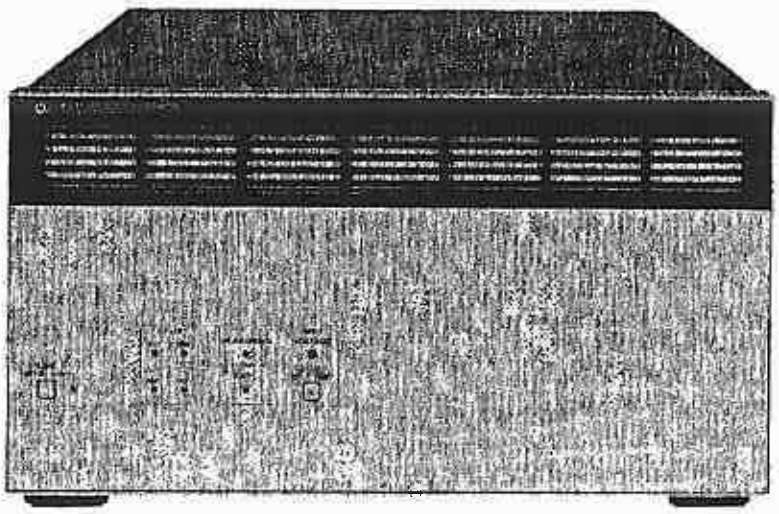
OPERATION MANUAL

# 4141B

## DC SOURCE/MONITOR



HEWLETT PACKARD

HP 4141B

## SAFETY SUMMARY

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific warnings given elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. Hewlett-Packard Company assumes no liability for the customer's failure to comply with these requirements.

### GROUND THE INSTRUMENT

To minimize shock hazard, the instrument chassis and cabinet must be connected to an electrical ground. The instrument is equipped with a three-conductor ac power cable. The power cable must either be plugged into an approved three-contact electrical outlet or used with a three-contact to two-contact adapter with the grounding wire (green) firmly connected to an electrical ground (safety ground) at the power outlet. The power jack and the mating plug of the power cable meet International Electrotechnical Commission (IEC) safety standards.

### DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE

Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment constitutes a definite safety hazard.

### KEEP AWAY FROM LIVE CIRCUITS

Operating personnel must not remove instrument covers. Component replacement and internal adjustments must be made by qualified maintenance personnel. Do not replace components with power cable connected. Under certain conditions, dangerous voltages may exist even with the power cable removed. To avoid injuries, always disconnect power and discharge circuits before touching them.

### DO NOT SERVICE OR ADJUST ALONE

Do not attempt internal service or adjustment unless another person, capable of rendering first aid and resuscitation, is present.

### DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT

Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to a Hewlett-Packard Sales and Service Office for service and repair to ensure that safety features are maintained.

### DANGEROUS PROCEDURE WARNINGS

Warnings, such as the example below, precede potentially dangerous procedures throughout this manual. Instructions contained in the warnings must be followed.

**WARNING**

**DANGEROUS VOLTAGES, CAPABLE OF CAUSING DEATH, ARE PRESENT IN THIS INSTRUMENT. USE EXTREME CAUTION WHEN HANDLING, TESTING, AND ADJUSTING.**

# MANUAL CHANGES

## 4141B

**DC SOURCE/MONITOR**

**MANUAL IDENTIFICATION**

**Model Number: 4141B**
**Date Printed: DEC. 1985**
**Part Number: 04141-90000**

This supplement contains information for correcting manual errors and for adapting the manual to newer instruments that contain improvements or modifications not documented in the existing manual.

To use this supplement
1. Make all ERRATA corrections
2. Make all appropriate serial-number-related changes listed below

| SERIAL PREFIX OR NUMBER | MAKE MANUAL CHANGES | SERIAL PREFIX OR NUMBER | MAKE MANUAL CHANGES |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

► New Item

► **ERRATA**

Page 1-5, Table 1-1. Specifications (2 of 4):

Add the following paragraph after the last paragraph on the page.

Maxiumum Capacitance Load : 1000pf

Page 4-1, Para 4-1, INTRODUCTION

Change the Part Number for the 4062B Service Manual to PN **04062-90501.**

**NOTE**

Manual change supplements are revised as often as necessary to keep manuals as current and accurate as possible. Hewlett-Packard recommends that you periodically request the latest edition of this supplement. Free copies are available from all HP offices. When requesting copies, quote the manual identification information from your supplement, or the model number and print date from the title page of the manual.

**Date/Div: MAY 29, 1986/33**
**Page: 1 of 1**

HEWLETT PACKARD

PRINTED IN JAPAN

## CERTIFICATION

Hewlett-Packard Company certifies that this product met its published specifications at the time of shipment from the factory. Hewlett-Packard further certifies that its calibration measurements are traceable to the United States National Bureau of Standards, to the extent allowed by the Bureau's calibration facility, and to the calibration facilities of other International Standards Organization members.

## WARRANTY

This Hewlett-Packard system product is warranted against defects in material and workmanship for a period of 90 days from date of installation, except that in the case of certain components listed in Section 1 of this manual, the warranty shall be for the specified period. During the warranty period, Hewlett-Packard Company will, at its option, either repair or replace products which prove to be defective.

For warranty service or repair, this product must be returned to a service facility designated by HP. Buyer shall prepay shipping charges to HP and HP shall pay shipping charges to return the product to Buyer. However, Buyer shall pay all shipping charges, duties, and taxes for products returned to HP from another country.

HP warrants that its software and firmware designated by HP for use with a system will execute its programming instructions when properly installed on that system. HP does not warrant that the operation of the system, or software, or firmware will be uninterrupted or error free.

## LIMITATION OF WARRANTY

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by Buyer, Buyer-supplied software or interfacing, unauthorized modification or misuse, operation outside of the environment specifications for the product, or improper site preparation or maintenance.

**NO OTHER WARRANTY IS EXPRESSED OR IMPLIED. HP SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILTY AND FITNESS FOR A PARTICULAR PURPOSE.**

## EXCLUSIVE REMEDIES

THE REMEDIES PROVIDED HEREIN ARE BUYER'S SOLE AND EXCLUSIVE REMEDIES. HP SHALL NOT BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER BASED ON CONTRACT, TORT, OR ANY OTHER LEGAL THEORY.

## ASSISTANCE

Product maintenance agreements and other customer assistance agreements are available for Hewlett-Packard products.

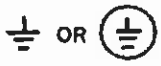
For any assistance, contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

## SAFETY SYMBOLS

General Definitions of Safety Symbols Used On Equipment or in Manuals.

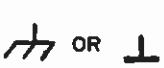
Instruction manual symbol: the product will be marked with this symbol when it is necessary for the user to refer to the instruction manual in order to protect against damage to the instrument.

Indicates dangerous voltage (terminals fed from the interior by voltage exceeding 1000 volts must be so marked).




Protective conductor terminal. For protection against electrical shock in case of a fault. Used with field wiring terminals to indicate the terminal which must be connected to ground before operating equipment.

Low-noise or noiseless, clean ground (earth) terminal. Used for a signal common, as well as providing protection against electrical shock in case of fault. A terminal marked with this symbol must be connected to ground in the manner described in the installation (operating) manual, and before operating the equipment.




Frame or chassis terminal. A connection to the frame (chassis) of the equipment which normally includes all exposed metal structures.

Alternating current (power line).

Direct current (power line).

Alternating or direct current (power line).

**WARNING** A **WARNING** denotes a hazard. It calls attention to a procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result in injury or death to personnel.

**CAUTION** The **CAUTION** sign denotes a hazard. It calls attention to an operating procedure, practice, condition or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of part or all of the product.

Note A Note denotes important information. It calls attention to a procedure, practice, condition or the like, which is essential to highlight.

## Herstellerbescheinigung

Hiermit wird bescheinigt, daß das Gerät HP 4141B (DC Source/Monitor) in Übereinstimmung mit den Bestimmungen von Postverfügung 1046/84 funkentstört ist.

Der Deutschen Bundespost wurde das Inverkehrbringen dieses Gerätes angezeigt und die Berechtigung zur Überprüfung der Serie auf Einhaltung der Bestimmungen eingeräumt.

Anm: Werden Meß- und Testgeräte mit ungeschirmten Kabeln und/oder in offenen Meßaufbauten verwendet, so ist vom Betreiber sicherzustellen, daß die Funk-Entstörbestimmungen unter Betriebsbedingungen an seiner Grundstücksgrenze eingehalten werden.

## Manufacturer's Declaration

This is to certify that this product, the HP 4141B DC Source/Monitor, meets the radio frequency interference requirements of directive 1046/84. The German Bundespost has been notified that this equipment was put into circulation and was granted the right to check the product type for compliance with these requirements.

Note: If test and measurement equipment is operated with unshielded cables and/or used for measurements on open setups, the user must insure that under these operating conditions, the radio frequency interference limits are met at the border of his premises.

HEWLETT PACKARD

# OPERATION MANUAL

# MODEL 4141B
# DC SOURCE/MONITOR

## (Including Option 011)



Manual Part No. 04141-90000
Microfiche Part No. 04141-90050

Printed: DEC. 1985

# CONTENTS

**SECTION 4**
**PERFORMANCE VERIFICATION**

# ILLUSTRATIONS

# TABLES

# SECTION 1
# GENERAL INFORMATION

## 1-1. INTRODUCTION

This manual contains the information required to install, operate, and maintain the Hewlett-Packard Model 4141B DC Source/Monitor. Figure 1-1 shows the 4141B and its furnished accessories. This section covers specifications, instrument identification, description, options, accessories, and other basic information.

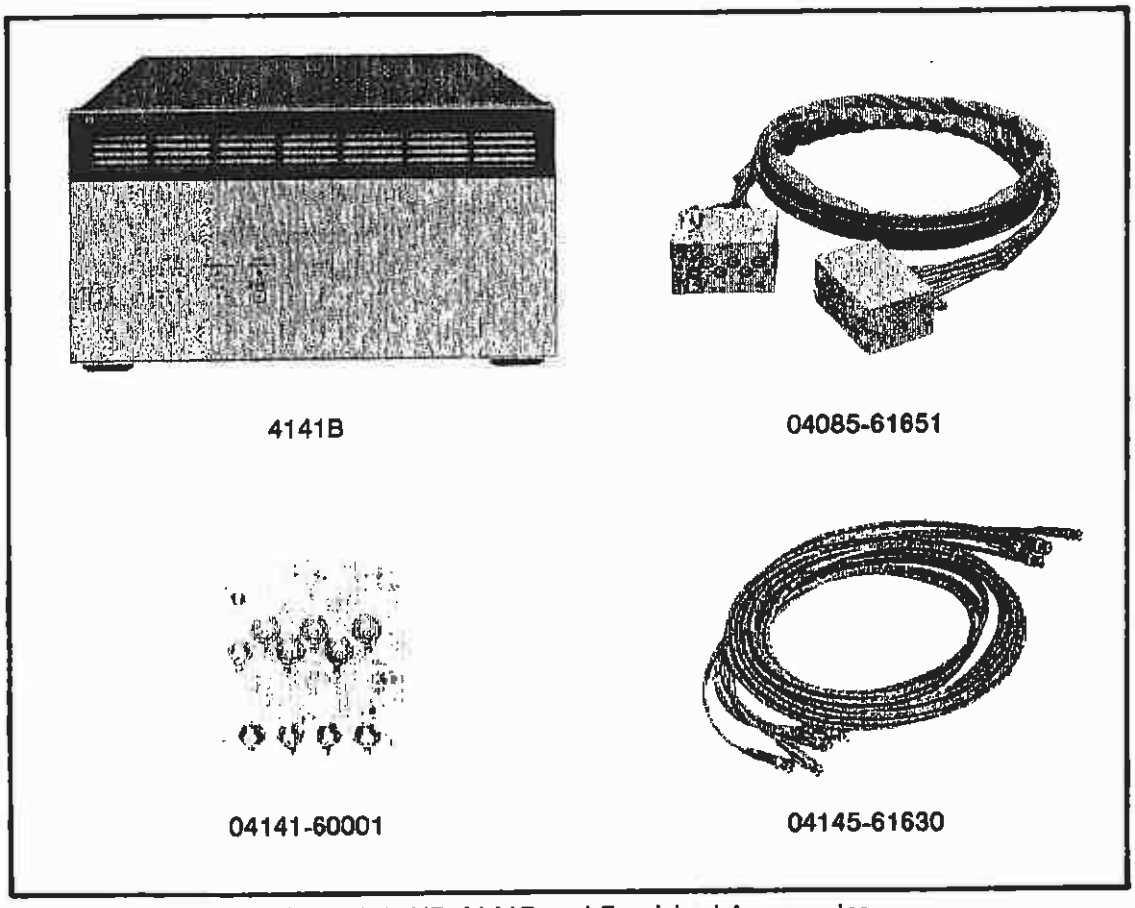



Figure 1-1. HP 4141B and Furnished Accessories

Listed on the title page of this manual is a microfiche part number that can be used to order 4 × 6 inch microfilm transparencies of the manual. Each microfiche contains up to 60 photo-duplicates of the manual pages. The microfiche package also includes the latest pertinent service notes. To order an additional manual, use the part number listed on the title page of this manual.

## 1-2. DESCRIPTION

The 4141B DC Source/Monitor is a high performance, fully programmable test instrument designed to stimulate voltage and current sensitive devices and measure the resulting current and voltage responses. Intended primarily for use in computer-controlled semiconductor test systems, the 4141B is ideal for a wide range of dc measurement applications such as computer-aided design (CAD), wafer process evaluation, wafer testing, packaged device testing, new process development, and incoming/outgoing inspection of diodes, transistors, and ICs.

The 4141B is equipped with four programmable source/monitor units, two programmable voltage sources, two voltage monitors, and an active ground unit, allowing the user to realize virtually any connection configuration, from a simple two-wire connection to the more sophisticated, more accurate full-Kelvin connection. The 4141B's driven guard capability and extensive internal shielding ensure measurement accuracy down to the microvolt and picoampere ranges.

All operations on the 4141B--measurement set up and execution, self test, and self calibration--are computer-controlled via the Hewlett-Packard Interface Bus (HP-IB).

## 1-3. SPECIFICATIONS

Table 1-1 lists complete specifications for the 4141B. These specifications are the performance standards against which the instrument is tested. Test procedures for verifying performance are covered in Section 4. When shipped from the factory, the 4141B meets all the specifications listed in Table 1-1. Table 1-2 lists supplemental performance characteristics. Supplemental performance characteristics are not specifications but are typical characteristics included as additional information for the operator.

## 1-4. SAFETY CONSIDERATIONS

The 4141B has been designed to conform to the International Electromechanical Committee's Safety Class I requirements and is shipped from the factory in a safe condition.

This manual contains information, cautions, and warnings which must be followed to ensure the safety of the operator and to maintain the instrument in a safe condition.

## 1-5. INSTRUMENTS COVERED BY MANUAL

Hewlett-Packard uses a two-section, nine character serial number which is stamped on the serial number plate (see Figure 1-2) attached to the instrument's rear-panel. The first four digits and the letter are the serial prefix and the last five digits are the suffix. The letter placed between the two sections identifies the country where the instrument was manufactured. The prefix is the same for all identical instruments; it changes only when a change is made to the instrument. The suffix, however, is assigned sequentially and is different for each instrument.

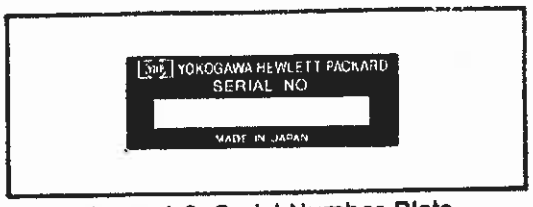



Figure 1-2. Serial Number Plate

Hewlett-Packard will publish a yellow Manual Changes supplement to inform you of any manual changes or errors (Errata). To keep this manual as current and as accurate as possible, request the latest Manual Changes supplement from time to time. The supplement for this manual is identified with this manual's print date and part number, both of which appear on the title page. Complimentary copies of the supplement are available from Hewlett-Packard.

## 1-6. OPTIONS

The following options are available for the 4141B.

OPT 011: Extra SMU board

OPT 050: For 50Hz line frequency

OPT 060: For 60Hz line frequency

OPT 907: Front Handle Kit

OPT 908: Rack Flange kit

OPT 909: Rack and Handle Kit

OPT 910: Extra Manual

For Option 907, 908, and 909 installation information, refer to Section 2.

## 1-7. ACCESSORIES

Figure 1-1 shows the 4141B and its furnished accessories. Also included but not shown is the 4141B's manual (PN 04141-90000). Table 1-3 lists all furnished and available 4141B accessories and provides a brief description of each.

Table 1-1. Specifications (sheet 1 of 4)

## GENERAL INFORMATION

Basic Functions:

To stimulate voltage and current sensitive devices and measure the resulting current and voltage responses. All instrument operations are computer-controlled via the HP-IB.

Source/Monitor Units (SMU):

Four SMU channels; each SMU can be programmed to function as a dc voltage source/current monitor or as a dc current source/voltage monitor.

Voltage Sources (Vs):

Two Vs channels; each Vs is programmable.

Voltage Monitors (VM):

Two VM channels; each VM can measure up to ±20Vdc.

Ground Unit (GNDU):

One GNDU channel. Maintains 0V output; enables full-Kelvin connections.

## SOURCE/MONITOR FUNCTIONS

Measurement and output accuracies are specified at the rear panel terminals under the following conditions.

| | |
|---|---|
| Warm-up Time: | 40 minutes |
| Ambient Temperature: | 23°C ±5°C |
| Voltage Reference: | Floating Ground (⏚) |
| Auto calibration: | On |
| Integration Time: | Short |

Specified accuracies double for operation between 10°C and 40°C.

**Source/Monitor Units (SMUs):**

Each of the four SMUs can measure current when operating as a voltage source, or voltage when operating as a current source. Each SMU is designed to provide full-Kelvin connection. Source and measurement ranges, resolution, and accuracy specifications are listed in the following table.

Accuracy is specified as ±% of setting or reading +% of range. Vo in the current accuracy table is SMU output voltage.

Table 1-1. Specifications (sheet 2 of 4)

Voltage Accuracy

| Range | Max. Res. | Accuracy |
|---|---|---|
| ±20V | 1mV | ±(0.1%+0.05%) |
| ±40V | 2mV | |
| ±100V | 5mV | |

Current Accuracy

| Range | Max. Res. | Accuracy |
|---|---|---|
| ±100mA | 100µA | ±[0.3%+(0.1+0.2 Vo/100)%] |
| ±10mA | 10µA | |
| ±1000µA | 1µA | |
| ±100µA | 100nA | |
| ±10µA | 10nA | |
| ±1000nA | 1nA | ±[0.5%+(0.1+0.2 Vo/100)%] |
| ±100nA | 100pA | |
| ±10nA | 10pA | ±[1%+(0.1+0.1 Vo/100)%+5pA] |
| ±1000pA | 1pA | |

Maximum Power Output from each SMU: 2 watts

Setting Resolution: Voltage, 4 1/2 digits (1mV max.), Current, 4 digits (1pA max.)

Measurement Resolution: Voltage, 4 1/2 digits (1mV max.), Current, 4 digits (0.05pA max.)

Ranging Modes: Auto/Limited-Auto

Residual dc Resistance (Voltage Source/Current Monitor Mode): 5mΩ

Input dc Resistance (Current Source/Voltage Monitor Mode): $10^{12}\Omega$

Maximum Residual dc Resistance (through furnished cables): 7Ω (Force), 14Ω (Sense)

Table 1-1. Specifications (sheet 3 of 4)

**Voltage Sources (Vs):**

Two Vs channels. Each can be programmed to function as a variable or constant dc voltage source. Output ranges, resolution, and accuracy specifications are listed in the following table.

| Range | Resolution | Accuracy | Max. Output Current |
|---|---|---|---|
| ±20V | 1mV | ±(0.5% of setting +10mV) | 10mA |

Output Resistance: ≤0.2Ω

Maximum Allowable Capacitive Load: ≤1000pF

**Voltage Monitors (VM):**

Two VM channels. Output ranges, resolution, and accuracy specifications are listed in the following table.

| Range | Resolution | Accuracy |
|---|---|---|
| ±2V | 100µV | ±(0.5% of reading+10mV) |
| ±20V | 1mV | ±(0.2% of reading+10mV) |

Input Resistance: 1MΩ ±1%

Capacitance in Parallel with Output: 150pF ±10%

**Ground Unit (GNDU):**

Maximum Output Current: ±500mA

Output Voltage: 0V ±2mV

Maximum Residual dc Resistance (through furnished cables): 2Ω (Force), 5Ω (Sense)

Maximum Allowable Capacitive Load: 10000pF

Table 1-1. Specifications (sheet 4 of 4)

## SPECIFICATIONS COMMON TO ALL UNITS

Maximum dc Withstand Voltage: 100V (SMUs, Vs and $V_M$ 1 and 2, and guard terminals)

Maximum dc Voltage between Common (COM) and GND: ±42V

Voltage/Current Sweep: Output from each SMU and Vs can be swept.

## GENERAL SPECIFICATIONS

Data Input/Output:
Controlled remotely via HP-IB. The 4141B may be interfaced with any HP-IB compatible controller. (HP-IB is Hewlett-Packard's implementation of IEEE 488 and ANSI-MC.1.1 standards.)

Self-Test Function:
Automatically performed each time the 4141B is turned on. The Self Test can also be performed at any time via HP-IB.

Operating Temperature Range: 10°C to 40°C @ ≤70% RH

Permissible Temperature Change: ≤1°C/5 min.

Power Requirements: 100V/120V/220V ±10%; 240V-10%+5%; 48 – 66Hz; 200VA max.

Dimensions: 426W x 235H x 612D (mm) (approx.)

Weight: Approximately 19kgs.

Table 1-2. Supplemental Performance Characteristics (sheet 1 of 2)

Supplemental characteristics are not guaranteed specifications but are typical characteristics that are included only as additional information.

**Source/Monitor Units (SMUs):**

Offset Current when operated as a voltmeter: 6pA + 2pA x Vo/100

Offset Voltage when operated as a current meter: 10mV

Noise Characteristics:

Voltage Source Noise: 0.01% of range (rms)

Current Source Noise: 0.1% of range + 3pA + 0.005pA x Cg(rms)
(Cg: Guard Capacitance in pF)

Voltage Monitor: 0.02% of range (peak-to-peak)

Current Monitor: 0.3% of range + 10pA (peak-to-peak)

Output Overshoot:

Voltage Source Overshoot: 5mV

Current Source Overshoot: 1% of setting

Current Range Switching Transient Noise:

Range Increment: 0.01% of voltage range + 10mV*

Range Decrement: 10mV*

* When switching to the 10nA or 1nA range, 10mV + 120/(3 + Cx)mV, where Cx is load capacitance (pF).

Maximum Internal Guard to Ground Capacitance: 700pF

Guard Offset Voltage: 1mV

Guard Current-Induced Voltage Error: 100Ω × Ig (Ig = guard current)

**Voltage Sources ($V_S$):**

Output Noise: 6mVrms

**Voltage Monitors ($V_M$):**

Noise Level: 0.3mV p-p on 2V range (when integration time is set to MEDIUM or LONG); 3mV p-p on 20V range.

