
| -0.499                                       |                       |                  | 0.0002895           |
| 0.5                                          |                       |                  | 0.00029             |
| -0.5                                         |                       |                  | 0.00029             |
| 1.35                                         |                       |                  | 0.000715            |
| -1.35                                        |                       |                  | 0.000715            |
| 2.19                                         |                       |                  | 0.001135            |
| -2.19                                        |                       |                  | 0.001135            |
| 2.2                                          |                       |                  | 0.00114             |
| -2.2                                         |                       |                  | 0.00114             |
| 6.6                                          |                       |                  | 0.00334             |
| -6.6                                         |                       |                  | 0.00334             |
| 10.99                                        |                       |                  | 0.005535            |
| -10.99                                       |                       |                  | 0.005535            |
| 11                                           |                       |                  | 0.00554             |
| -11                                          |                       |                  | 0.00554             |
| 70.5                                         |                       |                  | 0.03529             |
| -70.5                                        |                       |                  | 0.03529             |
| 130                                          |                       |                  | 0.06504             |
| -130                                         |                       |                  | 0.06504             |
| 6.599 (50 $\Omega$ )                         |                       |                  | 0.0165375           |

Table 9-3. SC600 Option AC Voltage Amplitude Verification

| (1 M $\Omega$ output impedance unless noted) |                |                        |                   |                      |
|----------------------------------------------|----------------|------------------------|-------------------|----------------------|
| Nominal Value (V p-p)                        | Frequency (Hz) | Measured Value (V p-p) | Deviation (V p-p) | 1-year Spec. (V p-p) |
| 0.001                                        | 1000           |                        |                   | 0.000041             |
| -0.001                                       | 1000           |                        |                   | 0.000041             |
| 0.01                                         | 1000           |                        |                   | 0.00005              |
| -0.01                                        | 1000           |                        |                   | 0.00005              |
| 0.025                                        | 1000           |                        |                   | 0.000065             |
| -0.025                                       | 1000           |                        |                   | 0.000065             |
| 0.11                                         | 1000           |                        |                   | 0.00015              |

Table 9-3. SC600 Option AC Voltage Amplitude Verification (cont.)

| (1 M $\Omega$ output impedance unless noted) |                |                           |                   |                         |
|----------------------------------------------|----------------|---------------------------|-------------------|-------------------------|
| Nominal Value<br>(V p-p)                     | Frequency (Hz) | Measured Value<br>(V p-p) | Deviation (V p-p) | 1-year Spec.<br>(V p-p) |
| -0.11                                        | 1000           |                           |                   | 0.00015                 |
| 0.5                                          | 1000           |                           |                   | 0.00054                 |
| -0.5                                         | 1000           |                           |                   | 0.00054                 |
| 2.2                                          | 1000           |                           |                   | 0.00224                 |
| -2.2                                         | 1000           |                           |                   | 0.00224                 |
| 11                                           | 1000           |                           |                   | 0.01104                 |
| -11                                          | 1000           |                           |                   | 0.01104                 |
| 130                                          | 1000           |                           |                   | 0.13004                 |
| -130                                         | 1000           |                           |                   | 0.13004                 |
| 6.599 (50 $\Omega$ )                         | 1000           |                           |                   | 0.0165375               |

Table 9-4. AC Voltage Frequency Verification

| (1 M $\Omega$ output impedance unless noted) |                |                        |                |                   |
|----------------------------------------------|----------------|------------------------|----------------|-------------------|
| Nominal Value<br>(V p-p)                     | Frequency (Hz) | Measured Value<br>(Hz) | Deviation (Hz) | 1-year Spec. (Hz) |
| 2.1                                          | 10             |                        |                | 0.000025          |
| 2.1                                          | 100            |                        |                | 0.00025           |
| 2.1                                          | 1000           |                        |                | 0.0025            |
| 2.1                                          | 10000          |                        |                | 0.025             |

Table 9-5. SC600 Option Wave Generator Amplitude Verification (1 M $\Omega$  output impedance)

| Wave Shape | Nominal Value<br>(V p-p) | Frequency<br>(Hz) | Measured<br>Value (V p-p) | Deviation<br>(V p-p) | 1-Year Spec.<br>(V p-p) |
|------------|--------------------------|-------------------|---------------------------|----------------------|-------------------------|
| square     | 0.0018                   | 1000              |                           |                      | 0.000154                |
| square     | 0.0119                   | 1000              |                           |                      | 0.000457                |
| square     | 0.0219                   | 1000              |                           |                      | 0.000757                |
| square     | 0.022                    | 1000              |                           |                      | 0.00076                 |
| square     | 0.056                    | 1000              |                           |                      | 0.00178                 |
| square     | 0.0899                   | 1000              |                           |                      | 0.002797                |
| square     | 0.09                     | 1000              |                           |                      | 0.0028                  |
| square     | 0.155                    | 1000              |                           |                      | 0.00475                 |

**Table 9-5. SC600 Option Wave Generator Amplitude Verification (1 M $\Omega$  output impedance) (cont.)**

| Wave Shape | Nominal Value<br>(V p-p) | Frequency<br>(Hz) | Measured<br>Value (V p-p) | Deviation<br>(V p-p) | 1-Year Spec.<br>(V p-p) |
|------------|--------------------------|-------------------|---------------------------|----------------------|-------------------------|
| square     | 0.219                    | 1000              |                           |                      | 0.00667                 |
| square     | 0.22                     | 1000              |                           |                      | 0.0067                  |
| square     | 0.56                     | 1000              |                           |                      | 0.0169                  |
| square     | 0.899                    | 1000              |                           |                      | 0.02707                 |
| square     | 0.9                      | 1000              |                           |                      | 0.0271                  |
| square     | 3.75                     | 1000              |                           |                      | 0.1126                  |
| square     | 6.59                     | 1000              |                           |                      | 0.1978                  |
| square     | 6.6                      | 1000              |                           |                      | 0.1981                  |
| square     | 30.8                     | 1000              |                           |                      | 0.9241                  |
| square     | 55                       | 10                |                           |                      | 1.6501                  |
| square     | 55                       | 100               |                           |                      | 1.6501                  |
| square     | 55                       | 1000              |                           |                      | 1.6501                  |
| square     | 55                       | 10000             |                           |                      | 1.6501                  |
| sine       | 0.0018                   | 1000              |                           |                      | 0.000154                |
| sine       | 0.0219                   | 1000              |                           |                      | 0.000757                |
| sine       | 0.0899                   | 1000              |                           |                      | 0.002797                |
| sine       | 0.219                    | 1000              |                           |                      | 0.00667                 |
| sine       | 0.899                    | 1000              |                           |                      | 0.02707                 |
| sine       | 6.59                     | 1000              |                           |                      | 0.1978                  |
| sine       | 55                       | 1000              |                           |                      | 1.6501                  |
| triangle   | 0.0018                   | 1000              |                           |                      | 0.000154                |
| triangle   | 0.0219                   | 1000              |                           |                      | 0.000757                |
| triangle   | 0.0899                   | 1000              |                           |                      | 0.002797                |
| triangle   | 0.219                    | 1000              |                           |                      | 0.00667                 |
| triangle   | 0.899                    | 1000              |                           |                      | 0.02707                 |
| triangle   | 6.59                     | 1000              |                           |                      | 0.1978                  |
| triangle   | 55                       | 1000              |                           |                      | 1.6501                  |

Table 9-6. SC600 Option Wave Generator Amplitude Verification (50  $\Omega$  output impedance)

| Wave Shape | Nominal Value<br>(V p-p) | Frequency<br>(Hz) | Measured<br>Value (V p-p) | Deviation<br>(V p-p) | 1-Year Spec.<br>(V p-p) |
|------------|--------------------------|-------------------|---------------------------|----------------------|-------------------------|
| square     | 0.0018                   | 1000              |                           |                      | 0.000154                |
| square     | 0.0064                   | 1000              |                           |                      | 0.000292                |
| square     | 0.0109                   | 1000              |                           |                      | 0.000427                |
| square     | 0.011                    | 1000              |                           |                      | 0.00043                 |
| square     | 0.028                    | 1000              |                           |                      | 0.00094                 |
| square     | 0.0449                   | 1000              |                           |                      | 0.001447                |
| square     | 0.045                    | 1000              |                           |                      | 0.00145                 |
| square     | 0.078                    | 1000              |                           |                      | 0.00244                 |
| square     | 0.109                    | 1000              |                           |                      | 0.00337                 |
| square     | 0.11                     | 1000              |                           |                      | 0.0034                  |
| square     | 0.28                     | 1000              |                           |                      | 0.0085                  |
| square     | 0.449                    | 1000              |                           |                      | 0.01357                 |
| square     | 0.45                     | 1000              |                           |                      | 0.0136                  |
| square     | 0.78                     | 1000              |                           |                      | 0.0235                  |
| square     | 1.09                     | 1000              |                           |                      | 0.0328                  |
| square     | 1.1                      | 1000              |                           |                      | 0.0331                  |
| square     | 1.8                      | 1000              |                           |                      | 0.0541                  |
| square     | 2.5                      | 10                |                           |                      | 0.0751                  |
| square     | 2.5                      | 100               |                           |                      | 0.0751                  |
| square     | 2.5                      | 1000              |                           |                      | 0.0751                  |
| square     | 2.5                      | 10000             |                           |                      | 0.0751                  |
| sine       | 0.0018                   | 1000              |                           |                      | 0.000154                |
| sine       | 0.0109                   | 1000              |                           |                      | 0.000427                |
| sine       | 0.0449                   | 1000              |                           |                      | 0.001447                |
| sine       | 0.109                    | 1000              |                           |                      | 0.00337                 |
| sine       | 0.449                    | 1000              |                           |                      | 0.01357                 |
| sine       | 1.09                     | 1000              |                           |                      | 0.0328                  |
| sine       | 2.5                      | 1000              |                           |                      | 0.0751                  |
| triangle   | 0.0018                   | 1000              |                           |                      | 0.000154                |
| triangle   | 0.0109                   | 1000              |                           |                      | 0.000427                |
| triangle   | 0.0449                   | 1000              |                           |                      | 0.001447                |



**Table 9-6. SC600 Option Wave Generator Amplitude Verification (50  $\Omega$  output impedance) (cont.)**

| Wave Shape | Nominal Value (V p-p) | Frequency (Hz) | Measured Value (V p-p) | Deviation (V p-p) | 1-Year Spec. (V p-p) |
|------------|-----------------------|----------------|------------------------|-------------------|----------------------|
| triangle   | 0.109                 | 1000           |                        |                   | 0.00337              |
| triangle   | 0.449                 | 1000           |                        |                   | 0.01357              |
| triangle   | 1.09                  | 1000           |                        |                   | 0.0328               |
| triangle   | 2.5                   | 1000           |                        |                   | 0.0751               |

**Table 9-7. SC600 Option Levelled Sine Wave Verification: Amplitude**

| Nominal Value (V p-p) | Frequency | Measured Value (V p-p) | Deviation (V p-p) | 1-Year Spec. (V p-p) |
|-----------------------|-----------|------------------------|-------------------|----------------------|
| 0.005                 | 50 kHz    |                        |                   | 0.0004               |
| 0.0075                | 50 kHz    |                        |                   | 0.00045              |
| 0.0099                | 50 kHz    |                        |                   | 0.000498             |
| 0.01                  | 50 kHz    |                        |                   | 0.0005               |
| 0.025                 | 50 kHz    |                        |                   | 0.0008               |
| 0.039                 | 50 kHz    |                        |                   | 0.00108              |
| 0.04                  | 50 kHz    |                        |                   | 0.0011               |
| 0.07                  | 50 kHz    |                        |                   | 0.0017               |
| 0.099                 | 50 kHz    |                        |                   | 0.00228              |
| 0.1                   | 50 kHz    |                        |                   | 0.0023               |
| 0.25                  | 50 kHz    |                        |                   | 0.0053               |
| 0.399                 | 50 kHz    |                        |                   | 0.00828              |
| 0.4                   | 50 kHz    |                        |                   | 0.0083               |
| 0.8                   | 50 kHz    |                        |                   | 0.0163               |
| 1.2                   | 50 kHz    |                        |                   | 0.0243               |
| 1.3                   | 50 kHz    |                        |                   | 0.0263               |
| 3.4                   | 50 kHz    |                        |                   | 0.0683               |
| 5.5                   | 50 kHz    |                        |                   | 0.1103               |

Table 9-8. SC600 Option Levelled Sine Wave Verification: Frequency

| Nominal Value<br>(V p-p) | Frequency | Measured Value<br>(Hz) | Deviation (Hz) | 1-Year Spec. (Hz) |
|--------------------------|-----------|------------------------|----------------|-------------------|
| 5.5                      | 50 kHz    |                        |                | 0.125             |
| 5.5                      | 500 kHz   |                        |                | 1.25              |
| 5.5                      | 5 MHz     |                        |                | 12.5              |
| 5.5                      | 50 MHz    |                        |                | 125               |
| 5.5                      | 500 MHz   |                        |                | 1250              |

Table 9-9. SC600 Option Levelled Sine Wave Verification: Harmonics

| Harmonic      | Nominal Value<br>(V p-p) | Frequency | Measured<br>Value (dB) | Deviation<br>(dB) | 1-Year Spec.<br>(dB) |
|---------------|--------------------------|-----------|------------------------|-------------------|----------------------|
| 2nd harmonic  | 0.0399                   | 50 kHz    |                        |                   | -33                  |
| 3rd+ harmonic | 0.0399                   | 50 kHz    |                        |                   | -38                  |
| 2nd harmonic  | 0.099                    | 50 kHz    |                        |                   | -33                  |
| 3rd+ harmonic | 0.099                    | 50 kHz    |                        |                   | -38                  |
| 2nd harmonic  | 0.399                    | 50 kHz    |                        |                   | -33                  |
| 3rd+ harmonic | 0.399                    | 50 kHz    |                        |                   | -38                  |
| 2nd harmonic  | 1.2                      | 50 kHz    |                        |                   | -33                  |
| 3rd+ harmonic | 1.2                      | 50 kHz    |                        |                   | -38                  |
| 2nd harmonic  | 5.5                      | 50 kHz    |                        |                   | -33                  |
| 3rd+ harmonic | 5.5                      | 50 kHz    |                        |                   | -38                  |
| 2nd harmonic  | 5.5                      | 100 kHz   |                        |                   | -33                  |
| 3rd+ harmonic | 5.5                      | 100 kHz   |                        |                   | -38                  |
| 2nd harmonic  | 5.5                      | 200 kHz   |                        |                   | -33                  |
| 3rd+ harmonic | 5.5                      | 200 kHz   |                        |                   | -38                  |
| 2nd harmonic  | 5.5                      | 400 kHz   |                        |                   | -33                  |
| 3rd+ harmonic | 5.5                      | 400 kHz   |                        |                   | -38                  |
| 2nd harmonic  | 5.5                      | 800 kHz   |                        |                   | -33                  |
| 3rd+ harmonic | 5.5                      | 800 kHz   |                        |                   | -38                  |
| 2nd harmonic  | 5.5                      | 1 MHz     |                        |                   | -33                  |
| 3rd+ harmonic | 5.5                      | 1 MHz     |                        |                   | -38                  |
| 2nd harmonic  | 5.5                      | 2 MHz     |                        |                   | -33                  |
| 3rd+ harmonic | 5.5                      | 2 MHz     |                        |                   | -38                  |

**Table 9-9. SC600 Option Levelled Sine Wave Verification: Harmonics (cont.)**

| Harmonic      | Nominal Value<br>(V p-p) | Frequency | Measured<br>Value (dB) | Deviation<br>(dB) | 1-Year Spec.<br>(dB) |
|---------------|--------------------------|-----------|------------------------|-------------------|----------------------|
| 2nd harmonic  | 5.5                      | 4 MHz     |                        |                   | -33                  |
| 3rd+ harmonic | 5.5                      | 4 MHz     |                        |                   | -38                  |
| 2nd harmonic  | 5.5                      | 8 MHz     |                        |                   | -33                  |
| 3rd+ harmonic | 5.5                      | 8 MHz     |                        |                   | -38                  |
| 2nd harmonic  | 5.5                      | 10 MHz    |                        |                   | -33                  |
| 3rd+ harmonic | 5.5                      | 10 MHz    |                        |                   | -38                  |
| 2nd harmonic  | 5.5                      | 20 MHz    |                        |                   | -33                  |
| 3rd+ harmonic | 5.5                      | 20 MHz    |                        |                   | -38                  |
| 2nd harmonic  | 5.5                      | 40 MHz    |                        |                   | -33                  |
| 3rd+ harmonic | 5.5                      | 40 MHz    |                        |                   | -38                  |
| 2nd harmonic  | 5.5                      | 80 MHz    |                        |                   | -33                  |
| 3rd+ harmonic | 5.5                      | 80 MHz    |                        |                   | -38                  |
| 2nd harmonic  | 5.5                      | 100 MHz   |                        |                   | -33                  |
| 3rd+ harmonic | 5.5                      | 100 MHz   |                        |                   | -38                  |
| 2nd harmonic  | 5.5                      | 200 MHz   |                        |                   | -33                  |
| 3rd+ harmonic | 5.5                      | 200 MHz   |                        |                   | -38                  |
| 2nd harmonic  | 5.5                      | 400 MHz   |                        |                   | -33                  |
| 3rd+ harmonic | 5.5                      | 400 MHz   |                        |                   | -38                  |
| 2nd harmonic  | 5.5                      | 600 MHz   |                        |                   | -33                  |
| 3rd+ harmonic | 5.5                      | 600 MHz   |                        |                   | -38                  |

**Table 9-10. SC600 Option Levelled Sine Wave Verification: Flatness**

| Nominal Value<br>(V p-p) | Frequency | Measured Value<br>(V p-p) | Deviation (V p-p) | 1-Year Spec.<br>(V p-p) |
|--------------------------|-----------|---------------------------|-------------------|-------------------------|
| 0.005                    | 50 kHz    |                           | na                | na                      |
| 0.005                    | 30 MHz    |                           |                   | 0.000175                |
| 0.005                    | 70 MHz    |                           |                   | 0.000175                |
| 0.005                    | 120 MHz   |                           |                   | 0.0002                  |
| 0.005                    | 290 MHz   |                           |                   | 0.0002                  |
| 0.005                    | 360 MHz   |                           |                   | 0.0003                  |
| 0.005                    | 390 MHz   |                           |                   | 0.0003                  |
| 0.005                    | 400 MHz   |                           |                   | 0.0003                  |

Table 9-10. SC600 Option Leveled Sine Wave Verification: Flatness (cont.)

| Nominal Value<br>(V p-p) | Frequency | Measured Value<br>(V p-p) | Deviation (V p-p) | 1-Year Spec.<br>(V p-p) |
|--------------------------|-----------|---------------------------|-------------------|-------------------------|
| 0.005                    | 480 MHz   |                           |                   | 0.0003                  |
| 0.005                    | 570 MHz   |                           |                   | 0.0003                  |
| 0.005                    | 580 MHz   |                           |                   | 0.0003                  |
| 0.005                    | 590 MHz   |                           |                   | 0.0003                  |
| 0.005                    | 600 MHz   |                           |                   | 0.0003                  |
| 0.0075                   | 50 kHz    |                           | na                | na                      |
| 0.0075                   | 30 MHz    |                           |                   | 0.0002125               |
| 0.0075                   | 70 MHz    |                           |                   | 0.0002125               |
| 0.0075                   | 120 MHz   |                           |                   | 0.00025                 |
| 0.0075                   | 290 MHz   |                           |                   | 0.00025                 |
| 0.0075                   | 360 MHz   |                           |                   | 0.0004                  |
| 0.0075                   | 390 MHz   |                           |                   | 0.0004                  |
| 0.0075                   | 400 MHz   |                           |                   | 0.0004                  |
| 0.0075                   | 480 MHz   |                           |                   | 0.0004                  |
| 0.0075                   | 570 MHz   |                           |                   | 0.0004                  |
| 0.0075                   | 580 MHz   |                           |                   | 0.0004                  |
| 0.0075                   | 590 MHz   |                           |                   | 0.0004                  |
| 0.0075                   | 600 MHz   |                           |                   | 0.0004                  |
| 0.0099                   | 50 kHz    |                           | na                | na                      |
| 0.0099                   | 30 MHz    |                           |                   | 0.0002485               |
| 0.0099                   | 70 MHz    |                           |                   | 0.0002485               |
| 0.0099                   | 120 MHz   |                           |                   | 0.000298                |
| 0.0099                   | 290 MHz   |                           |                   | 0.000298                |
| 0.0099                   | 360 MHz   |                           |                   | 0.000496                |
| 0.0099                   | 390 MHz   |                           |                   | 0.000496                |
| 0.0099                   | 400 MHz   |                           |                   | 0.000496                |
| 0.0099                   | 480 MHz   |                           |                   | 0.000496                |
| 0.0099                   | 570 MHz   |                           |                   | 0.000496                |
| 0.0099                   | 580 MHz   |                           |                   | 0.000496                |
| 0.0099                   | 590 MHz   |                           |                   | 0.000496                |
| 0.0099                   | 600 MHz   |                           |                   | 0.000496                |

**Table 9-10. SC600 Option Levelled Sine Wave Verification: Flatness (cont.)**

| Nominal Value<br>(V p-p) | Frequency | Measured Value<br>(V p-p) | Deviation (V p-p) | 1-Year Spec.<br>(V p-p) |
|--------------------------|-----------|---------------------------|-------------------|-------------------------|
| 0.01                     | 50 kHz    |                           | na                | na                      |
| 0.01                     | 30 MHz    |                           |                   | 0.00025                 |
| 0.01                     | 70 MHz    |                           |                   | 0.00025                 |
| 0.01                     | 120 MHz   |                           |                   | 0.0003                  |
| 0.01                     | 290 MHz   |                           |                   | 0.0003                  |
| 0.01                     | 360 MHz   |                           |                   | 0.0005                  |
| 0.01                     | 390 MHz   |                           |                   | 0.0005                  |
| 0.01                     | 400 MHz   |                           |                   | 0.0005                  |
| 0.01                     | 480 MHz   |                           |                   | 0.0005                  |
| 0.01                     | 570 MHz   |                           |                   | 0.0005                  |
| 0.01                     | 580 MHz   |                           |                   | 0.0005                  |
| 0.01                     | 590 MHz   |                           |                   | 0.0005                  |
| 0.01                     | 600 MHz   |                           |                   | 0.0005                  |
| 0.025                    | 50 kHz    |                           | na                | na                      |
| 0.025                    | 30 MHz    |                           |                   | 0.000475                |
| 0.025                    | 70 MHz    |                           |                   | 0.000475                |
| 0.025                    | 120 MHz   |                           |                   | 0.0006                  |
| 0.025                    | 290 MHz   |                           |                   | 0.0006                  |
| 0.025                    | 360 MHz   |                           |                   | 0.0011                  |
| 0.025                    | 390 MHz   |                           |                   | 0.0011                  |
| 0.025                    | 400 MHz   |                           |                   | 0.0011                  |
| 0.025                    | 480 MHz   |                           |                   | 0.0011                  |
| 0.025                    | 570 MHz   |                           |                   | 0.0011                  |
| 0.025                    | 580 MHz   |                           |                   | 0.0011                  |
| 0.025                    | 590 MHz   |                           |                   | 0.0011                  |
| 0.025                    | 600 MHz   |                           |                   | 0.0011                  |
| 0.039                    | 50 kHz    |                           | na                | na                      |
| 0.039                    | 30 MHz    |                           |                   | 0.000685                |
| 0.039                    | 70 MHz    |                           |                   | 0.000685                |
| 0.039                    | 120 MHz   |                           |                   | 0.00088                 |
| 0.039                    | 290 MHz   |                           |                   | 0.00088                 |
| 0.039                    | 360 MHz   |                           |                   | 0.00166                 |

