Errata

Title & Document Type: 4276A LCZ Meter Operating & Service Manual

Manual Part Number: 04276-90000

Revision Date: July 1983

HP References in this Manual

This manual may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, semiconductor products and chemical analysis businesses are now part of Agilent Technologies. We have made no changes to this manual copy. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A.

About this Manual

We've added this manual to the Agilent website in an effort to help you support your product. This manual provides the best information we could find. It may be incomplete or contain dated information, and the scan quality may not be ideal. If we find a better copy in the future, we will add it to the Agilent website.

Support for Your Product

Agilent no longer sells or supports this product. You will find any other available product information on the Agilent Test & Measurement website:

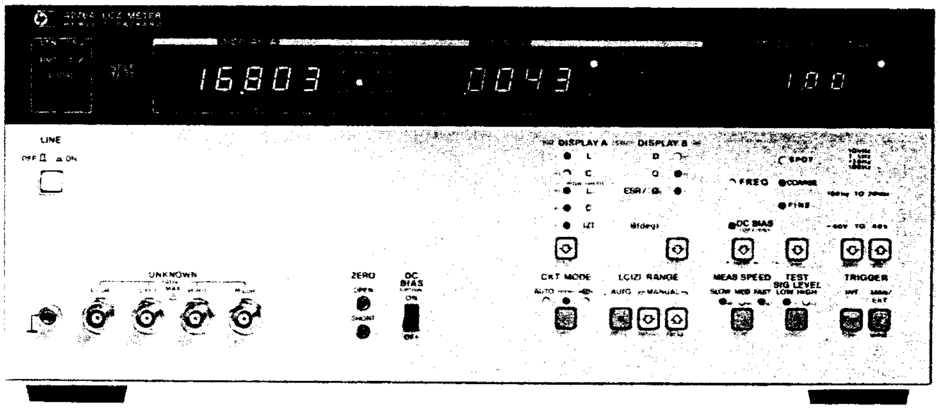
www.tm.agilent.com

Search for the model number of this product, and the resulting product page will guide you to any available information. Our service centers may be able to perform calibration if no repair parts are needed, but no other support from Agilent is available.

Agilent Technologies

OPERATION AND SERVICE MANUAL

4276A
LCZ METER



HEWLETT
PACKARD

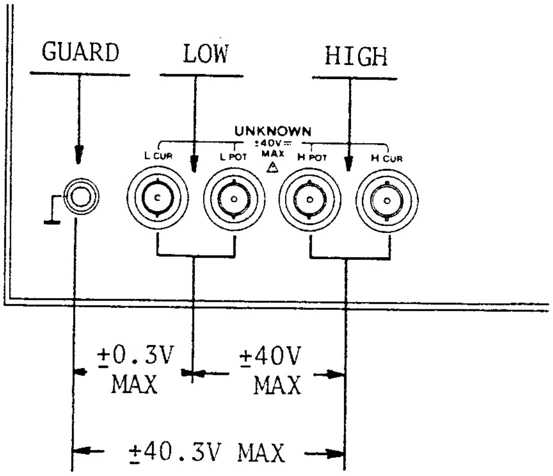
HP 4276A

CAUTIONS ON OPERATION

USING EXTERNAL BIASING

When measuring any device that is biased from an external bias source, you must observe certain precautions to protect the 4276A's sensitive measurement circuitry.

1) DO NOT apply a dc bias voltage exceeding ±40V between the LOW and HIGH UNKNOWN terminals as shown in the figure below.



Interterminal Bias Limitations

2) DO NOT, under any circumstances, connect a charged capacitor directly to the 4276A's UNKNOWN terminals.

If either of these precautions is ignored, the instrument may be damaged. Symptoms of the damage that may result are listed below.

(1) No test signal at the $\mathrm{H_{CUR}}$ terminal

(2) Excessive display fluctuation during measurement

(3) During SELF TEST, error codes E37 through E39 and E41 through E45 are displayed on DISPLAY A.

If your 4276A exhibits these symptoms, contact the nearest Hewlett-Packard Sales and Service Office.

Note

When making impedance measurements on an active circuit or a device biased from an external source, set the DC BIAS slide switch on the rear panel to EXT and connect nothing to the EXT INPUT/INT MONITOR connector.

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.

Herstellerbescheinigung

Hiermit wird bescheinigt, daß das Gerät HP 4276A (LCZ Meter) 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 4276A LCZ Meter, 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.

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

HEWLETT
PACKARD

OPERATION AND SERVICE MANUAL

MODEL 4276A

LCZ METER

(Including Options 001 and 002)

SERIAL NUMBERS

This manual applies directly to instruments with serial numbers prefixed 2227J.

9-1, TAKAKURA-CHO, HACHIOJI-SHI, TOKYO, JAPAN

MANUAL PART NO. 04276-90000
Microfiche Part No. 04276-90050

Printed : JULY 1983

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS

SECTION I
GENERAL INFORMATION

1-1. INTRODUCTION

1-2. This operation and service manual contains the information required to install, operate, test, adjust, and service the Hewlett-Packard Model 4276A LCZ Meter. Figure 1-1 shows the instrument and its supplied accessories. This section covers specifications, instrument identification, description, options, accessories, and other basic information.

1-3. Listed on the title page of this manual is a microfiche part number. This number can be used to order 4 x 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 manual changes supplement as well as all pertinent service notes. To order an additional manual, use the part number listed on the title page of this manual.

1-4. DESCRIPTION

1-5. The HP Model 4276A LCZ Meter is a fully automatic, high performance test instrument designed to measure the inductance, capacitance, dissipation factor, quality factor, conductance, equivalent series resistance, impedance magnitude, and phase of electronic components and devices. Its built-in test signal source covers the frequency range of 100Hz to 20kHz and provides 801 spot frequencies. Test frequency resolution is 1Hz (maximum), and frequency accuracy is ±0.01% of the selected spot frequency. Frequently used spot frequencies--100Hz, 120Hz, 1kHz, and 10kHz--can be quickly selected by the SPOT key. Test signal level is selectable at 1Vrms (HIGH) or 50mVrms (LOW). In exceptional measurement ranges, the test signal in HIGH mode is 2Vrms. The instrument's 5 terminal configuratin provides a basic measurement accuracy of 0.1% over a wide measurement range.

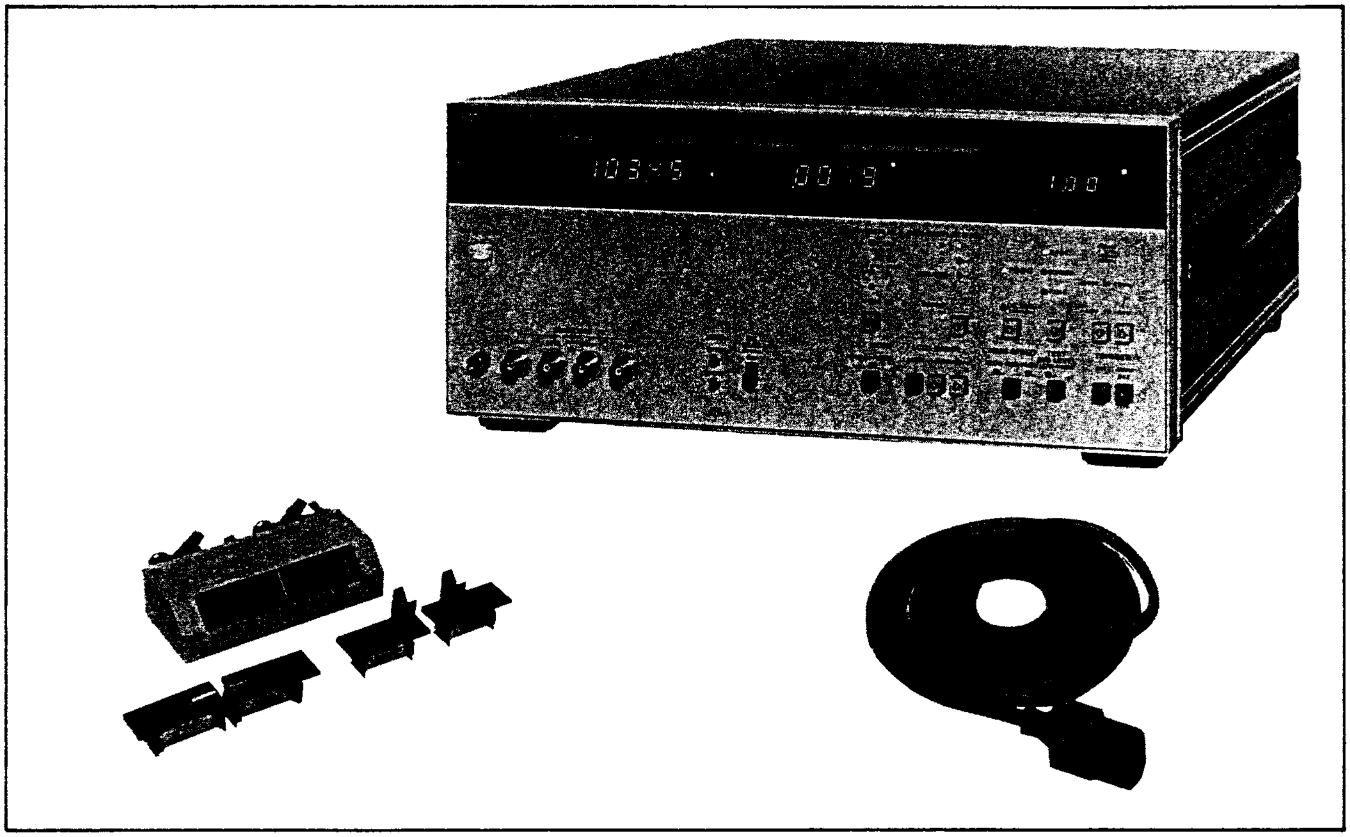


Figure 1-1. Model 4276A and Accessories.

1-6. The 4276A has three measurement speed modes: SLOW, MED, and FAST. When MED mode is selected, total time required for a C-D or L-Q measurement is approximately 100ms (at 1kHz). FAST mode measurement time is approximately 40 percent shorter than that of MED mode. Also, the HIGH SPEED C and HIGH SPEED L measurement functions reduce measurement time to approximately half that of a normal C-D or L-Q measurement. Shortest measurement time is approximately 25ms (HIGH SPEED C or L, FAST mode, at 20kHz). The 4276A is equipped with a (delta) measurement function to permit temperature dependency or dc bias dependency measurements.

1-7. All instrument operations--measurement, front panel control settings, self test, continuous memory, etc.—are controlled by a Z80 microprocessor. The built-in self test function can be initiated at any time to verify correct operation of the instrument's basic capabilities. The 4276A is also equipped with a continuous memory function that is automatically activated when the instrument is turned off or experiences a power failure. All front panel control settings (except dc bias), zero offset data, and comparator limits (Option 002) are memorized and automatically recalled when the instrument is turned on again.

1-8. The Hewlett-Packard Interface Bus (HP-IB) is standard on the 4276A. All of the instrument's standard and optional functions (except power on/off and DC BIAS ON/OFF) can be remotely controlled from an HP-IB compatible controller. When set to TALK ONLY mode, the 4276A can send measurement data to an external device (a printer, for example) without a controller.

1-9. The 4276A can be equipped with two special options: Option 001 Internal DC Bias and Option 002 Comparator/Handler Interface. Refer to paragraph 1-21 for a brief description of these options.

1-10. A wide selection of accessories—test fixtures and test leads—is available. A description of furnished accessories is given in paragraph 1-30. For details on available accessories, refer to paragraph 1-32.

1-11. SPECIFICATIONS

1-12. Complete specifications of the Model 4276A are given in Table 1-1. These specifications are the performance standards or limits against which the instrument is tested. The test procedures for verifying the specifications are covered in Section IV, Performance Tests. Table 1-2 lilsts supplemental performance characteristics. Supplemental performance characteristics are not specifications but are typical characteristics included as additional information for the operator. When the 4276A is shipped from the factory, it meets the specifications listed in Table 1-1.

1-13. SAFETY CONSIDERATIONS

1-14. The Model 4276A has been designed to conform to the safety requirements of an IEC (International Electromechanical Committee) Safety Class I instrument and is shipped from the factory in a safe condition.

1-15. This operating and service manual contains information, cautions, and warnings which must be followed by the user to ensure safe operation and to maintain the instrument in a safe condition.

1-16. INSTRUMENTS COVERED BY MANUAL

1-17. Hewlett-Packard uses a two-section nine character serial number which is stamped on the serial number plate (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. The contents of this manual apply to instruments with the serial number prefix(es) listed under SERIAL NUMBERS on the title page.

1-18. An instrument manufactured after the printing of this manual may have a serial number prefix that is not listed on the title page. This unlisted serial number prefix indicates the instrument is different from the one described in this manual. The manual for this newer instrument may be accompanied by a yellow Manual Changes supplement or have a different manual part number. This supplement contains "change information" that explains how to adapt the manual to the newer instrument.

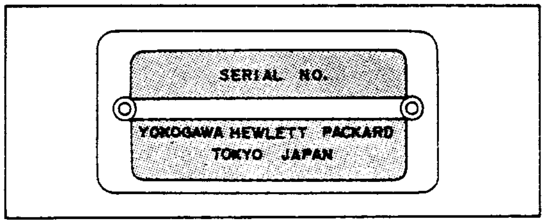


Figure 1-2. Serial Number Plate.

1-19. In addition to change information, the supplement may contain information for correcting errors (called Errata) in the manual. To keep this manual as current and accurate as possible, Hewlett-Packard recommends that you periodically request the latest Manual Changes supplement. The supplement for this manual is identified with this manual's print date and part number, both of which appear on the manual's title page. Complimentary copies of the supplement are available from Hewlett-Packard. If the serial prefix or number of an instrument is lower than that on the title page of this manual, see Section VII, Manual Changes.

1-20. For information concerning a serial number prefix that is not listed on the title page or in the Manual Change supplement, contact the nearest Hewlett-Packard office.

1-21. OPTIONS

1-22. Options are modifications to the standard instrument that implement the user's special requirements for minor functional changes. The 4276A has six options:

Option 001 :	Internal DC Bias Supply (0 -- ±40V)
Option 002 :	Comparator/Handler Interface
Option 907 :	Front Handle Kit
Option 908 :	Rack Flange Kit
Option 909 :	Rack Flange and Front Handle Kit
Option 910 :	Extra Manual

1-23. OPTION 001

1-24. Option 001 equips the standard 4276A with a built-in dc voltage source for biasing the device under test. Output voltage is user-selectable from 0 to ±40V with 10mV (0V to ±9.99V range) or 100mV (±10V to ±40V range) setting resolution, and can be keyed in directly from the front panel or remotely programmed via the HP-IB. Maximum display resolution is 3 digits.

1-25. OPTION 002

1-26. Option 002 equips the standard 4276A with the 16064A Comparator/Handler Interface for go/no-go testing and automatic bin sorting. Up to nine sets of HIGH/LOW limits for one DISPLAY A function (L, C, or | Z |) and one set of HIGH/LOW limits for one DISPLAY B function (D, Q, ESR, or G) can be manually keyed in from the 16064A, or entered from a remote controller via the HP-IB. Comparison results--HIGH, IN, or LOW—for each measurement parameter are indicated by LED lamps on the 16064A and by TTL level voltages (open collector) output from the handler interface connector.

HIGH :	Measured value exceeds the HIGH limit.
IN :	Measured value is within the HIGH and LOW limits, inclusive.
LOW :	Measured value is lower than the LOW limit.

1-27. OTHER OPTIONS

1-28. The following options provide the mechanical parts necessary for rack mounting and hand carrying:

Option 907 :	Front Handle Kit. Furnishes carrying handles for both ends of the front-panel.
Option 908 :	Rack Flange Kit. Furnishes flanges for rack mounting.
Option 909 :	Rack Flange and Front Handle Kit. Furnishes front handles (Opt. 907) and rack flanges (Opt. 908).

Installation instructions for these options are given in Section II.

1-29. Option 910 adds an extra copy of the Operation and Service Manual.

1-30. ACCESSORIES SUPPLIED

1-31. The standard HP Model 4276A LCZ Meter, along with its furnished accessories, is shown in Figure 1-1. The furnished accessories are also listed below:

16047A Test Fixture	(Refer to Table 1-3 for a brief description)
Power Cable	HP Part No. 8120-1378
Fuse	HP Part No. 2110-0007 or 2110-0360

Table 1-1. Specifications (Sheet 1 of 14)

Specifications

Parameters Measured:

C (capacitance), L (inductance), |Z| (impedance), D (dissipation factor), Q (quality factor), ESR (equivalent series resistance), G (conductance), θ (phase angle), HIGH SPEED C, HIGH SPEED L, Δ (deviation)

Parameter Combinations:

Circuit Mode	Parameter Combination
Series 	C-D, C-Q, C-ESR, L-D, L-Q, L-ESR, |Z|- θ , HIGH SPEED C, HIGH SPEED L
Parallel 	C-D, C-Q, C-G, L-D, L-Q, L-G, |Z|- θ , HIGH SPEED C, HIGH SPEED L

Measurement Circuit Modes:

Auto, Series (), and Parallel ()

Measurement Speed Modes:

SLOW, MED, and FAST

Displays:

Measurement Speed Mode	Display Digits	Maximum Display
SLOW	4 1/2	19999 counts
MED		
FAST	3 1/2	1999 counts

Note

Number of display digits depends on the test frequency, the test signal level, and the measurement range.

Measurement Terminals:

5-terminal configuration with guard terminal

Ranging Modes:

Auto and Manual (UP/DOWN keys)

Test Frequencies:

Test Frequency Range	Reduction
100Hz to 200Hz	1Hz
200Hz to 500Hz	2Hz
500Hz to 1kHz	5Hz
1kHz to 2kHz	10Hz
2kHz to 5kHz	20Hz
5kHz to 10kHz	50Hz
10kHz to 20kHz	100Hz

Frequency Control Modes:

SPOT (100Hz, 120Hz, 1kHz, 10kHz)
COARSE (10 Freq. points/decade)
FINE (Maximum resolution)

Frequency Accuracy: ±0.01%

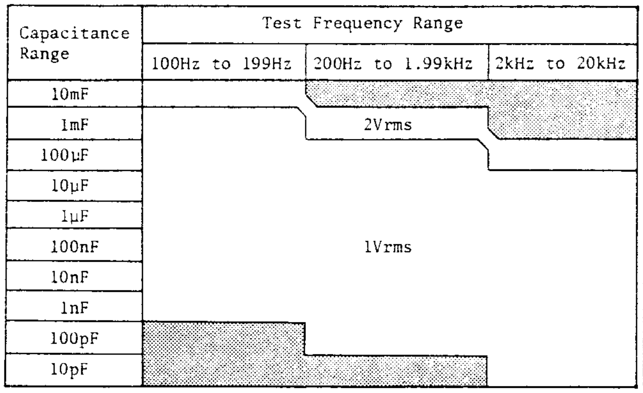
Test Signal Level:

HIGH (1Vrms) or LOW (50mVrms)

Note

HIGH test signal level is 2Vrms on the ranges shown in Tables A and B.

Table A.



Capacitance Range	Test Frequency Range		
	100Hz to 199Hz	200Hz to 1.99kHz	2kHz to 20kHz
10mF	2Vrms	▨	▨
1mF	1Vrms	2Vrms	▨
100µF	1Vrms	1Vrms	2Vrms
10µF	1Vrms	1Vrms	1Vrms
1µF	1Vrms	1Vrms	1Vrms
100nF	1Vrms	1Vrms	1Vrms
10nF	1Vrms	1Vrms	1Vrms
1nF	1Vrms	1Vrms	1Vrms
100pF	▨	1Vrms	1Vrms
10pF	▨	▨	1Vrms

Note: C Measurement in Series CKT Mode

Table 1-1. Specifications (Sheet 2 of 14)

Table B.

Impedance Range	Test Frequency Range
	100Hz to 20kHz
10MΩ	1Vrms
1MΩ	
100kΩ	
10kΩ	
1kΩ	
100Ω	
10Ω	
1Ω	
100mΩ	2Vrms

Note: | Z | Measurement

Level Accuracy:

Test Signal Level	Test Frequency	
	1kHz	Other than 1kHz
HIGH	±10%	±30%
LOW	±20%	

Output Impedance: 100Ω±20%

Deviation Measurement:
Calculates and displays the difference between stored reference values and measured values.

ZERO Offset Adjustment:
Compensation for residual impedance and stray admittance of the test fixture connected to the UNKNOWN terminals is automatically done by the ZERO OPEN/SHORT buttons.

* Compensation frequencies:
20kHz, 16kHz, 10kHz, 5kHz, 2kHz, 1kHz, 500Hz, 200Hz, and 100Hz. Compensation at other frequencies is automatically done by secondary interpolation.

* Maximum offset values:
C: Up to 20pF (OPEN)
G: Up to .2μS (OPEN)
| Z |: Up to 2Ω (SHORT)

SELF TEST:
Checks the 4276A's basic operation when the instrument is turned on or when the SELF TEST key is pressed. If an abnormality is detected, an error code is displayed on DISPLAY A.

External DC Bias:
Up to ±40V dc can be applied to the DUT from an external voltage source connected to the EXT INPUT/INT MONITOR BNC connector on the rear-panel.

Output impedance is 1020Ω±10%.

Trigger:
Internal, External, Manual, or HP-IB remote control

HP-IB (Hewlett-Packard Interface Bus):
Data output and remote control. Based on IEEE Std 488 and ANSI-MC1.1.

Interface Capabilities:
SH1, AH1, T5, L4, SR1, RL1, DC1, DT1, and E1

Remote Control:
All front panel control settings (except power switch, and DC BIAS ON/OFF switch) and all 16064A Comparator/ Handler Interface settings (option 002)

Data Output:
Parameter measured, equivalent circuit mode, display status, measured values, and comparator output. Output format is ASCII format or Binary Packed format.

Continuous Memory:
Memorizes all front panel control settings (except DC BIAS voltage setting), zero offset adjustment data, reference values, and comparator limits (option 002) when the instrument is turned off or experiences a power failure. Settings and data are recalled when the instrument is turned on.

Warm-up Time: Maximum 30minutes

Ambient Temperature:
23 °C±5 °C (At 0 °C to 55 °C, error doubles)

Table 1-1. Specifications (Sheet 3 of 14)

CAPACITANCE MEASUREMENT ACCURACY

C-D Measurement Accuracy:

C Accuracy: ±[(% of reading) + (number of counts)], see Tables A-1 and A-2.

D Accuracy: ±[(% of reading) + (D error) + (number of counts)], see Tables A-1 and A-2.

Note: Use Table A-1 when the test frequency is 100Hz, 120Hz, 1kHz, and 10kHz. Use Table A-2 for all other frequencies.

C-Q Measurement Accuracy:

C Accuracy: ±[(C accuracy of C-D measurement)]

Q Accuracy: ±[(D accuracy ÷ measured D value x 100)% of Q reading + 1 count]

Note: Q is the reciprocal of D.

Note: Q accuracy is calculated from the measured D value. Refer to Figure 3-16.

Table A-1. C-D Accuracies (100Hz, 120Hz, 1kHz, 10kHz only)

Capacitance Range	Test Frequency Range		
	100Hz and 120Hz	1kHz	10kHz
10mF	3% + 4 3% + .03 + 6	▨	▨
1mF	.75% + 2 .75% + .015 + 3	2% + 4 2% + .02 + 6	▨
100μF	.45% + 2 .45% + .015 + 3	.5% + 2 .5% + .01 + 3	3% + 2 3% + .03 + 3
10μF	.15% + 5 .15% + .0009A + 5	.3% + 2 .3% + .01 + 3	1.5% + 2 1.5% + .03 + 3
1μF		.1% + 5 .1% + .0006A + 5	.9% + 2 .9% + .03 + 3
100nF			.3% + 5 .3% + .0018A + 5
10nF			
1nF	.45% + 5 .45% + .0045A + 5		.6% + 10 .6% + .0036A + 10
100pF	▨	.3% + 5 .3% + .003A + 5	
10pF	▨	▨	1.2% + 4 1.2% + .0036A + 6

Table 1-1. Specifications (Sheet 4 of 14)

Table A-2. C-D Accuracies

Capacitance Range	Test Frequency Range						
	101Hz to 199Hz*	200Hz to 498Hz	500Hz to 995Hz	1.01kHz to 1.99kHz	2kHz to 4.98kHz	5kHz to 9.95kHz	10.1kHz to 20kHz
10mF							
1mF		2% + 2 2% + .02 + 3					
100µF		1% + 2 1% + .02 + 3				3% + 2 3% + .03 + 3	5% + 2 5% + .05 + 3
10µF	.2% + 5 .2% + .0012A + 5	.6% + 2 .6% + .02 + 3				1.5% + 2 1.5% + .03 + 3	2.5% + 2 2.5% + .05 + 3
1µF						.9% + 2 .9% + .03 + 3	1.5% + 2 1.5% + .05 + 3
100nF						.3% + 5 .3% + .0018A + 5	.5% + 5 .5% + .003A + 5
10nF							
1nF	.6% + 5 .6% + .006A + 5					.6% + 10 .6% + .0036A + 10	1% + 10 1% + .006A + 10
100pF			.4% + 2 .4% + .0012A + 3	.6% + 5 .6% + .006A + 5			2% + 20 2% + .012A + 20
10pF						1.2% + 4 1.2% + .0036A + 6	2% + 4 2% + .006A + 6

* Except 120Hz

Equations in Tables A-1 and A-2 represent

C Accuracy
D Accuracy

α: Full-scale factor (= measured C value ÷ full-scale C value). For example, when the measured C value is 850pF on the 1000pF range, α is 0.85.

A: $= [\alpha + (1/\alpha)]/2$

Note 1: Tables A-1 and A-2 are applicable under the following conditions:

(1) Test Signal Level: HIGH

(2) Measurement Speed: MED or SLOW

(3) Sample's D Value: ≤ 0.1

(4) Zero offset adjustment has been performed with the OPEN and SHORT terminations of the Model 16074A.

Note 2: Error doubles when LOW test signal level (50mVrms) is used. LOW test signal level can be used only on the ranges enclosed in the bold line in Tables A-1 and A-2.

Note 3: When FAST measurement speed is used, accuracies double on the ranges outside the area enclosed in the bold line in Tables A-1 and A-2.

HIGH SPEED C Measurement Accuracy:

C Accuracy: ±[(C accuracy of C-D measurement) + (X% of reading)], see Table A-3.

Note: HIGH SPEED C accuracy is specified on the ranges enclosed in the dotted line in Tables A-1 and A-2.

Table A-3. Additional Error

Test Signal Level	Sample's D Value			
	D≤.0004	.0004<D≤.002	.002<D≤.1	D>.1
HIGH	X = 0		X = 20D	Not specified.
LOW	X = 0	X = 100D		

Note: Table A-3 is applicable under the following condition:

(1) Zero offset adjustment has been performed with the OPEN and SHORT terminations of the Model 16074A.

Table 1-1. Specifications (Sheet 5 of 14)

C-ESR/G Measurement Accuracy:

C Accuracy: ±[(C accuracy of C-D measurement)]

ESR Accuracy: ±[(% of reading) + (ESR error in ohms), see Tables A-4 and A-5.

G Accuracy: ±[(% of reading) + (G error in siemens) + (number of counts)], see Tables A-4 and A-5.

Note: Use Table A-4 when the test frequency is 100Hz, 120Hz, 1kHz, or 10kHz. Use Table A-5 for all other frequencies.

Note: ESR range and G range depend on the selected C range and test frequency. Refer to Table A-6.

Note: DISPLAY B function, when ESR/G is selected, depends on the CIRCUIT MODE.

Table A-4. C-ESR/G Accuracies (100Hz, 120Hz, 1kHz, 10kHz only)

ESR/G Range		Test Frequency Range		
		100Hz and 120Hz	1kHz	10kHz
ESR	10MΩ	See Note 1 .6% + 6αnS + $\underline{5}$	See Note 1 .3% + 3αnS + $\underline{5}$	See Note 1 1.2% + 12αnS + $\underline{4}$
G	1μS			
ESR	1MΩ	See Note 1 .2% + 40αnS + $\underline{5}$	See Note 1 .1% + 20αnS + $\underline{5}$	See Note 1 .6% + .12αμS + $\underline{10}$
G	10μS			
ESR	100kΩ	See Note 1 .2% + .4αμS + $\underline{5}$	See Note 1 .1% + .2αμS + $\underline{5}$	See Note 1 .6% + 1.2αμS + $\underline{10}$
G	100μS			
ESR	10kΩ	See Note 1 .2% + 4αμS + $\underline{5}$	See Note 1 .1% + 2αμS + $\underline{5}$	See Note 1 .3% + 6αμS + $\underline{5}$
G	1mS			
ESR	1kΩ	See Note 1 .2% + 40αμS + $\underline{5}$	See Note 1 .1% + 20αμS + $\underline{5}$	See Note 1 .3% + 60αμS + $\underline{5}$
G	10mS			
ESR	100Ω	.4% + .4/αΩ + $\underline{5}$ See Note 2	.2% + .2/αΩ + $\underline{5}$ See Note 2	.6% + .6/αΩ + $\underline{5}$ See Note 2
G	100mS			
ESR	10Ω	1% + .1/αΩ + $\underline{2}$ See Note 2	.5% + 50/αmΩ + $\underline{2}$ See Note 2	1.5% + .15/αΩ + $\underline{2}$ See Note 2
G	1S			
ESR	1Ω	2% + 20/αmΩ + $\underline{2}$ See Note 2	1% + 10/αmΩ + $\underline{2}$ See Note 2	3% + 30/αmΩ + $\underline{2}$ See Note 2
G	10S			

Table 1-1. Specifications (Sheet 6 of 14)

Table A-5. C-ESR/G Accuracies

ESR/G Range		Test Frequency Range						
		101Hz to 199Hz*	200Hz to 498Hz	500Hz to 995Hz	1.01kHz to 1.99kHz	2kHz to 4.98kHz	5kHz to 9.95kHz	10.1kHz to 20kHz
ESR G	10MΩ 1µS	See Note 1 .6% + 6αnS + 5	▨	See Note 1 .4% + 4αnS + 2	See Note 1 .6% + 6αnS + 5	▨	See Note 1 1.2% + 12αnS + 4	See Note 1 2% + 20αnS - 4
ESR G	1MΩ 10µS	See Note 1 .2% + 40αnS + 5					See Note 1 .6% + .12αµS + 10	See Note 1 2% + .4αµS + 20
ESR G	100kΩ 100µS	See Note 1 .2% + .4αµS + 5					See Note 1 .6% + 1.2αµS + 10	See Note 1 1% + 2αµS + 10
ESR G	10kΩ 1mS	See Note 1 .2% + 4αµS + 5					See Note 1 .3% + 6αµS + 5	See Note 1 .5% + 10αµS + 5
ESR G	1kΩ 10mS	See Note 1 .2% + 40αµS + 5					See Note 1 .3% + 60αµS + 5	See Note 1 .5% + .1αmS + 5
ESR G	100Ω 100mS	.4% + .4/αΩ + 5 See Note 2					.6% + .6/αΩ + 5 See Note 2	1% + 1/αΩ + 5 See Note 2
ESR G	10Ω 1S	1% + .1/αΩ + 2 See Note 2					1.5% + .15/αΩ + 2 See Note 2	2.5% + .25/αΩ + 2 See Note 2
ESR G	1Ω 10S	2% + 20/αmΩ + 2 See Note 2					3% + 30/αmΩ + 2 See Note 2	5% + 50/αmΩ + 2 See Note 2

* Except 120Hz

Equations in Tables A-4 and A-5 represent:

ESR Accuracy

G Accuracy

α: Full-scale factor (= measured C value ÷ full-scale C value). For example, when the measured C value is 850pF on the 1000pF range, α is 0.85.

Note 1: ESR accuracy is ±[2 (C accuracy ÷ measured C x 100)% of ESR reading + (G accuracy ÷ measured G x 100)% of ESR reading + 1 count].

Note 2: G accuracy is ±[2 (C accuracy ÷ measured C x 100)% of G reading + (ESR accuracy ÷ measured ESR x 100)% of G reading) + 1 count].

Note 3: Tables A-4 and A-5 are applicable under the following conditions:

(1) Test Signal Level: HIGH

(2) Measurement Speed Mode: MED or SLOW

(3) Sample's D Value: ≤ 0.1

(4) Zero offset adjustment has been performed with the OPEN and SHORT terminations of the Model 16074A.

Note 4: Error doubles when LOW test signal level (50mVrms) is used. LOW test signal level can be used only on the ranges enclosed in the bold line in Tables A-4 and A-5.

Note 5: When FAST measurement speed is used, accuracies doule on the ranges outside the area enclosed in the bold line in Tables A-4 and A-5.

Table A-6. ESR/G Range Selection

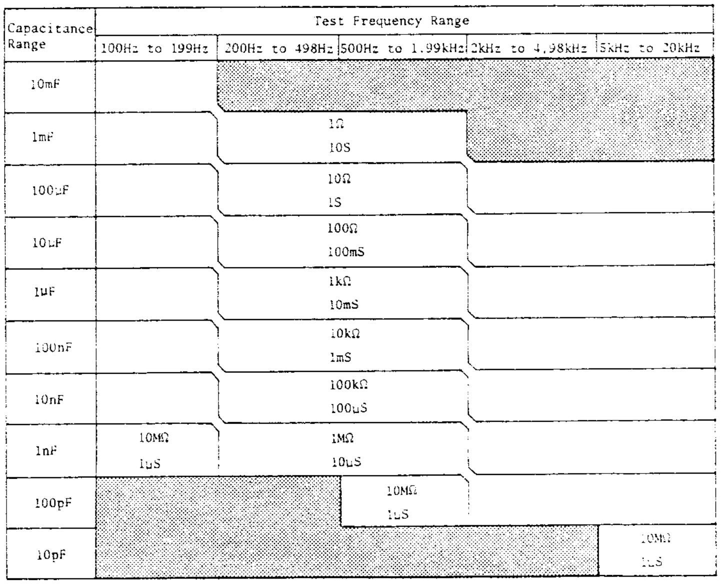


Table 1-1. Specifications (Sheet 7 of 14)

INDUCTANCE MEASUREMENT ACCURACY

L-D Measurement Accuracy:

L Accuracy: ±[(% of reading) + (L error) + (number of counts)], see Tables B-1 and B-2.

D Accuracy: ±[(% of reading) + (D error) + (number of counts)], see Tables B-1 and B-2.

Note: Use Table B-1 when the test frequency is 100Hz, 120Hz, 1kHz, or 10kHz. Use Table B-2 for all other frequencies.

L-Q Measurement Accuracy:

L Accuracy: ±[(L accuracy of L-D measurement)]

Q Accuracy: ±[(D accuracy ÷ measured D value x 100)% of Q reading + 1 count]

Note: Q value is the reciprocal of D.

Note: Q accuracy is calculated from the measured D value. Refer to Figure 3-15.

Table B-1. L-D Accuracies (100Hz, 120Hz, 1kHz, 10kHz only)

Inductance Range	Test Frequency Range		
	100Hz and 120Hz	1kHz	10kHz
1kH	(1 + α)% + 2 2% + .02 + 2		
100H	.4 (1 + α)% + 2 .8% + .02 + 2	.5 (1 + α)% + 2 1% + .01 + 2	
10H		.2 (1 + α)% + 2 .4% + .01 + 2	1.5 (1 + α)% + 2 3% + .03 + 2
1H			.6 (1 + α)% + 2 1.2% + .03 + 2
100mH	.4% + 5 .6% + .006/α + 5		
10mH	.6% + 5 .8% + .008/α + 5	.2% + 5 .3% + .003/α + 5	
1mH		.3% + 5 .4% + .004/α + 5	.6% + 5 .9% + .009/α + 5
100µH			.9% + 5 1.2% + .012/α + 5

Table 1-1. Specifications (Sheet 8 of 14)

Table B-2. L-D Accuracies

Inductance Range	Test Frequency Range			
	101Hz to 995Hz*	1.01kHz to 4.98kHz	5kHz to 9.95kHz	10.1kHz to 20kHz
1kH		▨	▨	▨
100H		$(1 + \alpha)\% + \underline{2}$ $2\% + .02 + \underline{2}$	$1.5\ (1 + \alpha)\% + \underline{2}$ $3\% + .03 + \underline{2}$	▨
10H				$2.5\ (1 + \alpha)\% + \underline{2}$ $5\% + .05 + \underline{2}$
1H		$.4\ (1 + \alpha)\% + \underline{2}$ $.8\% + .02 + \underline{2}$	$.6\ (1 + \alpha)\% + \underline{2}$ $1.2\% + .03 + \underline{2}$	
100mH				$(1 + \alpha)\% + \underline{2}$ $2\% + .05 + \underline{2}$
10mH		$.4\% + \underline{5}$ $.6\% + .006/\alpha + \underline{5}$	$.6\% + \underline{5}$ $.9\% + .009/\alpha + \underline{5}$	
1mH	▨	$.6\% + \underline{5}$ $.8\% + .008/\alpha + \underline{5}$	$.9\% + \underline{5}$ $1.2\% + .012/\alpha + \underline{5}$	$1\% + \underline{5}$ $1.5\% + .015/\alpha + \underline{5}$
100uH	▨	▨	▨	$1.5\% + \underline{5}$ $2\% + .02/\alpha + \underline{5}$

* Except 120Hz

Equations in Tables B-1 and B-2 represent:

L Accuracy
D Accuracy

α: Full-scale factor (= measured L value ÷ full-scale L value). For example, when the measured L is 850nH on the 1000nH range, α is 0.85.

Note 1: Tables B-1 and B-2 are applicable under the following conditions:

(1) Test Signal Level: HIGH

(2) Measurement Speed Mode: MED or SLOW

(3) Sample's D Value: ≤ 0.1

(4) Zero offset adjustment has been performed with the OPEN and SHORT terminations of the Model 16074A.

Note 2: When FAST measurement speed is used, accuracies double on the ranges outside the area enclosed in the bold line in Tables B-1 and B-2 .

Note 3: LOW test signal level cannot be used in L measurement mode.

HIGH SPEED L Measurement Accuracy:

L Accuracy: ±[(L accuracy of L-D measurement) + (Y% of reading)], see Table B-3.

Note: HIGH SPEED L accuracy is specified on the ranges enclosed in the dotted line in Tables B-1 and B-2.

Table B-3. Additional Error

Test Signal Level	Sample's D Value			
	D≤.0004	.0004<D≤.002	.002<D≤.1	D>.1
HIGH	Y = 0		Y = 20D	Not specified.

Note: Table B-3 is applicable under the following conditions:

(1) Zero offset adjustment has been performed with the OPEN and SHORT terminations of the Model 16074A.

Note: LOW test signal level cannot be used in L measurement mode.

Table 1-1. Specifications (Sheet 9 of 14)

L-ESR/G Measurement Accuracy:

L Accuracy: ±[(L accuracy of L-D measurement)]

ESR Accuracy: ±[(% of reading) + (ESR error in ohms) + (number of counts)], see Tables B-4 and B-5.

G Accuracy: ±[(% of reading) + (G error in siemens) + (number of counts)], see Tables B-4 and B-5.

Note: Use Table B-4 when the test frequency is 100Hz, 120Hz, 1kHz, or 10kHz. Use Table B-5 for all other frequencies.

Note: ESR range and G range depend on the selected L range and test frequency. Refer to Table B-6.

Note: DISPLAY B function, when ESR/G is selected, depends on the CIRCUIT MODE.

Table B-4. L-ESR/G Accuracies (100Hz, 120Hz, 1kHz, 10kHz only)

ESR/G Range		Test Frequency Range		
		100Hz and 120Hz	1kHz	10kHz
ESR	1MΩ	See Note 1 .4% + 40/αnS + 2	See Note 1 .2% + 20/αnS + 2	See Note 1 1.2% + .12/αµS + 4
G	10µS			
ESR	100kΩ	See Note 1 .4% + .4/αµS + 5	See Note 1 .2% + .2/αµS + 5	See Note 1 1.2% + 1.2/αµS + 10
G	100µS			
ESR	10kΩ	See Note 1 .4% + 4/αµS + 5	See Note 1 .2% + 2/αµS + 5	See Note 1 .6% + 6/αµS + 5
G	1mS			
ESR	1kΩ	See Note 1 .4% + 40/αµS + 5	See Note 1 .2% + 20/αµS + 5	See Note 1 .6% + 60/αµS + 5
G	10mS			
ESR	100Ω	.2% + .4αΩ + 5 See Note 2	.1% + .2αΩ + 5 See Note 2	.3% + .6αΩ + 5 See Note 2
G	100mS			
ESR	10Ω	.6% + 60αmΩ + 10 See Note 2	.3% + 30αmΩ + 10 See Note 2	.9% + 90αmΩ + 10 See Note 2
G	1S			

Table 1-1. Specifications (Sheet 10 of 14)

Table B-5. L-ESR/G Accuracies

ESR/G Range		Test Frequency Range		
		101Hz to 4.98kHz*	5kHz to 9.95kHz	10.1kHz to 20kHz
ESR G	1MΩ 10µS	See Note 1 .4% + 40/αnS + $\underline{2}$	See Note 1 1.2% + .12/αµS + $\underline{4}$	See Note 1 4% + .4/αµS + $\underline{8}$
ESR G	100kΩ 100µS	See Note 1 .4% + .4/αµS + $\underline{5}$	See Note 1 1.2% + 1.2/αµS + $\underline{10}$	See Note 1 2% + 2/αµS + $\underline{10}$
ESR G	10kΩ 1mS	See Note 1 .4% + 4/αµS + $\underline{5}$	See Note 1 .6% + 6/αµS + $\underline{5}$	See Note 1 1% + 10/αµS + $\underline{5}$
ESR G	1kΩ 10mS	See Note 1 .4% + 40/αµS + $\underline{5}$	See Note 1 .6% + 60/αµS + $\underline{5}$	See Note 1 1% + 100/αµS + $\underline{5}$
ESR G	100Ω 100mS	.2% + .4αΩ + $\underline{5}$ See Note 2	.3% + .6αΩ + $\underline{5}$ See Note 2	.5% + αΩ + $\underline{5}$ See Note 2
ESR G	10Ω 1S	.6% + 60αmΩ + $\underline{10}$ See Note 2	.9% + 90αmΩ + $\underline{10}$ See Note 2	1.5% + .15αΩ + $\underline{10}$ See Note 2

* Except 120Hz and 1kHz

Equations in Tables B-4 and B-5 represent:

ESR Accuracy
G Accuracy

α: Full-scale factor (= measured L value ÷ full-scale L value). For example, when measured C value is 850nH on the 1000nH range, α is 0.85.

Note 1: ESR accuracy is ±[(L accuracy ÷ measured L x 100)% of ESR reading + (G accuracy ÷ measured G x 100)% of ESR reading + 1 count].

Note 2: G accuracy is ±[2 (L accuracy ÷ measured L x 100)% of G reading + (ESR accuracy ÷ measured ESR x 100)% of G reading + 1 count].

Note 3: Tables B-4 and B-5 are applicable under the following conditions:

(1) Test Signal Level: HIGH

(2) Measurement Speed Mode: MED or SLOW

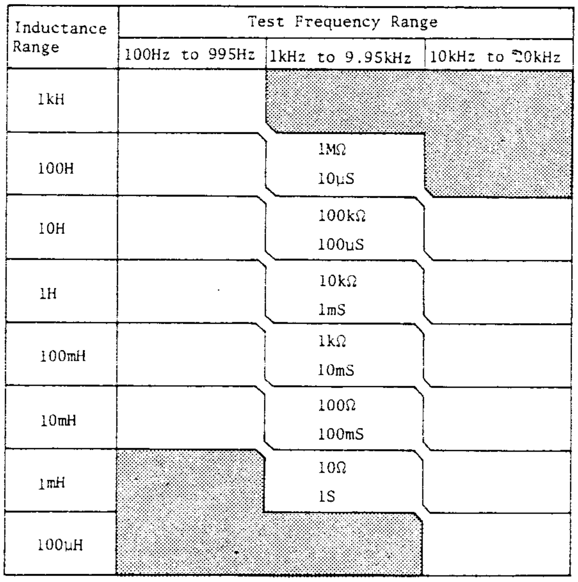
(3) Sample's D Value: ≤ 0.1

(4) Zero offset adjustment has been performed with the OPEN and SHORT terminations of the Model 16074A.

Note 4: When FAST measurement speed is used, accuracies double on the ranges outside the area enclosed in the bold line in Tables B-4 and B-5.

Note 5: LOW test signal level cannot be used in L measurement mode.

Table B-6. ESR/G Range Selection



Inductance Range	Test Frequency Range		
	100Hz to 995Hz	1kHz to 9.95kHz	10kHz to 20kHz
1kH		▨	▨
100H		1MΩ 10µS	▨
10H		100kΩ 100uS	
1H		10kΩ 1mS	
100mH		1kΩ 10mS	
10mH		100Ω 100mS	
1mH	▨	10Ω 1S	
100µH	▨	▨	

Table 1-1. Specifications (Sheet 11 of 14)

IMPEDANCE MEASUREMENT ACCURACY

|Z|-θ Measurement Accuracy:

|Z| Accuracy: ±[(% of reading) + (number of counts)], see Tables C-1 and C-2.

θ Accuracy: ±[(θ error in degrees) + (number of counts)], see Tables C-1 and C-2.

Note: Use Table C-1 when the test frequency is 100Hz, 120Hz, 1kHz, or 10kHz. Use Table C-2 for all other frequencies.

Table C-1. |Z|-θ Accuracies (100Hz, 120Hz, 1kHz, 10kHz only)

Impedance Range	Test Frequency Range		
	100Hz and 120Hz	1kHz	10kHz
10MΩ	(1 + α)% + 2 (1 + α)° + 2		2 (1 + α)% + 2 2 (1 + α)° + 2
1MΩ	.5 (1 + α)% + 2 .5 (1 + α)° + 2		(1 + α)% + 2 (1 + α)° + 2
100kΩ	.2 (1 + α)% + 2 .2 (1 + α)° + 2		.4 (1 + α)% + 2 .4 (1 + α)° + 2
10kΩ			
1kΩ			
100Ω	.1% + 5 .1/α° + 5		.2% + 5 .2/α° + 5
10Ω	.3% + 5 .3/α° + 5		.6% + 5 .6/α° + 5
1Ω	.7% + 2 .5/α° + 2		1.4% + 2 1/α° + 2
100mΩ	1% + 20 1/α° + 2		2% + 20 2/α° + 2

Table 1-1. Specifications (Sheet 12 of 14)

Table C-2. | Z | - θ Accuracies

Impedance Range	Test Frequency Range		
	101Hz to 995Hz*	1.01kHz to 9.95kHz	10.1kHz to 20kHz
10MΩ	(1 + α)% + 2 (1 + α)° + 2	2 (1 + α)% + 2 2 (1 + α)° + 2	5 (1 + α)% + 2 5 (1 + α)° + 2
1MΩ	.5 (1 + α)% + 2 .5 (1 + α)° + 2	(1 + α)% + 2 (1 + α)° + 2	2.5 (1 + α)% + 2 2.5 (1 + α)° + 2
100kΩ	.2 (1 + α)% + 2 .2 (1 + α)° + 2	.4 (1 + α)% + 2 .4 (1 + α)° + 2	(1 + α)% + 2 (1 + α)° + 2
10kΩ			
1kΩ			
100Ω	.1% + 5 .1/α° + 5	.2% + 5 .2/α° + 5	.5% + 5 .5/α° + 5
10Ω	.3% + 5 .3/α° + 5	.6% + 5 .6/α° + 5	1.5% + 5 1.5/α° + 5
1Ω	.7% + 2 .5/α° + 2	1.4% + 2 1/α° + 2	3.5% + 2 2.5/α° + 2
100mΩ	1% + 20 1/α° + 2	2% + 20 2/α° + 2	5% + 20 5/α° + 2

* Except 120Hz

Equations in Tables C-1 and C-2 represent:

Z Accuracy

θ Accracy

α: Full-scale factor (= measured | Z | value ÷ full-scale | Z | value). For example, when measured | Z | value is 850Ω on the 1000Ω range, α is 0.85.

Note 1: Tables C-1 and C-2 are available under the following conditions:

(1) Test Signal Level: HIGH

(2) Measurement Speed Mode: MED or SLOW

(3) Sample's D Value: ≤ 0.1

(4) Zero offset adjustment has been performed with the OPEN and SHORT terminations of the Model 16074A.

Note 2: When FAST measurement speed is used, accuracies double on the ranges outside the area enclosed in thd bold line in Tables C-1 and C-2.

Note 3: LOW test signal level cannot be used in | Z | measurement mode.

Table 1-1. Specifications (Sheet 13 of 14)

Options

Option 001:

Internal DC Bias. Equips the standard 4276A with a variable 0 to ±40V dc voltage source for biasing DUTs connected to the UNKNOWN terminals. Output voltage can be set from the front panel or via the HP-IB.

Bias Control Range and Accuracy:

Voltage Range	Step	Temperature	Accuracy
10.0 to 40.0V	100mV	23°C ± 5°C	±(.5%+35mV)
		0°C to 55°C	±(1%+70mV)
.00 to 9.99V	10mV	23°C ± 5°C	±(.3%+10mV)
		0°C to 55°C	±(1%+20mV)
-9.99 to -.01V	10mV	23°C ± 5°C	±(1%+10mV)
		0°C to 55°C	±(2%+20mV)
-40.0 to -10.0V	100mV	23°C ± 5°C	±(1%+35mV)
		0°C to 55°C	±(2%+70mV)

Note

DC bias voltage is specified 2 minutes after the voltage is set.

Output Impedance: 1020Ω±10%

Bias Voltage Monitor:

Bias voltage across the DUT can be monitored at the EXT INPUT/INT MONITOR BNC connector on the rear panel. INT MONITOR output impedance is approximately 730Ω.

Output Characteristics:

Range Resistor Value	Maximum Current
100Ω	1mA
1kΩ	0.5mA
10kΩ	50μA
100kΩ	5μA

Note

Refer to Figure 3-16 for the range resistor value.

Note

Measurement accuracies are not guaranteed if output current exceeds the maximum current for each range resistor.

Option 002: COMPARATOR/HANDLER INTERFACE

Contents:

Model 16064A COMPARATOR/HANDLER INTERFACE (Includes the 16064-66502 Interface board assembly and 1251-0084 36-pin male Amphenol connector)

Comparator Function:

Compares measured values to 9 sets (Bins) of stored high/low limits. Displays LOW/IN/HIGH judgements and bin number.

Handler Interface Function: Outputs comparison results and handler control signals (TTL, open-collectors). Detects KEY LOCK and EXT TRIGGER signals sent from component handler.