Table 1-2. Supplemental Performance Characteristics (sheet 2 of 2)

**Ground Unit (GNDU):**

Output Noise: 6mVrms

Maximum Load Capacitance: 10000pF

**Noise Rejection:** (integration time set to MEDIUM or LONG)

Normal Mode Rejection: ≥60dB

Common Mode Rejection:

Voltage monitor: ≥60dB
Current monitor: ≤2pA

**Measurement Speed:** (when using an HP 9000 series 200/300 computer)

Force (current or voltage) -- Approx. 35ms
Spot Measurement (current or voltage) -- Approx. 25ms
Sweep measurement (binary data transfer format) -- Approx. 490ms (51 points)

Note

The times listed, which apply only when SHORT integration is used, include the measurement data transfer time between the 4141B and the controller but do not include ranging time. These times do not apply on the 1nA or 10nA range.

Table 1-3. Accessories (sheet 1 of 2)

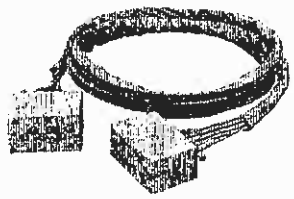
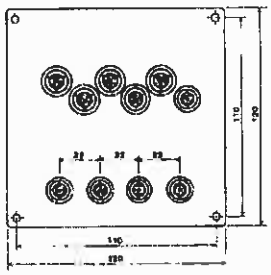
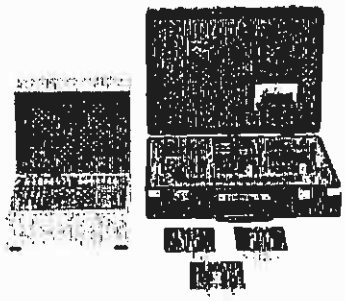
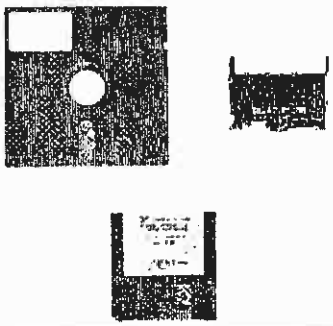
| Accessories | Description |
|---|---|
|  | PN 04085-61651 Interconnect Cable Assembly<br><br>For interconnecting the 4141B and the Connector Plate (PN 04141-60001). |
|  | PN 04141-60001 Connector Plate<br><br>For interfacing the 4141B with a wafer prober. Refer to Section 3 for details on Connector Plate usage.<br><br>  |
|  | PN 04145-61630 BNC Cables<br><br>For connecting the 4141B's Vs and VM terminals to the Connector Plate. Four cables are furnished; each cable is 3 meters long. |

Table 1-3. Accessories (sheet 2 of 2)

| Accessories | Description |
|---|---|
|  | *HP 16058A Test Fixture (not furnished)<br><br>Test fixture for performing measurements on packaged devices. Equipped with a safety lid and the following fixture accessories.<br><br>PN 16058-60003 Personality Board<br>PN 16058-61603 Triaxial Cables, 1.5m, 4ea.<br>PN 16058-61604 System Cable<br>Socket Boards/Connection Cable Set<br><br>Refer to the 16058A Operating Note for more information on how to use this test fixture. |
|  | *HP 16059A Adapter (not furnished)<br><br>For interconnecting the 4141B and the 16058A Test Fixture. Refer to Section 3 for details. |
|  | Performance Verification Software (not furnished)<br><br>Can be purchased on a 5-1/4" mini-flexible disc, PN 04141-65101 (for use with the HP 9000 Series 200 Model 236 Computer), on a tape cartridge, PN 04141-90501 (for use with the HP85 Computer), or on a 3-1/2" micro-flexible disc, PN 04141-65301 (for use with the HP 9000 Series 300 Computer).<br><br>This software is for servicing the 4141B only. Refer to Section 4 for more information. |

* The Ground Unit of the 4141B cannot be used for measurements through the 16058A/16059A, because the 16058A does not have a Ground Unit terminal.

# SECTION 2
# INSTALLATION

## 2-1. INTRODUCTION

This section provides installation instructions for the Model 4141B DC Source/Monitor. It also includes information on initial inspection and damage claims, on preparation for using the 4141B, and on packaging, storage, and shipment.

## 2-2. INITIAL INSPECTION

The 4141B, when shipped from the factory, meets all the specifications listed in Table 1-1. Upon receipt, inspect the shipping container for damage. If the shipping container or cushioning material is damaged, it should be kept until the contents of the shipment have been checked for completeness and the instrument has been checked mechanically and electrically. The contents of the shipment should be as shown in Figure 1-1. The procedures for checking the general electrical operation are given in Section 3 (Self Test) and the procedures for checking the 4141B against its specifications are given in Section 4. First, do the self test. If the 4141B is electrically questionable, then do the Performance Tests to determine whether the 4141B has failed or not.

If the shipment is incomplete, if the contents show any sign of mechanical damage or other defects (scratches, dents, broken switches, etc.), or if the instrument does not pass the self test or performance tests, notify the nearest Hewlett-Packard office (see list at back of this manual). The HP office will arrange for repair or replacement without waiting for claim settlement.

## 2-3. POWER REQUIREMENTS

The 4141B requires a power source of 100, 120, 220 Volts ac ±10%, or 240 Volts ac +5%/-10%, 48 to 66Hz, single phase. Maximum power consumption is 140VA.

**WARNING**

**IF THE INSTRUMENT IS TO BE ENERGIZED VIA AN EXTERNAL AUTOTRANSFORMER FOR VOLTAGE REDUCTION, BE SURE THE COMMON TERMINAL IS CONNECTED TO THE NEUTRAL POLE OF THE POWER SOURCE.**

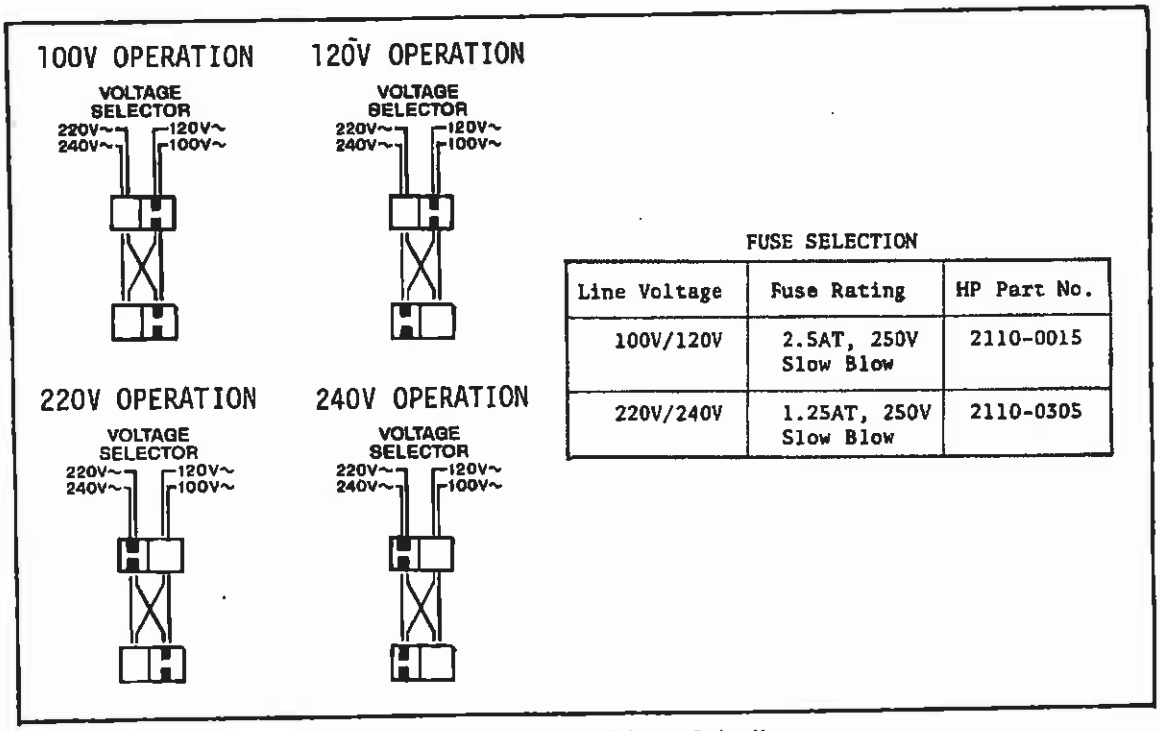
## 2-4. LINE VOLTAGE AND FUSE SELECTION

Figure 2-1 provides instructions for line voltage and fuse selection. The 4141B is shipped from the factory with the fuse and LINE VOLTAGE SELECTOR switch setting appropriate for the geographic area in which the instrument will be used.

**CAUTIONS**

**(1) BEFORE TURNING ON THE 4141B, VERIFY THAT THE LINE VOLTAGE SELECTOR SWITCH IS CORRECTLY SET FOR THE LINE VOLTAGE BEING USED. USE A FUSE PROPER FOR THE SELECTED LINE VOLTAGE.**

**(2) USE ONLY REPLACEMENT FUSES OF THE CORRECT CURRENT RATING AND OF THE SPECIFIED TYPE. DO NOT USE MENDED FUSES, AND DO NOT SHORT CIRCUIT THE FUSE HOLDERS.**




FUSE SELECTION

| Line Voltage | Fuse Rating | HP Part No. |
|---|---|---|
| 100V/120V | 2.5AT, 250V Slow Blow | 2110-0015 |
| 220V/240V | 1.25AT, 250V Slow Blow | 2110-0305 |

Figure 2-1. Voltage and Fuse Selection

## 2-5. LINE FREQUENCY FILTER

To reject the effects of line-frequency noise, set the FILTER switch on the rear panel to the frequency of the ac power source.

## 2-6. POWER CABLE

To protect operating personnel, the National Electrical Manufacturers Association (NEMA) recommends that the instrument panel and cabinet be grounded. The 4141B is equipped with a three-conductor power cable which, when plugged into an appropriate receptacle, grounds the instrument. The offset pin on the power cable is the ground wire.

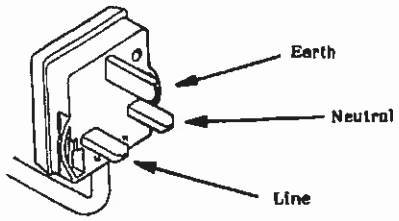
To preserve the protection feature when operating the instrument from a two contact outlet, use a three prong-to-two prong adapter (PN 1251-8196) and connect the green grounding tab on the adapter to power line ground.

**CAUTION**

**THE MAINS PLUG MUST ONLY BE INSERTED IN A SOCKET OUTLET PROVIDED WITH A PROTECTIVE EARTH CONTACT. THE PROTECTIVE ACTION MUST NOT BE NEGATED BY THE USE OF AN EXTENSION CORD (POWER CABLE) WITHOUT A PROTECTIVE CONDUCTOR (GROUNDING).**

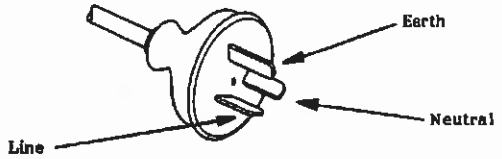
Figure 2-2 shows the available power cords for use in various countries including the standard power cord furnished with the instrument. HP Part number, applicable standards for power plug, power cord color, electrical characteristics and countries using each power cord are listed in the figure. If assistance is needed for selecting the correct power cable, contact the nearest Hewlett-Packard office.

OPTION 900 — United Kingdom



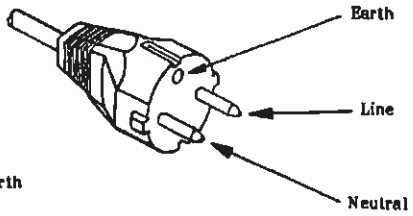

Plug : BS 1363A, 250V
Cable : HP 8120-1351

OPTION 901 — Australia/New Zealand



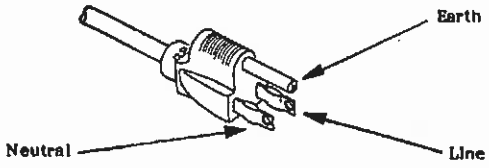

Plug : NZSS 198/AS C112, 250V
Cable : HP 8120-1369

OPTION 902 — European Continent



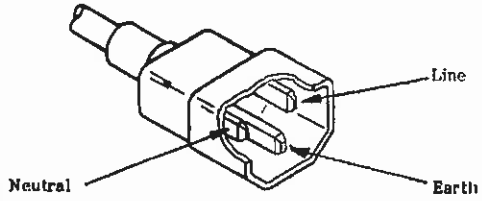

Plug : CEE-VII, 250V
Cable : HP 8120-1689

OPTION 903 — U.S./Canada



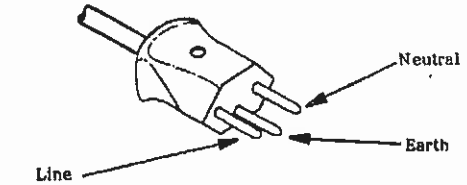

Plug : NEMA 5-15P, 125V, 15A
Cable : HP 8120-1378

OPTION 905* — Any country



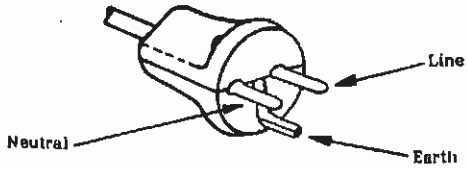

Plug : CEE 22-VI, 250V
Cable : HP 8120-1396

OPTION 906 — Switzerland



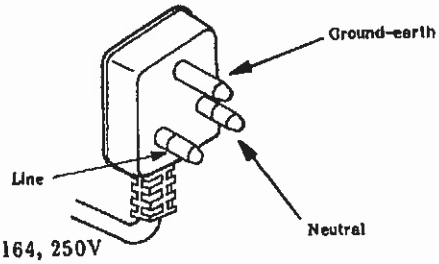

Plug : SEV 1011.1959-24507 Type 12, 250V
Cable : HP 8120-2104

OPTION 912 — Denmark




Plug : DHCR 107, 220V
Cable : HP 8120-2956

OPTION 917 — India/Republic of S.Africa




Plug : SABS 164, 250V
Cable : HP 8120-4211

NOTE: Each option number includes a 'family' of cords and connectors of various materials and plug body configurations (straight, 90° etc.).

* Plug option 905 is frequently used for interconnecting system components and peripherals.

Figure 2-2. Power Cables

## 2-7. INTERCONNECTIONS

To interconnect the 4141B to an external controller or peripheral device using the HP-IB interface capability (IEEE Std. 488/ANSI-MC1.1), connect an HP-IB interface cable between the HP-IB connector on the rear panel of the 4141B and the HP-IB connector on the peripheral device. Refer to Section 3 for details on the HP-IB.

## 2-8. OPERATING ENVIRONMENT

To maintain the proper operating environment for the 4141B, do not exceed the following limitations.

Temperature:
Operate the 4141B at temperatures from 0°C to 40°C.

Humidity:
The 4141B can be operated in environments with relative humidities up to 70% at 40°C, but must be protected from temperature extremes which cause internal condensation.

## 2-9. STORAGE AND SHIPMENT

The instrument may be stored or shipped under the following environmental conditions:

**Storage:**

Temperature: -22°C to +55°C

Humidity: 8% to 80% (RH)

**Shipment:**

Temperature: -40°C to +62°C

Humidity: 8% to 80% (RH)

The instrument must be protected from temperature extremes which cause internal condensation.

## 2-10. PACKAGING

**Original Packaging:** Containers and materials identical to those used in factory packaging are available from Hewlett-Packard.

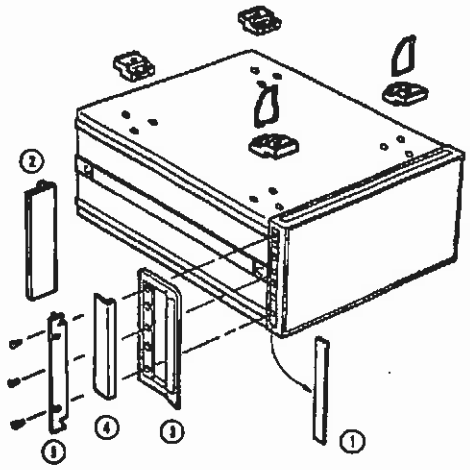
**Other Packaging:** The following general instructions should be used for repacking the 4141B with commercially available materials.

1. Wrap the instrument in heavy paper or plastic.
2. Use a strong shipping container. A double-walled carton made of 350 pound test material is adequate.
3. Use enough shock absorbing material (3-to 4-inch layer) around all sides of the instrument to provide a firm cushion and to prevent movement inside the container. Protect the front panel with cardboard.
4. Seal the shipping container securely and mark it FRAGILE to ensure careful handling.
5. In any correspondence with HP, refer to the instrument by model and serial number.

## 2-11. INSTALLATION INSTRUCTIONS

The 4141B can be operated from a bench or it can be rack-mounted for use in a measurement system. The instrument is equipped with two retractable stands which are mounted on the instrument's bottom cover. To use the stands, pull each one away from the bottom cover until it locks into position. To mount the 4141B in a rack, you'll need Options 907, 908, and 909. Rack-mounting information is given in Figure 2-3.

| Option | Kit Part Number |
|---|---|
| 907 | Handle Kit, 5061-9691 |
| 908 | Rack Flange Kit, 5061-9679 |
| 909 | Rack Flange & Handle Kit, 5061-9685 |




1. Remove the adhesive-backed trim strips ① from the right and left front sides of the 4141B.

2. HANDLE INSTALLATION: Attach the front handles ③ to the right and left front sides of the 4141B with the screws provided. Attach the trim ④ to the handles.

**Note**

To perform steps 3 and 4, remove the feet from the bottom cover. Lift the bar at the inner side of each foot and slide the foot towards the bar.

3. RACK MOUNTING: Attach the rack mount flanges ② to the right and left front sides of the 4141B with the screws provided.

4. HANDLE AND RACK MOUNTING: Attach the front handles ③ and the rack mount flanges ⑤ to the right and left front sides of the 4141B with the screws provided.

Figure 2-3. Rack Mount Kit

# SECTION 3
# OPERATION

## 3-1. INTRODUCTION

This section explains how to operate the HP 4141B DC Source/Monitor. Included are descriptions of the front- and rear-panels, lamps, and connectors; discussions of operating procedures and measurement techniques; and instructions on how to run instrument's SELF TEST. **WARNINGs**, **CAUTIONs**, and Notes are given throughout; they must be observed to ensure the safety of the operator and the integrity of the instrument. Figure 3-1 shows the organization of this section.

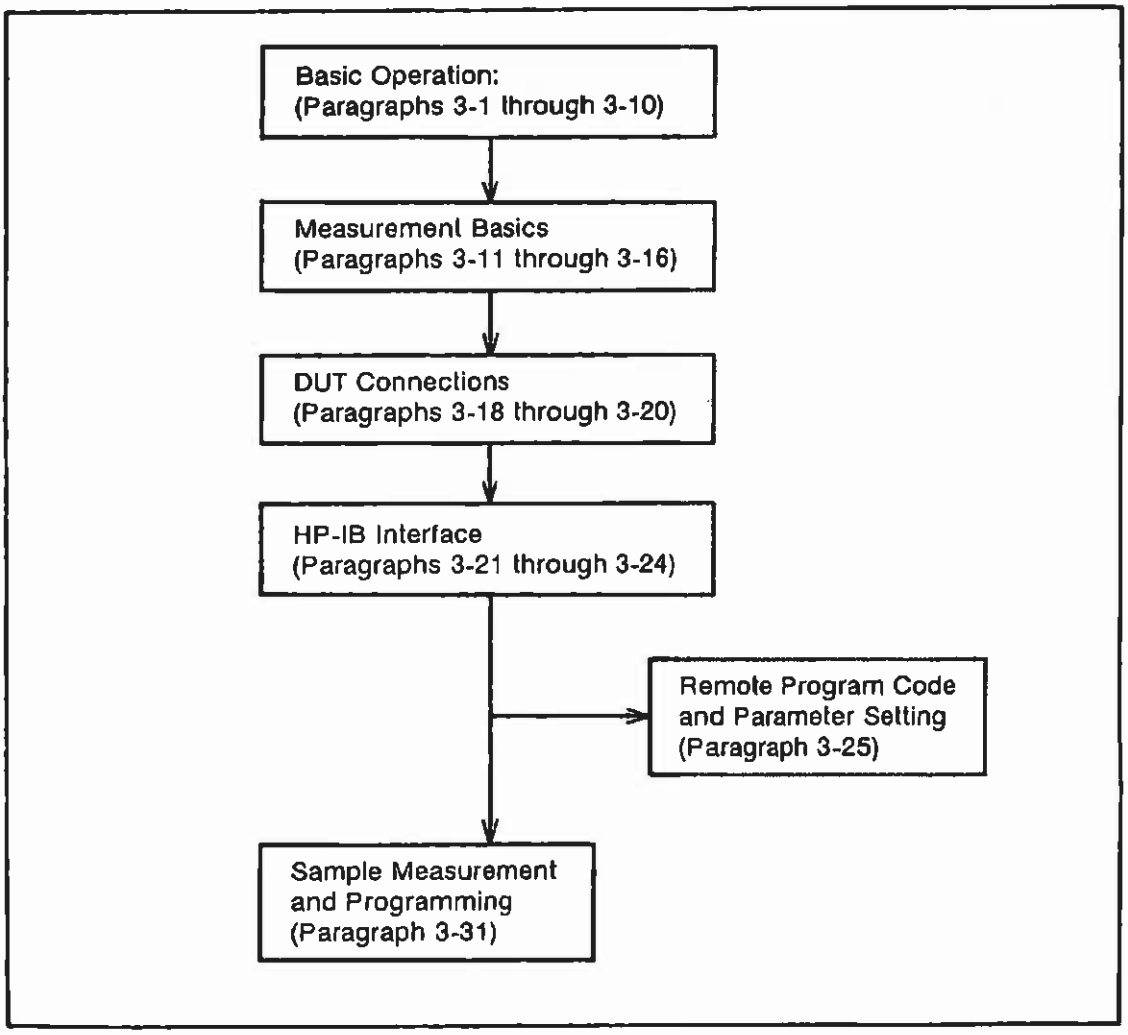



Figure 3-1. Organization of Section 3

**WARNING**

**BEFORE YOU TURN ON THE 4141B, CONNECT ALL PROTECTIVE EARTH TERMINALS, EXTENSION CORDS, AUTO-TRANSFORMERS, AND OTHER DEVICES CONNECTED TO THE INSTRUMENT TO A PROTECTIVE EARTH-GROUNDED SOCKET. ANY INTERRUPTION OF THE PROTECTIVE EARTH GROUNDING WILL CAUSE A POTENTIAL SHOCK HAZARD THAT COULD RESULT IN SERIOUS PERSONAL INJURY.**

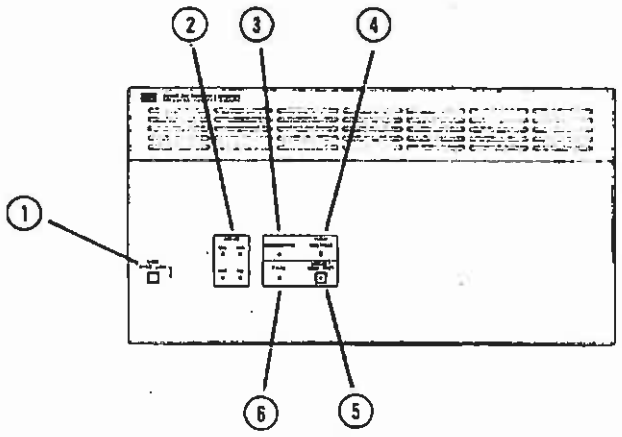
**ONLY FUSES OF THE REQUIRED CURRENT RATING AND OF THE SPECIFIED TYPE MAY BE USED. DO NOT USE REPAIRED FUSES OR SHORTED FUSE HOLDERS. TO DO SO COULD CAUSE A SHOCK OR FIRE HAZARD.**

**CAUTION**

**BEFORE THE INSTRUMENT IS TURNED ON, THE VOLTAGE SELECTOR SWITCH ON THE REAR-PANEL MUST BE SET TO MATCH THE LINE VOLTAGE BEING USED. FAILURE TO SET THE PROPER LINE VOLTAGE MAY RESULT IN DAMAGE TO THE INSTRUMENT.**

## 3-2. PANEL FEATURES

Figures 3-2 and 3-3 identify and briefly describe each key, indicator, and connector on the 4141B's front and rear panel, respectively.