Table 9-10. SC600 Option Levelled Sine Wave Verification: Flatness (cont.)

| Nominal Value<br>(V p-p) | Frequency | Measured Value<br>(V p-p) | Deviation (V p-p) | 1-Year Spec.<br>(V p-p) |
|--------------------------|-----------|---------------------------|-------------------|-------------------------|
| 0.039                    | 390 MHz   |                           |                   | 0.00166                 |
| 0.039                    | 400 MHz   |                           |                   | 0.00166                 |
| 0.039                    | 480 MHz   |                           |                   | 0.00166                 |
| 0.039                    | 570 MHz   |                           |                   | 0.00166                 |
| 0.039                    | 580 MHz   |                           |                   | 0.00166                 |
| 0.039                    | 590 MHz   |                           |                   | 0.00166                 |
| 0.039                    | 600 MHz   |                           |                   | 0.00166                 |
| 0.04                     | 50 kHz    |                           | na                | na                      |
| 0.04                     | 30 MHz    |                           |                   | 0.0007                  |
| 0.04                     | 70 MHz    |                           |                   | 0.0007                  |
| 0.04                     | 120 MHz   |                           |                   | 0.0009                  |
| 0.04                     | 290 MHz   |                           |                   | 0.0009                  |
| 0.04                     | 360 MHz   |                           |                   | 0.0017                  |
| 0.04                     | 390 MHz   |                           |                   | 0.0017                  |
| 0.04                     | 400 MHz   |                           |                   | 0.0017                  |
| 0.04                     | 480 MHz   |                           |                   | 0.0017                  |
| 0.04                     | 570 MHz   |                           |                   | 0.0017                  |
| 0.04                     | 580 MHz   |                           |                   | 0.0017                  |
| 0.04                     | 590 MHz   |                           |                   | 0.0017                  |
| 0.04                     | 600 MHz   |                           |                   | 0.0017                  |
| 0.07                     | 50 kHz    |                           | na                | na                      |
| 0.07                     | 30 MHz    |                           |                   | 0.00115                 |
| 0.07                     | 70 MHz    |                           |                   | 0.00115                 |
| 0.07                     | 120 MHz   |                           |                   | 0.0015                  |
| 0.07                     | 290 MHz   |                           |                   | 0.0015                  |
| 0.07                     | 360 MHz   |                           |                   | 0.0029                  |
| 0.07                     | 390 MHz   |                           |                   | 0.0029                  |
| 0.07                     | 400 MHz   |                           |                   | 0.0029                  |
| 0.07                     | 480 MHz   |                           |                   | 0.0029                  |
| 0.07                     | 570 MHz   |                           |                   | 0.0029                  |
| 0.07                     | 580 MHz   |                           |                   | 0.0029                  |
| 0.07                     | 590 MHz   |                           |                   | 0.0029                  |

**Table 9-10. SC600 Option Levelled Sine Wave Verification: Flatness (cont.)**

| Nominal Value<br>(V p-p) | Frequency | Measured Value<br>(V p-p) | Deviation (V p-p) | 1-Year Spec.<br>(V p-p) |
|--------------------------|-----------|---------------------------|-------------------|-------------------------|
| 0.07                     | 600 MHz   |                           |                   | 0.0029                  |
| 0.099                    | 50 kHz    |                           | na                | na                      |
| 0.099                    | 30 MHz    |                           |                   | 0.001585                |
| 0.099                    | 70 MHz    |                           |                   | 0.001585                |
| 0.099                    | 120 MHz   |                           |                   | 0.00208                 |
| 0.099                    | 290 MHz   |                           |                   | 0.00208                 |
| 0.099                    | 360 MHz   |                           |                   | 0.00406                 |
| 0.099                    | 390 MHz   |                           |                   | 0.00406                 |
| 0.099                    | 400 MHz   |                           |                   | 0.00406                 |
| 0.099                    | 480 MHz   |                           |                   | 0.00406                 |
| 0.099                    | 570 MHz   |                           |                   | 0.00406                 |
| 0.099                    | 580 MHz   |                           |                   | 0.00406                 |
| 0.099                    | 590 MHz   |                           |                   | 0.00406                 |
| 0.099                    | 600 MHz   |                           |                   | 0.00406                 |
| 0.1                      | 50 kHz    |                           | na                | na                      |
| 0.1                      | 30 MHz    |                           |                   | 0.0016                  |
| 0.1                      | 70 MHz    |                           |                   | 0.0016                  |
| 0.1                      | 120 MHz   |                           |                   | 0.0021                  |
| 0.1                      | 290 MHz   |                           |                   | 0.0021                  |
| 0.1                      | 360 MHz   |                           |                   | 0.0041                  |
| 0.1                      | 390 MHz   |                           |                   | 0.0041                  |
| 0.1                      | 400 MHz   |                           |                   | 0.0041                  |
| 0.1                      | 480 MHz   |                           |                   | 0.0041                  |
| 0.1                      | 570 MHz   |                           |                   | 0.0041                  |
| 0.1                      | 580 MHz   |                           |                   | 0.0041                  |
| 0.1                      | 590 MHz   |                           |                   | 0.0041                  |
| 0.1                      | 600 MHz   |                           |                   | 0.0041                  |
| 0.25                     | 50 kHz    |                           | na                | na                      |
| 0.25                     | 30 MHz    |                           |                   | 0.00385                 |
| 0.25                     | 70 MHz    |                           |                   | 0.00385                 |
| 0.25                     | 120 MHz   |                           |                   | 0.0051                  |
| 0.25                     | 290 MHz   |                           |                   | 0.0051                  |

Table 9-10. SC600 Option Levelled Sine Wave Verification: Flatness (cont.)

| Nominal Value<br>(V p-p) | Frequency | Measured Value<br>(V p-p) | Deviation (V p-p) | 1-Year Spec.<br>(V p-p) |
|--------------------------|-----------|---------------------------|-------------------|-------------------------|
| 0.25                     | 360 MHz   |                           |                   | 0.0101                  |
| 0.25                     | 390 MHz   |                           |                   | 0.0101                  |
| 0.25                     | 400 MHz   |                           |                   | 0.0101                  |
| 0.25                     | 480 MHz   |                           |                   | 0.0101                  |
| 0.25                     | 570 MHz   |                           |                   | 0.0101                  |
| 0.25                     | 580 MHz   |                           |                   | 0.0101                  |
| 0.25                     | 590 MHz   |                           |                   | 0.0101                  |
| 0.25                     | 600 MHz   |                           |                   | 0.0101                  |
| 0.399                    | 50 kHz    |                           | na                | na                      |
| 0.399                    | 30 MHz    |                           |                   | 0.006085                |
| 0.399                    | 70 MHz    |                           |                   | 0.006085                |
| 0.399                    | 120 MHz   |                           |                   | 0.00808                 |
| 0.399                    | 290 MHz   |                           |                   | 0.00808                 |
| 0.399                    | 360 MHz   |                           |                   | 0.01606                 |
| 0.399                    | 390 MHz   |                           |                   | 0.01606                 |
| 0.399                    | 400 MHz   |                           |                   | 0.01606                 |
| 0.399                    | 480 MHz   |                           |                   | 0.01606                 |
| 0.399                    | 570 MHz   |                           |                   | 0.01606                 |
| 0.399                    | 580 MHz   |                           |                   | 0.01606                 |
| 0.399                    | 590 MHz   |                           |                   | 0.01606                 |
| 0.399                    | 600 MHz   |                           |                   | 0.01606                 |
| 0.4                      | 50 kHz    |                           | na                | na                      |
| 0.4                      | 30 MHz    |                           |                   | 0.0061                  |
| 0.4                      | 70 MHz    |                           |                   | 0.0061                  |
| 0.4                      | 120 MHz   |                           |                   | 0.0081                  |
| 0.4                      | 290 MHz   |                           |                   | 0.0081                  |
| 0.4                      | 360 MHz   |                           |                   | 0.0161                  |
| 0.4                      | 390 MHz   |                           |                   | 0.0161                  |
| 0.4                      | 400 MHz   |                           |                   | 0.0161                  |
| 0.4                      | 480 MHz   |                           |                   | 0.0161                  |
| 0.4                      | 570 MHz   |                           |                   | 0.0161                  |
| 0.4                      | 580 MHz   |                           |                   | 0.0161                  |



**Table 9-10. SC600 Option Levelled Sine Wave Verification: Flatness (cont.)**

| Nominal Value<br>(V p-p) | Frequency | Measured Value<br>(V p-p) | Deviation (V p-p) | 1-Year Spec.<br>(V p-p) |
|--------------------------|-----------|---------------------------|-------------------|-------------------------|
| 0.4                      | 590 MHz   |                           |                   | 0.0161                  |
| 0.4                      | 600 MHz   |                           |                   | 0.0161                  |
| 0.8                      | 50 kHz    |                           | na                | na                      |
| 0.8                      | 30 MHz    |                           |                   | 0.0121                  |
| 0.8                      | 70 MHz    |                           |                   | 0.0121                  |
| 0.8                      | 120 MHz   |                           |                   | 0.0161                  |
| 0.8                      | 290 MHz   |                           |                   | 0.0161                  |
| 0.8                      | 360 MHz   |                           |                   | 0.0321                  |
| 0.8                      | 390 MHz   |                           |                   | 0.0321                  |
| 0.8                      | 400 MHz   |                           |                   | 0.0321                  |
| 0.8                      | 480 MHz   |                           |                   | 0.0321                  |
| 0.8                      | 570 MHz   |                           |                   | 0.0321                  |
| 0.8                      | 580 MHz   |                           |                   | 0.0321                  |
| 0.8                      | 590 MHz   |                           |                   | 0.0321                  |
| 0.8                      | 600 MHz   |                           |                   | 0.0321                  |
| 1.2                      | 50 kHz    |                           | na                | na                      |
| 1.2                      | 30 MHz    |                           |                   | 0.0181                  |
| 1.2                      | 70 MHz    |                           |                   | 0.0181                  |
| 1.2                      | 120 MHz   |                           |                   | 0.0241                  |
| 1.2                      | 290 MHz   |                           |                   | 0.0241                  |
| 1.2                      | 360 MHz   |                           |                   | 0.0481                  |
| 1.2                      | 390 MHz   |                           |                   | 0.0481                  |
| 1.2                      | 400 MHz   |                           |                   | 0.0481                  |
| 1.2                      | 480 MHz   |                           |                   | 0.0481                  |
| 1.2                      | 570 MHz   |                           |                   | 0.0481                  |
| 1.2                      | 580 MHz   |                           |                   | 0.0481                  |
| 1.2                      | 590 MHz   |                           |                   | 0.0481                  |
| 1.2                      | 600 MHz   |                           |                   | 0.0481                  |
| 1.3                      | 50 kHz    |                           | na                | na                      |
| 1.3                      | 30 MHz    |                           |                   | 0.0196                  |
| 1.3                      | 70 MHz    |                           |                   | 0.0196                  |
| 1.3                      | 120 MHz   |                           |                   | 0.0261                  |

Table 9-10. SC600 Option Levelled Sine Wave Verification: Flatness (cont.)

| Nominal Value<br>(V p-p) | Frequency | Measured Value<br>(V p-p) | Deviation (V p-p) | 1-Year Spec.<br>(V p-p) |
|--------------------------|-----------|---------------------------|-------------------|-------------------------|
| 1.3                      | 290 MHz   |                           |                   | 0.0261                  |
| 1.3                      | 360 MHz   |                           |                   | 0.0521                  |
| 1.3                      | 390 MHz   |                           |                   | 0.0521                  |
| 1.3                      | 400 MHz   |                           |                   | 0.0521                  |
| 1.3                      | 480 MHz   |                           |                   | 0.0521                  |
| 1.3                      | 570 MHz   |                           |                   | 0.0521                  |
| 1.3                      | 580 MHz   |                           |                   | 0.0521                  |
| 1.3                      | 590 MHz   |                           |                   | 0.0521                  |
| 1.3                      | 600 MHz   |                           |                   | 0.0521                  |
| 3.4                      | 50 kHz    |                           | na                | na                      |
| 3.4                      | 30 MHz    |                           |                   | 0.0511                  |
| 3.4                      | 70 MHz    |                           |                   | 0.0511                  |
| 3.4                      | 120 MHz   |                           |                   | 0.0681                  |
| 3.4                      | 290 MHz   |                           |                   | 0.0681                  |
| 3.4                      | 360 MHz   |                           |                   | 0.1361                  |
| 3.4                      | 390 MHz   |                           |                   | 0.1361                  |
| 3.4                      | 400 MHz   |                           |                   | 0.1361                  |
| 3.4                      | 480 MHz   |                           |                   | 0.1361                  |
| 3.4                      | 570 MHz   |                           |                   | 0.1361                  |
| 3.4                      | 580 MHz   |                           |                   | 0.1361                  |
| 3.4                      | 590 MHz   |                           |                   | 0.1361                  |
| 3.4                      | 600 MHz   |                           |                   | 0.1361                  |
| 5.5                      | 50 kHz    |                           | na                | na                      |
| 5.5                      | 30 MHz    |                           |                   | 0.0826                  |
| 5.5                      | 70 MHz    |                           |                   | 0.0826                  |
| 5.5                      | 120 MHz   |                           |                   | 0.1101                  |
| 5.5                      | 290 MHz   |                           |                   | 0.1101                  |
| 5.5                      | 360 MHz   |                           |                   | 0.2201                  |
| 5.5                      | 390 MHz   |                           |                   | 0.2201                  |
| 5.5                      | 400 MHz   |                           |                   | 0.2201                  |
| 5.5                      | 480 MHz   |                           |                   | 0.2201                  |
| 5.5                      | 570 MHz   |                           |                   | 0.2201                  |

**Table 9-10. SC600 Option Levelled Sine Wave Verification: Flatness (cont.)**

| Nominal Value<br>(V p-p) | Frequency | Measured Value<br>(V p-p) | Deviation (V p-p) | 1-Year Spec.<br>(V p-p) |
|--------------------------|-----------|---------------------------|-------------------|-------------------------|
| 5.5                      | 580 MHz   |                           |                   | 0.2201                  |
| 5.5                      | 590 MHz   |                           |                   | 0.2201                  |
| 5.5                      | 600 MHz   |                           |                   | 0.2201                  |

**Table 9-11. SC600 Option Edge Verification: Amplitude**

| Nominal Value<br>(V p-p) | Frequency (Hz) | Measured Value<br>(V p-p) | Deviation (V p-p) | 1-Year Spec.<br>(V p-p) |
|--------------------------|----------------|---------------------------|-------------------|-------------------------|
| 0.005                    | 1 kHz          |                           |                   | 0.0003                  |
| 0.005                    | 10 kHz         |                           |                   | 0.0003                  |
| 0.005                    | 100 kHz        |                           |                   | 0.0003                  |
| 0.01                     | 100 kHz        |                           |                   | 0.0004                  |
| 0.025                    | 100 kHz        |                           |                   | 0.0007                  |
| 0.05                     | 100 kHz        |                           |                   | 0.0012                  |
| 0.1                      | 100 kHz        |                           |                   | 0.0022                  |
| 0.25                     | 100 kHz        |                           |                   | 0.0052                  |
| 0.5                      | 100 kHz        |                           |                   | 0.0102                  |
| 1                        | 100 kHz        |                           |                   | 0.0202                  |
| 2.5                      | 100 kHz        |                           |                   | 0.0502                  |
| 2.5                      | 10 kHz         |                           |                   | 0.0502                  |
| 2.5                      | 1 kHz          |                           |                   | 0.0502                  |

**Table 9-12. SC600 Option Edge Verification: Frequency**

| Nominal Value<br>(V p-p) | Frequency | Measured Value<br>(Hz) | Deviation (Hz) | 1-Year Spec. (Hz) |
|--------------------------|-----------|------------------------|----------------|-------------------|
| 2.5                      | 1 kHz     |                        |                | 0.0025            |
| 2.5                      | 10 kHz    |                        |                | 0.025             |
| 2.5                      | 100 kHz   |                        |                | 0.25              |
| 2.5                      | 1 MHz     |                        |                | 2.5               |
| 2.5                      | 10 MHz    |                        |                | 25                |

Table 9-13. SC600 Option Edge Verification: Duty Cycle

| Nominal Value<br>(V p-p) | Frequency | Measured Value<br>(%) | Deviation<br>(from 50%) | 1-Year Spec. (%) |
|--------------------------|-----------|-----------------------|-------------------------|------------------|
| 2.5                      | 1 MHz     |                       |                         | 5                |

Table 9-14. SC600 Option Edge Verification: Rise Time

| Nominal Value<br>(V p-p) | Frequency | Measured Value<br>(s) | Deviation (ns) | 1-Year Spec.<br>(ns) |
|--------------------------|-----------|-----------------------|----------------|----------------------|
| 0.25                     | 1 kHz     |                       |                | 0.3 ns               |
| 0.25                     | 100 kHz   |                       |                | 0.3 ns               |
| 0.25                     | 10 MHz    |                       |                | 0.3 ns               |
| 0.5                      | 1 kHz     |                       |                | 0.3 ns               |
| 0.5                      | 100 kHz   |                       |                | 0.3 ns               |
| 0.5                      | 10 MHz    |                       |                | 0.3 ns               |
| 1                        | 1 kHz     |                       |                | 0.3 ns               |
| 1                        | 100 kHz   |                       |                | 0.3 ns               |
| 1                        | 10 MHz    |                       |                | 0.3 ns               |
| 2.5                      | 1 kHz     |                       |                | 0.3 ns               |
| 2.5                      | 100 kHz   |                       |                | 0.3 ns               |
| 2.5                      | 10 MHz    |                       |                | 0.3 ns               |

Table 9-15. SC600 Option Tunnel Diode Pulser Verification

| Nominal Value<br>(V p-p) | Frequency (Hz) | Measured Value<br>(V p-p) | Deviation (V p-p) | 1-Year Spec.<br>(V p-p) |
|--------------------------|----------------|---------------------------|-------------------|-------------------------|
| 11                       | 100            |                           |                   | 0.2202                  |
| 11                       | 10000          |                           |                   | 0.2202                  |
| 55                       | 100            |                           |                   | 1.1002                  |
| 55                       | 10000          |                           |                   | 1.1002                  |
| 100                      | 100            |                           |                   | 2.0002                  |
| 100                      | 10000          |                           |                   | 2.0002                  |

**Table 9-16. SC600 Option Marker Generator Verification**

| Period (s) | Measured Value (s) | Deviation (s) | 1-Year Spec. (s) |
|------------|--------------------|---------------|------------------|
| 5          |                    |               | 0.0251 s         |
| 2          |                    |               | 0.00405 s        |
| 0.05       |                    |               | 3.75E-06 s       |
| 0.02       |                    |               | 5E-8             |
| 0.01       |                    |               | 2.5E-8           |
| 1e-7       |                    |               | 2.5E-13          |
| 5e-8       |                    |               | 1.25E-13         |
| 2e-8       |                    |               | 5E-14            |
| 1e-8       |                    |               | 2.5E-14          |
| 5e-9       |                    |               | 1.25E-14         |
| 2e-9       |                    |               | 5E-15            |

**Table 9-17. SC600 Option Pulse Generator Verification: Period**

| Nominal Value (V p-p) | Pulse Width (s) | Period (s) | Measured Value (s) | Deviation (s) | 1-Year Spec. (s) |
|-----------------------|-----------------|------------|--------------------|---------------|------------------|
| 2.5                   | 8E-08           | 2E-06      |                    |               | 5E-12            |
| 2.5                   | 0.0000005       | 0.01       |                    |               | 2.5E-08          |
| 2.5                   | 0.0000005       | 0.02       |                    |               | 5E-08            |

**Table 9-18. SC600 Option Pulse Generator Verification: Pulse Width**

| Nominal Value (V p-p) | Pulse Width (s) | Period (s) | Measured Value (s) | Deviation (s) | 1-Year Spec. typical (s) |
|-----------------------|-----------------|------------|--------------------|---------------|--------------------------|
| 2.5                   | 4.0E-09         | 2.0E-06    |                    |               | 6.2E-9                   |
| 2.5                   | 4.0E-09         | 2.0E-05    |                    |               | 6.2E-9                   |
| 2.5                   | 4.0E-09         | 2.0E-04    |                    |               | 6.2E-9                   |
| 2.5                   | 4.0E-08         | 2.0E-03    |                    |               | 4.4E-8                   |

Table 9-19. SC600 Option Input Impedance Verification: Resistance

| Nominal Value ( $\Omega$ ) | Measured Value ( $\Omega$ ) | Deviation ( $\Omega$ ) | 1-Year Spec. ( $\Omega$ ) |
|----------------------------|-----------------------------|------------------------|---------------------------|
| 40 $\Omega$                |                             |                        | 0.04 $\Omega$             |
| 50 $\Omega$                |                             |                        | 0.05 $\Omega$             |
| 60 $\Omega$                |                             |                        | 0.06 $\Omega$             |
| 600000 $\Omega$            |                             |                        | 600 $\Omega$              |
| 1000000 $\Omega$           |                             |                        | 1000 $\Omega$             |
| 1500000 $\Omega$           |                             |                        | 1500 $\Omega$             |

Table 9-20. SC600 Option Input Impedance Verification: Capacitance

| Nominal Value (pF) | Measured Value (pF) | Deviation (pF) | 1-Year Spec. (pF) |
|--------------------|---------------------|----------------|-------------------|
| 5 pF               |                     |                | 0.75 pF           |
| 29 pF              |                     |                | 1.95 pF           |
| 49 pF              |                     |                | 2.95 pF           |

## Chapter 10

# SC300 Oscilloscope Calibration Option

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## Introduction

The SC300 Oscilloscope Calibration Option (the SC300 Option) has functions that help you keep your oscilloscope's accuracy by verifying and calibrating the subsequent oscilloscope qualities:

- Vertical deflection qualities are calibrated and verified. The VOLT function lets you compare the voltage gain to the graticule lines on the oscilloscope.
- Pulse transient response is examined and calibrated, verifying the accuracy of the measurement of pulse transitions of the oscilloscope with the EDGE function.
- Frequency response is examined by verifying the bandwidth with the leveled sine wave (LEVSINE) function. Vertical deflection is monitored until the -3 dB point is seen on the oscilloscope.
- Horizontal (time base) deflection qualities are calibrated and verified with the time MARKER function. This calibration procedure is like the one for verifying the vertical deflection qualities, but it examines the horizontal axis.
- The power to trigger on different waveforms is verified with the wave generator function of the oscilloscope.