Option 907: Front handle kit (Part No. 5061-0090)

Option 908: Rack flange kit (Part No. 5061-0078)

Option 909: Rack flange and handle kit (Part No. 5061-0084)

Option 910: Extra manual

Table 1-1. Specifications (Sheet 14 of 14)

Accessories Supplied

Test Fixture:
16047A Test Fixture. Includes three kinds of contact inserts

Power Cord: HP Part No. 8120-1378

Fuse:

Part No. 2110-0007 (100V/120V)
Part No. 2110-0360 (220V/240V)

Protective Fuse:

Part No. 2110-0011 (for dc bias input)

Accessories Available

HP-IB Cable:

10833A (1m)	10833C (4m)
10833B (2m)	10833D (0.5m)

Test Fixtures and Test Leads: Refer to Table 1-3.

General Specifications

Operating Temperature: 0 °C to 55 °C

Relative Humidity: 95% at 40 °C

Storage Temperature: -40 °C to +70 °C

Power Requirements:
90V to 132V, 198V to 250V. 48Hz to 66Hz.

Power Consumption:
65VAmax with any option

Dimensions:
425.5 (W) x 188 (H) x 430 (D) mm

Weight: Approximately 8.5kg

1-32. ACCESSORIES AVAILABLE

1-33. In addition to the furnished 16047A Test Fixture, seven special purpose test fixtures and test leads are available. Each is intended for a particular measurement or DUT type, and all were designed with careful consideration to accuracy, reliability, ease of use, and compatibility with other HP instruments. A brief description of each available accessory is given in Table 1-3.

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

Supplemental Performance Characteristics

Measurement Accuracy:

Additional Error in 1m/2m Test Lead Usage:

Add the following errors to the measurement accuracies listed in Table 1-1 when a 1m or 2m long test lead is used.

Measurement Function	Additional Error
L, C, |Z|	M% of reading
D	P
θ	60P°
G (C-G)	M% of reading + (G full-scale value) x αP
G (L-G)	M% of reading + (G full-scale value) x P/α

where, α is the full scale factor, and M and P are represented as follows:

$$M = K(.16 + .1\ell) \times (.3f^2 + f)/100$$
$$P = K(.16 + .1\ell) \times (.09f^2 + 1.6f)/1000$$

where, ℓ is the cable length in meters, f is test frequency in kHz, and K is the range resistor factor. See Figure 3-16.

Range Resistor Value	K
100kΩ	10
10kΩ	1
1kΩ	0.1
100Ω	0

The above errors are applicable under the following conditions:

(1) Test Cable: HP Model 16048A (1m long) or 16048D (2m long)

(2) Residual Capacitance to Ground: <100pF at HIGH terminals and <50pF at LOW terminals

(3) Sample's D Value: <0.1

(4) Zero offset adjustment has been performed with the OPEN and SHORT terminations of the 16074A.

Additional Error of Test Fixture:

Add the following errors to the measurement accuracies listed in Table 1-1 when these test fixtures or test leads are used:

Model	Additional Error
16047A, 16047C, 16048A, 16048B, 16048D, 16065A	-
16048C	C<5pF L<200nH R<10mΩ
16034B	C<0.02pF L<30nH R<50mΩ

Accuracies in D>0.1:

Multiply the measurement accuracies for C, L, or D listed in Table 1-1 by $(1 + D^2)$, where D is the sample's D value.

Ranging Time: Approximately 60ms

Test Signal Settling Time:

Approximately 270ms when the test frequency is changed.

Approximately 60ms when the test signal level is changed.

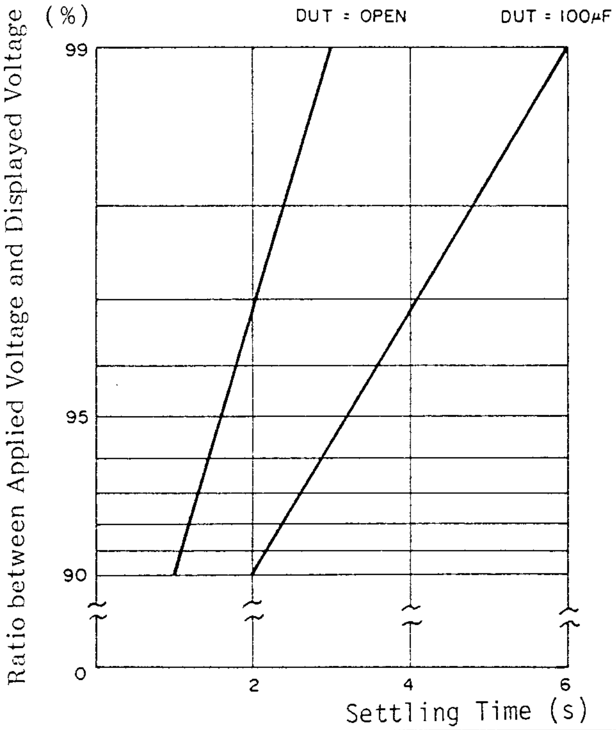
The same as the dc bias settling time when the dc bias voltage is changed.

Continuous Memory:

2 weeks at 23 °C

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

DC Bias Settling Time:
Typical data for OPEN or a 100μF capacitor measurement.



Measurement Time:
See the table below:

No.	Measurement Parameter	Measurement Speed Mode
①	L, C	MED
②	L, C	FAST
③	|Z|	MED
④	|Z|	FAST
⑤	HIGH SPEED L HIGH SPEED C	MED
⑥	HIGH SPEED L HIGH SPEED C	FAST

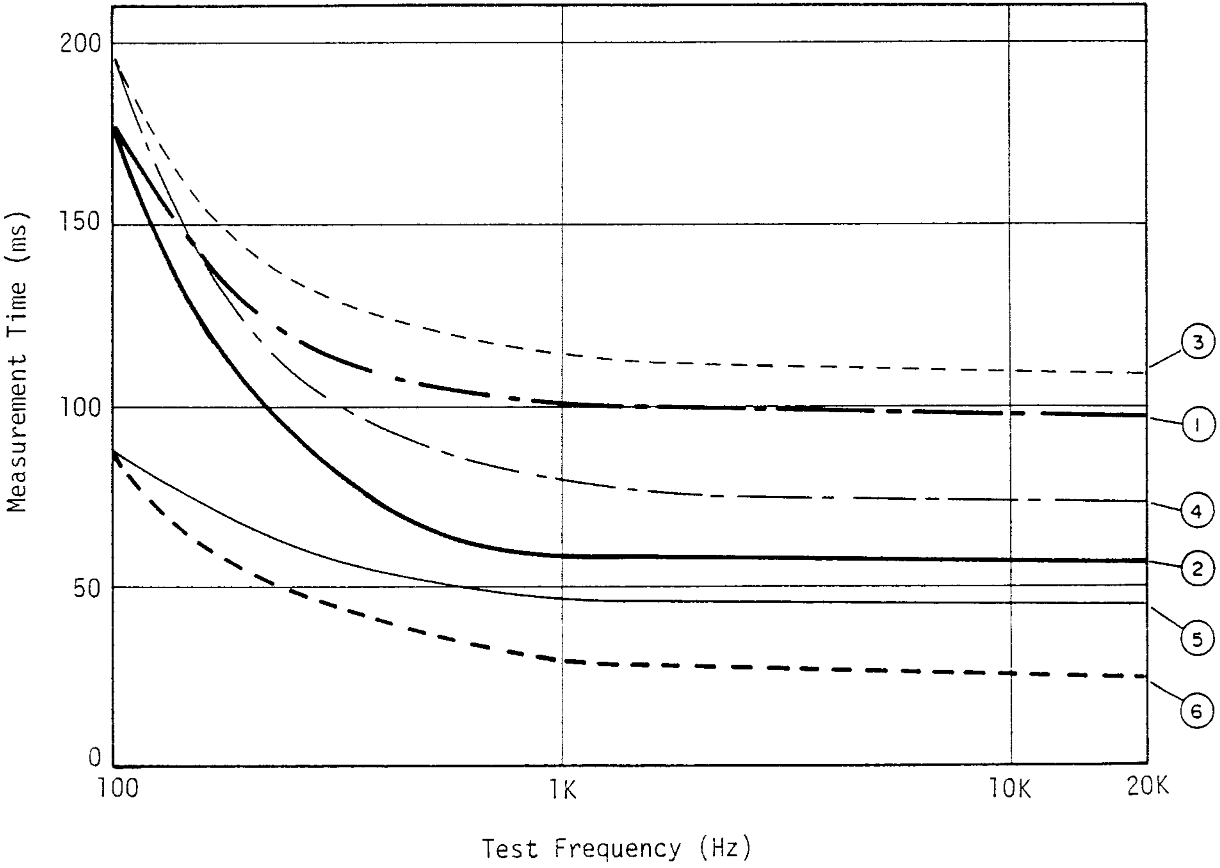


Table 1-3. Accessories Available (Sheet 1 of 3)

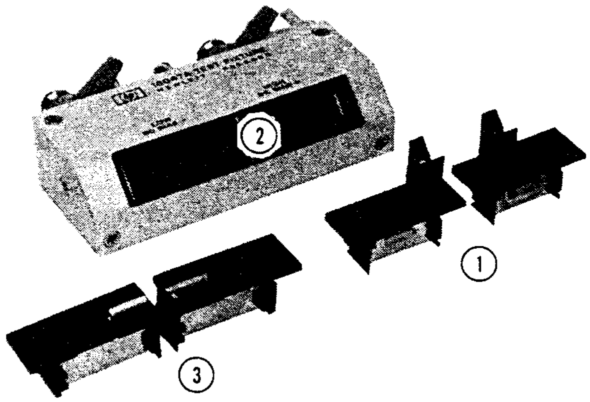
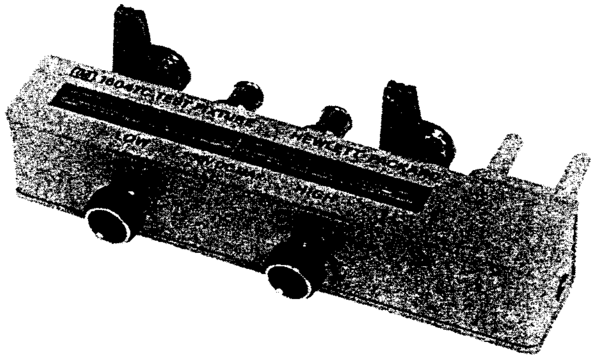
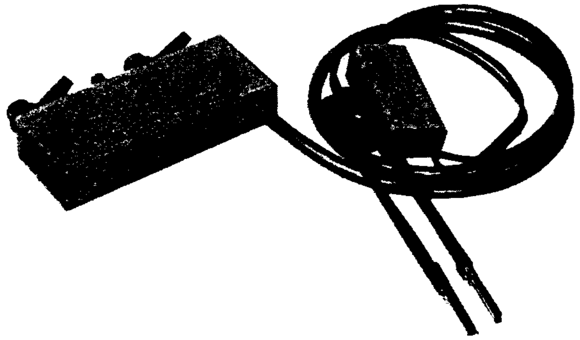
Model	Description
16047A  	Test Fixture (direct attachment type) for measurement of either axial-or radial-lead components. Three kinds of contact inserts are furnished: ① For axial-lead components, (HP P/N: 16061-70022) ② For general radial-lead components, (HP P/N: 16061-70021) ③ For radial short-lead components, (HP P/N: 16047-65001) DC bias up to ±40V* can be applied.
16047C 	Test Fixture (direct attachment type) designed especially for high frequency measurements requiring high accuracy. Two screw knobs facilitate and ensure optimum contact between the test fixture electrodes and the sample leads. DC bias up to ±40V* can be applied.
16034B 	Test Fixture (tweezer type) for measurement of miniature leadless components such as chip capacitors. Employs a three terminal configuration tweezer probe suitable for high impedance (above 50Ω) measurements. DC bias up to ±40V* can be applied. Cable length: 1m

Table 1-3. Accessories Available (Sheet 2 of 3)

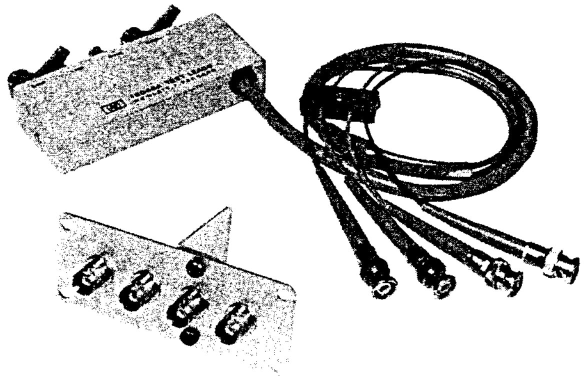
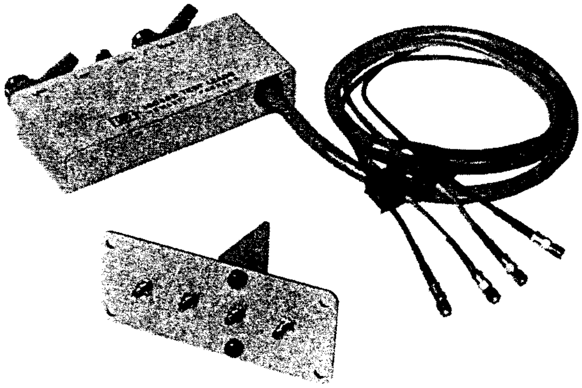
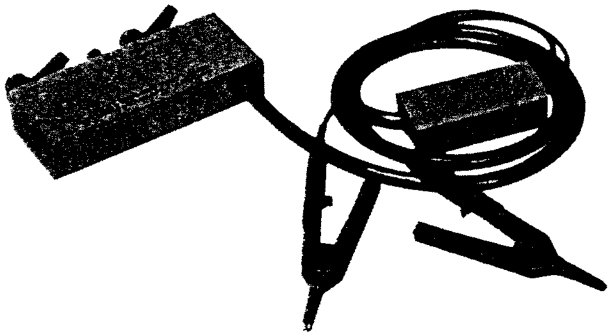
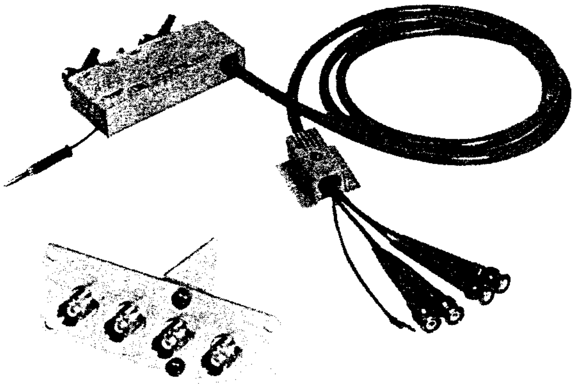
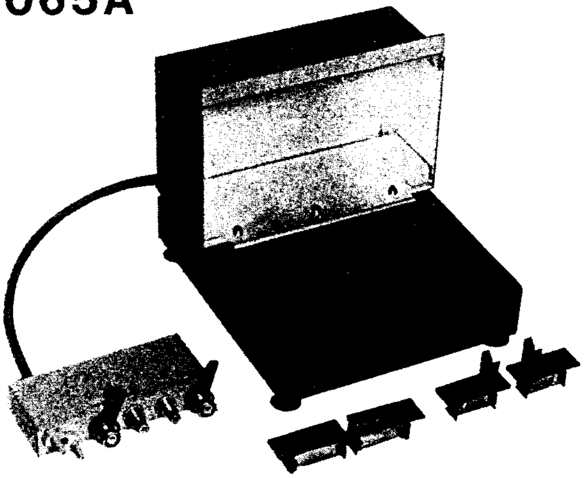
Model	Description
16048A 	Test Leads (four terminal pair) with BNC connectors for connecting user-fabricated test fixtures. DC bias up to ±40V* can be applied. Cable length: 1m
16048B 	Test Leads (four terminal pair) with miniature RF connectors suitable for connecting user-fabricated test fixtures in systems applications. DC bias up to ±40V* can be applied. Cable length: 1m
16048C 	Test Leads with dual alligator clips for testing components of non-standard shapes and sizes at frequencies below 100kHz. Applicable measurement ranges: Capacitance 1000pF Inductance 100μH DC bias up to ±40V* can be applied. Cable length: 1m

Table 1-3. Accessories Available (Sheet 3 of 3)

Model	Description
16048D 	Double-shielded Test Leads (four terminal pair) with BNC connectors for connecting user-fabricated test fixtures. DC bias up to ±40V* can be applied. Cable length: 2m
16065A 	Test Fixture (cable connection type) for measurement of either axial- or radial-lead components at frequencies between 50Hz and 2MHz. Three kinds of contact inserts are furnished (same as those for the 16047A Test Fixture). DC bias up to ±200V can be applied (a protective cover provides for operator safety). Cable length: Approximately 40cm

* Though "±35V DC MAX" is indicated on the test fixtures, they are capable of handling dc bias voltages up to ±40V when used with the 4276A.

SECTION II
INSTALLATION

2-1. INTRODUCTION

2-2. This section provides installation instructions for the Model 4276A LCZ Meter. It also includes information on initial inspection and damage claims, preparation for using the 4276A, and packaging, storage, and shipment.

2-3. INITIAL INSPECTION

2-4. The 4276A LCZ Meter, as 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 III (Paragraph 3-5 SELF TEST) and the procedures for checking the 4276A LCZ Meter against its specifications are given in Section IV. First, do the self test. If the 4276A is electrically questionable, then do the Performance Tests to determine whether the 4276A has failed or not.

If the contents are incomplete, if there is mechanical damage or defects (scratches, dents, broken switches, etc.), or if the performance does not meet 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.

2-5. PREPARATION FOR USE

2-6. POWER REQUIREMENTS

2-7. The 4276A requires a power source of 100, 120, 220 Volts ac ±10%, or 240 Volts ac +5%-10%, 48 to 66Hz single phase; power consumption is 65VA maximum.

WARNING

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

2-8. LINE VOLTAGE AND FUSE SELECTION

CAUTION

BEFORE TURNING THE 4276A LINE SWITCH TO ON, VERIFY THAT THE INSTRUMENT IS SET TO THE VOLTAGE OF THE POWER TO BE SUPPLIED.

2-9. Figure 2-1 provides instructions for line voltage and fuse selection. The line voltage selection switch and the proper fuse are factory installed for the voltage appropriate to instrument destination.

CAUTION

USE PROPER FUSE FOR LINE VOLTAGE SELECTED.

CAUTION

MAKE SURE THAT ONLY FUSES FOR THE REQUIRED RATED CURRENT AND OF THE SPECIFIED TYPE ARE USED FOR REPLACEMENT. THE USE OF MENDED FUSES AND THE SHORT-CIRCUITING OF FUSEHOLDERS MUST BE AVOIDED.

2-10. POWER CABLE

2-11. To protect operating personnel, the National Electrical Manufacturer's Association (NEMA) recommends that the instrument panel and cabinet be grounded. The Model 4276A 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.

2-12. To preserve the protection feature when operating the instrument from a two contact outlet, use a three prong to two prong adapter (HP Part No. 1251-0048) and connect the green pigtail 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 PROTECTIVE CONDUCTOR (GROUNDING).

2-13. Figure 2-2 shows the available power cords, which may be used 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.

2-14. INTERCONNECTIONS

2-15. When an external dc bias source is used, set the DC BIAS select switch on the rear panel to EXT. The output from the external bias source should be connected to EXT INPUT/INT MONITOR connector. The external dc bias fuse is installed in EXT DC BIAS FUSE Holder on rear panel to protect the instrument from excessive current. Fuse rating is as follows:

1/16A, 250V (HP Part No: 2110-0011)

CAUTION

MAKE SURE THAT ONLY FUSES OF THE REQUIRED RATED CURRENT AND OF THE SPECIFIED TYPE ARE USED FOR REPLACEMENT. THE USE OF MENDED FUSES AND THE SHORT-CIRCUITING OF FUSE-HOLDERS MUST BE AVOIDED.

2-16. OPERATING ENVIRONMENT

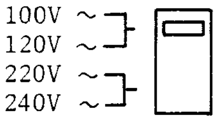
2-17. Temperature. The instrument may be operated in temperatures from 0 °C to +55 °C.

2-18. Humidity. The instrument may be operated in environments with relative humidities to 95% at 40 °C. However, the instrument must be protected from temperature extremes which cause condensation within the instrument.

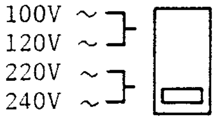
2-19. INSTALLATION INSTRUCTIONS

2-20. The HP Model 4276A can be operated on the bench or in a rack mount. The 4276A is ready for bench operation as shipped from the factory. For bench operation a two-leg instrument stand is used. For use, the instrument stands are designed to be pulled towards the front of instrument.

100V/120V OPERATION



220V/240V OPERATION

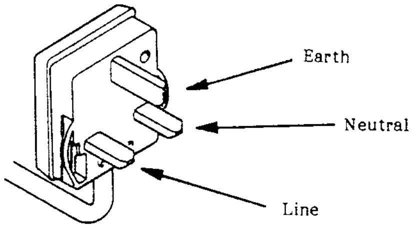


FUSE SELECTION

Line Voltage	Fuse Rating	HP Part No.
100V/120V	1.0AT, 250V, Slow Blow	2110-0007
220V/240V	0.75AT, 250V, Slow Blow	2110-0360

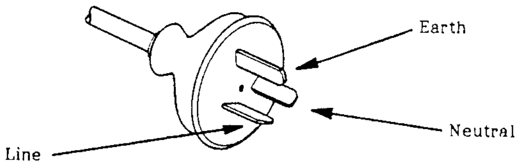
Figure 2-1. Voltage and Fuse Selection.

OPTION 900 United Kingdom



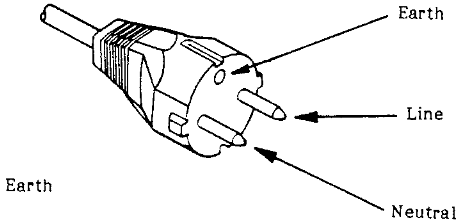
Plug : BS 1363A, 250V
Cable : HP 8120-1351

OPTION 901 Australia/New Zealand



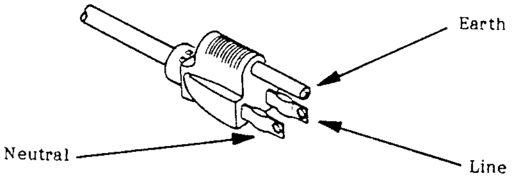
Plug : NZSS 198/AS C112, 250V
Cable : HP 8120-1369

OPTION 902 European Continent



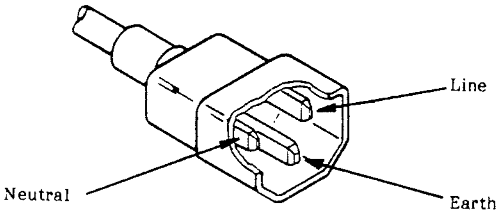
Plug : CEE-VII, 250V
Cable : HP 8120-1689

OPTION 903 U.S./Canada



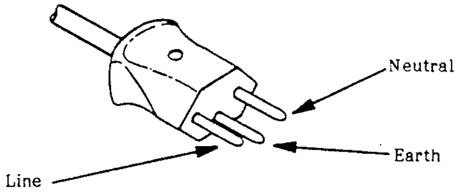
Plug : NEMA 5-15P, 125V, 15A
Cable : HP 8120-1378

OPTION 905* Any country



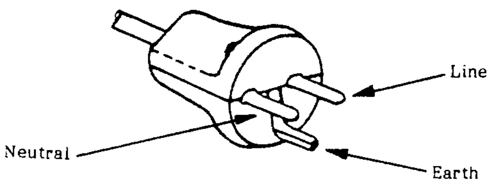
Plug : CEE 22-VI, 250V
Cable : HP 8120-1396

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

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

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

Figure 2-2. Power Cables Supplied.

2-21. Installation of Options 907, 908 and 909.

2-22. The 4276A can be installed in a rack and be operated as a component of a measurement system. Rack mounting information for the 4276A is presented in Figure 2-3.

2-23. STORAGE AND SHIPMENT

2-24. ENVIRONMENT

2-25. The instrument may be stored or shipped in environments within the following limits:

Temperature ······ -40 °C to +70 °C
Humidity ··········· to 95% at 40 °C

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

2-26. PACKAGING

2-27. Original Packaging. Containers and materials identical to those used in factory packaging are available from Hewlett-Packard. If the instrument is being returned to Hewlett-Packard for servicing, attach a tag indicating the type of service required, return address, model number, and full serial number. Also mark the container FRAGILE to assure careful handling. In any correspondence, refer to the instrument by model number and full serial number.

2-28. Other Packaging. The following general instructions should be used for re-packing with commercially available materials:

a. Wrap instrument in heavy paper or plastic. If shipping to Hewlett-Packard office or service center, attach tag indicating type of service required, return address, model number, and full serial number.

b. Use strong shipping container. A double-wall carton made of 350 pound test material is adequate.

c. Use enough shock absorbing material (3 to 4 inch layer) around all sides of instrument to provide firm cushion and prevent movement inside container. Protect control panel with cardboard.

d. Seal shipping container securely.

e. Mark shipping container FRAGILE to ensure careful handling.

f. In any correspondence, refer to instrument by model number and full serial number.

2-29. OPTION INSTALLATION

2-30. Installation procedures for DC Bias option (Option 001) and Comparator/Handler Interface option (Option 002) are given in Figure 2-4.

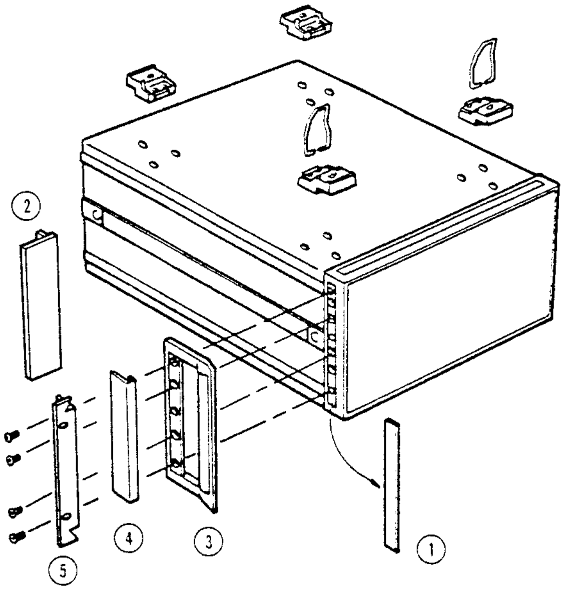
2-31. POWER FAILURE MONITOR INSTALLATION

2-32. To use the power failure monitor signal, you must solder two wires to a jumper on the mother board, remove a cap from a hole on the rear panel, and bring the wires out through the hole. The procedure is given below. A simplified drawing of the open collector circuit, a timing diagram, and the locations of the jumper and hole are shown in Figure 2-6. Refer to paragraph 3-114 for a description of the power failure monitor signal.

Procedure:

1. Turn off the 4276A.
2. Disconnect the 4276A from the ac power source.
3. Remove the top cover.
4. Disconnect the brown 4-terminal connector from the A5 board.
5. Remove the two screws that secure the A5 board to the chassis.
6. Remove the A5 board.
7. Solder a wire to each terminal of A6J3. The location of A6J3 is shown in Figure 2-6 (c).
8. Remove the cap from the access hole in the rear panel, as shown in Figure 2-6 (d).
9. Thread the wires first through the teflon clamp (securing the wires from A6J1) on the A6 board, and then through the access hole in the rear panel.
10. Reinstall the A5 board, reconnect the brown 4-terminal connector to the A5 board, and replace the top cover.

Option	Kit Part Number	Parts Included	Part Number	Q'ty	Remarks
907	Handle Kit 5061-0090	Front Handle Trim Strip X8-32 x 3/8 Screw	③ 5060-9900 ④ 5020-8897 2510-0195	2 2 8	9.525mm
908	Rack Flange Kit 5061-0078	Rack Mount Flange X8-32 x 3/8 Screw	② 5020-8863 2510-0193	2 8	9.525mm
909	Rack Flange & Handle Kit 5061-0084	Front handle Rack Mount Flange X8-32 x 3/8 Screw	③ 5060-9900 ⑤ 5020-8875 2510-0194	2 2 8	15.875mm



1. Remove adhesive-backed trim strips ① from side at right and left front of instrument.
2. HANDLE INSTALLATION : Attach front handle ③ to sides at right and left front of instrument with screws provided and attach trim ④ to handle.
3. RACK MOUNTING : Attach rack mount flange ② to sides at right and left front of instrument with screws provided.
4. HANDLE AND RACK MOUNTING : Attach front handle ③ and rack mount flange ⑤ together to sides at right and left front of instrument with screws provided.
5. When rack mounting (3 and 4 above), remove all four feet (lift bar at inner side of foot, and slide foot toward the bar).

Figure 2-3. Rack Mount Kit.

11. Connect the pull-up resistor and external voltage source as shown in Figure 2-6 (a).

Note

A +5V is recommended but higher voltage can be used as long as the current through A1T5 and A1Q4 does not exceed 25mA.

CAUTION: BEFORE PROCEEDING WITH INSTALLATION OF OPTION(S), TURN OFF THE INSTRUMENT AND DISCONNECT THE AC POWER CORD.

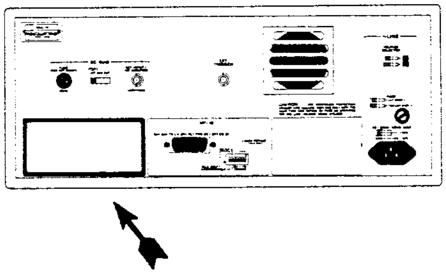
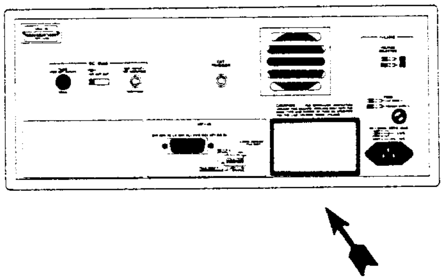
	OPTION 001 DC BIAS SUPPLY (0 to ±40V)	OPTION 002 COMPARATOR/ HANDLER INTERFACE
Option Parts	Board Assembly A22 04276-66522	Comparator 16064A Includes: Interface Board Assembly 16064-66502 and 36-pin male Amphenol connector 1251-0084
Installation Procedure (after removing top cover)	1. Remove the rear panel access plate shown below.  2. Insert the dc bias board (P/N: 04276-66522) into the access hole. 3. Insert the male edge connector of the interface board into the female edge connector of the 4276A mother board and push firmly until the interface board is completely seated. 4. Reinstall the screws removed in step (1).	1. Remove the rear panel access plate shown below.  2. Insert the interface board (P/N: 16064-66502) into the access hole. 3. Insert the male edge connector of the interface board into the female edge connector of the 4276A mother board and push firmly until the interface board is completely seated. 4. Reinstall the screws removed in step 1. 5. Connect the 16064A keyboard cable to the connector on the interface board (installed in step 3). 6. Adjust the power supply in accordance with the procedure given in Figure 2-5.

Figure 2-4. Option Installation.

1. Connect the 4276A to the ac power line.
2. Turn on the instrument. ("16064" should be displayed on DISPLAY B.)
3. Connect A DVM (HP 3478A is recommended) to A1TP1 and GND as shown below.
4. Adjust "V-ADJ" on the A4 board until the reading on the DVM is 5.10V±0.02V.

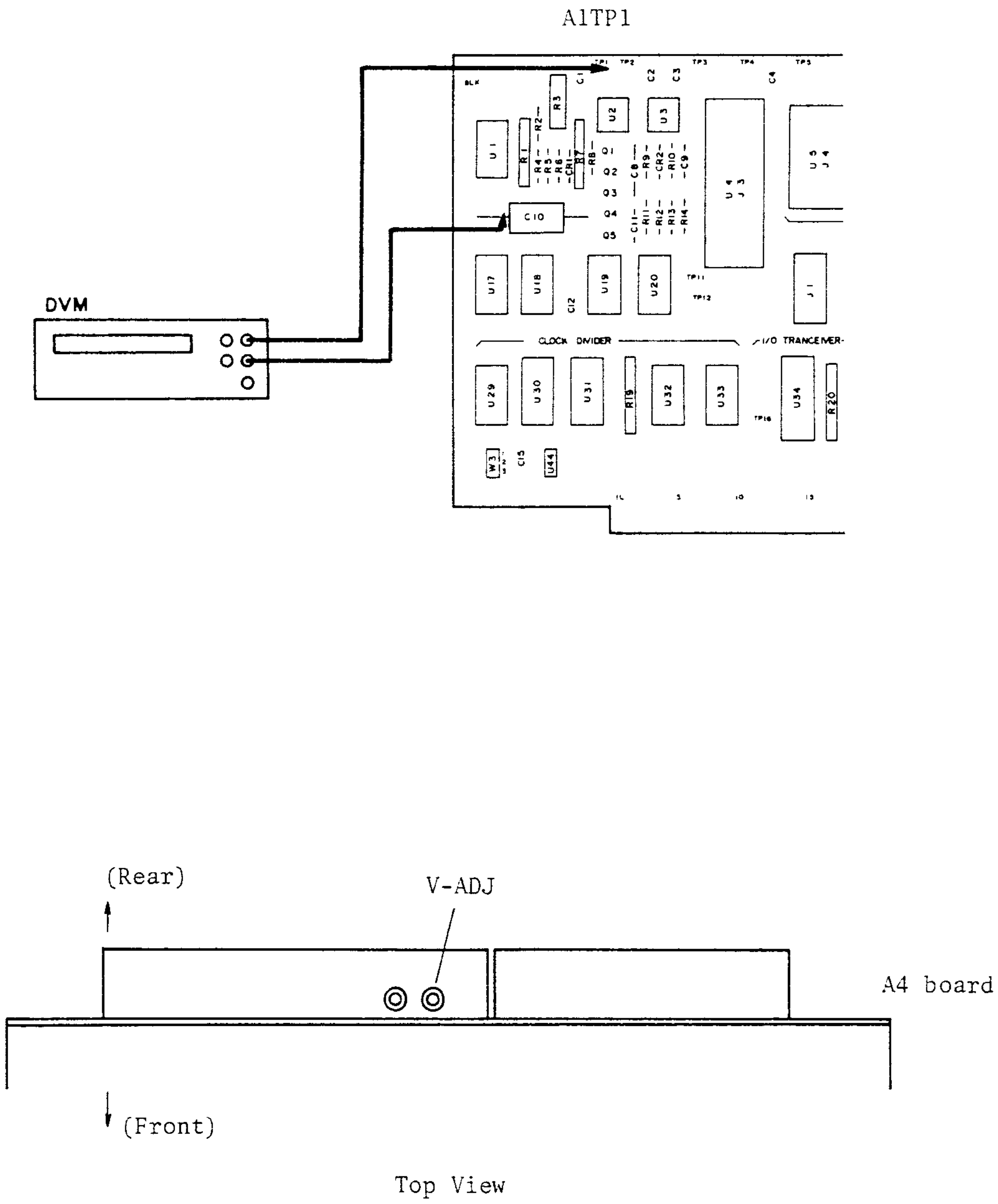


Figure 2-5. Power Supply Adjustment After Installing Option 002.

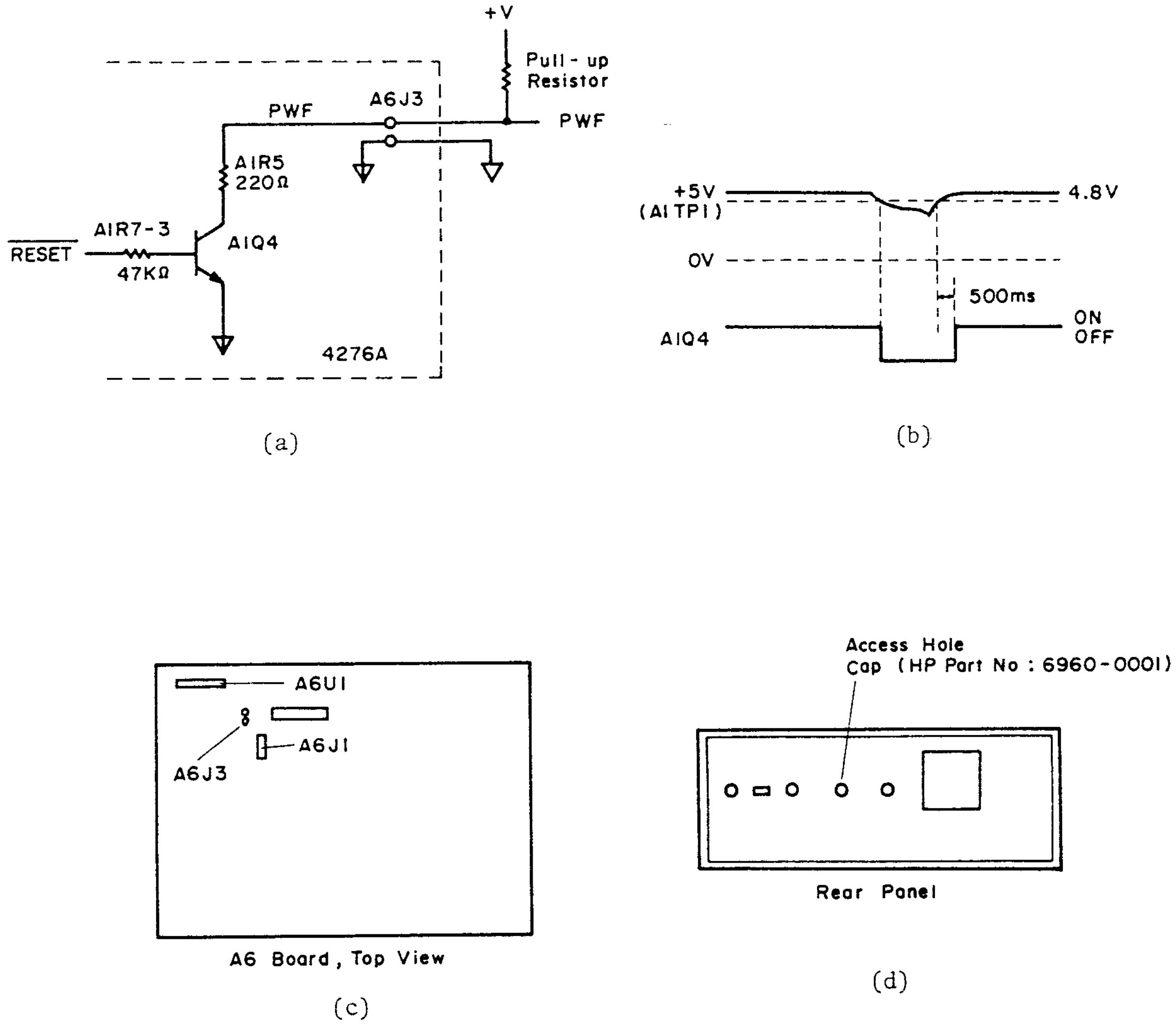


Figure 2-6. Power Failure Monitor Installation.

SECTION III
OPERATION

3-1. INTRODUCTION

3-2. This section provides all the information necessary to operate the Model 4276A LCZ Meter. Included are descriptions of the front- and rear-panels, displays, lamps and connectors; discussions on operating procedures and measuring techniques for various applications; and instructions on the instrument's SELF TEST function. Warnings, Cautions, and Notes are given throughout; they should be observed to insure the safety of the operator and the serviceability of the instrument.

WARNING

BEFORE THE INSTRUMENT IS SWITCHED ON, ALL PROTECTIVE EARTH TERMINALS, EXTENSION CORDS, AUTO-TRANSFORMERS AND DEVICES CONNECTED TO IT SHOULD BE CONNECTED 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 WITH THE REQUIRED RATED CURRENT AND OF THE SPECIFIED TYPE SHOULD BE USED. DO NOT USE REPAIRED FUSES OR SHORTED FUSEHOLDERS. TO DO SO COULD CAUSE A SHOCK OR FIRE HAZARD.

CAUTION

BEFORE THE INSTRUMENT IS SWITCHED ON, IT MUST BE SET TO THE VOLTAGE OF THE POWER SOURCE (MAINS), OR DAMAGE TO THE INSTRUMENT MAY RESULT.

3-3. PANEL FEATURES

3-4. Figures 3-1 and 3-2 identify and briefly describe the purpose of each key, indicator, and connector on the front panel and rear panel, respectively. More detailed information on front panel displays and controls is given starting in paragraph 3-5.

3-5. SELF TEST

3-6. The self test function confirms correct operation of the instrument's basic functions and facilitates troubleshooting. It consists of three parts: (1) ROM/RAM Test, (2) Display Test, and (3) Analog Circuit Test. Each is described in paragraphs 3-7 through 3-11.

3-7. ROM/RAM Test

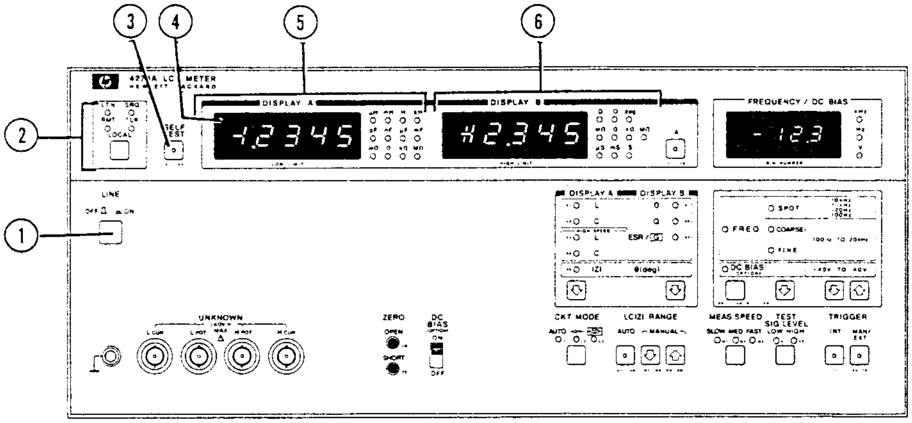
3-8. The ROM/RAM Test is performed each time the instrument is turned on. During this test, all ROMs and RAMs in the instrument's digital control section are tested using a check-sum test and a read/write test (RAMs only). If a malfunction is detected, the test will stop and an error-code will be displayed on DISPLAY A. If the ROMs and RAMs are functioning properly, the instrument will display the HP-IB address (or output data format if the HP-IB control switch is set to TALK ONLY) on DISPLAY A and the option annunciations on DISPLAY B and the FREQUENCY/DC BIAS DISPLAY. Error-codes are described in paragraph 3-20.

Note

If a ROM/RAM test error code, E61 through E68, appears on DISPLAY A when the instrument is turned on, contact the nearest Hewlett-Packard Sales or Service Office for repairs.

Note

ROM/RAM test error code E68 indicates that the instrument's continuous memory feature is not functioning properly. All other instrument functions, including measurement, are not affected.



① LINE OFF/ON Switch:

Applied ac line power to the instrument when set to the ON (▄ in) position. Removes ac line power when set to the OFF (█ out) position.

② HP-IB Status Indicators and LOCAL Key:

These four LED lamps--SRQ, LISTEN, TALK, and REMOTE--indicate the status of the 4276A when it is interfaced with a controller via the HP-IB.

The LOCAL key, when pressed, releases the instrument from REMOTE (HP-IB) control and enables front panel control. The LOCAL key is disabled (does not function) when the instrument is set to "local lockout" by the controller.

③ SELF TEST Key and Indicator:

This key initiates the instrument's SELF TEST function. During SELF TEST (when the indicator is on), nine tests that check the basic operation of the instrument are automatically performed. SELF TEST is repeated until this key is pressed again. If a fault is detected, an error code will be displayed on DISPLAY A ⑤. A complete description of the SELF TEST function is given in paragraph 3-5; error codes are described in paragraph 3-20.

④ Trigger Lamp:

Comes on each time the instrument is internally, externally, or manually triggered. Trigger mode is set by the TRIGGER keys ⑫.

⑤ DISPLAY A:

Displays measured values of inductance, capacitance, or impedance magnitude with a maximum 4-1/2 digits; maximum display is 19999. Number of display digits depends on instrument control settings. The nine LED lamps located to the right of the display are the engineering unit indicators for displayed values. Measurement error messages--OF, UF, CF--operation error codes, SELF TEST error codes, and the instrument's HP-IB address are also displayed on this display.

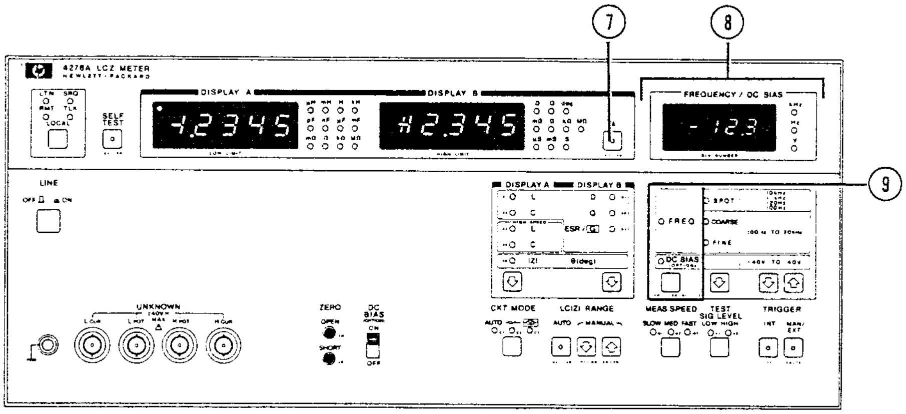
If the instrument is equipped with Option 002, Comparator/Handler Interface, the LOW LIMITs keyed in from the 16064A will be displayed on this display when the 16064A is set to ENABLE and RUN is off.

Decimal point location and engineering unit indicator lamp change when the LC|Z| RANGE ⑯ changes.

⑥ DISPLAYD B:

Displays measured values of dissipation factor, quality factor, equivalent series resistance, conductance or impedance phase angle with a maximum 4-1/2 digits; maximum display is 10000 for quality factor, 18000 for phase, and 19999 for all other parameters. Number of display digits depends on instrument control settings. The nine LED lamps located to the right of the display are the engineering unit indicators for displayed values. Measurement error messages--OF, UF, and CF--are also displayed on this display. When the DISPLAY A Function ⑱ is set to HIGH SPEED L or HIGH SPEED C, or when an error code is displayed on DISPLAY A ⑤, this display is blanked (turned off) by the microprocessor.

Figure 3-1. Front Panel Features (Sheet 1 of 6).



If the instrument is equipped with Option 002, Comparator/Handler Interface, and if the 16064A comparator is connected, the number 16064 will be displayed on this display when the instrument is turned on. Also, the HIGH LIMITs keyed in from the 16064A will be displayed on this display when the 16064A is set to ENABLE and RUN is off.

⑦ Δ Key and Indicator :

This key enables deviation (Δ) measurements on both displays. When this key is pressed, the values displayed on DISPLAY A ⑤ and DISPLAY B ⑥ are stored as reference values. The difference between values obtained in subsequent measurements and the stored reference values is calculated and displayed on each display. The formula used to calculate the deviation is

$$A-B$$

Where A is the measured value of the device under test and B is the stored reference value.

LC|Z| RANGE ⑯ is set to MANUAL when this key is pressed.

Also, the deviation measurement function is turned off by pressing this key again, or by changing the DISPLAY A function ⑱, DISPLAY B function ⑮, LC|Z| RANGE ⑯, or CIRCUIT MODE ⑰. It may be turned off also if the test frequency is changed when the DISPLAY B function is ESR/G.

⑧ FREQUENCY/DC BIAS Display :

Displays test frequency or DC bias voltage (Option 001 only) with 3 digits. The three LED lamps located to the right of the display are unit indicators for displayed values. On instruments equipped with Option 002, Comparator/Handler Interface, bin numbers are displayed on this display when the comparator is set to RUN. Also, on Option 001 instruments, the number 001 is briefly displayed here when the instrument is turned on.

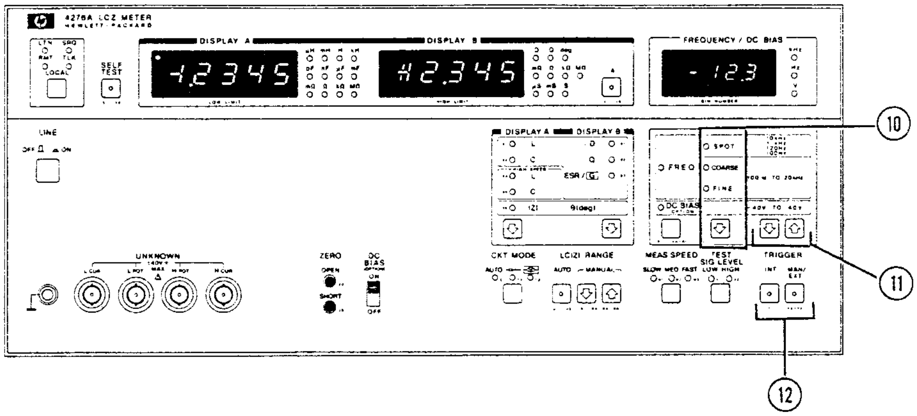
⑨ FREQUENCY/DC BIAS Select Key and Indicators :

This key sets the FREQUENCY/DC BIAS Display ⑧, the SPOT/COARSE/FINE Select key ⑩, and the FREQUENCY/DC BIAS Step Control Keys ⑪ to FREQUENCY control mode or DC BIAS control mode. The selected control mode is indicated by the corresponding LED lamp.

FREQ :	When this LED lamp is on, frequency is displayed on the FREQUENCY/DC BIAS Display and is controlled by the SPOT/COARSE/FINE Key and the FREQUENCY/DC BIAS Step Control Keys.
DC BIAS :	When this LED lamp is on, DC bias voltage is displayed on the FREQUENCY/DC BIAS Display and is controlled by the FREQUENCY/DC BIAS Step Control Keys.

FREQUENCY control mode and DC BIAS control mode are mutually exclusive, and DC BIAS can be selected only if the instrument is equipped with Option 001.

Figure 3-1. Front Panel Features (Sheet 2 of 6).



⑩ SPOT/COARSE/FINE Select Key and Indicators:

This key selects the SPOT, COARSE, or FINE vernier mode for frequency changes mode by the FREQUENCY/DC BIAS Step Control Keys ⑪. The selected vernier mode is indicated by the corresponding LED lamp. Frequencies possible in each vernier mode are listed below

SPOT:	100Hz, 120Hz, 1kHz, 10kHz
COARSE:	100Hz to 1kHz in 100Hz steps 1kHz to 10kHz in 1kHz steps 10kHz to 20kHz in 10kHz steps
FINE:	100Hz to 200Hz in 1Hz steps 200Hz to 500Hz in 2Hz steps 500Hz to 1kHz in 5Hz steps 1kHz to 2kHz in 10Hz steps 2kHz to 5kHz in 20Hz steps 5kHz to 10kHz in 50Hz steps 10kHz to 20kHz in 100Hz steps

Note

When the FREQUENCY/DC BIAS Select Key ⑨ is set to DC BIAS mode, this key is disabled and the SPOT, COARSE, and FINE indicators are turned off.