1. LINE OFF/ON:

   The Instruments ON/OFF switch.

Figure 3-2. Front Panel Features (sheet 1 of 2)

2. HP-IB Status Indicators:

   Four LEDs that indicate the 4141B's HP-IB status (SRQ, LISTEN, TALK and REMOTE) when interfaced to a controller.

3. MEASURING Lamp:

   Indicates that the 4141B is outputting a voltage or current and performing a measurement.

4. HIGH VOLTAGE Lamp:

   Indicates that the 4141B is set to output a voltage in excess of ±42V.

**WARNING**

**DO NOT TOUCH THE OUTER CONDUCTORS OF THE SMU OUTPUT CONNECTORS WHEN THE HIGH VOLTAGE LAMP IS LIT. THIS LAMP INDICATES THAT DANGEROUS VOLTAGES OF UP TO ±100V MAY BE PRESENT AT THESE CONNECTORS.**

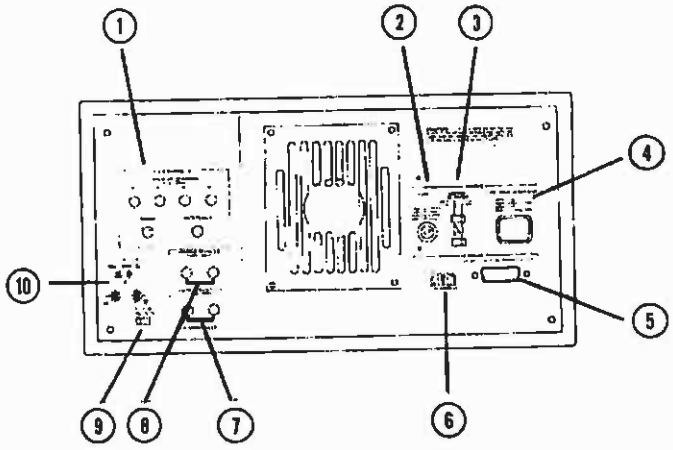
5. LOCAL/SELF TEST Key:

   This key initiates the 4141B's SELF TEST. The 4141B is released from HP-IB control (the REMOTE lamp will go out) when you press this key. This key is disabled when the 4141B is set to local lockout.

6. FAIL Lamp:

   Indicates the 4141B has failed SELF TEST.

Figure 3-2. Front Panel Features (sheet 2 of 2)




1. I•V CHANNELS:

Four SMU connectors (triaxial), one Ground Unit (GNDU) connector (triaxial), and one INTERLOCK connector (BNC). These connectors interconnect the 4141B to a test fixture or wafer prober using Interconnect Cable Assembly (PN 04085-61651). The INTERLOCK function prevents the SMUs from outputting more than ±42V unless a 0Ω termination or a shorting plug is used on the INTERLOCK connector. This function is discussed in paragraph 3-27.

**WARNING**

**VOLTAGES OF UP TO ±100V MAY BE PRESENT AT THE OUTER CONDUCTORS OF THE SMU OUTPUT CONNECTORS. DO NOT TOUCH THE OUTPUT CONNECTORS IF THE FRONT-PANEL HIGH VOLTAGE LAMP IS ON. CONNECT ONLY THE FURNISHED INTERCONNECT CABLE ASSEMBLY TO THE I•V CHANNELS.**

2. LINE FUSE Holder:

The instruments power line fuse is installed into this holder.

100/120V operation: 2.5A/250V. PN 2110-0015
200/240V operation: 1.25A/250V. PN 2110-0305

3. LINE VOLTAGE SELECTOR Switches:

These switches are used to select the ac operating voltage. The voltages selectable are 100, 120, 220, and 240V. Refer to Section 2 for more information on the 4141B's power requirements.

Figure 3-3. Rear Panel Features (sheet 1 of 2)

4. LINE Input Receptacle:

Power cord receptacle.

5. HP-IB Connector:

A 24-pin connector for interconnecting the 4141B to HP-IB.

6. HP-IB ADDRESS Switches:

Used to set the 4141B's HP-IB address to any setting between 0 and 30.

7. VOLTAGE MONITORS (VM) Input Connectors:

Two female BNC connectors used with a user-furnished test fixture. The outer conductors are connected to common ( ⏚ ).

8. VOLTAGE SOURCES (VS) Output Connectors:

Two female BNC connectors used with a user-furnished test fixture. The outer conductors are connected to common ( ⏚ ).

9. FILTER Switch:

Used to set the measurement integration time to minimize the effects of line-frequency related noise. Set this switch to the frequency of the ac power source.

10. COM (COMMON) - GROUND Terminals:

Common ( ⏚ ) and Ground ( ⊥ ) terminals are used when making floating or grounded measurements. The Common terminal is connected to the outer-conductors of the VM (7) and VS (8) connectors. The Ground terminal is tied to the 4141B's chassis. When making floating measurements, disconnect the shorting-bar.

**WARNING**

**A POTENTIAL SHOCK HAZARD EXISTS WHEN THE COMMON TERMINALS ARE NOT GROUNDED (SHORTING-BAR DISCONNECTED). REGARDLESS OF THE OUTPUT VOLTAGE, DO NOT TOUCH THE COMMON TERMINAL OR THE OUTER CONDUCTORS OF THE VS OR VM CONNECTORS WHILE A MEASUREMENT IS IN PROGRESS.**

Figure 3-3. HP 4141B Rear Panel Features (sheet 2 of 2)

## 3-3. SELF TEST

The 4141B has self-diagnostic capabilities which are initiated each time the instrument is turned on to confirm normal operation. SELF TEST can also be initiated using the HP-IB or the LOCAL/SELF TEST key on the front panel. When the instrument is turned on, three SELF TESTs (Table 3-1) are performed. When a SELF TEST is initiated by an HP-IB command or with the LOCAL/SELF TEST key, only two tests are performed (MPU Test and SMU Test). A SELF TEST takes about ten seconds to perform. If the instrument fails SELF TEST, the FAIL lamp on the front panel will light and an error code will be output when a Test Result command "TR" is sent via HP-IB.

Note

If exposed to an extreme change of ambient temperature, the 4141B might fail SELF TEST. If you suspect this to be the case, let the instrument warm-up, then turn it OFF and ON one time.

Table 3-1. 4141B Self Test

| Test Name | Description |
|---|---|
| MPU test | Checks the basic functions of the MPU (Microprocessor Unit by checking four ROMs (Read-only Memory) and sixteen RAMs (Ramdom-Access Memory) |
| HP-IB test | Checks all HP-IB interface capability. |
| SMU test | Checks the basic functions of the four SMUs. |

## 3-4. 4141B OPERATING OUTLINE

A simplified block diagram of the 4141B appears in Figure 3-4. The 4141B has eight channels for device source and monitors. Four of these channels are used for Source/Monitor units (SMU1 to 4). The remaining channels are used as Voltage Source Units (VS1 and VS2) and Voltage Monitor Units (VM1 and VM2). All channels are individually controlled by the control section, which via HP-IB transmits all setup instructions to the appropriate channels, and then receives the measurement results from the channels. The control section also controls sweep measurements. Receiving sweep measurement commands, the 4141B automatically enables a sweep measurement and outputs all measurement data after completion of the measurement. The ground unit (GNDU) is used as the SMUs' common to help the SMU make accurate voltage measurements by reducing the residual resistance of the output cable.

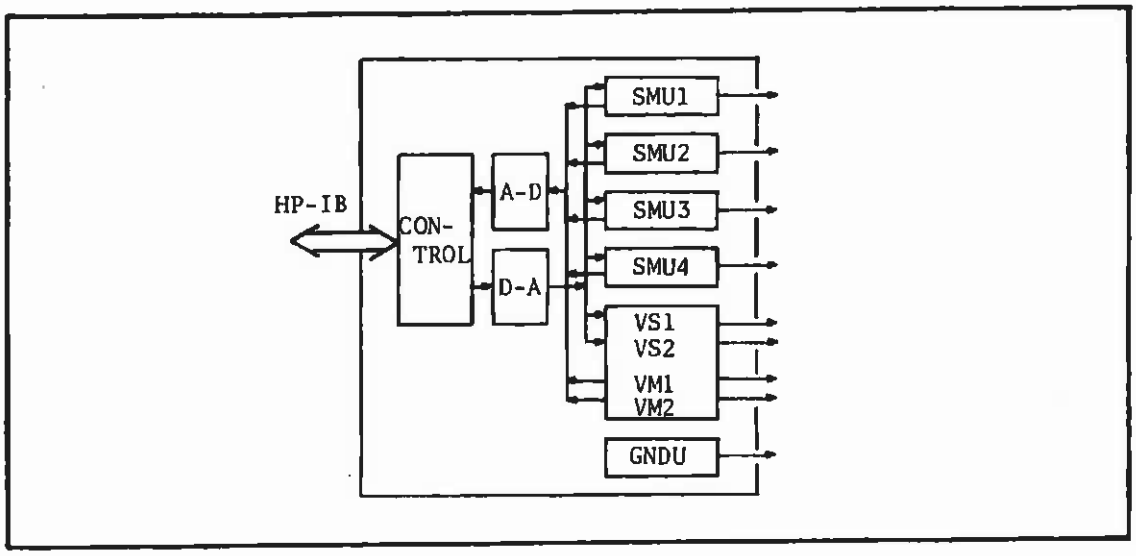



Figure 3-4. 4141B Overview

## 3-5. SOURCE/MONITOR UNITS (SMUs)

Figure 3-5 shows a simplified circuit diagram of an SMU. You can set each SMU to function as a voltage source/current monitor or as a current source/voltage monitor by specifying source the V or I mode, respectively. When set to the V source mode, each SMU can source 0 to ±100V with a maximum resolution of 1mV, and can measure up to 100mA. Conversely, when set to I source mode, each SMU can source (or sink) up to 100mA with a maximum resolution of 1pA, and can measure up to ±100V. The SMU's ranges when in the V or I modes are listed in Table 3-2 along with the resolution and maximum output in each range. Also listed in the table are the applied voltage and the measured current of the SMU (maximum current measurement resolution of 0.05pA). The range changing can be set to either to auto or manual. The output power is internally limited to 2W. Graphs which show the specifiable voltage or current output are shown in Figure 3-6 Specifiable Voltage/Current Output. The voltage and current values enclosed within the bold lines are specifiable. The output voltage and current can be set within the limits specified and can be swept as a linear or logarithmic function.

Each SMU's output connected to a triaxial output connector and the center conductor is connected to the Sense line, a high input impedance voltage monitor. The inter-conductor, the Force line, is the output of the voltage source or current source. This "Force" and "Source" construction enables accurate voltage measurement regardless of voltage drop along the output cable. Detailed information about Force and Sense is contained in paragraph 3-18. The outer-conductor of the SMU is connected to the guard terminal (maintains the same voltage as that of the "Force" terminal), which helps to accurately measure low current. COM (COMMON) is a common reference for all channels. The SMU is electrically disconnected from its output terminal when a measurement is not in progress or when a zero output HPIB "DZ" command is sent.

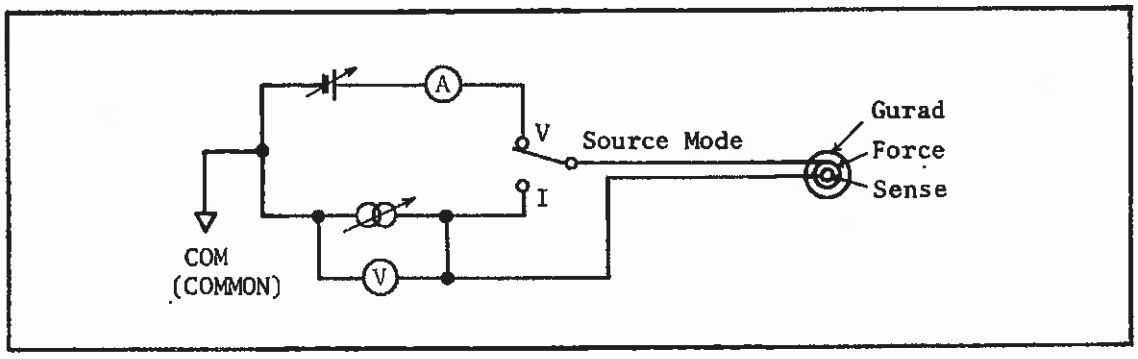
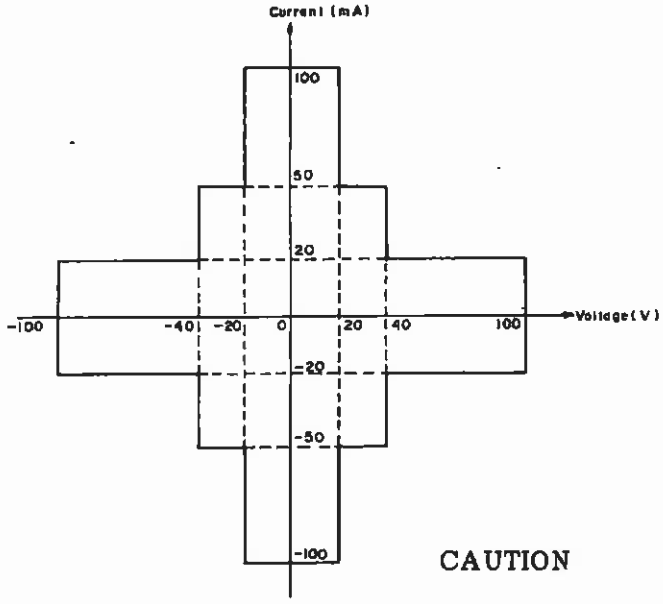



Figure 3-5. Simplified SMU Circuit Diagram




CAUTION

NEVER APPLY VOLTAGE OR CURRENT EXCEEDING LIMITS SHOWN IN THIS FIGURE.

Figure 3-6. Specifiable Voltage/Current Output

## 3-6. VOLTAGE SOURCES (VS) AND VOLTAGE MONITORS (VM)

A simplified circuit diagram of the VS1 and VS2 voltage sources are shown in Figure 3-7, and that of the VM1 and VM2 voltage monitors in Figure 3-8. The voltage source has only one range with a maximum output voltage of ±20V, a maximum output current of 10mA, and a measurement resolution of 1mV. The output voltage of each VS can be held constant or can be swept as a linear or log function. The VM channels have two measurement ranges, ±2V with a resolution of 100µV and ±20V with a resolution of 1mV.

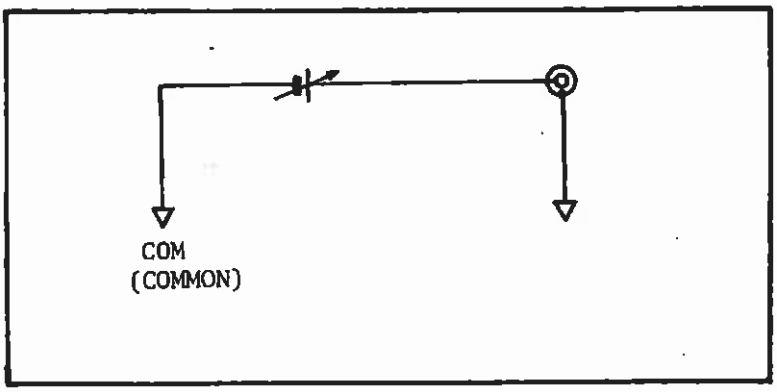



Figure 3-7. VS Simplified Circuit Diagram

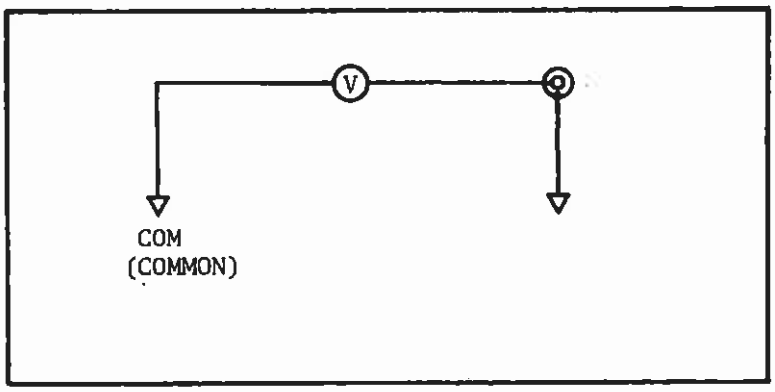



Figure 3-8. VM Simplified Circuit Diagram

## 3-7. GROUND UNIT (GNDU)

A simplified circuit diagram of the ground unit (GNDU) is shown in Figure 3-9. The GNDU has a "Force" and "Sense" line similar to that of the SMU. The force line connects to a voltage source and the sense line to a high input impedance voltage monitor. The voltage monitor controls the voltage source and keeps the input voltage at 0V by feeding the input voltage back to the voltage source. The GNDU reduces the residual resistance of the cable connected to the device under test to help ensure accurate voltage measurements by the SMU.

Note

The ground unit cannot be used with the 16058A Test Fixture.

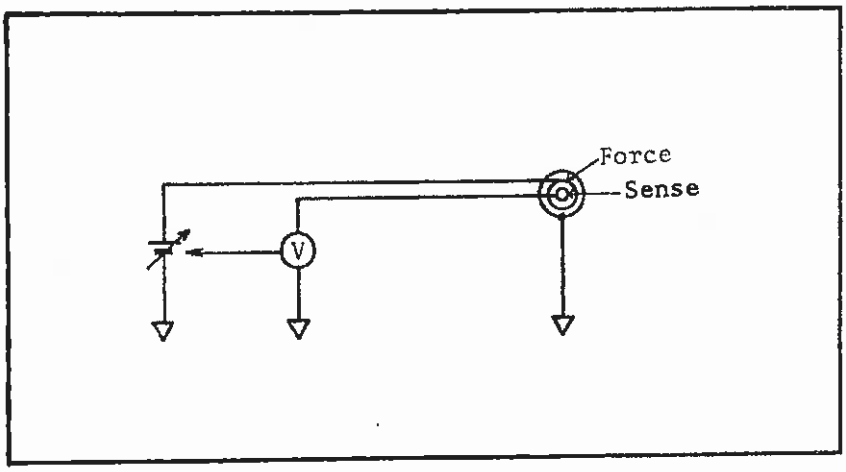



Figure 3-9. GNDU Simplified Circuit Diagram

## 3-8. COMPLIANCE

To prevent over-voltage or over-current damage to the device under test, several levels of output protection (compliance), are used in the 4141B. The maximum output voltage or current from an SMU, operating as a current or voltage source, can be specified. The maximum specifiable compliance depends on the voltage or current range over which the source is operating. To determine the maximum output value see Table 3-2. Here, because the compliance has the same range and resolution as the output voltage and current, Table 3-2 also applies. Once an SMU has reached its compliance limit, the output voltage or current will not increase any further. Compliance is valid for the polarity specified. The VS (voltage source) has no user definable current compliance function.

Table 3-2. SMU Source Range

<table>
<tr><th>Source Mode</th><th colspan="2">Range</th><th>Resolution</th><th>Maximum Output</th></tr>
<tr><td rowspan="3">V</td><td colspan="2">±20V</td><td>1mV</td><td>100mA</td></tr>
<tr><td colspan="2">±40V</td><td>2mV</td><td>50mA</td></tr>
<tr><td colspan="2">±100V</td><td>5mV</td><td>20mA</td></tr>
<tr><td rowspan="10">I</td><td colspan="2">±1nA</td><td>1pA</td><td rowspan="8">100V</td></tr>
<tr><td colspan="2">±10nA</td><td>10pA</td></tr>
<tr><td colspan="2">±100nA</td><td>100pA</td></tr>
<tr><td colspan="2">±1µA</td><td>1nA</td></tr>
<tr><td colspan="2">±10µA</td><td>10nA</td></tr>
<tr><td colspan="2">±100µA</td><td>100nA</td></tr>
<tr><td colspan="2">±1mA</td><td>1µA</td></tr>
<tr><td colspan="2">±10mA</td><td>10µA</td></tr>
<tr><td rowspan="3">±100mA*</td><td>20mA</td><td rowspan="3">100µA</td><td></td></tr>
<tr><td>50mA</td><td>40V</td></tr>
<tr><td>100mA</td><td>20V</td></tr>
</table>

*: The 100mA range consists of three subranges.

## 3-9. KELVIN CONNECTIONS

When a device is connected to an instrument through a long cable or through many switch contacts, the residual resistance of the cable or the contacts will add to the measurement error due to the voltage drop across the total residual resistance. To reduce the errors caused by residual resistance, Kelvin connections are used in the 4141B's SMU and GNDU circuits. In a measurement example using a non-Kelvin SMU and GNDU (Figure 3-10 (a)), the SMU is set to the I mode (Current Source/Voltage Monitor) and the DUT's resistance is calculated using the specified current value and the measured voltage value. When the DUT's resistance is low, the residual resistance (r1+r2) adversely affects the measurement result. When a Kelvin SMU and non-Kelvin GNDU (Figure 3-10 (b)) is used, and when the voltage monitor input impedance is high enough, only the residual resistance (r2) affects the measurement result. Point A stays at some non-zero voltage because of r2. When the voltage at point A is 0V, the measurement is satisfactory regardless of the effects of r1 and r2. When the Kelvin GNDU is connected as in Figure 3-10 (c), the GNDU regulates point A to 0V through the use of feedback.

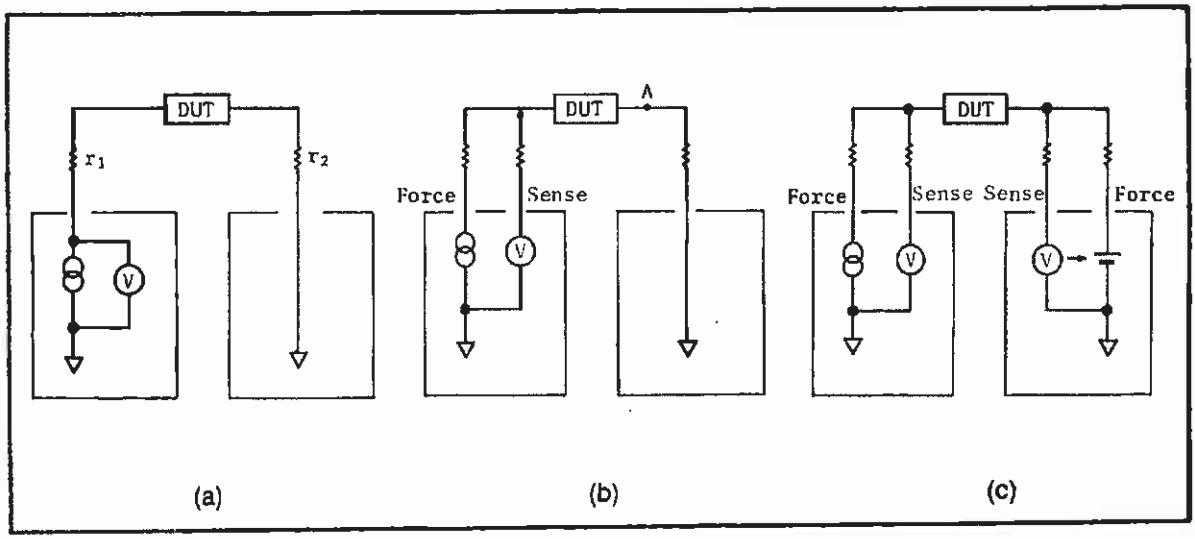



Figure 3-10. Kelvin Connections

## 3-10. GUARDING

When you are making low-current measurements (SMU set to current monitor), guarding helps to reduce the effects of leakage current. In the current measurement example without guarding (Figure 3-11a), when the insulation resistance between the current path and ground line is low, the resultant leakage current will affect the measurement result. When guarding techniques are used (Figure 3-11b), the the effects of leakage will be cancelled. Leakage current does not flow between the current path and the guard terminal because the guard terminal's voltage is held at the same potential as the SMU's output voltage, and the the leakage current between the guard terminal and ground line does not affect the measurement result. (See Figure 3-12, SMU output terminal configuration).