The menus that implement these functions also include parameters to change how the output signal reacts to voltage, frequency, and time settings. This gives you control of the signal at calibration, and gives more methods to see the properties of the signal.

## SC300 Oscilloscope Calibration Option Specifications

These specifications apply only to the SC300 Oscilloscope Calibration Option. General specifications that apply to the 5502A Calibrator can be found in Chapter 1. The specifications are correct given the 5502A is operated with the conditions specified in Chapter 1, and has completed a warm-up period of no less than two times the length of time the Calibrator was powered off, to a maximum of 30 minutes.

### Volt Function Specifications

| Volt Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | DC Signal                                                                        |                   | Square Wave Signal  |                                    |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------|---------------------|------------------------------------|
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Into 50 $\Omega$                                                                 | Into 1 M $\Omega$ | Into 50 $\Omega$    | Into 1 M $\Omega$                  |
| Amplitude Characteristics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                  |                   |                     |                                    |
| Range                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 0 V to $\pm 2.2$ V                                                               | 0 V to $\pm 33$ V | 1.8 mV to 2.2 V p-p | 1.8 mV to 105 V p-p <sup>[1]</sup> |
| Resolution                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | $<100$ V: 4 digits or 10 $\mu$ V, whichever is greater<br>$\geq 100$ V: 5 digits |                   |                     |                                    |
| Adjustment Range                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Continuous <sup>[1]</sup>                                                        |                   |                     |                                    |
| 1-Year Absolute Uncertainty, tcal $\pm 5^{\circ}\text{C}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | $\pm (0.25\% \text{ of output} + 100 \mu\text{V})$ <sup>[2] [3]</sup>            |                   |                     |                                    |
| Sequence                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 1-2-5 (for example 10 mV, 20 mV, 50 mV)                                          |                   |                     |                                    |
| Square Wave Frequency Characteristics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                  |                   |                     |                                    |
| Range                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | 10 Hz to 10 kHz                                                                  |                   |                     |                                    |
| 1-Year Absolute Uncertainty, tcal $\pm 5^{\circ}\text{C}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | $\pm (25 \text{ ppm of setting} + 15 \text{ mHz})$                               |                   |                     |                                    |
| Typical Aberration within 20 $\mu$ s from leading edge                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | $< (2\% \text{ of output} + 100 \mu\text{V})$                                    |                   |                     |                                    |
| <div>[1] The square wave signal into 1 M<math>\Omega</math> is a positive square wave from 1.8 mV to 55 V p-p. From 95 V to 105 V, its output is a square wave-like signal that alternates between the negative peak and the positive peak, with the centerline at <math>-10</math> V. Signals between 55 V and 95 V p-p are not available.</div> <div>[2] The uncertainty for 50 <math>\Omega</math> loads does not include the input impedance uncertainty of the oscilloscope. Square wave signals below 4.5 mV p-p have an uncertainty of <math>\pm (0.25\% \text{ of output} + 200 \mu\text{V})</math>.</div> <div>[3] Signals from 95 to 105 V p-p have an uncertainty of 0.5% of output in the frequency range 100 Hz to 1 kHz. Typical uncertainty is 1.5% of output for 95 V to 105 V p-p signals in the frequency range 10 Hz to 100 Hz, and 0.5% of output in the frequency range 1 kHz to 10 kHz.</div> |                                                                                  |                   |                     |                                    |

### Edge Function Specifications

| Edge Characteristics into 50 $\Omega$ |                                                               | 1-Year Absolute Uncertainty, tcal $\pm$ 5°C |
|---------------------------------------|---------------------------------------------------------------|---------------------------------------------|
| Amplitude                             |                                                               |                                             |
| Range (p-p)                           | 4.5 mV to 2.75 V                                              | $\pm(2\%$ of output + 200 $\mu$ V)          |
| Resolution                            | 4 digits                                                      |                                             |
| Adjustment Range                      | $\pm 10\%$ around each sequence value (shown below)           |                                             |
| Sequence                              | 5 mV, 10 mV, 25 mV, 50 mV, 100 mV, 250 mV, 500 mV, 1 V, 2.5 V |                                             |
| Other Edge Characteristics            |                                                               |                                             |
| Frequency Range                       | 1 kHz to 1 MHz                                                | $\pm(25$ ppm of setting + 15 mHz)           |
| Rise Time                             | < 400 ps                                                      |                                             |
| Leading Edge Aberrations              | within 10 ns                                                  | <(3% of output + 2 mV)                      |
|                                       | 10 to 30 ns                                                   | <(1% of output + 2 mV)                      |
|                                       | after 30 ns                                                   | <(0.5% of output + 2 mV)                    |
| Typical Duty Cycle                    | 45 % to 55 %                                                  |                                             |

### Leveled Sine Wave Function Specifications

| Leveled Sine Wave                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Frequency Range                              |                                      |                                      |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|--------------------------------------|--------------------------------------|
| Characteristics into 50 $\Omega$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | 50 kHz Reference                             | 50 kHz to 100 MHz                    | 100 to 300 MHz <sup>[1]</sup>        |
| Amplitude Characteristics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                              |                                      |                                      |
| Range (p-p)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | 5 mV to 5.5 V <sup>[1]</sup>                 |                                      |                                      |
| Resolution                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <100 mV: 3 digits<br>$\geq$ 100 mV: 4 digits |                                      |                                      |
| Adjustment Range                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | continuously adjustable                      |                                      |                                      |
| 1-Year Absolute Uncertainty, tcal<br>$\pm$ 5 $^{\circ}$ C                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | $\pm$ (2% of output + 200 $\mu$ V)           | $\pm$ (3.5% of output + 300 $\mu$ V) | $\pm$ (4% of output + 300 $\mu$ V)   |
| Flatness (relative to 50 kHz)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | not applicable                               | $\pm$ (1.5% of output + 100 $\mu$ V) | $\pm$ (2.0% of output + 100 $\mu$ V) |
| Short-term Stability                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | $\leq$ 1% <sup>[2]</sup>                     |                                      |                                      |
| Frequency Characteristics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                              |                                      |                                      |
| Resolution                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 10 Hz                                        | 10 kHz <sup>[3]</sup>                | 10 kHz                               |
| 1-Year Absolute Uncertainty, tcal<br>$\pm$ 5 $^{\circ}$ C                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | $\pm$ (25 ppm + 15 mHz)                      | $\pm$ 25 ppm <sup>[4]</sup>          | $\pm$ 25 ppm                         |
| Distortion Characteristics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                              |                                      |                                      |
| 2nd Harmonic                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | $\leq$ -35 dBc                               |                                      |                                      |
| 3rd and Higher Harmonics                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | $\leq$ -40 dBc                               |                                      |                                      |
| <div>[1] Extended frequency range to 350 MHz is provided, but flatness is not specified. Amplitude is limited to 3 V for frequencies above 250 MHz.</div> <div>[2] Within one hour after reference amplitude setting, provided temperature varies no more than <math>\pm</math> 5<math>^{\circ}</math>C.</div> <div>[3] At frequencies below 120 kHz, the resolution is 10 Hz. For frequencies between 120 kHz and 999.9 kHz, the resolution is 100 Hz.</div> <div>[4] <math>\pm</math>(25 ppm + 15 mHz) for frequencies of 1 MHz and below.</div> |                                              |                                      |                                      |

### Time Marker Function Specifications

| Time Marker into 50 Ω                              | 5 s to 100 μs                                                | 50 μs to 2 μs                | 1 μs to 20 ns   | 10 ns to 2 ns |
|----------------------------------------------------|--------------------------------------------------------------|------------------------------|-----------------|---------------|
| 1-Year Absolute Uncertainty, tcal ± 5 °C           | ±(25 + t *1000) ppm<br>[1]                                   | ±(25 + t *15,000) ppm<br>[1] | ±25 ppm         | ±25 ppm       |
| Wave Shape                                         | pulsed sawtooth                                              | pulsed sawtooth              | pulsed sawtooth | sine          |
| Typical Output Level                               | > 1 V pk                                                     | > 1 V pk                     | > 1 V pk        | > 2 V p-p [2] |
| Sequence                                           | 5-2-1 from 5 s to 2 ns (for example, 500 ms, 200 ms, 100 ms) |                              |                 |               |
| Adjustment Range                                   | At least ±10 % around each sequence value shown above.       |                              |                 |               |
| Resolution                                         | 4 digits                                                     |                              |                 |               |
| [1] t is the time in seconds.                      |                                                              |                              |                 |               |
| [2] The 2 ns time marker is typically > 0.5 V p-p. |                                                              |                              |                 |               |

### Wave Generator Specifications

| Wave Generator Characteristics                                          | Square Wave, Sine Wave, and Triangle Wave into 50 $\Omega$ or 1 M $\Omega$       |
|-------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| <b>Amplitude</b>                                                        |                                                                                  |
| Range                                                                   | into 1 M $\Omega$ : 1.8 mV to 55 V p-p<br>into 50 $\Omega$ : 1.8 mV to 2.2 V p-p |
| 1-Year Absolute Uncertainty, tcal $\pm$ 5 $^{\circ}$ C, 10 Hz to 10 kHz | $\pm(3$ % of p-p output + 100 $\mu$ V)                                           |
| Sequence                                                                | 1-2-5 (for example, 10 mV, 20 mV, 50 mV)                                         |
| Typical DC Offset Range                                                 | 0 to $\pm(\geq 40\%$ of p-p amplitude) <sup>[1]</sup>                            |
| <b>Frequency</b>                                                        |                                                                                  |
| Range                                                                   | 10 Hz to 100 kHz                                                                 |
| Resolution                                                              | 4 or 5 digits depending upon frequency                                           |
| 1-Year Absolute Uncertainty, tcal $\pm$ 5 $^{\circ}$ C                  | $\pm(25$ ppm + 15 mHz)                                                           |
| [1] The DC offset plus the wave signal must not exceed 30 V rms.        |                                                                                  |

### Trigger Signal Specifications for the Time Marker Function

| Time Marker Period                                                                                                                                | Division Ratio [1] | Amplitude into 50 $\Omega$ (p-p) | Typical Rise Time |
|---------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|----------------------------------|-------------------|
| 5 to 1 s                                                                                                                                          | off/1              | $\geq 1$ V                       | $\leq 2$ ns       |
| 0.5 to 0.1 s                                                                                                                                      | off/1/10           | $\geq 1$ V                       | $\leq 2$ ns       |
| 50 ms to 100 ns                                                                                                                                   | off/1/10/100       | $\geq 1$ V                       | $\leq 2$ ns       |
| 50 to 10 ns                                                                                                                                       | off/10/100         | $\geq 1$ V                       | $\leq 2$ ns       |
| 5 to 2 ns                                                                                                                                         | off/100            | $\geq 1$ V                       | $\leq 2$ ns       |
| [1] Divider is internally limited to prevent trigger output from frequencies that are either lower than 0.2 Hz (5s period) or higher than 10 MHz. |                    |                                  |                   |

### Trigger Signal Specifications for the Edge Function

| Edge Signal Frequency | Division Ratio | Amplitude into 50 $\Omega$ (p-p) | Typical Rise Time |
|-----------------------|----------------|----------------------------------|-------------------|
| 1 kHz to 1 MHz        | off/1          | $\geq 1$ V                       | $\leq 2$ ns       |

## Oscilloscope Connections

Use the cable supplied with the Oscilloscope Calibration Option to connect the SCOPE connector on the 5502A to one of the channel connectors on your oscilloscope (see Figure 8-3).

To use the external trigger, connect the TRIG connector on the 5502A to the external trigger connection on your oscilloscope. To use the external trigger and see its signal with the calibration signal, connect the TRIG connector to a different channel. See your oscilloscope manual for information about connections and how to see an external trigger.

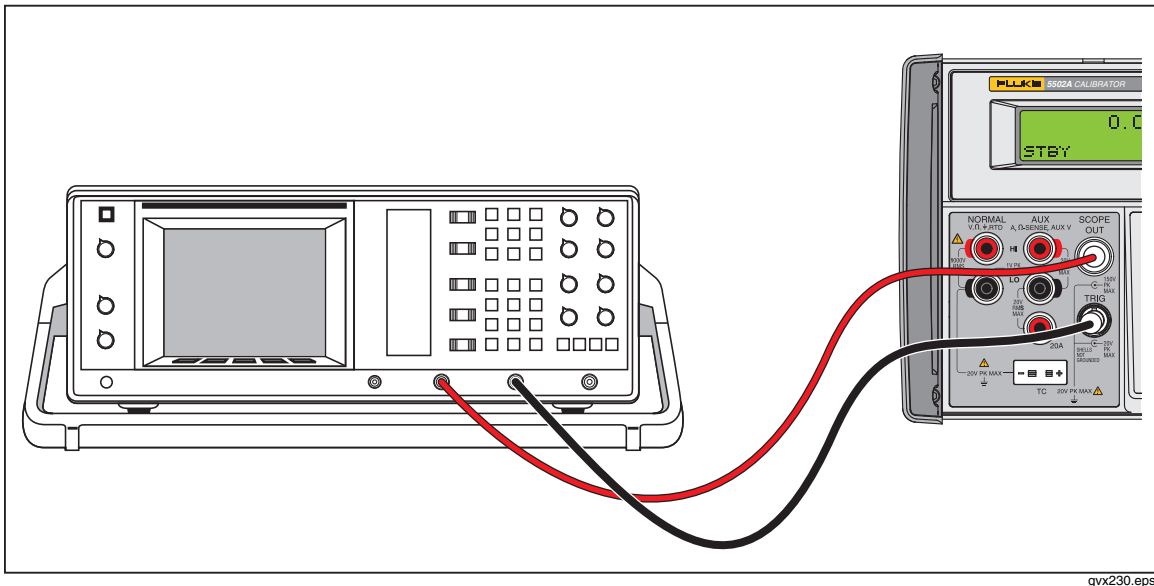
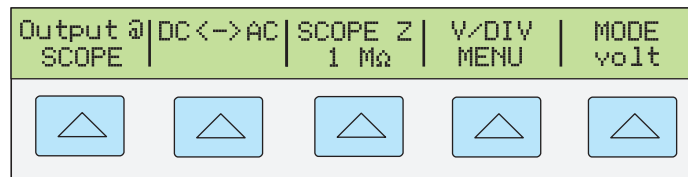


Figure 10-3. Oscilloscope Connection: Channel and External Trigger

## Start the Oscilloscope Calibration Option

Push **SCOPE** to start the Oscilloscope Calibration Option. The Control Display opens the volt menu, shown below, which contains options to calibrate the vertical gain on your oscilloscope. This is the first of five calibration menus, which you can scroll through. Push the softkey below MODE. Each menu is given in this chapter, see below.

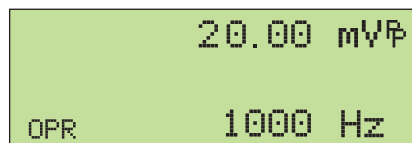


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## The Output Signal

The location of the output signal is shown on the Control Display (the display on the right side). If your 5502A is connected, but the output does not show on the oscilloscope, you can have the 5502A in standby mode.

The settings for the output signal are shown in the Output Display (the display on the left side). The subsequent example shows the default settings for volt mode, which are set when you start the Oscilloscope Calibration Option, see below.



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If STBY is shown, push the **OPR** key. The Output Display will show OPR and the output will show on the oscilloscope.

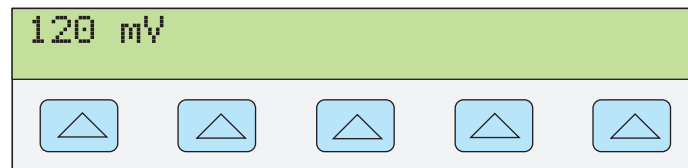
## Adjust the Output Signal

The 5502A gives different methods to change the settings for the output signal during calibration. Since many adjustments of the output signal are necessary for oscilloscope calibration, the three available methods to change these settings for oscilloscope calibration are summarized below. These methods give the means of jumping to a new value or sweep through a range of values.

### Key in a Value

To key a special value directly into the 5502A from its front panel:

1. Key in the value and include the units and prefixes. For example to key in 120 mV push **1** **2** **0**  **$\mu$ m**  **$\text{dBm}$ V**. The Control Display will show:



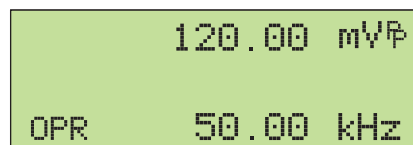
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#### Note

Units and prefixes printed in purple in the top left corner of the keys are accessed through the **SHIFT** key. For example, to record 200  $\mu$ s, push **2** **0** **0** **SHIFT**  **$\mu$ m** **SHIFT**  **$\text{sec}$ Hz**.

If you make an error, push **CE** to clear the Control Display and go to the menu.

2. Push **ENTER** to start the value and move it to the Output Display, see below.



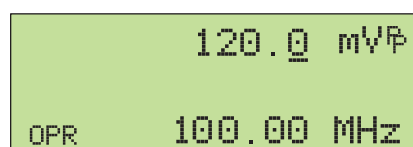
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Other settings in the display will stay unaltered unless you key in an entry and specify the units for that setting.

### Adjust Values with the Rotary Knob

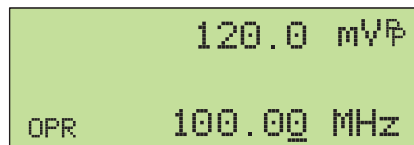
To adjust values in the Output Display with the rotary knob:

1. Turn the rotary knob. A cursor shows in the output display below the lowest digit and starts to change that digit. If you wish to put the cursor in the field without a digit change, push **EDIT FIELD**, see below.



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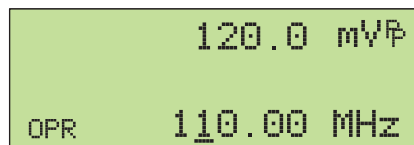
2. To move the cursor between the voltage and frequency fields, push **EDIT FIELD**, see below.



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3. Use the **◀** and **▶** keys to move the cursor to the digit that you will change.
4. Turn the rotary knob to change the value.

When you use the rotary knob in volt mode or marker mode, the Control Display shows the percentage change of the new value from the reference value. This is useful to learn the percentage of error on the oscilloscope. You can set the reference value to the new value. Push **NEW REF**, see below.



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5. Push **ENTER** to remove the cursor from the Output Display and save the new value as the reference value.

#### Note

*If you try to use the rotary knob to adjust a value to an quantity that is invalid for the function that you use, or is out of the range limit of the value, the value will not change and the 5502A will beep. If it is necessary to go to a different range of values, turn the knob quickly to jump to the new range.*

Use **MULT X** and **DIV 10**

The **MULT X** and **DIV 10** keys cause the current value of the signal to jump to a predetermined cardinal value. The current function determines this value. These keys are explained more under the descriptions for each function.

### Reset the Oscilloscope Option

You can reset all parameters in the 5502A to their default settings during front panel operations. Push **RESET** on the front panel.

After you reset the 5502A, push **SCOPE** to go to the Oscilloscope Calibration Option (the Volt menu shows). Push **OPR** to connect the signal output.

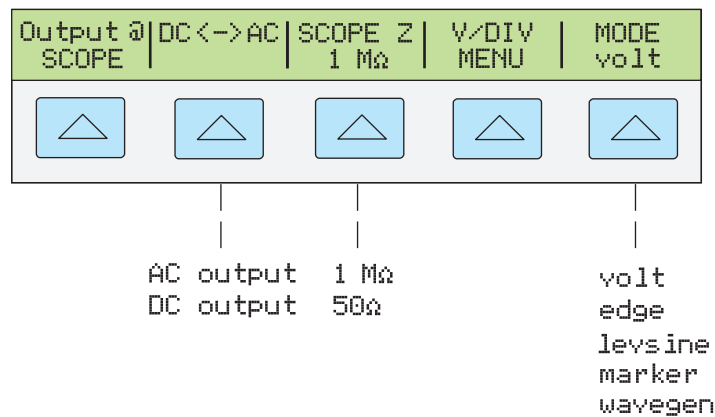


## Calibrate the Voltage Amplitude on an Oscilloscope

To calibrate oscilloscope voltage gain, apply a low frequency square wave signal and adjust its gain to the height specified for different voltage levels, designated by the graticule line divisions on the oscilloscope. Apply the signal from the 5502A in Volt mode. The voltages that you must use for calibration, and the graticule line divisions that are necessary to be matched, can be different for different oscilloscopes. These are specified in your service manual for your oscilloscope.

### The Volt Function

The Voltage gain is calibrated with the volt function. This function is accessed through the Volt menu, which shows when you start the SCOPE option, or when you push the softkey below MODE to scroll through the oscilloscope calibration menus, see below.



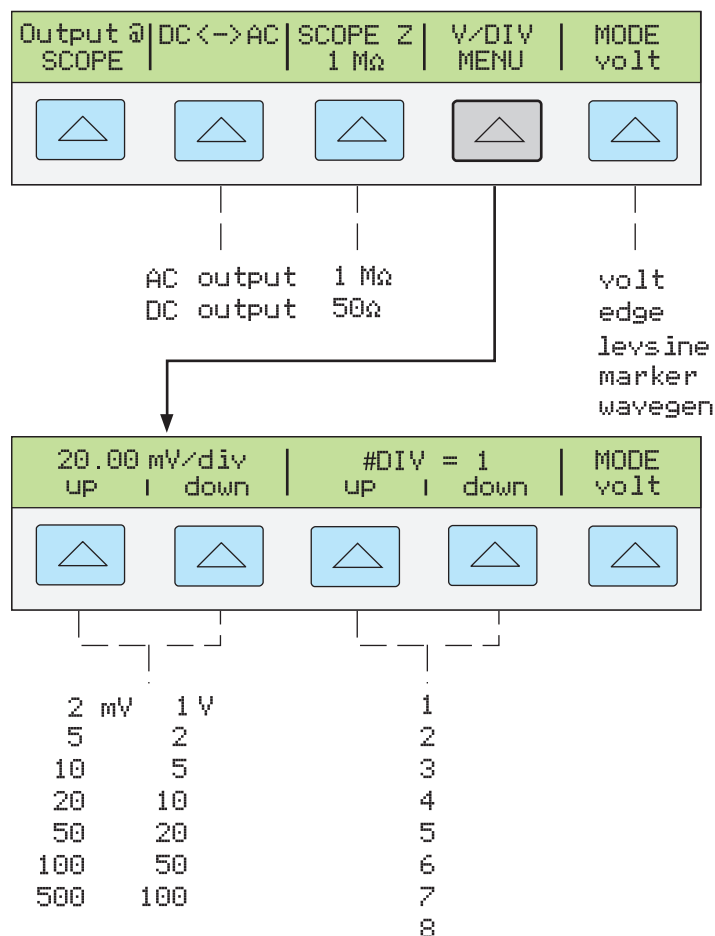
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Each menu item is described below:

- **OUTPUT @ SCOPE** Shows the location of the signal output. If the signal does not show on the oscilloscope, push **OPR**. To disconnect the signal, push **STBY**.
- **DC <-> AC** Toggles between a dc and ac signal. Push the softkey from the ac signal to make the dc equivalent output.
- **SCOPE Z** Toggles the output impedance setting of the Calibrator between 1 MΩ and 50 Ω.
- **V/DIV MENU** Opens the voltage scaling menu, which lets you select the scale of the signal in volts per division. This menu is shown below in the “The V/DIV Menu” section.
- **MODE** Shows you are in volt mode. Use the softkey to change modes and open its menus for the other four oscilloscope calibration modes.