⑪ FREQUENCY/DC BIAS Step Control Keys:

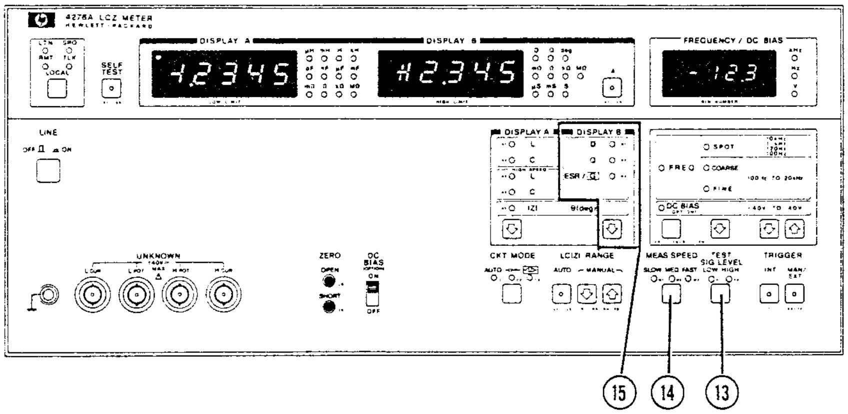
These keys-- ⇩ and ⇧ —are used in conjunction with the FREQUENCY/DC BIAS Select Key ⑨ and the SPOT/COARSE/FINE Select Key ⑩ to set the test frequency and DC bias voltage (Option 001 instruments only). When FREQUENCY mode is selected by the FREQUENCY/DC BIAS Select Key ⑨, test frequency is increased in accordance with the selected vernier mode (SPOT, COARSE, FINE) each time the ⇧ is pressed, and is decreased each time the ⇩ key is pressed. These keys control DC bias in a similar manner when DC BIAS mode is selected by the FREQUENCY/DC BIAS Select Key ⑨. When either of these keys is pressed and held, the value displayed on the FREQUENCY/DC BIAS Display will continuously change in the indicated direction. The actual value, however, will not change until the key is released.

⑫ TRIGGER Keys:

These keys select the trigger mode for triggering measurement (Internal or Manual/External):

INT:	Internal trigger signal enables instrument to make repeated automatic measurements.
MAN/EXT:	Measurement is triggered each time this key is pressed. Measurement data is held until the next time the key is pressed. Or in this mode measurement is triggered by an external trigger signal applied to the rear panel EXT TRIGGER connector (④ in Figure 3-2).

Figure 3-1. Front Panel Features (Sheet 3 of 6).



⑬ TEST SIGNAL LEVEL Selector Key and Indicators:

This key selects two test signal levels : HIGH and LOW. HIGH level is 1Vrms and LOW level is 50mVrms. The selected test signal level is indicated by the corresponding LED lamp.

Note

The 4276A cannot measure L, HIGH SPEED L, or Z when TEST SIGNAL LEVEL is set to LOW.

⑭ MEASUREMENT SPEED Select Key and Indicators:

This key selects three measurement speeds: SLOW, MEDIUM or FAST. Actual measurement speed depends on test frequency, LC | Z | range ⑯, DISPLAY A Function ⑱, and the value of the device under test. The selected measurement speed mode is indicated by the corresponding LED lamp.

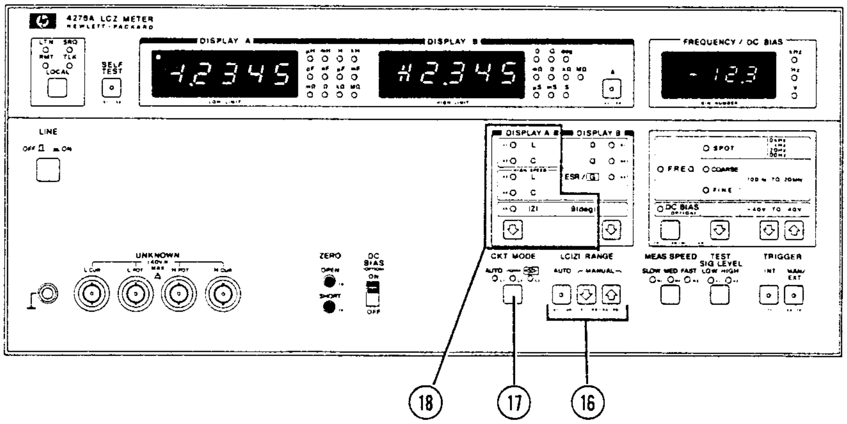
SLOW :	Measurement speed is approximately 1/4 that of medium measurement speed.
MED :	Measurement speed is approximately 11 measurements per second in C-G measurement mode.
FAST :	Measurement speed is approximately twice that of medium measurement speed.

⑮ DISPLAY B Function Select Key and Indicators:

This key, ⇩ , selects the measurement parameter for display on DISPLAY B ⑥. The selected parameter is indicated by the corresponding LED lamp. Pressing this key shifts the selected parameter in a top-to-bottom sequence. Selectable parameters are as follows:

D :	Measures the dissipation factor of the DUT. DISPLAY A Function ⑱ must be set to L (inductance) or C (capacitance).
Q :	Measures the quality factor of the DUT. DISPLAY A Function ⑱ must be set to L (inductance) or C (capacitance). Q values are calculated as the reciprocal dissipation factor.
ESR/G :	Measures the equivalent series resistance or conductance of the DUT. DISPLAY A Function ⑱ must be set to L (inductance) or C (capacitance). ESR is selected when CIRCUIT MODE ⑰ is set to ○-□-∿-○ ; G is selected when CIRCUIT MODE ⑰ is set to ○-⊟-○ .

Figure 3-1. Front Panel Features (Sheet 4 of 6).



⑯ LC | Z | RANGE Selector Keys and Indicator:

These keys select the measurement range and the ranging method for inductance, capacitance and impedance measurements.

AUTO (when indicator is lit):

Optimum range for the DUT's value is automatically selected.

MANUAL (when indicator is not lit):

Measurement range is fixed (even when the DUT is changed). Manual ranging is done by pressing the adjacent DOWN (⇩) or UP (⇧) key.

Note

Pressing the DOWN or UP key sets the ranging mode to MANUAL even if the ranging mode was initially set to AUTO.

⑰ CIRCUIT MODE Select Key and Indicators:

This key selects the measurement circuit mode to be used during measurement. The selected circuit mode is indicated by the corresponding LED lamp.

AUTO: Automatically selects the equivalent circuit (parallel or series) most appropriate for the DUT's value. When LC | Z | RANGE ⑯ is set to the 100Ω range or lower, circuit mode is set to ∘-□-ww-∘. When LC | Z | RANGE ⑯ is set to the 1kΩ range or higher, circuit mode is set to ∘-[□‖ww]-∘.

∘-□-ww-∘: Selects equivalent series circuit.

∘-[□‖ww]-∘: Selects equivalent parallel circuit.

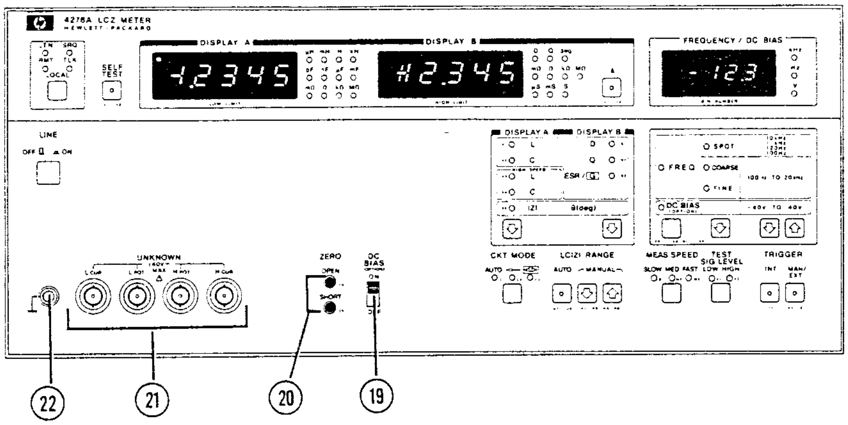
⑱ DISPLAY A Function Select Key and Indicators:

This key, ⇩ , selects the measurement parameter for display on DISPLAY A ⑤. The selected parameter is indicated by the corresponding LED lamp. Pressing this key shifts the selected parameter in a top-to-bottom sequence. The selectable parameters are as follows:

L: Measures inductance and—depending on the setting of DISPLAY B Function ⑮—D (dissipation factor), Q (quality factor), or ESR/G (equivalent series resistance or equivalent parallel conductance).

C: Measures capacitance and—depending on the setting of DISPLAY B Function ⑮—D (Dissipation factor), Q (quality factor), or ESR/G (equivalent series resistance or equivalent parallel conductance).

Figure 3-1. Front Panel Features (Sheet 5 of 6).



HIGH SPEED L:
Measures only inductance.

HIGH SPEED C:
Measures only capacitance.

| Z | - θ(deg):
Measures impedance magnitude and phase angle. The results are displayed on DISPLAY A (| Z |) and DISPLAY B (θ) to provide a polar representation (| Z | $\angle \theta$) of the DUT's impedance.

⑲ DC BIAS SWITCH:

On instruments equipped with Option 001, DC BIAS, this switch turns the internal DC bias source on and off. When this switch is set to ON and the DC BIAS Select Switch (② in Figure 3-2) on the rear panel is set to INT, the DC voltage selected by the FREQUENCY/DC BIAS Step Control Keys ⑪ is output from the H_{CUR} UNKNOWN terminal ㉑. When set to OFF, this switch turns off the internal DC bias source; no DC voltage is output from the H_{CUR} UNKNOWN terminal ㉑, and "OFF" will be briefly displayed on the FREQUENCY/DC BIAS Display 8 each time a new DC bias voltage is set by the FREQUENCY/DC BIAS Step Control Keys 11 or via the HP-IB.

Note

This switch controls the internal DC bias source only. It does not control external DC bias voltage applied to the EXT INPUT/INT MONITOR connector (③ in Figure 3-2) on the rear panel. Also, this switch is not HP-IB programmable.

⑳ ZERO Offset:

These buttons perform ZERO offset compensation (OPEN and SHORT) for the residuals of the test fixture, test leads, and measurement circuit. ZERO offset is performed at the following spot frequencies:

20kHz, 16kHz, 10kHz, 5kHz, 2kHz, 1kHz, 500Hz, 200Hz, and 100Hz.

OPEN: If this button is pressed when the test fixture or test leads are terminated open, measured values at this time are stored as residual admittance data.

SHORT: If this button is pressed when the test fixture or test leads are shorted, measured values at this time are stored as residual impedance data.

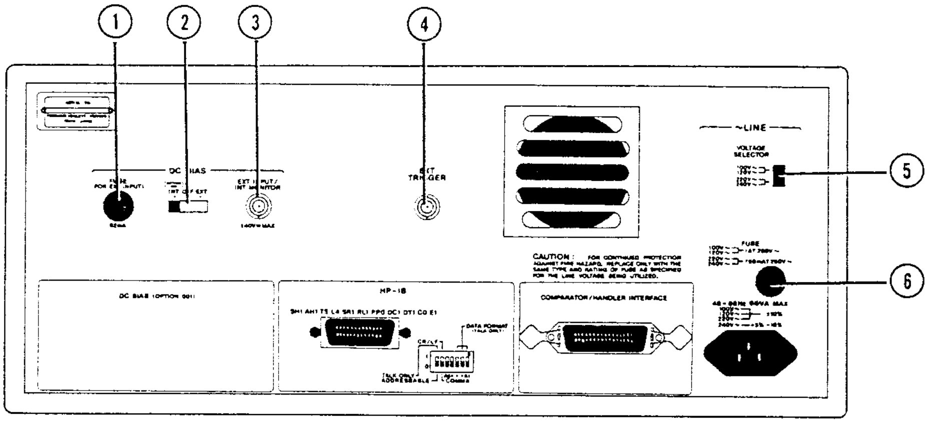
㉑ UNKNOWN Terminals:

These four BNC connectors provide the means to connect DUT's in a five-terminal configuration: High current terminal (H_{CUR}), High potential terminal (H_{POT}), Low potential terminal (L_{POT}), and Low current terminal (L_{CUR}). Four-terminal pair test fixtures attach directly to these terminals.

㉒ GUARD Terminal:

This terminal is tied to the instrument's chassis and can be used in measurements that require guarding.

Figure 3-1. Front Panel Features (Sheet 6 of 6).



① EXT DC BIAS FUSE Holder :

External DC bias fuse is installed in this holder. The fuse must be installed when an external bias source is used. Fuse rating is 1/16A, 250V (HP P/N : 2110-0011).

② DC BIAS Select Switch :

This switch selects the DC bias source that will be used for biasing DUTs connected to the UNKNOWN terminals.

INT : On instruments equipped with Option 001, DC BIAS, the DC voltage output from the internal DC bias source will be applied to the DUT when the DC BIAS Switch (⑲ in Figure 3-2) is set to ON.

OFF : No DC bias voltage will be applied to the DUT.

EXT : DC voltage provided by an external voltage source connected to the EXT INPUT/INT MONITOR Connector ③ will be applied to the DUT regardless of the setting of the DC BIAS Switch (⑲ in Figure 3-2). Maximum allowable voltage is ±40V.

③ EXT INPUT/INT MONITOR Connector :

The function of this connector depends on the setting of the DC BIAS Select Switch ②. When the DC BIAS Select Switch ② is set to EXT, this connector is the input terminal for an external DC voltage source. When the DC BIAS Select Switch ② is set to INT, this connector is the monitor output terminal for the internal DC bias source (Option 001 instruments only).

④ EXT TRIGGER Connector :

This connector is for external trigger input. TRIGGER key on front panel should be set to MAN/EXT. Specific information is provided in paragraph 3-70.

⑤ ~LINE VOLTAGE SELECTOR Switch :

This switch selects the appropriate ac operating voltage. Selectable voltages are 100V/120V±10% and 220V±10%/240V+5%-10% (48 - 66Hz).

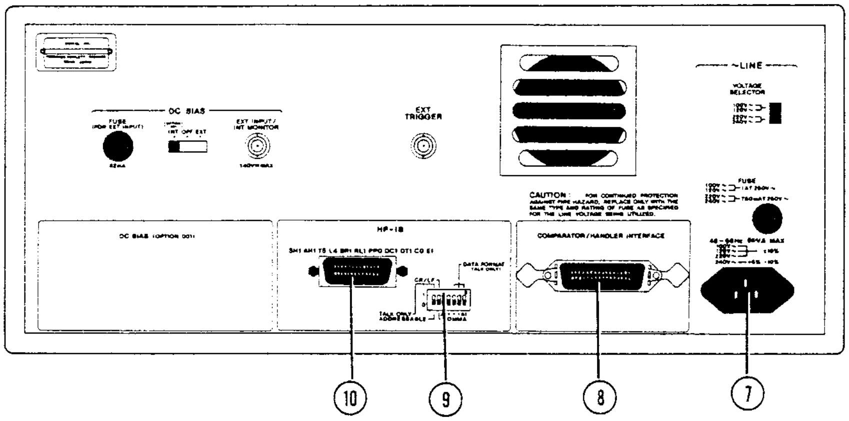
⑥ ~LINE FUSE Holder :

Instrument's power-line fuse is installed in this holder.

100V/120V operation :
1AT, 250V
(HP P/N : 2110-0007)

220V/240V operation :
750mAT, 250V
(HP P/N : 2110-0360)

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



⑦ ∿ LINE Input Receptacle :

AC power cord connects to this receptacle.

⑧ COMPARATOR/HANDLER INTERFACE Connector :

Thirty-six pin connector, Option 002 instruments only, connects the 16064A COMPARATOR/HANDLER INTERFACE to the instrument.

⑨ HP-IB Control Switch :

This switch sets the instrument's HP-IB address (0 - 30), data output format (F1 - F6), and interface capability (Addressable or Talk Only). Specific information on this switch is given in paragraph 3-82.

⑩ HP-IB Connector :

Twenty-four pin connector; connects the instrument to an HP-IB controller or other HP-IB instruments via an HP-IB cable.

Figure 3-2. Rear Panel Features (Sheet 2 of 2).

3-9. DISPLAY TEST

3-10. All LED lamps and 7-segment displays on the front panel are lit for approximately one second when the instrument's self-test function is initiated from the front panel or via the HP-IB. This test is repeated until the self-test function is turned off.

Note

> If an LED lamp or 7-segment display fails to light during the Display test, contact the nearest Hewlett-Packard Sales or Service Office for repairs.

Note

> If the instrument is equipped with Option 002, Comparator/Handler Interface, and if the 16064A Comparator/Handler Interface is connected to the instrument, all 16064A LED lamps except D/Q/ESR/G and LIMIT LOW lamps will be lit during the Display test.

3-11. ANALOG CIRCUIT TEST

3-12. The Analog Circuit test is performed when the instrument's self-test function is initiated from the front panel or via the HP-IB. It is performed after the Display test, described in paragraph 3-9, and it confirms correct operation of the instruments analog circuits. Like the Display test, this test is repeated until the self-test function is turned off. The test lasts approximately three seconds. If a malfunction is detected, an error-code will be displayed on DISPLAY A. Refer to Table 3-4.

Note

> The Analog Circuit test must be performed with an open-terminated (no DUT) test fixture (e.g., 16047A) connected to the UNKNOWN terminals.

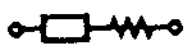
Note

> If one or more of the error codes listed in Table 3-4 appear on DISPLAY A during the Analog Circuit test, contact the nearest Hewlett-Packard Sales or Service Office for repairs.

3-13. MEASUREMENT FUNCTIONS

3-14. Values displayed on DISPLAY A and DISPLAY B are for the parameters selected by the DISPLAY A and DISPLAY B function keys. Inductance (L), capacitance (C), or impedance magnitude (|Z|) values are displayed on DISPLAY A; dissipation factor (D), quality factor (Q), equivalent series resistance (ESR), conductance (G), or impedance phase (θ) values are displayed on DISPLAY B. The DISPLAY B measurement function depends on the selected DISPLAY A function and the selected CKT MODE, as listed in Table 3-1. When DISPLAY A function is HIGH SPEED C or HIGH SPEED L, DISPLAY B is always blank.

Table 3-1. Measurement Functions

	DISPLAY B	
DISPLAY A	Circuit Mode	
		
L	D, Q, or ESR	D, Q, or G
C	D, Q, or ESR	D, Q, or G
HIGH SPEED L	—	—
HIGH SPEED C	—	—
|Z|	θ	θ

3-15. DISPLAYS

3-16. The 4276A has three front panel displays: DISPLAY A, DISPLAY B, and FREQUENCY/DC BIAS. Each is described in paragraphs 3-17 through 3-19, respectively. The number of display digits depends on measurement range, test frequency, and test signal level. Refer to Figure 3-39.

3-17. DISPLAY A provides direct readout of measured C, L, or |Z|, with 4 1/2-digit display resolution. The actual number of display digits depends on measurement range, test frequency, and test signal level. The least significant digit may be displayed as a small zero, ▣ , or may be blank, █ , to indicate that the digit does not provide a specified value. Maximum number of counts is ±19999. DISPLAY A also displays error-codes, operational annunciations, and the HP-IB address or output data format (refer to paragraphs 3-72 through 104 for details).

3-18. DISPLAY B provides direct readout of measured D, Q, ESR, G, or θ, with 4 1/2-digit display resolution. The actual number of display digits depends on measurement range, test frequency, test signal level, and number of DISPLAY A counts. The least significant digit may be displayed as a small zero, ▣ , or may be blank, ■ , to indicate that the digit does not provide a specified value. Maximum number of display counts depends on the DISPLAY B function. Refer to Table 3-2. DISPLAY B also displays error-codes, operational annunciations, and option annunciation "16064" when the instrument is equipped with option 002. When the DISPLAY A function is HIGH SPEED C or HIGH SPEED L, DISPLAY B is blank.

Note

Option annunciation "16064" appears only when the 16064A Comparator is connected to the rear panel.

Table 3-2. Number of Counts on DISPLAY B

Measurement Function	Display Counts
D	Max. 1.9999
Q	Max. 10▫▫.▫
ESR/G	- 19999 to 19999 counts
θ	- 180.00° to 180.00°

3-19. The FREQUENCY/DC BIAS display provides direct readout of test frequency and, if the instrument is equipped with option 001, the voltage output from the internal dc bias source. If option 001 is installed, option annunciation 001 is displayed on this display each time the instrument is turned on. If the DC BIAS ON/OFF switch is set to OFF when the dc bias voltage is changed, OFF will be briefly displayed on this display after the new value has been set. Refer to paragraph 3-24. Also, if the instrument is equipped with option 002, BIN numbers are displayed on this display when the 16064A Comparator is enabled.

3-20. ERROR-CODES

3-21. Error-codes related to the ROM/RAM test (see paragraph 3-7) are listed in Table 3-3. If one of these errors is displayed on DISPLAY A when the instrument is turned on, measurements can not be made.

Note

If E68 is displayed, measurements can be made. The instrument's continuous memory function, however, is disabled.

3-22. Error-codes related to the Analog Circuit test (see paragraph 3-11) are listed in Table 3-4. If one or more of these errors are displayed on DISPLAY A during Self Test, the specifications listed in Table 1-1 are not guaranteed.

Note

If one of the error-codes listed in Table 3-3 or Table 3-4 is displayed, contact the nearest Hewlett-Packard Sales or Service Office for repairs.

3-23. Error-codes related to operator errors are listed in Table 3-5. Corrective action for each error is also given in the table.

3-24. OPERATIONAL ANNUNCIATION

3-25. On instruments equipped with option 001, DC BIAS, the annunciation shown in Table 3-6 may briefly appear on the FREQUENCY/DC BIAS display after a new dc bias voltage has been set. It indicates that the DC BIAS ON/OFF switch on the front panel is set to OFF. This switch must be set to ON if voltage from the internal dc bias source is to be applied to the DUT.

Note

For applications using the internal dc bias source, the DC BIAS select switch on the rear panel must be set to INT.

Table 3-3. Error-Codes for ROM/RAM Self Test

Error Code	Meaning
E 6 1	A1U5 ROM is faulty.
E 6 2	A1U6 ROM is faulty.
E 6 3	A1U7 ROM is faulty.
E 6 4	A1U8 ROM is faulty.
E 6 5	A1U9 ROM is faulty.
E 6 6	A1U10 ROM is faulty.
E 6 7	A1U12 RAM is faulty.
E 6 8	A1U12 RAM or A6BT1 is faulty.

Table 3-4. Error-Codes for Analog Circuit Self Test

Display	Meaning
E 3 7 ~ E 4 5	Analog Circuit is not functioning properly.

Table 3-6. Operation Error Codes Displayed on FREQUENCY/DC BIAS Display

DISPLAY A	DISPLAY B	FREQ/DC BIAS	Meanings	Treatment
1 2 3 4 5 (any reading)	1 2 3 4 5 (any reading)	O F F	Illegal INTERNAL DC BIAS operation (Option 001). The internal dc bias voltage was set manually or via the HP-IB when the DC BIAS ON/OFF switch on the front panel was set to OFF.	Set the DC BIAS switch to ON. Note Make sure that the DC BIAS switch on the rear panel is set to INT.

Table 3-5. Operation Error Codes Displayed on DISPLAY A/B (Sheet 1 of 3)

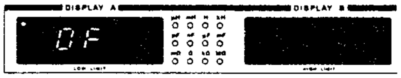
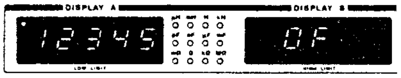
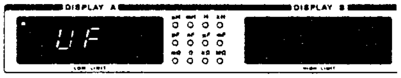
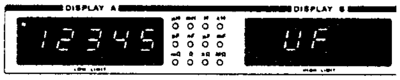
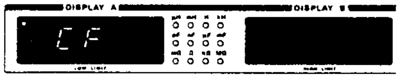
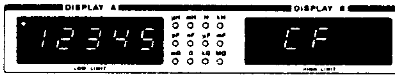
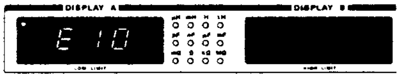
ERROR CODE	Meaning	Treatment
	Overflow - The inductance, capacitance, or impedance of the DUT is too high to be measured on the selected LC|Z| RANGE.	Select a higher LC|Z| RANGE.
 (any reading)	Overflow - The dissipation factor, quality factor, ESR, or conductance of the DUT is too high.	Change the DISPLAY B function, or change the DISPLAY A function to |Z|.
	Underflow -The inductance, capacitance, or impedance of the DUT is too low to be measured on the selected LC|Z| RANGE.	Select a lower LC|Z| RANGE.
 (any reading)	Underflow -The dissipation factor, quality factor, ESR, or conductance of the DUT is too low.	Change the DISPLAY B function, or change the DISPLAY A function to |Z|.
	Change Function -The selected parameter cannot be measured with the present control settings.	Change the DISPLAY A function to another parameter.
 (any reading)		Change the DISPLAY B function, or change the DISPLAY A function to |Z|.
	Zero Offset Adjustment error. The residuals of the test fixture or test leads are too high to be offset, or nothing is connected to the UNKNOWN terminals. Previous Zero Offset data are unchanged.	Use a different test fixture or test leads; or, if nothing is connected to the UNKNOWN terminals, connect an appropriate test fixture or test leads. Refer to paragraph 3-48 for details on Zero Offset Adjustments.

Table 3-5. Operation Error Codes Displayed on DISPLAY A/B (Sheet 2 of 3)

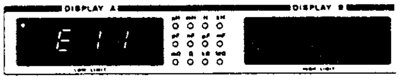
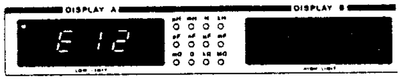
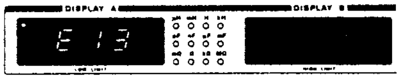
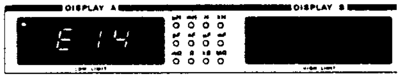
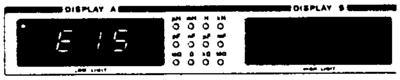
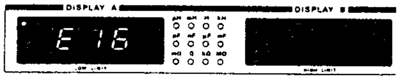
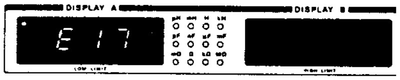
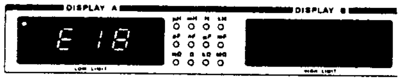
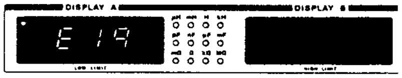
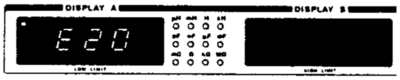
ERROR CODE	Meaning	Treatment
	TEST SIG LEVEL was set to LOW when DISPLAY A function is set to L, HIGH SPEED L, or |Z|.	LOW TEST SIG LEVEL can be used only for C and HIGH SPEED C measurements.
	Illegal LC|Z| RANGE, DISPLAY A, FREQ, or TEST SIG LEVEL setting.	The instrument will automatically select the correct setting.
	Illegal DC BIAS or COMPARATOR operation. Internal dc bias voltage was set via the HP-IB, but the instrument is not equipped with Option 001; or the comparator enable code (E1) was sent via the HP-IB; but the instrument is not equipped with Option 002.	Install the desired option. Refer to Section II.
	Illegal COMPARATOR operation. The D/Q/ESR/G key on the 16064A was pressed or was set via the HP-IB while the DISPLAY A function was set to HIGH SPEED C , HIGH SPEED L, or |Z|.	D, Q, ESR, or G comparison cannot be performed. The instrument is set to HIGH SPEED L or HIGH SPEED C measurement mode.
	Illegal COMPARATOR operation. One of the 4276A's front panel keys (except TRIGGER, LOCAL, or DC BIAS) was pressed or was set via the HP-IB.	To change a front panel control setting on the 4276A, first disable (turn off) the 16064A. Press the COMPARATOR ENABLE key (the lamp at the center of the key should go off).
	Illegal COMPARATOR operation. One of the 16064A's keys (except the COMPARATOR ENABLE key) was pressed or was set via HP-IB while the 16064A was disabled.	To operate the COMPARATOR, first enable (turn on) the 16064A. Press the COMPARATOR ENABLE key (the lamp at the center of the key should come on).

Table 3-5. Operation Error Codes Displayed on DISPLAY A/B (Sheet 3 of 3)

ERROR CODE	Meaning	Treatment
	Illegal COMPARATOR operation. The 4276A's front panel control settings are different from those that existed when the present bin limits were entered.	Reset the front panel controls to the previous settings, or clear the stored bin limits by pressing the ERASE button.
	Illegal COMPARATOR operation. The RUN key on the 16064A was pressed or was set via HP-IB when no bin limits were entered, or a bin's LOW LIMIT is higher than its HIGH LIMIT.	Enter LOW and HIGH limits, or correct the displayed LOW and HIGH LIMITs.
	Illegal parameter setting. The test frequency setting, internal dc bias setting, or a bin limit setting is outside the specified limits.	Reset the incorrect parameter.
	Illegal HP-IB address. The HP-IB address switches on the rear panel were set to 31 (11111) when the instrument was turned on.	Turn off the instrument and set the HP-IB address to one between 0 (00000) and 30 (11110).
	Illegal deviation measurement operation. The Δ key on the front panel was pressed or was set via HP-IB when OF , UF , or CF was displayed on DISPLAY A or DISPLAY B.	Only valid reference values can be used for deviation measurement.

3-26. TEST FREQUENCY

3-27. There are seven test frequency ranges, as listed in Table 3-7. Frequency accuracy is 0.01% of the value displayed on the FREQUENCY/DC BIAS display.

Table 3-7. Test Frequency

Test Frequency	Resolution
100Hz - 200Hz	1Hz
200Hz - 500Hz	2Hz
500kHz - 1.00kHz	5Hz
1.00kHz - 2.00kHz	10Hz
2.00kHz - 5.00kHz	20Hz
5.00kHz - 10.0kHz	50Hz
10.0kHz - 20.0kHz	100Hz

3-28. TEST SIGNAL LEVEL

3-29. The 4276A has two test signal levels: HIGH (1Vrms) and LOW (50mVrms). The output impedance of the test signal source is 100Ω±20%, so the voltage across the DUT depends on the DUT's impedance. Refer to Figure 3-3.

Note

On several ranges, HIGH test signal level is 2Vrms. Refer to Table 1-1.

Note

Low test signal level can be used only when DISPLAY A function is set to C or HIGH SPEED C.

3-30. MEASUREMENT RANGE

3-31. Measurement range depends on the test frequency. The ranges which can be selected at each test frequency and the range resistor used on each range are shown in Figure 3-16. Each range allows a 100% overrange of the 10000 full scale counts (maximum 19999 counts). Measurement range is selected by the LC|Z| RANGE keys. When the LC|Z| RANGE control is set to AUTO, the optimum range is automatically selected for each measurement. Manual ranging is also possible. When an inappropriate range is selected, OF or UF is displayed on DISPLAY A or DISPLAY B.

3-32. CIRCUIT MODE

3-33. An impedance can be represented by a simple series or parallel equivalent circuit consisting of resistive and reactive elements. This is possible because both equivalent circuits have identical impedances at a given test frequency by properly establishing the values of the equivalent circuit elements. The equivalent circuit measurement mode is selected by setting the CIRCUIT MODE control. When the CIRCUIT MODE is set to AUTO, the 4276A will automatically select the circuit mode most appropriate for the range and function settings. Equivalent series circuit mode is automatically selected when the measurement range is inside the area enclosed in the dotted line in Figure 3-16. Equivalent parallel circuit mode is automatically selected when the measurement range is outside the area enclosed in the dotted line in Figure 3-16. By setting CIRCUIT MODE manually, either circuit mode can be selected, regardless all measurement ranges.

3-34. Capacitance and inductance measurements can be performed in either equivalent series circuit mode or equivalent parallel circuit mode. However, measured values obtained in each mode are different. The difference in measured values is related to the loss factor of the sample being measured. The impedance of a sample measured in both series and parallel circuit mode is the same at a particular frequency. Therefore, the following equations are satisfied:

$$Z = R + jX \qquad Y = \frac{1}{Z} = G + jB$$

$$G + jB = \frac{1}{R + jX}$$

$$= \frac{R}{R^2 + X^2} - j\frac{X}{R^2 + X^2}$$

Expanding the above equation, we have

$$G + j\omega Cp = \frac{R}{R^2 + \frac{1}{\omega^2 Cs^2}} + j\,\frac{\frac{1}{\omega Cs}}{R^2 + \frac{1}{\omega^2 Cs^2}}$$

where, $Cs\ (= -\frac{1}{\omega X})$: equivalent series circuit capacitance

$Cp\ (= \frac{B}{\omega})$: equivalent parallel circuit capacitance

Obviously, if no series resistance (R) or parallel conductance (G) are present, the equivalent series circuit capacitance (Cs) and equivalent parallel circuit capacitance (Cp) are identical. Likewise, if R and G are not present, the equivalent series circuit inductance (Ls) and equivalent parallel circuit inductance (Lp) are identical.

However, a sample value measured in a parallel measurement circuit can be correlated with that of a series circuit by a simple conversion formula which covers the effect of dissipation factor. See Table 3-8. Figure 3-4 graphically shows the relationships of parallel and series parameters for various dissipation factor values. Applicable diagrams and equations are given in the chart. For example, a parallel capacitance (Cp) of 1000pF with a dissipation factor of 0.5 is equivalent to a series capacitance (Cs) of 1250pF with an identical dissipation factor. As shown in Figure 3-4, inductance or capacitance values for parallel and series equivalents are nearly equal when the dissipation factor is less than 0.03. The dissipation factor of a component always has the same value at a given frequency for both parallel and series equivalents.

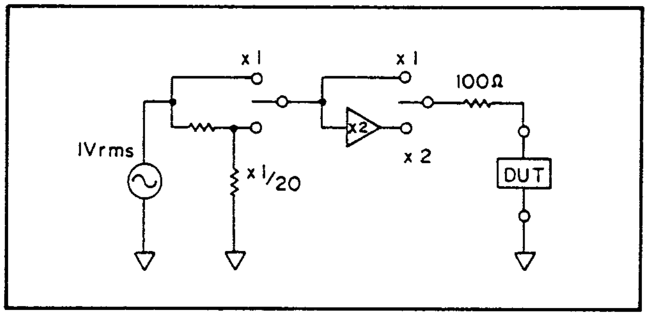


Figure 3-3. Equivalent Circuit of the Test Signal Source.

In ordinary LCR measuring instruments, the measurement circuit is set (automatically or manually) to a predetermined equivalent circuit with respect to either the selected range or to the dissipation factor value of the sample. The wider circuit mode selection capability of the 4276A, which is free from these restrictions, permits taking measurements in the desired circuit mode and of comparing such measured values directly with those obtained by another instrument. This obviates the inconvenience and necessity of employing instruments capable of taking measurements with the same equivalent circuit to assure measurement result correspondence.

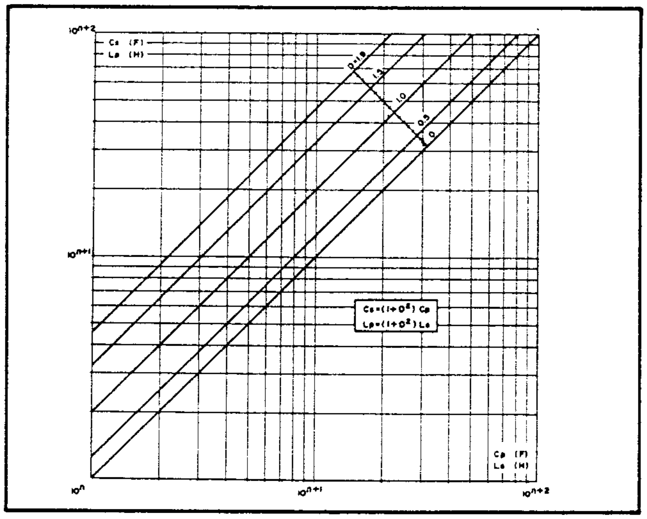
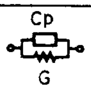
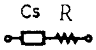
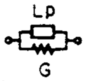


Figure 3-4. Parallel and Series Parameter Relationship.

Table 3-8. Dissipation Factor Equations and Equivalent Circuit Conversion Formulas

Circuit Mode		Dissipation Factor	Conversion to Other Modes
C		$D = \frac{G}{\omega Cp} = \frac{1}{Q}$	$Cs = (1 + D^2)\ Cp,\ R = \frac{D^2}{1 + D^2} \cdot \frac{1}{G}$
		$D = \omega CsR = \frac{1}{Q}$	$Cp = \frac{1}{1 + D^2}\ Cs,\ G = \frac{D^2}{1 + D^2} \cdot \frac{1}{R}$
L		$D = \omega LpG = \frac{1}{Q}$	$Ls = \frac{1}{1 + D^2}\ Lp,\ R = \frac{D^2}{1 + D^2} \cdot \frac{1}{G}$
		$D = \frac{R}{\omega Ls} = \frac{1}{Q}$	$Lp = (1 + D^2)\ Ls,\ G = \frac{D^2}{1 + D^2} \cdot \frac{1}{R}$

3-35. INITIAL DISPLAY AND INDICATIONS

3-36. Each time the instrument is turned on, the option codes for installed options and the HP-IB address are displayed on the front panel for approximately two seconds. The HP-IB address is displayed on DISPLAY A, as shown below. The factory set address is 17 (10001), but any address from 0 (00000) to 30 (11110) can be set. Refer to the HP-IB discussion starting in paragraph 3-72.

DISPLAY A

Note

If the instrument is set to TALK ONLY mode, the output data format number (see paragraph 3-95) will appear on DISPLAY A instead of the HP-IB address.

The following option code is displayed on DISPLAY B if the instrument is equipped with Option 002, Comparator/Handler Interface.

DISPLAY B

Note

The above option code will not be displayed if the 16064A Comparator/Handler Interface is not connected to the instrument.

The following option code is displayed on the FREQUENCY/DC BIAS display if the instrument is equipped with Option 001, Internal DC Bias.

FREQUENCY / DC BIAS

3-37. After the HP-IB address and option codes have been displayed, the continuous memory function automatically recalls the front panel control settings that existed when the instrument was turned off.

Note

Output from the internal dc bias source (option 001 instruments) is automatically set to 0V at instrument power on as a safety precaution.

3-38. INITIAL CONTROL SETTINGS

3-39. The 4276A is automatically set to the control settings listed below when the continuous memory function (refer to paragraph 3-40) is reset as described in paragraph 3-42.

DISPLAY A Function	C
DISPLAY B Function	G
CIRCUIT MODE	AUTO
LC | Z | RANGE	AUTO
MEASUREMENT SPEED	MED
TEST SIGNAL LEVEL	HIGH
TRIGGER	INT
SELF TEST	OFF
Δ	OFF
FREQ/DC BIAS	FREQ
SPOT/COARSE/FINE	SPOT
Frequency	1.00kHz
OPEN ZERO DATA	0Ω
SHORT ZERO DATA	OS

When the instrument is equipped Option 001:

DC BIAS	.00V

When the instrument is equipped Option 002, control settings of the 16064A Comparator are as follows:

ENABLE	OFF
LC | Z | //D/Q/ESR/G	L/C/ | Z |
LIMIT LOW/HIGH	LOW
BIN NUMBER	1
RUN	OFF
BIN LIMITS	blank

3-40. CONTINUOUS MEMORY

3-41. The continuous memory function of the 4276A automatically memorizes all front panel control settings when the instrument is turned off or experiences a power failure. When the instrument is turned on, the memorized settings are automatically recalled. Continuous memory is powered by a rechargeable 2.4V nickel-cadmium battery that lasts for approximately 2 weeks when the instrument is turned off. The battery is recharged while the 4276A is turned on.

Note

It takes approximately 24 hours to recharge up the battery.

Note

When turned on, the 4276A automatically performs a Check Sum Test as part of its turn-on Self Test. The Check Sum Test checks the contents of memory. If incorrect, E68 will be displayed on DISPLAY A and memory will be cleared. The instrument will be set to the initial control settings (refer to paragraph 3-38).

OPEN and SHORT Zero Offset values (refer to paragraph 3-48) and reference values for deviation measurements (refer to paragraph 3-57) are also memorized by the continuous memory function. On instruments equipped with the Comparator/Handler Interface option (Option 002), all high and low limits and all 16064A control settings (except RUN) are memorized. DC bias voltage (Option 001) settings, however, are not memorized.

3-42. RESETTING CONTINUOUS MEMORY

3-43. To reset, or clear, continuous memory, proceed as follows:

(1) Turn off the 4276A.

(2) Press and hold both FREQ/DC BIAS Step Control Keys (⇩⇧).

(3) Turn on the 4276A.

3-44. UNKNOWN TERMINALS

3-45. The UNKNOWN terminals of the 4276A are arranged in a five-terminal configuration. The five-terminal configuration provides accurate measurements over a broad impedance range. Low impedance errors caused by residual inductance and residual resistance, are lower than those of measurements made using the three-terminal configuration. Also, high impedance measurement errors caused by residual conductance and residual capacitance are lower than those of measurements made using the four-terminal configuration.

In the five-terminal configuration, the current through the DUT is fed back to the oscillator via the outer conductors of L_{CUR} and H_{CUR} terminals so as to reduce electromagnetic coupling between the current terminals (H_{CUR} and L_{CUR}) and the voltage terminals (H_{POT} and L_{POT}). This feature reduces the voltage detection error when a low-impedance DUT is measured at a high frequencies. Refer to Figure 3-5.

Note

It is recommended that four short BNC cables be used as test leads.

Note

Do not connect the outer conductors of the test leads to ground. If the outer conductors are grounded, displayed values will fluctuate when a low-impedance measurement is made at high frequencies.

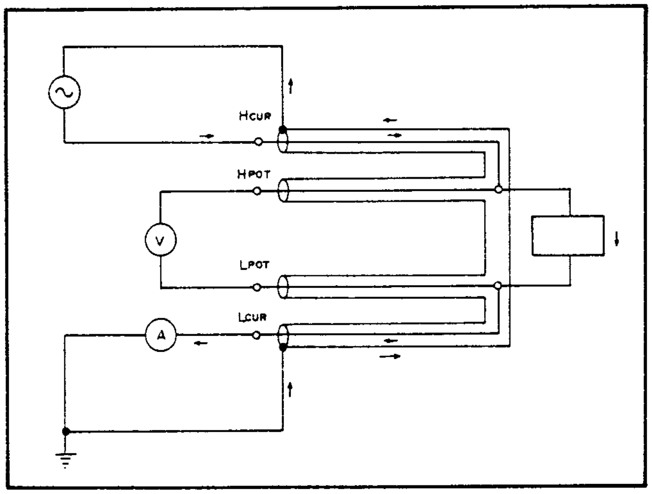


Figure 3-5. Five Terminal Configuration.

3-46. MEASUREMENT OF GROUNDED SAMPLES

3-47. Samples which have one terminal (except GROUND terminal) grounded to earth cannot normally be measured by the 4276A. Such measurement conditions are, for example, the distributed capacitance measurement of a coaxial cable with a grounded shield conductor or the input/output impedance measurement of a single ended amplifier. When a one-side-grounded sample is connected for measurement, the 4276A may display a measurement error message or incorrect measurement results. This is because the current though the DUT does not flow in the I-to-V Convertor which converts the current to the voltage, with LOW measurement terminals grounded.

Note

If HIGH terminals are grounded, the test signal is not supplied to the DUT.

3-48. ZERO OFFSET ADJUSTMENT

3-49. The test fixtures and test leads used to connect samples to the instrument's UNKNOWN terminals have inherent residual impedance and stray admittance which, unless compensated for in some way, affect measurement accuracy. To minimize the effects of these residuals and strays, the 4276A is equipped with OPEN and SHORT Zero Offset Adjustment functions that can be executed from the front panel or via the HP-IB. Each Zero Offset Adjustment is performed at the following frequencies:

20kHz	16kHz	10kHz	5kHz	2kHz
1kHz	500Hz	200Hz	100Hz	

Zero Offset data for test frequencies other than those listed above are calculated from the Zero Offset data obtained at the above test frequencies by using second degree interpolation. Thus, Zero Offset is provided for measurements made at all test frequencies. Brief descriptions of the Zero Offset Adjustments (OPEN and SHORT) are given below.

ZERO OPEN:

The procedure for performing OPEN Zero Offset Adjustment is as follows:

(1) Connect the test fixture or test leads to the instrument's UNKNOWN terminals.

Note

If test leads are used, you must convert the five-terminal configuration to a two-terminal configuration. Refer to paragraph 3-44 and Figure 3-5.

(2) Connect nothing as the DUT.

(3) Press the ZERO OPEN button.

When the ZERO OPEN button is pressed, the instrument will be automatically set to C-G measurement mode. It will then measure the test fixture's stay admittance at each of the previously mentioned test frequencies. The measured values are stored in the instrument's internal memory. When offset adjustment is completed, DISPLAY A and DISPLAY B will be blank for 1 or 2 seconds, after which the front panel controls will be reset to the settings that existed when the ZERO OPEN button was pressed.

The purpose of OPEN Zero Offset Adjustment is to measure the test fixture's stray admittance, which, as shown in Figure 3- 6 , consists of G and C . (This stray admittance is equivalent to a high impedance, which will "swamp out" a high impedance DUT connected to the test fixture.) The residual impedance of the test fixture—R_0 and L_0 in Figure 3- 6 --is negligibly low and therefore does not affect the accuracyof OPEN Zero Offset Adjustments.

ZERO SHORT:

The procedure for performing SHORT Zero Offset Adjustment is as follows:

(1) Connect the test fixture or test leads to the instrument's UNKNOWN terminals.

Note

If test leads are used, you must convert the five terminal configuration to a two-terminal configuration. Refer to paragraph 3-44 and Figure 3-5.

(2) Connect a low impedance shorting-bar to the test fixture. If you're using test leads, simply connect the ends of the leads together.

(3) Press the ZERO SHORT button.

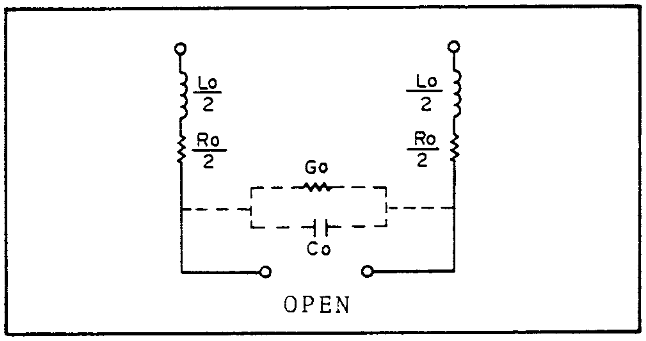


Figure 3-6. ZERO OPEN Circuit.

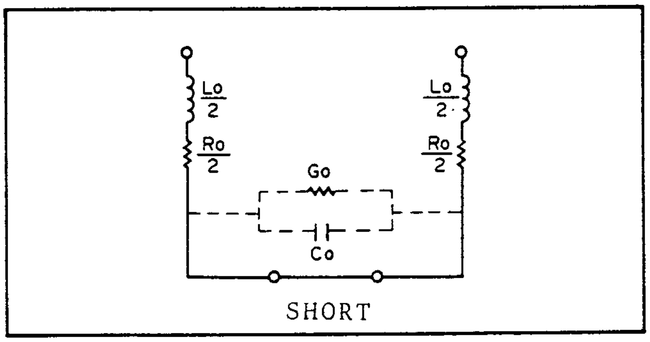


Figure 3-7. ZERO SHORT Circuit.

When the ZERO SHORT button is pressed, the instrument will be automatically set to |Z|-θ measurement mode. It will then measure the test fixture's residual impedance at each of the previously mentioned test frequencies. The measured values are stored in the instrument's internal memory. When offset adjustment is completed, DISPLAY A and DISPLAY B will be blank for 1 or 2 seconds, after which the front panel controls will be reset to the settings that existed when the ZERO SHORT button was pressed. The purpose of SHORT Zero Offset Adjustment is to measure the test fixture's (or test lead's) residual impedance, which, as shown in Figure 3-7 , consists of R_0 and L_0. This residual impedance, although small, degrades the accuracy of low impedance measurements. The stray admittance of the test fixture--G_0 and C_0 in Figure 3-7 — is shunted by the low impedance shorting-bar and therefore is not measured.

Once OPEN and SHORT Zero Offset Adjustments have been made, the instrument automatically compensates all subsequent measurements for the residuals and strays of the test fixture or test leads. The values displayed on the front panel are the actual values of the DUT. Also, because the Zero Offset data is maintained by the instrument's continuous memory function, OPEN and SHORT Zero Offset Adjustments do not have to be repeated each time the instrument is turned on. You need to repeat Zero Offset Adjustments only when you change test fixtures (the residuals and strays of one test fixture are different from those of another). Maximum values that can be offset are listed below.

Capacitance:	Up to 20pF	OPEN
Conductance:	Up to 2µS	
Impedancee:	Up to 2Ω	SHORT

Note

During Zero Offset Adjustment, OF or CF may appear on DISPLAY A or DISPLAY B. Zero Offset Adjustment, however, is performed correctly unless error code "E10" is displayed.

Note

After Zero Offset Adjustments, CF and 0000 may be alternately displayed on DISPLAY A if the measurement mode is other than C-G and nothing is connected to the test fixture. This is normal; it is not a malfunction.

Note

OPEN and SHORT Zero Offset Adjustments cannot be performed without a test fixture.

3-50. ACTUAL MEASUREMENT EQUIVALENT CIRCUIT

3-51. The test fixture or test leads used to connect a sample to the instrument's UNKNOWN terminals becomes part of the sample which the instrument measures. The five terminal configuration employed in the 4276A minimizes residual impedance circuit. The residual impedance, inherent in the test fixture or test leads, can be eliminated by the 4276A's ZERO offset function (refer to paragraph 3-48).

However, the five terminal measurement system must be converted to a two terminal configuration at the sample because most components have only two terminals. Moreover, additional stray capacitance is introduced when the sample is connected to the test fixture. Figure 3-8 illustrates lead impedance and the stray capacitances between the component's leads.