**WARNING**

**THE GUARD POTENTIAL IS THE SAME AS THE SMU'S OUTPUT POTENTIAL. THEREFORE, DO NOT TOUCH THE GUARD TERMINAL WHILE A MEASUREMENT IS IN PROGRESS.**

Note

Do not connect the guard terminal to any of the Sense, Force, or Common terminals.

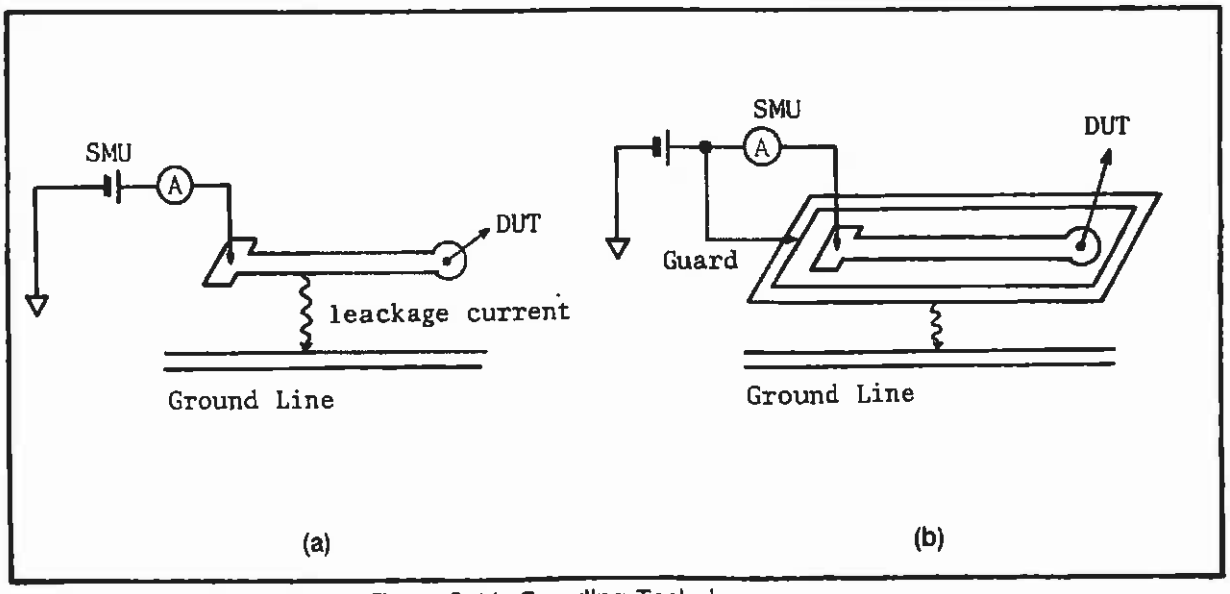



Figure 3-11. Guarding Techniques

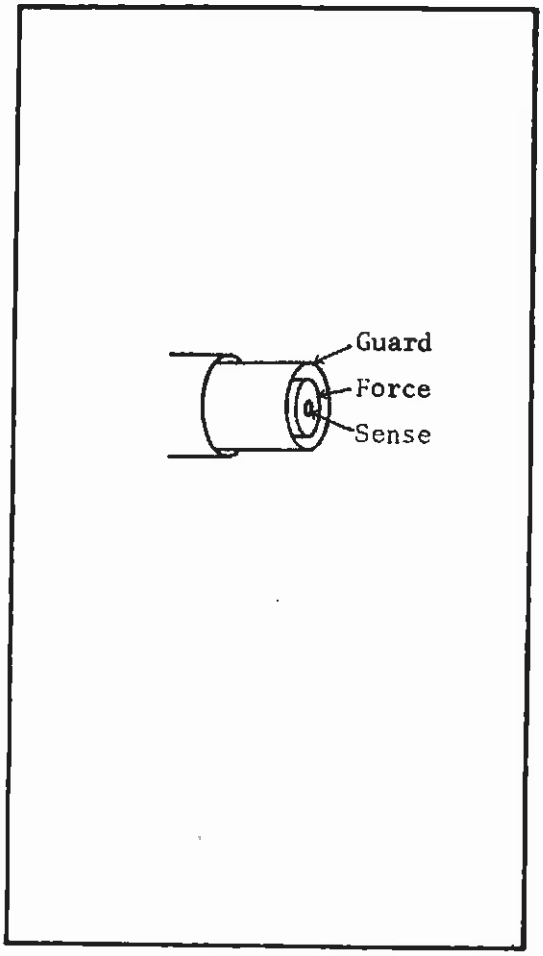



Figure 3-12. SMU Output Terminal Configuration

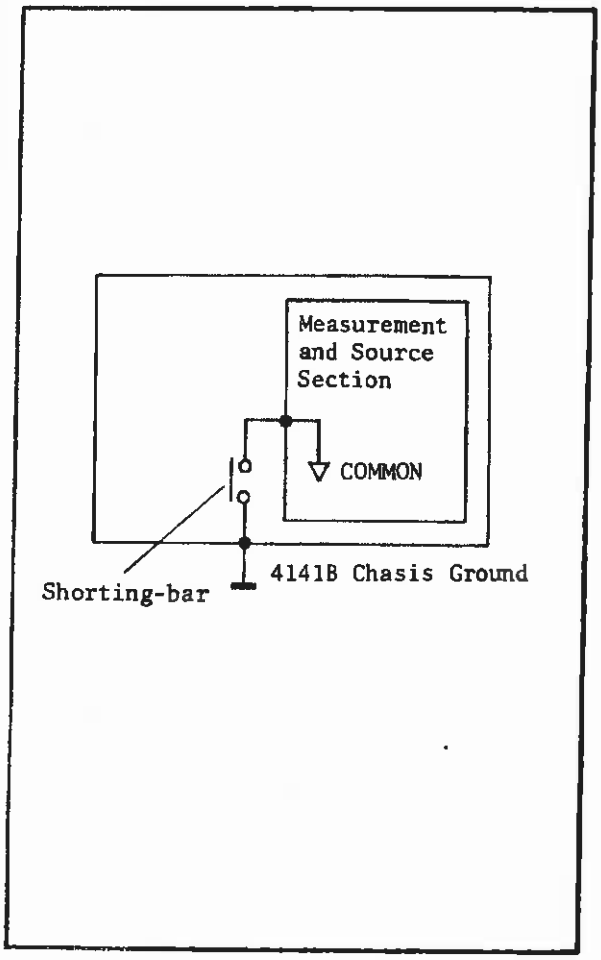



Figure 3-13. COMMON-GROUND Terminal

## 3-11. FLOATING MEASUREMENTS

When the DUT is grounded or the DUT's external voltage source or shield case is grounded, the measurement results can sometimes be affected by ground loops. Therefore when using the 4141B for floating measurements, disconnect the shorting bar on the rear panel (Figure 3-13). The measurement and source circuit can be floated ±42V above chassis ground and a voltage of over ±42V can be obtained at the COM (common) terminal.

### WARNING

**A POTENTIAL SHOCK HAZARD MAY RESULT IF THE COMMON TERMINAL IS NOT GROUNDED (SHORTING-BAR DISCONNECTED). THEREFORE, REGARDLESS OF THE OUTPUT VOLTAGE, DO NOT TOUCH THE COMMON TERMINAL ( ⏚ ) OR ANY OF THE OUTER-CONDUCTORS OF THE GNDU, INTERLOCK TERMINAL, VS, OR VM CONNECTORS WHILE A FLOATING MEASUREMENT IS IN PROGRESS.**

### CAUTION

**DO NOT FLOAT THE COMMON TERMINAL AT VOLTAGES ABOVE ±42V REFERENCED TO CHASSIS GROUND.**

## 3-12. INTEGRATION TIME

Three integration times can be selected via HP-IB to prevent line frequency and other noise sources from affecting the measurement accuracy, The following is a description of each:

SHORT: Four samples are taken independent of line frequency and averaged.

MEDIUM: Sixteen samples are taken during one line frequency period and averaged.

LONG: 256 samples are taken during 16 line frequency periods and averaged.

When the 4141B is turned on, the default integration time selection is SHORT.

## 3-13. SELF CALIBRATION

To minimize output drift and measurement fluctuations (caused primarily by changes in the ambient temperature), the 4141B enables self-calibration of the SMUs and their control circuits (A/D and D/A converters). Long or short self-calibration can be selected. Allow for a 40 minute warmup time before performing the 4.2 second long self-calibration. The long self-calibration is usually performed after instrument turn on and the 0.6 second short-calibration is usually performed every thirty minutes, or if the ambient temperature changes by more than 3 °C (6 °F).

## 3-14. MEASUREMENT RANGES AND RESOLUTION

The measurement ranges and resolution of the SMUs and voltage monitors are given in Figure 3-14. An SMU's ranging function is dependent on the compliance setting. When under HP-IB control, the data is output as five digits for both current and voltage measurements.

SMU Voltage Output:
Output can be selected in ranges of 20V, 40V, or 100V.

SMU Voltage measurement:
Auto-ranging with the highest range depending on the specified voltage compliance.

SMU Current Output:
Auto-ranging and limited auto-ranging spans nine ranges from 1nA to 100mA.

SMU Current measurement:
Auto-ranging and limited auto-ranging spans nine ranges from 1nA to 100mA.

Vs Output:
Only the 20V range is available.

VM Measurement:
Auto-ranging over the 2V and 20V ranges, or a fixed 20V range.

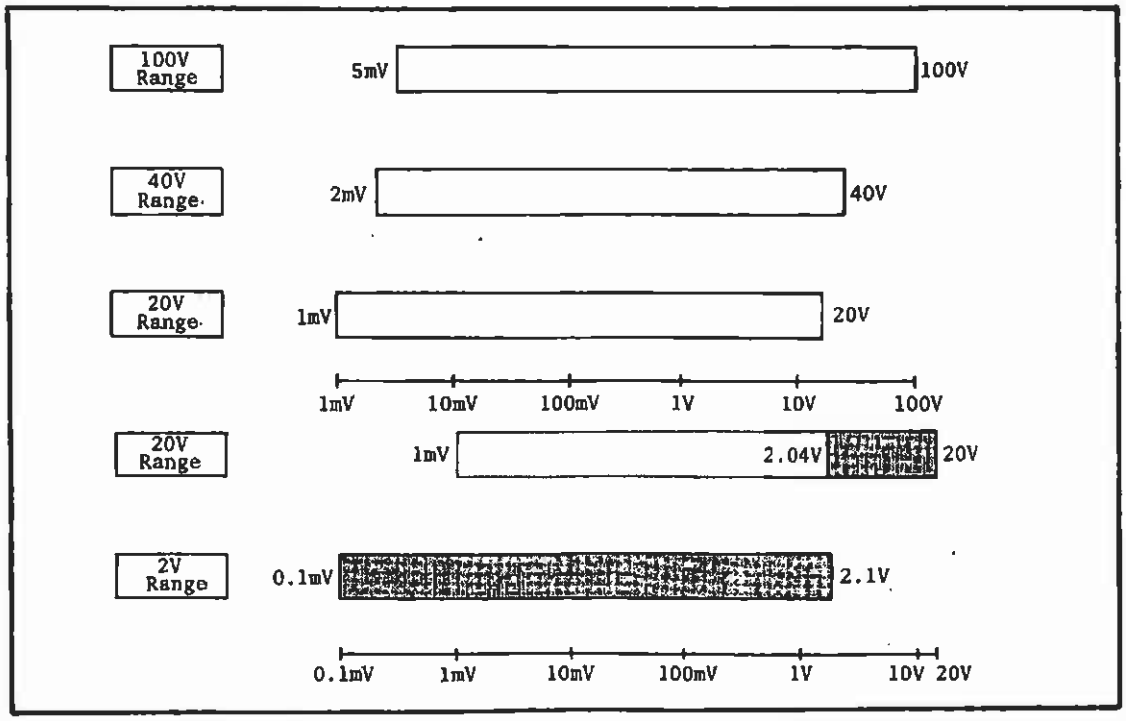



Figure 3-14. Measurement Range and Resolution (Sheet 1 of 2)

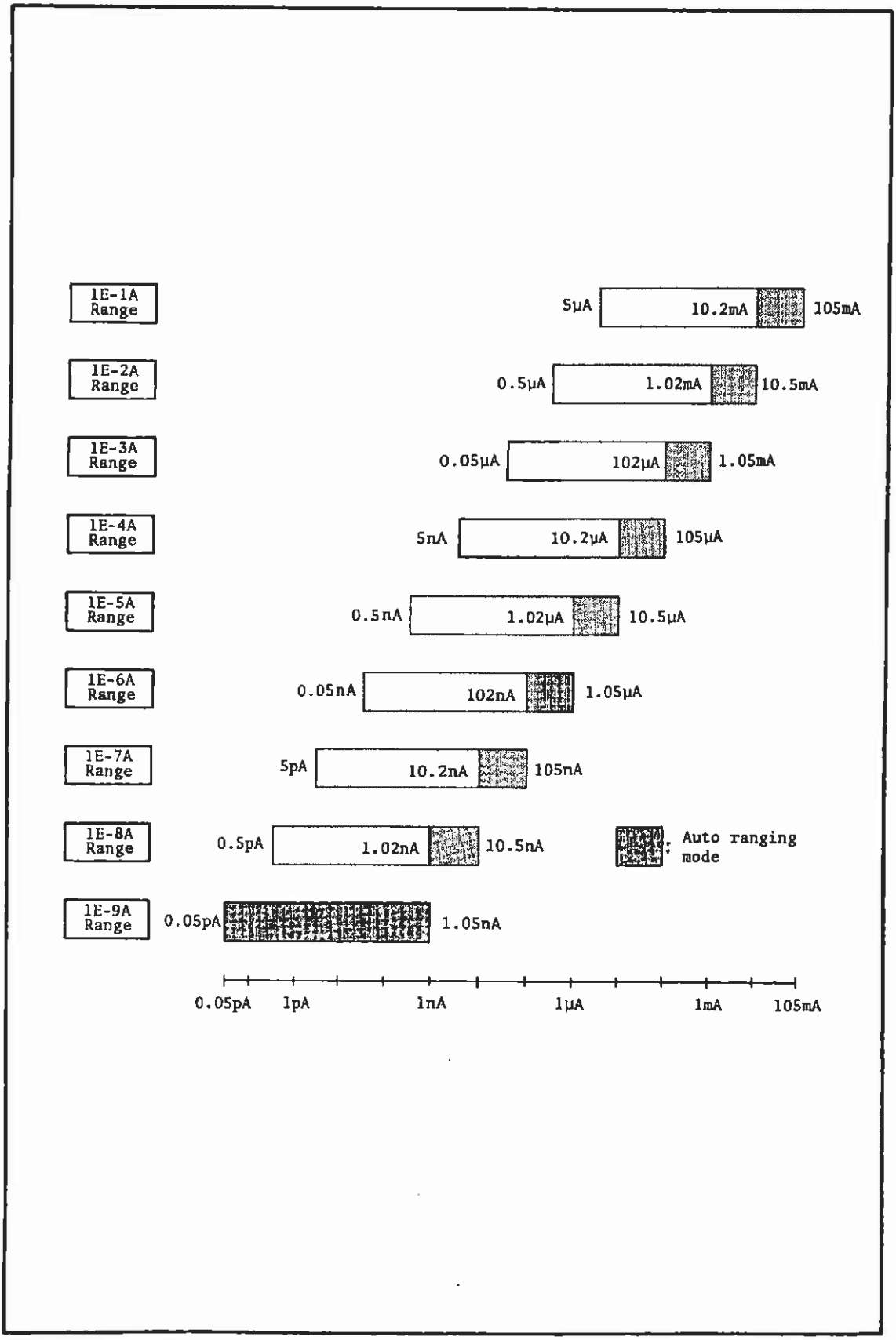



Figure 3-14. Measurement Range and Resolution (sheet 2 of 2)

## 3-15. SPOT MEASUREMENT

The output of the SMUs and VSs can be kept constant and can be measured by triggering the specified monitor channels. Internal or external triggering can be selected, each of which is described below:

Internal Trigger:
Triggering automatically with specified monitor channel at 0.3 second intervals.

External Trigger:
Triggering with the specified monitor channel each time a trigger command ("XE","TV",or"TI") is sent via HP-IB.

## 3-16. SWEEP MEASUREMENT

The SMUs and voltage sources (VSs) outputs can be swept as a staircase function (Figure 3-15). In the HP-IB mode a sweep setup command is sent with the following sweep parameters.

START: The starting value of voltage or current value when a sweep begins

STOP: The end value of voltage or current when a sweep stops

STEP: The sweep increment or decrement value specified in the LINEAR SWEEP MODE only.

SWEEP MODE: LINEAR or LOG. In the LINEAR mode, the output is swept linearly according to the specified STEP value; with the maximum number of steps set at 1021. The 4141B stores 1021 points of measurement data. In the LOG mode, the STEP value in [dB] can be up to 20 dB with a resolution of 0.2dB.

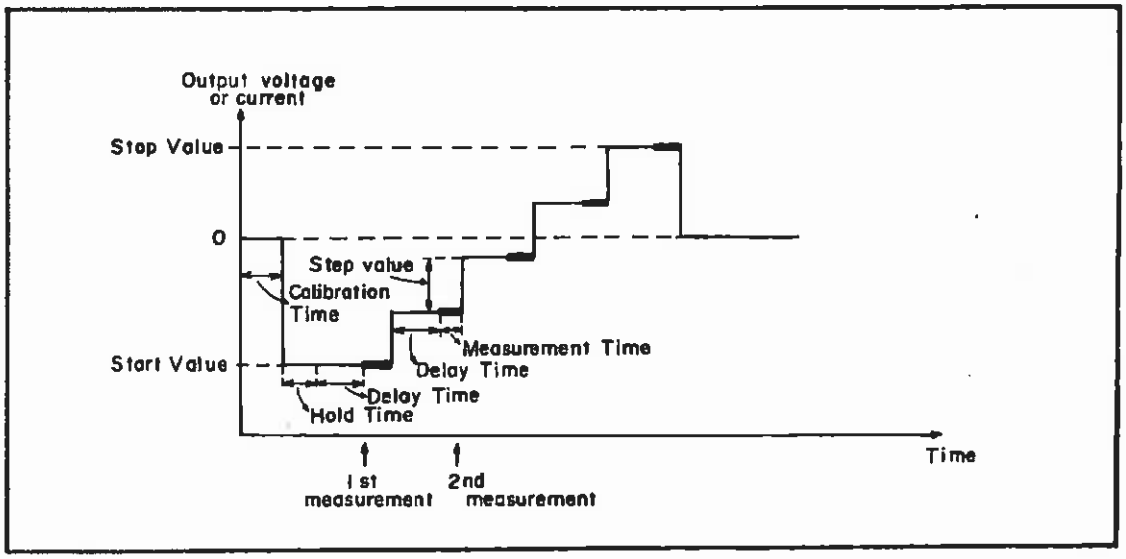



Figure 3-15. Staircase Sweep Output

Of the six source channels (four SMUs and two voltage sources), the only two channels, which can be swept simultaneously, are the primary sweep channel and the secondary sweep channel. The secondary sweep channel must differ from the primary sweep channel, but the sweep mode (LINEAR or LOG), source mode (I or V), and the number of steps must agree. The start, stop, and compliance values, however, may differ.

## 3-17. MEASUREMENT TIME

Measurement time is defined below. The times given are not guaranteed, and are intended only for reference. They are obtainable using an HP 9000 Series 200/300 Computer and the BASIC language system.

(1) Sweep Measurement

Measurement Time = Overhead Time + (Response Time + Ranging Time + Integration Time)/ point

*Overhead Time: Interprets sweep command at 80 to 200ms

*Response Time: The following calculation applies when the current range does not change. The response time consists of the settling time, setup time, HP-IB and SMU wait times.

| Current Range | Setting, Set-up, HP-IB Time | SMU Wait Time |
|---|---|---|
| 100nA to 100mA | 3.8ms | 2ms |
| 1nA to 10nA | | 30ms |

*Ranging Time: 0 to 196ms

Measurement Time/ point

| Settling, Set-Up and HP-IB Time | Delay Time | SMU Wait Time | Ranging Time | Integration Time |
|---|---|---|---|---|
| 3.8 ms | Setting value | 2ms or 30ms | 0ms to 196ms | 1.4ms to 320ms |

Example: For the minimum measurement time, the current range does not change:

$= 80 + (3.8 + 2 + 1.4) \times$ (Number of steps)

(2) Spot Measurement

Measurement Time: Forcing Time + Measuring Time

* Forcing Time

| Overhead, HP-IB | SMU wait time | Ranging time |
|---|---|---|
| 23ms | 2ms or 30ms | 0ms to 196ms |

*Measurement Time

| Settling, Set-up and HP-IB | SMU Wait Time | Ranging Time | Integration Time |
|---|---|---|---|
| 30ms | 2ms or 30ms | 0ms to 196ms | 1.4ms to 320ms |

Example: For the minimum measurement time, the current range does not change:

= ( 23 + 2 ) + ( 30 + 2 + 1.4 ) = 58.4ms

The measurement techniques explained below minimize or eliminate range changes during high speed measurements. To exemplify these techniques, see Sample Program 5.

1) Eliminate Range Changes

The simplest and most effective way to reduce the measurement time is to fix the force and monitor ranges to eliminate range changes from occurring during a measurement. For example, to source from 1µA to 10mA using the "DI" command, specify the 10mA (10.000mA) range in the command, since it provides 1µA resolution and 10mA full-scale capability. Similarly, to trigger a current measurement, fix the required current monitor range and the measurement resolution using the "RI" command. Set the "DV" or "WV" command's current compliance to a value within the current monitor range specified in the "RI" command because the current monitor range is determined by the compliance value specified.

2) Minimize Range Changes and Avoid Using "Slow" Ranges

If the resolution requirements prevent using a fixed range, then limit the number of range changes that can occur during the measurement. This can be done by specifying a range of ranges with regard to the compliance settings.

Measurement time depends on the current range set: the lower the current range, the longer a measurement will take. If measurement speed is more important than resolution, use the higher current ranges.