## The V/DIV Menu

The V/DIV menu, shown below, sets the number of volts shown by each division on the oscilloscope. This menu gives alternative methods to change the output amplitude that can be more convenient for special oscilloscope uses. To access the V/DIV menu, push V/DIV from the Volt menu, see below.



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Each item in the V/DIV menu is given below.

- **V/div** Changes the scale of the output display with a change to the number of volts that are shown by each division. The available settings, shown in the figure above, are given in 1-2-5 step increments. Push the softkey below UP to increase the volts per division. Push the softkey below DOWN to decrease the volts per division.
- **# DIV** Specifies the number of divisions that make the p-p value of the waveform. The value can be adjusted from one to eight divisions. The quantity shown by each division is shown in the V/div field. Push the softkey below UP to increase the height of the signal, and push the softkey below DOWN to decrease it.

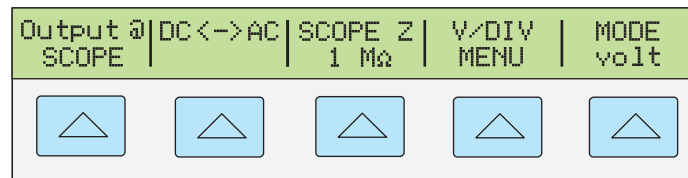
### Shortcuts to Set the Voltage Amplitude

The **MULT** and **DIV** keys step the voltages through cardinal point values of an oscilloscope in a 1-2-5 step sequence. For example, if the voltage is 40 mV, then push **MULT** to increase the voltage to the nearest cardinal point, which is 50 mV. Push **DIV** to decrease the voltage to the nearest cardinal point, which is 20 mV.

### Amplitude Calibration Procedure for an Oscilloscope

This example procedure tells you how to use the Volt menu to calibrate the amplitude gain of the oscilloscope. When you calibrate the oscilloscope, it will be necessary to set different voltages and verify that the gain matches the graticule lines on the oscilloscope with reference to the specifications for your oscilloscope. See your oscilloscope manual for the recommended calibration settings and correct gain values.

Before you start this procedure, verify that you are running the oscilloscope option in Volt mode. If you are, the Control Display shows the subsequent menu, see below.

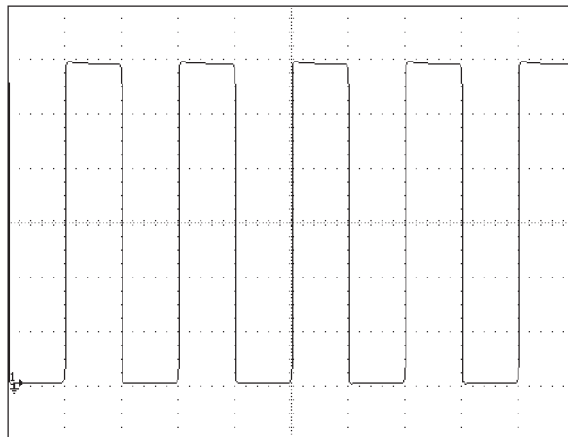


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Do the subsequent sample procedure to calibrate the vertical gain.

1. Connect the Calibrator to Channel 1 on the oscilloscope. Make sure the oscilloscope is terminated at the correct impedance (1 MΩ for this example). Make sure that the **OPR** key on the 5502A is lit. This shows that the signal is connected.
2. Key in the voltage level that is recommended for your oscilloscope. For example to record 20 mV, push **2** **0** **μm** **V**, then push **ENTER**. See “Keying in a Value” in this chapter.
3. Adjust the oscilloscope as necessary. The waveform must be similar to the one shown below, with the gain set as specified for the calibration settings for your oscilloscope.

The example below shows the gain at 20 mV to be 4 divisions, at 5 mV per division.



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4. Change the calibration voltage to the subsequent value that is recommended for your oscilloscope model, and do this procedure again at the new voltage level. Make sure that the gain is correct with reference to the specifications in your manual.
5. Do the procedure again for each channel.

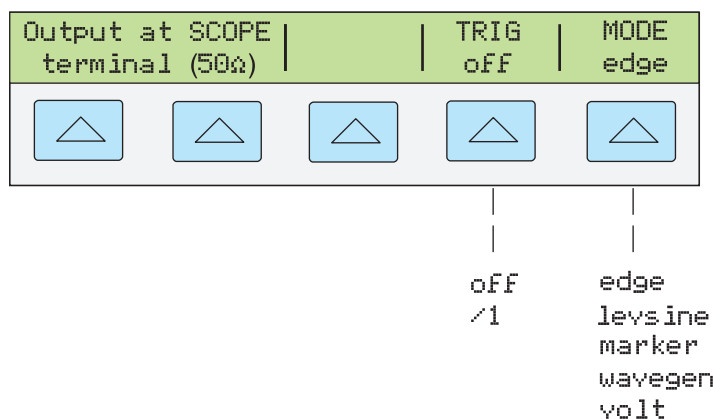
## Calibrate the Pulse and Frequency Response on an Oscilloscope

The pulse response is calibrated with a square-wave signal that has a fast leading edge rise-time. With this signal, you adjust the oscilloscope as necessary until it is in specification for rise time and pulse aberrations.

After pulse verification, the frequency response is verified with a leveled sine wave applied and by a frequency indication at the -3 dB point, when the amplitude drops approximately 30 %.

### The Edge Function

The Edge function is used to calibrate the pulse response for your oscilloscope. To get to the Edge menu, push the softkey below MODE until “edge” shows, see below.



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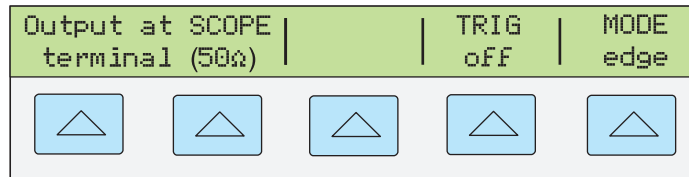
Each option in the Edge menu is shown below.

- **OUTPUT @ SCOPE terminal (50Ω)** Shows the location and impedance of the signal output. If the signal does not show on the oscilloscope, push **OPR**. To disconnect the signal, push **STBY**.  
 You cannot change the output impedance in Edge mode.
- **TRIG** If you use the external trigger, use this key to toggle the trigger off and on. When on, the indication will show “1” which shows that the external trigger is at the same frequency as the edge output.  
 You can also toggle the trigger off and on with . The external trigger can be useful for many digital storage oscilloscopes where triggering on fast rise time signals cannot be done easily.
- **MODE** Shows you are in Edge mode. Use the softkey to change modes and open the related menus for the other three oscilloscope calibration modes.

### **Pulse Response Calibration Procedure for an Oscilloscope**

This sample procedure shows how to verify the pulse response of the oscilloscope. Before you verify your oscilloscope, see the oscilloscope manual for the recommended calibration settings.

Before you start this procedure, make sure that you use the oscilloscope option in Edge mode. If you are, the Control Display shows the subsequent menu.



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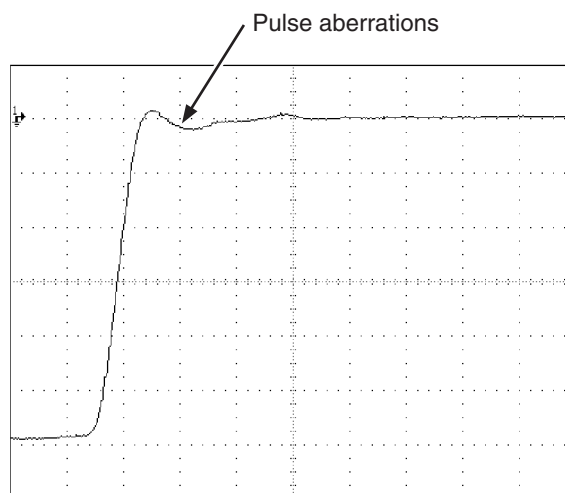
Do the subsequent sample procedure to calibrate the pulse response.

1. Connect the 5502A to Channel 1 on the oscilloscope. Select 50Ω impedance or use a 50 Ω termination at the oscilloscope input. Make sure that the **OPR** key is lit. This shows that the signal is connected.
2. Change the voltage adjustment for the signal so it agrees with the amplitude value recommended by your oscilloscope manufacturer to calibrate the edge response. The default is 25 mV @ 1 MHz.

For example, on a Fluke PM3392A oscilloscope, start with a signal of 1 V @ 1 MHz.

3. Adjust the scale on your oscilloscope to get a good picture of the edge. For example, on a Fluke PM3392A oscilloscope with a 1 V @ 1 MHz signal, use 200 mV/div.

4. Adjust the time base on your oscilloscope to the fastest position available (20.0 or 50.0 ns/div), see below.



5. Make sure that your oscilloscope shows the correct rise time and pulse aberration properties.
6. To remove the input signal, push **STBY**.

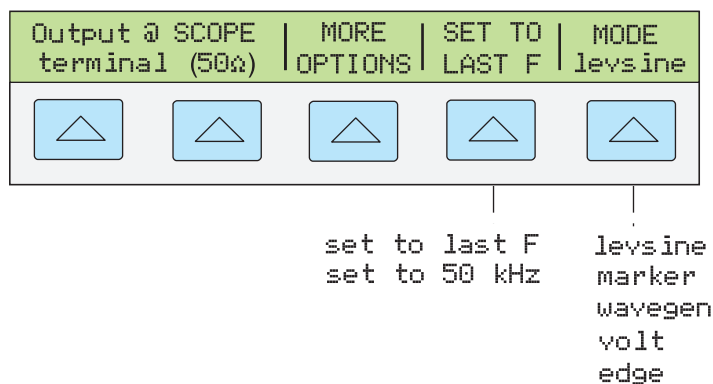
### The Leveled Sine Wave Function

The Leveled Sine Wave (Levsine) function uses a leveled sine wave, whose amplitude stays relatively constant over a range of frequencies, to verify the bandwidth of the oscilloscope. When you verify your oscilloscope, you change the frequency of the wave until the amplitude shown on the oscilloscope drops 30%, which is the amplitude that refers to the -3 dB point.

To access the Levsine menu, push the softkey below MODE until “levsine” shows, see below.

#### Note

*Make sure there is no cable connected to TRIG while you use the Levsine function.*



Each option in the Levsine menu is shown below.

- **OUTPUT @ SCOPE terminal (50Ω)** Shows the location and impedance of the signal output. If the signal does not show on the oscilloscope, push **OPR**. To disconnect the signal, push **STBY**. You cannot change the impedance while you are in Levsine mode.
- **MORE OPTIONS** Opens more menu items, which are given in the “The MORE OPTIONS Menu” section.
- **SET TO LAST F** Toggles between the current frequency setting and the reference value of 50 kHz. This option is useful for reverting to the reference to examine the output after you make adjustments at A different frequency.
- **MODE** Shows you are in Levsine mode. Use the softkey to change modes and open the corresponding menus for the other four calibration modes.

*Note*

*If a question mark shows in the Output Display, then no specifications are available for the frequency that is used. This will occur at frequencies more than 250 MHz.*

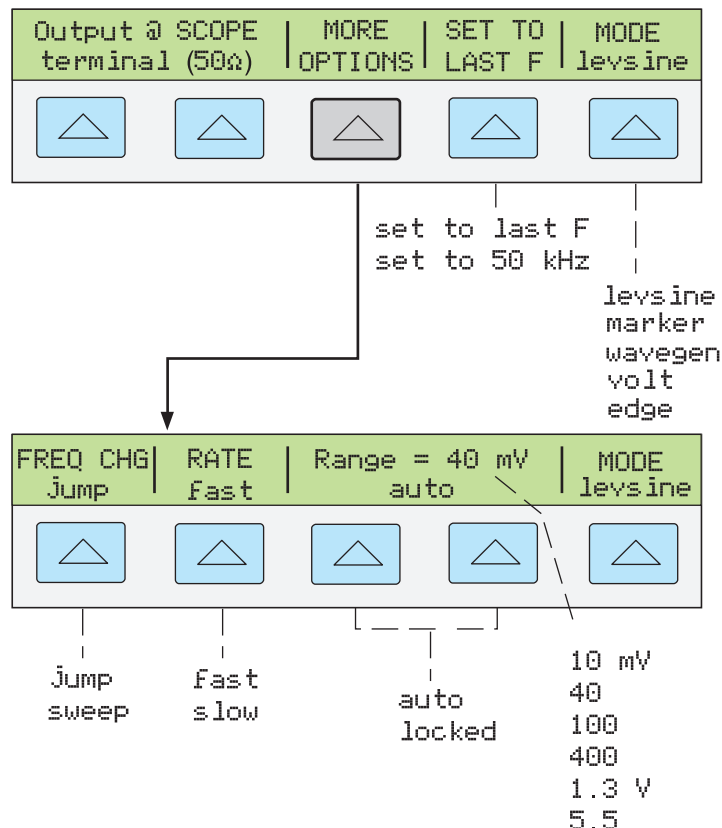
### **Shortcuts to Set the Frequency and Voltage**

Three options are available to control the sine wave settings.

- **SET TO LAST F** Toggles between the last frequency used and the reference frequency of 50 kHz. This lets you examine the output at the reference after you make adjustments at a different frequency.
- **MORE OPTIONS** Lets you use an automatic frequency sweep and lock the voltage range, if necessary. The subsequent section gives details about this menu.
- **The  $\boxed{\text{MULT}}_{\times}$  and  $\boxed{\text{DIV}}_{\div}$  keys** step frequencies up or down to let you quickly access a new set of frequencies. For example, if the value is 250 kHz,  $\boxed{\text{MULT}}_{\times}$  changes it to 300 kHz, and  $\boxed{\text{DIV}}_{\div}$  changes it to 200 kHz. For voltage values,  $\boxed{\text{MULT}}_{\times}$  and  $\boxed{\text{DIV}}_{\div}$  step through cardinal point values in a 1.2-3-6 sequence.

## The MORE OPTIONS Menu

When you select MORE OPTIONS, you open options that give you more control over the frequency and voltage. To access the MORE OPTIONS menu, push the softkey below MORE OPTIONS in the levsine menu, see below.



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Each option in the MORE OPTIONS menu is given below.

- FREQ CHANGE** Toggles between two settings that control the way the output signal adjusts to a new frequency. This is the default setting.
 

“Jump” causes the output signal to jump immediately to a new frequency setting. “Sweep” causes the signal to sweep through a series of frequency values, over a range you set. Use the sweep function to monitor the signal gradually change over a given bandwidth and see the point at which its amplitude changes. More about the sweep function is given in the “Sweeping Through a Frequency Range” section.
- RATE** Used when FREQ CHANGE is set to “sweep” to toggle the sweep speed between “fast” and “slow.” The slow speed is one tenth the fast speed.
 

The slow sweep rate lets you monitor the frequency change very slowly. After a fast sweep, it can be necessary to pinpoint a special frequency with a slow sweep over a subset of your previous frequency range.



- **RANGE** The softkeys toggle between two settings: “auto,” which adjusts the range limit automatically in accordance with the voltage level, and “locked,” which sets the available voltages to one range.

There are six range limits in Levsine mode: 10 mV, 40 mV, 100 mV, 400 mV, 1.3 V, and 5.5 V. When set to “auto” the Calibrator uses your voltage setting to automatically set the range limit that gives the most accurate output. When set to “locked” the range limit stays fixed and you can decrease the voltage down to 0 V for all range limits.

For example, if the range limit is 40 mV. If you set the 40 mV range to “auto” and then key in 1 mV, the Calibrator will adjust the range limit to 10 mV and will output 1 mV from the 10 mV range. If you set the 40 mV range to “locked” and then key in 1 mV, the Calibrator will output 1 mV from the 40 mV range.

The default range setting is “auto,” which must be used unless you are troubleshooting discontinuities in the vertical gain of your oscilloscope. The range setting will always go to “auto” after you go out of Levsine mode.

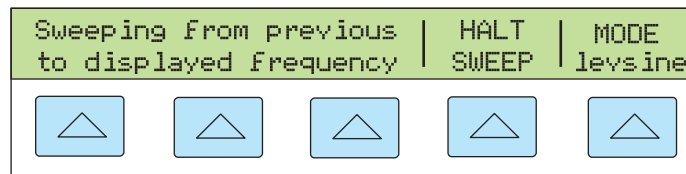
### Sweep through a Frequency Range

When you change frequencies with the sweep method, the output sine wave sweeps through a specified range of frequencies. This lets you identify the frequency at which the signal of the oscilloscope shows special behavior (e.g., changes amplitude). Before you start this procedure, make sure you are in the MORE OPTIONS menu and the sine wave is shown on the oscilloscope.

Do the subsequent procedure to sweep through frequencies.

1. Make sure the output signal shows the starting frequency. If not, key in the starting frequency and then push **ENTER**.
2. Toggle **FREQ CHANGE** to “sweep.” Toggle the **RATE** to “slow” to see a very slow sweep over a small range.
3. Key in the end frequency and then push **ENTER**.

After you push **ENTER**, the signal sweeps through frequencies between the two values you recorded, and the Sweep menu shows on the Control Display as shown below.



gl031i.eps

4. You can let the signal sweep through the complete range, or you can stop the sweep if necessary to record the frequency at a certain point.

To interrupt the sweep, push the softkey below **HALT SWEEP**. The current frequency will show on the Output Display and the MORE OPTIONS menu will show again on the Control Display.

#### Note

*When you interrupt the frequency sweep by a **HALT SWEEP** softkey push, the **FREQ CHANGE** method changes to “jump.”*

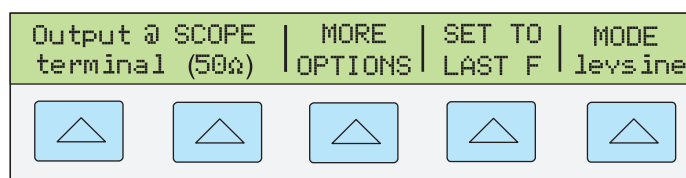
- Do the procedure again if necessary. For example, if you did a fast sweep, it can be necessary to pinpoint a special frequency with a slow sweep over a subset of your previous frequency range.

### Frequency Response Calibration Procedure for an Oscilloscope

This sample procedure, which verifies the frequency response on your oscilloscope, is usually done after the pulse response is verified.

To verify the bandwidth, this procedure finds the frequency at the -3 dB point for your oscilloscope. The reference sine wave in this procedure has an amplitude of 6 divisions, so that the -3 dB point can be found when the amplitude drops to 4.2 divisions.

Before you start this example procedure, verify that you run the oscilloscope option in Levsine mode. If you are, the Control Display shows the subsequent menu, see below.

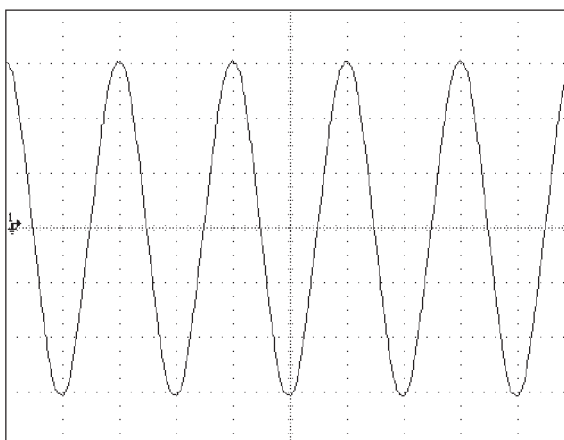


gl032i.eps

Do the subsequent sample procedure to calibrate the frequency response.

- Push the **OPR** key on the 5502A to reconnect the signal. Select 50  $\Omega$  impedance or use a 50  $\Omega$  external termination directly at the oscilloscope input
- Adjust the sine wave settings in the Output Display to the calibration recommendations in your oscilloscope manual. For example, for the Fluke PM3392A oscilloscope, start at 120 mV @ 50 kHz. To key in 120 mV, push **1** **2** **0**  **$\mu$ m**  **$\text{dBmV}$** , and then push **ENTER**.
- Adjust the oscilloscope as necessary. The sine wave must show at six divisions, p-p, as shown below.

If necessary, make small adjustments to the voltage amplitude until the wave gets to exactly six divisions. To fine-tune the voltage, push **EDIT FIELD** to move a cursor into the Output Display, move the cursor with the **◀** key, and turn the rotary knob to adjust the value. (See “Fine-Tuning Values” earlier in this chapter.)

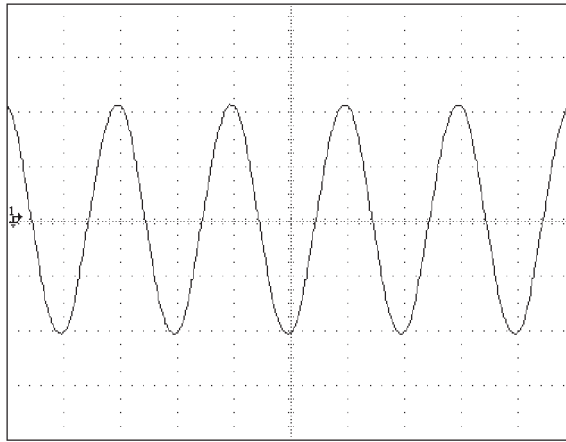


gl009i.bmp

4. Increase the frequency to 60 MHz (for 100 MHz instruments), or 150 MHz (for 200 MHz instruments). To key in 60 MHz, push **6** **0** **M** **Hz** and then push **ENTER**.
5. Continue to increase the frequency slowly until the waveform decreases to 4.2 divisions, as shown below.

To increase the frequency slowly, fine-tune it with the rotary knob. To do this, push **EDIT FIELD** to put a cursor in the Output Display. Push **EDIT FIELD** again to put it in the frequency field, and use the **◀** and **▶** keys to move it to the digit you will change. Then turn the rotary knob to change the value.