3-52. Diverse parasitic elements present between the sample and the UNKNOWN terminals will affect measurement results. These parasitic elements are series resistive and reactive elements and parallel conductive and susceptive elements. Figure 3-9 shows the equivalent circuit of the samples parasitic elements (R + jX is the sample's impedance). In Figure 3-9 , L_0 represents the residual inductance of the component's leads, and R_0 is lead resistance. G_0 is the conductance between the leads, and C_0 is the sum of all stray capacitances shown in Figure 3-8 . Reactive factors in the residual impedance and susceptive factors in the stray admittance have a greater effect on measurements made at higher frequencies.

3-53. Figure 3-10 shows the effect of residual impedance on C-G measurement and the effect of stray admittance on L-R measurement. Generally, L_0 resonates with the capacitance of the sample (series resonance) and C_0 resonates with the inductance of the sample (parallel resonance), respectively, at a specific high frequency. Thus, the impedance of the test sample will have a minimum value corresponding to resonant peaks, as shown in Figure 3-11. The presence of L_0 and C_0 causes measurement errors, as the phase of the test signal current varies over a broad frequency region around the resonant frequencies. Additional errors, due to the resonance, increase in proportion to the square of the measurement frequency (below resonant frequency) and can be theoretically approximated as follows:

$$C_{ERROR} = \omega^2 L_0 Cx \cdot 100\ (\%)$$
$$L_{ERROR} = \omega^2 C_0\ Lx \cdot 100\ (\%)$$

where,

ω = $2\pi f$ (f: test frequency)
Cx = Capacitance value of sample
Lx = Inductance value of sample

At low frequencies, L_0 and C_0 affect measured inductance and capacitance values, respectively, as simple additive errors. These measurement errors cannot be fully eliminated by the ZERO offset adjustment (which compensates for residual factors inherent in the test fixture). This is because L_0 and C_0 are peculiar to the component being measured. Their values depend on component lead length and on the distance between the sample and test fixture. The measurement results, then, are substantially the sample values including the parasitic impedances present under the conditions necessary to connect and hold the sample.

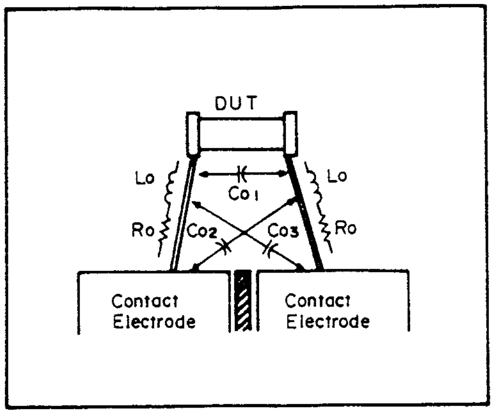


Figure 3-8. Parasitic Elements Incident to DUT Connections.

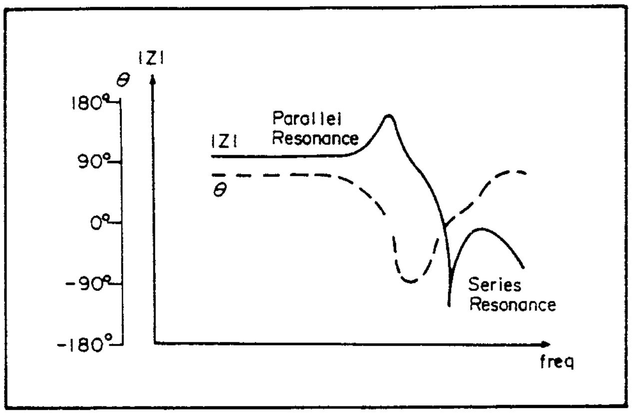
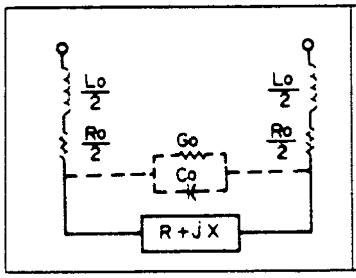


Figure 3-11. Effect of Resonance in Sample (Example).

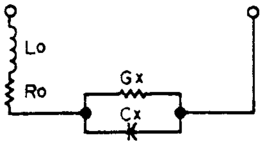


Measured impedance (Rm + jXm) is:

$$Rm = \frac{R\ (1 + RGo)\ + GoX^2}{(1 - \omega CoX + RGo)^2 + (\omega RCo + GoX)^2} + Ro$$

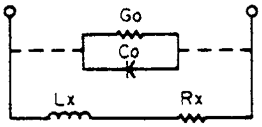
$$jXm = j\ \{\frac{X\ (1 - \omega CoX)\ - \omega CoR^2}{(1 - \omega CoX + RGo)^2 + (\omega RCo + GoX)^2} + \omega Lo\}$$

Figure 3-9. Equivalent Circuit Including Residual Impedance.



Effect of residual impedance on C-G measurement:

$$Cm \approx Cx\ (1 + \omega^2 LoCx - 2RoGx - LoGx^2/Cx)$$
$$Gm \approx Gx\ (1 + 2\omega^2 LoCx - RoGx + \omega^2 RoCx^2/Gx)$$



Effect of stray admittance on L - ESR measurement:

$$Lm \approx Lx\ (1 - 2GoRx + \omega^2 CoLx - CoRx^2/Lx)$$
$$Rm \approx Rx\ (1 - GoRx + 2\omega^2 CoLx + \omega^2 Lx^2 Go/Rx)$$

Figure 3-10. Effects of Residual Impedance.

3-54. MEASURED VALUES AND BEHAVIOR OF COMPONENTS

3-55. A component's measured value and its nominal value can, and often do, differ considerably because of various electromagnetic effects; for example, skin-effect of a conductor, the ferromagnetic properties of inductors, and the effects of dielectric materials in capacitors. Here, will discuss only the effects which result from the interaction of the reactive elements (L, C, etc.) of a component.

3-56. The impedance of a component can be graphically represented in vector form as shown in Figure 3-12. In such representation, the effective resistance and effective reactance correspond to the projections of the impedance vector $|Z|\angle\theta$; that is, the real (R) axis and the imaginary (jX) axis, respectively, as shown below:

$$Re = |Z| \cos\theta$$

$$Xe = |Z| \sin\theta$$

$$D = \frac{\cos\theta}{\sin\theta} = \frac{1}{\tan\theta}$$

where, Re: Effective resistance

Xe: Effective reactance

Z: Impedance of the sample (Re + jXe).

D: Dissipation factor

When the phase angle, θ, changes, both Re and Xe change in accordance with the definitions above. As component measurement parameters L, C, R, D, etc., are also representations of components related to the impedance vector, the phase angle dominates their values. Consider, for example, the inductance and the loss of an inductive component at frequencies around its self-resonant frequency. Figure 3-13 shows the equivalent circuit of the inductor. The inductance, Lx, resonates with the distributed capacitance C_0 at frequency f_0. The phase angle (θ) of the impedance vector approaches 0 degrees (the vector approaches the R axis) when the frequency is close to the resonant frequency. Thus, the inductance of this component decreases while the resistive factor (loss) increases. At the resonant frequency, f_0, this component is purely resistive. The effective resistance increases at resonance even if the inductor has no resistance (ideal inductor) at dc. Consequently, the loss factor varies sharply at frequencies around the resonant point.

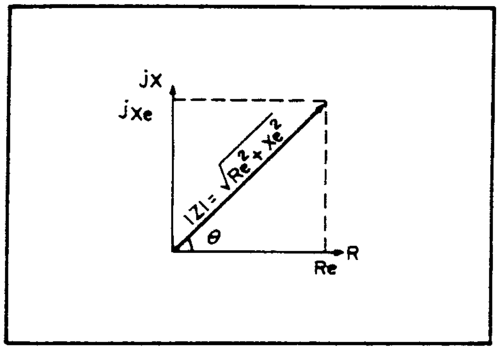


Figure 3-12. Impedance Vector Representation.

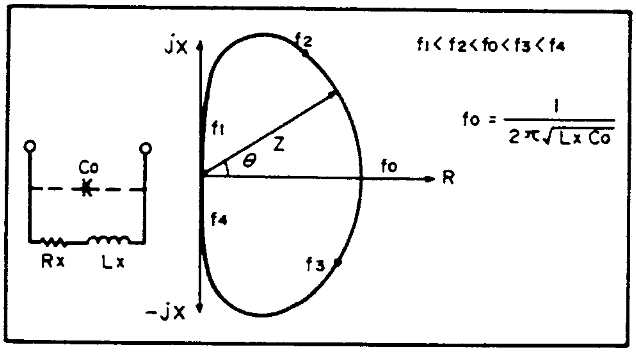


Figure 3-13. Typical Impedance Locus of an Inductor.

3-57. DEVIATION MEASUREMENT FUNCTION

3-58. When many components of similar value are to be tested, it may be more practical to measure the difference between the value of the component and a predetermined, or ideal, reference value than measuring the DUT value itself. When the purpose of the measurement is to observe the change of a component's value versus changes in temperature, frequency, bias, etc., a direct measurement of this change (deviation) makes examination more meaningful and easier.

When the key is pressed, the values (measurement results) displayed on DISPLAY A and DISPLAY B are stored in the instrument's memory and are then used as the reference values for all subsequent measurements. The value displayed on each display is not the sample's measured value, it is the difference between the stored reference value and the measured value. Stored reference values are maintained by the 4276A's continuous memory function when the instrument is turned off. The deviation measurement function is automatically turned off when the DISPLAY A function, DISPLAY B function, LC | Z | RANGE, or CKT MODE is changed. It may be turned off also if the test frequency is changed when the DISPLAY B function is ESR/G, because the measurement range for ESR and G is frequency dependent.

3-59. CHARACTERISTICS OF TEST FIXTURES

3-60. Characteristics and applicable measurement ranges of the HP test fixtures and test leads for the 4276A are summarized in Table 3-9. To facilitate measurement and to minimize measurement errors, a test fixture appropriate for the measurement should be chosen from among HP's standard accessories. Select the test fixture or leads that have the desired performance characteristics.

Table 3-9 . Typical Characteristics of Test Fixtures and Leads

Model	Applicable Measurement Ranges	
	Parameter Value	Measurement Frequency
16047A	Full range	Full range
16047C	Full range	Full range
16048A 16048B	Full range	Full range
16048C	C>1000pF L>100μH	Below 100kHz
16048D	Full range	Full range
16034B	Ranges satisfied |Z|>50Ω	Full range
16065A	Full range	50Hz to 2MHz

3-61. RANGE RESISTOR

3-62. The relation between the range resistor value and the measurement range is listed in Figure 3-16.

3-63. MEASUREMENT ACCURACY

3-64. The measurement reference plane for the accuracies specified in Section I is the UNKNOWN terminals. The measurement accuracy of the 4276A is guaranteed at the UNKNOWN terminals. The conditions under which accuracy is specified are described in Table 1-1. An example of the how to calculate measurement accuracy is shown in Figure 3-15.

3-65. MEASUREMENT EXAMPLE

3-66. The procedures for measuring general components—inductors, capacitors, resistors—are given in Figure 3-17. Almost any discrete component, except for those having special shapes or dimensions, can be measured with this setup. Special components may be measured by using test leads 16048A, 16048D, 16034B, etc., or by using specially designed user-built fixtures instead of the 16047A Test Fixture.

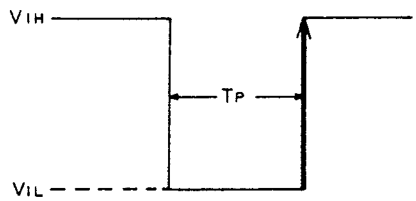
3-67. As an example of a typical semiconductor measurement, the procedures for measuring the base-collector juncton capacitance(C_{ob}) of an NPN transistor are given in Figure 3-18.

3-68. EXTERNAL DC BIAS

3-69. The special biasing circuits and procedures for using external voltage or current bias (required for certain capacitance or inductance measurements) are given in Figures 3-19, 3-20, and 3-21. The figures show sample circuits appropriate for 4276A applications. When applying a dc voltage to capacitors, be sure the applied voltage does not exceed the maximum specified voltage of the capacitor and that the capacitor is connected with correct polarity. Note that the externally applied bias voltage is present at the H_{CUR} and H_{POT} terminals.

3-70. EXTERNAL TRIGGERING

3-71. The 4276A can be externally triggered by connecting an external triggering device to the EXT TRIGGER connector on the rear panel and setting the TRIGGER control on the front panel to MAN/EXT on front panel. The instrument is triggered (measurement is made) each time a positive-going TTL level pulse is applied to this connector (refer to Figure 3-14). External triggering can be also done by alternately shorting and opening the center conductor of the EXT TRIGGER connector to ground (chassis).



Input Levels:	$V_{IL} < 0.4V$ $2.4V < V_{IH}$
Pulse Width:	$T_p \geq 100$ s
Trigger Timing:	Leading Edge

Figure 3-14. External Trigger Pulse.

[Examples of Calculating C, D, and Q Measurement Accuracies]

Front Panel Settings:

Test Frequency: 1kHz
LC|Z| RANGE: 1nF
TEST SIG LEVEL: HIGH
MEAS SPEED: MED

Measured Values:

C: 1.9945nF
D: .0008
Q: OF (Assume a value of Qm)

Accuracies (Refer to Table 1-1):

C: ±.1% of reading + 5 counts
1.9945nF x (.1/100) + .0005nF
= (±) 2.49pF
D: ±.1% of reading + .0006A + 5 counts
.0008 x (.1/100) + .0006 x 1.248 + .0005
= (±) .00125
Q: Q_m x (.00125/.0008) + .1
= ± (Q_m x 1.5625 + .1)

Note

In this case, Q accuracy (1.5625 times Qm) has no meaning, because Q_m is overflow (OF).

[Examples of Calculating C and ESR/G Measurement Accuracies]

Front Panel Settings:

Test Frequency: 10kHz
LC|Z| RANGE: 1μF
TEST SIG LEVEL: HIGH
MEAS SPEED: MED

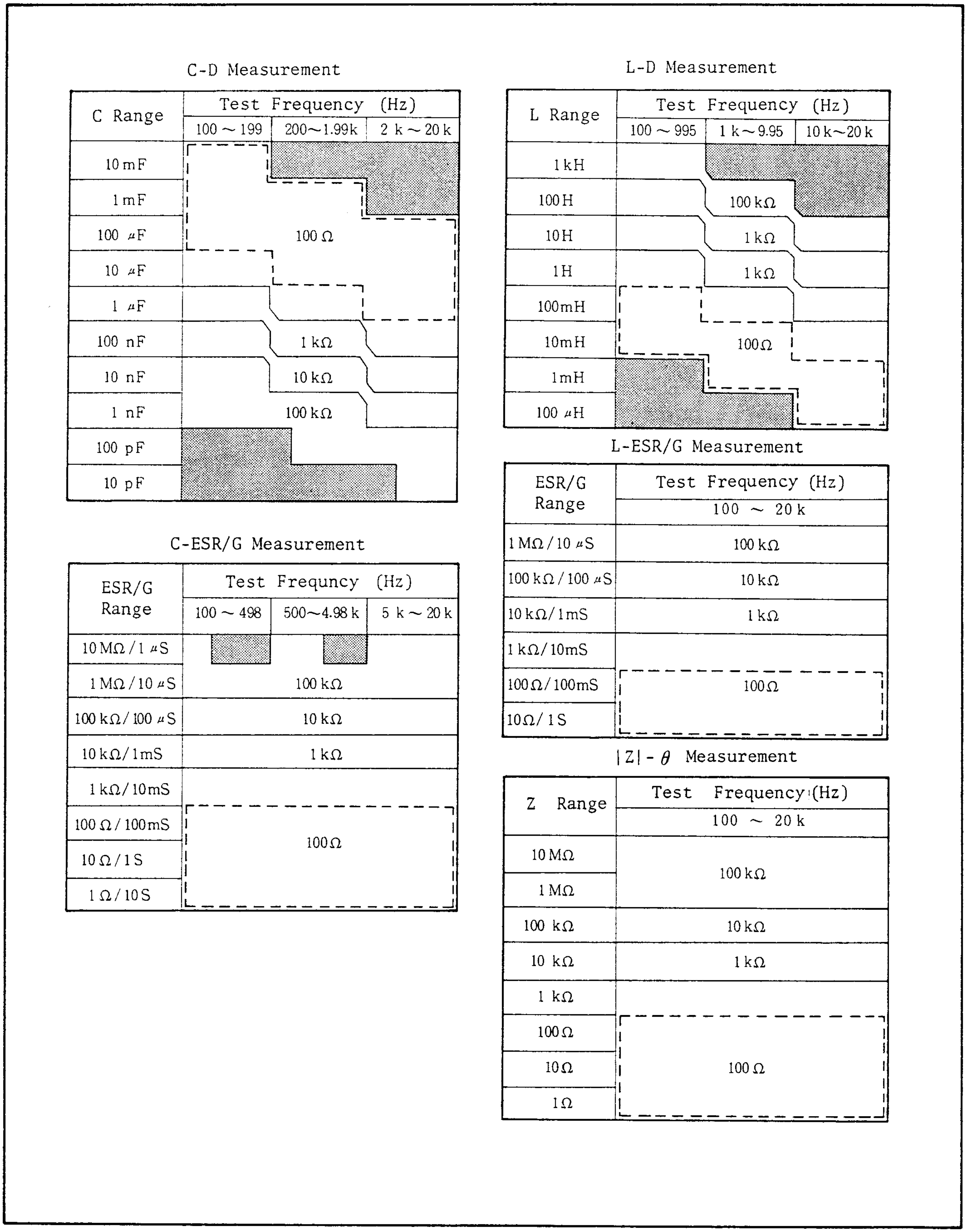
Measured Values:

C: .852μF
ESR: .42Ω
G: 1.2mS

Accuracies:

C: .9% of reading + 2 counts
.852μF x (.9/100) + .002μF
= (±) 9.67nF
ESR: .6% of reading + .6/αΩ + 5 counts
.42Ω x (.6/100) + .6/.852 + .05Ω
= (±) .757Ω
G: 1.2mS x (.757/.42) + .1mS
= (±) 2.16mS

Figure 3-15. How to Calculate Measurement Accuracies.



C-D Measurement

C Range	Test Frequency (Hz)		
	100 ~ 199	200~1.99k	2 k ~ 20 k
10 mF	100 Ω	▨	▨
1 mF	100 Ω	100 Ω	▨
100 μF	100 Ω	100 Ω	100 Ω
10 μF	100 Ω	100 Ω	100 Ω
1 μF	1 kΩ	100 Ω	100 Ω
100 nF	10 kΩ	1 kΩ	100 Ω
10 nF	100 kΩ	10 kΩ	1 kΩ
1 nF	100 kΩ	100 kΩ	10 kΩ
100 pF	▨	100 kΩ	100 kΩ
10 pF	▨	▨	100 kΩ

L-D Measurement

L Range	Test Frequency (Hz)		
	100 ~ 995	1 k ~ 9.95	10 k~20 k
1 kH	100 kΩ	▨	▨
100 H	1 kΩ	100 kΩ	▨
10 H	1 kΩ	1 kΩ	100 kΩ
1 H	100 Ω	1 kΩ	1 kΩ
100 mH	100 Ω	100 Ω	1 kΩ
10 mH	100 Ω	100 Ω	100 Ω
1 mH	▨	100 Ω	100 Ω
100 μH	▨	▨	100 Ω

L-ESR/G Measurement

ESR/G Range	Test Frequency (Hz)
	100 ~ 20 k
1 MΩ / 10 μS	100 kΩ
100 kΩ / 100 μS	10 kΩ
10 kΩ / 1 mS	1 kΩ
1 kΩ / 10 mS	100 Ω
100 Ω / 100 mS	
10 Ω / 1 S	

C-ESR/G Measurement

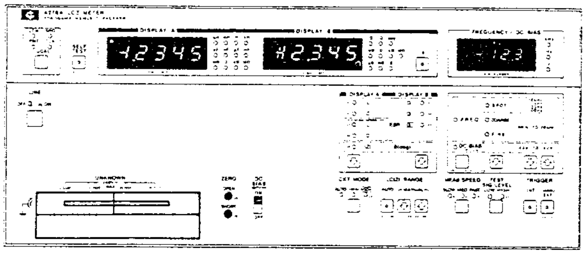
ESR/G Range	Test Frequncy (Hz)		
	100 ~ 498	500~4.98 k	5 k ~ 20 k
10 MΩ / 1 μS	▨	▨	100 kΩ
1 MΩ / 10 μS	100 kΩ		
100 kΩ / 100 μS	10 kΩ		
10 kΩ / 1 mS	1 kΩ		
1 kΩ / 10 mS	100 Ω		
100 Ω / 100 mS			
10 Ω / 1 S			
1 Ω / 10 S			

|Z| - θ Measurement

Z Range	Test Frequency (Hz)
	100 ~ 20 k
10 MΩ	100 kΩ
1 MΩ	
100 kΩ	10 kΩ
10 kΩ	1 kΩ
1 kΩ	100 Ω
100 Ω	
10 Ω	
1 Ω	

Figure 3-16. Range Resistor.

GENERAL MEASUREMENT



1. Connect the 16047A Test Fixture to the UNKNOWN terminals.
2. Turn on the 4276A.
3. Verify that the HP-IB address and option codes (16064 and 001) are displayed on DISPLAY A, DISPLAY B, and the FREQUENCY/DC BIAS display, respectively.

Note

Option codes are displayed only if the corresponding option is installed.

Note

The HP-IB address is set to 17 (10001) when the instrument is shipped from the factory.

4. Press the SELF TEST key to verify that the instrument is functioning properly. Refer to paragraph 3-5, SELF TEST. If no error-codes are displayed, press the SELF TEST key again to turn off the SELF TEST function.
5. Select the measurement functions for DISPLAY A and DISPLAY B.
6. Set the test frequency, test signal level, and measurement speed.

Note

SLOW measurement speed minimizes display fluctuation.

Note

Best measurement accuracy is obtained when test signal level is set to HIGH and measurement speed is set to MED.

7. Perform OPEN and SHORT Zero Offset adjustments as described in paragraph 3-48.
8. Connect the device to be measured to the test fixture.
9. Read the measured values from DISPLAY A and DISPLAY B.

Note

Refer to paragraph 3-20 for the meaning of any error-codes that may appear on DISPLAY A.

Note

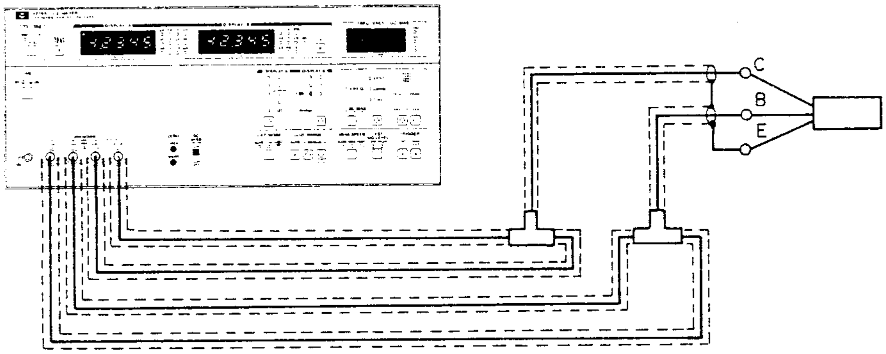
When the instrument is set to C-D or C-Q measurement mode and nothing is connected to the measurement terminals, CF and .0000 may be alternately displayed on DISPLAY A. This is not a malfunction, however.

Note

For C or L measurement, if the dissipation factor of the DUT is higher than 0.1, C, L, and D measurement accuracy tolerances increase by a factor of $1 + D^2$. If D is higher than 1, AUTO ranging cannot be performed correctly. $|Z|$ measurement mode should be selected.

Figure 3-17. General Measurement.

SEMICONDUCTOR DEVICE MEASUREMENT



Parameters of semiconductor devices have a strong dependency on the applied voltage and device temperature. Because of the non-linear impedance characteristics of semiconductor devices, a semiconductor measurement is subject to exact establishment of the test conditions to make measured values meaningful. For a detailed analysis of the device under its operating test conditions, a low level test signal is employed in order to obtain measured values with respect to a local region around the operating test point selected for plotting characteristic parameter curves of the sample. A typical procedure for measuring semiconductor junction capacitance in P-N and MOS junction devices is outlined below.

Measurement Setup:

The figure above shows a typical test setup for measuring the base-collector junction capacitance (Cob) of an NPN transistor. For this measurement, the test fixture may be user designed. A 4276A equipped with option 001 is ideal for controlling the dc bias required for the measurement. If dc bias is not necessary, setup and procedures associated with this measurement may be deleted.

PROCEDURE:

1. Connect the test fixture or test cables to the UNKNOWN terminals of the 4276A.

2. Turn on the 4276A.

3. Set the 4276A's front panel controls as follows:

   DISPLAY A: C
   DISPLAY B: G
   Test Freq.: 1kHz
   TEST SIG LEVEL: LOW

4. Perform OPEN and SHORT Zero Offset adjustments as described in paragraph 3-48.

5. Set the DC BIAS SELECT switch on the rear panel to INT.

Note

If an external voltage source is used for dc biasing, set the DC BIAS SELECT switch to EXT, and connect the voltage source output to the EXT INPUT/INT MONITOR connector on the rear panel.

Note

DC bias voltage, whether supplied from the internal bias source or from an external bias source, should be set to 0V at this time.

Note

Use the HP Model 16065A EXTERNAL VOLTAGE BIAS FIXTURE for high voltage bias applications up to ±200V.

6. Connect the transistor to the measurement terminals.

7. Monitor the bias voltage actually applied to the transistor.

Note

If the 16065A is used, close the lid after you connect the transistor to the measurement terminals. Measurement cannot be made while the lid is open.

8. Set the DC BIAS switch on the front panel to ON, and set the desired bias voltage.

Figure 3-18. Semiconductor Device Measurement (Sheet 1 of 2).

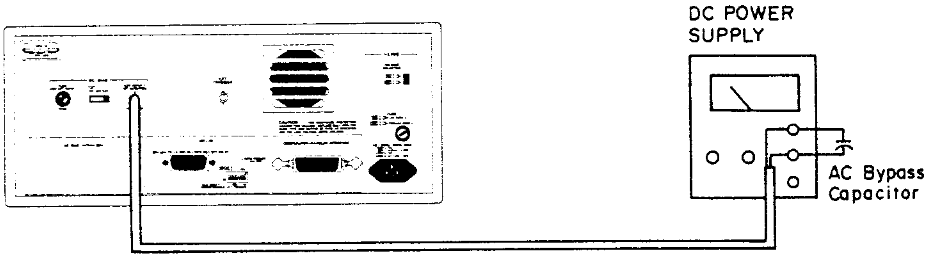
Note

If the P-N junction becomes forward biased at either peak of the test signal, correct measurement cannot be made.

9. Read the capacitance value from DISPLAY A.

Figure 3-18. Semiconductor Device Measurement (Sheet 2 of 2).

EXTERNAL DC BIAS OPERATION (≤±40V)



To make capacitance measurements using externally supplied dc bias voltages up tp ±40V, connect a dc voltage source to EXT INPUT/INT MONITOR connector on the rear panel as shown in the diagram.

CAUTION

DO NOT APPLY GREATER THAN ±40V TO THE 4276A'S EXT INPUT/INT MONITOR CONNECTOR. IF THE APPLIED VOLTAGE EXCEEDS ±40V, THE 4276A MAY BE DAMAGED.

CAUTION

BE SURE THE CORRECT FUSE (HP P/N 2110-0011) IS INSTALLED IN THE DC BIAS FUSE HOLDER ON THE REAR PANEL.

PROCEDURE:

1. Set DC BIAS select switch on rear panel to EXT.
2. Connect the test fixture or test leads to the UNKNOWN terminals of the 4276A.
3. Turn on the instruments.
4. Set the 4276A's controls as described in steps 3 through 6 of Figure 3-17. Set the DISPLAY A function to "C" measurement mode.
5. Perform OPEN and SHORT ZERO offset adjustments as described in paragraph 3-48.
6. Connect a sample to the test fixture or test leads.

CAUTION

DO NOT SHORT THE HIGH AND LOW TERMINALS.

CAUTION

WHEN A POSITIVE BIAS VOLTAGE IS USED, THE POSITIVE TERMINAL OF ELECTROLYTIC CAPACITORS MUST BE CONNECTED TO THE INSTRUMENT'S HIGH TERMINAL. WHEN USING A NEGATIVE BIAS VOLTAGE, CONNECT THE CAPACITOR'S NEGATIVE TERMINAL TO THE INSTRUMENT'S HIGH TERMINAL.

7. Set the external dc voltage source to the desired output voltage.
8. Read the measured values. Wait until the applied dc bias across the sample becomes stable.
9. Reset the external voltage source to 0V.
10. Remove the sample from test fixture or test leads.

Note

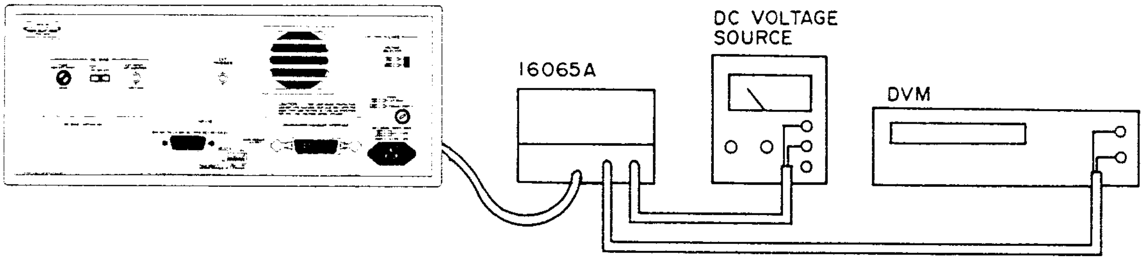
Use a stable dc voltage source.

Note

To make stable measurements, connect an ac bypass capacitor (approximately 1μF) between positive terminal and negative terminal of the external dc voltage source.

Figure 3-19. External DC Bias Operation (≤±40V).

EXTERNAL DC BIAS OPERATION (≤±200V)



To make capacitance measurements using externally supplied dc bias voltages up to ±200V, use the HP 16065A Test Fixture. Connect a dc voltage source to the 16065A as shown in the diagram.

CAUTION

DO NOT APPLY GREATER THAN ±40V TO THE 4276A'S EXT INPUT/INT MONITOR CONNECTOR. IF THE APPLIED VOLTAGE EXCEEDS ±40V, THE 4276A MAY BE DAMAGED.

PROCEDURE:

1. Set DC BIAS select switch on rear panel to OFF.
2. Connect the 16065A to the UNKNOWN terminals of the 4276A.
3. Connect the dc voltage source to DC BIAS INPUT connector of the 16065A.
4. Connect a DVM or an oscilloscope to the DC BIAS MONITOR connector of the 16065A.
5. Turn on the instruments.
6. Set the 4276A's controls as described in steps 3 through 6 (Figure 3-17). Set the DISPLAY A function to "C" measurement mode.
7. Perform OPEN and SHORT ZERO offset adjustments.
8. Connect a sample to the 16065A test fixture.

CAUTION

DO NOT SHORT THE HIGH AND LOW TERMINALS.

CAUTION

WHEN A POSITIVE BIAS VOLTAGE IS USED, THE POSITIVE TERMINAL OF ELECTROLYTIC CAPACITORS MUST BE CONNECTED TO THE INSTRUMENT'S HIGH TERMINAL. WHEN USING A NEGATIVE BIAS VOLTAGE, CONNECT THE CAPACITOR'S NEGATIVE TERMINAL TO THE INSTRUMENT'S HIGH TERMINAL.

9. Set the external dc voltage source to the desired output voltage and close the cover of the 16065A.
10. Read the measured values. Wait until the monitored voltage becomes stable.
11. Open the cover of the 16065A.

Note

When the cover of the 16065A is opened, the charge on the sample is discharged through two paralleled 20Ω resistors.

12. Remove the sample from the 16065A.

Note

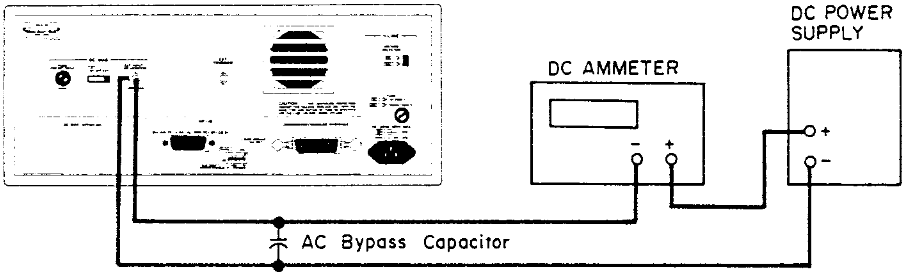
Use a stable dc voltage source.

Note

The test signal will appear at the DC BIAS MONITOR connector. This does not affect measurement results, however.

Figure 3-20. External DC Bias Operation (≤±200V).

EXTERNAL DC CURRENT BIAS OPERATION (≤ 1mA)



DC bias current can be applied to the sample through the UNKNOWN terminals by connecting a dc voltage source to the instrument. The procedure for making inductance measurements using current biasing is given below.

PROCEDURE:

1. Set the DC BIAS select switch on the rear panel to EXT.
2. Connect an external dc voltage source and dc ammeter (for current monitoring) to the EXT INPUT/INT MONITOR connector on the rear panel, as shown in the diagram.
3. Connect a test fixture or test leads to the UNKNOWN terminals of the 4276A.
4. Turn on the instruments.
5. Set the 4276A's controls as described in steps 3 through 6 of Figure 3-17. Set the DISPLAY A function to "L" measurement mode.
6. Perform OPEN and SHORT ZERO offset adjustments.
7. Connect the sample to the test fixture or test leads.
8. Gradually increase the dc voltage source output voltage until the desired bias current, as indicated on the dc ammeter, is obtained.

CAUTION

DO NOT ALLOW THE BIAS CURRENT TO EXCEED 35mA AND DO NOT ALLOW THE OUTPUT VOLTAGE FROM THE EXTERNAL DC VOLTAGE TO EXCEED SOURCE ±40V. IF CURRENT EXCEEDS 35mA OR IF VOLTAGE EXCEEDS ±40V, THE INSTRUMENT MAY BE DAMAGED.

Note

DC bias current flowing through sample can be calculated by the following equation:

$$I_{DC} = \frac{E_{bias}}{Rx + 1} \text{ (mA)}$$

where E_{bias} is the bias voltage (V) applied to EXT INPUT/INT MONITOR connector and Rx is the dc resistance (kΩ) of the sample.

9. Read the measured values.
10. Gradually decrease the dc voltage source output voltage until the dc bias current is 0mA, then remove the sample from the test fixture or test leads.

Note

To make stable measurements, connect an ac bypass capacitor (near 1μF) between the positive terminal and the negative terminal of the dc voltage source.

Note

Maximum allowable current depends on the range resistor, as listed in the table below.

Range Resistor Value	Maximum Current
100Ω	1mA
1kΩ	0.5mA
10kΩ	50μA
100kΩ	5μA

Refer to Figure 3-16 for details on the relation between range resistor and measurement range. Note that measurement accuracies, as specified in Section I, are not guaranteed if bias current is allowed to exceed the limits given in the above table.

Figure 3-21. External DC Current Bias Operation (≤±1mA).

3-72. HP-IB INTERFACE

3-73. The 4276A can be remotely controlled via the HP-IB, a carefully defined instrument interface which simplifies integration of programmable instruments and a calculator or computer into a system.

Note

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

3-74. HP-IB INTERFACE CAPABILITIES

3-75. The 4276A has eight HP-IB interface functions, as listed in Table 3-11.

Table 3-10. HP-IB Interface Capabilities

Code	Interface Function * (HP-IB Capabilities)
SH1**	Source Handshake
AH1	Acceptor Handshake
T5	Talker (basic talker, serial poll, talk only mode, 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 provide the means for a device to receive, process, and tansmit messages over the bus.

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

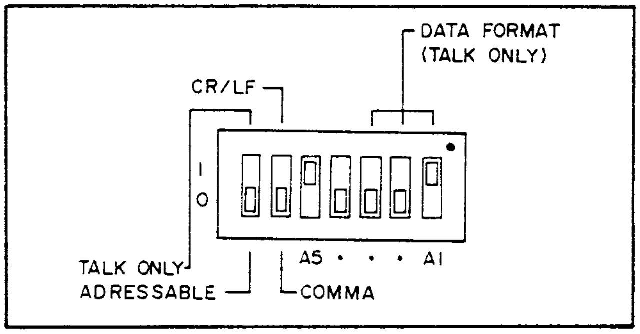


Figure 3-22. HP-IB Control Switch.

3-76. CONNECTION TO HP-IB

3-77. The 4276A can be connected into an HP-IB bus configuration with or without a controller (i.e., with or without an HP calculator). In an HP-IB system without a controller, the instrument functions as a "talk only" device (refer to paragraph 3-84).

3-78. HP-IB STATUS INDICATORS

3-79. The HP-IB Status Indicators are four LED lamps located on the front panel. When lit, these lamps show the existing status of the 4276A in the HP-IB system as follows:

SRQ:	SRQ signal from the 4276A to the controller is on the HP-IB line. Refer to paragraph 3-101.
LISTEN:	The 4276A is set to listener.
TALK:	The 4276A is set to talker.
REMOTE:	The 4276A is under remote control.

3-80. LOCAL KEY

3-81. The LOCAL key releases the 4276A from HP-IB remote control and allows measurement conditions to be set from the front-panel. The REMOTE lamp will go off when this key is pressed. LOCAL control is not available when the 4276A is set to "local lockout" status by the controller.

3-82. HP-IB CONTROL SWITCH

3-83. The HP-IB Control Switch, located on the rear panel, has seven bit switches. See Figure 3-22. Each bit switch has two settings: logical 0 (down position) and logical 1 (up position). The left-most bit switch, bit 7, determines whether the instrument will be addressed by the controller in a multidevice system, or will function as a "talk only" device to output measurement data and/or instructions to an external "listener," e.g., printer. The switch settings, when the instrument is shipped from the factory, are shown in Figure 3-22.

When bit switch 7 is set to 0, the instrument is in ADDRESSABLE mode and bit switches 1 through 5 determine the instrument address. When this bit switch is set to 1, however, the instrument is in TALK ONLY mode.

Bit switch 6 determines the output data delimiter. When this bit switch is set to 0, the delimiter is a comma (,); when set to 1, the delimiter is a carriage return and line feed (CR/LF).

Note

The HP-IB Control Switch setting is memorized only at instrument turn on. Thus, even if the HP-IB Control Switch setting is changed while the instrument is turned on, the memorized setting is not changed until the instrument is turned off and on.

3-84. TALK ONLY MODE

3-85. When bit switch 7 of the HP-IB Control Switch is set to TALK ONLY (i.e., set to 1), the instrument functions as a "talker," outputting data to a "listener" (e.g., printer). In TALK ONLY mode, bit switches 1, 2, and 3 determine the format in which data is output. There are six formats, F1 through F6, and the bit switch setting for each format is shown in Table 3-11. Refer to paragraph 3-95 for details on the output data formats.

Note

If the instrument is set to TALK ONLY mode, the Output Data Format number will be briefly displayed on DISPLAY A (instead of the HP-IB address) when the instrument is turned on. The displayed number, however, will be the format number plus 50. For example, if the Output Data Format is F2, the number displayed on DISPLAY A at turn on will be 52.

Note

When the instrument is used in TALK ONLY mode, devices connected to the instrument must be set to LISTEN ONLY mode.

3-86. In TALK ONLY mode, both bit switches 4 and 5 have no function.

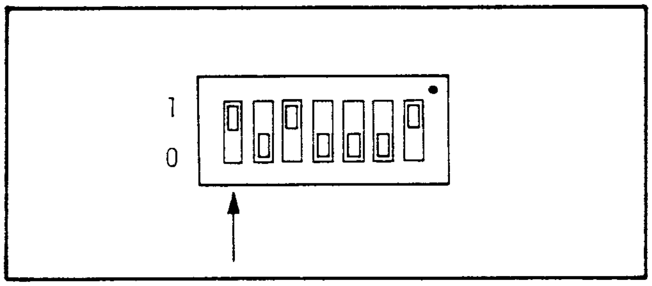


Figure 3-23. TALK ONLY Mode.

Table 3-11. Data Output Format Selection

Bit Switch Settings			Output Data Format
Bit 3	Bit 2	Bit 1	
0	0	0	F1
0	0	1	F2
0	1	0	F3
0	1	1	F4
1	0	0	F5
1	0	1	F6
1	1	0	F1
1	1	1	F2

Note: Refer to paragraph 3-95 for details.

3-87. ADDRESSABLE MODE

3-88. When bit switch 7 of the HP-IB Control Switch is set to ADDRESSABLE (i.e., set to 0), bit switches 1 through 5 represent the HP-IB address of the instrument, in binary. These switches are set to 10001 (decimal 17) when the instrument leaves the factory but can be set to any desired address between 0 and 30.

Note

When the instrument is turned on, the HP-IB address is displayed, in decimal, on DISPLAY A. For example, the factory-set address (10001) is displayed as "17."

Note

HP-IB address 11111 (decimal 31) cannot be used. If this address is set, E19 will be displayed on DISPLAY A (after 31 has been displayed) when the instrument is turned on.

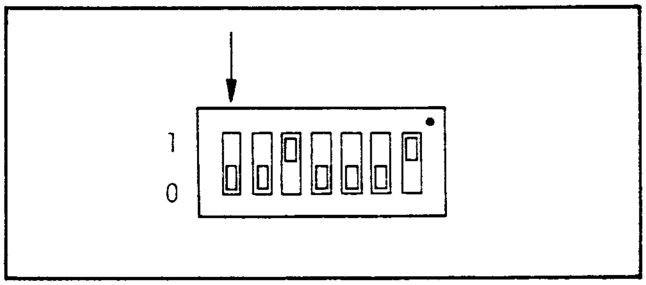


Figure 3-24. ADDRESSABLE Mode.

3-89. REMOTE PROGRAM CODES

3-90. Remote program codes for the 4276A are listed in Table 3-12.

3-91. PARAMETER SETTING

3-92. Test frequency, DC bias (option 001), and bin limits (option 002) can be set via remote programming.

[1] Test Frequency Setting

$\text{FR} \quad \underset{(1)}{\underline{\text{XXX.X}}} \quad \text{EN}$

(1) Setting value, in kHz.

Note

When an illegal frequency that is within the instrument's frequency range is set, the frequency below the illegal setting is automatically selected. For example:

"FR7.59EN" 7.55kHz displayed on FREQUENCY/DC BIAS DISPLAY

[2] DC Bias setting

$\text{BI} \quad \underset{(1)}{\underline{\pm\text{XX.X}}} \quad \text{EN}$

(1) Setting value, in volts.

Note

If not set, polarity sign is automatically set to positive (+).

[3] Comparator Limit Setting (Option 002 only)

(Low Limit) $\text{LL} \quad \underset{(1)}{\underline{\text{XX.XXX}}} \quad \text{EN}$

(High Limit) $\text{LH} \quad \underset{(1)}{\underline{\text{XX.XXX}}} \quad \text{EN}$

(1) Setting value. The position of the decimal point must agree with the measurement range. Unit is in accordance with the unit indicators of DISPLAY A or DISPLAY B.

3-93. DATA OUTPUT

3-94. Measurement and status data are output to external devices in bit parallel, byte serial format via the eight DIO signal lines of the HP-IB. Data can be output in ASCII mode or PACKED BINARY mode. Each mode is described below.

[1] ASCII mode

Output data in this mode includes status data, key status (function) data, and measurement data (including range) for DISPLAY A and DISPLAY B. If the instrument is equipped with Option 002, comparison data (LOW, IN, HIGH) for L/C/|Z| and D/Q/ESR/G, and BIN number data can be output, too. The output format is shown in Figure 3-25. All characters are coded in accordance with ASCII coding conventions.

[2] PACKED BINARY mode

Output data in this mode is output as one or two binary bytes, rather than as a character representation. This data output format is for high speed data transfer. Contents of output data, however, is less than that of ASCII mode. Output data in this mode includes status data for DISPLAY A and DISPLAY B, measurement range data as an 8-bit byte, and measurement data of DISPLAY A and DISPLAY B (not including unit and decimal point) as a 16-bit, 2's complement binaryword. If the instrument is equipped with Option 002, comparison data (LOW, IN, HIGH) for L/C/|Z| and D/Q/ESR/G, and BIN number data can be output as an 8-bit byte. The displayed data is output as the equivalent decimal values of the resulting words. The output format is shown in Figure 3-26.

3-95. OUTPUT DATA FORMAT

3-96. The 4276A can output measurement data to a controller or can output data directly to an external "listener" device (i.e., printer). There are six Output Data Formats, F1 through F6. The contents of the output data for each format are listed in Table 3-15.

Note

In ADDRESSABLE MODE, only F1 through F4 can be set by HP-IB remote control. Output data can be in either ASCII mode or BINARY PACKED mode. Also, in ADDRESSABLE mode, bit switch settings have no relation to Output Data Format.

Note

In TALK ONLY mode, any Output Data Format, F1 through F6, can be set by HP-IB Control Switch settings (bit 1 through bit 3). Also, in TALK ONLY mode, data can be output in ASCII mode only.

Table 3-12. Remote Program Codes (Sheet 1 of 2)

<table>
<tr><th>Item</th><th>Control</th><th>Program Code</th><th>Description</th></tr>
<tr><td>DISPLAY A Function</td><td>L
C
HIGH SPEED L
HIGH SPEED C
|Z|*</td><td>A1
A2·
A3
A4
A5</td><td rowspan="2">DISPLAY A and DISPLAY B combinations are listed in the table below:
<table><tr><th>A \ B</th><th>1</th><th>2</th><th>3</th></tr><tr><td>1</td><td>L-D</td><td>L-Q</td><td>L-ESR/G</td></tr><tr><td>2</td><td>C-D</td><td>C-Q</td><td>C-ESR/G</td></tr></table>* When DISPLAY A is set to |Z|,DISPLAY B is automatically set to θ.</td></tr>
<tr><td>DISPLAY B Function</td><td>D
Q
ESR/G</td><td>B1
B2
B3·</td></tr>
<tr><td>CKT MODE</td><td>AUTO

</td><td>C1·
C2
C3</td><td></td></tr>
<tr><td>MEAS SPEED</td><td>SLOW
MED
FAST</td><td>M1
M2·
M3</td><td></td></tr>
<tr><td>Auto Range</td><td>OFF
ON</td><td>U0
U1·</td><td>: Range is fixed.
: Range is automatically selected.</td></tr>
<tr><td>LC|Z| Range</td><td>100mΩ
10pF/1Ω
100μH/100pF/10Ω
1mH/1nF/100Ω
10mH/10nF/1kΩ
100mH/100nF/10kΩ
1H/1μF/100kΩ
10H/10μF/1MΩ
100H/100μF/10MΩ
1kH/1mF
10mF</td><td>R1
R2
R3
R4
R5
R6
R7
R8
R9
RA
RB</td><td>If the instrument is set to a range which cannot make the measurement, range is automatically reset to the nearest range capable of making the measurement.</td></tr>
<tr><td>Test Signal Level</td><td>LOW
HIGH</td><td>V1
V2·</td><td></td></tr>
<tr><td>Trigger Mode</td><td>INT
MAN/EXT</td><td>T1·
T2</td><td>This code only sets the trigger mode; it does not trigger the instrument.</td></tr>
<tr><td>Execute</td><td></td><td>EX</td><td>This code is used to trigger the instrument.</td></tr>
<tr><td>Self Test</td><td>OFF
ON</td><td>S0·
S1</td><td></td></tr>
<tr><td>Deviation Measurement</td><td>OFF
ON</td><td>X0·
X1</td><td></td></tr>
<tr><td>Zero Offset</td><td>OPEN
SHORT</td><td>ZO
ZS</td><td></td></tr>
</table>

Table 3-12. Remote Program Codes (Sheet 2 of 2)

Item	Control	Program Code	Description
Data Ready	OFF	D0·	If Data Ready is set to ON, an SRQ signal is output when the measurement is completed.
	ON	D1	
Comparator Enable	OFF	E0·	If the instrument is not equipped with Option 002, an error will result if E1 is sent via the HP-IB.
	ON	E1	
Comparator Run	OFF	G0·	
	ON	G1	
Comparator Limit	L/C/Z input	L1·	
	D/Q/ESR/G input	L2	
Comparator Bin Number	BIN1	N1·	These codes are used when setting L/C/|Z| limits.
	BIN2	N2	
	BIN3	N3	
	BIN4	N4	
	BIN5	N5	
	BIN6	N6	
	BIN7	N7	
	BIN8	N8	
	BIN9	N9	
Comparator Limit Recall		LR	Refer to paragraph 3-100.
Comparator Limit Erase		ER	Comparator limits stored in all bins are cleared.
Output Data Abort		DA	HP-IB output data are erased from the output buffer.
Output Data Format	Displays A/B or Comparator	F1·	Refer to paragraph 3-96 and Table 3-16.
	Displays A/B/Comparator	F2	
	Display A or Comparator	F3	
	Display A/Comparator	F4	
Learn Mode		LN	Refer to paragraph 3-98.
Output Data Mode	ASCII	P0·	
	BINARY	P1	

Note: · indicates an initial control setting (Refer to paragraph 3-38.)

[1] ASCII mode (Set using HP-IB remote program code "P0")

1 DISPLAY A/B

$$\underset{(1)}{\underline{X}}\ \underset{(2)}{\underline{X}}\ \underset{(3)}{\underline{X}}\ \underset{(4)}{\underline{\pm NN.NNN}}\ \underset{(5)}{\underline{E\pm NN}}\ \underset{(6)}{,}\ \underset{(7)}{\underline{X}}\ \underset{(8)}{\underline{X}}$$

$$\underset{(9)}{\underline{\pm N.NNNN}}\ \underset{(10)}{\underline{E\pm NN}}\ \underset{(11)}{\underline{\text{CR LF}}}$$

(1) Measurement circuit mode

(2) Status of DISPLAY A

(3) Function of DISPLAY A

(4) Value of DISPLAY A (position of decimal point is coincident with display)

(5) Unit of DISPLAY A

(6) Unit of DISPLAY A

(7) Status of DISPLAY B

(8) Function of DISPLAY B

(9) Value of DISPLAY B (position of decimal point is coincident with display)

(10) Unit of DISPLAY B

(11) Data Terminator

2 COMPARATOR (Option 002 only)

$$\underset{(1)}{\underline{X}}\ \underset{(2)}{\underline{X}}\ \underset{(3)}{\underline{N}}\ \underset{(4)}{\underline{\text{CR LF}}}$$

(1) Status of L/C/|Z|

(2) Status of D/Q/ESR/G

(3) BIN number

(4) Data Terminator

Note

Status and function data of DISPLAY A and DISPLAY B, and status of Comparator are each represented as one alphabetic character, as listed in Table 3-14.