The following table lists range changing times. If more than one range change is required, total ranging time is the sum of the times required for each range change. For example, to change from the 10mA range to the 1µA range will require 13 + 21 + 13 + 25ms = 72ms.

| 100mA | 10mA | 1mA | 100µA | 10µA | 1µA | 100nA | 10nA | 1nA |
|---|---|---|---|---|---|---|---|---|
| 22ms | 13ms | 21ms | 13ms | 25ms | 14ms | 70ms | 58ms | |

## 3-18. DUT CONNECTIONS

DUTs can be connected to the 4141B using the Interconnect Cable Assembly (PN 04085-61651) and the four BNC cables for VSs, VMs or by using the 16059A Adaptor. The Interconnect Cable Assembly connects with the Connector Plate (PN 04141-60001). The 16059A Adapter enables connection of the 16058A Test Fixture. Connection using the furnished Connector Plate is described in paragraph 3-19 and connection using the 16058A is described in paragraph 3-20.

**WARNING**

**DO NOT USE THE TRIAXIAL CABLES DIRECTLY BECAUSE A POTENTIAL SHOCK HAZARD EXISTS IN THE OUTER CONDUCTOR (GUARD).**

## 3-19. DUT Connection Using the Connector Plate

The furnished Connector Plate (PN 04141-60001) is for use with the Interconnect Cable Assembly (PN 04085-61651) and BNC Cables (PN 04145-61630). This Assembly has four triaxial connectors for the SMUs, one triaxial connector for the GNDU, and one BNC connector for the Interlock. Four BNC cables for the VSs and VMs are intended for use with user-fabricated test fixtures. For the best measurement results, enclose the test fixture in a shielding-box and mount the Connector Plate onto the box, as shown in Figure 3-16. This will significantly reduce the effects of RFI and EMI. This is especially important when making low-current measurements of wafers at a probe station. To connect the Connector Plate, shielding-box, and 4141B, see Figure 3-16.

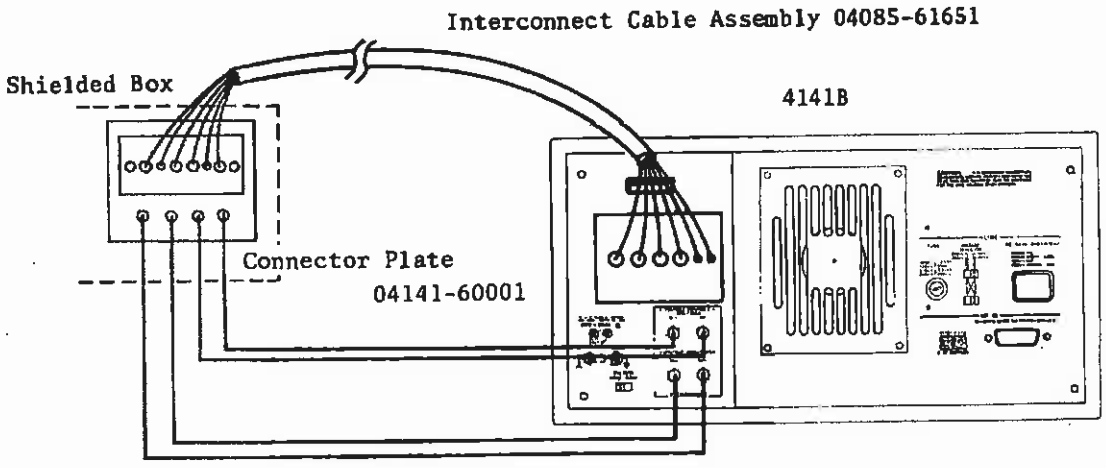
Mounting the Connector Plate and Connecting 4141B:

1. Drill holes to mount the Connector Plate onto the shielding-box. (See spacing in Table 1-3).
2. Mount the Connector Plate on the shielded-box, and ensure that there is good electrical contact between the plate and shielded-box.
3. Turn the 4141B off.
4. Connect 4141B to Interconnect Cable Assembly (PN 04085-61651), and connect the four BNC cables (PN 041415-61630) to the Connector Plate as shown in the following figure.

Note

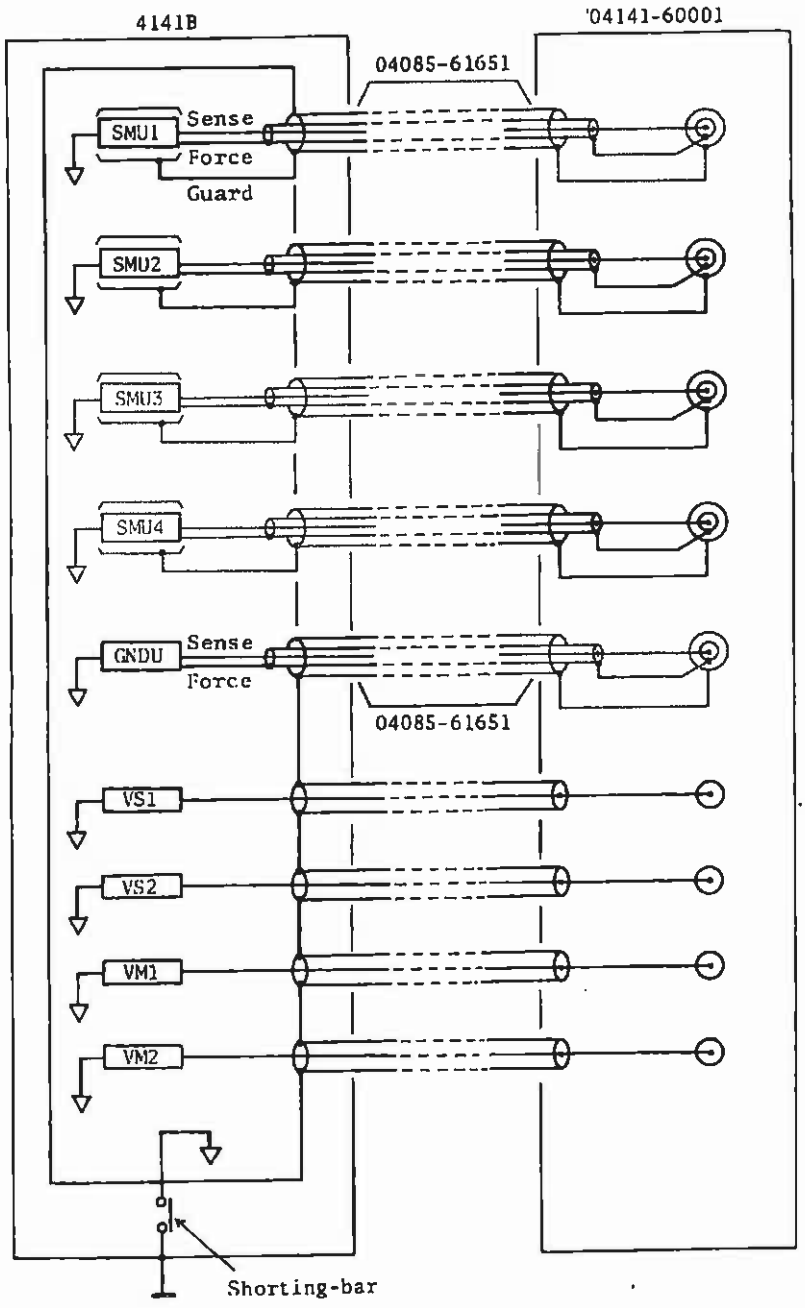
When the Interconnect Cable Assembly is connected to the Connector Plate, the output of the SMUs is limited to ±42V as if the 4141B is detecting the fixture-lid-open condition. Short the INTERLOCK terminal USING A 0Ω to get an output of up to ±100V.

Figure 3-16. DUT Connection Using the Connection Plate (sheet 1 of 4)




The figure on the opposite page shows the connections between the 4141B and the furnished Connector Plate.

Figure 3-16. DUT Connection Using the Connector Plate (sheet 2 of 4)




5. Turn the 4141B on and make the required connection for the measurement setup.

**WARNING**

**A POTENTIAL SHOCK HAZARD EXISTS WHEN INTERCONNECTION CABLE (PN 04085-61651) IS CONNECTED TO CONNECTOR PLATE. THEREFORE, DO NOT TOUCH THE OUTPUT TERMINAL OR THE OUTER CONDUCTOR OF THE SMUs WHILE A MEASUREMENT IS IN PROGRESS.**

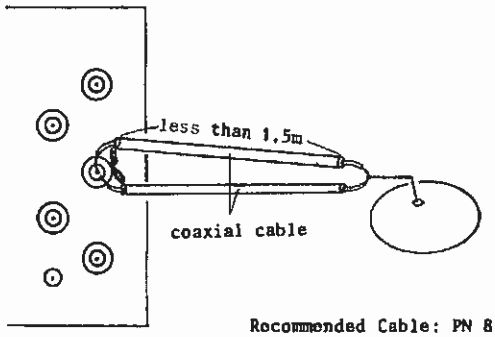
Figure 3-16. DUT Connection Using the Connector Plate (sheet 3 of 4)

Note

Do not connect the outer shield (guard) of an SMU to ground ( ⊥ ) or common ( ⏚ ).

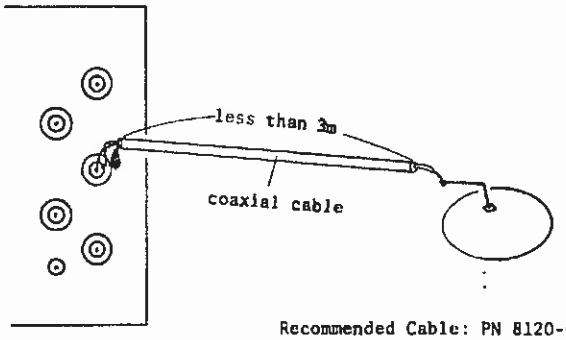
[Cable Connection from Connector Plate]

1) For the best measurement results, use two separate leads for extending cables to a wafer prober in order to maintain the Kelvin connection. Use the low-noise coaxial cables, PN 8120-0102 or 8120-3674 cable (See the following Figure). Connect the center conductor of one cable to SENSE, connect the other cable to FORCE and connect the outer conductors (shields) of both cables to GUARD. The outer conductors of these cables need not be connected at the wafer prober. To prevent oscillations when making dc measurements, do not use a cable whose length exceeds 1.5m.




Recommended Cable: PN 8120-0102 or
PN 8120-3674

2) The cable length can be increased to 3m using a single cable and shorting SENSE to FORCE at the Connector Plate, as in the following Figure. Since this connection is not a Kelvin connection, the measurement results will include the residual resistance of the connection cable and will be affected by environmental noise.




Recommended Cable: PN 8120-0120 or
PN 8120-3674

The cables will cause significant errors, so do not make low current measurements using the Connector Plate.

Figure 3-16. DUT Connection Using the Connector Plate (sheet 4 of 4)

## 3-20. DUT Connection Using the 16058A

The 16058A Test Fixture is designed to connect packaged devices, such as transistors, diodes and ICs, to the SMUs, voltage sources and voltage monitors of the 4141B. Eight interchangeable DUT Socket Boards are furnished with the 16058A. Use the 16059A Adaptor which is designed for connections between the 4141B and 16058A. Connection between the 16058A and the 4141B is shown in Figure 3-17.

Note

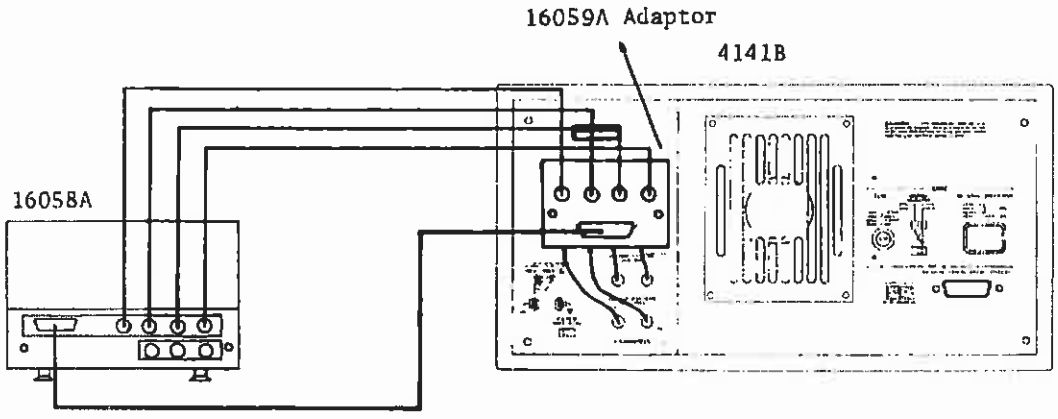
The Ground Unit in the 4141B cannot be connected to the 16059A because there is no connection for the Ground Unit on the 16058A.

Note

The 16059A cannot be used for Kelvin connections because it is designed for use with the 16058A which does not use Kelvin connections.

To connect the 16058A

1. Turn the 4141B off.
2. Connect the 16059A to the 4141B.
3. Connect the 16058A to 16059A as shown below. Use the System Cable (PN 16058-61604) furnished with the 16058A and the triaxial cables (PN 16058-61603). The System Cable includes the VS lines, VM lines, and a fixture-lid-open detection line.




4. Select a DUT socket board and connect the SMU, VS and VM terminals to the terminals on the DUT socket board.

Figure 3-17. DUT Connection Using the 16058A (sheet 1 of 3)

5. Turn the 4141B on and make the connections for the measurement setup.

6. Close test fixture lid and perform the measurement.

Note

If the output voltage of an SMU or VS will exceed ±42V during measurement, close the test fixture lid to start the measurement. If an attempt is made to start the measurement while the test fixture lid is open, the 4141B will generate an SRQ signal that indicates the 4141B is not interlocked and the measurement will not start.

Note

If test fixture lid opens while a measurement is in progress and the output voltage is greater than ±42V, the measurement will stop immediately and all SMU's and VS's outputs will be set to zero just as if an "DZ" command had been sent.

Figure 3-17. DUT Connection Using the 16058A (sheet 2 of 3)

The following figure shows the connections between the 4141B and the 16059A Adapter.

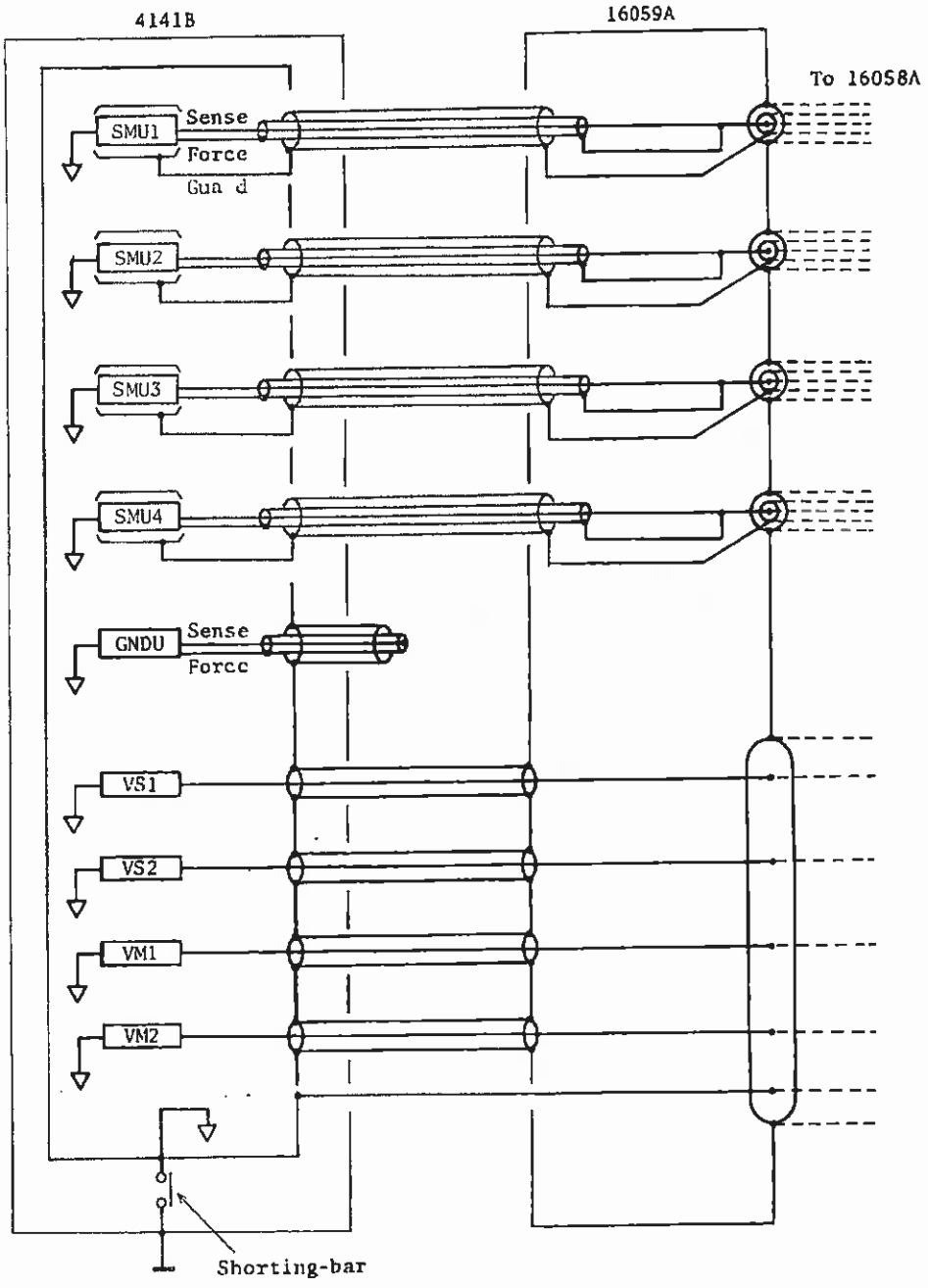



Figure 3-17. DUT Connection Using the 16058A (sheet 3 of 3)

## 3-21. HP-IB INTERFACE

The 4141B can be remote controlled via the HP-IB instrument/computer interface.

Note

HP-IB is Hewlett-Packard's implementation of IEEE Standard 488, "Standard Digital Interface for Programmable Instrumentation."

## 3-22. HP-IB INTERFACE CAPABILITIES

The 4141B has eight HP-IB interface functions. (See list in Table 3-3).

Table 3-3. HP-IB Interface Capability

| Code | Interface Function * (HP-IB Capabilities) |
|---|---|
| SH1** | Source Handshake |
| AH1 | Acceptor Handshake |
| T6 | Talker (basic talker, serial poll, unaddress to talk if addressed to listen) |
| L4 | Listener (basic listener, unaddress to listen if addressed to talk) |
| SR1 | Service Request |
| RL1 | Remote/local (with local lockout) |
| DC1 | Device Clear |
| DT1 | Device Trigger |

* Interface functions provides the means for a device to receive, process, and transmit messages over the bus.

** The numeric suffix of the interface code indicates the limitation of the function, as defined in Appendix C of IEEE Standard 488-1978.

## 3-23. HP-IB CONNECTION

The 4141B can be connected to the HP-IB bus with or without a controller.

## 3-24. HP-IB STATUS INDICATORS

The four HP-IB Status Indicator LED lamps on the front panel will light to show the status of the 4141B on the HP-IB bus as follows:

SRQ: SRQ SIGNAL FROM 4141B to controller on the HP-IB line. Refer to paragraph 3-30.

LISTEN: 4141B set to listener.

TALK: 4141B set to talker.

REMOTE: 4141B is in the remote mode.

## 3-25. REMOTE PROGRAM CODES AND PARAMETER SETTINGS

The available remote program codes and parameter settings are briefly described in Table 3-4, and detailed format information is given below.

### REMOTE PROGRAM CODE FORMAT

Remote program code sent to 4141B must be in upper case because the The 4141B ignores lower case characters.

(1) Delimiters

Commas, spaces, and carriage returns (CR, ASCII Code 13) separate (delimit) multiple commands and command operands. Delimiters are always ignored to prevent their influencing commands or program execution.

(2) Execution

The 4141B executes single commands and command strings when it receives a line terminator, a semicolon or a line feed (LF<ASCII Code 10). After command execution, the input buffer is cleared and the next command or command string is read into the buffer, and executed when a line terminator is encountered.

Note

Commands that require output data, such as "TV", "TI", "XE", "WS", "ID", or "TR", must be followed by a terminator if they are not the last command in a string, otherwise, a PROG ERROR SRQ message will be displayed. For example, the command string, "ID,XE", is illegal because the 4141B will try to execute both commands simultaneously. The correct format is "ID;XE". When executed, these commands will first clear the HP-IB output buffer and then fill it with new output data.

Note

Up to eight commands can be included in a command string, but the parameter buffer may overflow, even if the command string contains fewer than eight commands. When this happens, a PROG ERROR SRQ message will be displayed.

(3) Command Operand

| | |
|---|---|
| * Channel Number: | A one digit integer specifying an SMU, VS or VM. |
| * num_exp: | A one digit integer. |
| * value: | Numeric values can be entered in fixed or floating decimal format, with up to 12 digits including "+","-" and "E" being acceptable. The exponent can be no greater than two digits and leading zeros are ignored. For example, |

| | |
|---|---|
| Floating decimal: | 1.234E+01 |
| | 1.23456E-12 |
| Fixed decimal: | 1.234 |
| | -.123456 |

Note

Units for voltage, current and time are not needed when entering numeric values because these units are fixed as V (volts), A (amperes) and s (seconds).

* [ ] : Operands enclosed in brackets are optional, i.e., omissible.

* @ : @ indicates initial control setting. (This symbol need not be included in operands.)

Table 3-4. Remote Program Codes and Parameter Settings (sheet 1 of 13)

**(1) GENERAL CONTROL GROUP**

The following program codes control the 4141B's functions:

*** Clear all (CL)**

Initiallzes 4141B measurement function.

--- Turns off all SMUs (SMU 1 TO 4) [Sets all SMUs to NOT USE].
--- Turns off VS1 and VS2 [Sets VSs to ZERO OUTPUT].
--- Sets VM1 and VM2 to auto range,
--- Aborts the sweep in progress,
--- Sets integration time to short,
--- Sets HP-IB data output format to ASCII, and
--- Clears the HP-IB data buffer.

Syntax: CL

Note

NOT USE: This is the SMU's default setting. The output relays are open.

ZERO OUTPUT: The VS's default setting, 0V output.SMUs are also set to ZERO OUTPUT under certain conditions. When in ZERO OUTPUT status, the SMU has the following settings: Output relays are on, voltage source mode, 20V range, 0V output, 10μA current limit.

*** Test Start (TS)**

Initiates a SELF TEST.

Syntax: TS

*** Test Result (TR)**

Copies the SELF TEST results to the 4141B's output buffer. An ENTER command will read and display the contents of the output buffer.

Syntax: TR

*** Identification (ID)**

Copies DEVICE ID and software revision code to the output buffer. An ENTER command will read and display the contents of the buffer.

Syntax: ID

Table 3-4. Remote Program Codes and Parameter Settings (sheet 2 of 13)

*** Auto Callbration (CM)**

Enables or disables the auto calibration function and can not be performed unless all SMUs are set to NOT USE.

Syntax: CM num-exp

num-exp: 0: Auto calibration disabled
@1: Auto calibration enabled

*** Calibration (CA)**

Performs a calibration.

Syntax: CA num-exp

num-exp: 1: Executes a short calibration (0.6s).
2: Executes a long calibration (4.2).

*** Buffer Clear (BC)**

Clears the HP-IB output data buffer and sweep data buffer before outputting data from the 4141B. This command resets the DATA READY status bit.

Syntax: BC

*** Binary Data Format (BD)**

Selects the HP-IB data output format. Does not affect the data already stored in the HP-IB output buffer.

Syntax: BD num-exp

num-exp: @0: ASCII data output.
1: Binary data output.