Continue to make small adjustments in the frequency until the signal drops to 4.2 divisions. At 4.2 divisions, the signal is at the frequency that corresponds to the -3 dB point, see below.



gl010i.bmp

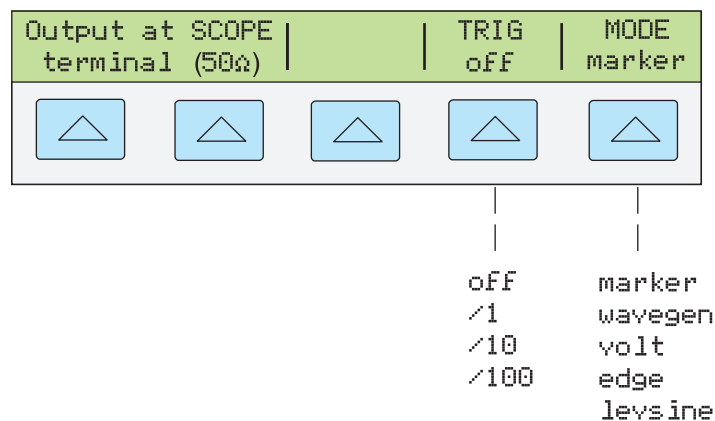
6. Push **STBY** to remove the input signal.
7. Do this procedure again for the channels on your oscilloscope that have not been done.

## Calibrate the Time Base of an Oscilloscope

The horizontal deflection (time base) of an oscilloscope is calibrated with a method not unlike the vertical gain calibration. A time marker signal is made from the Calibrator and the peaks of the signal are aligned to the graticule line divisions on the oscilloscope.

### The Time Marker Function

The Time Marker function, which is available through the Marker menu, lets you calibrate the timing response of your oscilloscope. To access the Marker menu, push the softkey below MODE until “marker” shows, see below.



g1033i.eps

Each option in the Marker menu is shown below.

- **OUTPUT @ SCOPE terminal** Shows the location of the signal output. If the signal does not show on the oscilloscope, push **OPR**. To disconnect the signal, push **STBY**.
- **TRIG** If you use the external trigger, use this key to move through the trigger settings. The available trigger settings are: off, /1 (trigger signal shows on each marker), /10 (trigger signal shows on every tenth marker), and /100 (trigger signal shows at every 100th marker).

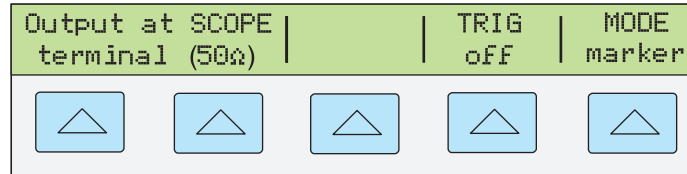
You can also toggle the trigger off and on with **TRIG OUT**.

- **MODE** Shows you are in Marker mode. Use the softkey to change modes and open the related menus for the other four oscilloscope calibration modes.

### Time Base Marker Calibration Procedure for an Oscilloscope

This sample procedure uses the Time Marker function to verify the horizontal deflection (time base) of your oscilloscope. See your manual for the oscilloscope for the time base values recommended for calibration.

Before you start this procedure, make sure that you are in Marker mode. If you are, the Control Display shows the subsequent menu, see below.



gl034i.eps

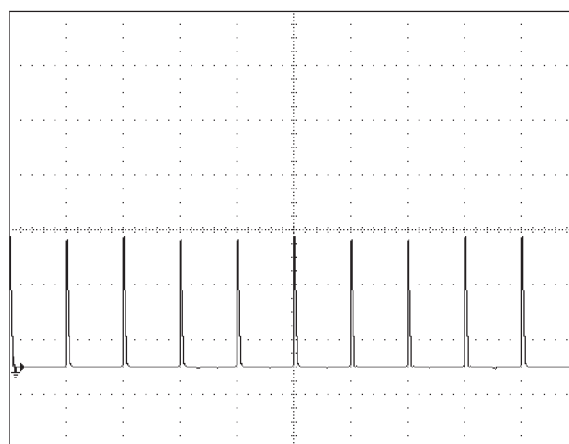
Do the subsequent sample procedure to calibrate the time base.

1. Connect the Calibrator to Channel 1 on the oscilloscope. Select 50Ω impedance or use an external 50 Ω termination. Make sure the oscilloscope is dc-coupled.
2. Apply a time marker value. Refer to the recommended calibration settings in your oscilloscope manual. For example, to key in 200 ns, push **2** **0** **0** **SHIFT** **n** **K** **SHIFT** **Hz**, and then push **ENTER**.

#### Note

*You can record the equivalent frequency as an alternative to the time marker value. For example, as an alternative to 200 ns, you can record 5 MHz.*

3. Set the time base of your oscilloscope to show 10 time markers. The time markers must align with the oscilloscope divisions, as shown in the example below. For an accurate indication, align the peaks of the signal with the horizontal center axis, see below.



Peaks are aligned with center axis

gl011i.eps

4. Do this procedure again for all time marker values recommended for your oscilloscope. Do this again for digital and analog mode as necessary. It can be necessary to change some oscilloscopes magnification while you calibrate in analog mode.
5. Remove the signal with **STBY**.

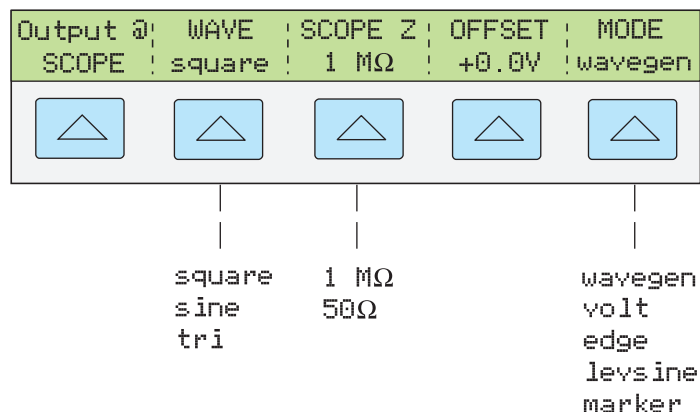
## Test the Trigger

The oscilloscope can trigger on different waveforms. This can be verified with the wave generator. When the wave generator is used, a square, sine, or triangle wave is transmitted and the output impedance of the wave, offset, and voltage can be changed to examine the trigger function at different levels.

### Note

*The wave generator must not be used to verify the accuracy of your oscilloscope. The question mark in the Output Display shows the amplitude values are not sufficiently accurate for this function.*

The wave generator is available through the Wavegen menu, shown below. To access this menu, push the softkey below MODE until “wavegen” shows, see below.



gl035i.eps

Each option in the Wavegen menu is given below.

- **OUTPUT @ SCOPE** Shows the location of the signal output. If the signal does not show on the oscilloscope, push **OPR**. To disconnect the signal, push **STBY**.
- **WAVE** Moves through the three types of waveforms that are available. You can select a square, sine, or triangle wave as the output.
- **SCOPE Z** Toggles the output impedance setting of the Calibrator between 50Ω and 1 MΩ.
- **OFFSET** Shows the offset of the generated wave. To change the offset, key in the new value, and push **ENTER**. The rotary knob does not change the offset, it changes the actual voltage output.

When you change the offset, you must stay between specified limits to prevent clipping the peaks. The limit depends on the p-p value of the wave. The maximum peak excursion is equal to the offset plus half of the p-p value of the wave. See “Wave Generator Specifications” in this chapter.

- **MODE** Shows that you are in Wavegen mode. Use the softkey to change modes and open the related menus for the other four oscilloscope calibration modes.

## Summary of Commands and Queries

This section tells you about commands and queries that are used only for the oscilloscope calibration option. Each command description shows if it can be used with IEEE-488 and RS-232 remote interfaces and identifies it as a Sequential, Overlapped, or Coupled command.

**IEEE-488 (GPIB) and RS-232 Applicability** ☒ IEEE-488 ☒ RS-232 Each command and query have a check box that shows applicability to IEEE-488 (general purpose interface bus, or GPIB) and RS-232 remote operations.

**Sequential Commands** ☒ Sequential Commands done immediately as occur in the data stream are named sequential commands. For more information, see “Sequential Commands” in Chapter 5.

**Overlapped Commands** ☒ Overlapped Commands SCOPE, TRIG, and OUT\_IMP are overlapped commands because they can be overlapped (interrupted) by the subsequent command before they are complete. When an overlapped command is interrupted, it can take longer to do the command while it stops for other commands to complete. To prevent an overlapped command from interruption during execution, use \*OPC, \*OPC?, or \*WAI. These commands prevent interruptions until they sense that the command is complete. For more information, see “Overlapped Commands” in Chapter 5.

**Coupled Commands** ☒ Coupled SCOPE and OUT\_IMP are coupled commands because they can be coupled (combined) with other commands to make a compound command sequence. Precautions are necessary to make sure that commands are not coupled so that they can cause them to disable each other, since this can end in a fault. For more information, see “Coupled Commands” in Chapter 5.

**SCOPE**   ☒ IEEE-488   ☒ RS-232   ☒ Sequential   ☐ Overlapped   ☐ Coupled

Programs the oscilloscope calibration option hardware, if installed. The instrument settings are sensed by this parameter of this command. When in SCOPE mode, use the OUT command to program new output.

OPER, STBY, \*OPC, \*OPC?, and \*WAI all operate as given in Chapter 6. The condition of the oscilloscope output while in SCOPE mode is reflected by the bit in the ISR that is assigned to SETTLED.

The FUNC? query shows SDCV, SACV, LEVSINE, MARKER, EDGE, and WAVEGEN for the related oscilloscope modes.

|             |         |                                                                                                                                                                    |
|-------------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Parameters: | OFF     | Turns off the oscilloscope hardware. Programs 0 V, 0 Hz, output at the NORMAL terminals, standby.                                                                  |
|             | VOLT    | Oscilloscope ac and dc voltage mode. Programs 20 mV p-p, 1 kHz, output at the SCOPE BNC, output impedance 1 M $\Omega$ , standby if from OFF or in standby before. |
|             | EDGE    | Oscilloscope Edge mode. Programs 25 mV peak-to-peak, 1 MHz, output at the SCOPE BNC, standby if from OFF or in standby before.                                     |
|             | LEVSINE | Oscilloscope-leveled sine mode. Programs 30 mV p-p, 50 kHz, output at the SCOPE BNC, standby if from OFF or in standby before.                                     |
|             | MARKER  | Oscilloscope Marker mode. Programs the period to 1 ms, output at the SCOPE BNC, standby if from OFF or in standby before.                                          |
|             | WAVEGEN | Oscilloscope Wavegen mode. Programs 20 mV p-p, square wave, 1 kHz, no offset, output impedance 1 M $\Omega$ , standby if from OFF or in standby before.            |

|          |                |                  |                                        |
|----------|----------------|------------------|----------------------------------------|
| Example: | SCOPE VOLT;    | OUT -2 V, 0 Hz   | (dc voltage, -2 V)                     |
|          | SCOPE VOLT;    | OUT 4 V, 1 kHz   | (ac voltage, 4 V peak-to-peak, 1 kHz.) |
|          | SCOPE EDGE;    | OUT 0.5 V, 5 kHz | (Edge, 0.5 V p-p, 5 kHz.)              |
|          | SCOPE LEVSINE; | OUT 1 V, 20 kHz  | (Leveled sine wave, 2 V p-p, 20 kHz.)  |
|          | SCOPE MARKER;  | OUT 2 MS         | (Marker, period of 2 ms.)              |
|          | SCOPE WAVEGEN; | OUT 1 V, 1 kHz   | (Wave Generator, 1 V p-p, 1 kHz.)      |



---

**SCOPE?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

Shows the current mode of operation for the oscilloscope. Shows OFF if the oscilloscope is off.

Parameter: (None)

Response: <character> (Shows OFF, VOLT, EDGE, LEVSINE, MARKER, or WAVEGEN.)

---

**TRIG** ☒ IEEE-488 ☒ RS-232 ☐ Sequential ☒ Overlapped ☐ Coupled

Programs the trigger output BNC of the oscilloscope.

|                 |                                                                                     |
|-----------------|-------------------------------------------------------------------------------------|
| Parameters: OFF | (Turns off the trigger output.)                                                     |
| DIV1            | (Turns on the trigger output. Frequency is the same as the signal at SCOPE output.) |
| DIV10           | (Turns on the trigger output. Frequency is 1/10 of the signal at SCOPE output.)     |
| DIV100          | (Turns on the trigger output. Frequency is 1/100 of the signal at SCOPE output.)    |

---

**TRIG?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

Shows the trigger output setting of the oscilloscope.

Parameters: (None)

Response: <character> (Shows OFF, DIV1, DIV10, or DIV100.)

---

**OUT\_IMP** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

Programs the output impedance of the oscilloscope.

|                 |                                                              |
|-----------------|--------------------------------------------------------------|
| Parameters: Z50 | (Programs the output impedance of the oscilloscope to 50Ω.)  |
| Z1M             | (Programs the output impedance of the oscilloscope to 1 MΩ.) |

---

**OUT\_IMP?** ☒ IEEE-488 ☒ RS-232 ☒ Sequential ☐ Overlapped ☐ Coupled

Shows the output impedance setting of the oscilloscope.

Parameters: (None)

Response: <character> (Shows Z50 or Z1M.)

## Verification Tables

At the Fluke Calibration factory, the SC300 Option is verified to its specifications at the subsequent test points. The verification test points are given here as a guide when verification is necessary.

**Table 10-1. Voltage Function Verification: AC Voltage into a 1 M $\Omega$  Load**

| Nominal Value (p-p) | Frequency | Measured Value (p-p) | Deviation (mV) | 1-Year Spec. |
|---------------------|-----------|----------------------|----------------|--------------|
| 5.0 mV              | 10 Hz     |                      |                | 0.11 mV      |
| 5.0 mV              | 100 Hz    |                      |                | 0.11 mV      |
| 5.0 mV              | 1 kHz     |                      |                | 0.11 mV      |
| 5.0 mV              | 5 kHz     |                      |                | 0.11 mV      |
| 5.0 mV              | 10 kHz    |                      |                | 0.11 mV      |
| 10.0 mV             | 10 kHz    |                      |                | 0.12 mV      |
| 20.0 mV             | 100 Hz    |                      |                | 0.15 mV      |
| 20.0 mV             | 1 kHz     |                      |                | 0.15 mV      |
| 20.0 mV             | 10 kHz    |                      |                | 0.15 mV      |
| 50.0 mV             | 10 kHz    |                      |                | 0.23 mV      |
| 89.0 mV             | 10 Hz     |                      |                | 0.32 mV      |
| 89.0 mV             | 10 kHz    |                      |                | 0.32 mV      |
| 100.0 mV            | 10 kHz    |                      |                | 0.35 mV      |
| 200.0 mV            | 100 Hz    |                      |                | 0.60 mV      |
| 200.0 mV            | 1 kHz     |                      |                | 0.60 mV      |
| 200.0 mV            | 10 kHz    |                      |                | 0.60 mV      |
| 500.0 mV            | 10 kHz    |                      |                | 1.35 mV      |
| 890.0 mV            | 10 Hz     |                      |                | 2.32 mV      |
| 890.0 mV            | 10 kHz    |                      |                | 2.32 mV      |
| 1.0 V               | 100 Hz    |                      |                | 2.60 mV      |
| 1.0 V               | 1 kHz     |                      |                | 2.60 mV      |
| 1.0 V               | 10 kHz    |                      |                | 2.60 mV      |
| 2.0 V               | 10 kHz    |                      |                | 5.10 mV      |
| 5.0 V               | 10 Hz     |                      |                | 12.60 mV     |
| 5.0 V               | 10 kHz    |                      |                | 12.60 mV     |
| 10.0 V              | 10 kHz    |                      |                | 25.10 mV     |
| 20.0 V              | 10 kHz    |                      |                | 50.10 mV     |

Table 10-1. Voltage Function Verification: AC Voltage into a 1 M $\Omega$  Load (cont.)

| Nominal Value (p-p) | Frequency | Measured Value (p-p) | Deviation (mV) | 1-Year Spec. |
|---------------------|-----------|----------------------|----------------|--------------|
| 50.0 V              | 10 Hz     |                      |                | 125.10 mV    |
| 50.0 V              | 100 Hz    |                      |                | 125.10 mV    |
| 50.0 V              | 1 kHz     |                      |                | 125.10 mV    |
| 50.0 V              | 10 kHz    |                      |                | 125.10 mV    |
| 105.0 V             | 100 Hz    |                      |                | 262.60 mV    |
| 105.0 V             | 1 kHz     |                      |                | 262.60 mV    |

Table 10-2. Voltage Function Verification: AC Voltage into a 50  $\Omega$  Load

| Nominal Value (p-p) | Frequency | Measured Value (p-p) | Deviation (mV) | 1-Year Spec. |
|---------------------|-----------|----------------------|----------------|--------------|
| 5.0 mV              | 10 Hz     |                      |                | 0.11 mV      |
| 5.0 mV              | 100 Hz    |                      |                | 0.11 mV      |
| 5.0 mV              | 1 kHz     |                      |                | 0.11 mV      |
| 5.0 mV              | 5 kHz     |                      |                | 0.11 mV      |
| 5.0 mV              | 10 kHz    |                      |                | 0.11 mV      |
| 10.0 mV             | 100 Hz    |                      |                | 0.12 mV      |
| 10.0 mV             | 1 kHz     |                      |                | 0.12 mV      |
| 10.0 mV             | 10 kHz    |                      |                | 0.12 mV      |
| 20.0 mV             | 10 kHz    |                      |                | 0.15 mV      |
| 44.9 mV             | 10 Hz     |                      |                | 0.21 mV      |
| 44.9 mV             | 10 kHz    |                      |                | 0.21 mV      |
| 50.0 mV             | 10 kHz    |                      |                | 0.23 mV      |
| 100.0 mV            | 100 Hz    |                      |                | 0.35 mV      |
| 100.0 mV            | 1 kHz     |                      |                | 0.35 mV      |
| 100.0 mV            | 10 kHz    |                      |                | 0.35 mV      |
| 200.0 mV            | 10 kHz    |                      |                | 0.60 mV      |
| 449.0 mV            | 10 Hz     |                      |                | 1.22 mV      |
| 449.0 mV            | 10 kHz    |                      |                | 1.22 mV      |
| 500.0 mV            | 10 kHz    |                      |                | 1.35 mV      |
| 1.0 V               | 100 Hz    |                      |                | 2.60 mV      |
| 1.0 V               | 1 kHz     |                      |                | 2.60 mV      |
| 1.0 V               | 10 kHz    |                      |                | 2.60 mV      |
| 2.0 V               | 10 Hz     |                      |                | 5.10 mV      |

**Table 10-2. Voltage Function Verification: AC Voltage into a 50  $\Omega$  Load (cont.)**

| Nominal Value (p-p) | Frequency | Measured Value (p-p) | Deviation (mV) | 1-Year Spec. |
|---------------------|-----------|----------------------|----------------|--------------|
| 2.0 V               | 100 Hz    |                      |                | 5.10 mV      |
| 2.0 V               | 1 kHz     |                      |                | 5.10 mV      |
| 2.0 V               | 5 kHz     |                      |                | 5.10 mV      |
| 2.0 V               | 10 kHz    |                      |                | 5.10 mV      |

**Table 10-3. Voltage Function Verification: DC Voltage into a 50  $\Omega$  Load**

| Nominal Value (dc) | Measured Value (dc) | Deviation (mV) | 1-Year Spec. |
|--------------------|---------------------|----------------|--------------|
| 0.0 mV             |                     |                | 0.10 mV      |
| 5.0 mV             |                     |                | 0.11 mV      |
| -5.0 mV            |                     |                | 0.11 mV      |
| 10.0 mV            |                     |                | 0.12 mV      |
| -10.0 mV           |                     |                | 0.12 mV      |
| 22.0 mV            |                     |                | 0.15 mV      |
| -22.0 mV           |                     |                | 0.15 mV      |
| 25.0 mV            |                     |                | 0.16 mV      |
| -25.0 mV           |                     |                | 0.16 mV      |
| 55.0 mV            |                     |                | 0.24 mV      |
| -55.0 mV           |                     |                | 0.24 mV      |
| 100.0 mV           |                     |                | 0.35 mV      |
| -100.0 mV          |                     |                | 0.35 mV      |
| 220.0 mV           |                     |                | 0.65 mV      |
| -220.0 mV          |                     |                | 0.65 mV      |
| 250.0 mV           |                     |                | 0.72 mV      |
| -250.0 mV          |                     |                | 0.72 mV      |
| 550.0 mV           |                     |                | 1.47 mV      |
| -550.0 mV          |                     |                | 1.47 mV      |
| 700.0 mV           |                     |                | 1.85 mV      |
| -700.0 mV          |                     |                | 1.85 mV      |
| 2.2 V              |                     |                | 5.60 mV      |
| -2.2 V             |                     |                | 5.60 mV      |

Table 10-4. Voltage Function Verification: DC Voltage into a 1 M $\Omega$  Load

| Nominal Value (dc) | Measured Value (dc) | Deviation (mV) | 1-Year Spec. |
|--------------------|---------------------|----------------|--------------|
| 0.0 mV             |                     |                | 0.10 mV      |
| 5.0 mV             |                     |                | 0.11 mV      |
| -5.0 mV            |                     |                | 0.11 mV      |
| 22.0 mV            |                     |                | 0.15 mV      |
| -22.0 mV           |                     |                | 0.15 mV      |
| 25.0 mV            |                     |                | 0.16 mV      |
| -25.0 mV           |                     |                | 0.16 mV      |
| 45.0 mV            |                     |                | 0.21 mV      |
| -45.0 mV           |                     |                | 0.21 mV      |
| 50.0 mV            |                     |                | 0.23 mV      |
| -50.0 mV           |                     |                | 0.23 mV      |
| 220.0 mV           |                     |                | 0.65 mV      |
| -220.0 mV          |                     |                | 0.65 mV      |
| 250.0 mV           |                     |                | 0.72 mV      |
| -250.0 mV          |                     |                | 0.72 mV      |
| 450.0 mV           |                     |                | 1.22 mV      |
| -450.0 mV          |                     |                | 1.22 mV      |
| 500.0 mV           |                     |                | 1.35 mV      |
| -500.0 mV          |                     |                | 1.35 mV      |
| 3.3 V              |                     |                | 8.35 mV      |
| -3.3 V             |                     |                | 8.35 mV      |
| 4.0 V              |                     |                | 10.10 mV     |
| -4.0 V             |                     |                | 10.10 mV     |
| 33.0 V             |                     |                | 82.60 mV     |
| -33.0 V            |                     |                | 82.60 mV     |

**Table 10-5. Edge Function Verification**

| Nominal Value (p-p) | Frequency | Pulse Response Time (ns) | 1-Year Spec. |
|---------------------|-----------|--------------------------|--------------|
| 25.0 mV             | 1 MHz     |                          | 400 ps       |
| 250.0 mV            | 1 MHz     |                          | 400 ps       |
| 250.0 mV            | 10 kHz    |                          | 400 ps       |
| 250.0 mV            | 100 kHz   |                          | 400 ps       |
| 250.0 mV            | 1 MHz     |                          | 400 ps       |
| 2.5 V               | 1 MHz     |                          | 400 ps       |