Note

When measurement error code, OF, UF, CF or blank, is indicated on DISPLAY A or DISPLAY B, value of DISPLAY A or DISPLAY B ((4) or (9)) is output as follows:

OF (overflow) ················ ±19999E+20
UF (underflow) ················ +00000E-20
CF (change function)/
blank ·························· +0000E-30

Note

DISPLAY A and DISPLAY B ranges are expressed as an exponent as follows:

10^{-12} (p) ································ E-12
10^{-9} (n) ································ E-09
10^{-6} (μ) ································ E-06
10^{-3} (m) ································ E-03
10^{0} ································ E+00
10^{3} (k) ································ E+03
10^{6} (M) ································ E+06

Note

The data delimiter, bit switch 6 on the HP-IB Control Switch, is set at the factory to comma (,). This causes the instrument to output all data (DISPLAY A data, DISPLAY B data, and, if Comparator is used, Comparator data) as a continuous string. When the data delimiter is set to CR/LF, a carriage return and line feed signal is output after each field. This is useful when outputting data to certain peripherals, such as a printer.

Note

The E0I signal is output with the LF signal.

Figure 3-25. Data Output (ASCII).

[2] PACKED BINARY mode (Set using HP-IB remote program code "P1")

1 DISPLAY A/B

1st byte 2nd byte 3rd byte
BB BB BBBB BBBBBBBB BBBBBBBB
(1) (2) (3) (4)

4th byte 5th byte
BBBBBBBB BBBBBBBB
(5) (B: 0 or 1)

(1) Status of DISPLAY A

(2) Status of DISPLAY B

(3) Measurement Range

(4) Value* of DISPLAY A (not including decimal point and unit)

(5) Value* of DISPLAY B (not including decimal point and unit)

* Output data is the binary equivalent of the measured value.

Note

The first byte includes DISPLAY A status, DISPLAY B status, and measurement range. The value of the byte is output in decimal. For example, DISPLAY A status is OF (1), DISPLAY B status is "blank" (3), and measurement range is 5 (see Table 3-15), the byte will be as shown below.

01 11 0101
1 3 5

The decimal equivalent of this is 117. This is the value that will be output.

2 COMPARATOR (Option 002 only)

BB BB BBBB
(1) (2) (3)

(1) Status of L/C/ | Z |

(2) Status of D/Q/ESR/G

(3) BIN number

Note

Status data of DISPLAY A and DISPLAY B, measurement range, and status and BIN number data of Comparator are each represented as a number as listed in Table 3-15.

Note

Values displayed on DISPLAY A and DISPLAY B are output as number of counts. Actual measured values are obtained with measurement range and output data values.

Note

Comparator data is output when the comparator is in RUN mode. When F1, F3, or F5 is selected, if comparator is not in RUN mode, or if the comparator is not connected to the instrument, contents of output data is Type I.

Note

If the instrument is set to TALK ONLY mode, the Output Data Format number will be briefly displayed on DISPLAY A (instead of the HP-IB address) when the instrument is turned on. The displayed number, however, will be the format number plus 50. For example, if the Output Data Format is F2, the number displayed on DISPLAY A at turn on will be 52.

Figure 3-26. Data Output (Packed Binary).

Table 3-13. Data Output Codes for ASCII Mode

Item	Information	Code
Circuit Mode	 	P S
Data Status of DISPLAY A/B	Normal Normal on Deviation Measurement Overflow Underflow Change Function Blank (used only for DISPLAY B)	N D O U C B
Function of DISPLAY A	L C HIGH SPEED L HIGH SPEED C |Z|	L C L C Z
Function of DISPLAY B	D Q ESR G θ HIGH SPEED L*[1] HIGH SPEED C*[1]	D Q R G T N
Data Status of L/C/|Z| for Comparator	Bin IN HIGH LOW Embedded Undefined	I H L E*[2] U*[3]
Data Status of D/Q/ESR/G for Comparator	Limit IN HIGH LOW Undefined	I H L U*[3]
Bin Number	Out of Bin BIN1 BIN2 BIN3 BIN4 BIN5 BIN6 BIN7 BIN8 BIN9	0 1 2 3 4 5 6 7 8 9

*[1] HIGH SPEED C and HIGH SPEED L have the same output codes.

*[2] This code appears when the measurement value is between two continued bins.

*[3] This code appears when DISPLAY A or B indicates "CF" or blank.

Table 3-14. Data Output Codes for PACKED BINARY Mode

Item	Information	Code
Data Status of DISPLAY A/B	Normal	0
	Overflow	1
	Underflow	2
	Change Function or Blank	3
Measurement Range	100mΩ	1
	10pF/1Ω	2
	100μH/100pF/10Ω	3
	1mH/1nF/100Ω	4
	10mH/10nF/1kΩ	5
	100mH/100nF/10kΩ	6
	1H/1μF/100kΩ	7
	10H/10μF/1MΩ	8
	100H/100μF/10MΩ	9
	1kH/1mF	10
	10mF	11
Data Status of L/C/|Z| for Comparator	Bin IN	0
	HIGH	1
	LOW	2
	Embedded or Undefined	3
Data Status of D/Q/ESR/G for Comparator	Bin IN	0
	HIGH	1
	LOW	2
	Undefine	3
Bin Number	Out of Bin	0
	BIN1	1
	BIN2	2
	BIN3	3
	BIN4	4
	BIN5	5
	BIN6	6
	BIN7	7
	BIN8	8
	BIN9	9

Table 3-15. Data Output Format

Data Output Format		Output Data			Output Mode	
		DISPLAY A	DISPLAY B	COMPARATOR	ASCII	BINARY PACKED
F1	I	YES	YES	NO	YES	YES
	II	NO	NO	YES		
F2	I	YES	YES	YES	YES	YES
	II	YES	YES	NO		
F3	I	YES	NO	NO	YES	YES
	II	NO	NO	YES		
F4	I	YES	NO	NO	YES	YES
	II	YES	NO	YES		
F5	I	NO	YES	NO	YES	NO
	II	NO	NO	YES		
F6	I	NO	YES	NO	YES	NO
	II	NO	YES	YES		

I: Without the comparator (Model 16064A)

II: Using the comparator (Model 16064A).

3-97. LEARN MODE DATA

3-98. All front panel settings and comparator key settings are output from the 4276A when the program code "LN" is used (refer to Figure 3-29). The data is output in the following format:

$$\underset{(1)}{\underline{\text{FRnnnnEN}}}\ \underset{(2)}{\underline{\text{An}}}\ \underset{(3)}{\underline{\text{Bn}}}\ \underset{(4)}{\underline{\text{Cn}}}\ \underset{(5)}{\underline{\text{Dn}}}\ \underset{(6)}{\underline{\text{Fn}}}\ \underset{(7)}{\underline{\text{Mn}}}\ \underset{(8)}{\underline{\text{Pn}}}$$

$$\underset{(9)}{\underline{\text{Rn}}}\ \underset{(10)}{\underline{\text{Sn}}}\ \underset{(11)}{\underline{\text{Tn}}}\ \underset{(12)}{\underline{\text{Un}}}\ \underset{(13)}{\underline{\text{Vn}}}\ \underset{(14)}{\underline{\text{Xn}}}\ \underset{(15)}{\underline{\text{BI}\pm\text{nnnnEN}}}$$

$$\underset{(16)}{\underline{\text{En}}}\ \underset{(17)}{\underline{\text{Gn}}}\ \underset{(18)}{\underline{\text{Ln}}}\ \underset{(19)}{\underline{\text{Nn}}}\ \underset{(20)}{\underline{\text{CR LF}}}$$

(1) Test Frequency Setting

(2) A1 - A5: DISPLAY A Function

(3) B1 - B3: DISPLAY B Function

(4) C1 - C3: Circuit Mode

(5) D0, D1: Data Ready

(6) F1 - F4: Output Data Format

(7) M1 - M3: Measurement Speed

(8) P0, P1: Output Data Mode (ASCII or Packed Binary)

(9) R1 - R9, RA, RB: LC | Z | Range

(10) S0, S1: Self Test

(11) T1, T2: Trigger Mode

(12) U0, U1: Auto Range

(13) V1, V2: Test Signal Level

(14) X0, X1: Deviation Measurement

(15) DC Bias Setting

(16) E0, E1: Comparator Enable

(17) G0, G1: Comparator Run

(18) L1, L2: Comparator Limit Input

(19) N1 - N9: Comparator Bin Number for L/C/ | Z |

(20) Data Terminator

Note

DC Bias data is not output when DC Bias option (OPTION 001) is not installed. Similarly, when the comparator (OPTION 002) is not installed, comparator data is not output.

Note

Don't open the UNKNOWN terminals no test fixture or test leads when LEARN mode data is output in AUTO range. If so, measurement range is not fixed in some cases. there is no problem when a test fixture is connected to the UNKNOWN terminals or when measurement range is set to MANUAL mode.

3-99. RECALL COMPARATOR LIMIT DATA

3-100. Low and high bin limits can be output from the 4276A when the program code "LR" is used (refer to Figure 3-31). The L/C/ | Z | limits for the designated bin are output when code "L1" is used, D/Q/ESR/G limits are output. The data is output in the following format:

$$\underset{(1)}{\underline{\text{LLXX.XXXEN}}}\ \underset{(2)}{\underline{\text{LHXX.XXXEN}}}\ \underset{(3)}{\underline{\text{CR LF}}}$$

(1) Value of Low Limit (position of decimal point is coincident with display)

(2) Value of High Limit (position of decimal point is coincident with display)

(3) Data Terminator

3-101. SERVICE REQUEST STATUS BYTE

3-102. The 4276A outputs an RQS (Request Service) signal whenever it is set to one of the five possible service request states. Figure 3-27 shows the contents of the Status Byte.

Bit	8	7	6	5	4	3	2	1
Content		RQS		Error	Trigger Too Fast	Zero Offset Self Test End	Syntax Error	Data Ready

Bit 7 (RQS) indicates whether or not a service request exists. Bits 6 and 8 are always zero (0). Bits 1 through 5 identify the type of service request. Following are the service request states of the 4276A:

(1) Bit 1: This bit is set when measurement data is ready for output.

(2) Bit 2: This bit is set when the remote program contains a syntax error.

(3) Bit 3: This bit is set when Zero Offset or Self Test is completed under remote control.

(4) Bit 4: This bit is set when the 4276A is externally triggered before the measurement has been completed.

(5) Bit 5:

1 This bit is set when the 4276A has one of the following operation errors:

OFF, E10, E11, E13, E14, E15, E16, E17, E18, E10

2 If Self Test is set to ON, this bit is set when the instrument fails Self Test.

E37 - E39, E40 - E45

Figure 3-27. Status Byte for the 4276A.

3-103. PROGRAMMING GUIDE FOR 4276A

3-104. Sample programs that can be run on the HP-85, 9835A/B, 9845B, 9826A, or 9836A are given in Figures 3-28 through 3-31. These programs are listed in Table 3-16.

Note

Controller-specific HP-IB programming information is given in the controller's programming manual.

Note

Following equipment is required to run the sample programs:

(1)	4276A	LCZ Meter
(2)	HP-85	Personal Computer 00085-15003 I/O ROM
(3)	82937A	HP-IB INTERFACE
or		
(2)	9835A/B	Desktop Computer 98332A I/O ROM
(3)	98034A	HP-IB INTERFACE CARD
or		
(2)	9826A	Desktop Computer
(3)	10833B	HP-IB INTERFACE CABLE
or		
(2)	9836A	Desktop Computer
(3)	10833B	HP-IB INTERFACE CABLE

Table 3-16. Sample Programs Using HP-85

Sample Program	Figure	Description
1	3-28	Remote control and data output program
2	3-29	How to use remote program code "LN."
3	3-30	How to input low and high bin limits for the Comparator.
4	3-31	How to use remote program code "LR."

Sample Program 1

Description:

This program has three capabilities:

(1) Control of the 4276A via the HP-IB

(2) Trigger of the 4276A via the HP-IB

(3) Data output from the 4276A via the HP-IB

Program:

```
10    REMOTE 717
20    CLEAR 717
30    DIM A$[50]
40    OUTPUT 717; " A2B1T2P0F1 "
            (1)(2)      (3)

50    OUTPUT 717; " FR10EN "
                    (4)

60    OUTPUT 717; " EX "
            (5)

70    ENTER 717; A$
80    DISP A$
90    PRINT A$
100   END
```

(1) HP-IB INTERFACE Select Code (82937A or 98034A)

(2) HP-IB Address of the 4276A

(3) Program codes for the 4276A (refer to Table 3-13)

(4) Program codes for parameter setting of the 4276A (refer to paragraph 3-96)

(5) This is equivalent to: TRIGGER 717

Figure 3-28. Sample Program 1 (Sheet 1 of 2).

If program code "P1" is used, refer to the following program:

Program:

```
10   REMOTE 717
20   CLEAR 717
30   OUTPUT 717; "A2B1T2P1F1"
40   OUTPUT 717; "EX"
50   ENTER 717 USING "%, B, W, W" ; A, B, C
                      -  -  -  -
                     (1)(2)(3)(3)

60   DISP A;B;C
70   PRINT A;B;C
80   END
```

(1) ENTER terminator. "#" can also be used.

(2) Specifier for entering one byte (8-bit) of binary data

(3) Specifier for entering two bytes (16-bit) of binary data

Figure 3-28. Sample Program 1 (Sheet 2 of 2).

Sample Program 2

Description:

The remote program code "LN" can be used to read the front panel control settings and comparator settings. This program shows how to use "LN."

Program:

```
10   REMOTE 717
20   CLEAR 717
30   DIM A$[60]
40   OUTPUT 717; "LN"
50   ENTER 717;A$
60   DISP A$
70   PRINT A$
80   END
```

Figure 3-29. Sample Program 2.

Sample Program 3

Description:

This program shows how to input low and high bin limits via the HP-IB when the instrument is equipped with Option 002.

Program:

```
 10   REMOTE 717
 20   CLEAR 717
 30   DIM A$[50]
 40   OUTPUT 717;"A2B1R4T2P0F2"
                         (1)

 50   OUTPUT 717;"FR10EN"
 60   OUTPUT 717;"E1G0ER"
                   (2)

 70   OUTPUT 717;"L1N1LL.995ENLH.998EN"
                  (2)      (3)

 80   OUTPUT 717;"N2LL1 ENLH1.1EN"
 90   OUTPUT 717;"N3LL 1.1001ENLH1.2EN"
100   OUTPUT 717;"L2LL0ENLH.001EN"
110   OUTPUT 717;"G1"
120   OUTPUT 717:"EX"
130   ENTER 717;A$
140   DISP A$
150   PRINT A$
160   END
```

(1) Measurement range must be set.

(2) Program codes for comparator setting

(3) Program codes for inputting low and high bin limits

Figure 3-30. Sample Program 3.

Sample Program 4

Description

The remote program code "LR" can be used to recall the high and low limits for each bin. This program shows how to use "LR."

Program:

```
10    REMOTE 717
20    DIM A$[30]
30    OUTPUT 717; "E1G0"
40    FOR I = 1 TO 9
50    OUTPUT 717;"L1N";I, "LR"
60    ENTER 717 ; A$
70    PRINT A$
80    NEXT I
90    OUTPUT 717 ; "L2LR"
100   ENTER 717 ; A$
110   PRINT A$
120   END
```

Figure 3-31. Sample Program 4.

3-105. OPTIONS

3-106. Options are standard modificaions to the instrument that implement user's special requirements for minor functional changes. Operating instructions for the 4276A's options (except rack mount and handle installation kit options) and associated information are described in the following paragraphs.

3-107. Two options are available, as listed in the following tables:

Option No.	Option
001	Internal Dc Bias
002	Comparator/Handler Interface

Option contents are as follows:

Option NO.	Contents
001	HP Part No.04276-66522
002	HP 16064A

3-108. OPTION 001 INTERNAL DC BIAS (-40V to +40V)

3-109. Option 001 adds an internal dc bias supply variable from .00 volts to ±40.0 volts. The dc bias voltage can be controlled manually from the frontpanel or remotely via the HP-IB. Manual control is described in Figure 3-32. For dc bias applications under HP-IB control, refer to Figure 3-33. The internal dc bias source has two ranges and a maximum resolution of 10mV. Refer to Table 3-17. Output from the bias source is automatically set to 0V each time the instrument is turned on or when the CLEAR command is sent via the HP-IB. DC bias voltage is applied to the DUT only when the DC BIAS select switch on the rear panel is set to INT and the DC BIAS switch on the front panel is set to ON. If the DC BIAS switch is set to OFF, OFF will be briefly displayed on the FREQUENCY/DC BIAS display each time a new bias voltage is set. The dc bias voltage actually applied to the DUT depends on the impedance of the DUT and in most cases will be less than the voltage value displayed on the FREQUENCY/DC BIAS display. By connecting a DVM or an oscilloscope to the EXT INPUT/INT MONITOR connector on the rear panel, the dc bias voltage actually applied across the DUT can be monitored. Refer to Figure 3-34.

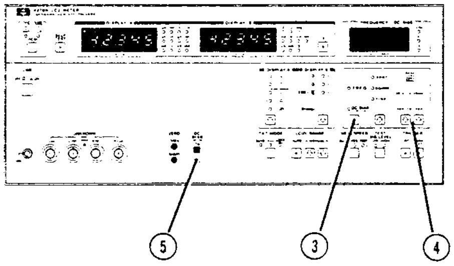
Table 3-17. Bias Voltage Resolution

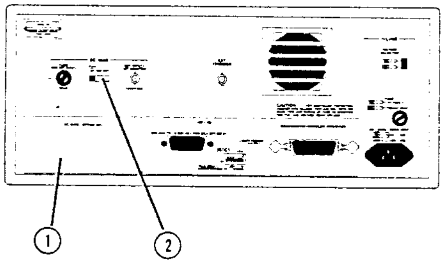
Bias Voltage Range	Resolution
OV∼± 9.99 V	10 mV
±10.0 V∼± 40.0 V	100 mV

Note

For the option 001 operation, set the DC BIAS select switch on the rear-panel to INT.

OPTION 001 INTERNAL DC BIAS OPERATION





1. Set the DC BIAS select switch ② to INT.

2. Connect the 16047A Test Fixture to the UNKNOWN terminals.

Note

Any of the test fixtures and test leads listed in Table 1-3 can be used for measurements requiring dc bias.

3. Turn on the 4276A.

4. Perform OPEN and SHORT Zero Offset adjustments as described in paragraph 3-48.

5. Set the instrument's front panel controls as appropriate for the desired measurement.

6. Press the FREQ/DC BIAS select key ③. The DC BIAS lamp will come on.

7. Set the desired voltage by pressing the appropriate FREQ/DC BIAS control key ④. The voltage value will be displayed on the FREQUENCY/DC BIAS display.

Note

OFF will be briefly displayed on the FREQUENCY/DC BIAS display when the FREQ/DC BIAS control key is released, if the DC BIAS ON/OFF switch ⑤ is set to OFF.

8. Connect the DUT to the test fixture.

CAUTION

DO NOT CONNECT A CHARGED DUT TO THE TEST FIXTURE. DOING SO MAY DAMAGE THE INSTRUMENT.

9. Set the DC BIAS switch ⑤ to ON.

10. If you are measuring a capacitive DUT, allow sufficient time for the DUT to charge up to the applied voltage.

11. Read the measured values displayed on DISPLAY A and DISPLAY B.

12. Set the DC BIAS switch ⑤ to OFF.

13. Wait until the voltage across the DUT return to 0V.

14. Remove the DUT from the test fixture.

Note

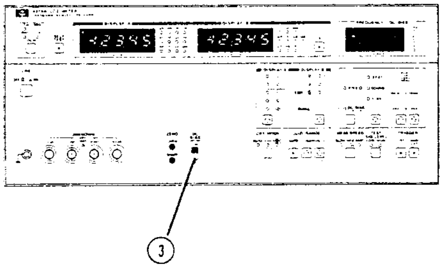
For reasons of safety and measurement accuracy, the voltage actually applied to the DUT should be monitored. Refer to Figure 3-34.

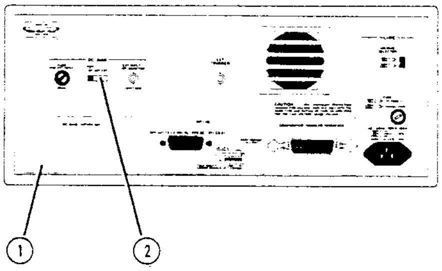
Note

When the DC BIAS switch on the front panel has been set to ON and the desired bias voltage is entered, the instrument automatically takes a wait time of approximately 0.8 seconds before outputting the bias voltage (after completion of the bias data input). Accordingly, it takes approximately (0.8 seconds + bias settling time) for the bias voltage to be applied to the DUT as well as to be settled after the bias data has been set. For the bias settling time, refer to Figure 1-2 Supplemental Performance Characteristics.

Figure 3-32. Option 001 Internal DC Bias Operation.

OPTION 001 INTERNAL DC BIAS HP-IB OPERATION





[HP-IB Operation]

The following procedure is an example of dc bias remote control via the HP-IB.

1. Set the DC BIAS select switch ② to INT.
2. Connect the 16047A Test Fixture to the UNKNOWN terminals.

Note

Any of the test fixtures and test leads listed in Table 1-3 can be used for measurements requiring dc bias.

3. Turn on the 4276A.
4. Perform OPEN and SHORT Zero Offset adjustments as described in paragraph 3-48.
5. Set the DC BIAS switch ③ to ON.

Note

The dc bias voltage is automatically set to 0V each time the instrument is turned on.

6. Set the front panel control via the HP-IB.

   * Example of setting the instrument for a C-D measurement at 10kHz, external trigger.

```
CLEAR 717
OUTPUT 717; "A2B1FR10ENF1T2"
```

7. Connect the DUT to the test fixture.
8. Set the desired dc bias voltage via the HP-IB.

   * Example of setting a dc bias voltage of +10V.

```
OUTPUT 717; "BI10EN"
```

9. Wait until the dc bias voltage settles.

   * Example of programming a 2-second wait.

```
WAIT 2000
```

10. Trigger the instrument via the HP-IB.

```
OUTPUT 717; "EX"
```
or
```
TRIGGER 717
```

11. Read and print the measured values.

```
ENTER 717; A, B
PRINT A, B
```

12. Set the bias voltage to 0V via the HP-IB.

```
OUTPUT 717; "BI 0EN"
```

13. Wait until the dc bias voltage returns to 0V.

    * Example of programming a 1-second wait.

```
WAIT 1000
```

14. Remove the DUT from the test fixture.

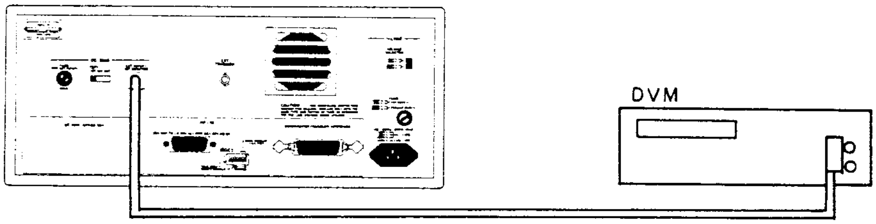
Note

The above remote programming examples can be used on the HP Model 85 (with 00085-15003 I/O ROM), Model 9835A, Model 9845B/C, Model 9826A, and Model 9836A.

In the above examples, HP-IB address 17 was used.

Figure 3-33. Option 001 Internal DC Bias HP-IB Operation.

INTERNAL DC BIAS VOLTAGE MONITOR



The internal dc bias voltage is monitored by a DVM or an oscilloscope at the EXT INPUT/INT MONITOR connector on the rear panel.

Note

The dc bias voltage monitored at the EXT INPUT/INT MONITOR connector may contain a small ac component.

When the DUT impedance is higher than 100kΩ, the monitored voltage is equal to the dc voltage source voltage, and to the voltage applied to the DUT. These voltages, however, are different when the DUT impedance is less than 100kΩ. The following paragraph describes how to measure the actual bias voltage across the DUT.

1. $R_1/R_2/R_L$ Detection (See Figure A.)
   - (a) Set the TEST SIG LEVEL to LOW.
   - (b) Set the LC | Z | range so that the range resistor value will be 100Ω. Refer to Figure 3-16.
   - (c) Set the DC BIAS voltage to +5V on the FREQUENCY/DC BIAS display.
   - (d) Connect nothing to the test fixture.
   - (e) Set the DC BIAS switch on the front panel to ON.
   - (f) Measure the monitor voltage (V_0) at the EXT INPUT/INT MONITOR connector.
   - (g) Connect a reference resistor (R_0) (e.g., 100Ω±1%) to the test fixture.
   - (h) Measure the dc voltages at the HIGH and LOW terminals of the test fixture and at the EXT INPUT/INT MONITOR connector (V_H, V_L, and V_K).

Note

Connect the LOW terminal of the DVM or the oscilloscope to the GUARD terminal of the instrument.

   - (i) Calculate the resistances, R_1, R_2, and R_L, using the following equations:

$$R_1 = (V_0 - V_K) \cdot R\ /(V_H - V_L)$$
$$R_2 = (V_K = V_H) \cdot R\ /(V_H - V_L)$$
$$R_L = V_L \cdot R_0 /(V_H - V_L)$$

2. Actual Bias Voltage/Current Measurement
   - (a) Connect nothing to the test fixture.
   - (b) Measure the monitor voltage (V_0).
   - (c) Connect the desired sample to the test fixture.
   - (d) Measure the monitor voltage (V_M).
   - (e) Calculate the actual voltage applied to the DUT (V) or the actual current through the DUT (I) using the following equations:

$$I = (V_0 - V_M)/R_1$$
$$V = V_0 - (R_1 + R_2 + R_L) \cdot I$$

Note

Repeat step 2 each time the DUT is changed since the monitor voltage (V_M) depends on the DUT impedance.

Figure 3-34. Internal DC Bias Voltage Monitor (Sheet 1 of 2).

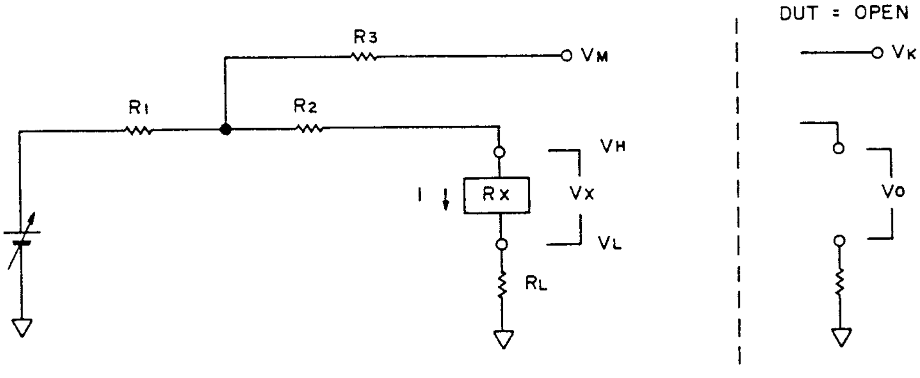


Figure A.

Figure 3-34. Internal DC Bias Voltage Monitor (Sheet 2 of 2).

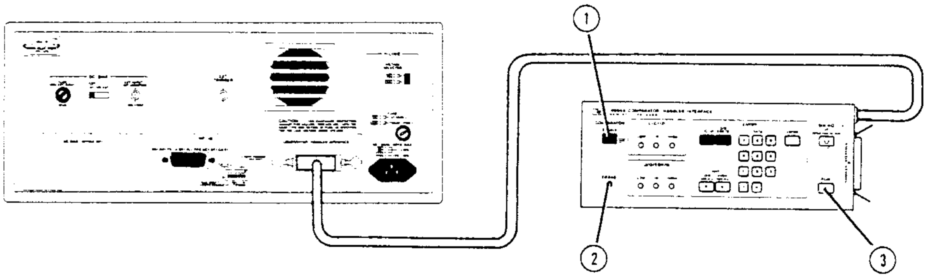
3-110. OPTION 002 COMPARATOR/HANDLER INTERFACE

3-111. Option 002 equips the standard 4276A with a comparator function and a handler (component sorter) interface capability. The comparator provides go/no-go testing and ten-bin sorting. The handler interface is for control of an automatic component handler.

3-112. Up to nine sets of high/low limits for L, C, or |Z| measurement, and one set of high/low limits for D, Q, ESR, or G measurement can be keyed in from the 16064A keyboard or entered via the HP-IB. When measurement is made, the comparator compares the measured values displayed on DISPLAY A and DISPLAY B with the stored high/low limits. If the measured values fit any set of limits, the bin number for that set is displayed on the FREQUENCY/DC BIAS display. If the measured values do not fit any of the limits, zero (0), the number for the out-of-limits bin, is displayed. Go/no-go decisions are indicated by two sets of LOW/IN/HIGH LED lamps on the 16064A keyboard. Comparator/Handler Interface operation is described in Figures 3-35 through 3-38.

3-113. The 16064A has a 36-pin female Amphenol connector for interfacing with an automatic component handler. The 16064A sends comparison results—LOW/IN/HIGH decisions and bin number--to the handler, and receives control signals via a user-fabricated interface cable constructed using the furnished 36-pin male Amphenol connector (P/N 1251-0084). Pin assignments are given in Figure 3-38. For complete information, refer to the 16064A Operation Note.

OPTION 002 COMPARATOR OPERATION



1. Connect the Model 16064A COMPARATOR/HANDLER INTERFACE to the COMPARATOR/HANDLER INTERFACE connector on the 4276A's rear-panel.
2. Connect the desired test fixture to UNKNOWN terminals.
3. Turn on the instrument.
4. Perform OPEN and SHORT Zero Offset adjustments as described in paragraph 3-48.
5. Set the front panel controls as appropriate for the desired measurement.
6. Press the ENABLE key on the 16064A. The LED lamp at the center of the key should come on.

Note

If E16 is displayed on DISPLAY A, press the ERASE button on the 16064A to erase previously stored limits.

7. Enter the high/low limits for L/C/|Z| or D/Q/ESR/G as described in Figure 3-36.
8. Press the RUN key on the 16064A. The comparator will then begin comparing all measured values with the high/low limits entered in step 7. The appropriate LED lamps--LOW, IN, HIGH--will be lit and the number of the bin whose high/low limits fit the measured values will be displayed on the FREQUENCY/DC BIAS display.

Example:

If the bin limits listed in Tables A and B are entered, the measured values listed in Table C will cause the comparison results shown in Table D.

Table A. Limits for L/C/|Z|

BIN No.	LOW LIMIT	HIGH LIMIT
1	1 nF	1.1 nF
2	1.1 nF	1.2 nF
3	1.2 nF	1.3 nF
4	1.3 nF	1.4 nF
5	1.4 nF	1.5 nF
6	2 nF	2.5 nF
7	2.5 nF	3 nF

Figure 3-35. Option 002 Comparator Operation (Sheet 1 of 2).

Table B. Limits for D/Q/ESR/G

LOW LIMIT	HIGH LIMIT
.01	.05

Table C. Measured Values

Sample	Measured Value		Sample	Measured Value	
1	C	1.22 nF	6	C	1.1 nF
	D	.013		D	.02
2	C	1.08 nF	7	C	1.18 nF
	D	.005		D	.071
3	C	.8 nF	8	C	4.1 nF
	D	.025		D	.033
4	C	2.75 nF	9	C	1.5 nF
	D	.06		D	.029
5	C	.95 nF	10	C	1.72 nF
	D	.055		D	.025

Table D. Comparison Results

Sample	L/C/ Z Lamp			D/Q ESR Lamp			FREQUENCY/ DC BIAS Display
	LOW	IN	HIGH	LOW	IN	HIGH	
1	○	●	○	○	●	○	3
2	○	●	○	●	○	○	0
3	●	○	○	○	●	○	0
4	○	●	○	○	○	●	0
5	●	○	○	○	○	●	0
6	○	●	○	○	●	○	1
7	○	●	○	○	○	●	0
8	○	○	●	○	●	○	0
9	○	●	○	○	●	○	5
10	●	○	●	○	●	○	0

Note

LOW and HIGH limits are inclusive; that is, if the measured value is exactly equal to the LOW or HIGH limit of a bin, the measured value fits the limits for that bin. Also, if a measured value fits the limits of more than one bin (bin limits overlap), the comparator selects the bin with the lower number. An example follows.

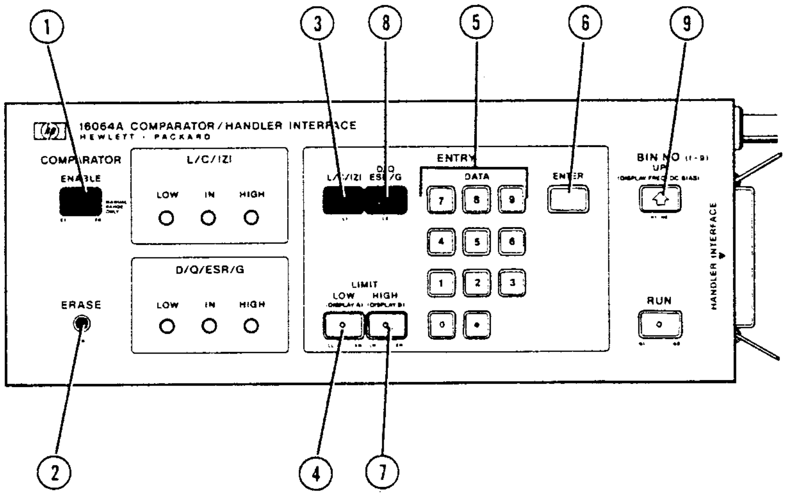
Bin 1: 100pF to 200pF
Bin 2: 150pF to 250pF
Measured Value: 190pF
Selected Bin: Bin 1

Note

If the LOW/HIGH limits for D/Q/ESR/G are not entered, or when the instrument is set to HIGH SPEED L or HIGH SPEED C, the IN lamp for D/Q/ESR/G will be always lit. D/Q/ESR/G comparison is not performed, however.

Figure 3-35. Option 002 Comparator Operation (Sheet 2 of 2).

COMPARATOR LIMIT SETTING



1. Press the ENABLE key ①. The LED lamp at the center of the key should come on.

2. Press the ERASE button ② to erase previously stored limits. One (1) will be displayed on the FREQUENCY/DC BIAS display.

[L/C/ | Z | Limit Entry]

3. Press the L/C/ | Z | key ③.

4. Press the LIMIT LOW key ④.

5. Key in the desired LOW limit using the DATA keys ⑤. The LOW limit value will be displayed on DISPLAY A.

6. Press the ENTER key ⑥. The LOW limit will be stored for bin 1. Also, the maximum allowable value that can be entered for the HIGH limit on the present LC | Z | RANGE will be displayed on DISPLAY B.

Note

If the LOW or HIGH limit is higher than the full scale value of the existing LC | Z | RANGE, E18 will be briefly displayed on DISPLAY A when the ENTER key is pressed. Re-enter the limits correctly.

7. Press the LIMIT HIGH key ⑦.

8. Key in the desired HIGH limit using the DATA keys ⑤. The HIGH limit value will be displayed on DISPLAY B.

9. Press the ENTER key ⑥. The HIGH limit will be stored for bin 1.

10. Press the BIN NO UP key ⑨. Two (2) will be displayed on the FREQUENCY/DC BIAS display.

11. Repeat steps 4 through 9 to enter the LOW and HIGH limits for bin 2.

12. Repeat steps 10 and 11 for bins 3 through 9.

[D/Q/ESR/G Limit Entry]

13. Press the D/Q/ESR/G key ⑧.

Note

When D/Q/ESR/G limits are being entered, no bin number is displayed on the FREQUENCY/DC BIAS display.

14. Press the LIMIT LOW key ④.

15. Key in the desired LOW limit using the DATA keys ⑤. The LOW limit value will be displayed on DISPLAY A.

16. Press the ENTER key ⑥. The LOW limit will be stored. Also, the maximum allowable value that can be entered for the HIGH limit will be displayed on DISPLAY B.

Figure 3-36. Comparator Limit Setting (Sheet 1 of 2).

Note

If the LOW or HIGH limit is higher than the full scale value of the existing DISPLAY B range, E18 will be briefly displayed on DISPLAY A when the ENTER key is pressed. Re-enter the limits correctly.

17. Press the LIMIT HIGH key ⑦.

18. Key in the desired HIGH limit using the DATA keys ⑤. The HIGH limit value will be displayed on DISPLAY B.

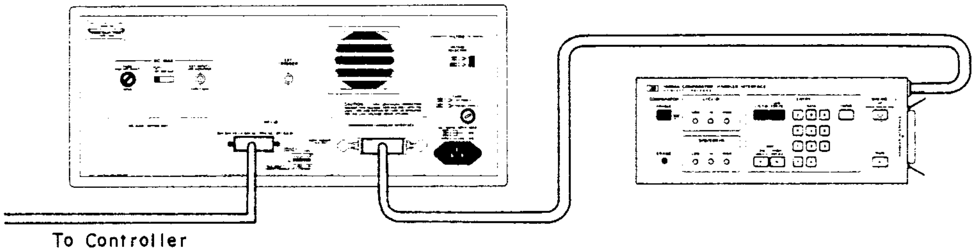
19. Press the ENTER Key.

Note

Press the ERASE button ②, erases the high/low limits of all bins.

Figure 3-36. Comparator Limit Setting (Sheet 2 of 2).

OPTION 002 COMPARATOR HP-IB OPERATION



[HP-IB OPERATION]

1. Connect the Model 16064A COMPARATOR/HANDLER INTERFACE to the COMPARATOR/HANDLER INTERFACE connector on the 4276A's rear-panel.

2. Connect the desired test fixture to the UNKNOWN terminals.

3. Turn on the instrument.

4. Perform OPEN and SHORT Zero Offset Adjustments.

5. Set the front panel controls as appropriate for the desired measurement and enable the 16064A via the HP-IB.

   * Example of setting C-D measurement, 1nF range, and 10kHz test frequency

```
DIM A$[1],B$[1]
CLEAR 717
OUTPUT 717;"A2B1R4T2FR10EN"
OUTPUT 717;"E1ER"
```

6. Enter the LOW/HIGH limits for L/C/|Z| via the HP-IB.

   * Example of setting a low limit of .950nF and a high limit = 1.1nF

```
OUTPUT 717;"LL.95ENLH1.1EN"
```

If necessary, enter the limits for the next bin (Bin 2).

* Example of setting bin 2's low limit to 1.1001nF and high limit to 1.2nF

```
OUTPUT 717;"N2"
OUTPUT 717;"LL1.1001ENLH1.2EN"
```

Note

The same setting can be made by the following program :

```
OUTPUT 717;"N2"
OUTPUT 717;"LH1.2EN"
```

7. Enter the limits for D/Q/ESR/G via the HP-IB.

   * Example of setting a low limit of .0000 and a high limit of .005

```
OUTPUT 717;"L2"
OUTPUT 717;"LL0ENLH.005EN"
```

Note

The same setting can be made by the following program:

```
OUTPUT 717;"L2"
OUTPUT 717;"LH.005EN"
```

Note

Comparator operations can be done without high/low limits for D/Q/ESR/G.

Figure 3-37. Option 002 Comparator HP-IB Operation (Sheet 1 of 2).

8. Start the comparator operation by HP-IB program.

   * Example of starting the comparator operation:

```
OUTPUT 717;"G1"
```

9. Connect the DUT to the test fixture.

10. Trigger the instrument via the HP-IB.

    * Example of triggering the instrument:

```
OUTPUT 717;"EX"
```

    or

```
TRIGGER 717
```

    If necessary, read the comparison results via the HP-IB.

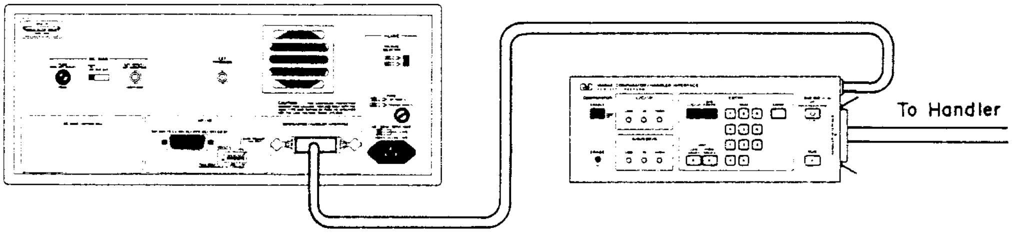
```
ENTER 717;A$,B$,N
PRINT A$,B$,N
```

Note

The HP-IB address code in the above examples is 17 (10001).

Figure 3-37. Option 002 Comparator HP-IB Operation (Sheet 2 of 2).

OPTION 002 HANDLER INTERFACE OPERATION



The 16064A outputs four types of signals to the component handler.

(1) Comparison result signals (LCHI, LCIN, LCLO, DQHI, DQIN, DQLO)

(2) Bin number signals (BIN1 ... BIN9, OUT-OF-BIN)

(3) DUT change signal (INDEX)

(4) Comparison complete signal (EOM)

Type (1) signals correspond to the LOW/IN/HIGH LED lamps on the 16064A keyboard. Type (1) signals are divided into two groups of three. When the signal line corresponding to the lit LED lamp goes LOW, the other signal lines in that group stay HIGH.

Type (2) signals correspond to the bin numbers displayed on the FREQUENCY/DC BIAS display. When the signal line corresponding to the displayed bin number goes LOW, the other signal lines stay HIGH.

The type (3) signal, INDEX, goes LOW when the 4276A has completed the analog portion of the measurement. The DUT can be disconnected from the measurement terminals and the next one can be connected. Comparison results, however, are not yet valid.

The type (4) signal, EOM, goes LOW when the 4276A has completed the measurement and the comparator has made a judgement. Comparison results are now valid.

All signals are negative true, and all are from TTL open-collector outputs. Pull-up resistors are installed. TTL voltage levels or higher voltages (up to 30V) are possible by changing a few jumper settings inside the 16064A. Refer to the 16064A Operating Note for details.

Signals sent from the external component handler to the 16064A are a trigger signal (EXT TRIG) that starts measurement and a key lock signal (KEY LOCK) that disables all control keys during comparator operation. To trigger the 4276A, apply a LOW signal (at least 100μs duration) to the EXT TRIG line. To disable the control keys of the 4276A and 16064A, apply a LOW signal to the KEY LOCK line.

Note

The INDEX and KEY LOCK signals are not mandatory for comparator/handler interface applications.

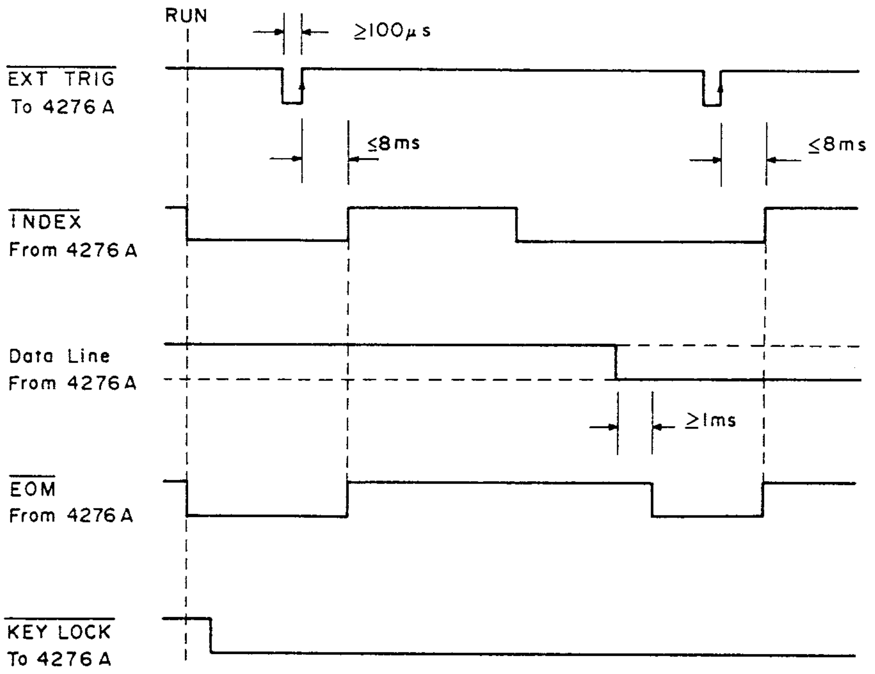
Note

More information on the Option 002 Handler Interface is given in the 16064A Operating Note.

Note

When the RUN key on the 16064A is pressed to start the comparator's operation, the $\overline{\text{OUT OF BIN}}$ line, pin 10 of the Handler Interface connector, is initially set to its active level (LOW).

Figure 3-38. Option 002 Handler Interface Operation (Sheet 1 of 2).



PIN ASSIGNMENTS FOR THE HANDLER INTERFACE CONNECTOR (HP 16064A)

<table>
<tr><th>PIN No.</th><th>Signal</th><th>PIN No.</th><th>Signal</th></tr>
<tr><td>1</td><td>BIN 1</td><td>19</td><td>LC|Z| HI</td></tr>
<tr><td>2</td><td>BIN 2</td><td>20</td><td>LC|Z| IN</td></tr>
<tr><td>3</td><td>BIN 3</td><td>21</td><td>LC|Z| LO</td></tr>
<tr><td>4</td><td>BIN 4</td><td>22</td><td>DQESRG HI</td></tr>
<tr><td>5</td><td>BIN 5</td><td>23</td><td>DQESRG IN</td></tr>
<tr><td>6</td><td>BIN 6</td><td>24</td><td>DQESRG LO</td></tr>
<tr><td>7</td><td>BIN 7</td><td>25</td><td>KEY LOCK*</td></tr>
<tr><td>8</td><td>BIN 8</td><td>26</td><td>NC</td></tr>
<tr><td>9</td><td>BIN 9</td><td>27</td><td>EXT DCV 1*</td></tr>
<tr><td>10</td><td>OUT OF BINS</td><td>28</td><td>EXT DCV 1*</td></tr>
<tr><td>11</td><td>NC</td><td>29</td><td>NC</td></tr>
<tr><td>12</td><td>EXT TRIG*</td><td>30</td><td>INDEX</td></tr>
<tr><td>13</td><td>EXT TRIG*</td><td>31</td><td>EOM</td></tr>
<tr><td>14</td><td>EXT DCV2*</td><td>32</td><td>EXT DCV COM*</td></tr>
<tr><td>15</td><td>EXT DCV2*</td><td>33</td><td>EXT DCV COM*</td></tr>
<tr><td>16</td><td>+5V</td><td>34</td><td>GROUND</td></tr>
<tr><td>17</td><td>+5V</td><td>35</td><td>GROUND</td></tr>
<tr><td>18</td><td>+5V</td><td>36</td><td>GROUND</td></tr>
</table>

*: Externally Applied Signals

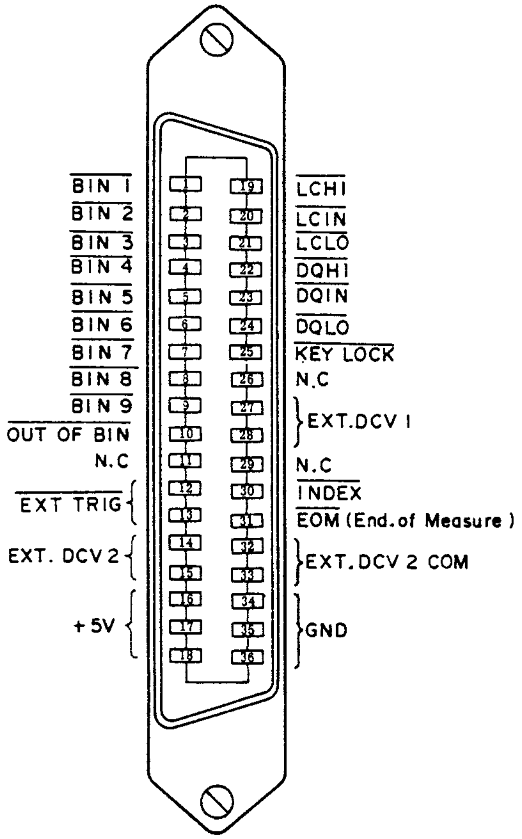


Figure 3-38. Option 002 Handler Interface Operation (Sheet 2 of 2).

3-114. POWER FAILURE MONITOR SIGNAL

3-115. If the instrument experiences a transient power failure such that the output voltage from the +5V power supply on the A1 board drops below +4.8V, all measurement circuits will be reset when the voltage returns to normal. Usually the duration of a transient power failure and the time required for the reset operation are so short that the operator may not be aware that the instrument has experienced a power failure. In most applications, this is not a problem, because the instrument's continuous memory function restores all settings (except the DC bias setting on option 001 instruments) after the reset operation. In some applications, though, a transient power failure, however brief, can adversely affect measurement results. In such applications it is important to know whether a power failure has occurred.

The 4276A is equipped with a power failure monitor signal (PWF) which can be used to inform the operator or peripherals of a transient power failure. The PWF signal is of the open collector type, and therefore requires an external (user-supplied) voltage source (+5V max.) and a pull-up resistor. Also, two wires must be connected to a jumper inside the 4276A and brought out through a hole in the rear panel. Complete instructions are given in paragraph 2-31.

Number of Display Digits

The number of display digits on DISPLAY A/B for C-D measurement, C-ESR/G measurement, L-D measurement, L-ESR/G measurement, and $|Z| - \theta$ measurement is listed in Tables 1 through 5. The number of display digits for a Q measurement depends on the D value and is listed in Table 6.

Note

Tables 1 through 5 are valid under the following conditions:

(1) Circuit Mode: AUTO

(2) Test Signal Level: HIGH

Note

When the test signal level is set to LOW, the number of display digits is one less than the number of display digits when the test signal level is set to HIGH.