*** Set Ready Mask (SS)**

Masks the Set Ready bit of the HP-IB status byte (Disables Set Ready RQS).

**Data Ready Mask (SD)**

Masks data ready bit of HP-IB status byte (Disables Data Ready RQS).

Table 3-4. Remote Program Codes and Parameter Settings (sheet 3 of 13)

**End Status Mask (SE)**

Masks the End Status bit of the HP-IB status byte (Disables End Status RQS).

Syntax: SS num-exp
SD num-exp
SE num-exp

num-exp: @0: Masks (Disables RQS)
1: Not mask (Enables RQS)

**(2) COMMON MEASUREMENT CONTROL GROUP**

The following program codes are used when making spot or sweep measurements.

*** Integration Time (IT)**

Determines 4141B's integration time.

Syntax: IT num-exp

num-exp: @1: SHORT
2: MEDIUM
3: LONG

*** VM Voltage Monitor Range (RV)**

Selects the voltage range of voltage monitors VM1 and VM2.

Syntax: RV Channel Number, num-exp

Channel Number: 1 or 5: VM1
2 or 6: VM2

num-exp: @0: Auto-ranging
1: 20V

Table 3-4. Remote Program Codes and Parameter Settings (sheet 4 of 13)

*** SMU Current Monitor Range (RI)**

Used to select the current monitor range of the specified SMU. The current monitor range is varied when SMU is set to voltage source/current monitor mode.

Note

The current range actually used is either the current range set by the RI command or the range most suitable for the compliance value specified with the "DV" or "WV" commands.

Syntax: RI Channel Number, num-exp

Channel Number: SMU number (1 to 4)

num-exp: 0 to 9, same as current output command (DI). Refer to the DI command in the spot measurement control group. Default setting is auto-ranging.

*** Monitor Channel (MC)**

Sets up a monitor channel. When a specified SMU is set to NOT USE, the "MC" command sets the SMU to ZERO OUTPUT.

Syntax: MC Channel Number, num-exp

Channel Number: SMU number (1 to 4), VM number (VM1 or VM2 corresponds to 5 or 6 respectively)

num-exp: @0: Measurement disabled
1: Measurement enabled

Note

The monitor range or channel set by an "RV", "RI" or "MC" command is valid only for an "XE" command, device trigger, internal trigger, and a sweep measurement. The "TV" and "TI" commands, always assume auto-ranging and cannot be used to trigger a measurement channel set by an "MC" command.

**(3) SPOT MEASUREMENT CONTROL GROUP**

The following program codes are used to make spot measurements.

Table 3-4. Remote Program Codes and Parameter Settings (sheet 5 of 13)

*** SMU and VS Voltage Output (DV)**

Enables an SMU and VS, and outputs the voltage specified.

Syntax: DV Channel Number [,num-exp, value1 [,value2] ]

Channel Number: SMU number (2 to 4), VS number (VS1 or VS2 corresponds to 5 or 6 respectively)

When only a channel number is specified, the SMU is set to NOT USE and the measurement is disabled just as if "MC#,0" had been sent, and the VS is set to ZERO OUTPUT.

num-exp:
- 0: auto-ranging
- 1: 20 V range (100mA max)
- 2: 40 V range (50mA max)
- 3: 100V range (20mA max)
- 4-9: previous range setting

When 4-9 is specified as an SMU set to NOT USE or to current source mode, a PROG ERROR SRQ is generated. When 5 or 6 is specified for the Channel Number, this parameter is ignored because a VS has a range of only 20V.

value1: source voltage value in [V]

The source voltage value must be within the range specified. The resolution of value1 depends on the range specified by the num-exp.

value2: current compliance value (optional) in [A]

When this parameter is omitted, the previous current compliance setting remains in effect. When a DV command without this parameter is sent to a NOT USE SMU or to an SMU set to a current source mode, a PROG ERROR SRQ is generated. When the channel number is set to 5 or 6, this parameter is ignored because a VS has no user definable current compliance function. The maximum output current depends on the range specified by the num-exp. The current compliance resolution depends on the current range being used.

*** VS Voltage Output (DS)**

Enables voltage source VS to output the specified voltage.

Syntax: DS Channel Number [, value]

Channel Number: VS number (1 or 2)

When only the channel number is sent, the VS is set to ZERO OUTPUT.

value: source voltage value in [V]

Value must not exceed ±20V.

Table 3-4. Remote Program Codes and Parameter Settings (sheet 6 of 13)

*** SMU Current Output (DI)**

Enables the SMU to output the specified current.

Syntax: DI Channel Number [, num-exp, value1 [,value2 ]]

Channel Number: SMU number (1 to 4).

When only the channel number operand is specified, the SMU is set to NOT USE and the measurement is disabled just as if "MC#,0" has been sent.

num-exp:
0: Auto-ranging
1: 1nA or higher (same as auto-ranging)
2: 10nA or higher
3: 100nA or higher
4: 1µA or higher
5: 10µA or higher
6: 100µA or higher
7: 1mA or higher
8: 10mA or higher
9: 100mA

When the num-exp is 1 to 8 inclusive, the SMU is set to the limited auto-ranging mode. When value1 exceeds the specified range the SMU up-ranges to the appropriate range. The value cannot exceed ±100mA on any range.

value1: source current value in [A]

The Resolution of value1 depends on the output range in use.

value2: voltage compliance value (optional) in [V]

When this parameter is omitted, the previous voltage compliance setting remains in effect. When a "DI" command without this parameter is sent to a NOT USE SMU or to an SMU that set to the voltage source mode, a PRG ERROR SRQ is displayed. The maximum output voltage depends on the range specified by the num-exp. The voltage compliance resolution depends on the voltage range in use.

*** Zero Output (DZ)**

Sets any SMU and VS to ZERO OUTPUT.

Syntax: DZ Channel Number

Channel Number:
0: all channels
1-4: SMU 1-4
5-6: VS1, VS2

When this command is sent, the range setting and the current compliance value for the SMU are changed to auto-ranging and 10µA.

Table 3-4. Remote Program Codes and Parameter Settings (sheet 7 of 13)

*** Trigger Mode (TM)**

Selects internal or external trigger.

Syntax: TM num-exp

num-exp: @0: External
1: Internal

Internal trigger works as if an "XE" command had been sent in an 0.3 second interval.

This command is valid only for SMUs or VMs assigned to measure by "MC" command.

*** Trigger (XE)**

Triggers a multi-channel measurement. The voltage source mode SMU measures current and the current source mode SMU measures voltage.

Syntax: XE

Only SMUs and VMs assigned to measure by an "MC" command can perform a measurement

*** Trigger V Measurement (TV)**

Triggers a single-channel voltage measurement.

Syntax: TV Channel Number

Channel Number: SMU number (1 to 4), VM number (VM1 or VM2 corresponds to 5 or 6 respectively).

*** Trigger I Measurement (TI)**

Triggers a single-channel current measurement.

Syntax: TI Channel Number

Channel Number: SMU number (1 to 4)

**(4) SWEEP MEASUREMENT CONTROL GROUP**

The 4141B can sweep the output of two channels simultaneously. One channel is called the "primary sweep" channel and the other is called the "Secondary sweep" channel. The sweep mode (linear or log), source mode (I or V), and the number of steps must be the same. Start, stop, and compliance values however may differ. For the following the program codes, the primary sweep parameters first used must be specified using a "WV" or "WI" command and the secondary sweep parameters using a "WP" command.

Table 3-4. Remote Program Codes and Parameter Settings (sheet 8 of 13)

*** Voltage Sweep Setup (WV)**

Sets the primary sweep channel and sweep parameters for a voltage sweep.

Syntax: WV Channel Number [,num-exp1, num-exp2, value1, value2, value3 [,value4]]

Channel Number: SMU number (1 through 4), VS number (VS1 or VS2 corresponds to 5 or 6 respectively).

When only the channel number operand is sent, the previous primary sweep parameter settings are used, that is, only the primary channel changes. When no valid voltage sweep parameter exists, a PROG ERROR SRQ is generated.

num-exp1: 1: Linear sweep
2: Log sweep

num-exp2: 0: Auto-ranging
1: 20V range
2: 40V range
3: 100V range

When the channel number is 5 or 6, this parameter is ignored because the VS is automatically set to the 20V range.

value1: sweep start voltage in [V]
value2: sweep stop voltage in [V]

When the channel number is from 1 to 4, value1 must be within the range specified by num-exp2. If the channel number is 5 or 6, value1 must not exceed ±20V.

value3: sweep step value

When num-exp1 is 1, the step value is specified in [V]

When num-exp1 is 2, the step value must be specified in [dB] up to 20dB with a resolution of 0.2dB, and the signs of value1 and value2 must be the same. The maximum number of steps is 1021. Therefore, 4141B can store 1021 data points for each measurement channel in the output data buffer.

value4: current compliance value (optional) in [A]

When this parameter is omitted, the previous current compliance settings are used. When a WV command without the current compliance parameter is sent to the NOT USE SMU or to the current source mode SMU, a PROG ERROR SRQ is generated. The maximum output power is calculated using value1 and value2. When the output power exceeds 2 watts, a PROG ERROR SRQ is generated and the sweep is disabled. When the channel number is 5 or 6, this parameter is ignored because a VS has no user definable current compliance function.

Table 3-4. Remote Program Codes and Parameter Settings (sheet 9 of 13)

Note

The "WV" command clears all secondary sweep parameters. Therefore this command must precede the secondary sweep declaration.

Note

The actual stop voltage, equal to the start voltage value plus the accumulated step values, may exceed value2 because of rounding error and the instrument's finite measurement resolution.

*** Current Sweep Setup (WI)**

Sets the primary sweep channel and sweep parameters for the current sweep.

Syntax: WI Channel Number [, num-exp1, num-exp2, value1, value2, value3 [, value4]]

Channel Number: SMU number (1 to 4)

When only the channel number operand is sent, the previous primary settings are used and only the primary sweep channel is changed. When no valid current sweep parameters exists, a PROG ERROR SRQ is generated.

num-exp1:
1: Linear sweep
2: Log sweep

num-exp2:
0: Auto-ranging
1: 1nA or higher (same as auto-range)
2: 10nA or higher
3: 100nA or higher
4: 1µA or higher
5: 10µA or higher
6: 100µA or higher
7: 1mA or higher
8: 10mA or higher
9: 100mA

When num-exp1 is 1 (linear sweep), the auto-ranging function selects the optimum range for the entire sweep.

When num-exp1 is 2 (log sweep), the instrument will up-range or down-range as necessary.

value1: sweep start current in [A]

value2: sweep stop current in [A]

value3: sweep step value

Table 3-4. Remote Program Codes and Parameter Settings (sheet 10 of 13)

When num-exp1 is 1, the step value is in [A]

When num-exp1 is 2, the step value is in [dB], up to 20dB with a resolution of 0.2dB resolution.

The maximum number of steps is 1021. The 4141B will store the data for each point in the output data buffer.

value4: voltage compliance value (optional) in [V]

When this parameter is omitted, the previous voltage setting will be used. When the "WI" command is sent to a NOT USE SMU, or to an SMU set as a voltage source without the voltage compliance operand, a PROG ERROR SRQ is generated.

The maximum output power is calculated using value1 and value2. When the output power exceeds 2 watts, a PROG ERROR SRQ is generated and the sweep is disabled.

Note

The "WI" command clears all secondary sweep parameters. Therefore, this command must precede the secondary sweep declaration.

Note

The actual stop current, equal to the start current plus the accumulated step values, may exceed value2 because of rounding errors and finite resolution.

*** Secondary Sweep Setup (WP)**

Sets up the sweep parameters for a secondary sweep. Secondary sweep channel must differ from primary sweep channel specified by the "WV" or "WI" command. When only the Channel Number operand is sent, the previous secondary sweep parameter settings are used, only secondary sweep channel changes. When no valid secondary sweep parameters exists, a PROG ERROR SRQ is generated.

Syntax: WP Channel Number [, num_exp, value1, value2 [,value3] ]

Table 3-4. Remote Program Codes and Parameter Settings (sheet 11 of 13)

**Case 1** Primary sweep channel is specified by "WV" command (voltage sweep).

Channel Number: SMU number (1 to 4), VS number (VS1 or VS2 corresponds to 5 or 6 respectively). When 0 is specified, the secondary sweep is disabled.

num_exp: 0: Auto-ranging
1: 20V range
2: 40V range
3: 100V range

The auto-ranging function selects the optimum range for the entire sweep.

value1: sweep start voltage in [V]

value2: sweep stop voltage in [V]

value3: current compliance value (optional) in [A]

When the Channel Number is 5 or 6, this parameter is ignored because VS has no user definable current compliance function.

**Case 2** Primary sweep channel is specified by the "WI" command (current sweep).

Channel Number: SMU number (1 to 4). If 0 is specified, the secondary sweep will be disabled.

num_exp: 0: Auto-ranging
1: 1nA or higher
2: 10nA or higher
3: 100nA or higher
4: 1µA or higher
5: 10µA or higher
6: 100µA or higher
7: 1mA or higher
8: 10mA or higher
9: 100mA or higher

When num_exp is 1 (linear sweep), the auto-ranging function selects the optimum range for the sweep. If num_exp is 2 (log sweep), however, the range changes as necessary.

value1: sweep start current in [A]

value2: sweep stop current in [A]

value3: voltage compliance value (optional) in [V]

Table 3-4. Remote Program Codes and Parameter Settings (sheet 12 of 13)

Note

The sweep mode (linear/log), source mode (I/V) and the number of steps of the secondary sweep must be the same as those of the primary sweep. The step value is calculated from value1, value2, and the number of steps. If the log sweep mode is specified, the sign of value1 and value2 must be the same. The actual step value is equal to the start value plus the accumulated step values, and may exceed value2 because of rounding errors and the instruments finite measurement resolution.

Note

If the value3 parameter is omitted, the previous current/voltage compliance settings will be used, and the SMU specified by the channel number will be set to voltage/current source mode. If a "WP" command without this parameter is sent to a NOT USE SMU or an SMU set to current/voltage source mode, a PROG ERROR SRQ will be generated.

Note

The maximum output power is calculated using value1 and value2. If the output power exceeds 2 watts, A PROG ERROR SRQ will be generated and the secondary sweep will be disabled.

*** Sweep Point Output (WN)**

Returns number of sweep points data available for output.

Syntax: WN

*** Hold Time (WH)**

Sets sweep hold time.

Syntax: WH value

Value: The maximum hold time is 655.35 [sec] with a resolution of 0.01 [sec], and the sign is ignored.

*** Step Delay Time (WT)**

Sets step delay time.

Syntax: WT value

value: The maximum step delay time is 655.35 [sec] with a resolution of 0.01sec, and the sign is ignored.

Table 3-4. Remote Program Codes and Parameter Settings (sheet 13 of 13)

**Note**

If the hold/step delay time exceeds 655.35 seconds, a PROG ERROR SRQ will be generated. The Hold/Step Delay time is initialized to zero (minimum) when the power is turned on and when the 4141B receives a Device Clear command.

*** Sweep Start (WS)**

Starts sweep measurement and sels output data formula

num_exp: 0: Sweep source data not returned
1: Primary sweep source data returned
2: Secondary sweep source data returned

A valid sweep parameter set must be set before entering the "WS" command.

*** Sweep Abort (WB)**

Aborts the sweep measurement.

Syntax: WB

Once a sweep is aborted using this command, all outputs are disabled as if the sweep had finished normally.

**[ PROGRAMMING ERROR ]**

The 4141B generates a PROG ERROR SRQ to inform the controller that the 4141B cannot execute commands because of a syntax error in the operand, or that the 4141B has received an illegal program code.

When a PROG ERROR SRQ is generated, the PROG ERROR and RQS bits of the status byte are set and:

1. The SMU and VS settings, measurement range settings, measurement channel assignments, and the sweep parameter settings are not affected.
2. The sweep measurement is not affected while in progress, and can be continued.
3. The HP-IB input buffer is cleared of all commands.
4. The Sweep data buffer and HP-IB output buffer are not affected.

## 3-26. DATA OUTPUT

The 4141B outputs measurement and status data to external devices via HP-IB using the ASCII (American Standard Code for Information Interchange) data format or the Binary data format. The self-test result and Device ID can be output. The output format appears in Table 3-5.

Table 3-5. Data Output Format (sheet 1 of 4)

**SELF TEST Result**

When the 4141B receives a "TR" (Test Result) command, the 4141B prepares to output the previous SELF TEST results.

Format:

S1 status S2 status S3 status S4 status (CR)(LF)

S1 to S4 correspond to SMU 1 to 4, respectively.

Status:
0: No error
1: V offset error
2: I offset error
3: I leak error
4: V range error
5: I range error
6: I-in offset error
7: Loop change detector error
9: Communication error

**Device ID**

When the 4141B receives a remote program code "ID" (Identification), it outputs an identification code.

Format:

ID HP 4141B REV. Revision code (CR)(LF)

Revision code: A 3-character revision number for identifying the 4141B's software.

Table 3-5. Data Output Format (sheet 2 of 4)

Measurement data and Sweep source data Format

(1) ASCII Data Format

Definition: Data= <status><channel><mode><value>

<status>
- N: Normal measurement data.
- T: Another (not assigned to measure) channel has reached compliance.
- C: This channel has reached compliance.
- X: This channel is oscillating.
- V: AD converter is saturated in voltage measurement. The <value> is +149.99E+00 or -149.99E+00.
- D: SMU shutdown (SMU will not output during a sweep).
- W: Sweep source data.
- E: Last sweep source data.

Priority --- E > W > D > V > X > C > T > N

<channel>
- A: SMU 1
- B: SMU 2
- C: SMU 3
- D: SMU 4
- E: VS1 OR VM1
- F: VS2 OR VM2
- G: SMU shutdown

<mode>
- I: Current data
- V: Voltage data

<value> 5 digit point decimal number in engineering format. When <status> is D, <value> is meaningless.

sn.nnnnEsnn
snn.nnnEsnn
snnn.nnEsnn

- s: sign + or -
- n: digit 0 → 9
- .: decimal point
- E: exponent sign

(1-1). Single channel measurement (response to "TV" and "TI")

Syntax: <data><CR><LF>

(1-2). Multichannel measurement (response to "XE" command, Internal trigger and Device trigger).

Syntax: <data>[,<data>[.....]]<CR><LF>

The number of <data> is specified with the "MC" command. <data> for SMU1 is first and <data> for VM2 is last.

Table 3-5. Data Output Format (sheet 3 of 4)

(1-3). Sweep measurement

Syntax: <block>[,<block>[.....]]<CR><LF>

<block>=[<data>[,<data>.....] ]

The amount of data is specified with the "MC" and "WS" commands. The <data> for SMU1 is output first and the <data> for VM2 is next to last. The last <data> is the sweep source value when it has been specified. The number of <block> is equal to the number of steps reported by the "WN" command, unless the sweep is aborted by a "WB" command or by SMU shutdown.

(2) Binary Data Format

Definition: b_data=<byte1><byte2><byte3><byte4>

<byte1>: status

| bit7 | bit6 | bit5 | bit4 | bit3 | bit2 | bit1 | bit0 |
|---|---|---|---|---|---|---|---|

bit2, bit1, bit0: channel number

000 011: SMU 1 to 4
100 101: VM1 and VM2
110: Source value
111: SMU shut down

bit3 1: ADC saturation
bit4 1: SMU oscillation
bit5 1: Another (not assigned to measure) channel has reached compliance

bit6 1: Channel has reached compliance
bit7 0: Voltage data
1: Current data

<byte2>: range

<byte3>, <byte4>: 16 bits signed integer ( 2's complement)

voltage data --- value = {<byte2>}×{<byte3><byte4>}/20000

current data --- value = $(10^{\{-<byte2>\}})\times\{<byte3><byte4>\}/20000$

(2-1) Single channel measurement (response to "TV" and "TI")

Syntax: <b_data>

Last byte returned with an EOI (End Or Identify)

Table 3-5. Data Output Format (sheet 4 of 4)

(2-2) Multichannel measurement (response to "XE" command, Internal trigger, and Device trigger)

Syntax: <b_data>[ <b_data>[.....] ]

The amount of <b data> is specified with "MC" command. The <b data> of SMU1 is output first and the <b_data> of VM2 is last. The last byte is returned with an EOI.

(2-3) Sweep measurement

Syntax: <b_block>[<b_block[.....] ]

<b_block>=[<b_data>[ <b_data>[.....] ] ]

The amount of <b_data> is specified using the "MC" or "WS" command. The <b_data> for SMU1 is output first and the <b_data> for VM2 is next to last. The last <b_data> is the sweep source data when it has been specified. The number of <b_block> is equal to the number of steps reported with the "WN" command, unless the sweep is aborted by a "WB" command or by SMU shutdown. The last byte is returned with an EOI.

## 3-27. INTERLOCK

The 4141B outputs voltages of up to ±100V with the output voltage appearing at the outer conductors of the SMU output terminals on the rear panel. To prevent potential shock hazards, the outer-conducters of the SMU output terminals should not be exposed when the 4141B interconnected to other devices (e.g., wafer prober, or user-fabricated test fixture). The interconnection must be secured, use the INTERLOCK function! The output of the SMU is limited to ±42V, if the INTERLOCK terminal is not terminated.

## 3-28. DEVICE CLEAR

The 4141B control settings will return to the initial control settings when a Selected Device Clear or Group Device Clear is received. The 4141B's initial control settings are given in Table 3-6.

Table 3-6. Initial Control Settings

| 4141B Status | Equivalent Program Code |
|---|---|
| All SMUs turned off.<br>VS1 and VS2 turned off.<br>VM1 and VM2 set to auto-range<br>Sweep aborted.<br>Integration time set to SHORT.<br>HP-IB data output format set to ASCII.<br>HP-IB data buffer cleared. | CL |
| Internal Trigger set to OFF. | TMO |
| All monitor functions set to OFF> | RI1 - 4.0<br>RV5 - 6.0 |
| Auto-calibration available. | CM1 |
| Sweep parameter settings cleared.<br>HP-IB Status byte cleared. | |

## 3-29. DEVICE TRIGGER

When the 4141B receives a Device Trigger, Group Execute Trigger or the program code "XE", each specified channel performs a measurement.

## 3-30. SERVICE REQUEST STATUS BYTE

The make-up of the 4141B Status Byte and a brief description of each bit appear in Table 3-6. Bit 7, an SRQ (Request Service), makes the 4141B output an RQS signal whenever any other bit of the Status Byte is set. The RQS mask can be set to bit 0, 2 and 3, independently. Once masked, the RQS bit is not set even if bits 0, 2 and 3 are set.

Table 3-7. 4141B Status Byte (sheet 1 of 2)

| Bit 7 (128) | Bit 6 (64) | Bit 5 (32) | Bit 4 (16) | Bit 3 (8) | Bit 2 (4) | Bit 1 (2) | Bit 0 (1) |
|---|---|---|---|---|---|---|---|
| SMU Shut Down | RQS | Self-Test Fail | Inter-lock Open | Set* Ready | END* Status | Prog. Error | Data* Ready |

( ): Decimal Value
* : RQS Maskable

Bit 0: Data Ready (Maskable)

Bit 0 is set when all measurement data is ready for output via HP-IB. It is reset when the data transfer starts or when the HP-IB data buffer is cleared.

Bit 1: Program Error

Bit 1 is set when the 4141B receives an Erroneous remote program code or when the syntax is wrong. It is reset when the 4141B receives a Serial Poll or Device Clear.

Bit 2: End Status (Maskable)

Bit 2 is set when a sweep measurement or SELF TEST is completed. It is reset when the next sweep measurement or SELF TEST starts, or when the 4141B receives a Serial Poll or Device Clear.