**Table 10-6. Wave Generator Function Verification: 1 MΩ Load**

| Waveform | Nominal Value (p-p) | Frequency | Measured Value (p-p) | Deviation (mV) | 1-Year Spec. |
|----------|---------------------|-----------|----------------------|----------------|--------------|
| Square   | 5.0 mV              | 10 kHz    |                      |                | 0.25 mV      |
| Square   | 20.0 mV             | 10 kHz    |                      |                | 0.70 mV      |
| Square   | 89.0 mV             | 10 kHz    |                      |                | 2.77 mV      |
| Square   | 219.0 mV            | 10 kHz    |                      |                | 6.67 mV      |
| Square   | 890.0 mV            | 10 kHz    |                      |                | 26.80 mV     |
| Square   | 6.5 V               | 10 kHz    |                      |                | 195.10 mV    |
| Square   | 55.0 V              | 10 kHz    |                      |                | 1.65 V       |
| Sine     | 5.0 mV              | 10 kHz    |                      |                | 0.25 mV      |
| Sine     | 20.0 mV             | 10 kHz    |                      |                | 0.70 mV      |
| Sine     | 89.0 mV             | 10 kHz    |                      |                | 2.77 mV      |
| Sine     | 219.0 mV            | 10 kHz    |                      |                | 6.67 mV      |
| Sine     | 890.0 mV            | 10 kHz    |                      |                | 26.80 mV     |
| Sine     | 6.5 V               | 10 kHz    |                      |                | 195.10 mV    |
| Sine     | 55.0 V              | 10 kHz    |                      |                | 1.65 V       |
| Triangle | 5.0 mV              | 10 kHz    |                      |                | 0.25 mV      |
| Triangle | 20.0 mV             | 10 kHz    |                      |                | 0.70 mV      |
| Triangle | 89.0 mV             | 10 kHz    |                      |                | 2.77 mV      |
| Triangle | 219.0 mV            | 10 kHz    |                      |                | 6.67 mV      |
| Triangle | 890.0 mV            | 10 kHz    |                      |                | 26.80 mV     |
| Triangle | 6.5 V               | 10 kHz    |                      |                | 195.10 mV    |
| Triangle | 55.0 V              | 10 kHz    |                      |                | 1.65 V       |

Table 10-7. Wave Generator Function Verification: 50  $\Omega$  Load

| Waveform | Nominal Value (p-p) | Frequency | Measured Value (p-p) | Deviation (mV) | 1-Year Spec. |
|----------|---------------------|-----------|----------------------|----------------|--------------|
| Square   | 5.0 mV              | 10 kHz    |                      |                | 0.25 mV      |
| Square   | 10.9 mV             | 10 kHz    |                      |                | 0.43 mV      |
| Square   | 44.9 mV             | 10 kHz    |                      |                | 1.45 mV      |
| Square   | 109.0 mV            | 10 kHz    |                      |                | 3.37 mV      |
| Square   | 449.0 mV            | 10 kHz    |                      |                | 13.57 mV     |
| Square   | 1.1 V               | 10 kHz    |                      |                | 32.50 mV     |
| Square   | 2.2 V               | 10 kHz    |                      |                | 66.10 mV     |
| Sine     | 5.0 mV              | 10 kHz    |                      |                | 0.25 mV      |
| Sine     | 10.9 mV             | 10 kHz    |                      |                | 0.43 mV      |
| Sine     | 44.9 mV             | 10 kHz    |                      |                | 1.45 mV      |
| Sine     | 109.0 mV            | 10 kHz    |                      |                | 3.37 mV      |
| Sine     | 449.0 mV            | 10 kHz    |                      |                | 13.57 mV     |
| Sine     | 1.1 V               | 10 kHz    |                      |                | 32.50 mV     |
| Sine     | 2.2 V               | 10 kHz    |                      |                | 66.10 mV     |
| Triangle | 5.0 mV              | 10 kHz    |                      |                | 0.25 mV      |
| Triangle | 10.9 mV             | 10 kHz    |                      |                | 0.43 mV      |
| Triangle | 44.9 mV             | 10 kHz    |                      |                | 1.45 mV      |
| Triangle | 109.0 mV            | 10 kHz    |                      |                | 3.37 mV      |
| Triangle | 449.0 mV            | 10 kHz    |                      |                | 13.57 mV     |
| Triangle | 1.1 V               | 10 kHz    |                      |                | 32.50 mV     |
| Triangle | 2.2 V               | 10 kHz    |                      |                | 66.10 mV     |

Table 10-8. Levelled Sine Wave Function Verification: Amplitude

| Nominal Value (p-p) | Frequency | Measured Value (p-p) | Deviation (mV) | 1-Year Spec. |
|---------------------|-----------|----------------------|----------------|--------------|
| 5.0 mV              | 50 kHz    |                      |                | 0.300 mV     |
| 10.0 mV             | 50 kHz    |                      |                | 0.400 mV     |
| 20.0 mV             | 50 kHz    |                      |                | 0.600 mV     |
| 40.0 mV             | 50 kHz    |                      |                | 1.000 mV     |
| 50.0 mV             | 50 kHz    |                      |                | 1.200 mV     |
| 100.0 mV            | 50 kHz    |                      |                | 2.200 mV     |
| 200.0 mV            | 50 kHz    |                      |                | 4.200 mV     |

**Table 10-8. Levelled Sine Wave Function Verification: Amplitude (cont.)**

| Nominal Value (p-p) | Frequency | Measured Value (p-p) | Deviation (mV) | 1-Year Spec. |
|---------------------|-----------|----------------------|----------------|--------------|
| 400.0 mV            | 50 kHz    |                      |                | 8.200 mV     |
| 500.0 mV            | 50 kHz    |                      |                | 1.200 mV     |
| 1.3 V               | 50 kHz    |                      |                | 26.200 mV    |
| 2.0 V               | 50 kHz    |                      |                | 40.200 mV    |
| 5.5 V               | 50 kHz    |                      |                | 110.200 mV   |

**Table 10-9. Levelled Sine Wave Function Verification: Flatness**

| Nominal Value (p-p) | Frequency | Measured Value (p-p) | Deviation (mV) | 1-Year Spec. |
|---------------------|-----------|----------------------|----------------|--------------|
| 5.0 mV              | 500 kHz   |                      |                | 0.17 mV      |
| 5.0 mV              | 1 MHz     |                      |                | 0.17 mV      |
| 5.0 mV              | 1 MHz     |                      |                | 0.17 mV      |
| 5.0 mV              | 2 MHz     |                      |                | 0.17 mV      |
| 5.0 mV              | 5 MHz     |                      |                | 0.17 mV      |
| 5.0 mV              | 10 MHz    |                      |                | 0.17 mV      |
| 5.0 mV              | 20 MHz    |                      |                | 0.17 mV      |
| 5.0 mV              | 50 MHz    |                      |                | 0.17 mV      |
| 5.0 mV              | 100 MHz   |                      |                | 0.17 mV      |
| 5.0 mV              | 125 MHz   |                      |                | 0.20 mV      |
| 5.0 mV              | 160 MHz   |                      |                | 0.20 mV      |
| 5.0 mV              | 200 MHz   |                      |                | 0.20 mV      |
| 5.0 mV              | 220 MHz   |                      |                | 0.20 mV      |
| 5.0 mV              | 235 MHz   |                      |                | 0.20 mV      |
| 5.0 mV              | 250 MHz   |                      |                | 0.20 mV      |
| 10.0 mV             | 500 kHz   |                      |                | 0.25 mV      |
| 10.0 mV             | 1 MHz     |                      |                | 0.25 mV      |
| 10.0 mV             | 1 MHz     |                      |                | 0.25 mV      |
| 10.0 mV             | 2 MHz     |                      |                | 0.25 mV      |
| 10.0 mV             | 5 MHz     |                      |                | 0.25 mV      |
| 10.0 mV             | 10 MHz    |                      |                | 0.25 mV      |
| 10.0 mV             | 20 MHz    |                      |                | 0.25 mV      |
| 10.0 mV             | 50 MHz    |                      |                | 0.25 mV      |
| 10.0 mV             | 100 MHz   |                      |                | 0.25 mV      |
| 10.0 mV             | 125 MHz   |                      |                | 0.30 mV      |



Table 10-9. Levelled Sine Wave Function Verification: Flatness (cont.)

| Nominal Value (p-p) | Frequency | Measured Value (p-p) | Deviation (mV) | 1-Year Spec. |
|---------------------|-----------|----------------------|----------------|--------------|
| 10.0 mV             | 160 MHz   |                      |                | 0.30 mV      |
| 10.0 mV             | 200 MHz   |                      |                | 0.30 mV      |
| 10.0 mV             | 220 MHz   |                      |                | 0.30 mV      |
| 10.0 mV             | 235 MHz   |                      |                | 0.30 mV      |
| 10.0 mV             | 250 MHz   |                      |                | 0.30 mV      |
| 40.0 mV             | 500 kHz   |                      |                | 0.70 mV      |
| 40.0 mV             | 1 MHz     |                      |                | 0.70 mV      |
| 40.0 mV             | 1 MHz     |                      |                | 0.70 mV      |
| 40.0 mV             | 2 MHz     |                      |                | 0.70 mV      |
| 40.0 mV             | 5 MHz     |                      |                | 0.70 mV      |
| 40.0 mV             | 10 MHz    |                      |                | 0.70 mV      |
| 40.0 mV             | 20 MHz    |                      |                | 0.70 mV      |
| 40.0 mV             | 50 MHz    |                      |                | 0.70 mV      |
| 40.0 mV             | 100 MHz   |                      |                | 0.70 mV      |
| 40.0 mV             | 125 MHz   |                      |                | 0.90 mV      |
| 40.0 mV             | 160 MHz   |                      |                | 0.90 mV      |
| 40.0 mV             | 200 MHz   |                      |                | 0.90 mV      |
| 40.0 mV             | 220 MHz   |                      |                | 0.90 mV      |
| 40.0 mV             | 235 MHz   |                      |                | 0.90 mV      |
| 40.0 mV             | 250 MHz   |                      |                | 0.90 mV      |
| 100.0 mV            | 500 kHz   |                      |                | 1.60 mV      |
| 100.0 mV            | 1 MHz     |                      |                | 1.60 mV      |
| 100.0 mV            | 1 MHz     |                      |                | 1.60 mV      |
| 100.0 mV            | 2 MHz     |                      |                | 1.60 mV      |
| 100.0 mV            | 5 MHz     |                      |                | 1.60 mV      |
| 100.0 mV            | 10 MHz    |                      |                | 1.60 mV      |
| 100.0 mV            | 20 MHz    |                      |                | 1.60 mV      |
| 100.0 mV            | 50 MHz    |                      |                | 1.60 mV      |
| 100.0 mV            | 100 MHz   |                      |                | 1.60 mV      |
| 100.0 mV            | 125 MHz   |                      |                | 2.10 mV      |
| 100.0 mV            | 160 MHz   |                      |                | 2.10 mV      |
| 100.0 mV            | 200 MHz   |                      |                | 2.10 mV      |

**Table 10-9. Levelled Sine Wave Function Verification: Flatness (cont.)**

| Nominal Value (p-p) | Frequency | Measured Value (p-p) | Deviation (mV) | 1-Year Spec. |
|---------------------|-----------|----------------------|----------------|--------------|
| 100.0 mV            | 220 MHz   |                      |                | 2.10 mV      |
| 100.0 mV            | 235 MHz   |                      |                | 2.10 mV      |
| 100.0 mV            | 250 MHz   |                      |                | 2.10 mV      |
| 400.0 mV            | 500 kHz   |                      |                | 6.10 mV      |
| 400.0 mV            | 1 MHz     |                      |                | 6.10 mV      |
| 400.0 mV            | 1 MHz     |                      |                | 6.10 mV      |
| 400.0 mV            | 2 MHz     |                      |                | 6.10 mV      |
| 400.0 mV            | 5 MHz     |                      |                | 6.10 mV      |
| 400.0 mV            | 10 MHz    |                      |                | 6.10 mV      |
| 400.0 mV            | 20 MHz    |                      |                | 6.10 mV      |
| 400.0 mV            | 50 MHz    |                      |                | 6.10 mV      |
| 400.0 mV            | 100 MHz   |                      |                | 6.10 mV      |
| 400.0 mV            | 125 MHz   |                      |                | 8.10 mV      |
| 400.0 mV            | 160 MHz   |                      |                | 8.10 mV      |
| 400.0 mV            | 200 MHz   |                      |                | 8.10 mV      |
| 400.0 mV            | 220 MHz   |                      |                | 8.10 mV      |
| 400.0 mV            | 235 MHz   |                      |                | 8.10 mV      |
| 400.0 mV            | 250 MHz   |                      |                | 8.10 mV      |
| 1.3 V               | 500 kHz   |                      |                | 19.60 mV     |
| 1.3 V               | 1 MHz     |                      |                | 19.60 mV     |
| 1.3 V               | 1 MHz     |                      |                | 19.60 mV     |
| 1.3 V               | 2 MHz     |                      |                | 19.60 mV     |
| 1.3 V               | 5 MHz     |                      |                | 19.60 mV     |
| 1.3 V               | 10 MHz    |                      |                | 19.60 mV     |
| 1.3 V               | 20 MHz    |                      |                | 19.60 mV     |
| 1.3 V               | 50 MHz    |                      |                | 19.60 mV     |
| 1.3 V               | 100 MHz   |                      |                | 19.60 mV     |
| 1.3 V               | 125 MHz   |                      |                | 26.10 mV     |
| 1.3 V               | 160 MHz   |                      |                | 26.10 mV     |
| 1.3 V               | 200 MHz   |                      |                | 26.10 mV     |
| 1.3 V               | 220 MHz   |                      |                | 26.10 mV     |
| 1.3 V               | 235 MHz   |                      |                | 26.10 mV     |

Table 10-9. Leveled Sine Wave Function Verification: Flatness (cont.)

| Nominal Value (p-p) | Frequency | Measured Value (p-p) | Deviation (mV) | 1-Year Spec. |
|---------------------|-----------|----------------------|----------------|--------------|
| 1.3 V               | 250 MHz   |                      |                | 26.10 mV     |
| 5.5 V               | 500 kHz   |                      |                | 82.5 mV      |
| 5.5 V               | 1 MHz     |                      |                | 82.5 mV      |
| 5.5 V               | 1 MHz     |                      |                | 82.5 mV      |
| 5.5 V               | 2 MHz     |                      |                | 82.5 mV      |
| 5.5 V               | 5 MHz     |                      |                | 82.5 mV      |
| 5.5 V               | 10 MHz    |                      |                | 82.5 mV      |
| 5.5 V               | 20 MHz    |                      |                | 82.5 mV      |
| 5.5 V               | 50 MHz    |                      |                | 82.5 mV      |
| 5.5 V               | 100 MHz   |                      |                | 82.5 mV      |
| 5.5 V               | 125 MHz   |                      |                | 110.00 mV    |
| 5.5 V               | 160 MHz   |                      |                | 110.00 mV    |
| 5.5 V               | 200 MHz   |                      |                | 110.00 mV    |
| 5.5 V               | 220 MHz   |                      |                | 110.00 mV    |
| 5.5 V               | 235 MHz   |                      |                | 110.00 mV    |
| 5.5 V               | 250 MHz   |                      |                | 110.00 mV    |

Table 10-10. Leveled Sine Wave Function Verification: Frequency

| Nominal Value (p-p) | Frequency | Measured Frequency | Deviation | 1-Year Spec. |
|---------------------|-----------|--------------------|-----------|--------------|
| 1.3 V               | 50 kHz    |                    |           | 0.0013 kHz   |
| 1.3 V               | 10 MHz    |                    |           | 0.0003 MHz   |
| 1.3 V               | 250 MHz   |                    |           | 0.0063 MHz   |

**Table 10-11. Marker Generator Function Verification**

| Nominal Interval | Measured Interval | Deviation | 1-Year Spec.   |
|------------------|-------------------|-----------|----------------|
| 5s               |                   |           | 25.12 ms       |
| 2.00s            |                   |           | 4.05 ms        |
| 1s               |                   |           | 1.03 ms        |
| 500.00 ms        |                   |           | 262.50 $\mu$ s |
| 200.00 ms        |                   |           | 45.00 $\mu$ s  |
| 100.00 ms        |                   |           | 12.50 $\mu$ s  |
| 50.00 ms         |                   |           | 3.75 $\mu$ s   |
| 20.00 ms         |                   |           | 900.000 ns     |
| 10.00 ms         |                   |           | 350.00 ns      |
| 5.00 ms          |                   |           | 150.00 ns      |
| 2.00 ms          |                   |           | 54.000 ns      |
| 1.00 ms          |                   |           | 26.000 ns      |
| 500.00 $\mu$ s   |                   |           | 12.750 ns      |
| 200.00 $\mu$ s   |                   |           | 5.040 ns       |
| 100.00 $\mu$ s   |                   |           | 2.510 ns       |
| 50.00 $\mu$ s    |                   |           | 1.287 ns       |
| 20.00 $\mu$ s    |                   |           | 0.506 ns       |
| 10.00 $\mu$ s    |                   |           | 0.252 ns       |
| 5.00 $\mu$ s     |                   |           | 0.125 ns       |
| 2.00 $\mu$ s     |                   |           | 0.050 ns       |
| 1.00 $\mu$ s     |                   |           | 0.025 ns       |
| 500.000 ns       |                   |           | 0.013 ns       |
| 200.000 ns       |                   |           | 5.000 ps       |
| 100.000 ns       |                   |           | 2.500 ps       |
| 50.000 ns        |                   |           | 1.250 ps       |
| 20.000 ns        |                   |           | 0.500 ps       |
| 10.000 ns        |                   |           | 0.250 ps       |
| 5.000 ns         |                   |           | 0.125 ps       |
| 2.000 ns         |                   |           | 0.050 ps       |

# **Appendix A**

## **Glossary**

### **adc (analog-to-digital converter)**

A device or circuit that changes an analog signal to digital signals.

### **absolute uncertainty**

Uncertainty specifications that include the error contributions made by all equipment and standards used to calibrate the instrument. Absolute uncertainty is the numbers to compare with the UUT to verify uncertainty ratio.

### **accuracy**

The degree to which the measured value of a quantity agrees with the correct value of that quantity. For example, an instrument specified to  $\pm 1\%$  uncertainty is 99% accurate.

### **apparent power**

The power value that you get when you multiply the ac current by the ac voltage on a circuit without consideration of phase relationships between the two waveforms. (See “true power” for comparison.)

### **assert**

To cause a digital signal to go into a logic true condition.

### **af (audio frequency)**

The frequency range of human hearing, typically 15,000 - 20,000 Hz.

### **artifact standard**

An object that makes or embodies a physical quantity to be standardized, for example a Fluke Calibration 732A DC Voltage Reference Standard.

### **base units**

Units in the SI system that are dimensionally independent. All other units are derived from base units. The only base unit in electricity is the ampere.

**buffer**

1. An area of digital memory for temporary storage of data.
2. An amplifier stage before the final amplifier.

**burden voltage**

The maximum sustainable voltage across the terminals of a load.

**compliance voltage**

The maximum voltage a constant-current source can supply.

**control chart**

A chart made to monitor one or more procedures to sense the radical deviation from a necessary value of a component or procedure.

**crest factor**

The ratio of the peak voltage to the rms voltage of a waveform (with the dc component removed).

**dac (digital-to-analog converter)**

A device or circuit that changes a digital waveform to an analog voltage.

**dBm**

A reference power level of 1 mW expressed in decibels.

**derived units**

Units in the SI system that are derived from base units. Volts, ohms, and watts are derived from amperes and other base and derived units.

**displacement power factor**

Refers to the displacement component of power factor; the ratio of the active power of the fundamental wave, in watts, to the apparent power of the fundamental wave, in volt-amperes.

**distortion**

Undesired changes in the waveform of a signal. Harmonic distortion disturbs the initial relationship between a frequency and other frequencies naturally related to it. Intermodulation distortion (imd) introduces new frequencies by the mixing of two or more initial frequencies. Other types of distortion are phase distortion and transient distortion.

**errors**

The different types of errors given in this glossary are “offset error,” “linearity error,” “random error,” “scale error,” “systematic errors,” and “transfer error.”

**flatness**

A measure of the variation of the actual output of an ac voltage source at different frequency points when set to the same nominal output level. A flat voltage source shows very little error in its frequency range.

**floor**

The part of the uncertainty specification of an instrument that is typically a set offset plus noise. Floor can be shown as units, such as microvolts or counts of the least significant digit. For the 5502A, the floor specification is combined with set range errors in one term to find total uncertainty.

**full scale**

The maximum indication of a range of a meter, analog-to-digital converter, or other measurement device, or the maximum attainable output on a range of a calibrator.

**gain error**

Same as scale error. Scale or gain error results when the slope of the response curve of the meter is not exactly 1. A meter with only gain error (no offset or linearity error), will read 0 V with 0 V applied, but something other than 10 V with 10 V applied.

**ground**

The voltage reference point in a circuit. Earth ground is a connection through a ground rod or other conductor to the earth, usually accessible through the ground conductor in an ac power receptacle.

**ground loops**

Undesirable currents induced when there is more than one chassis ground potential in a system of instruments. Ground loops can be minimized by connecting all instruments in a system to ground to one point.

**guard**

See “voltage guard”.

**harmonics**

A waveform that is an integral multiple of the fundamental frequency. For example, a waveform that is two times the frequency of a fundamental is called the second harmonic.

**IPTS-68**

Refers to the International Provisional Temperature Standard (1968), replaced by the International Temperature Standard (1990). This specifies the definition of the °C temperature standard.

**ITS-90**

Refers to the International Temperature Standard (1990), which replaced the International Provisional Temperature Standard (1968). This specifies the definition of the °C temperature standard.

**International Systems of Units**

Same as “SI System of Units,” the accepted system of units. See also “units,” “base units,” and “derived units.”

**legal units**

The highest echelon in a system of units, for example the U.S. National Bureau of Standards volt.

**life-cycle cost**

The consideration of all elements that contribute to the cost of an instrument through its useful life. This includes initial purchase cost, service and maintenance cost, and the cost of support equipment.

**linearity**

The relationship between two quantities when a change in the first quantity is directly proportional to a change in the second quantity.

**linearity error**

Linearity error occurs when the response curve of a meter is not exactly a straight line. This type of error is measured by fixing two points on the response curve, drawing a line through the points, then measuring how far the curve deviates from the straight line at different points in the response curve.

**MAP (Measurement Assurance Program)**

A program for measurement process. A MAP provides information to demonstrate that the total uncertainty of the measurements (data), that includes random error and systematic components of error relative to national or other designated standards is quantified, and sufficiently small to meet requirements.

**MTBF (Mean Time Between Failures)**

The time interval in operating hours that can be expected between failure of equipment. MTBF can be calculated from direct observation or mathematically derived through extrapolation.

**MTTF (Mean Time To Fail)**

The time interval in operating hours that can be expected until the first failure of equipment. MTTF can be calculated from direct observation or mathematically derived through extrapolation.