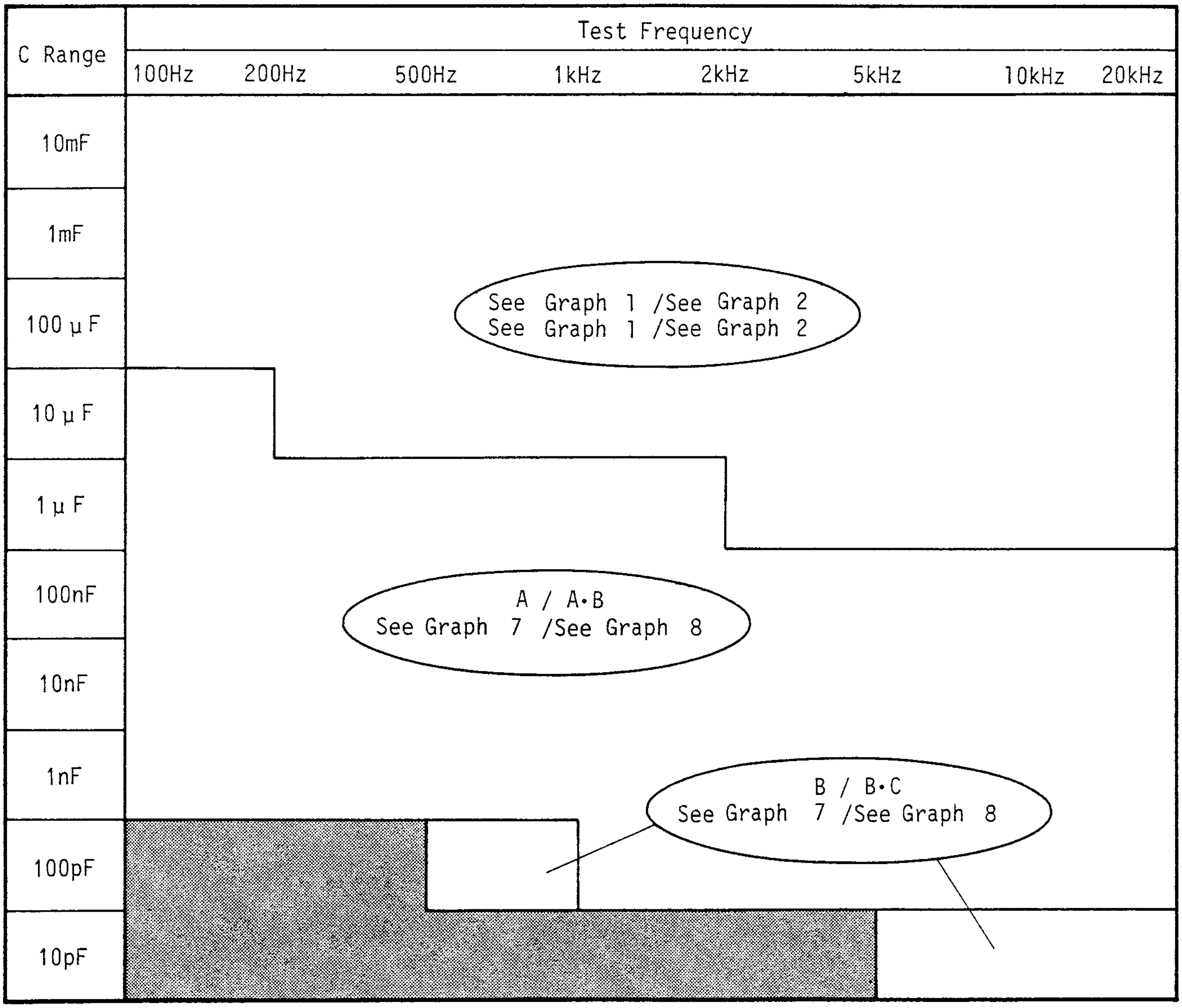
Note

Alphabetic characters used in the Tables represent the number of display digits as follows:

Symbol	Display
A	
B	
C	
D	

Figure 3-39. Number of Display Digits (Sheet 1 of 13).

Table 1. C-D Measurement



Alphabetic characters used in Table 1 represent:

Number of C Display Digits(*/**)
Number of D Display Digits(*/**)

* : MED measurement speed mode.
** : SLOW or FAST measurement speed mode (SLOW•FAST).

Figure 3-39. Number of Display Digits (Sheet 2 of 13).

Table 2. C-ESR/G Measurement

ESR/G Range	Test Frequency							
	100Hz	200Hz	500Hz	1kHz	2kHz	5kHz	10kHz	20kHz
1 µ S	A / A·B	▨	B / B·C	A / A·B	▨	B / B·C	B / B·C	B / B·C
10 µ S	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B
100 µ S	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B
1mS	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B
10mS	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B
100 Ω	A / A·B	B / B·C	B / B·C	A / A·B	B / B·C	B / B·C	A / A·B	A / A·B
10 Ω	B / B·C	B / B·C	B / B·C	B / B·C	B / B·C	B / B·C	B / B·C	B / B·C
1 Ω	B / B·C	B / B·C	B / B·C	B / B·C	B / B·C	B / B·C	B / B·C	B / B·C

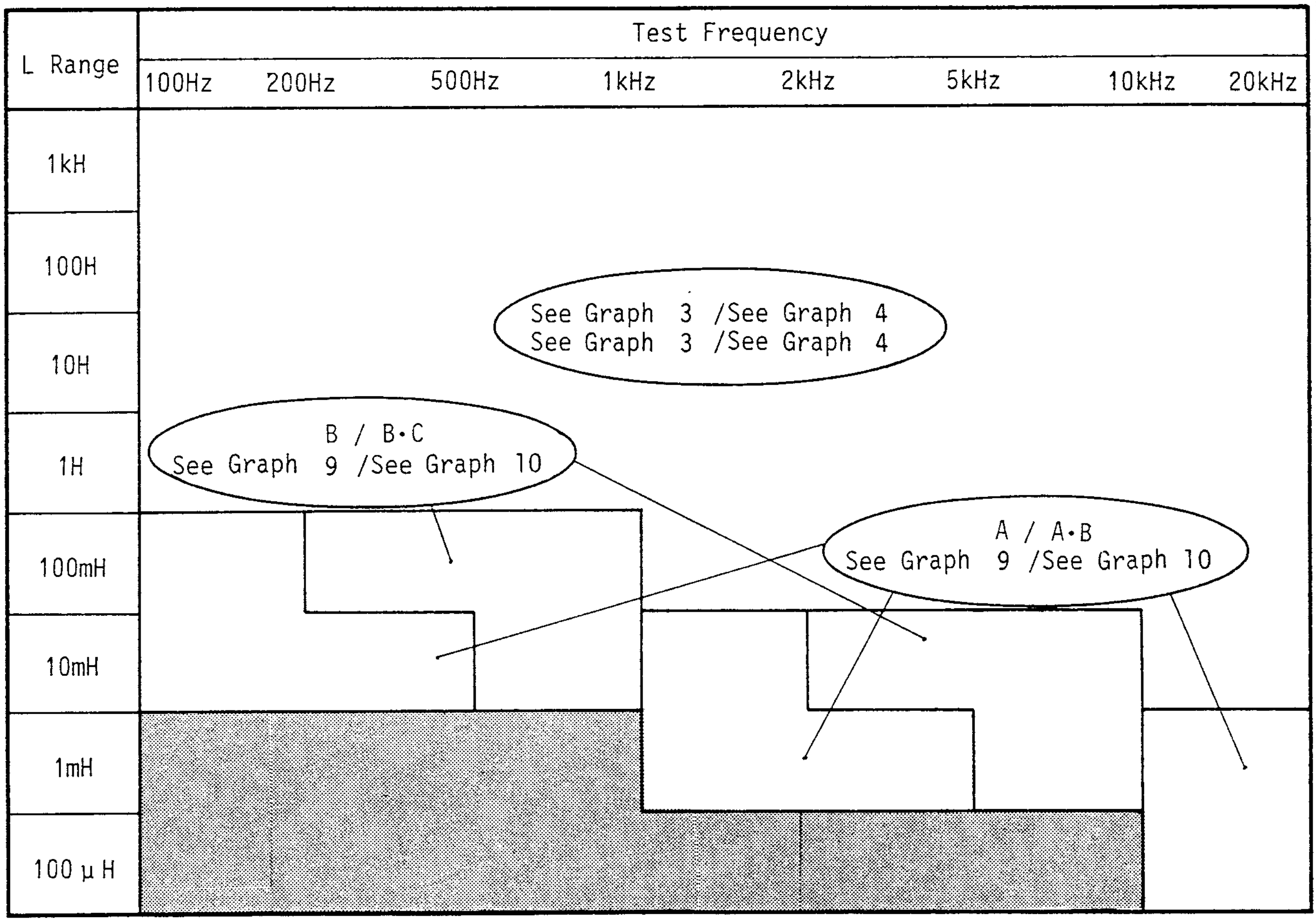
Alphabetic characters used in Table 2 represent:

Number of ESR/G Display Digits(*/**)

* : MED measurement speed mode.
** : SLOW or FAST measurement speed mode (SLOW·FAST).

Figure 3-39. Number of Display Digits (Sheet 3 of 13).

Table 3. L-D Measurement



Alphabetic characters used in Table 3 represent:

Number of L Display Digits(*/**)
Number of D Display Digits(*/**)

* : MED measurement speed mode.
** : SLOW or FAST measurement speed mode (SLOW•FAST).

Figure 3-39. Number of Display Digits (Sheet 4 of 13).

Table 4. L-ESR/G Measurement

ESR/G Range	Test Frequency							
	100Hz	200Hz	500Hz	1kHz	2kHz	5kHz	10kHz	20kHz
10 µ S	B / B·C	B / B·C	B / B·C	B / B·C	B / B·C	B / B·C	B / B·C	B / B·C
100 µ S	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B
1mS	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B
10mS	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B	A / A·B
100 Ω	A / A·B	B / B·C	C / C·D	A / A·B	B / B·C	C / C·D	A / A·B	A / A·B
10 Ω	A / A·B	B / B·C	B / B·C	A / A·B	B / B·C	B / B·C	A / A·B	A / A·B

Alphabetic characters used in Table 4 represent:

Number of ESR/G Display Digits(*/**)

* : MED measurement speed mode.
** : SLOW or FAST measurement speed mode (SLOW·FAST).

Figure 3-39. Number of Display Digits (Sheet 5 of 13).

Table 5. Z - θ Measurement

<table>
<tr><th rowspan="2">Z Range</th><th colspan="8">Test Frequency</th></tr>
<tr><th>100Hz</th><th>200Hz</th><th>500Hz</th><th>1kHz</th><th>2kHz</th><th>5kHz</th><th>10kHz</th><th>20kHz</th></tr>
<tr><td>10M Ω</td><td colspan="8" rowspan="5">See Graph 5 /See Graph 6
See Graph 5 /See Graph 6</td></tr>
<tr><td>1M Ω</td></tr>
<tr><td>100k Ω</td></tr>
<tr><td>10k Ω</td></tr>
<tr><td>1k Ω</td></tr>
<tr><td>100 Ω</td><td colspan="8" rowspan="2">A / A•B
See Graph 11 /See Graph 12</td></tr>
<tr><td>10 Ω</td></tr>
<tr><td>1 Ω</td><td colspan="8" rowspan="2">B / B•C
See Graph 11 /See Graph 12</td></tr>
<tr><td>100m Ω</td></tr>
</table>

Alphabetic characters used in Table 5 represent:

Number of Z Display Digits(*/**)
Number of θ Display Digits(*/**)

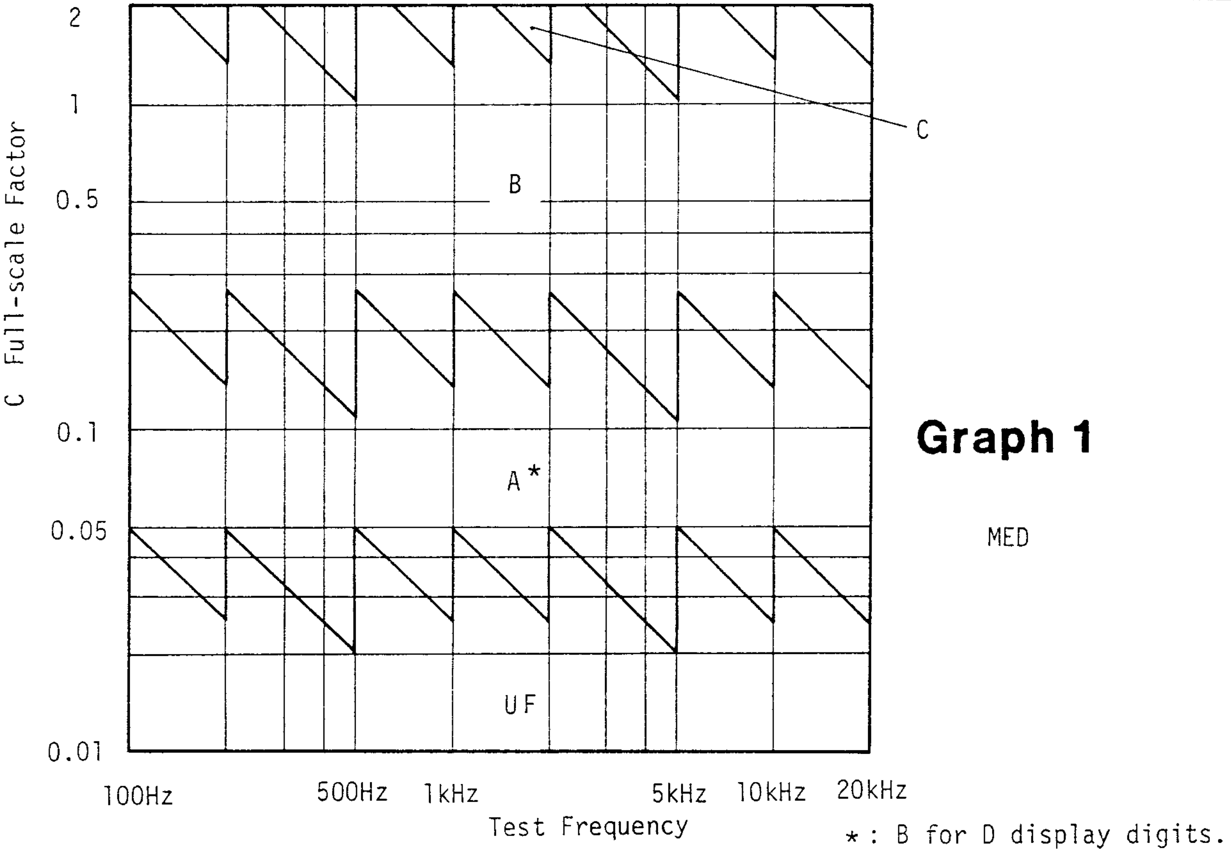
* : MED measurement speed mode.
** : SLOW or FAST measurement speed mode (SLOW•FAST).

Figure 3-39. Number of Display Digits (Sheet 6 of 13).

Table 6. Q Measurement.

D Display	Q Display	D Display	Q Display
.0001 to .0006	0F	.001 to .006	0F
.0007 to .0010	1ooo.	.007 to .010	1oo.
.0011 to .0033	9oo. to 3oo.	.011 to .033	9o. to 30.
.0034 to .0099	29o. to 10o.	.034 to 1.999	30. to 1.
.0100 to .0333	100. to 30.		
.0334 to 1.9999	29.9 to .5		
.0F	.o		

Figure 3-39. Number of Display Digits (Sheet 7 of 13).



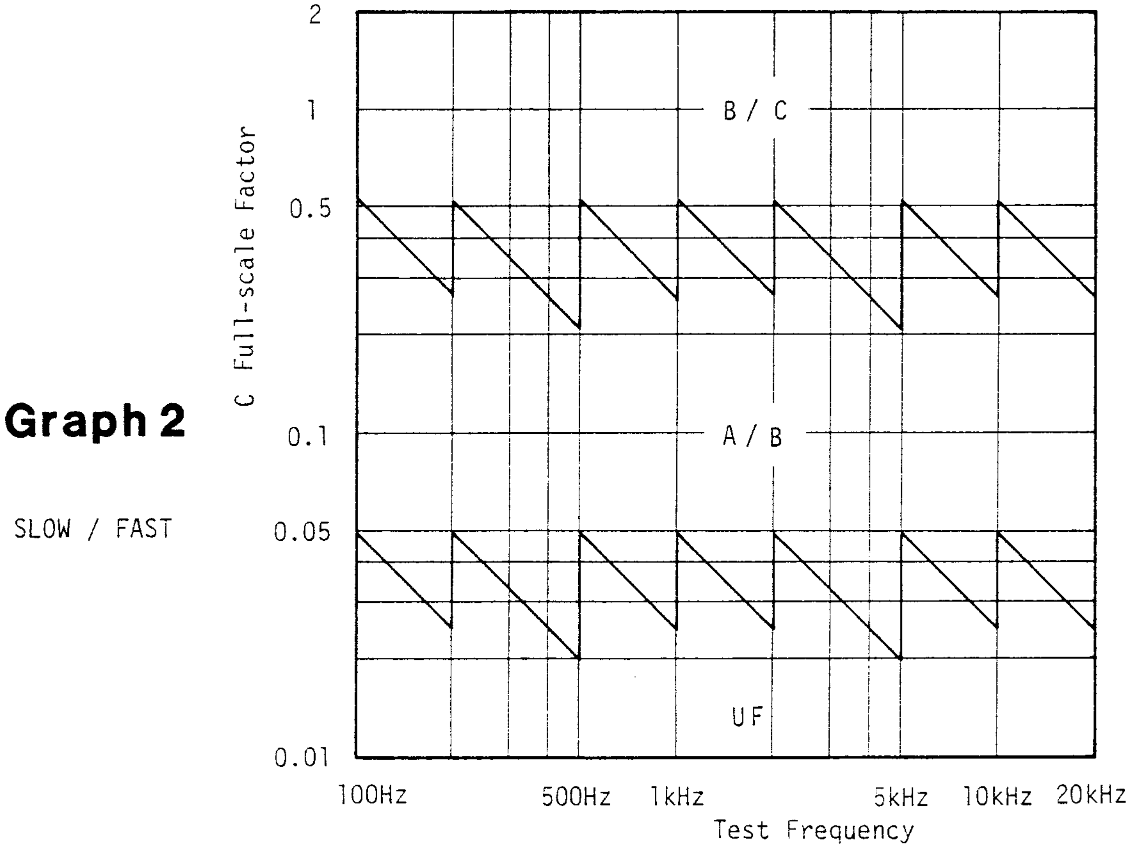


Figure 3-39. Number of Display Digits (Sheet 8 of 13).

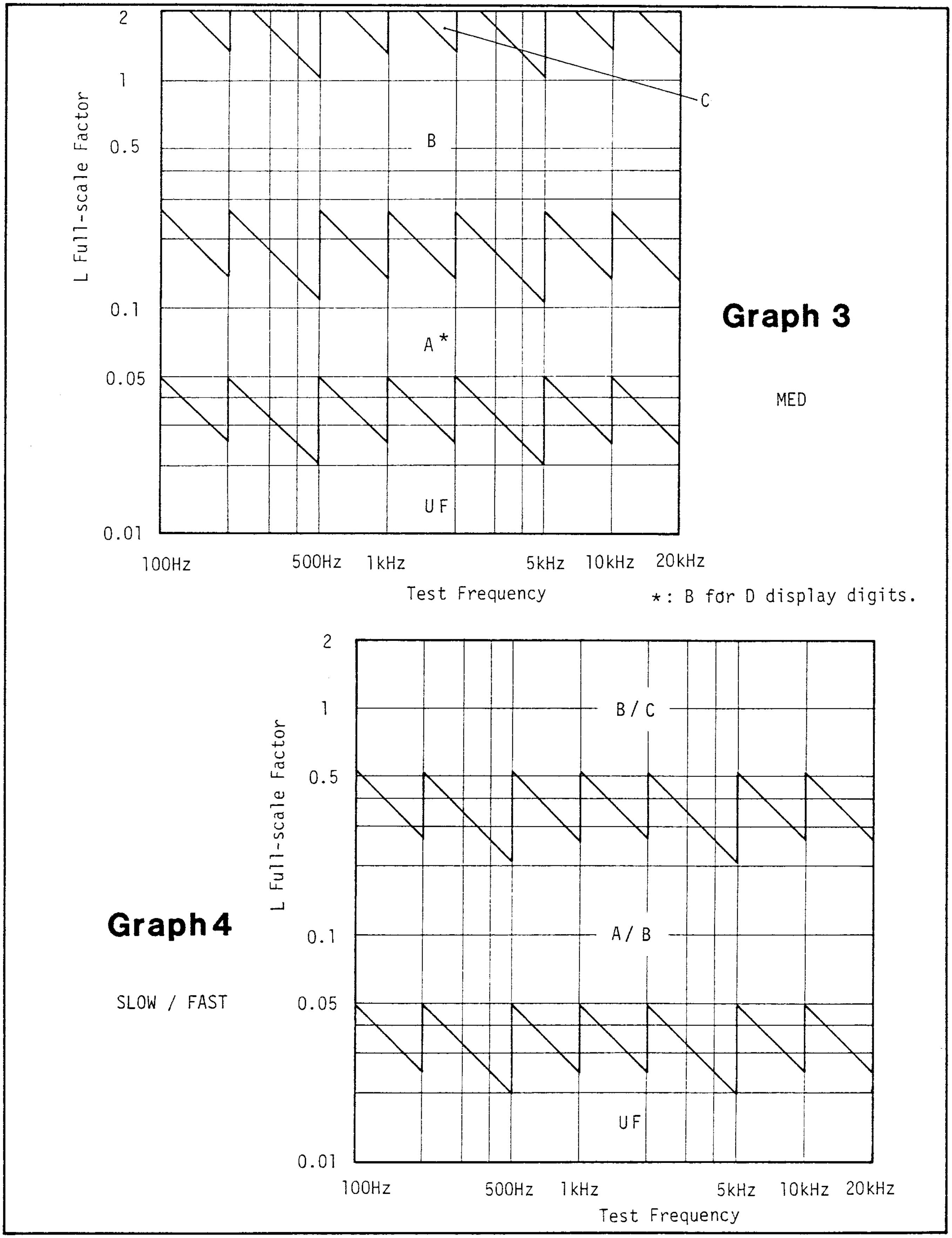
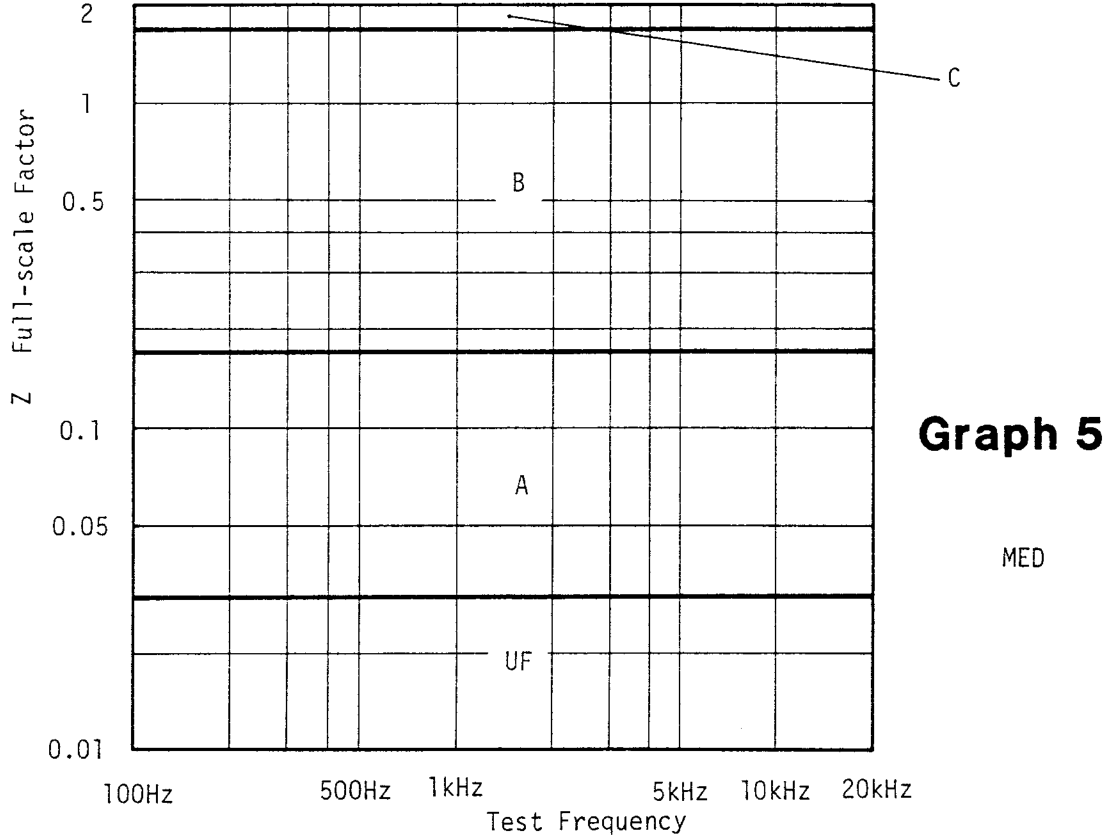


Figure 3-39. Number of Display Digits (Sheet 9 of 13).



Graph 5

MED

Graph 6

SLOW / FAST

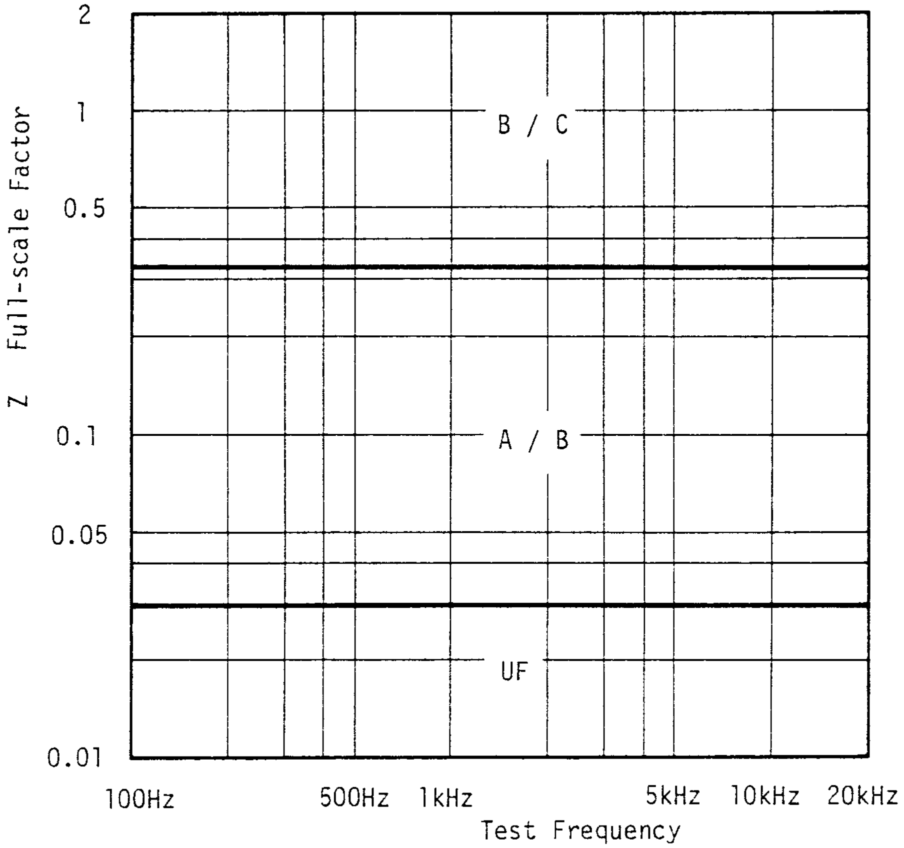
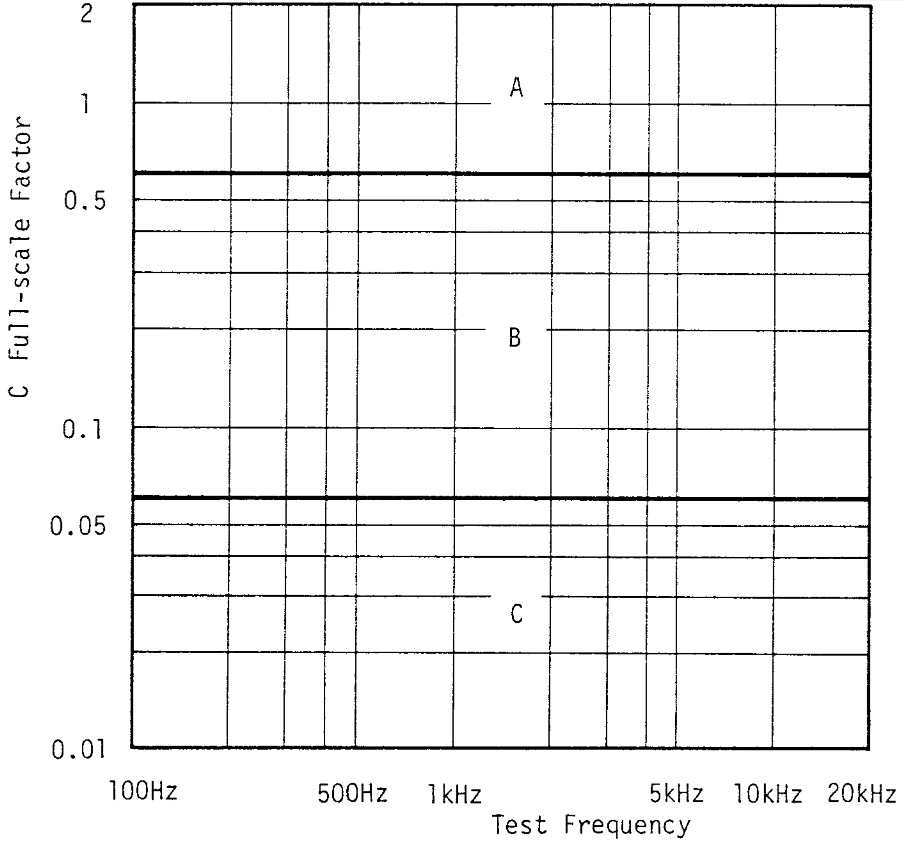


Figure 3-39. Number of Display Digits (Sheet 10 of 13).



Graph 7

MED

Graph 8

SLOW / FAST

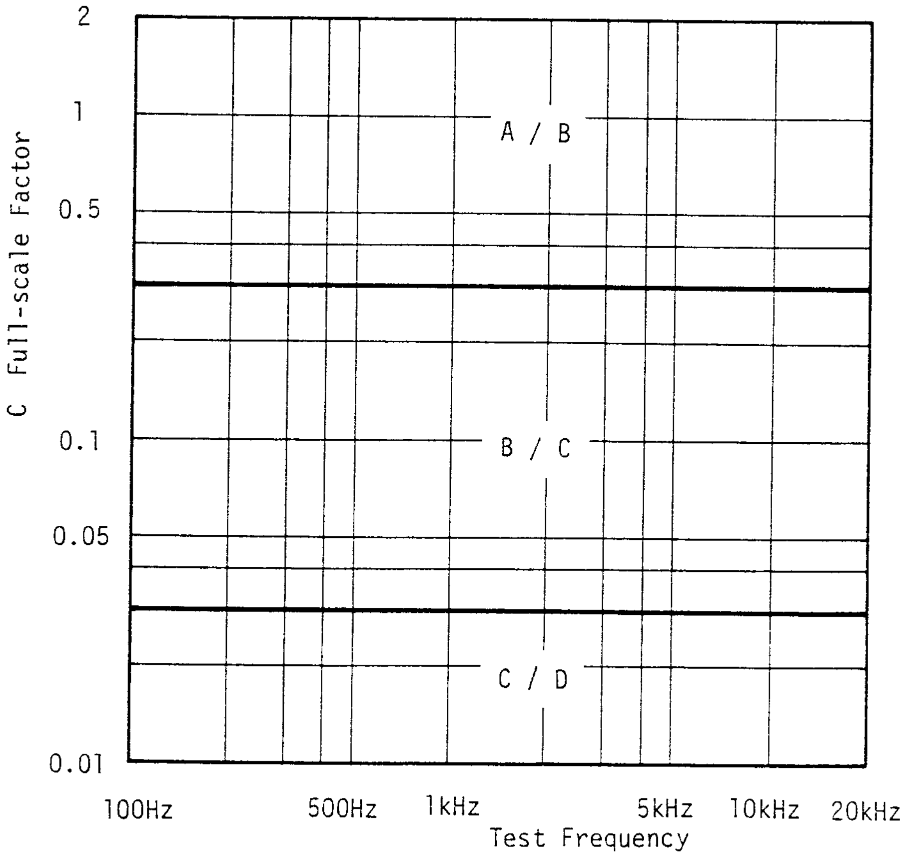
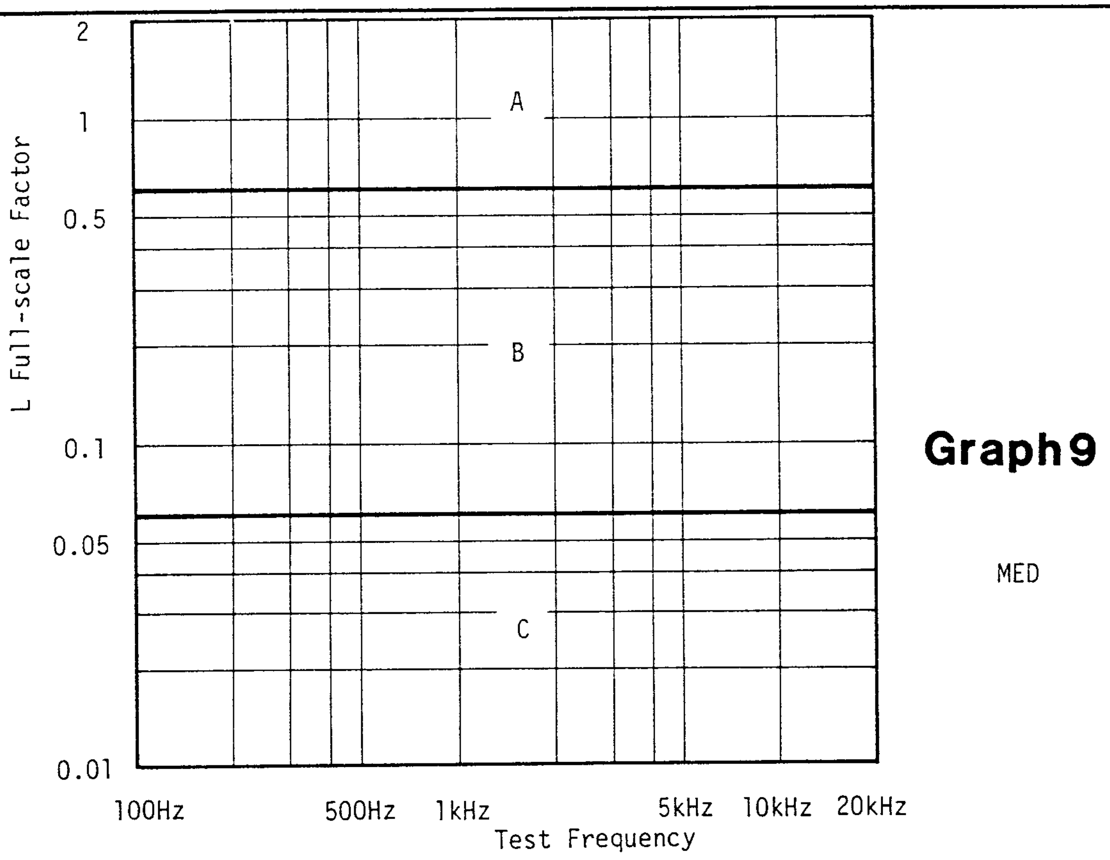


Figure 3-39. Number of Display Digits (Sheet 11 of 13).



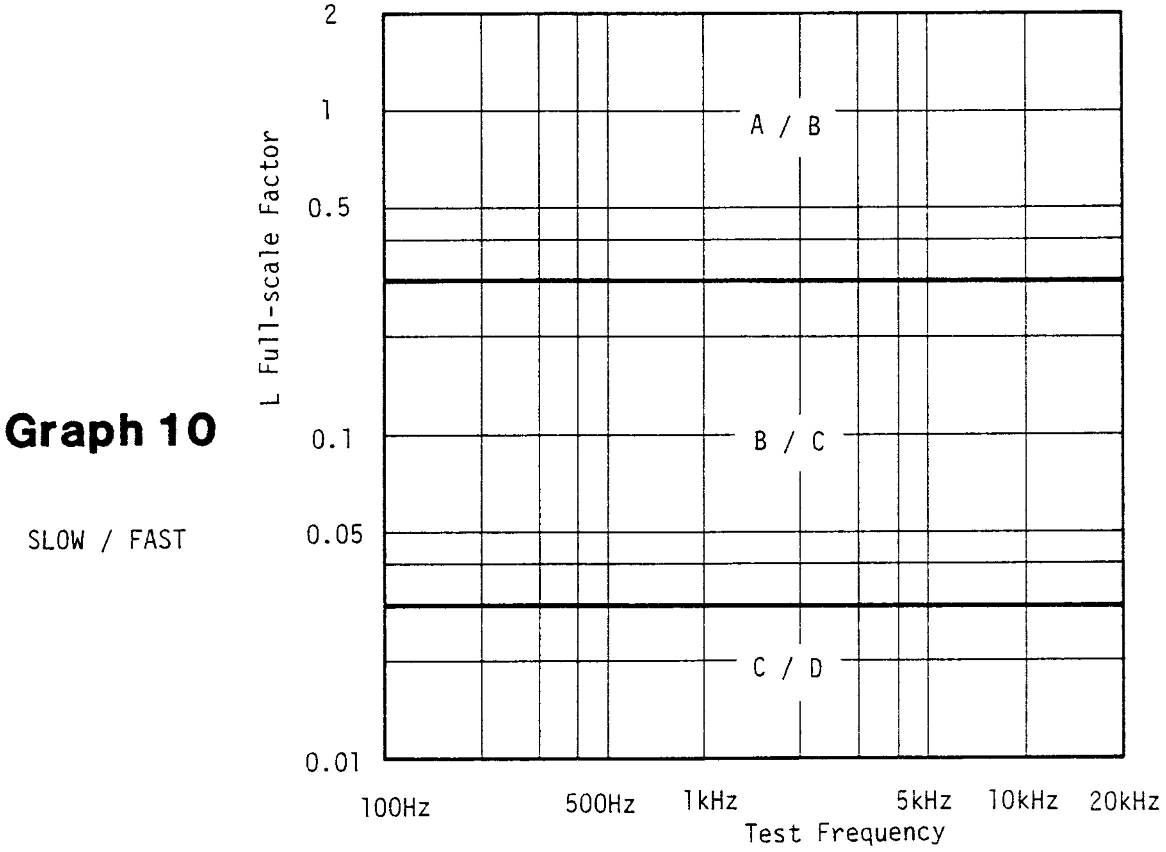
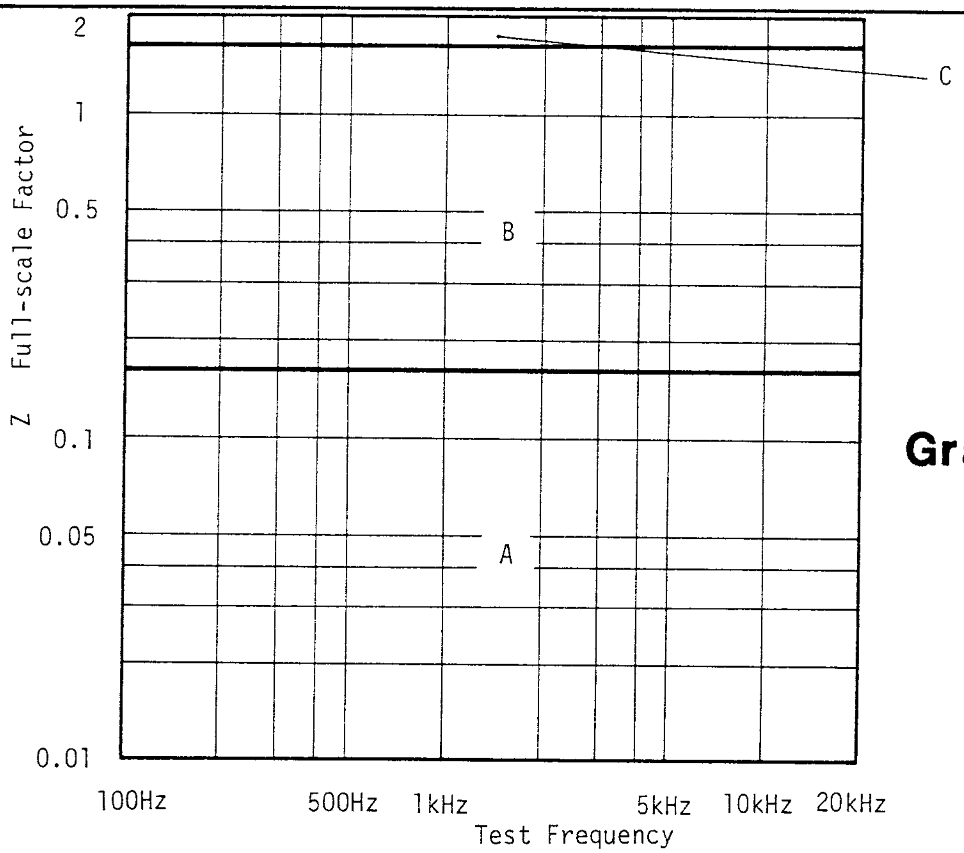
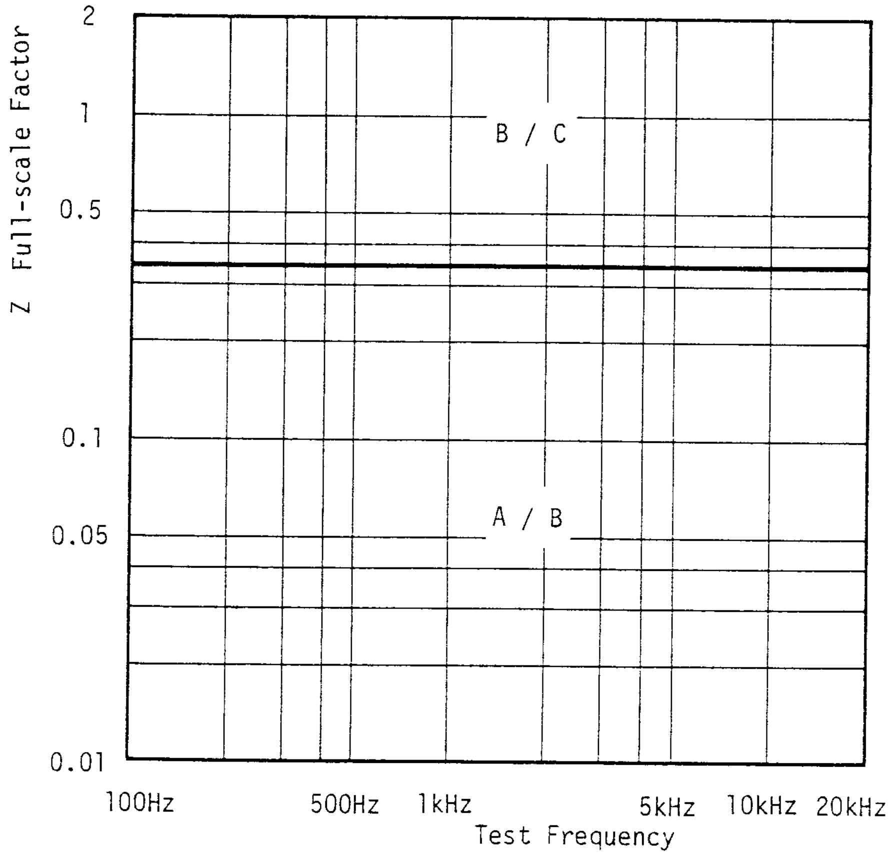


Figure 3-39. Number of Display Digits (Sheet 12 of 13).



Graph 11

MED



Graph 12

SLOW / FAST

Figure 3-39. Number of Display Digits (Sheet 13 of 13).

Table 4-1. Recommended Performance Test Equipment

Equipment	Critical Specifications	Recommended Model	Use
Capacitance Standards	10pF±0.4% 100pF±0.1% 1000pF±0.03% Usable frequencies: Up to 20kHz	HP 16382A HP 16383A HP 16384A	P, A
Resistance Standards	0.1Ω 1Ω 10Ω 100Ω±0.03% 1kΩ±0.06% 10kΩ±0.06% 100kΩ±0.06% Usable frequencies: Up to 20kHz	HP 16074A Standard Resistor Set	P, A, T
Terminations	0Ω SHORT OPEN Usable frequencies: Up to 20kHz	HP 16074A Standard Resistor Set	P, A
Frequency Counter	Frequency range: 100Hz to 100kHz f.s. Resolution: 1 x 10^{-5} of f.s. Accuracy: 0.001%	HP 5314A	P, A
Digital Multimeter	DCV: Voltage range: 10mV to 100V f.s. Resolution: 1 x 10^{-5} of f.s. Accuracy: 0.1% ACV: Voltage range: 100mV to 1Vrms f.s. Resolution: 1 x 10^{-2} of f.s. Accuracy: 3% in 100Hz to 20kHz	HP 3478A	P, A, T
RC Oscillator	Frequency: 1kHz Level: 1mV	HP 652A	T
Oscilloscope	Bandwidth: 100MHz Storage capability	HP 1741A	T
Signature Analyzer		HP 5004A	T
Test Cables	BNC-to-BNC cable (<1m) 2EA	HP 11170A	P, A, T
	BNC-to-dual banana plug cable (<1m)	HP 11035A	P, A
	Dual banana plug-to-alligator clip cable	HP 11002A	A
	BNC-to-dual alligator clip cable	(HP 11002A/w 10110B)	A
	Alligator clip-to-alligator clip cable (<20cm)		
BNC Adapter	BNC-T-Adapter	HP 1250-0781	T
Test Fixture	Four terminal pair configuration design	HP 16047A	P
HP-IB Controller		HP 85/ w0085-15003/ w82936A/ w82937A	P
Extender Board	Large extender board	HP 04276-66561	T
	small extender board (for INTERNAL DC BIAS Adjustment)	HP 04276-66562	A

P: Performance Test, A: Adjustment, T: Troubleshooting

SECTION IV

PERFORMANCE TESTS

4-1. INTRODUCTION

4-2. This section provides the tests and the procedures used to verify the 4276A specifications listed in Table 1-1. All tests can be performed without access to the interior of the instrument. A simpler operational test is presented in Section III under Self Test. The performance tests can be used when performing incoming inspection of the instrument and when verifying that the instrument meets performance specifications after troubleshooting or adjustment or both. If the performance tests indicate that the instrument is operating outside specified limits, check to see if the controls on the instrument used in the test and the test setup itself are correct and then proceed with adjustments or troubleshooting or both.

Note

> To ensure proper test results and instrument operation, Hewlett-Packard recommends a 30-minute warm-up and stabilization period before performing any of the performance tests.

Note

> All performance tests except for the HP-IB Interface Test should be performed in an ambient temperature range of 23 °C±5 °C.

4-3. EQUIPMENT REQUIRED

4-4. Equipment required to perform all of the performance tests is listed in Table 4-1. Any equipment that satisfies or exceeds the critical specifications listed in the table may be used as a substitute for the recommended models.

Accuracy checks described in this section use the HP 16380A series standard capacitors (16382A, 16383A and 16384A) and 16074A Standard Resistor Set. The characteristics of the equipment satisfy the performance requirements for the accuracy checks and are especially suited for use as the 4276A's accuracy test standards.

Note

> Components used as standards should be calibrated by an instrument whose specifications are traceable to NBS or an equivalent standards group; or calibrated directly by an authorized calibration organization such as NBS. The calibration cycle should be in accordance with the stability specifications for each component.

4-5. TEST RECORD

4-6. Performance test results can be recorded on the Test Record at the completion of the test. The Test Record is at the end of this section and it lists all the tested specifications and their acceptable limits. Test results recorded at incoming inspection can be used for comparison in periodic maintenance, troubleshooting, and after repair or adjustment.

4-7. CALIBRATION CYCLE

4-8. This instrument requires periodic verification of performance. Depending on the conditions under which the instrument is used, e.g., environmental conditions or frequency of use, the instrument should be checked with the performance tests described here at least once a year. To keep instrument down-time to a minimum and to insure optimum operation, preventive maintenance should be performed at least twice a year.

ACCURACY TEST CONSIDERATIONS

This paragraph discusses how the 4276A accuracy is tested and verified. As the 4276A has wider measurement capabilities in regard to the selectable measurement parameters, frequency, measurement range and accuracy, the performance tests include some critical measuring regions where accuracy is difficult to verify directly by measuring available standards.

Measurement accuracy is tested by measuring standard capacitors, resistors and other reference devices. The standards must have been calibrated and certified by transfer of values of national standards. However, a portion of the measurement range of the 4276A is out of the applicable ranges of the available standards. The method then, is to check accuracies by comparison with references on the specific ranges at which the standards are applicable, and to apply alternative tests for verification of accuracies on the other ranges.

Theoretical Background of Accuracy Checks

The 4276A, in accordance with its measurement principles, determines the vector impedance (or its reciprocal value: admittance) of the unknown device under test. The various measurement data provided, with respect to the 8 selectable measurement parameters (L, C, D, etc.), are arithmetically derived from measured values of the orthogonal vector components (resistance and reactance). For example, the capacitance value of a DUT is calculated by the following equation relative to the capacitance-to-reactance values:

$$Cx = \frac{1}{2\pi f Xm}$$

where, Cx is capacitance value of DUT,
f is test frequency,
Xm is measured reactance value of DUT.

As stated above, each measurement parameter is interrelated with the impedance (or admittance) value; consequently, the accuracies on all ranges can be verified if the instrument satisfies specified accuracies for each one of its resistive and reactive measurement parameters; that is, resistance and capacitance from the lowest through the highest test frequencies.

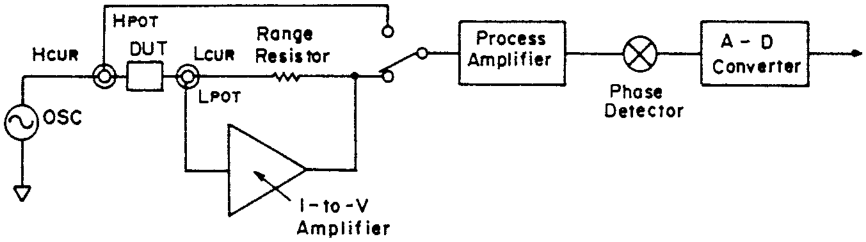
The technician should note that accuracy here is based on arithmetic relationships as are the parameter relationships. Therefore, the accuracy tests can be done by simplified procedures instead of time-consuming tests on the approximately 250000 possible combinations of the fundamental test parameters such as measurement parameter, frequency and range.

Verification Check Considerations

The measurement accuracy test can be made by using calibrated standards on specific ranges only. On other ranges, which would be uncertifiable because of the limitations of the standards, the test takes the method proven to be theoretically and experimentally practicable for verification of accuracy. If the results of these checks meet all the individual test limits, the instrument should satisfy its specified accuracy across its entire range. How then can these methods be explained? Let us look at the performance test articles.