Bit 3: Set Ready (Maskable)

Bit 3 is set when the voltage or current output are settled. It is reset when the output changes or when the 4141B receives a Serial Poll or Device Clear.

Table 3-7. 4141B Status Byte (sheet 2 of 2)

| | |
|---|---|
| Bit 4: | Interlock Open<br><br>Bit 4 is set when the INTERLOCK terminal is not terminated during or at the start of a measurement in which the output voltage exceeds ±42V. It is reset when the 4141B receives a Serial Poll, Device Clear or the remote program code "CL." |
| Bit 5: | Self-test Fail<br><br>Bit 5 is set when the Self-Test fails in the REMOTE mode. It is reset when the Self-Test is performed again and the result passes or when the 4141B receives a Serial Poll or Device Clear. |
| Bit 6: | RQS<br><br>Bit 6 is set whenever any other nonmasked bit is set. It is reset when the 4141B receives a Serial Poll. |
| Bit 7: | SMU Shut Down<br><br>Bit 7 is set when the SMU output shuts down by a command from the instrument to prevent damage to the SMU or the SMU output resets (NOT USE) because of a momentary power loss. |

## 3-31. SAMPLE MEASUREMENT AND PROGRAMMING

Some examples of basic semiconductor measurements using the 4141B with an HP-IB controller are shown in Figures 3-19 through 3-24. The DUTs for the sample measurements include bipolar transistors and MOSFETs. Measurement programs are given for the HP 9000 Series 200 Model 236 Computer using the BASIC 3.0 Language System. To use these sample programs, the BIN (Binary) Files in Table 3-8 must be loaded. Specific information for HP-IB programming with the computer is provided in the Series 200 BASIC programming manual. See Figure 3-18 for measurement setup procedures.

Table 3-8. Binary Files Required for Programming

| | BASIC 3.0 Drivers Disc | BASIC 3.0 Language Extension Disc |
|---|---|---|
| File Name | HP-IB | IO, MAT GRAPH, ERR |

Note

The equipment required to run these sample programs includes an HP 9000 Series 200 Model 216S, 236A/S, 236C/CS Desktop Computer or an HP 9000 Series 300 Technical Workstation with HP-IB Interface (select code 7).

**MEASUREMENT SETUP**

**PROCEDURE:**

The following explains how to use the Interconnect Cable Assembly.

1. Turn off the 4141B and the HP-IB Controller.
2. Connect the 4141B to the HP-IB Controller using an HP-IB Cable and connect your user-fabricated fixture using the Interconnect Cable Assembly and Connection Plate as shown below. To test packaged devices, connect the 4141B to the 16058A Test Fixture using the 16059A Adaptor.

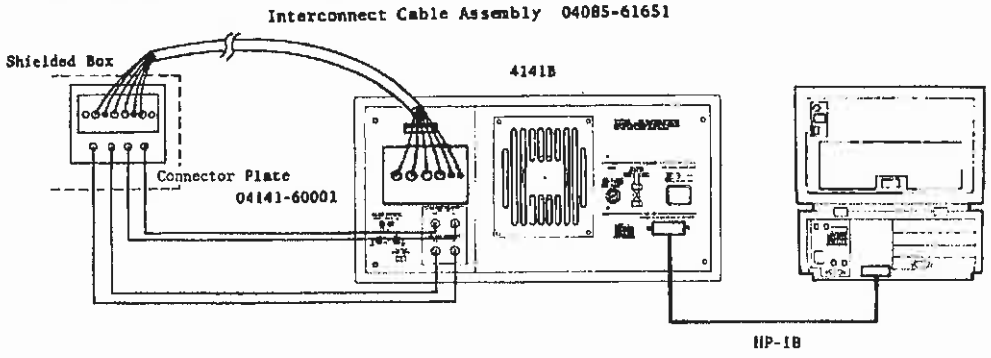



Figure 3-18. Measurement Setup (sheet 1 of 2)

3. Set 4141B HP-IB Address Switch on the rear panel to 23. See the figure below.


4. Turn the 4141B and HP-IB controller on.

5. Load the BASIC 3.0 Language System and the required Binary Files.

**Connecting DUTs**

Use Interconnect Cable Assembly (PN 04085-61651) and Connector Plate (PN 04141-60001) for interconnection with the user-fabricated fixture, and use BNC Cable (PN 04145-61630) for the VM and VS if necessary. Avoid using triaxial cables which have the outer-conducters exposed. The outer-conducter of each SMU is tied directly to the guard terminal which can have up to ±100V on it.

**WARNING**

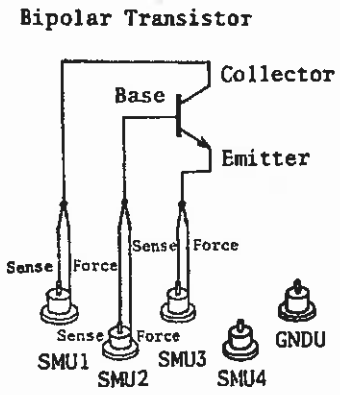
**DANGEROUS VOLTAGE OF UP TO ±100V MAY BE PRESENT ON THE OUTER-CONDUCTORS OF THE SMU OUTPUT CONNECTORS.**

**1) DO NOT TOUCH THE OUTER-CONDUCTORS DURING MEASUREMENT.**

**2) DO NOT USE A CABLE WHICH DOES NOT GO THROUGH ON THE INTERCONNECT CABLE ASSEMBLY AND THE CONNECTOR PLATE**

Figures (1) and (2) below show some connection examples.

(1) Bipolar Transistor




(2) MOSFET

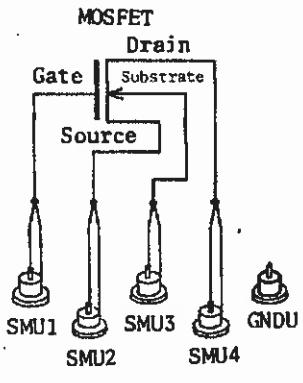
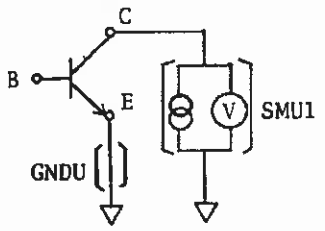



Figure 3-18. Measurement Setup (sheet 2 of 2)




**Sample Program 1 Description:**

This is an example of a Breakdown Voltage (BVceo) measurement on an npn bipolar transistor. DUT connections are shown on the left. BVceo is the collector-emitter voltage needed to cause a specified value of collector current when the base is open.

```
10    ! *** Bipolar Tr Breakdown Voltage (BVceo) Measurement ****
20    !
30    DIM A$[14]
40    Dc=723
50    OUTPUT Dc;"CL"
60    OUTPUT Dc;"IT1"
70    OUTPUT Dc;"BDO"
80    !
90    Smu=1
100   Force_ic=1.E-3
110   Comp=100
120   OUTPUT Dc;"DI";Smu;",8,";Force_ic,Comp
130   OUTPUT Dc;"TV";Smu
140   OUTPUT Dc;"DZ1"
150   ENTER Dc;A$
160   PRINT "BVceo=";A$[4,14];"[V]"
170   END
```

BVceo=+47.875E+00[V]

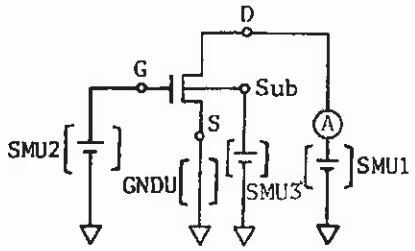
The following comments explain Sample Program 1.

| Line | Description |
|---|---|
| 30 | Defines the string variable, A$, which is used to store the measurement data. |
| 40 | Defines the 4141B's device selector. |
| 50 | Initializes the 4141B. |

Figure 3-19. Sample Program 1 (sheet 1 of 2)

| | |
|---|---|
| 60 | Sets the integration time to short. |
| 70 | Sets the data output format to ASCII. |
| 90-120 | Sets up SMU1's current output parameters. |
| 130 | Outputs a Trigger to start a V measurement by SMU1. |
| 140 | Sets SMU1's output to zero. |
| 150 | Enters the measurement data into the string variable, A$. |
| 160 | Displays the result showing only the data value. |

Figure 3-19. Sample Program 1 (sheet 2 of 2)




**Sample Program 2 Description:**

This program measures the Leakage Current (Idss) of an MOSFET. The DUT connection is shown at the left. The gate and substrate voltages are held constant and the source is grounded. The drain current is increased until the predetermined value of drain voltage is reached, this current is Idss. The data is stored in the Binary Data Format.

```
10    ! *** MOSFET Leakage Current (Idss) Measurement ***
20    !
30    INTEGER A,B,C,Dc
40    REAL Id
50    Dc=723
60    OUTPUT Dc;"CL"
70    OUTPUT Dc;"IT1"
80    OUTPUT Dc;"BD1"
90    !
100   Vds=12.
110   Vgs=2.
120   Vsub=-2.
130   !
140   OUTPUT Dc;"DV1,1,";Vds;",1E-6"
150   OUTPUT Dc;"DV2,1,";Vgs;",1E-6"
160   OUTPUT Dc;"DV3,1,";Vsub;",1E-6"
170   OUTPUT Dc;"TI1"
180   OUTPUT Dc;"DZ0"
190   !
200   IMAGE #,B,B,W
210   ENTER Dc USING 200;A,B,C
220   Id=10^(-B)*C/20000
230   IMAGE 5A,MZ.4DE,4A
240   PRINT USING 230;"Idss=",Id," (A)"
250   END
```

```
Idss= 6.1300E-11 (A)
```

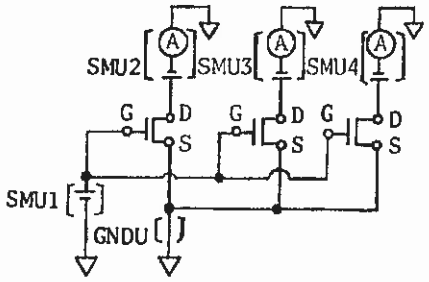
The following comments explain Sample Program 2.

| Line | Description |
|---|---|
| 30-40 | Defines the integers and the real variable Id. |
| 50-70 | Sets up the same conditions as in Sample 1. |
| 80 | Sets the output format to the Binary data format. |
| 100-160 | Sets up SMU1-SMU3's voltage output parameters |

Figure 3-20. Sample Program 2 (sheet 1 of 2)

| | |
|---|---|
| 170 | Triggers a current measurement by SMU1. |
| 180 | Sets all SMUs to zero output. |
| 200-210 | Enters binary data (bytes) using the IMAGE function. |
| 220 | Converts the binary data type to the real data type (voltage data). |
| 230-240 | Displays the real variable Id. |

Figure 3-20. Sample Program 2 (sheet 2 of 2)




**Sample Program 3 Description:**

This program measures the drain current of MOSFETs with different channel lengths and widths in order to evaluate the influence of diffusion. Connection to the DUTs is as shown on the left. The drain current of the three MOSFETs are simultaneously obtained with a gate-source voltage constant in the nonsaturation region. The 4141B enables multichannel measurement.

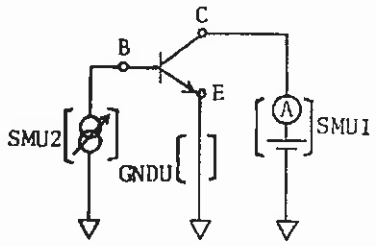
```
10    ! *** MOSFETs Drain Current Measurement
20    !                using Multi Channel Measurement Function***
30    !
40    DIM A$[45]
50    INTEGER Dc
60    Dc=723
70    OUTPUT Dc;"CL"
80    OUTPUT Dc;"IT1"
90    OUTPUT Dc;"BD0"
100   !
110   Vgs=5.
120   Vds=.5
130   OUTPUT Dc;"DV1,1,";Vgs;",1E-6"
140   OUTPUT Dc;"DV2,1,";Vds;",0.1"
150   OUTPUT Dc;"DV3,1,";Vds;",0.1"
160   OUTPUT Dc;"DV4,1,";Vds;",0.1"
170   OUTPUT Dc;"MC2,1";"MC3,1";"MC4,1"
180   OUTPUT Dc;"RI2,9";"RI3,9";"RI4,9"
190   OUTPUT Dc;"XE"
200   OUTPUT Dc;"DZ0"
210   !
220   ENTER Dc;A$
230   PRINT "Id1=";A$[4,14];"(A)"
240   PRINT "Id2=";A$[19,29];"(A)"
250   PRINT "Id3=";A$[34,44];"(A)"
260   END

   Id1=+3.2500E-03(A)
   Id2=+5.8000E-03(A)
   Id3=+11.500E-03(A)
```

Figure 3-21. Sample Program 3 (sheet 1 of 2)

The following comments explains Sample Program 3.

| Line | Description |
|---|---|
| 40 | Defines three string variables for data. |
| 50-80 | Sets up the same conditions as in Sample 1. |
| 90 | Sets the data output format to ASCII. |
| 110-160 | Sets up SMU1-4's voltage output parameters. |
| 170 | Assigns three channels for measurements. |
| 180 | Sets up the measurement channels's ranges. |
| 190 | Triggers a multichannel measurement. |
| 200 | Sets all SMUs to zero output. |
| 220-250 | Enters ASCII data and prints it on CRT. |

Figure 3-21. Sample Program 3 (sheet 2 of 2)




**Sample Program 4 Description:**

This program measures bipolar transistor hFE-Ic characteristics using the sweep function. Dut connection is shown on the left. The base current is varied while holding the Collector-Emitter voltage constant, and the base current Ib which results in a collector current of 10mA is used to calculate hFE-IC.

```
10    ! *** Bipolar Tr Hfe-Ic Measurement using Sweep Function ***
20    !
30    OPTION BASE 1
40    DIM A$[4830]
50    REAL Ic,Ib,Hfe
60    INTEGER Dc,Status_byte,Data_ready
70    !
80    Dc=723
90    OUTPUT Dc;"CL"
100   OUTPUT Dc;"IT1"
110   OUTPUT Dc;"BD0"
120   !
130   OUTPUT Dc;"DV1,1,5,0.01"              !search Hfe at Ic=10mA
140   OUTPUT Dc;"WI2,2,1,1E-9,100E-3,1,20"
150   OUTPUT Dc;"RI1,8"
160   OUTPUT Dc;"MC1,1"
170   !
180   OUTPUT Dc;"WS1"
190   !
200   OUTPUT Dc;"SD1"
210   ON INTR 7,2 GOSUB Service
220   ENABLE INTR 7;2
230   LOOP
240   EXIT IF Data_ready=1
250   END LOOP
```

Figure 3-22. Sample Program 4 (sheet 1 of 3)

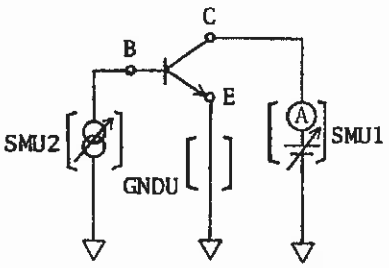
```
260   !
270   ENTER Dc;A$
280   I=0
290   LOOP
300     I=I+1
310   EXIT IF A$[((2*I-1)-1)*15+1;1]="C"      ! reached Compliance
320   END LOOP
330   Ic=VAL(A$[((2*I-1)-1)*15+4,15*(2*I-1)-1])
340   Ib=VAL(A$[(2*I-1)*15+4,15*2*I-1])
350   Hfe=Ic/Ib
360   PRINT "Hfe=";Hfe;"[Ic=10mA]"
370   STOP
380   !
390 Service:   !
400   Status_byte=SPOLL(Dc)
410   IF BIT(Status_byte,0)=1 THEN
420     Data_ready=1
430   END IF
440   IF BIT(Status_byte,4)=1 THEN
450     PRINT "!!!!!!! NOT INTERLOCKED !!!!!!"
460     BEEP
470     STOP
480   END IF
490   ENABLE INTR 7;2
500   RETURN
510   END


    Hfe= 153.615384615 [Ic=10mA]
```

Figure 3-22. Sample Program 4 (sheet 2 of 3)

The following comments explain Sample Program 4.

| Line | Description |
|---|---|
| 30-60 | Defines the variables. |
| 80-100 | Sets up the same conditions as in Sample 1. |
| 110 | Sets the data output format to ASCII. |
| 130 | Sets up SMU1's voltage output parameters. |
| 140 | Sets up SMU2's sweep parameters for a current sweep. |
| 150 | Sets the current measurement range to 10 mA or higher. |
| 160 | Sets up measurement channel. |
| 180 | Starts a sweep and sets source data returned. |
| 200 | Sets the "DATA READY" bit of the HP-IB status byte to enable SRQ generation. |
| 210-250 | Sets the priority of HP-IB interrupt to continue |
| 270 | Enters all string variables. |
| 280-360 | Searches for a collector current of 10mA using the compliance function and calculates the hFE. |
| 390-500 | This is the execution path when the measurement data is ready and the interlock function is not set. |

Figure 3-22. Sample Program 4 (sheet 3 of 3)




**Sample Program 5 Description:**

This program is an example of the high speed measurement of the bipolar transistor static collector characteristics using the sweep function. It is effective for minimizing the range changes in high speed measurements. Connection to the DUT is shown below. To get the desired characteristics, the collector is stimulated while the base current is held constant. The source base current then changes as a second variable.

```
10    ! *** Bipolar Tr Ic-Vce Measurement using Sweep Function ***
20    !
30    OPTION BASE 1
40    INTEGER Dc,Var2
50    REAL K
60    DIM A$(3)[1515]
70    !
80    Dc=723
90    OUTPUT Dc;"CL"
100   OUTPUT Dc;"IT1"
110   OUTPUT Dc;"BD0"
120   !
130   Start=0
140   Stop=5
150   Step=.05
160   Compliance=.001
170   !
180   FOR Var2=1 TO 3
190     K=Var2*1.0E-6
200     OUTPUT Dc;"DI2,5,";K;",10"
210     OUTPUT Dc;"WV1,1,1,";Start;",";Stop;",";Step;",";Compliance
220     OUTPUT Dc;"R11,7MC1,1WS0"
230   !
240     ENTER Dc;A$(Var2)
250   !
260   NEXT Var2
270   !
280   GOSUB Graphics
290   STOP
300   !
```

Figure 3-23. Sample Program 5 (sheet 1 of 4)

```
310 Graphics:  !                                                    !
320            !          GRAPHICS DISPLAY                         !
330            !                                                   !
340   !
350   GINIT
360   GRAPHICS ON
370   PRINT CHR$(12)
380   Xmax=100*MAX(1,RATIO)
390   Ymax=100*MAX(1,1/RATIO)
400   LORG 6
410   MOVE Xmax/2,Ymax
420   LABEL "COLLECTOR CHARACTERISTICS"
430   DEG
440   LDIR 90
450   CSIZE 4.5
460   MOVE 0,Ymax/2
470   LABEL "Ic(A)"
480   LORG 4
490   LDIR 0
500   MOVE Xmax/2,0
510   LABEL "Vce(V)"
520   VIEWPORT .15*Xmax,.99*Xmax,.15*Ymax,.9*Ymax
530   FRAME
540   WINDOW 0,100,0,1.E-3
550   !
560   AXES 1,1.E-4,0,0,10,1,3
570   CLIP OFF
580   CSIZE 4.0,.5
590   LORG 6
600   FOR I=0 TO 100 STEP 10
610     MOVE I,0.
620     LABEL USING "#,K";I*.05
630   NEXT I
640   LORG 8
650   FOR I=0 TO 1.E-3 STEP 2.E-4
660     MOVE -.5,I
670     LABEL USING "#,D.DE";I
680   NEXT I
690   !
700   FOR Var2=1 TO 3
710     FOR X=1 TO 101
720       PLOT X-1,VAL(A$(Var2)[15*(X-1)+4,15*X-1])
730     NEXT X
740     PENUP
750   NEXT Var2
760   RETURN
770   END
```

Figure 3-23. Sample Program 5 (sheet 2 of 4)

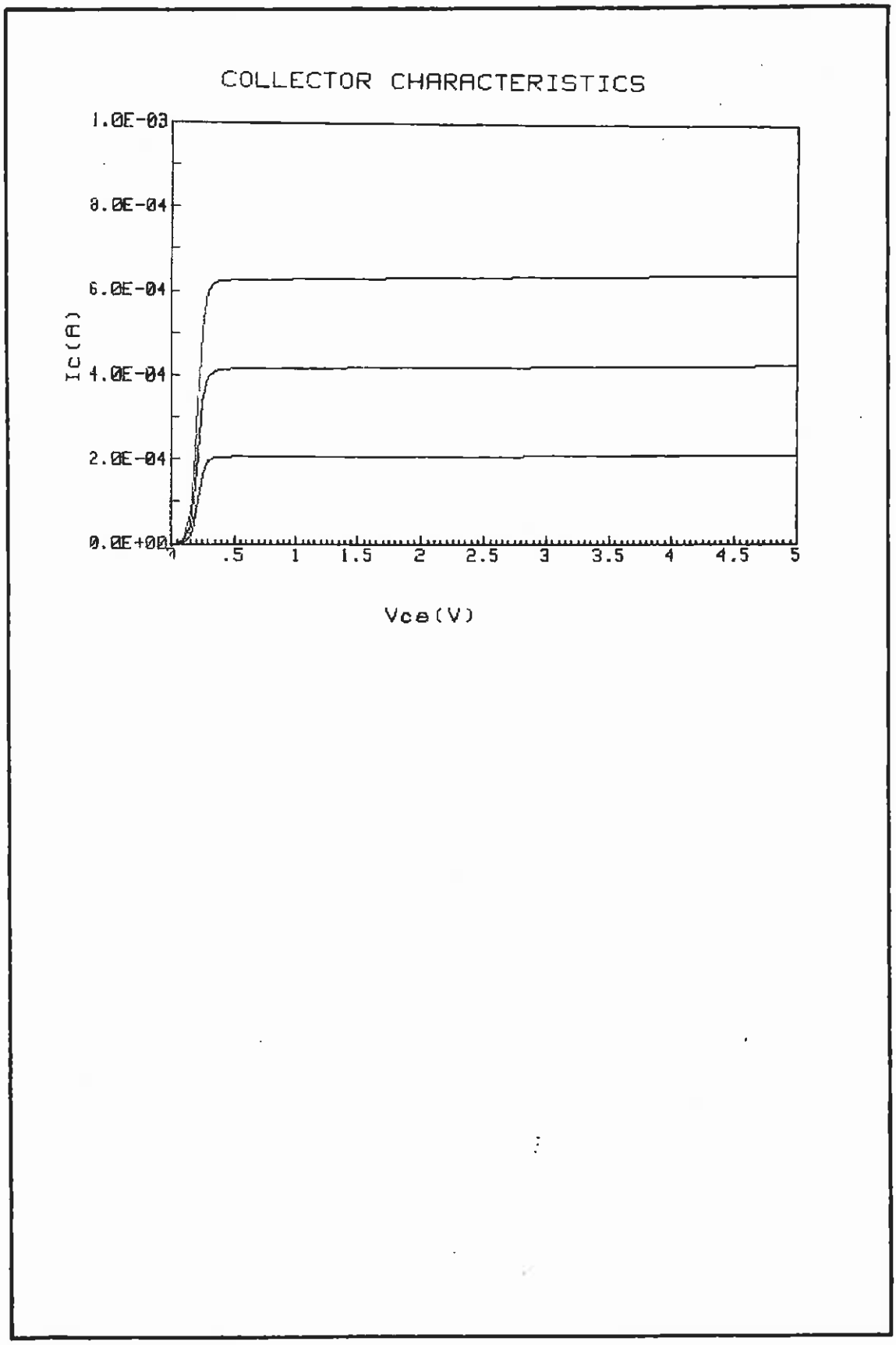
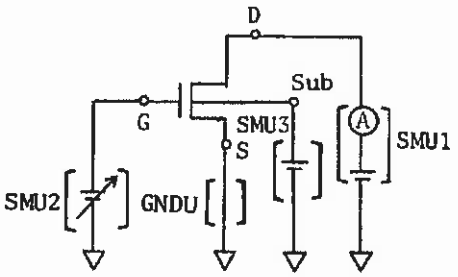