**MTTR (Mean Time to Repair)**

The average time in hours necessary to repair failed equipment.

**metrology**

The science of, and the field of knowledge concerned with measurement.

**minimum use specifications**

A compilation of specifications that satisfies the calibration requirements of a measurement system or device. The minimum use specifications are usually determined by maintaining a specified test uncertainty ratio between the calibration equipment and the unit under test.

**noise**

A signal that contains no useful information that is superimposed on a necessary or expected signal.

**normal mode noise**

An undesired signal that shows between the terminals of a device.



**offset error**

Same as zero error. The indication shown on a meter when an input value of zero is applied is its offset or zero error.

**parameters**

Independent variables in a measurement procedure such as temperature, humidity, test lead resistance, etc.

**power factor**

The ratio of actual power used in a circuit, shown in watts, to the power which is apparently pulled from the source, expressed in volt-amperes.

**precision**

The precision of a measurement procedure is the coherence, or the closeness to the one result, of all measurement results. High precision, for example, completes in a tight pattern of arrow hits on a target, without respect to where on the target the tight pattern falls.

**predictability**

A measure of how accurately the output value of a device can be assumed after a known time after calibration. If a device is highly stable, it is also predictable. If a device is not highly stable, but its value changes at the same rate each time after calibration, its output has a higher degree of predictability than a device that exhibits random change.

**primary standard**

A standard specified and maintained by some authority and used to calibrate all other secondary standards.

**process metrology**

When the accuracy drift of calibration and other equipment is monitored with statistical analysis to correction factors received during calibration.

**random error**

All errors which can change in an unpredictable manner in absolute value and in sign when measurements of the same value of a quantity are made under effectively the same conditions.

**range**

The stated maximum end of a measurement span of a device. Typically, a measurement device can measure quantities for a specified percentage overrange. (The absolute span that includes overrange capability is named “scale.”) In the 5502A, range and scale are identical.

**reference standard**

The highest-echelon standard in a laboratory. The standard that is used to maintain working standards that are used in regular calibration and comparison procedures.

**relative uncertainty**

5502A uncertainty specifications that exclude the effects of external dividers and standards, for use when range constants are adjusted. Relative uncertainty includes only the stability, temperature coefficient, noise, and linearity specifications of the 5502A itself.

**reliability**

A measure of the “uptime” of an instrument.

**repeatability**

The degree of agreement among independent measurements of a quantity under the same conditions.

**resistance**

A property of a conductor that finds the amount of current that will flow when a given amount of voltage exists across the conductor. Resistance is measured in ohms. One ohm is the resistance through which one volt of potential will cause one ampere of current to flow.

**resolution**

The smallest change in quantity that can be sensed by a measurement system or device. For a given parameter, resolution is the smallest increment that can be measured, generated, or shown.

**rf (radio frequency)**

The frequency range of radio waves; from 150 kHz to the infrared range.

**rms (root-mean-square)**

The value given to an ac voltage or current that ends in the same power dissipation in a resistance as a dc current or voltage of equal value.

**rms sensor**

A device that changes ac voltage to dc voltage with very good accuracy. RMS sensors operate by measuring the heat caused by a voltage through a known resistance (i.e., power). They sense true rms voltage.

**resistance temperature detector (RTD)**

A resistance device that gives a proportional resistance output for a temperature of the device. Most RTDs are characterized by their resistance at 0 °C, called the ice point. The most common ice point is 100  $\Omega$  at 0 °C. The curve of resistance vs. temperature can be one of several: pt385 (0.00385 ohms/ohm/°C) and pt3926 (0.003926 ohms/ohm/°C) are examples.

**scale**

The absolute span of the reading range of a measurement device that includes overrange capability.

**scale error**

Same as gain error. Scale or gain error results when the slope of the meter's response curve is not exactly 1. A meter with only scale error (no offset or linearity error), will read 0V with 0V applied, but something other than 10V with 10V applied.

**secondary standard**

A standard maintained by comparison against a primary standard.

**sensitivity**

The degree of response of a measuring device to the change in input quantity, or a figure of merit that expresses the ability of a measurement system or device to respond to an input quantity.

**shield**

A grounded covering device that is made to protect a circuit or cable from electromagnetic interference.

**SI System of Units**

The accepted International System of Units. See also "units," "base units," and "derived units."

**specifications**

An accurate statement of the set of requirements satisfied by a measurement system or device.

**stability**

A measure of the freedom from drift in value over time and over changes in other variables such as temperature. Note that stability is not the same as uncertainty.

**standard**

A device that is used as an exact value for reference and comparison.

**standard cell**

A primary cell that serves as a standard of voltage. The term “standard cell” often refers to a “Weston normal cell,” which is a wet cell with a mercury anode, a cadmium mercury amalgam cathode, and a cadmium sulfate solution as the electrolyte.

**systematic errors**

Errors in repeated measurement results that stay constant or change in a predictable way.

**temperature coefficient**

A factor per °C deviation from a nominal value or range that the uncertainty of an instrument increases. This specification is necessary to account for the thermal coefficients of analog circuitry in the Calibrator.

**test uncertainty ratio**

The numerical ratio of the uncertainty of the measurement system or device being calibrated to the uncertainty of the measurement system or device used as the calibrator. (Also called “test accuracy ratio.”)

**thermal emf**

The voltage made when two dissimilar metals connected together are heated.

**thermocouple**

Two dissimilar metals that, when welded together, develop a small voltage dependent on the relative temperature between the hotter and colder junction.

**traceability**

The power to show individual measurement results to national standards or nationally accepted measurement systems through an unbroken chain of comparisons, i.e., a calibration “audit trail.”

Measurements, measurement systems or devices have traceability to the designated standards if and only if scientifically rigorous evidence is given on a continuing basis to show that the measurement procedure is producing measurement results for which the total measurement uncertainty relative to national or other designated standards is qualified.

**transfer error**

The sum of all new errors induced in the process of comparing one quantity against A different quantity.

**transfer standard**

A working standard used to compare a measurement process, system, or device at one location or level with a different measurement process, system, or device at a different location or level.

**transport standard**

A transfer standard that is rugged enough for shipment by common carrier to a different location.

**true power**

The actual power (real power) used to cause heat or work. Compare to “apparent power.”

**true value**

Also named legal value, the accepted, consensus, for example, the correct value of the quantity that is measured.

**uncertainty**

The maximum difference between the accepted, consensus, or true value and the measured value of a quantity. Uncertainty is typically shown in units of ppm (parts per million) or as a percentage.

**units**

Symbols or names that specify the measured quantities. Examples of units are: V, mV, A, kW, and dBm. See also “SI System of Units.”

**UUT (Unit Under Test)**

An abbreviated name for an instrument that is verified or calibrated.

**var**

Symbol for voltampere reactive, the unit of reactive power, as opposed to real power in watts.

**verification**

When the functional performance and uncertainty of an instrument or standard is examined without adjustments or changes to its calibration constants.

**volt**

The unit of emf (electromotive force) or electrical potential in the SI system of units. One volt is the difference of electrical potential between two points on a conductor that transmits one ampere of current, when the power being dissipated between these two points is equal to one watt.

**voltage guard**

A shield that floats around voltage measurement circuitry inside an instrument. The voltage guard gives a low-impedance path to ground for common-mode noise and ground currents. This removes errors introduced by such interference.

**watt**

The unit of power in the SI system of units. One watt is the power necessary to do work at the rate of one joule/second. In terms of volts and ohms, one watt is the power dissipated by one ampere that flows through a one-ohm load.

**working standard**

A standard that is used in routine calibration and comparison procedures in the laboratory and is maintained by comparison to reference standards.

**zero error**

Same as offset error. The indication shown on a meter when an input value of zero is applied is its zero or offset error.

***Appendix B***  
***ASCII and IEEE-488 Bus Codes***



| ASCII<br>CHAR. | DECIMAL | OCTAL | HEX | BINARY<br>7654 3210 | DEV.<br>NO. | MESSAGE<br>ATN=TRUE | ASCII<br>CHAR. | DECIMAL | OCTAL | HEX | BINARY<br>7654 3210 | DEV.<br>NO. | MESSAGE<br>ATN=TRUE |
|----------------|---------|-------|-----|---------------------|-------------|---------------------|----------------|---------|-------|-----|---------------------|-------------|---------------------|
| NUL            | 0       | 000   | 00  | 0000 0000           |             |                     | @              | 64      | 100   | 40  | 0100 0000           | 0           | MTA                 |
| SQH            | 1       | 001   | 01  | 0000 0001           |             | GTL                 | A              | 65      | 101   | 41  | 0100 0001           | 1           | MTA                 |
| STX            | 2       | 002   | 02  | 0000 0010           |             |                     | B              | 66      | 102   | 42  | 0100 0010           | 2           | MTA                 |
| ETX            | 3       | 003   | 03  | 0000 0011           |             |                     | C              | 67      | 103   | 43  | 0100 0011           | 3           | MTA                 |
| EOT            | 4       | 004   | 04  | 0000 0100           |             | SDC<br>PPC          | D              | 68      | 104   | 44  | 0100 0100           | 4           | MTA                 |
| ENQ            | 5       | 005   | 05  | 0000 0101           |             |                     | E              | 69      | 105   | 45  | 0100 0101           | 5           | MTA                 |
| ACH            | 6       | 006   | 06  | 0000 0110           |             |                     | F              | 70      | 106   | 46  | 0100 0110           | 6           | MTA                 |
| BELL           | 7       | 007   | 07  | 0000 0111           |             |                     | G              | 71      | 107   | 47  | 0100 0111           | 7           | MTA                 |
| BS             | 8       | 010   | 08  | 0000 1000           |             | GET<br>TCT          | H              | 72      | 110   | 48  | 0100 1000           | 8           | MTA                 |
| HT             | 9       | 011   | 09  | 0000 1001           |             |                     | I              | 73      | 111   | 49  | 0100 1001           | 9           | MTA                 |
| LF             | 10      | 012   | 0A  | 0000 1010           |             |                     | J              | 74      | 112   | 4A  | 0100 1010           | 10          | MTA                 |
| VT             | 11      | 013   | 0B  | 0000 1011           |             |                     | K              | 75      | 113   | 4B  | 0100 1011           | 11          | MTA                 |
| FF             | 12      | 014   | 0C  | 0000 1100           |             |                     | L              | 76      | 114   | 4C  | 0100 1100           | 12          | MTA                 |
| CR             | 13      | 015   | 0D  | 0000 1101           |             |                     | M              | 77      | 115   | 4D  | 0100 1101           | 13          | MTA                 |
| SO             | 14      | 016   | 0E  | 0000 1110           |             |                     | N              | 78      | 116   | 4E  | 0100 1110           | 14          | MTA                 |
| SI             | 15      | 017   | 0F  | 0000 1111           |             |                     | O              | 79      | 117   | 4F  | 0100 1111           | 15          | MTA                 |
| DLE            | 16      | 020   | 10  | 0001 0000           |             | LLO                 | P              | 80      | 120   | 50  | 0101 0000           | 16          | MTA                 |
| DC1            | 17      | 021   | 11  | 0001 0001           |             |                     | Q              | 81      | 121   | 51  | 0101 0001           | 17          | MTA                 |
| DC2            | 18      | 022   | 12  | 0001 0010           |             |                     | R              | 82      | 122   | 52  | 0101 0010           | 18          | MTA                 |
| DC3            | 19      | 023   | 13  | 0001 0011           |             |                     | S              | 83      | 123   | 53  | 0101 0011           | 19          | MTA                 |
| DC4            | 20      | 024   | 14  | 0001 0100           |             | DCL<br>PPU          | T              | 84      | 124   | 54  | 0101 0100           | 20          | MTA                 |
| NAK            | 21      | 025   | 15  | 0001 0101           |             |                     | U              | 85      | 125   | 55  | 0101 0101           | 21          | MTA                 |
| SYN            | 22      | 026   | 16  | 0001 0110           |             |                     | V              | 86      | 126   | 56  | 0101 0110           | 22          | MTA                 |
| ETB            | 23      | 027   | 17  | 0001 0111           |             |                     | W              | 87      | 127   | 57  | 0101 0111           | 23          | MTA                 |
| CAN            | 24      | 030   | 18  | 0001 1000           |             | SPE<br>SPD          | X              | 88      | 130   | 58  | 0101 1000           | 24          | MTA                 |
| EM             | 25      | 031   | 19  | 0001 1001           |             |                     | Y              | 89      | 131   | 59  | 0101 1001           | 25          | MTA                 |
| SUB            | 26      | 032   | 1A  | 0001 1010           |             |                     | Z              | 90      | 132   | 5A  | 0101 1010           | 26          | MTA                 |
| ESC            | 27      | 033   | 1B  | 0001 1011           |             |                     | [              | 91      | 133   | 5B  | 0101 1011           | 27          | MTA                 |
| FS             | 28      | 034   | 1C  | 0001 1100           |             |                     | \              | 92      | 134   | 5C  | 0101 1100           | 28          | MTA                 |
| GS             | 29      | 035   | 1D  | 0001 1101           |             |                     | ]              | 93      | 135   | 5D  | 0101 1101           | 29          | MTA                 |
| RS             | 30      | 036   | 1E  | 0001 1110           |             |                     | ^              | 94      | 136   | 5E  | 0101 1110           | 30          | MTA                 |
| US             | 31      | 037   | 1F  | 0001 1111           |             |                     | _              | 95      | 137   | 5F  | 0101 1111           | 31          | UNT                 |
| SPACE          | 32      | 040   | 20  | 0010 0000           | 0           | MLA                 | ‘              | 96      | 140   | 60  | 0111 0000           | 0           | MSA                 |
| !              | 33      | 041   | 21  | 0010 0001           | 1           | MLA                 | a              | 97      | 141   | 61  | 0111 0001           | 1           | MSA                 |
| "              | 34      | 042   | 22  | 0010 0010           | 2           | MLA                 | b              | 98      | 142   | 62  | 0111 0010           | 2           | MSA                 |
| #              | 35      | 043   | 23  | 0010 0011           | 3           | MLA                 | c              | 99      | 143   | 63  | 0111 0011           | 3           | MSA                 |
| \$             | 36      | 044   | 24  | 0010 0100           | 4           | MLA                 | d              | 100     | 144   | 64  | 0111 0100           | 4           | MSA                 |
| %              | 37      | 045   | 25  | 0010 0101           | 5           | MLA                 | e              | 101     | 145   | 65  | 0111 0101           | 5           | MSA                 |
| &              | 38      | 046   | 26  | 0010 0110           | 6           | MLA                 | f              | 102     | 146   | 66  | 0111 0110           | 6           | MSA                 |
| '              | 39      | 047   | 27  | 0010 0111           | 7           | MLA                 | g              | 103     | 147   | 67  | 0111 0111           | 7           | MSA                 |
| (              | 40      | 050   | 28  | 0010 1000           | 8           | MLA                 | h              | 104     | 150   | 68  | 0111 1000           | 8           | MSA                 |
| )              | 41      | 051   | 29  | 0010 1001           | 9           | MLA                 | i              | 105     | 151   | 69  | 0111 1001           | 9           | MSA                 |
| *              | 42      | 052   | 2A  | 0010 1010           | 10          | MLA                 | j              | 106     | 152   | 6A  | 0111 1010           | 10          | MSA                 |
| +              | 43      | 053   | 2B  | 0010 1011           | 11          | MLA                 | k              | 107     | 153   | 6B  | 0111 1011           | 11          | MSA                 |
| ,              | 44      | 054   | 2C  | 0010 1100           | 12          | MLA                 | l              | 108     | 154   | 6C  | 0111 1100           | 12          | MSA                 |
| -              | 45      | 055   | 2D  | 0010 1101           | 13          | MLA                 | m              | 109     | 155   | 6D  | 0111 1101           | 13          | MSA                 |
| .              | 46      | 056   | 2E  | 0010 1110           | 14          | MLA                 | n              | 110     | 156   | 6E  | 0111 1110           | 14          | MSA                 |
| /              | 47      | 057   | 2F  | 0010 1111           | 15          | MLA                 | o              | 111     | 157   | 6F  | 0111 1111           | 15          | MSA                 |
| 0              | 48      | 060   | 30  | 0011 0000           | 16          | MLA                 | p              | 112     | 160   | 70  | 0111 0000           | 16          | MSA                 |
| 1              | 49      | 061   | 31  | 0011 0001           | 17          | MLA                 | q              | 113     | 161   | 71  | 0111 0001           | 17          | MSA                 |
| 2              | 50      | 062   | 32  | 0011 0010           | 18          | MLA                 | r              | 114     | 162   | 72  | 0111 0010           | 18          | MSA                 |
| 3              | 51      | 063   | 33  | 0011 0011           | 19          | MLA                 | s              | 115     | 163   | 73  | 0111 0011           | 19          | MSA                 |
| 4              | 52      | 064   | 34  | 0011 0100           | 20          | MLA                 | t              | 116     | 164   | 74  | 0111 0100           | 20          | MSA                 |
| 5              | 53      | 065   | 35  | 0011 0101           | 21          | MLA                 | u              | 117     | 165   | 75  | 0111 0101           | 21          | MSA                 |
| 6              | 54      | 066   | 36  | 0011 0110           | 22          | MLA                 | v              | 118     | 166   | 76  | 0111 0110           | 22          | MSA                 |
| 7              | 55      | 067   | 37  | 0011 0111           | 23          | MLA                 | w              | 119     | 167   | 77  | 0111 0111           | 23          | MSA                 |
| 8              | 56      | 070   | 38  | 0011 1000           | 24          | MLA                 | x              | 120     | 170   | 78  | 0111 1000           | 24          | MSA                 |
| 9              | 57      | 071   | 39  | 0011 1001           | 25          | MLA                 | y              | 121     | 171   | 79  | 0111 1001           | 25          | MSA                 |
| :              | 58      | 072   | 3A  | 0011 1010           | 26          | MLA                 | z              | 122     | 172   | 7A  | 0111 1010           | 26          | MSA                 |
| ;              | 59      | 073   | 3B  | 0011 1011           | 27          | MLA                 | {              | 123     | 173   | 7B  | 0111 1011           | 27          | MSA                 |
| <              | 60      | 074   | 3C  | 0011 1100           | 28          | MLA                 |                | 124     | 174   | 7C  | 0111 1100           | 28          | MSA                 |
| =              | 61      | 075   | 3D  | 0011 1101           | 29          | MLA                 | }              | 125     | 175   | 7D  | 0111 1101           | 29          | MSA                 |
| >              | 62      | 076   | 3E  | 0011 1110           | 30          | MLA                 | ~              | 126     | 176   | 7E  | 0111 1110           | 30          | MSA                 |
| ?              | 63      | 077   | 3F  | 0011 1111           |             | UNL                 |                | 127     | 177   | 7F  | 0111 1111           |             | UNS                 |





## Appendix C

# RS-232/IEEE-488 Cables and Connectors

### IEEE-488 Connector

The IEEE-488 connector on the rear panel connects with an IEEE-488 standard cable. The pin assignments of the rear-panel IEEE-488 connector are shown in Figure C-1. IEEE-488 connection cables are available from Fluke Calibration as shown in Table C-1. See Chapter 8, “Accessories,” for order information.

Table C-1. IEEE-488 Connection Cables

| IEEE-488 Connection Cable | Fluke Calibration Part Number |
|---------------------------|-------------------------------|
| 1 m (3.28 feet)           | Y8021                         |
| 2 m (6.56 feet)           | Y8022                         |

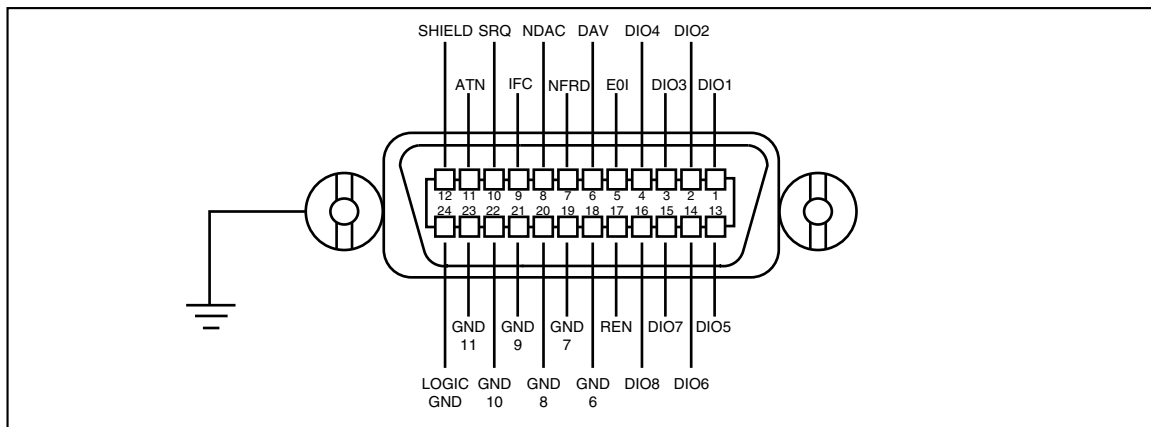


Figure C-1. IEEE-488 Connector Pinout (connection side)

fe-01.eps

## Serial Connectors

The two 9-pin serial connectors on the rear panel of the 5502A Calibrator are used to interface with a computer, or controller, and an instrument serial port. The pin assignments of the rear-panel serial connectors are in conformance to EIA/TIA-574 standard and are shown in Figures C-2 (Host) and C-3 (UUT).