Accuracy test procedures include checks for the following circuit sections:

1) Range Resistors
2) Process Amplifier
3) I-to-V Amplifier
4) Phase Detector
5) A-D (Analog to Digital) Converter



4276A Measurement Section

CAPACITANCE ACCURACY TEST verifies Range Resistor accuracy for reactive impedance measurements from the lowest through the highest test frequencies. I-to-V Amplifier linearity and normal operation of the Phase Detector and A-D Converter are also verified.

IMPEDANCE ACCURACY TEST is similar to the Capacitance Accuracy test, but for resistive impedance measurements. Thus, accuracy for both reactive and resistive components of the vector impedance is verified. In this test, phase-flatness characteristics (minimum phase shift) of the overall measurement section, and Phase Detector accuracy from the lowest through highest test frequencies are verified.

SELF-OPERATING TEST verifies the accuracy of the Process Amplifier which extends the measurement ranges. The A-D Converter accuracy is also checked by this combined self-test function which enables automatic check of each one of these circuits.

Note

A set of detection phases, each different by 90 degrees, is used in the Phase Detector. If the relative phase difference between the detection phases is exactly 90 degrees, the Phase Detector is operated at the maximum detection accuracy.

The accuracy of the right-angle detection phases is verified by both this test and dissipation factor checks associated with the Capacitance Accuracy Test.

ACCURACY TEST STANDARDS

1) Standard Capacitors

The HP 16380A Series Standard Capacitors, featuring the four terminal pair configuration, are recommended for use as performance test standards. The four standard capacitors, 16381A (1pF), 16382A (10pF), 16383A (100pF) and 16384A (1000pF) are calibrated at 0.01% accuracy at 1kHz (and have capacitances within 0.1% of their nominal values).

2) Standard Resistors

The standard resistors used for accuracy checks should be nearly pure resistances and should maintain an extremely low residual reactance at frequencies to 1MHz. The HP 16074A Standard Resistor Set, especially designed as standards useable over a broad frequency region, with thin film resistors and four terminal pair configurations, is suitable for the accuracy checks. Because of low residual inductance and less skin effect of the thin film resistors, the 16074A provides the standard resistance values of 0Ω, 0.1Ω, 1Ω and 10Ω at ±10% and 100Ω, 1kΩ, 10kΩ and 100kΩ at ±0.01% calibration accuracies to 10MHz (1MHz at 100kΩ). Open (OS) and Short terminations, which facilitate optimum zero offset adjustment, and two quasi-inductors are included in the 16074A.

Note

The 0Ω, 0.1Ω, 1Ω and 10Ω resistors are used as the (pure resistance) reference device in the Impedance Accuracy Test. Two quasi-inductors are not used in the 4276A performance tests.

3) The principle of Inductance Accuracy Test

The 4276A inductance accuracy is theoretically certified if the capacitance accuracy meets the specifications. Generally, inductors have unwanted parasitic impedances such as coil resistance and distributed capacitance. As these residuals significantly affect the inductance values at high frequencies, inductance standards useable in the RF region above 100kHz are substantially unavailable. Inductors with higher inductance values have lower frequency limits.

If it is desired to check inductance measurement accuracy, use standard capacitors as a substitution test device. The capacitors act as negative inductors when measured in inductance measurement function of the 4276A. The equivalent inductance value of capacitor is calculated by the following equation:

$$Z = \frac{1}{j\omega C} = j\omega L$$

$$L = \frac{1}{-\omega^2 C}$$

C: Calibrated value of standard capacitor
ω: 2π·[test frequency]

GENERAL

The standards should be of four terminal pair configuration design to provide compatibility with the instrument. This minimizes reduction in reliability of the values due to the effects of the residuals associated with cabling and connections.

PERFORMANCE TESTS

4-9. *TEST FREQUENCY ACCURACY TEST*

4-10. This test verifies that the test signal frequencies for the 4276A meet the specified frequency accuracy of 0.01%.

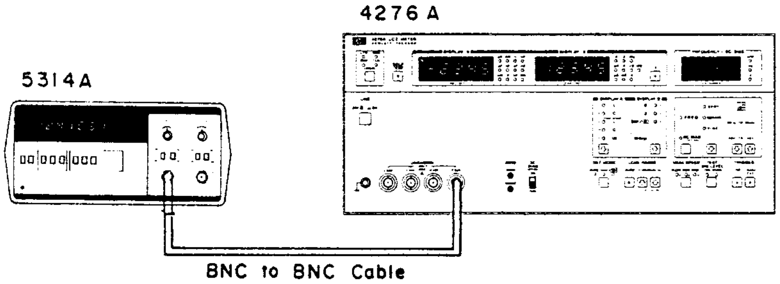


Figure 4-1. Test Frequency Accuracy Test Setup.

EQUIPMENT:

Frequency Counter	HP 5314A
BNC-to-BNC cable	HP 11170A

PROCEDURE:

1. Connect the BNC-to-BNC cable to the 4276A UNKNOWN H_{CUR} terminal and to the 5314A's input as shown in Figure 4-1.

2. Set the 4276A's controls as follows:

Test Frequency	1.00kHz
DC BIAS	OFF
TEST SIG LEVEL	HIGH
TRIGGER	MAN/EXT
Other controls	Any setting

3. Verify that the frequency reading on the 5314A is 1.000kHz±0.1Hz.

4. Set test frequency in accordance with Table 4-2 and confirm that the frequency readings on the 5314A are within the test limits given in the table.

Note

1) Test limit values in the table do not account for the tolerance dependent on the specified accuracy of the 5314A.

2) If this test fails, the instrument requires troubleshooting.

Table 4-2. Test Frequency Accuracy Test

Frequency Setting	Test Limits
100Hz	99.99 - 100.01Hz
200Hz	199.98 - 200.02Hz
500Hz	499.95 - 500.05Hz
1.00kHz	999.9 - 1000.1Hz
2.00kHz	1.9998 - 2.0002kHz
5.00kHz	4.9995 - 5.0005kHz
10.0kHz	9.999 - 10.001kHz
20.0kHz	19.998 - 20.002kHz

4-11. *TEST SIGNAL LEVEL ACCURACY TEST*

4-12. This test verifies that the test signal level for the 4276A meets the specified test signal level accuracy.

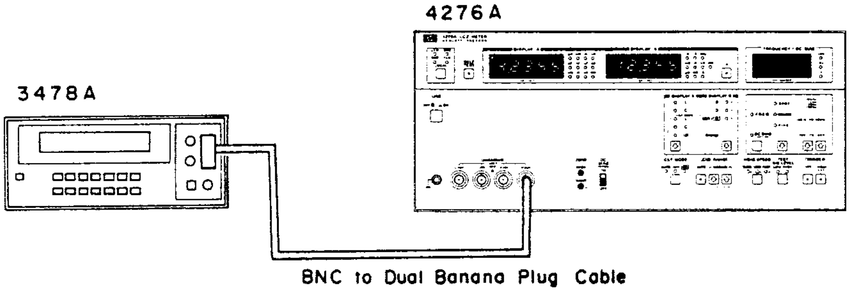


Figure 4-2. Test Signal Level Accuracy Test Setup.

EQUIPMENT:

Digital Multimeter .... HP 3478A
BNC-to-dual banana plug cable .... HP 11035A

Note

Use a digital multimeter calibrated for a frequency response of 100Hz to 20kHz.

PROCEDURE:

1. Connect the BNC-to-dual banana plug cable to the UNKNOWN H_{CUR} terminal of the 4276A and to the 3478A's input as shown in Figure 4-2.

2. Set the 4276A's controls as follows:

   DISPLAY A/B functions .... C-D
   Test Frequency 1.00kHz
   DC BIAS .... OFF
   LC | Z | RANGE 1nF
   TEST SIG LEVEL .... HIGH
   TRIGGER .... MAN/EXT
   Other controls .... Any setting

3. Set the function of the 3478A to ACV.

4. Verify that the voltage reading on the 3478A is 1.0Vrms±0.1Vrms.

5. Change test frequency and test signal level settings in accordance with Table 4-3. Verify that the voltage readings on the 3478A are within the test limits given in the table.

Table 4-3. Test Signal Level Accuracy Test

Control Settings		
Test Level	Test Frequency	Test Limits
HIGH	100Hz	.7 - 1.3Vrms
	200Hz	.7 - 1.3Vrms
	500Hz	.7 - 1.3Vrms
	1.00kHz	.9 - 1.1Vrms
	2.00kHz	.7 - 1.3Vrms
	5.00kHz	.7 - 1.3Vrms
	10.0kHz	.7 - 1.3Vrms
	20.0kHz	.7 - 1.3Vrms
LOW	100Hz	35 - 65mVrms
	1.00kHz	40 - 60mVrms
	10.0kHz	35 - 65mVrms

4-13. *SELF-OPERATING TEST*

4-14. The Self-operating Test checks operating conditions of the circuits which are critical to sustaining specified accuracies. To verify that these circuits satisfy the performance requirements for ensuring the specified accuracies, the values displayed in the SELF TEST are compared with test limits. Because basic circuit operating conditions related to the accuracy are verified in this test, the instrument should be initially checked with this test.

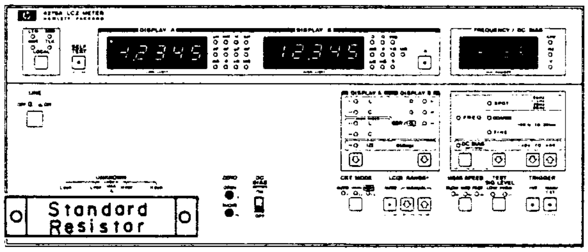


Figure 4-3. Self Operating Test Setup.

EQUIPMENT:

Standard Resistors	1Ω 100Ω 1kΩ 10kΩ 100kΩ	HP 16074A Standard Resistor Set
Termination	OPEN	

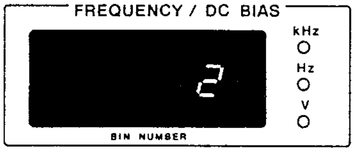
PROCEDURE:

1. Connect the 100kΩ Standard Resistor directly to UNKNOWN terminals of the 4276A as shown in Figure 4-3.

2. Set the 4276A's controls as follows:

   DISPLAY A/B functions .... | Z | - θ
   Test Frequency 1.00kHz
   DC BIAS .... OFF
   CKT MODE .... Any setting
   LC | Z | RANGE 1MΩ
   MEAS SPEED .... MED
   TEST SIG LEVEL .... HIGH
   TRIGGER .... INT

3. Press the SELF TEST key and then press the FREQUENCY/DC BIAS Select key. Press the FREQUENCY/DC BIAS Step Control ⇧ key until Self test item number "2" is displayed on the FREQUENCY/DC BIAS display as shown below.



4. Verify that the value displayed on DISPLAY A is 10.00µS±0.01µS.

5. Change Standard Resistor to 10kΩ, 1kΩ and 100Ω in that order and change LC | Z | RANGE ⇩ key each time. Verify that the display outputs are within the test limits given in the table below.

Standard Resistor	Range	Limits
100kΩ	10µS	1/C.V. ± 0.01µS
10kΩ	100µS	1/C.V. ± 0.1µS
1kΩ	1mS	1/C.V. ± 0.001mS
100Ω	10mS	1/C.V. ± 0.01mS

1/C.V. = Reciprocal of Calibrated Value

6. Press SELF TEST to resume measurement mode and set the 4276A's controls as follows:

   DISPLAY A/B functions .... C-G
   Test Frequency 1.00kHz
   DC BIAS .... OFF
   CKT MODE .... Any setting
   LC | Z | RANGE 1mF
   MEAS SPEED .... MED
   TEST SIG LEVEL .... HIGH
   TRIGGER .... INT

7. Connect the 1Ω Standard Resistor directly to the UNKNOWN terminals as shown in Figure 4-3.

8. Repeat step 3.

9. Verify that the values displayed on DISPLAY A and DISPLAY B are within the following test limits.

   DISPLAY A: C.V.±.02Ω
   DISPLAY B: 0±.012Ω

10. Set the MEAS SPEED to SLOW and connect the OPEN termination to the UNKNOWN terminals in place of the 1Ω standard.

11. Select SELF TEST "8" by pressing the FREQUENCY/DC BIAS Step Control key until "8" appears on the FREQUENCY/DC BIAS display.

12. Confirm that the values displayed on DISPLAY A and DISPLAY B are within the following test limits:

   DISPLAY A: .0020±.0003
   DISPLAY B: -.0020±.0003

13. Perform the test for the self test steps and the test frequencies shown in the table below in the same way. Confirm that the values displayed on DISPLAY A and DISPLAY B are within the test limits given in the table.

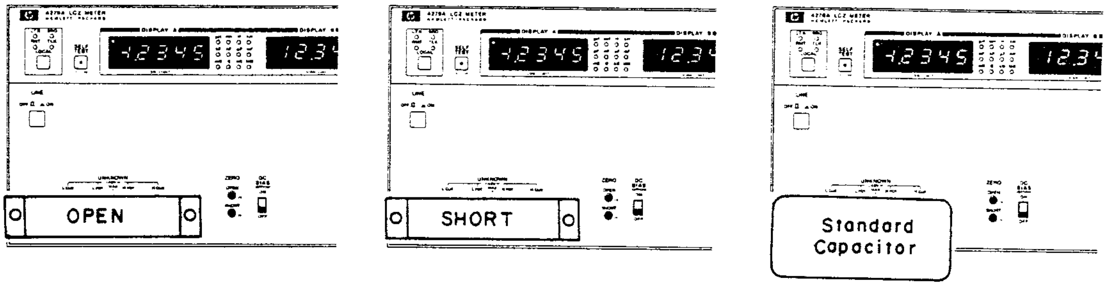
Note

To change the test frequency setting while the 4276A is in SELF TEST mode, press the FREQUENCY/DC BIAS Select key (FREQ lamp should light), set the frequency with the FREQUENCY/DC BIAS Control keys (⇩ and ⇧), and then press the FREQUENCY/DC BIAS Select key again (DC BIAS lamp should light).

SELF TEST NUMBER	1.00kHz		20.0kHz	
	DISP A	DISP B	DISP A	DISP B
8	.0020±.0003	-.0020±.0003		
9	0±.0020	0±.0013	0±.0080	0±.0052
12	0±.0012	0±.0020	0±.0048	0±.0043
13	0±.0012	0±.0020	0±.0048	0±.0043
14	0±.0024	0±.0020	0±.0096	0±.0036
15	0±.0048	0±.0020	0±.0192	0±.0360

4-15. *CAPACITANCE ACCURACY TEST*

4-16. This test checks capacitance measurement accuracies for various combinations of test frequency and test signal level. The checks are made by connecting a standard capacitor to the instrument and comparing measurement results with the calibrated values of the standard. Accuracies for dissipation factors near zero are also checked in this test.



(a) (b) (c)

Figure 4-4. Capacitance Accuracy Test Setups.

EQUIPMENT:

Standard Capacitors	10pF: HP 16382A 100pF: HP 16383A 1000pF: HP 16384A
Terminations	SHORT OPEN } HP 16074A Standard Resistor Set

PROCEDURE:

1. Set the 4276A's controls as follows:

DISPLAY A/B functions	C-D
DC BIAS	OFF
CKT MODE	AUTO
LC | Z | RANGE	AUTO
TRIGGER	INT
Other controls	Any setting

2. Perform OPEN and SHORT Zero Offset Adjustments as described in paragraph 3-48.

Note

Use the OPEN and SHORT terminations of the 16074A for Zero offset Adjustment.

3. Connect the 10pF Standard Capacitor directly to the UNKNOWN terminals as shown in Figure 4-4 (c).

4. Set the test frequency in accordance with Table 4-4. Verify that the capacitance and dissipation factor readings on the 4276A are within the test limits given in the table.

5. Change the standard capacitor to 100pF and 1000pF in that order and perform the test. Verify that the values displayed on the 4276A are within the test limits given in the table.

Table 4-4. Capacitance Accuracy Tests

Standard Capacitance	Function	Speed	Level	Frequency	Test Limits	
10pF	C-D	MED	HIGH	9.95kHz	C.V.±.16pF	0±.010
				10.0kHz	C.V.±.16pF	0±.010
				20.0kHz	C.V.±.24pF	0±.012
100pF	C-D	MED	HIGH	995Hz	C.V.±.6pF	0±.004
				1.00kHz	C.V.±.35pF	0±.0035
				1.99kHz	C.V.±.65pF	0±.0065
				4.98kHz	C.V.±.25pF	0±.0017
				9.95kHz	C.V.±.70pF	0±.0046
				10.0kHz	C.V.±.70pF	0±.0046
				20.0kHz	C.V:±2.20pF	0±.0140
1000pF	C-D	MED	HIGH	100Hz	C.V.±5.0pF	0±.0050
				120Hz	C.V.±5.0pF	0±.0050
				199Hz	C.V.±6.5pF	0±.0065
				498Hz	C.V.±2.5pF	0±.0017
				995Hz	C.V.±2.5pF	0±.0017
				1.00kHz	C.V.±1.5pF	0±.0011
				1.99kHz	C.V.±2.5pF	0±.0017
				4.98kHz	C.V.±2.5pF	0±.0017
				9.95kHz	C.V.±7.0pF	0±.0046
				10.0kHz	C.V.±7.0pF	0±.0046
				20.0kHz	C.V.±11.0pF	0±.0070
		SLOW	HIGH	100Hz	C.V.±5.0pF	0±.0050
				1.00kHz	C.V.±1.50F	0±.0011
				10.0kHz	C.V.±7.0pF	0±.0046
		FAST	HIGH	100Hz	C.V.±10pF	0±.010
				1.00kHz	C.V.±6pF	0±.006
				10.0kHz	C.V.±16pF	0±.014
		MED	LOW	1.00kHz	C.V.±12pF	0±.011
		FAST		1.00kHz	C.V.±100pF	0±.100
		MED		10.0kHz	C.V.±32pF	0±.027
	HIGH SPEED	MED	HIGH	1.00kHz	C.V.±1.5pF	
			LOW	1.00kHz	C.V.±12pF	
			HIGH	10.0kHz	C.V.±7.0pF	

C.V. = Calibrated Value of Standard Capacitor

4-17. *IMPEDANCE ACCURACY TEST*

4-18. This test checks impedance measurement accuracies at four spot test frequencies. The checks are made by connecting a standard resistor to the instrument and comparing the measurement readouts with the calibrated values of the standard.

Range / Freq.	0.1Ω	1Ω	10Ω	100Ω	1kΩ	10kΩ	100kΩ
100Hz	△	△	△	○	○	○	○
120Hz	△	△	△	○	○	○	○
1.00kHz	△	△	△	○	○	○	○
10.0kHz	△	△	△	○	○	○	○

○ : tested for both | Z | and θ.
△ : tested for θ only.

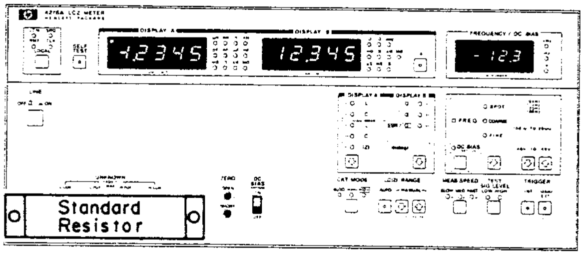


Figure 4-5. Impedance Accuracy Test Setup.

EQUIPMENT:

Standard Resistors	0.1Ω 1Ω 10Ω 100Ω 1kΩ 10kΩ 100kΩ	HP 16074A Standard Resistor Set
Terminations	0Ω OPEN	

PROCEDURE:

1. Set the 4276A's controls as follows:

DISPLAY A/B functions	| Z | - θ
Test Frequency	Any setting
DC BIAS	OFF
CKT MODE	AUTO
LC | Z | RANGE	AUTO
MEAS SPEED	MED
TEST SIG LEVEL	HIGH
TRIGGER	INT

2. Perform OPEN and SHORT Zero Offset Adjustment as described in paragraph 3-48.

Note

Use the OPEN and 0Ω terminations of the 16074A for Zero Offset Adjustment. DO NOT use the SHORT termination.

3. Connect the 0.1Ω standard resistor directly to UNKNOWN terminals as shown in Figure 4-5 and set test frequency to 100Hz, 120Hz, 1kHz and 10kHz. Verify that the impedance and phase angle readings on the 4276A are within the test limits given in Table 4-5.

4. Repeat step 3 with the each of the standard resistors listed in Table 4-5. Verify that the values displayed on the 4276A meet the test limits given in the table.

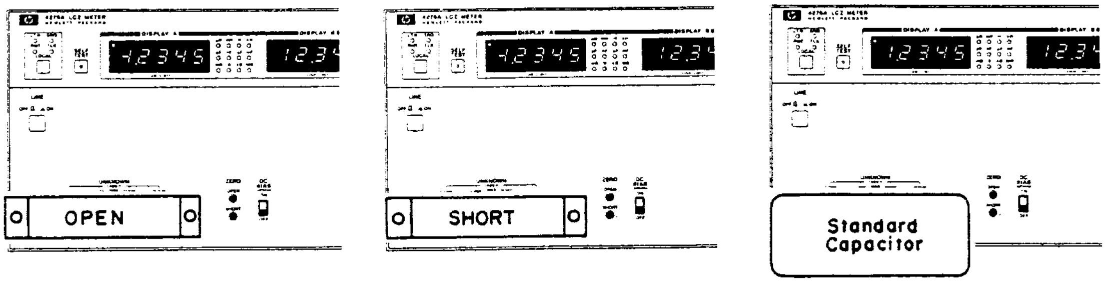
Table 4-5. Impedance Accuracy Tests

|Z| Range Freq.		Test Limits						
		0.1Ω	1Ω	10Ω	100Ω	1kΩ	10kΩ	100kΩ
100Hz	Z				C.V.±.15Ω	C.V.±6Ω	C.V.±.06kΩ	C.V.±.6kΩ
	θ	0±1.2°	0±.7°	0±.35°	0±.15°	0±.6°	0±.6°	0±.6°
120Hz	Z				C.V.±.15Ω	C.V.±6Ω	C.V.±.06kΩ	C.V.±.6kΩ
	θ	0±1.2°	0±.7°	0±.35°	0±.15°	0±.6°	0±.6°	0±.6°
1.00kHz	Z				C.V.±.15Ω	C.V.±6Ω	C.V.±.06kΩ	C.V.±.6kΩ
	θ	0±1.2°	0±.7°	0±.35°	0±.15°	0±.6°	0±.6°	0±0.6°
10.0kHz	Z				C.V.±.25Ω	C.V.±10Ω	C.V.±.1kΩ	C.V.±1kΩ
	θ	0±2.2°	0±1.2°	0±.65°	0±.25°	0±1.0°	0±1.0°	0±1.0°

C.V. = Calibrated Value of Standard Resistors

4-19. *INDUCTANCE ACCURACY TEST*

4-20. Inductance accuracy is verified if the instrument meets both capacitance and impedance accuracy test limits. If it is desired to confirm the inductance accuracy on at least at one range, perform the following test:



(a) (b) (c)

Figure 4-6. Inductance Accuracy Test Setup.

EQUIPMENT:

Terminations	SHORT OPEN	HP 16074A Standard Resistor Set
Standard Capacitor	1000pF:	HP 16384A

PROCEDURE:

1. Set the 4276A's controls as follows:

DISPLAY A/B functions	L-D
Test Frequency	1.00kHz
DC BIAS	OFF
CKT MODE	AUTO
LC |Z| RANGE	AUTO
MEAS SPEED	MED
TEST SIG LEVEL	HIGH
TRIGGER	INT

2. Perform OPEN and SHORT Zero Offset Adjustment as described in paragraph 3-48.

Note

Use the OPEN and SHORT terminations of the 16074A for Zero Offset Adjustment.

3. Connect the 1000pF standard capacitor directly to the UNKNOWN terminals. See Figure 4-6 (c).

4. Verify that the inductance and dissipation factor readings on the 4276A are within the following test limits:

DISPLAY A: -25.33±0.18
DISPLAY B: 0±0.012

4-21. *INTERNAL DC BIAS ACCURACY TEST (OPTION 001)*

4-22. This test verifies that the Option 001 Internal DC BIAS Supply applies the specified bias voltages to the device under test.

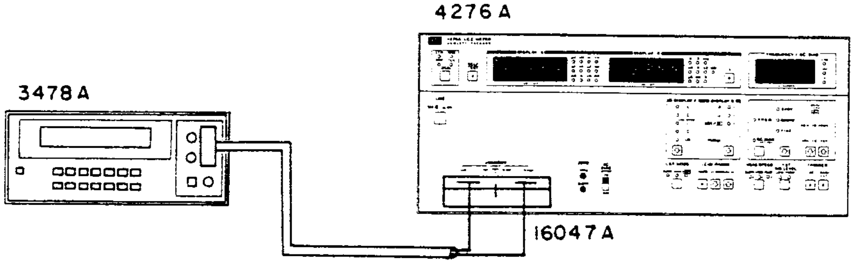


Figure 4-7. Option 001 Internal DC Bias Accuracy Test Setup.

EQUIPMENT:

Digital Multimeter	HP 3478A
Test Fixture	HP 16047A

PROCEDURE:

1. Set the 4276A's controls as follows:

DISPLAY A/B functions	C-D
Test Frequency	20.0kHz
LC | Z | RANGE	100nF
TFST SIG LEVEL	LOW
TRIGGER	MAN/EXT
DC BIAS (Front Panel)	ON
DC BIAS (Rear Panel)	INT
Other controls	Any setting

2. Interconnect the 4276A, 16047A, and 3478A as shown in Figure 4-7.

3. Set dc bias voltage to +40V with the FREQUENCY/DC BIAS Select key and the FREQUENCY/DC BIAS Step Control ⇧ key. Wait approximately 10 seconds after setting the voltage.

4. Set DC bias voltage in accordance with Table 4-6. After the wait time specified in the table, read the voltage displayed on the 3478A. Verify that the voltage readings are within the test limits given in the table.

Table 4-6. Internal DC Bias Accuracy Test

DC BIAS Setting	Wait Time	Test Limits
+40.0V	10 seconds	Precharge
.00	30	0±.01V
+.01	20	.01±.01V
+9.99	10	9.99±.04V
+10.0	10	10.0±.085V
+40.0	15	40.0±.24V
-.01	30	-.01±.01V
-9.99	10	-9.99±.11V
-10.0	10	-10.0±.135V
-40.0	15	-40.0±.44V

4-23. *16064A COMPARATOR/HANDLER INTERFACE TEST (OPTION 002)*

4-24. The test in this paragraph, verifies the functions of the 16064A Comparator/Handler Interface.

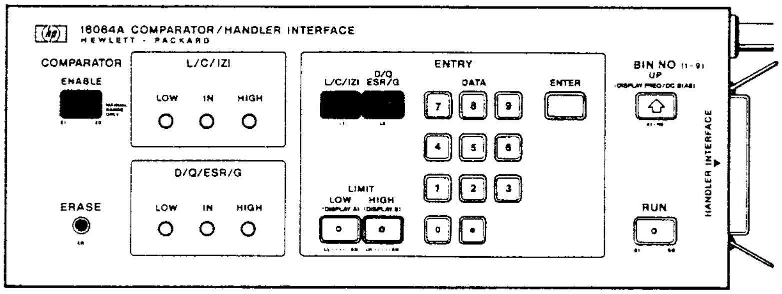


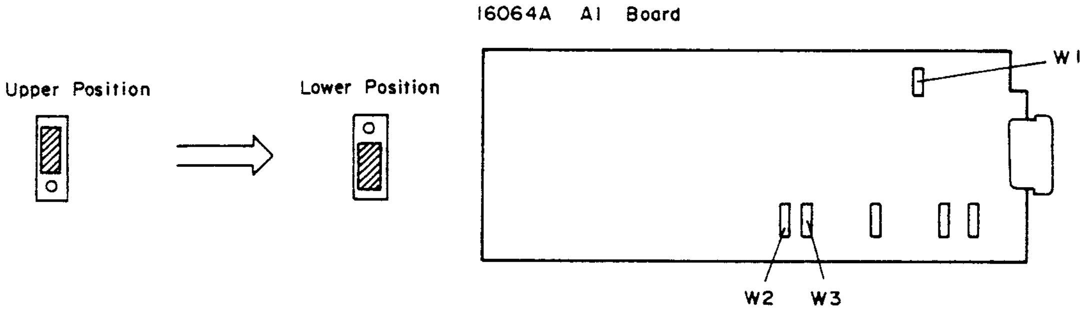
Figure 4-8. 16064A Comparator/Handler Interface.

EQUIPMENT:

Digital Multimeter	HP 3478A
100kΩ Standard resistor	HP 16074A
1000pF Standard capacitor	HP 16384A

PROCEDURE:

1. Set jumpers A1 W1/W2/W3 in the 16064A to the lower position as shown below:



2. Connect the 16064A to the COMPARATOR/HANDLER INTERFACE connector on the rear panel of the 4276A.

3. Turn on the 4276A. "16064" should be displayed on DISPLAY B.

4. Set the 4276A's controls as follows:

DISPLAY A/B functions	C-G
Test Frequency	1.00kHz
DC BIAS	OFF
CKT MODE	
LC | Z | RANGE	1nF
MEAS SPEED	MED
TEST SIG LEVEL	HIGH
TRIGGER	INT

5. Set the 3478A's controls as follows:

Function	DCV
RANGE	300V
Display	3 1/2 digits

6. Connect the 3478A's LO input to the 4276A's GUARD terminal.

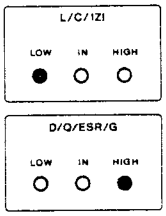
7. Press the ERASE key on the 16064A and set the following comparator limits:

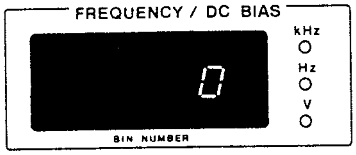
L/C/|Z| LOW LIMIT (BIN1):	.3
L/C/|Z| HIGH LIMIT (BIN1):	.9
D/Q/ESR/G LOW LIMIT:	2
D/Q/ESR/G HIGH LIMIT:	8

8. Connect the 100kΩ standard resistor directly to the 4276A's UNKNOWN terminals.

9. Press the RUN key on the 16064A's control panel.

10. Verify that the L/C/|Z| LOW and D/Q/ESR/G HIGH lamps light, and that "0" is displayed on the 4276A's FREQUENCY/DC BIAS DISPLAY.

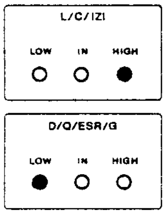


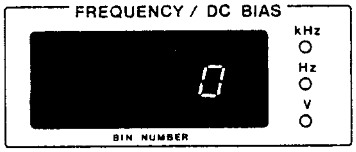


11. Check the states of the comparison data output (TTL) at the HANDLER INTERFACE connector using the 3478A. The pin assignments and the data states are shown in Figure 4-9 and Table 4-7.

12. Disconnect the 100kΩ resistor and connect the 1000pF standard capacitor.

13. Verify that the L/C/|Z| HIGH and D/Q/ESR/G LOW lamps light, and that "0" is displayed on the 4276A's FREQUENCY/DC BIAS DISPLAY.





14. Check the comparison data output at the HANDLER INTERFACE connector by comparing it with the Data States shown in Table 4-7.

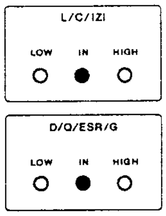
PERFORMANCE TESTS

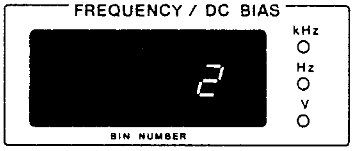
15. Press the ERASE key and set the following comparator limits:

L/C/|Z| HIGH LIMIT: BIN1: .9
BIN2: 1.1
BIN3: 1.9999
D/Q/ESR/G HIGH LIMIT: .01

16. Press the RUN key on the 16064A's control panel.

17. Verify that the L/C/|Z| IN and D/Q/ESR/G IN lamps light, and that "2" is displayed on the 4276A's FREQUENCY/DC BIAS DISPLAY.





18. Check the comparison data output at the HANDLER INTERFACE connector by comparing it with the Data States shown in Table 4-7.

Table 4-7. Handler Interface Output Data States

TEST STEP	Connector Pin Numbers															
	1	2	3	4	5	6	7	8	9	10	19	20	21	22	23	24
11	H	H	H	H	H	H	H	H	H	L	H	H	L	L	H	H
14	H	H	H	H	H	H	H	H	H	L	L	H	H	H	H	L
18	H	L	H	H	H	H	H	H	H	H	H	L	H	H	L	H

H: Approximately 5V
L: Approximately 0V

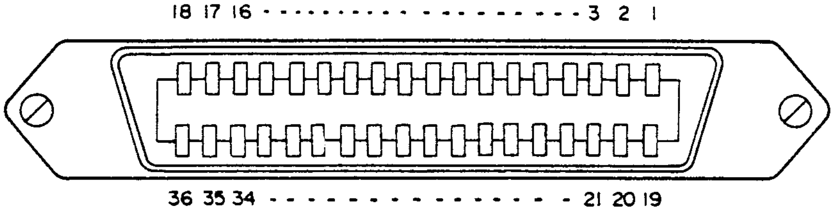


Figure 4-9. Handler Interface Connector Pin Assignments.

4-25. *HP-IB INTERFACE TEST*

4-26. This test verifies the instrument's HP-IB capabilities.

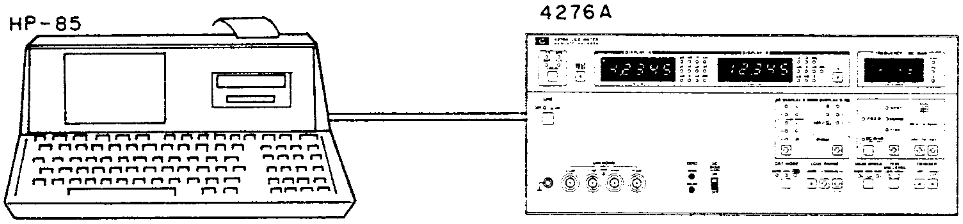


Figure 4-10. HP-IB Interface Test Setup.

EQUIPMENT:

Personal Computer	HP-85
I/O ROM	HP 00085-15003
ROM Drawer	HP 82936A
HP-IB Interface	HP 82937A
100pF Standard	HP 16383A

PROCEDURE:

1. Turn off the 4276A and the HP-85.

2. Connect the 82937A HP-IB Interface between the HP-85 and the 4276A as shown in Figure 4-8, and install the I/O ROM into the HP-85.

3. Set the 4276A's HP-IB Control switch, located on the rear panel, as follows:

   bits 5-1 : 10001 (17_{10})
   bit 6 : 0
   bit 7 : 0

4. Turn on the 4276A and the HP-85.

5. Load one of the three test programs into the personal computer. Test programs are listed on pages 4-21, 4-23 and 4-25.

6. Execute the program and follow the prompts and instructions output by the HP-85. Details on the controller's (personal computer) instructions and the appropriate operator response are given in Tables 4-8 through 4-10.

TEST PROGRAM 1

PURPOSE:

This test verifies that the 4276A has the following HP-IB capabilities:

(1) Remote/Local Capability
(2) Local Lockout
(3) Talk Disable
(4) Listen Disable

PROGRAM LISTING:

```
10 ! 4276A HP-IB TEST No.1
20 ! REMOTE/LOCAL TEST
30 DIM A$[1]
40 N=0 @ M=7 @ M1=717
50 S=SPOLL(M1)
60 CLEAR
70 PRINT "*** 4276A HP-IB TEST No.1 ***"
80 DISP "REMOTE/LOCAL TEST"
90 REMOTE M
100 OUTPUT M1 ;"T1"
110 DISP "LISTEN=1,TALK=0,REMOTE=1"
120 GOSUB 580
130 ABORTIO M
140 DISP "LISTEN=0,TALK=0,REMOTE=1"
150 GOSUB 580
160 LOCAL M
170 DISP "LISTEN=0,TALK=0,REMOTE=0"
180 GOSUB 580
190 REMOTE M1
200 DISP "LISTEN=1,TALK=0,REMOTE=1"
210 GOSUB 580
220 LOCAL LOCKOUT M
230 DISP "PRESS LOCAL KEY"
240 DISP "LISTEN=1,TALK=0,REMOTE=1"
250 GOSUB 580
260 LOCAL M1
270 DISP "LISTEN=1,TALK=0,REMOTE=0"
280 GOSUB 580
290 REMOTE M1
300 OUTPUT M1 ;"T1"
310 DISP "LISTEN=1,TALK=0,REMOTE=1"
320 GOSUB 580
330 IF N=1 THEN 340 ELSE 370
340 PRINT "REMOTE/LOCAL TEST FAIL"
350 DISP "REMOTE/LOCAL TEST FAIL"
360 GOTO 390
370 PRINT "REMOTE/LOCAL TEST PASS"
380 DISP "REMOTE/LOCAL TEST PASS"
390 N=0
400 DISP "LISTEN/TALK  TEST"
410 ENTER M1 ; A
420 DISP "LISTEN=0,TALK=1,REMOTE=1"
430 GOSUB 580
440 OUTPUT M1 ;"T1"
450 DISP "LISTEN=1,TALK=0,REMOTE=1"
460 GOSUB 580
470 IF N=1 THEN 480 ELSE 510
480 PRINT "LISTEN/TALK TEST FAIL"
490 DISP "LISTEN/TALK TEST FAIL"
500 GOTO 530
510 PRINT "LISTEN/TALK TEST PASS"
520 DISP "LISTEN/TALK TEST PASS"
530 PRINT "END"
540 DISP "END"
550 CLEAR M
560 LOCAL M
570 END
580 INPUT A$
590 IF A$="N" THEN N=1
600 RETURN
```

Table 4-8. Controller Instructions and Operator Responses for Test Program 1

Controller Instructions		Operator Response
Displays	Printout	
	*** 4276A HP-IB TEST NO.1 ***	
REMOTE/LOCAL TEST		
LISTEN=1*, TALK=0, REMOTE=1 LISTEN=0, TALK=0, REMOTE=1 LISTEN=0, TALK=0, REMOTE=0 LISTEN=1, TALK=0, REMOTE=1		If the 4276A HP-IB Status Indicators and Controller Display are the same, press Y, and END LINE. If not, press N, and END LINE.
PRESS LOCAL KEY		Press Local Key.
LISTEN=1, TALK=0, REMOTE=1 LISTEN=1, TALK=0, REMOTE= LISTEN=1, TALK=0, REMOTE=1		If the 4276A HP-IB Status Indicators and Controller Display are the same, press Y, and END LINE. If not, press N, and END LINE.
REMOTE/LOCAL TEST PASS	REMOTE/LOCAL TEST PASS	If all steps are correct, this message is output.
REMOTE/LOCAL TEST FAIL	REMOTE/LOCAL TEST FAIL	If any step fails, this message is output.
LISTEN/TALK TEST		
LISTEN=0, TALK=1, REMOTE=1 LISTEN=1, TALK=0, REMOTE=1		If the 4276A HP-IB Status Indicators and Controller Display are the same, press Y, and END LINE. If not, press N, and END LINE.
LISTEN/TALK TEST PASS	LISTEN/TALK TEST PASS	If both steps are correct, this message is output.
LISTEN/TALK TEST FAIL	LISTEN/TALK TEST FAIL	If any step fails, this message is output.
END	END	

*1 indicates ON; 0 indicates OFF.

TEST PROGRAM 2

PURPOSE:

This test verifies that the 4276A has the following HP-IB capabilities:

(1) Talker
(2) Device Trigger

PROGRAM LISTING:

```
10 ! 4276A HP-IB TEST No.2
20 ! TALKER TEST
30 DIM A$[100],B$[1]
40 M=7 @ M1=717
50 S=SPOLL(M1)
60 PRINT "*** 4276A HP-IB TEST No.2 ***"
70 CLEAR
80 DISP "TALKER TEST"
90 DISP "CONNECT 100pF"
100 BEEP
110 PAUSE
120 DISP "DATA OUTPUT TEST"
130 REMOTE M
140 ABORTIO M
150 CLEAR M1
160 OUTPUT M1 ;"A2B1F1T2"
170 DISP "TEST FREQUENCY IN kHz ";
180 INPUT F
190 OUTPUT M1 ;"FR",F,"EN"
200 TRIGGER M1
210 ENTER M1 ; A,B
220 DISP A*1.E12;"pF",B
230 DISP "IS OUTPUT DATA CORRECT (Y or N) ";
240 INPUT B$
250 IF B$="N" THEN 260 ELSE 290
260 PRINT "DATA OUTPUT TEST FAIL"
270 DISP "DATA OUTPUT TEST FAIL"
280 GOTO 310
290 PRINT "DATA OUTPUT TEST PASS"
300 DISP "DATA OUTPUT TEST PASS"
310 DISP "COMPLETE DATA OUTPUT TEST"
320 TRIGGER M1
330 ENTER M1 ; A$
340 DISP A$
350 DISP "IS OUTPUT DATA CORRECT (Y or N) ";
360 INPUT B$
370 IF B$="N" THEN 380 ELSE 410
380 PRINT "COMPLETE DATA OUTPUT TEST FAIL"
390 DISP "COMPLETE DATA OUTPUT TEST FAIL"
400 GOTO 430
410 PRINT "COMLPETE DATA OUTPUT TEST PASS"
420 DISP "COMPLETE DATA OUTPUT TEST PASS"
430 PRINT "END"
440 DISP "END"
450 CLEAR M
460 LOCAL M
470 END
```

Table 4-9. Controller Instructions and Operator Responses for Test Program 2

Controller Instructions		Operator Responses
Displays	Printout	
	*** 4276A HP-IB TEST No.2 ***	
TALKER TEST		
CONNECT 100pF		Connect the 16383A (100pF Standard) to the UNKNOWN terminals.
DATA OUTPUT TEST TEST FREQUENCY IN kHz ?		Key in the desired test frequency value, from 0.1 to 20, and press END LINE .
[Capacitance] [Dissipation Factor] IS OUTPUT DATA CORRECT (Y or N) ?		If the output data is the same as the values displayed on each 4276A display, press Y and END LINE . If not, press N and END LINE .
	DATA OUTPUT TEST PASS	DATA OUTPUT TEST result.
	DATA OUTPUT TEST FAIL	
COMPLETE DATA OUTPUT TEST		
PNC[Capacitance],ND[Dissipation Factor] IS OUTPUT DATA CORRECT (Y or N) ?		If the output data is the same as the left values, press Y and END LINE . If not, press N and END LINE .
	COMPLETE DATA OUTPUT TEST PASS	COMPLETE DATA OUTPUT TEST result.
	COMPLETE DATA OUTPUT TEST FAIL	
	END	

TEST PROGRAM 3

PURPOSE:

This test program verifies that the 4276A has the following HP-IB capabilities:

(1) Service Request
(2) Serial Poll

PROGRAM LISTING:

```
10 ! 4276A HP-IB TEST No.3
20 ! SRQ TEST
30 S=0 @ M=7 @ M1=717
40 ON INTR 7 GOSUB 560
50 CLEAR
60 PRINT "*** 4276A HP-IB TEST No.3 ***"
70 PRINT "SRQ TEST"
80 DISP "SRQ TEST"
90 REMOTE M
100 ABORTIO M
110 CLEAR M1
120 DISP "DATA READY SRQ TEST"
130 OUTPUT M1 ;"D1T2"
140 TRIGGER M1
150 GOSUB 480
160 PRINT "DATA READY   SRQ TEST PASS"
170 S=0
180 DISP "SYNTAX ERROR SRQ TEST"
190 OUTPUT M1 ;"DOA6DA"
200 GOSUB 480
210 PRINT "SYNTAX ERROR SRQ TEST PASS"
220 S=0
230 DISP "SELF TEST END SRQ TEST"
240 OUTPUT M1 ;"S1"
250 DISP "SELF TEST in progress"
260 GOSUB 480
270 IF BIT(S,2)=0 THEN GOSUB 480
280 OUTPUT M1 ;"S0"
290 PRINT "SELF TEST END SRQ TEST PASS"
300 S=0
310 DISP "TRIGGER TOO FAST SRQ TEST"
320 DISP "MOMENTARILY GROUND"
330 DISP "        EXT TRG CONNECTOR"
340 GOSUB 510
350 GOSUB 480
360 PRINT "TRG TOO FAST SRQ TEST PASS"
370 S=0
380 DISP "OPERATIONAL ERROR SRQ TEST"
390 OUTPUT M1 ;"N1N2"
400 GOSUB 480
410 PRINT "OPERATIONAL ERROR SRQ TEST PASS"
420 PRINT "SRQ TEST END"
430 CLEAR M1
440 ABORTIO M
450 LOCAL M
460 DISP "END"
470 END
480 ENABLE INTR 7;8
490 IF S>0 THEN DISP S @ RETURN
500 GOTO 480
510 OUTPUT M1 ;"F1T2DA"
520 TRIGGER M1
530 ENTER M1 ; A,B
540 IF S=0 THEN 510
550 RETURN
560 S=SPOLL(M1) @ STATUS 7,1 ; Z
570 IF BIT(S,6)=1 THEN 590
580 DISP "OTHER DEVICE SRQ"
590 ENABLE INTR 7;8
600 RETURN
```

Table 4-10. Controller Instructions and Operator Responses for Test Program 3

Controller Instructions		Operator Response
Displays	Printout	
	*** 4276A HP-IB TEST No.3 ***	
SRQ TEST	SRQ TEST	
DATA READY SRQ TEST 65	DATA READY SRQ TEST PASS	SRQ Status Byte data should be 65 [=01000001].
SYNTAX ERROR SRQ TEST 66	SYNTAX ERROR SRQ TEST PASS	SRQ Status Byte data should be 66 [=01000010].
SELF TEST END SRQ TEST SELF TEST in progress 68	SELF TEST END SRQ TEST PASS	SRQ Status Byte data should be 68 [=01000100]. If the instrument fails SELF TEST, it should be 84 [=01010100].
TRIGGER TOO FAST SRQ TEST MOMENTARILY GROUND EXT TRG CONNECTOR 72*[1]	TRG TOO FAST SRQ TEST PASS	Ground EXT TRG Connector on rear panel momentarily. SRQ Status Byte data should be 72 [=01001000].
OPERATIONAL ERROR SRQ TEST 80*[2]	OPERATIONAL ERROR SRQ TEST PASS	SRQ Status Byte data should be 80 [=01010000].
	SRQ TEST END	

*$_1$: SRQ Status Byte data may be 73 [=01001001] due to the timing of connecting the EXT TRG pin to ground.

*$_2$: SRQ Status Byte data may be 81 [=01010001] due to the timing of connecting the EXT TRG pin to ground.