Figure 3-23. Sample Program 5 (sheet 3 of 4)

The following comments explain Sample Program 5.

| Line | Description |
|---|---|
| 30-60 | Defines the variables. |
| 80-100 | Sets the same conditions as in Sample 1. |
| 110 | Sets the data output format to ASCII. |
| 130-210 | Sets up SMU1's voltage sweep parameters and sets up SMU2's current output parameters as a second sweep parameter. |
| 220 | Sets SMU1's current measurement range to the compliance range previously set with the "WV" command and start the sweep (sweep source data set to not returned). |
| 240 | Enter ASCII data. |
| 280-760 | Call the "Graphics" subroutine to draw data on the graphics screen. |

Figure 3-23. Sample Program 5 (sheet 4 of 4)




**Sample Program 6 Description:**

This program is an example of searching for the MOSFET threshold voltage by repeated spot measurements. Connection to the DUT is shown below. This parameter can be obtained as a gate voltage when the drain current is 1µA.

```
10    ! *** MOSFET Threshold Voltage (Vth) Measurement ***
20    !
30    INTEGER Dc,I,A
40    !
50    Dc=723
60    OUTPUT Dc;"CL"
70    OUTPUT Dc;"IT1"
80    OUTPUT Dc;"BD1"
90    !
100   Id_comp=1.E-6                ! search Vgs at Id=1uA
110   V_sub=-.4
120   OUTPUT Dc;"DV1,1,5,";Id_comp
130   OUTPUT Dc;"DV3,1,";V_sub;",0.1"
140   I=0
150   LOOP
160     OUTPUT Dc;"DV2,1,";I*.05;",1E-6"
170     OUTPUT Dc;"TI1"
180   !
190     IMAGE #,B
200     ENTER Dc USING 190;A
210     IF BIT(A,6)=1 THEN
220       PRINT "Vgs=";I*.05;"(V)  [Id=1uA]"
230       STOP
240     END IF
250     I=I+1
260   END LOOP
270   END
```

```
Vgs= 2.4 (V)  [Id=1uA]
```

Figure 3-24. Sample Program 6 (sheet 1 of 2)

The following comments explain Sample Program 6.

| Line | Description |
|---|---|
| 30 | Defines the integer variables. |
| 50-70 | Sets same conditions as in Sample 1. |
| 80 | Sets the data output format to Binary. |
| 100-130 | Sets compliance of drain current to 1μA and forces voltage to the Drain and Substrate. |
| 140-260 | Starts to force voltage onto gate from 0 volt in 0.05V steps, and when drain current reaches the compliance level, 1μA, the program terminates and prints the gate voltage. |

Figure 3-24. Sample Program 6 (2 of 2)

# SECTION 4
# PERFORMANCE VERIFICATION

## 4-1. INTRODUCTION

This section provides information on the HP 4141B's performance verification software (PV4141), for confirming the 4141B's specifications. This program is not a furnished accessory, but may be purchased separately. Included here is information on PV4141 contents, the test equipment required, and how to execute the performance verification program. Additionally, a brief description of each test and its operating theory, instructions on how to interpret test results, and how to remove and replace SMU boards is also included. For detailed 4141B service information (troubleshooting, repair, replaceable parts, etc.), refer to the 4062B Semiconductor Parameteric Test System's Service Manual, PN 04062-90501.

**Note**

To ensure proper test results and instrument operation, allow the 4141B to warm-up and stabilize for at least 40 minutes before you execute any performance tests.

## 4-2. PV4141 CONTENTS

The 4141B's performance verification software comes on a 5-1/4" mini-flexible disc (PN 04141-65101) for use with HP 9000 Series 200 Model 236 computers, on a tape cartridge (PN 04141-90501) for use with HP 85 computers, or on a 3-1/2" micro-flexible disc (PN 04141-65301) for use with HP 9000 Series 300 Computers. The tests included in the performance verification software are listed below. PV4141 takes approximately 15 minutes to execute.

| | |
|---|---|
| ALL TESTS: | Performs the GNDU, SMU, and VS/VM tests. |
| SMU TEST: | Tests current and voltage measurement and control (monitor) accuracy, and provides a Kelvin connection check for each Source/Monitor Unit (SMU). |
| VS/VM TEST: | Checks the specifications of the Voltage Sources (Vs) and Voltage Monitors ($V_M$). |
| GNDU TEST: | Checks the specifications of the 4141B's Ground Unit (GNDU). |

## 4-3. EQUIPMENT REQUIRED

The test equipment required during the performance verification program is listed here.

HP 3456A: Digital Voltmeter (DVM)

HP 16347A ~ E: SMU Calibrators 1 through 5

PN 1251-2277 (or equivalent): Dual Banana Plug-to-BNC Adapter

PN 1250-0781 (or equivalent): BNC-T Adapter

HP 11170A : BNC-to-BNC Cable (30cm)

One BNC-to-BNC cable (3m minimum)

For detailed information on the 16347A ~ E SMU Calibrators, refer to the Operating Note included with the calibrators.

## 4-4. PROGRAM EXECUTION

The following procedure explains how to execute the PV4141 program when using the HP 9000 Series 200 Model 236 computer. This program can be executed in a similar manner on HP 85 computers and on HP 9000 Series 300 Computers.

(1) Insert the BASIC 3.0 Disc into the computer's right-hand disc drive and turn the computer on. The language system will load automatically and the following message will be displayed when BASIC is loaded.

BASIC Ready 3.0

Remove the disc.

(2) Load the following BIN files from the BASIC 3.0 Drivers Disc and the Language Extensions Disc.

| Basic 3.0 Drivers Disc | BASIC 3.0 Language Extensions Disc |
|---|---|
| HPIB | ERR<br>IO |

Remove the discs.

(3) Insert the performance verification disc into the right-hand disc drive and load the PV4141 program.

(4) Press the **'RUN'** key to start the program. The HP4141B Performance Test page will be displayed as shown below.

```
******** HP4141B PERFORMANCE TEST ********

This program verifies performance of the HP4141B.  (HP-IB ADDRESS = 723)
Required test equipment is listed below.

   HP16347A-E                        (SMU CALIBRATOR 1-5)
   HP3456A (HP-IB ADDRESS = 710)     (Digital Voltmeter)
   HP P/N 1251-2277 or equivalent    (Dual Banana - BNC)
   BNC - BNC Cable                   (30 cm)
   BNC - BNC Cable                   (3 m)
   HP P/N 1250-0781 or equivalent    (BNC T-Adapter : Dual-Female to Male)


  Press START to begin.

| | | | | |
|---|---|---|---|---|
| START | | | | EXIT |
```

(5) Press the **'START'** softkey and the following MENU will be displayed.

```
******** HP4141B PERFORMANCE TEST ********

Press desired softkey.


**** MENU ****

K5: ALL TESTS
K6: SMU TEST
K7: Vs/Vm TEST
K8: GNDU TEST

| | | | | |
|---|---|---|---|---|
| ALL TESTS | SMU TEST | Vs/Vm TEST | GNDU TEST | EXIT |
```

Select the test(s) you wish to perform by pressing the corresponding softkey. Follow the displayed instructions.

If you're using the HP 85 instead of a Series 200/300, there will be several differences in the PV4141 program. These differences are listed in the following table.

| | Series 200/300 | Model 85 |
|---|---|---|
| Data Output | CRT display or external printer | Internal printer only |
| Operation | Softkey | Hardkey |
| Messages | Full messages and displays | Omitted or as short as possible |

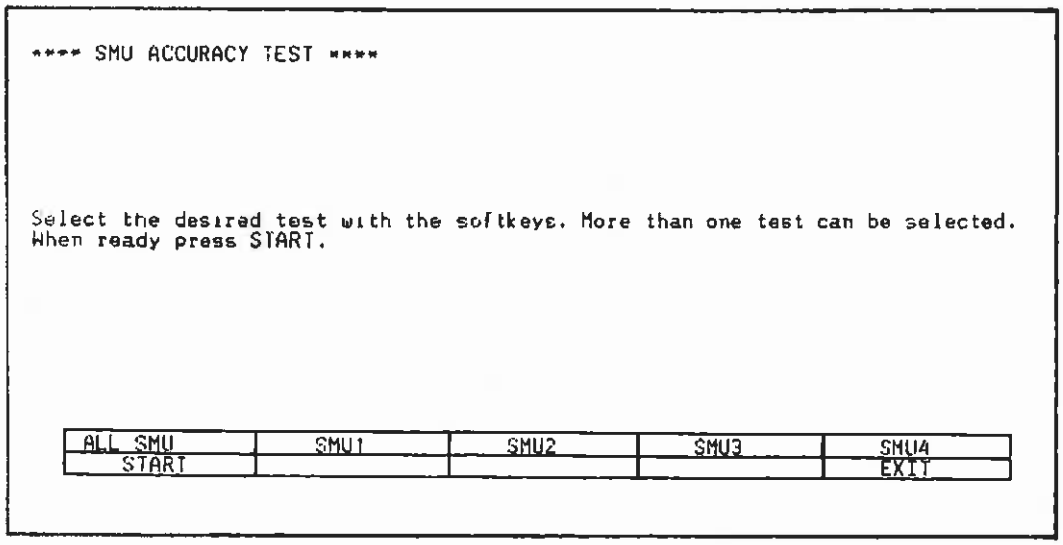
## 4-5. SMU TEST

The SMU accuracy test consists of:

Kelvin Connection Check
Voltage Control Test
Voltage Measurement Test
Current Control Test
Current Measurement Test

The procedure for performing the SMU test is as follows.

(1) From the MENU page, press the **'SMU TEST'** softkey. The SMU ACCURACY TEST display, as shown below, will appear. From this display, you can select the SMU(s) you wish to test by pressing the corresponding softkey(s). For example, to test SMUs 1 and 3, press the **'SMU1'** and **'SMU3'** softkeys, then press the **'START'** softkey.



(2) Connect the 16347A Calibrator to the 4141B's rear panel I•V CHANNELS connectors. Next, connect the DVM to the GNDU-V connector of the 16347A with a BNC-to-BNC cable as shown in Figure 4-1. Press the **'NEXT'** softkey to start the GNDU Test.

Note

Before the SMU Accuracy Test can be run, the 4141B must pass the GNDU Test. The GNDU Test, therefore, is included in the SMU Test. If the 4141B fails the GNDU Test, contact the nearest HP Service office.

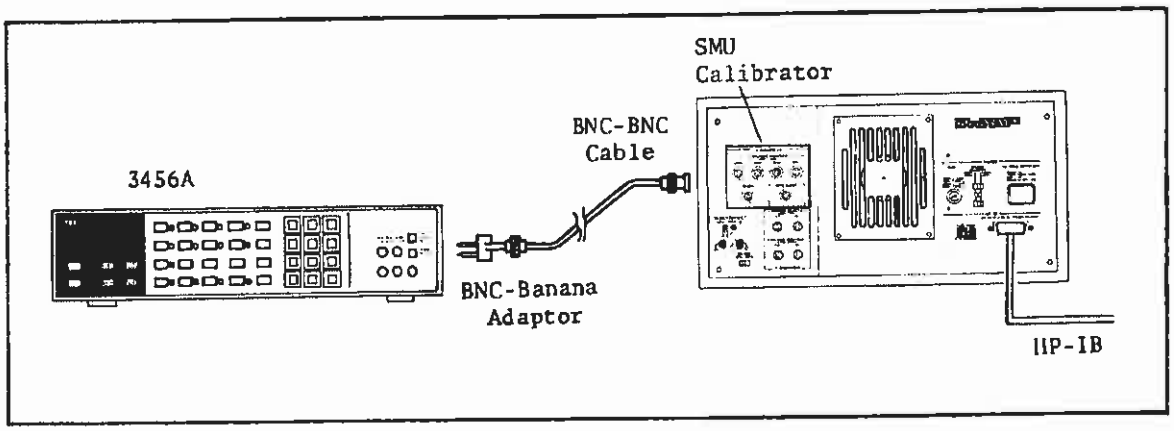



Figure 4-1. SMU Accuracy Test Setup

(3) Upon completion of the GNDU Test, follow the displayed instructions. After each SMU is tested, test results will be output, as shown in the following example. If an SMU fails the accuracy tests, a failure message will be output at the end of the test. Should a failure occur, replace the faulty SMU board, as described later in this section.

```
*** SMU ACCURACY TEST ***

* SMU1 *

KELVIN CONNECTION OK

** VOLTAGE CONTROL ACCURACY **

RANGE  ERROR/    ACTUAL      TEST
       OFFSET    RESULTS     LIMITS
                             0+/-
20V      E          -.021%    0.1%
         0          -.067mV   10mV

40V      E          -.022%    0.1%
         0          1.282mV   20mV

100V     E          -.022%    0.1%
         0           .728mV   50mV

** VOLTAGE MEASUREMENT ACCURACY **

RANGE  ERROR/    ACTUAL      TEST
       OFFSET    RESULTS     LIMITS
                             0+/-
20V      E           .011%    0.1%
         0           .450mV   10mV

40V      E           .010%    0.1%
         0         -1.800mV   20mV

100V     E           .007%    0.1%
         0           .750mV   50mV
```

** CURRENT MEASUREMENT ACCURACY **

| RANGE | ERROR/ OFFSET | ACTUAL RESULTS | TEST LIMITS 0+/- |
|---|---|---|---|
| 1E-1A | E | -.030% | 0.3% |
| | O | -4.128E-06A | 1E-4A |
| 1E-2A | E | .070% | 0.3% |
| | O | 4.338E-08A | 1E-5A |
| 1E-3A | E | .064% | 0.3% |
| | O | -3.384E-08A | 1E-6A |
| 1E-4A | E | .038% | 0.3% |
| | O | -4.615E-09A | 1E-7A |
| 1E-5A | E | .030% | 0.3% |
| | O | -3.682E-10A | 1E-8A |
| 1E-6A | E | -.023% | 0.5% |
| | O | -1.813E-11A | 1E-9A |
| 1E-7A | E | -.034% | 0.5% |
| | O | -8.227E-12A | 1E-10A |
| 1E-8A | E | .651% | 1.0% |
| | O | -7.221E-13A | 1.5E-11A |
| 1E-9A | E | .641% | 1.0% |
| | O | -2.149E-14A | 6E-12A |

** CURRENT CONTROL ACCURACY **

| RANGE | ERROR/ OFFSET | ACTUAL RESULTS | TEST LIMITS 0+/- |
|---|---|---|---|
| 1E-1A | E | .013% | 0.3% |
| | O | 1.146E-05A | 1E-4A |
| 1E-2A | E | -.092% | 0.3% |
| | O | 7.652E-07A | 1E-5A |
| 1E-3A | E | -.086% | 0.3% |
| | O | 1.053E-07A | 1E-6A |
| 1E-4A | E | -.060% | 0.3% |
| | O | 8.185E-09A | 1E-7A |
| 1E-5A | E | -.052% | 0.3% |
| | O | 1.133E-09A | 1E-8A |
| 1E-6A | E | .006% | 0.5% |
| | O | 3.119E-11A | 1E-9A |
| 1E-7A | E | .025% | 0.5% |
| | O | 1.435E-11A | 1E-10A |
| 1E-8A | E | -.668% | 1.0% |
| | O | 4.998E-13A | 1.5E-11A |
| 1E-9A | E | -.656% | 1.0% |
| | O | 4.661E-14A | 6E-12A |

Note

Be sure to connect each 16347A-E SMU Calibrator correctly. The PV4141 program will detect a bad connection, and will display a "### Check Connection ####" message if a bad connection exists. This detect and display function, however, will occur only the first time a Calibrator is connected.

## 4-6. VS/VM TEST

To test the accuracy of the 4141B's Voltage Sources and Monitors at each range, press the **'VS/VM TEST'** softkey when the MENU page is displayed. Connect the DVM to the 4141B's rear panel Vs1 and Vm1 terminals as shown in Figure 4-2. Press the **'NEXT'** softkey to start the test.

When Vs1 and Vm1 are tested, follow the displayed instructions. Connect the DVM to the Vs2 and Vm2 terminals as shown in Figure 4-2 for Vs1 and Vm1.

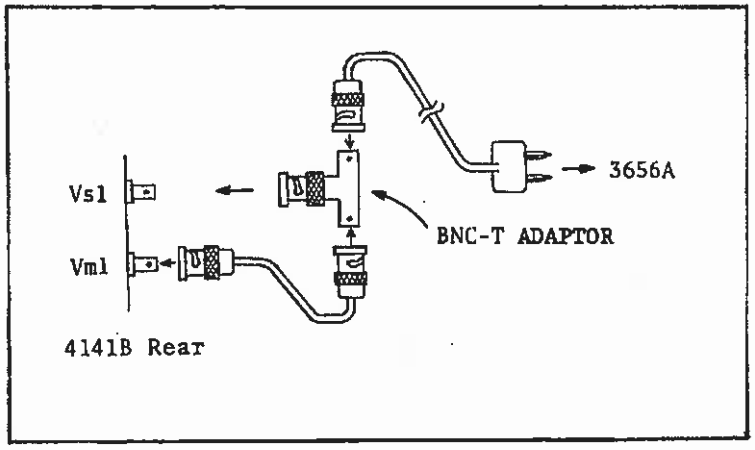



Figure 4-2. VS/VM Test Setup

When the VS/VM Test is finished, test results will be output as shown below.

** Vm ACCURACY **

| Vm1 RANGE | ERROR/ OFFSET | ACTUAL RESULTS | TEST LIMITS 0+/- |
|---|---|---|---|
| 2V | E | -.112% | 0.5% |
| | 0 | -.010mV | 10mV |
| 20V | E | -.019% | 0.2% |
| | 0 | -1.500mV | 10mV |

| Vm2 RANGE | ERROR/ OFFSET | ACTUAL RESULTS | TEST LIMITS 0+/- |
|---|---|---|---|
| 2V | E | -.168% | 0.5% |
| | 0 | -.169mV | 10mV |
| 20V | E | -.018% | 0.2% |
| | 0 | -1.500mV | 10mV |

** Vs ACCURACY **

| Vs1 RANGE | ERROR/ OFFSET | ACTUAL RESULTS | TEST LIMITS 0+/- |
|---|---|---|---|
| 20V | E | .007% | 0.5% |
| | 0 | .210mV | 10mV |

| Vs2 RANGE | ERROR/ OFFSET | ACTUAL RESULTS | TEST LIMITS 0+/- |
|---|---|---|---|
| 20V | E | .006% | 0.5% |
| | 0 | 1.069mV | 10mV |

**Note**

The 16347A through E SMU Calibrators are not needed for the VS/VM Test, but will not affect the test results if connected to the 4141B during the Vs/Vm test.

## 4-7. GNDU TEST

To test the accuracy of the 4141B's Ground Unit, press the **'GNDU TEST'** softkey on the MENU page and follow the displayed instructions. Connect the 16347A to the 4141B, and connect the DVM to the 16347A as shown in Figure 4-1. During this test, all four SMUs force ±400mA to the GNDU, and the DVM measures the offset value. The PV4141 program then calculates the offset value as if ±500mA were forced to the GNDU, and uses the measured offset value and this calculated value to obtain and output measurement results. An example of GNDU test results is as follows.

```
-- GNDU ACCURACY --

   ACTUAL          TEST
   RESULT          LIMIT

     -.18mV        0+/-2mV
```

## 4-8. SMU BOARD REPLACEMENT

If an error message indicating a faulty SMU, such as the one below, is displayed, the 4141B can be repaired by replacing the faulty SMU board.

S10S20S31S40

This error message indicates that SMU3 is faulty. If any of the error messages shown below are displayed, however, the 4141B cannot be repaired by replacing an SMU.

S19S29S39S49, S11S20S30S41, S10S21S31S40

If any of these errors occur, contact the nearest HP Service office.

Replace SMU boards as follows:

**WARNING**

**TO PREVENT SHOCK HAZARDS, UNPLUG THE 4141B BEFORE YOU REMOVE ANY COVERS. REFER ALL REPAIRS TO EXPERIENCED SERVICE PERSONNEL ONLY.**

(1) Turn off and unplug the 4141B.

(2) Remove the top cover.

(3) Remove the shielding plate. The instrument's interior will be visible, as shown in Figure 4-3. SMU 1 is the one closest to the LINE ON/OFF switch, SMU 4 the farthest.

(4) Remove the faulty SMU board by lifting the green and black tabs on the ends of the board. Pull the SMU board halfway out of its slot and disconnect the cables from the 10-pin connector and the two SMU connectors. Pull the board out.

(5) Insert the new board about half way, reconnect all cables, then insert the board the rest of the way. Make sure the board is properly seated in the connectors on the mother board.

To order new SMU boards, order PN 04141-66505 from your nearest HP Service office.

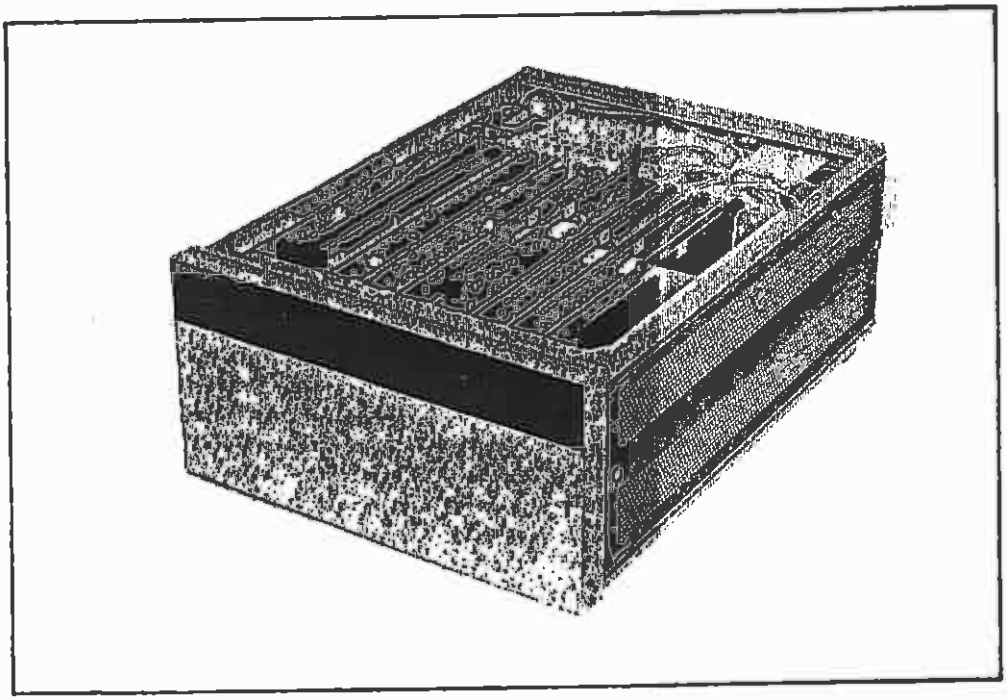


Figure 4-3. SMU Board Removal


Part No. 04141-90000

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