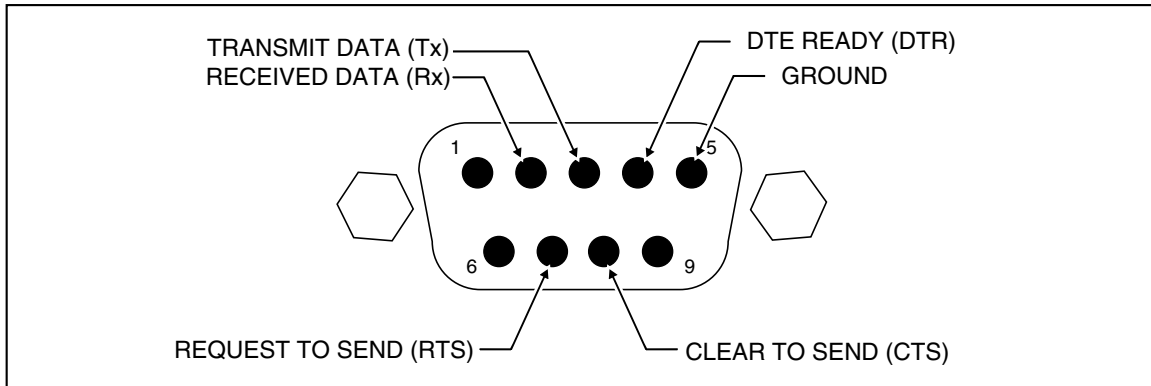


Figure C-2. Serial 1 From Host Port Connector Pinout

fe-02.eps

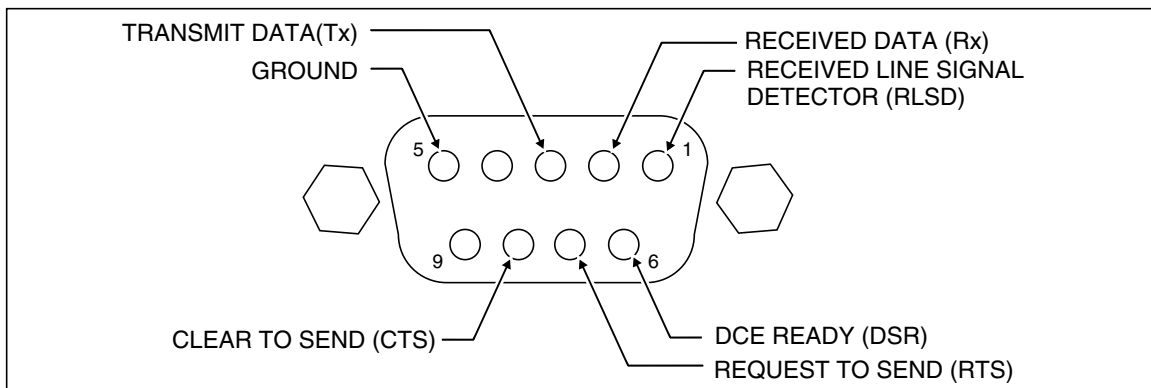


Figure C-3. SERIAL 2 TO UUT Port Connector Pinout (connection side)

fe-03.eps

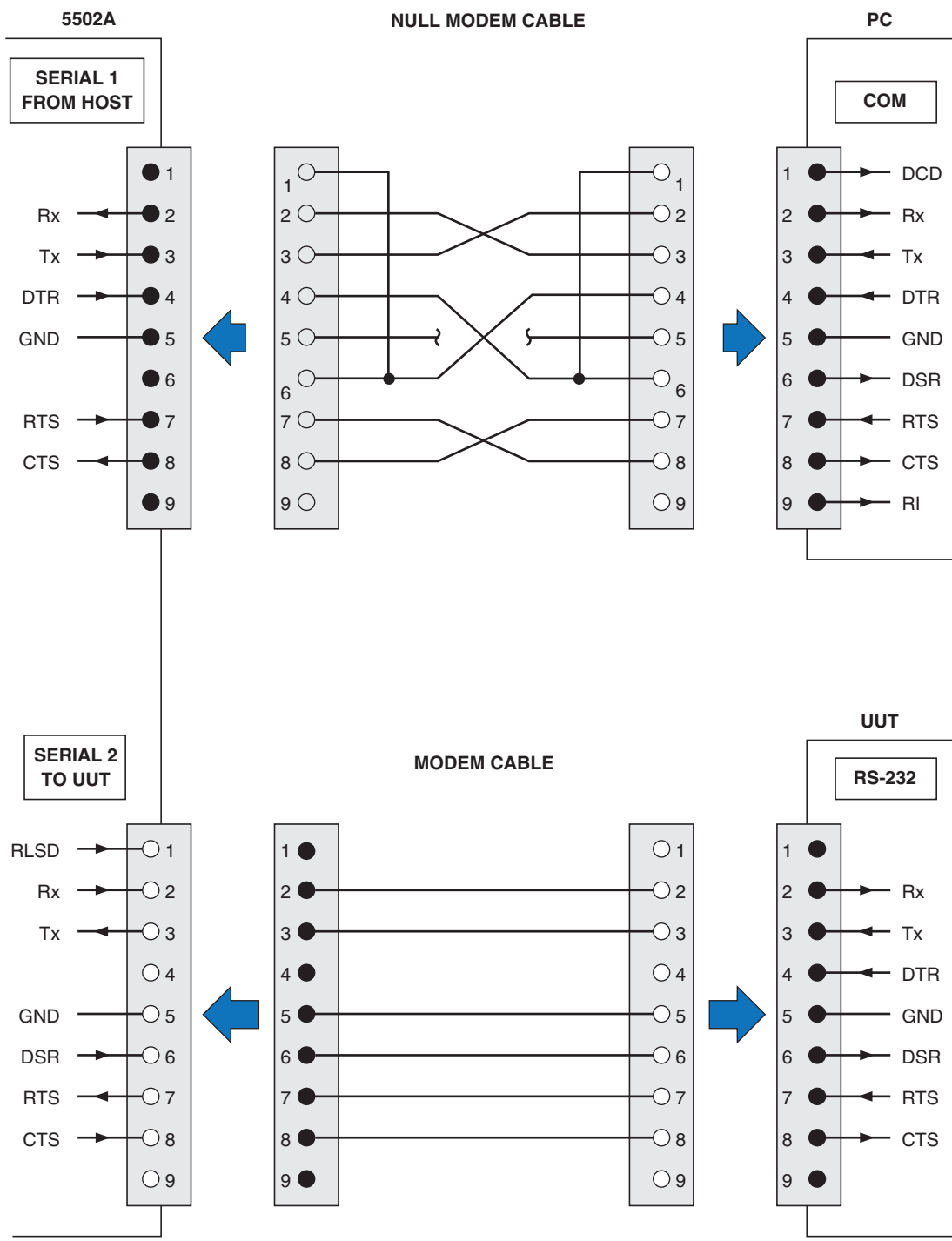


Figure C-4. Serial Port Connections (DB-9/DB-9)

gjh069.eps

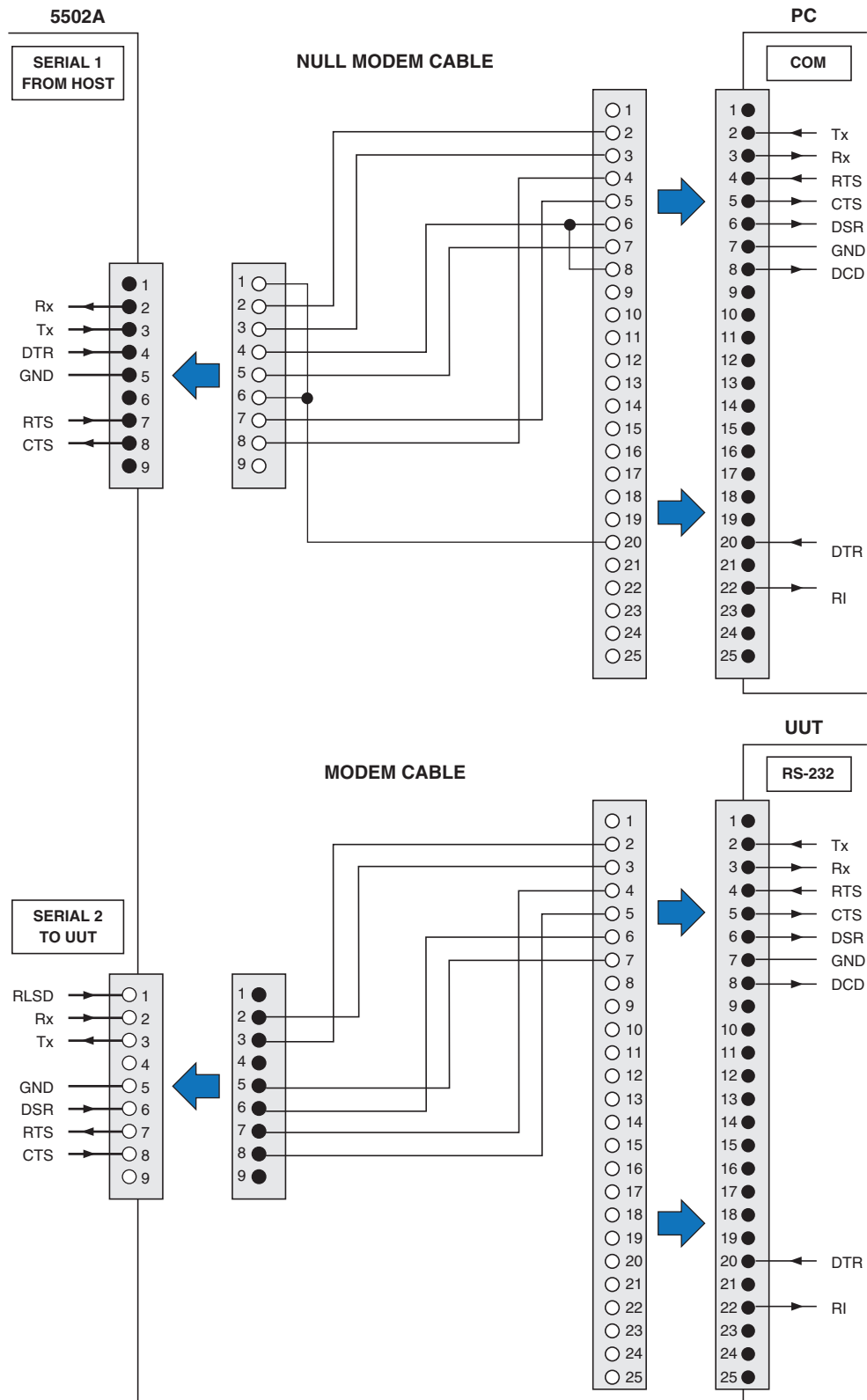


Figure C-5. Serial Port Connections (DB-9/DB-25)

gjh071.eps

## Appendix D Error Messages

### Error Messages

The subsequent is a list of the Calibrator error messages. The error message format is shown in Table D-1.

**Table D-1. Error Messages Format**

| Error Number | (Message Class : Description)                                                                                         | Text Characters                                                                         |
|--------------|-----------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| 0 to 65535   | <b>QYE</b> Query Error, caused by a full input buffer, unterminated procedure or interrupted procedure                | <b>F</b> Error is shown on the front panel as it occurs                                 |
|              | <b>DDE</b> Device-Specific Error, caused by the 5502A because of some condition, for example, overrange               | <b>R</b> Error is queued to the remote interface as it occurs                           |
|              | <b>EXE</b> Execution Error, caused by an element that is inconsistent with the 5502A functions                        | <b>S</b> Error causes instrument to go to Standby                                       |
|              | <b>CME</b> Command Error, caused by incorrect command syntax, unrecognized header, or parameter of the incorrect type | <b>D</b> Error causes instrument to go to the power up condition                        |
|              |                                                                                                                       | (none) Error is given to the initiator only (i.e., local initiator or remote initiator) |

|     |            |                               |
|-----|------------|-------------------------------|
| 0   | (QYE: )    | No Error                      |
| 1   | (DDE:FR )  | Error queue overflow          |
| 100 | (DDE:FR D) | Inguard not responding (send) |
| 101 | (DDE:FR D) | Inguard not responding (recv) |
| 102 | (DDE:FR D) | Lost sync with inguard        |
| 103 | (DDE:FR)   | Invalid guard xing command    |
| 104 | (DDE:FR D) | Hardware relay trip occurred  |
| 105 | (DDE:FR D) | Inguard got impatient         |

|     |            |                                 |
|-----|------------|---------------------------------|
| 106 | (DDE:FR D) | A/D fell asleep                 |
| 107 | (DDE:FR D) | Inguard watchdog timeout        |
| 108 | (DDE:FR)   | Inguard is obsolete             |
| 109 | (DDE:FR D) | Inguard parity error            |
| 110 | (DDE:FR D) | Inguard overrun error           |
| 111 | (DDE:FR D) | Inguard framing error           |
| 112 | (DDE:FR D) | Inguard fault error             |
| 113 | (DDE:FR D) | Inguard fault input error       |
| 114 | (DDE:FR D) | Inguard fault detect error      |
| 115 | (DDE:FR D) | Inguard read/write error        |
| 116 | (DDE:FR D) | Received unexpected data (IG)   |
| 200 | (DDE:DR D) | Cannot download waveform        |
| 300 | (DDE: )    | Invalid procedure number        |
| 301 | (DDE: )    | No such step in procedure       |
| 302 | (DDE: )    | Cannot change that while busy   |
| 303 | (DDE: )    | Cannot begin/resume cal there   |
| 304 | (DDE: )    | Wrong unit for reference        |
| 305 | (DDE: )    | Entered value out of bounds     |
| 306 | (DDE: )    | Not waiting for a reference     |
| 307 | (DDE: )    | Continue command ignored        |
| 308 | (DDE:FR )  | Cal constant outside limits     |
| 309 | (DDE:FR )  | Cal try to null failed          |
| 310 | (DDE:FR D) | Sequence failed during cal      |
| 311 | (DDE:FR D) | A/D measurement failed          |
| 312 | (DDE:FR )  | Invalid cal step parameter      |
| 313 | (DDE: )    | Cal switch must be ENABLED      |
| 314 | (DDE:FR )  | Divide by zero encountered      |
| 315 | (DDE:FR )  | Must be in OPER at this step    |
| 316 | (DDE:FR )  | Open thermocouple for RJ cal    |
| 317 | (DDE:FR )  | Bad reference Z or entry        |
| 318 | (DDE:FR )  | Cal takes DAC over top limit    |
| 319 | (DDE: R )  | Zero cal needed every 7 days    |
| 320 | (DDE: R )  | Ohms zero needed every 12 hours |
| 398 | (QYE:F )   | Unusual cal fault %d            |
| 399 | QYE:F )    | Fault during %s                 |
| 400 | (DDE:FR D) | Encoder not responding VERS     |
| 401 | (DDE:FR D) | Encoder not responding COMM     |
| 402 | (DDE:FR D) | Encoder not responding STAT     |
| 403 | (DDE:FR )  | Encoder self-test failed        |
| 405 | (DDE:FR )  | Message over display R side     |
| 406 | (DDE:FR )  | Unmappable character # %d       |
| 407 | (DDE:FR )  | Encoder did not reset           |
| 408 | (DDE:FR )  | Encoder got invalid command     |
| 409 | (DDE:FR D) | Encoder unexpectedly reset      |
| 500 | (DDE: )    | Internal state error            |
| 501 | (DDE: )    | Invalid keyword or choice       |
| 502 | (DDE: )    | Harmonic must be 1 - 50         |
| 503 | (DDE: )    | Frequency must be >= 0          |
| 504 | (DDE: )    | AC magnitude must be > 0        |
| 505 | (DDE: )    | Impedance must be >= 0          |
| 506 | (DDE: )    | Function not available          |
| 507 | (DDE: )    | Value not available             |

|     |           |                                   |
|-----|-----------|-----------------------------------|
| 508 | (DDE: )   | Cannot enter watts by itself      |
| 509 | (DDE: )   | Output exceeds user limits        |
| 510 | (DDE: )   | Duty cycle must be 1.0-99.0       |
| 511 | (DDE: )   | Power factor must be 0.0-1.0      |
| 512 | (DDE: )   | Cannot select that field now      |
| 513 | (DDE: )   | Edit digit out of range           |
| 514 | (DDE: )   | Cannot switch edit field now      |
| 515 | (DDE: )   | Not editing output now            |
| 516 | (DDE: )   | dBm only for single sine ACV      |
| 517 | (DDE: )   | Freq too high for non-sine        |
| 518 | (DDE: )   | Value outside locked range        |
| 519 | (DDE: )   | Must specify an output unit       |
| 520 | (DDE: )   | Cannot do two frequencies at once |
| 521 | (DDE: )   | Cannot source 3 values at once    |
| 522 | (DDE: )   | Temp must be degrees C or F       |
| 523 | (DDE: )   | Cannot do that now                |
| 526 | (DDE: )   | Limit too small or large          |
| 527 | (DDE: )   | No changes except RESET now       |
| 528 | (DDE: )   | Offset out of range               |
| 529 | (DDE: )   | Cannot edit to or from 0 Hz       |
| 530 | (DDE: )   | Bad state image - not loaded      |
| 531 | (DDE: )   | TC offset limited to +/-500 C     |
| 532 | (DDE: )   | Cannot go to STBY in Meas TC      |
| 533 | (DDE: )   | Cannot set an offset now          |
| 534 | (DDE: )   | Cannot lock this range            |
| 535 | (DDE: )   | Cannot set phase or PF now        |
| 536 | (DDE: )   | Cannot set wave now               |
| 537 | (DDE: )   | Cannot set harmonic now           |
| 538 | (DDE: )   | Cannot change duty cycle now      |
| 539 | (DDE: )   | Cannot change compensation now    |
| 540 | (DDE:FR ) | Current OUTPUT moved to 5725A     |
| 541 | (DDE: )   | TC ref must be valid TC temp      |
| 542 | (DDE: )   | Cannot turn EARTH on now          |
| 543 | (DDE: D)  | STA couldn't update OTD           |
| 544 | (DDE: )   | Cannot enter W with non-sine      |
| 545 | (DDE: )   | Cannot edit now                   |
| 546 | (DDE: )   | Cannot set trigger to that now    |
| 547 | (DDE: )   | Cannot set output imp. now        |
| 548 | (DDE:FR ) | Compensation is now OFF           |
| 549 | (DDE: )   | Period must be >= 0               |
| 550 | (DDE: )   | A report is already printing      |
| 551 | (DDE: )   | ScopeCal option not installed     |
| 552 | (DDE: )   | Not a ScopeCal function           |
| 553 | (DDE: )   | Cannot set marker shape now       |
| 554 | (DDE: )   | Cannot set video parameter now    |
| 555 | (DDE: )   | Marker location out of range      |
| 556 | (DDE: )   | Pulse width must be 1 - 255       |
| 557 | (DDE: )   | Cannot set range directly now     |
| 558 | (DDE: )   | Not a range for this function     |
| 559 | (DDE: )   | Cannot set TD pulse now           |
| 560 | (DDE: )   | ZERO_MEAS only for C              |
| 561 | (DDE:FR ) | That requires a -SC option        |

|      |            |                                       |
|------|------------|---------------------------------------|
| 562  | (DDE:FR )  | That requires a -SC600 option         |
| 563  | (DDE: )    | Time limit must be 1s-60s             |
| 564  | (DDE: )    | Cannot set ref. phase now             |
| 565  | (DDE: )    | ZERO_MEAS reading not valid           |
| 568  | (DDE: )    | Slave cannot send SYNCOUT             |
| 569  | (DDE:FR)   | That takes a -SC1100 option           |
| 570  | (DDE: )    | Invalid harmonic number               |
| 571  | (DDE: )    | Invalid harmonic amplitude            |
| 572  | (DDE: )    | Duplicate harmonic number             |
| 573  | (DDE: )    | No trig unless OPER & settled         |
| 574  | (DDE: )    | Max 15 harmonics in CHwave            |
| 575  | (DDE: )    | Square or sine flicker only           |
| 578  | (DDE: )    | Cannot set that now                   |
| 579  | (DDE: )    | Parameter setting too big             |
| 600  | (DDE:FR D) | Outguard watchdog timeout             |
| 601  | (DDE:FR )  | Power-up RAM test failed              |
| 602  | (DDE:FR )  | Power-up GPIB test failed             |
| 700  | (DDE: R )  | Saving to NV memory failed            |
| 701  | (DDE: R )  | NV memory invalid                     |
| 702  | DDE: R )   | NV invalid so default loaded          |
| 703  | (DDE: R )  | NV obsolete so default loaded         |
| 800  | (DDE:FR )  | Serial parity error %s                |
| 801  | (DDE:FR )  | Serial framing error %s               |
| 802  | (DDE:FR )  | Serial overrun error %s               |
| 803  | (DDE:FR )  | Serial characters dropped %s          |
| 900  | (DDE:FR )  | Report timeout - aborted              |
| 1000 | (DDE:FR )  | Sequence failed during diag           |
| 1200 | (DDE:FR )  | Sequence name too long                |
| 1201 | (DDE:FR )  | Sequence RAM table full               |
| 1202 | (DDE:FR )  | Sequence name table full              |
| 1300 | (CME: R )  | Bad syntax                            |
| 1301 | (CME: R )  | Unknown command                       |
| 1302 | (CME: R )  | Bad parameter count                   |
| 1303 | (CME: R )  | Bad keyword                           |
| 1304 | (CME: R )  | Bad parameter type                    |
| 1305 | (CME: R )  | Bad parameter unit                    |
| 1306 | (EXE: R )  | Bad parameter value                   |
| 1307 | (QYE: R )  | 488.2 I/O deadlock                    |
| 1308 | (QYE: R )  | 488.2 interrupted query               |
| 1309 | (QYE: R )  | 488.2 unterminated command            |
| 1310 | (QYE: R )  | 488.2 query after indefinite response |
| 1311 | (DDE: R )  | Invalid from GPIB interface           |
| 1312 | (DDE: R )  | Invalid from serial interface         |
| 1313 | (DDE: R )  | Service only                          |
| 1314 | (EXE: R )  | Parameter too long                    |
| 1315 | (CME: R )  | Invalid device trigger                |
| 1316 | (EXE: R )  | Device trigger recursion              |
| 1317 | (CME: R )  | Serial buffer full                    |
| 1318 | (EXE: R )  | Bad number                            |
| 1319 | (EXE: R )  | Service command failed                |
| 1320 | (CME: R )  | Bad binary number                     |
| 1321 | (CME: R )  | Bad binary block                      |



|       |            |                                      |
|-------|------------|--------------------------------------|
| 1322  | (CME: R )  | Bad character                        |
| 1323  | (CME: R )  | Bad decimal number                   |
| 1324  | (CME: R )  | Exponent magnitude too large         |
| 1325  | (CME: R )  | Bad hexadecimal block                |
| 1326  | (CME: R )  | Bad hexadecimal number               |
| 1328  | (CME: R )  | Bad octal number                     |
| 1329  | (CME: R )  | Too many characters                  |
| 1330  | (CME: R )  | Bad string                           |
| 1331  | (DDE: R )  | OPER not allowed while error pending |
| 1332  | (CME:FR )  | Cannot change UUT settings now       |
| 1500  | (DDE:FRS ) | Compliance voltage exceeded          |
| 1501  | (DDE:FRS ) | Shunt amp over or underload          |
| 1502  | (DDE:FRS ) | Current Amp Thermal Limit Exceeded   |
| 1503  | (DDE:FRS ) | Output current limit exceeded        |
| 1504  | (DDE:FRS ) | Input V or A limit exceeded          |
| 1505  | (DDE:FRS ) | VDAC counts out of range             |
| 1506  | (DDE:FRS ) | IDAC counts out of range             |
| 1507  | (DDE:FRS ) | AC scale dac counts out of range     |
| 1508  | (DDE:FRS ) | DC scale dac counts out of range     |
| 1509  | (DDE:FRS ) | Frequency dac counts out of range    |
| 1510  | (DDE:FRS ) | IDAC counts (DC OFFSET) out of range |
| 1511  | (DDE:FRS ) | ZDAC counts out of range             |
| 1515  | (DDE:FR D) | Cannot load waveform for scope mode  |
| 1516  | (DDE:FRS ) | Peak or avg amplitude too high       |
| 1600  | (DDE:FR D) | OPM transition error                 |
| 1601  | (DDE:FR D) | TC measurement fault                 |
| 1602  | (DDE:FR D) | Z measurement fault                  |
| 65535 | (DDE:FR )  | Unknown error %d                     |