PERFORMANCE TEST RECORD

Hewlett-Packard

Model 4276A
LCZ METER

Tested by ____________________

Serial Number ____________________

Date ____________________

Paragraph Number	TEST		Results	
		Minimum	Actual	Maximum
4-9	TEST FREQUENCY ACCURACY TEST			
	Frequency setting			
	100Hz	99.99Hz	________	100.01Hz
	200Hz	199.98Hz	________	200.02Hz
	500Hz	499.95Hz	________	500.05Hz
	1.00kHz	999.9Hz	________	1000.1Hz
	2.00kHz	1.9998kHz	________	2.0002kHz
	5.00kHz	4.9995kHz	________	5.0005kHz
	10.0kHz	9.999kHz	________	10.001kHz
	20.0kHz	19.998kHz	________	20.002kHz
4-11	TEST SIGNAL LEVEL ACCURACY TEST			
	Test Signal Level: HIGH			
		Vrms		Vrms
	Frequency 100Hz	0.7	________	1.3
	200Hz	0.7	________	1.3
	500Hz	0.7	________	1.3
	1.00kHz	0.9	________	1.1
	2.00kHz	0.7	________	1.3
	5.00kHz	0.7	________	1.3
	10.0kHz	0.7	________	1.3
	20.0kHz	0.7	________	1.3
	Test Signal Level: LOW			
		mVrms		mVrms
	Frequency 100Hz	35	________	65
	1.00kHz	40	________	60
	10.0kHz	35	________	65
4-13	SELF-OPERATING TEST			
	SELF TEST #2 100kΩ	1/C.V.- .01µS	________	1/C.V.+ .01µS
	10kΩ	1/C.V.- .1µS	________	1/C.V.+ .1µS
	1kΩ	1/C.V.-.001mS	________	1/C.V.+.001mS
	100Ω	1/C.V.- .01mS	________	1/C.V.+ .01mS
	1Ω [DISPLAY A	C.V. - .02Ω	________	C.V. + .02Ω
	DISPLAY B	- 0.012Ω	________	0.012Ω

1/C.V. = Reciprocal of Calibrated Value   C.V. = Calibrated Value

PERFORMANCE TEST RECORD

Paragraph Number	TEST	Results		
		Minimum	Actual	Maximum
4-13	SELF-OPERATING TEST (Cont'd)			
	1.00kHz			
	SELF TEST #8 DISPLAY A	0.0017		0.0023
	DISPLAY B	-0.0023		-0.0017
	SELF TEST #9 DISPLAY A	-0.0020		0.0020
	DISPLAY B	-0.0013		0.0013
	SELF TEST #12 DISPLAY A	-0.0012		0.0012
	DISPLAY B	-0.0020		0.0020
	SELF TEST #13 DISPLAY A	-0.0012		0.0012
	DISPLAY B	-0.0020		0.0020
	SELF TEST #14 DISPLAY A	-0.0024		0.0024
	DISPLAY B	-0.0020		0.0020
	SELF TEST #15 DISPLAY A	-0.0048		0.0048
	DISPLAY B	-0.0020		0.0020
	20.0kHz			
	SELF TEST #9 DISPLAY A	-0.0080		0.0080
	DISPLAY B	-0.0052		0.0052
	SELF TEST #12 DISPLAY A	-0.0048		0.0048
	DISPLAY B	-0.0043		0.0043
	SELF TEST #13 DISPLAY A	-0.0048		0.0048
	DISPLAY B	-0.0043		0.0043
	SELF TEST #14 DISPLAY A	-0.0096		0.0096
	DISPLAY B	-0.0036		0.0036
	SELF TEST #15 DISPLAY A	-0.0192		0.0192
	DISPLAY B	-0.0360		0.0360
4-15	CAPACITANCE ACCURACY TEST			
	10pF Range Speed: MED Level: HIGH			
	9.95kHz C	C.V. - .16pF		C.V. + .16pF
	D	- .010		.010
	10.0kHz C	C.V. - .16pF		C.V. + .16pF
	D	- .010		.010
	20.0kHz C	C.V. - .24pF		C.V. + .24pF
	D	- .012		.012

C.V. = Calibrated Value

PERFORMANCE TEST RECORD

Paragraph Number	TEST	Results		
		Minimum	Actual	Maximum
4-15	CAPACITANCE ACCURACY TEST (Cont'd)			
	100pF Range Speed: MED Level: HIGH			
	995Hz C	C.V. - .6pF		C.V. + .6pF
	D	- .004		.004
	1.00kHz C	C.V. - .35pF		C.V. + .35pF
	D	- .0035		.0035
	1.99kHz C	C.V. - .65pF		C.V. + .65pF
	D	- .0065		.0065
	4.98kHz C	C.V. - .25pF		C.V. + .25pF
	D	- .0017		.0017
	9.95kHz C	C.V. - .70pF		C.V. + .70pF
	D	- .0046		.0046
	10.0kHz C	C.V. - .70pF		C.V. + .70pF
	D	- .0046		.0046
	20.0kHz C	C.V. - 2.20pF		C.V. + 2.20pF
	D	- .0140		.0140
	1000pF Range Speed: MED Level: HIGH			
	100Hz C	C.V. - 5.0pF		C.V. + 5.0pF
	D	- .0050		.0050
	120Hz C	C.V. - 5.0pF		C.V. + 5.0pF
	D	- .0050		.0050
	199Hz C	C.V. - 6.5pF		C.V. + 6.5pF
	D	- .0065		.0065
	498Hz C	C.V. - 2.5pF		C.V. + 2.5pF
	D	- .0017		.0017
	995Hz C	C.V. - 2.5pF		C.V. + 2.5pF
	D	- .0017		.0017
	1.00kHz C	C.V. - 1.5pF		C.V. + 1.5pF
	D	- .0011		.0011
	1.99kHz C	C.V. - 2.5pF		C.V. + 2.5pF
	D	- .0017		.0017
	4.98kHz C	C.V. - 2.5pF		C.V. + 2.5pF
	D	- .0017		.0017
	9.95kHz C	C.V. - 7.0pF		C.V. + 7.0pF
	D	- .0046		.0046

C.V. = Calibrated Value

PERFORMANCE TEST RECORD

Paragraph Number	TEST	Results		
		Minimum	Actual	Maximum
4-15	CAPACITANCE ACCURACY TEST (Cont'd)			
	10.0kHz C	C.V. - 7.0pF		C.V. + 7.0pF
	D	- .0046		.0046
	20.0kHz C	C.V. - 11.0pF		C.V. + 11.0pF
	D	- .0070		.0070
	1000pF Range Speed: SLOW Level: HIGH			
	100Hz C	C.V. - 5.0pF		C.V. + 5.0pF
	D	- .0050		.0050
	1.00kHz C	C.V. - 1.5pF		C.V. + 1.5pF
	D	- .0011		.0011
	10.0kHz C	C.V. - 7.0pF		C.V. + 7.0pF
	D	- .0046		.0046
	1000pF Range Speed: FAST Level: HIGH			
	100Hz C	C.V. - 10pF		C.V. + 10pF
	D	- .010		.010
	1.00kHz C	C.V. - 6pF		C.V. + 6pF
	D	- .006		.006
	10.0kHz C	C.V. - 16pF		C.V. + 16pF
	D	- .014		.014
	1000pF Range Level: LOW			
	Speed: MED 1.00kHz C	C.V. - 12pF		C.V. + 12pF
	D	- .011		.011
	Speed: FAST 1.00kHz C	C.V. - 100pF		C.V. + 100pF
	D	- .100		.100
	Speed: MED 10.0kHz C	C.V. - 32pF		C.V. + 32pF
	D	- .027		.027
	1000pF Range HIGH SPEED C Speed: MED			
	Level: HIGH 1.00kHz	C.V. - 1.5pF		C.V. + 1.5pF
	Level: LOW 1.00kHz	C.V. - 12pF		C.V. + 12pF
	Level: HIGH 10.0kHz	C.V. - 7.0pF		C.V. + 7.0pF

C.V. = Calibrated Value

PERFORMANCE TEST RECORD

Paragraph Number	TEST			Results		
				Minimum	Actual	Maximum
4-17	IMPEDANCE ACCURACY TEST					
	100mΩ Range	100Hz	θ	- 1.2°	______	1.2°
		120Hz	θ	- 1.2°	______	1.2°
		1.00kHz	θ	- 1.2°	______	1.2°
		10.0kHz	θ	- 2.2°	______	2.2°
	1Ω Range	100Hz	θ	- .7°	______	.7°
		120Hz	θ	- .7°	______	.7°
		1.00kHz	θ	- .7°	______	.7°
		10.0kHz	θ	- 1.2°	______	1.2°
	10Ω Range	100Hz	θ	- .35°	______	.35°
		120Hz	θ	- .35°	______	.35°
		1.00kHz	θ	- .35°	______	.35°
		10.0kHz	θ	- .65°	______	.65°
	100Ω Range	100Hz	$\|Z\|$	C.V. - .15Ω	______	C.V. + .15Ω
			θ	- .15°	______	.15°
		120Hz	$\|Z\|$	C.V. - .15Ω	______	C.V. + .15Ω
			θ	- .15°	______	.15°
		1.00kHz	$\|Z\|$	C.V. - .15Ω	______	C.V. + .15Ω
			θ	- .15°	______	.15°
		10.0kHz	$\|Z\|$	C.V. - .25Ω	______	C.V. + .25Ω
			θ	- .25°	______	.25°
	1kΩ Range	100Hz	$\|Z\|$	C.V. - 6Ω	______	C.V. + 6Ω
			θ	- .6°	______	.6°
		120Hz	$\|Z\|$	C.V. - 6Ω	______	C.V. + 6Ω
			θ	- .6°	______	.6°
		1.00kHz	$\|Z\|$	C.V. - 6Ω	______	C.V. + 6Ω
			θ	- .6°	______	.6°
		10.0kHz	$\|Z\|$	C.V. - 10Ω	______	C.V. + 10Ω
			θ	- 1.0°	______	1.0°
	10kΩ Range	100Hz	$\|Z\|$	C.V. - .06kΩ	______	C.V. + .06kΩ
			θ	- .6°	______	.6°
		120Hz	$\|Z\|$	C.V. - .06kΩ	______	C.V. + .06kΩ
			θ	- .6°	______	.6°

C.V. = Calibrated Value

PERFORMANCE TEST RECORD

Paragraph Number	TEST	Results		
		Minimum	Actual	Maximum
4-17	IMPEDANCE ACCURACY TEST (Cont'd)			
	1.00kHz $\lvert Z \rvert$	C.V. - .06kΩ	______	C.V. + .06kΩ
	θ	- .6°	______	.6°
	10.0kHz $\lvert Z \rvert$	C.V. - .1kΩ	______	C.V. + .1kΩ
	θ	- 1.0°	______	1.0°
	100kΩ Range 100Hz $\lvert Z \rvert$	C.V. - .6kΩ	______	C.V. + .6kΩ
	θ	- .6°	______	.6°
	120Hz $\lvert Z \rvert$	C.V. - .6kΩ	______	C.V. + .6kΩ
	θ	- .6°	______	.6°
	1.00kHz $\lvert Z \rvert$	C.V. - .6kΩ	______	C.V. + .6kΩ
	θ	- .6°	______	.6°
	10.0kHz $\lvert Z \rvert$	C.V. - 1kΩ	______	C.V. + 1kΩ
	θ	- 1.0°	______	1.0°
4-19	INDUCTANCE ACCURACY TEST			
	Frequency: 1.00kHz Speed: MED Level: HIGH			
	DISPLAY A	- 25.51	______	- 25.15
	DISPLAY B	- .012	______	.012
4-21	INTERNAL DC BIAS ACCURACY TEST (OPTION 001 ONLY)			
	Precharge + 40V Wait: 10sec.			
	.00V Wait: 30sec.	- .01V	______	.01V
	+ .01V Wait: 20sec.	0V	______	.02V
	+ 9.99V Wait: 10sec.	9.95V	______	10.03V
	+ 10.0V Wait: 10sec.	9.015V	______	10.85V
	+ 40.0V Wait: 15sec.	39.76V	______	40.24V
	- .01V Wait: 30sec.	- .02V	______	0V
	- 9.99V Wait: 10sec.	- 10.1V	______	- 9.88V
	- 10.0V Wait: 10sec.	- 10.135V	______	- 9.865V
	- 40.0V Wait: 15sec.	- 40.44V	______	- 39.56V

C.V. = Calibrated Value

Table 5-1. Adjustable Components (Sheet 1 of 2)

Reference Designator	Name of Control	Purpose
A1 R3 (Para. 5-18)		Sets the reset voltage level.
A2 R1 (Para. 5-19)	OSC/LEVEL	Sets the test signal level.
A2 R4 A2 R5 A2 R6 A2 R7 (Para. 5-24)	10K/MAG 1K/MAG 100/MAG 100K/MAG	Fine adjustment for range resistor.
A2 R13 (Para. 5-20)	ER/OFS	Eliminates dc offset voltage from E_{RR} buffer amplifier.
A2 R14 (Para. 5-23)	LF TRK	Compensates for phase offset between the E_{DUT} and E_{RR} buffer amplifiers.
A2 R15 (Para. 5-20)	ED/OFS	Eliminates dc offset voltage from the E_{DUT} buffer amplifier.
A2 R16 (Para. 5-20)	LC/OFS	Eliminates dc offset voltage from the I/V amplifier.
A2 R17 (Para. 5-20)	DIF/OFS	Eliminates dc offset voltage from the differential amplifier and the process amplifier.
A2 R25 (Para. 5-20)	AM1/OFS	Eliminates dc offset voltage from the AM1 amplifier.
A2 R26 A2 R27 A2 R35 (Para. 5-22)	AF 1/2 AF 1/5 AM 1/10	Sets AM/AF attenuation.
A2 R39 (Para. 5-20)	AF/OFS	Eliminates dc offset voltage from the AF amplifier.
A2 R40 (Para. 5-20)	AM2/OFS	Eliminates dc offset voltage from the AM2 amplifier.
A2 R99 A2 R100 (Para. 5-21)	ZERO ZERO SHIFT	Sets the zero detect voltage level.
A2 C2 C3 (Para. 5-25)	10K/PH 100K/PH	Eliminates range resistor phase offset.
A2 C7 (Para. 5-23)	HF TRK	Compensates for phase offset between the E_{DUT} and E_{RR} buffer amplifiers.
A2 C12 A2 C13 A2 C18 (Para. 5-22)	PH 1/2 PH 1/5 PH 1/10	Eliminates AM/AF attenuator phase offset.

Table 5-1. Adjustable Components (Sheet 2 of 2)

Reference Designator	Name of Control	Purpose
A4 R14 (Para. 5-17) (Para. 5-18)	V-ADJ	Sets power supply voltage.
A4 R15 (Para. 5-17)	F-ADJ	Sets power supply switching frequency.
A22 R6 A22 R7 A22 R8 (Para. 5-26)	ZERO FS	Eliminates bias voltage offset and gain error.

SECTION V

ADJUSTMENTS

5-1. INTRODUCTION

5-2. This section describes the adjustments and checks required to return the 4276A to the specifications listed in Table 1-1 after repairs have been made. These adjustments and checks can also be performed along with periodic maintenance to keep the instrument in optimum operating condition. The recommended adjustment cycle for the 4276A is twice a year. All adjustable components referred to in the adjustment procedures are listed in Table 5-1. If proper performance cannot be achieved after adjustment, refer to the troubleshooting procedures described in Section VIII.

Note

All options that the instrument is normally equipped with must be installed before the adjustments described in this section are made. If the options are installed after the instrument is adjusted, the specifications listed in Table 1-1 are not guaranteed.

Note

To ensure proper results and correct instrument operation, Hewlett- Packard suggests a 30-minute warm-up and stabilization period before performing any of the adjustments described here.

5-3. SAFETY REQUIREMENTS

5-4. Although the 4276A was designed in accordance with international safety standards, this manual contains information, cautions, and warnings which must be followed to ensure operator safety and to keep the instrument in a safe and serviceable condition. Adjustments described in this section should be performed by qualified service personnel only.

WARNING

ANY INTERRUPTION OF THE PROTECTIVE (GROUNDED) CONDUCTOR (INSIDE OR OUTSIDE THE INSTRUMENT) OR DISCONNECTION OF THE PROTECTIVE EARTH TERMINAL IS LIKELY TO MAKE THE INSTRUMENT DANGEROUS. INTENTIONAL INTERRUPTION, FOR ANY REASON, IS PROHIBITED.

5-5. The removal or opening of covers for removal or adjustment of parts, other than those which are accessible by hand, will expose live parts.

5-6. Capacitors in the instrument may still be charged even if the instrument has been disconnected from the power source (AC line) for an extended period of time.

WARNING

ADJUSTMENTS DESCRIBED IN THIS SECTION ARE PERFORMED WITH POWER SUPPLIED AND PROTECTIVE COVERS REMOVED. ENERGY EXISTING AT MANY POINTS MAY, IF CONTACTED, RESULT IN SERIOUS PERSONAL INJURY.

5-7. EQUIPMENT REQUIRED

5-8. All the equipment required to perform the adjustments described in this section are listed in Table 4-1 on page 4-0. Each piece of equipment listed in Table 4-1 should be calibrated to satisfy its own specifications, as well as those of the required characteristics. If the recommended model is not available, any instrument whose specifications equal or surpass those of the recommended model may be used instead.

5-9. FACTORY SELECTED COMPONENTS

5-10. Factory selected components are identifiable by an asterisk (*) adjacent to the reference designator on the schematic diagrams in Section VIII (only nominal values are given). Table 5-2 lists the reference designators of all factory selected components. Also listed in Table 5-2 are the nominal value range of each component and a brief description of how each component affects instrument performance.

Adjustable components, with reference designators, are listed in Table 5-1. This table also lists the name of the adjustment and its purpose.

5-11. ADJUSTMENT RELATIONSHIPS

5-12. The adjustment procedures described in this section, beginning with paragraph 5-17, are interactive and therefore should be performed in the sequence given. Ignoring or changing the order of the procedures may make it impossible to obtain optimum instrument performance. Table 5-3 lists the necessary adjustment procedures to follow after the instrument has been repaired.

5-13. ADJUSTMENT LOCATIONS

5-14. To help locate the appropriate adjustment points, the locations of the components to be adjusted are illustrated throughout the adjustment procedures. The locations of factory selected components, connectors, and other components related to the adjustments are shown in the individual board assembly-component illustrations (fold-out service sheets) in Section VIII.

5-15. INITIAL OPERATING PROCEDURE

5-16. Before proceeding with the adjustments described starting in paragraph 5-17, perform the following preliminary procedure. This procedure provides access to the various adjustment points and facilitates a thoroughgoing adjustment.

[BASIC OPERATING CHECK]

Check that the instrument's line voltage selector switch, located on the rear panel, is set to the position appropriate for the local line voltage. This should be performed before proceeding with any of the adjustments.

After the recommended 30-minute warm-up period, the instrument should pass the SELF TEST (no error message should appear). If the instrument displays an error message or does not have the correct control settings, refer to the troubleshooting procedures given in Section VIII.

[TOP COVER REMOVAL]

a. Fully loosen the top-cover retaining screw located at the rear of the top cover.

b. Slide the top cover towards the rear and lift off.

WARNING

DC VOLTAGES—MAXIMUM ±16V—ARE PRESENT AT TEST POINTS ON THE A1, A2, AND A4 BOARDS. AS A SAFETY PRECAUTION AGAINST POSSIBLE ELECTRICAL SHOCK HAZARDS AND RESULTANT INJURY, USE INSULATED TOOLS FOR ALL ADJUSTMENTS.

Note

1. To select a numbered SELF TEST:

a) Press the SELF TEST key and the FREQUENCY/DC BIAS Select key in order.

b) The number displayed on the FREQUENCY/DC BIAS DISPLAY is the SELF TEST number.

c) The SELF TEST number can be changed by pressing the FREQUENCY/ DC BIAS Step Control Key.

2. To obtain initial control settings (erase continuous memory):

a) Turn off the instrument.

b) Press and hold both FREQUENCY/ DC BIAS Step Control keys (⇧ and ⇩).

c) Turn on the instrument.

d) Release both FREQUENCY/DC BIAS Step Control Keys after the displays appears.

Table 5-2. Factory Selected Components

Reference Designator	Nominal Value Range	Effect on Performance
A2 R58 (Para. 5-19)	HP P/N: 0757-0278 , R: FXD 1.78kΩ ▶HP P/N: 0698-0084 , R: FXD 2.15kΩ HP P/N: 0698-0085 , R: FXD 2.61kΩ	Changes test signal level. If signal level is too high, use more resistance; if too low, use less resistance.
A2 C72 (Para. 5-21)	▶HP P/N: 0160-5597 , C: FXD 5pF HP P/N: 0160-5593 , C: FXD 12pF	Compensates for junction capacitance of FET switch. If [DISP A] <72, remove C72; if [DISP A]>88, use more capacitance.
A2 C14 (Para. 5-22)	HP P/N: 0140-0191 , C: FXD 56pF ▶HP P/N: 0160-2202 , C: FXD 75pF HP P/N: 0160-2204 , C: FXD 100pF HP P/N: 0140-0196 , C: FXD 150pF	Eliminates phase offset in the AF attenuator. If [DISP B]<-4, use more capacitance; if [DISP B]>+4, use less capacitance.
A2 C15 (Para 5-22)	HP P/N: 0160-4794 , C: FXD 5.6pF ▶HP P/N: 0160-4789 , C: FXD 15pF HP P/N: 0160-4787 , C: FXD 22pF	Eliminates phase offset in the AF attenuator. If [DISP B]<-4, use more capacitance; if [DISP B]>+4, use less capacitance.
A2 C16 (Para 5-22)	HP P/N: 0160-2204 , C: FXD 100pF ▶HP P/N: 0140-0196 , C: FXD 150pF HP P/N: 0140-0198 , C: FXD 200pF	Eliminates phase offset in the AM2 attenuator. If [DISP B]<-4, use less capacitance; if [DISP B]>+4, use more capacitance.
A2 R93 (Para. 5-23)	HP P/N: 0757-0463 , R: FXD 82.5kΩ ▶HP P/N: 0757-0464 , R: FXD 90.9kΩ HP P/N: 0757-0465 , R: FXD 100kΩ	Compensates for buffer amplifier phase offset. If [DISP B]<-1, use more resistance; if [DISP B]>+1, use less resistance.
A2 C55 (Para. 5-23)	HP P/N: 0160-4806 , C: FXD 39pF ▶HP P/N: 0160-4803 , C: FXD 68pF HP P/N: 0160-4801 , C: FXD 100pF	Compensates for buffer amplifier phase offset. If [DISP B]<-1, use more capacitance; if [DISP B]>+1, use less capacitance.
A2 C5 (Para. 5-25)	HP P/N: 0160-4795 , C: FXD 4.7pF ▶HP P/N: 0160-4788 , C: FXD 18pF HP P/N: 0160-4786 , C: FXD 27pF HP P/N: 0160-4806 , C: FXD 39pF HP P/N: 0160-4804 , C: FXD 56pF	Eliminates phase offset of range resistor. If [DISP B]<-2, use less capacitance; if [DISP B]>+2, use more capacitance.
A2 C4 (Para. 5-25)	HP P/N: 0160-4795 , C: FXD 4.7pF ▶HP P/N: 0160-4791 , C: FXD 10pF HP P/N: 0160-4789 , C: FXD 15pF HP P/N: 0160-4787 , C: FXD 22pF	Eliminates phase offset of range resistor. If [DISP B]<-2, use less capacitance; if [DISP B]>+2, use more capacitance.

Note: ▶ indicates the component usually used.

Table 5-3. Adjustment Requirements

Assembly Repaired or Replaced	Required Adjustments
A1 (04276-66501)	Para. 5-17 and 5-18
A2 (04276-66502)	Para. 5-19 through 5-25
A4 (04276-66504)	Para. 5-17 and 5-18
A5 (04276-66505)	None
A6 (04276-66506)	None
A21 (04276-66521)	None
A22 (04276-66522)	Para. 5-17, 5-18 and 5-26 (only if A22 is added or removed)
16064A A2 (16064-66502)	Para. 5-17 and 5-18 (only if 16064A A2 is added or removed)

5-17. *A4 POWER SUPPLY ADJUSTMENT*

PURPOSE:

Adjusts the output voltages and the switching frequency of the switching power supply.

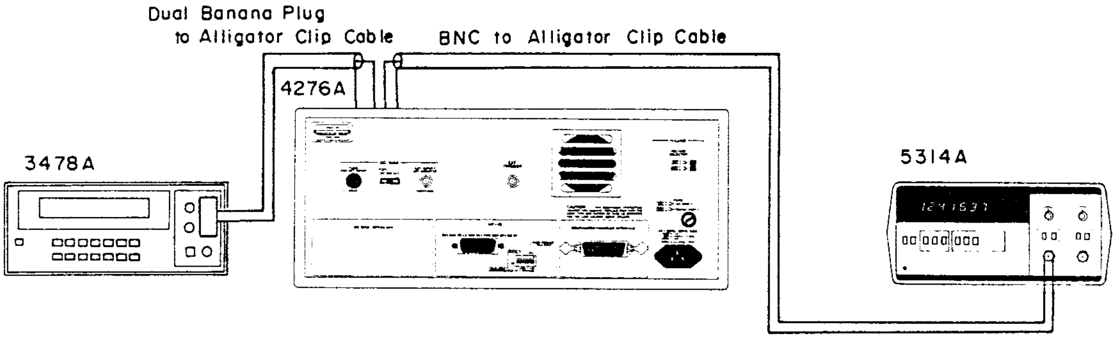


Figure 5-1. A4 Power Supply Adjustment Setup.

EQUIPMENT:

Digital Voltmeter	HP 3478A
Frequency Counter	HP 5314A
BNC-to-Alligator Clip Cable	HP 11000A
Dual Banana Plug-to-Alligator Clip Cable	HP 11002

PROCEDURE:

1. Connect the 3478A HI and LOW inputs to A4TP1 (+5V DIG) and A4TP2 (DIG GND), respectively, with the dual banana plug-to-alligator clip cable as shown in Figure 5-1.

2. Set the 3478A function to DCV.

3. Turn on the 4276A.

4. Adjust A4R14 (V-ADJ) until the reading on the 3478A is +5.10V±0.01V.

5. Connect the 3478A LOW input to A4TP10 (GND).

6. Verify that the voltages at A4TP5 (+16V)/TP6(-16V)/TP7(+8V) are within test limits in the table below:

Test Point	Test Limits
A4TP5 (+16V)	+15V to +17V
A4TP6 (-16V)	-15V to -17V
A4TP7 (+8V)	+8V to +10V

7. Connect the 5314A to A4TP9 (DIG PWM) and A4TP10 (GND) with a BNC-to-alligator clip cable as shown in Figure 5-1.

8. Adjust A4R15 (F-ADJ) until the reading on the 5314A is 21kHz±0.1kHz.

Note

If necessary, adjust the trigger level on the 5314A.

5-18. A1 RESET VOLTAGE ADJUSTMENT

PURPOSE:

Adjusts the threshold voltage for instrument reset to +4.80V.

Note

Perform the adjustment described in paragraph 5-17 before performing this adjustment.

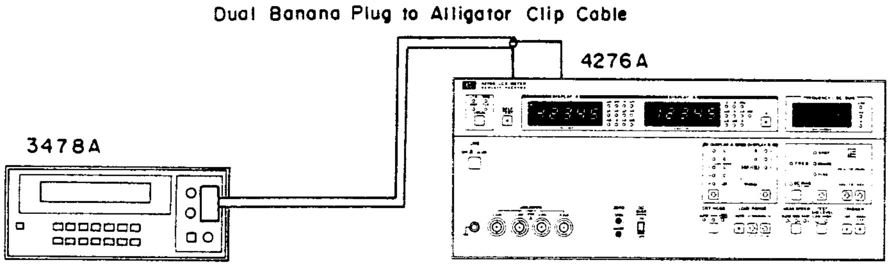


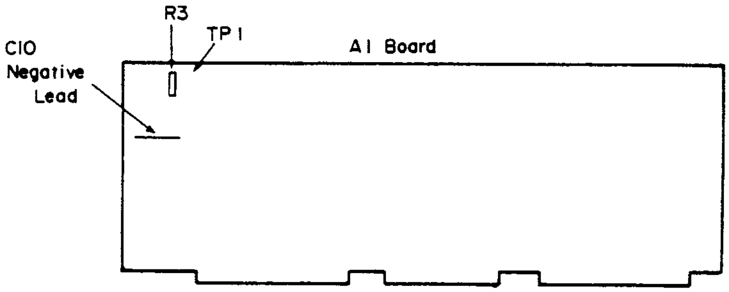
Figure 5-2. A1 Reset Voltage Adjustment Setup.

EQUIPMENT:

Digital Voltmeter	HP 3478A
Dual Banana Plug-to-Alligator Clip Cable	HP 11002A

PROCEDURE:

1. Connect the HI and LOW inputs of the 3478A to A1TP1 and the negative lead of A1C10, respectively, with a dual banana-to-alligator clip cable as shown in Figure 5-2.
2. Set the 3478A function to DCV.
3. Turn on the 4276A.
4. Adjust A1R3 fully CCW.
5. Adjust A4R14 (V-ADJ) until the reading on the 3478A is +4.80V±0.02V.
6. Gradually adjust A1R3 CW until the 4276A display lamps go on and off.



[Reset Voltage Level Check]

7. Adjust A4R14 (V-ADJ) until the reading on the 3478A is +5V.

8. Gradually adjust A4R14 (V-ADJ) until the reading on the 3478A is +4.83V. Verify that the 4276A display lamps have not gone off.

9. Gradually adjust A4R14 (V-ADJ) until the reading on the 3478A is +4.77V. Verify that the 4276A display lamps have gone on and off.

10. If the state of display lamps is different from the state described in steps 8. and 9., repeat steps 3. through 9.

11. Adjust A4R14 (V-ADJ) until the reading on the 3478A is +5.10V±0.02V.

Note

When the Comparator/Handler Interface board assembly (HP P/N 16064-66502) has been installed, connect the model 16064A to the connector on the rear panel before making this adjustment.

5-19. *A2 TEST SIGNAL LEVEL ADJUSTMENT*

PURPOSE:

Adjusts the test signal level.

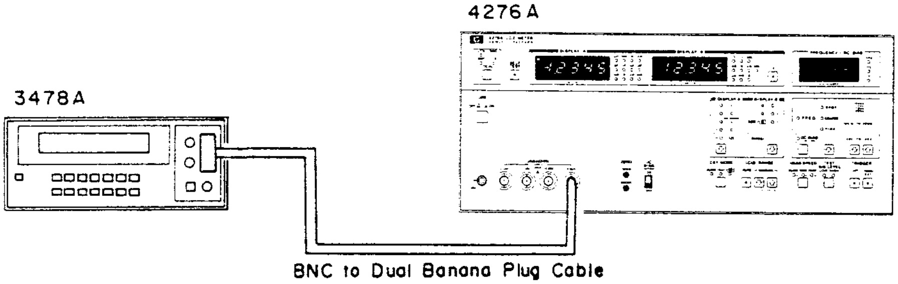


Figure 5-3. A2 Test Signal Level Adjustment Setup.

EQUIPMENT:

Digital Voltmeter	HP 3478A
BNC-to-Dual Banana Plug Cable	HP 11000A

PROCEDURE:

1. Connect the 3478A to the 4276A H_{CUR} terminal with a BNC-to dual banana plug cable, as shown in Figure 5-3.

2. Set the 3478A function to ACV.

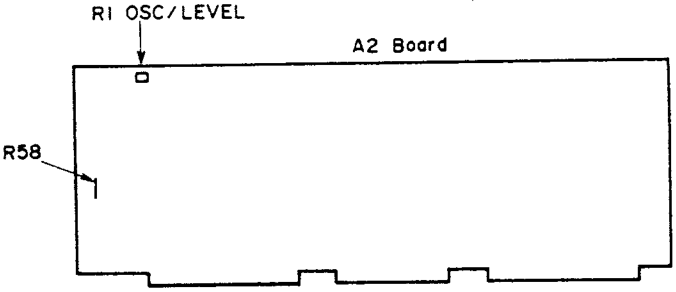
3. Turn on the 4276A and set the controls as follows:

DISPLAY A/B functions	C-ESR/G
Test Frequency	1.00kHz
DC BIAS	OFF
LC | Z | RANGE	100nF
TEST SIG LEVEL	HIGH
Other Controls	Any Settings

ADJUSTMENTS

4. Adjust A2R1 (OSC/LEVEL) until the reading on the 3478A is 1Vrms ±10mVrms.

5. Set the test signal level to LOW, and verify that the reading on the 3478A is 50mVrms ±10mVrms.



Note

If this adjustment cannot be performed successfully, replace A2R58 in accordance with the instructions given in Table 5-2.

5-20. *A2 DC OFFSET ADJUSTMENT*

PURPOSE:

Eliminates residual dc offset voltages from amplifier output voltages on the A2 board.

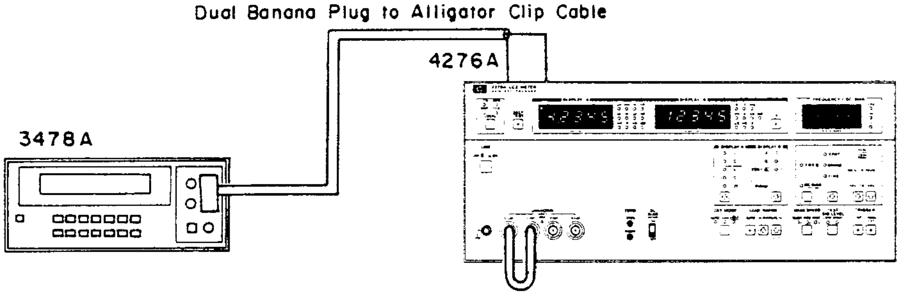


Figure 5-4. A2 DC Offset Adjustment Setup.

EQUIPMENT:

Digital Voltmeter	HP 3478A	
Terminations	OPEN SHORT	HP 16074A Standard Resistor Set
Dual Banana Plug-to-Alligator Clip Cable	HP 11002A	

PROCEDURE:

1. Connect the 4276A's L_{CUR} and L_{POT} terminals to each other with a BNC-to-BNC cable.

[Differential Amplifier and Process Amplifier DC Offset Adjustment]

2. Connect the 3478A HI and LOW inputs to A2TP7 (PD/IN) and A2TP4 (GND), respectively, as shown in Figure 5-4.

3. Set the 3478A function to DCV.

4. Turn on the 4276A.

5. Set the 4276A to SELF TEST 16. (Refer paragraph 5-15 for the procedure.)

6. Adjust A2R17 (DIF/OFS) until the reading on the 3478A is 0V±0.2mV.

[AM-1 Amplifier DC Offset Adjustment]

7. Connect the 3478A HI input to A2TP8 (AM1).

8. Adjust A2R25 (AM1/OFS) until the reading on the 3478A is 0V±0.5mV.

[AF Amplifier DC Offset Adjustment]

9. Connect the 3478A HI input to A2TP9 (AF).

10. Adjust A2R39 (AF/OFS) until the reading on the 3478A is 0V±1mV.

[AM-2 Amplifier DC Offset Adjustment]

11. Connect the 3478A HI input to A2TP10 (PD/IN).

12. Adjust A2R40 (AM2 OFS) until the reading on the 3478A is 0V±5mV.

[I/V Amplifier DC Offset Adjustment]

13. Set the 4276A to SELF TEST 17. (Refer to paragraph 5-15 for the procedure.)

14. Connect the 3478A HI input to A2TP5 (I/V OUT).

15. Adjust A2R16 (LC/OFS) until the reading on the 3478A is 0V±0.5mV.

[Err Buffer Amplifier DC Offset Adjustment]

16. Connect the 3478A HI input to A2TP7 (VRD/IN).

17. Adjust A2R13 (ER/OFS) until the reading on the 3478A is 0V±0.2mV.

[H_{POT} Buffer Amplifier DC Offset Adjustment]

18. Set the 4276A to SELF TEST 18. (Refer to paragraph 5-15 for the procedure.)

19. Adjust A2R15 (ED/OFS) until the reading on the 3478A is 0V±0.2mV.

20. Press the SELF TEST key to release the self test mode.

Procedure	SELF TEST Number	Digital Voltmeter Inputs		Adjustment Component	Limit
		HI	LO		
(1)	16	A2TP7 (VRD/IN)	A2TP4 (GND)	A2R17 (DIF/OFS)	0±0.2mV
(2)	16	A2TP8 (AM1)	A2TP4 (GND)	A2R25 (AM1/OFS)	0±0.5mV
(3)	16	A2TP9 (AF)	A2TP4 (GND)	A2R39 (AF/OFS)	0±1mV
(4)	16	A2TP10 (PD/IN)	A2TP4 (GND)	A2R40 (AM2 OFS)	0±5mV
(5)	17	A2TP5 (IV OUT)	A2TP4 (GND)	A2R16 (LC/OFS)	0±0.5mV
(6)	17	A2TP7 (VRD IN)	A2TP4 (GND)	A2R13 (ER/OFS)	0±0.2mV
(7)	18	A2TP7 (VRD IN)	A2TP4 (GND)	A2R15 (ED/OFS)	0±0.2mV

Note

Use a BNC-to-BNC coaxial cable to interconnect the L_{CUR} and L_{POT} UNKNOWN terminals.

[[DC Offset Check]]

[SHORT Offset Check]

1. Set the 4276A's controls as follows:

DISPLAY A/B functions	|Z| - θ
Test Frequency	1.00kHz
DC BIAS	OFF
LC |Z| RANGE	100mΩ
MEAS SPEED	MED
TRIGGER	INT
Other Controls	Any Settings

2. Connect the 3478A HI and LOW inputs to A2TP10 (PD/IN) and A2TP4 (GND), respectively, with a dual banana plug-to-alligator clip cable.
3. Set the 4276A to SELF TEST 23. (Refer to paragraph 5-15 for the procedure.)
4. Press the MAN/EXT key on the front-panel once.
5. Connect the SHORT termination to the UNKNOWN terminals.
6. Verify that the reading on the 3478A is 0mV±100mV.

[OPEN Offset Check]

7. Press the SELF TEST key to release the self test mode.
8. Set the 4276A's controls as follows:

DISPLAY A/B functions	C - D
Test Frequency	5.00kHz
DC BIAS	OFF
CKT MODE	Any Setting
LC |Z| RANGE	10pF
MEAS SPEED	MED
TEST SIG LEVEL	LOW
TRIGGER	INT

9. Set the 4276A to SELF TEST 23.
10. Press MAN/EXT key on the front-panel once.
11. Connect the OPEN termination to the UNKNOWN terminals.
12. Verify that the reading on the 3478A is 0mV±100mV.

Note

If the SHORT and OPEN Offset checks cannot be performed successfully, repeat steps 1 throgh 20 of the main procedure.

5-21. *A2 ADC ZERO ADJUSTMENT*

PURPOSE:

Eliminates residual dc offset voltage from the integrator output.

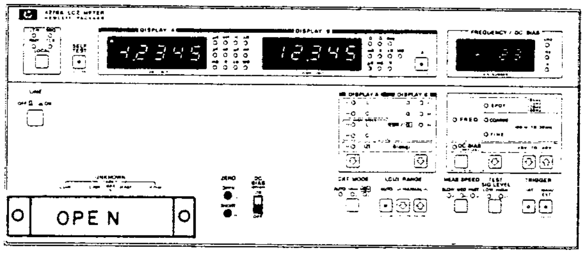


Figure 5-5. A2 ADC Zero Adjustment Setup.

Note

DO NOT extend A2 board assembly in this adjustment.

EQUIPMENT:

Termination .... OPEN: HP 16074A

PROCEDURE:

1. Turn on the 4276A.
2. Connect the OPEN termination of the 16074A directly to the UNKNOWN terminals.
3. Set the 4276A's controls as follows:

Test Frequency 1.00kHz
DC BIAS .... OFF
MEAS SPEED .... MED
TEST SIG LEVEL .... HIGH
TRIGGER .... INT
Other Controls .... Any setting

4. Set the 4276A to SELF TEST 8. (Refer to paragraph 5-15 for the procedure.)
5. Set A2R100 (ZERO SHIFT) at the midway point.
6. Adjust A2R99 (ZERO) until [A] equals - [B].

Note

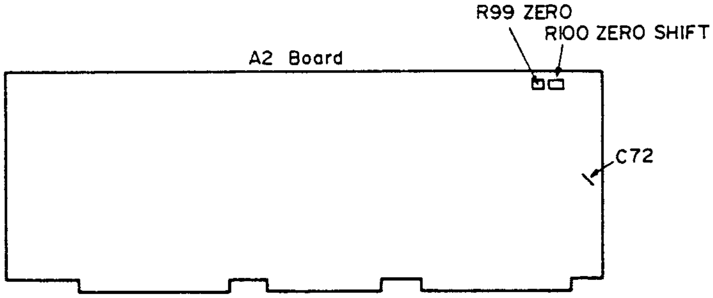
[A] and [B] are defined as the values displayed on DISPLAY A and DISPLAY B, respectively.

7. Adjust A2R100 (ZERO SHIFT) until

[A] = 20 counts±1 count and [B] = -20 counts±1 count.

8. Set the measurement speed mode to FAST. Verify that

[A] = 80 counts±8 count and [B] = -80 counts±8 counts.



Note

If the test in step 8 cannot be performed successfully, replace A2C72 in accordance with the instructions given in Table 5-2.

5-22. *A2 AM/AF ATTENUATOR ADJUSTMENT*

PURPOSE:

Adjusts the attenuation and phase of the attenuators in the AM and AF circuits.

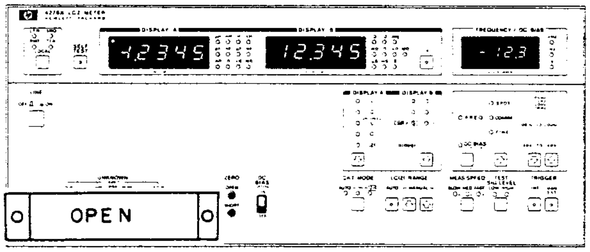


Figure 5-6. A2 AM/AF Attenuator Adjustment Setup.

EQUIPMENT:

Termination	OPEN: HP 16074A

PROCEDURE:

1. Connect the OPEN termination of the 16074A directly to the UNKNOWN terminals.
2. Turn on the 4276A.
3. Set the 4276A's controls as follows:

Test Frequency	1.00kHz
DC BIAS	OFF
MEAS SPEED	SLOW
TEST SIG LEVEL	HIGH
TRIGGER	INT
Other Controls	Any settings

ADJUSTMENTS

[AF 1/2 Attenuator Adjustment]

4. Set the 4276A to SELF TEST 12. (Refer to paragraph 5-15 for the procedure.)

5. Adjust A2R26 (AF 1/2) until [A] is 0 counts±4 counts. Verify that [B] is 0 count±10 counts.

Note

[A] and [B] are defined as the values displayed on DISPLAY A and DISPLAY B, respectively.

[AF 1/5 Atteunator Adjustment]

6. Set the 4276A to SELF TEST 13.

7. Adjust A2R27 (AF 1/5) until [A] is 0 counts±4 counts. Verify that [B] is 0 counts±10 counts.

[AM2 1/10 Attenuator Adjustment]

8. Set the 4276A to SELF TEST 14.

9. Adjust A2R35 (AM 1/10) until [A] is 0 counts±4 counts. Verify that [B] is 0 counts±10 counts.

[AM1 Attenuator Check]

10. Set the 4276A to SELF TEST 15.

11. Verify that [A] and [B] are 0 counts±40 counts and 0 counts±15 counts, respectively.

[VRD Full Scale Check]

12. Press the SELF TEST key to release the SELF TEST mode.

13. Set the test frequency to 20kHz.

14. Set the 4276A to SELF TEST 9

15. Verify that [A] and [B] are 0 counts±20 counts and 0 counts±10 counts, respectively.

[AF 1/2 Attenuator Phase Adjustment]

16. Set the 4276A to SELF TEST 12.

17. Adjust A2C12 (PH 1/2) until [B] is 0 counts±20 counts. Verify that [A] is 0 counts±4 counts.

Note

If this adjustment cannot be performed successfully, replace A2C14 in accordance with the instructions given in described in Table 5-2.

[AF 1/5 Attenuator Phase Adjustment]

18. Set the 4276A to SELF TEST 13.
19. Adjust A2C13 (PH 1/5) until [B] is 0 counts±4 counts. Verify that [A] is 0 counts±20 counts.

Note

If this adjustment cannot be performed successfully, replace A2C15 in accordance with the instructions given in Table 5-2.

[AM2 1/10 Attenuator Phase Adjustment]

20. Set the 4276A to SELF TEST 14.
21. Adjust A2C18 (PH 1/10) until [B] is 0 counts±4 counts. Verify that [A] is 0 counts±40 counts.

Note

If this adjustment cannot be performed successfully, replace A2C16 in accordance with the instructions given in Table 5-2.

[AM1 Attenuator Phase Check]

22. Set the 4276A to SELF TEST 15.
23. Verify that [A] and [B] are 0 counts±120 counts and 0 counts±200 counts, respectively.

Procedure	SELF TEST Number	Test Frequency	Adjustment Component	Adjustment Limit (counts)		Check Limit (counts)	
				DISPLAY A	DISPLAY B	DISPLAY A	DISPLAY B
(1)	12	1kHz	A2R26 (AF 1/2)	0±4			0±10
(2)	13	1kHz	A2R29 (AF 1/5)	0±4			0±10
(3)	14	1kHz	A2R35 (AM 1/10)	0±4			0±10
(4)	15	1kHz				0±40	0±15
(5)	9	20kHz				0±20	0±10
(6)	12	20kHz	A2C12 (PH 1/2)		0±4	0±20	
(7)	13	20kHz	A2C13 (PH 1/5)		0±4	0±20	
(8)	14	20kHz	A2C18 (PH 1/10)		0±4	0±40	
(9)	15	20kHz				0±120	0±200

5-23. *A2 LF/HF TRACKING ADJUSTMENT*

PURPOSE:

Compensates for the difference between the phase shift caused by the Err circuit and the phase shift caused by the Edut circuit in the low frequency range (LF) and high frequency (HF) ranges.

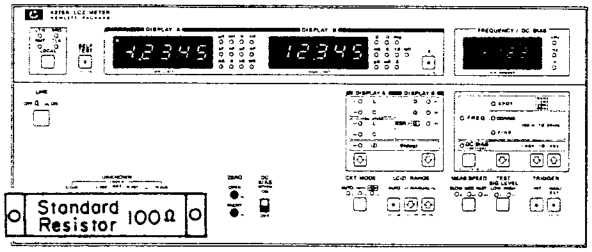


Figure 5-7. A2 LF/HF Tracking Adjustment Setup.

EQUIPMENT:

Standard Resistor	100Ω: HP 16074A Standard Resistor Set

PROCEDURE:

[LF Adjustment]

1. Connect the 100Ω standard resistor directly to the UNKNOWN terminals.
2. Reset continuous memory (see Note 2 in paragraph 5-15) and turn on the 4276A.
3. Set the 4276A's controls as follows:

DISPLAY A/B functions	|Z| - θ
Test Frequency	100Hz
DC BIAS	OFF
CKT MODE	Any Setting
LC|Z| RANGE	1kΩ
MEAS SPEED	MED
TEST SIG LEVEL	HIGH
TRIGGER	INT

4. Set the 4276A to SELF TEST 2. (Refer to paragraph 5-15 for the procedure.)
5. Adjust A2R14 (LF TRK) until the 4276A displays 0 counts±1 count on DISPLAY B.

Note

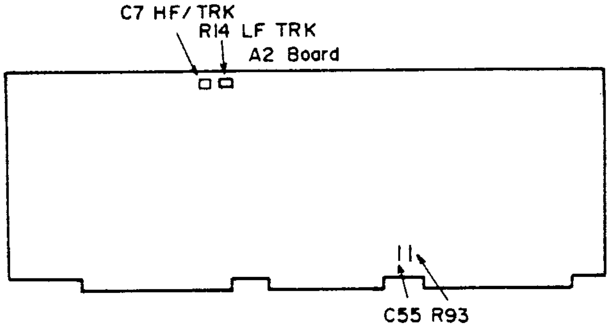
If this adjustment cannot be paformed successfully, replace A2R93 in accordance with the instructions given in Table 5-2.

[HF Adjustment]

6. Press the SELF TEST key to release the SELF TEST mode.
7. Set the test frequency to 20kHz.
8. Set the 4276A to SELF TEST 2.
9. Adjust A2C7 (HF/TRK) until the 4276A displays 0 counts±1 count on DISPLAY B.

Note

If this test cannot be performed successfully, replace A2C55 in accordance with instructions given in Table 5-2.



5-24. *A2 RANGE RESISTOR MAGNITUDE ADJUSTMENT*

PURPOSE:

Adjusts the range resistor values.

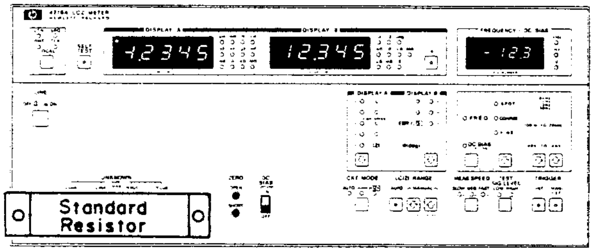


Figure 5-8. A2 Range Resistor Magnitude Adjustment Setup.

EQUIPMENT:

Standard Resistors 100Ω
1kΩ
10kΩ
100kΩ
HP 16074A Standard Resistor Set

ADJUSTMENTS

PROCEDURE:

1. Calculate the reciprocal of the calibrated values of the 100Ω/1kΩ/10kΩ and 100kΩ standard resistors; [1/c.v.].

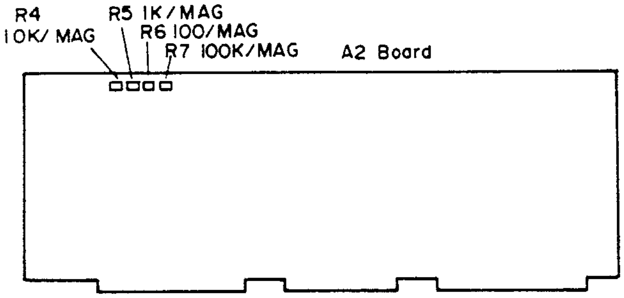
2. Reset continuous memory (see Note 2 in paragraph 5-15).

3. Connect the 100kΩ standard resistor directly to the UNKNOWN terminals.

4. Set the 4276A's controls as follows:

DISPLAY A/B functions	|Z| - θ
Test Frequency	1.00kHz
DC BIAS	OFF
CKT MODE	Any Setting
LC |Z| RANGE	1MΩ
MEAS SPEED	MED
TEST SIG LEVEL	HIGH
TRIGGER	INT

5. Set the 4276A to SELF TEST 2. (Refer to paragraph 5-15 for the procedure.)



[100K/MAG Adjustment]

6. Adjust A2R7 (100K/MAG) until the 4276A displays [1/c.V.]±1 count on DISPLAY A. Verify that the DISPLAY B value is 0±10 counts.

Note

The units for both DISPLAY A and DISPLAY B values are µS.

[10K/MAG Adjustment]

7. Set the DISPLAY A range to the 100µS range. (Use the LC |Z| RANGE key.)

8. Connect the 10kΩ standard resistor directly to the UNKNOWN terminals.

9. Adjust A2R4 (10k/MAG) until the 4276A displays [1/c.v.] ±1 count on DISPLAY A. Verify that the DISPLAY B value is 0±5 counts.

[1K/MAG Adjustment]

10. Set the DISPLAY A range to the 1mS range.

11. Connect the 1kΩ standard resistor directly to the UNKNOWN terminals.

12. Adjust A2R5 (1K/MAG) until the 4276A displays [1/c.v.]±1 count on DISPLAY A. Verify that the DISPLAY B value is 0±5 counts.

[100/MAG Adjustment]

13. Set the DISPLAY A range to the 10mS range.

14. Connect the 100Ω standard resistor directly to the UNKNOWN terminals.

15. Adjust A2R6 (100/MAG) until the 4276A displays [1/c.v.] ±1 count on DISPLAY A. Verify that the DISPLAY B value is 0±5 count.

5-25. *A2 RANGE RESISTOR PHASE ADJUSTMENT*

PURPOSE:

Eliminates the phase shift caused by the range resistor circuit.

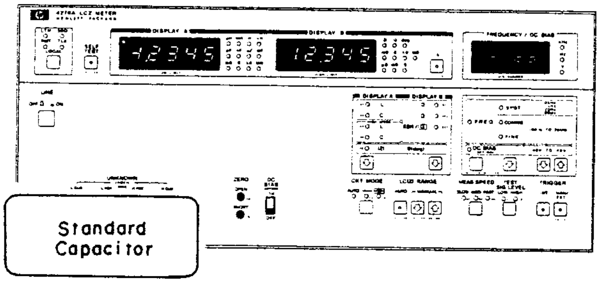


Figure 5-9. A2 Range Resistor Phase Adjustment Setup.

EQUIPMENT:

Standard Capacitor	100pF:	HP 16383A
	1000pF:	HP 16384A

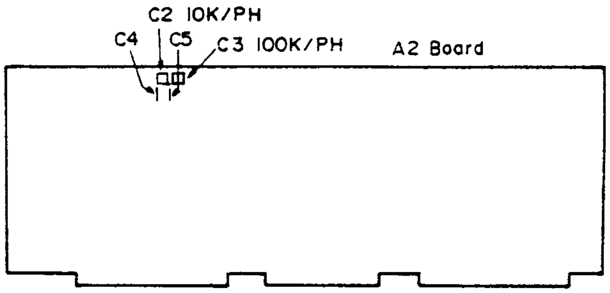
PROCEDURE:

1. Connect the 100pF standard capacitor directly to the UNKNOWN terminals.

2. Reset continuous memory (see Note 2 in paragraph 5-15) and turn on the 4276A.

3. Set the 4276A's controls as follows:

DISPLAY A/B functions	C - D
Test Frequency	10.0kHz
DC BIAS	OFF
CKT MODE	AUTO
LC | Z | RANGE	AUTO
MEAS SPEED	MED
TEST SIG LEVEL	HIGH
TRIGGER	INT



ADJUSTMENTS

4. Adjust A2C3 (100K/PH) until the 4276A displays 0 counts±2 counts on DISPLAY B. Verify that the 4276A displays C.V. ±30 counts on DISPLAY A.

Note

If this test cannot be performed successfully, replace A2C5 in accordance with the instructions given in Table 5-2.

5. Connect the 1000pF standard capacitor directly to the UNKNOWN terminals.
6. Adjust A2C2 (10K/PH) until the 4276A displays 0 counts±2 counts on DISPLAY B. Verify that the 4276A displays C.V.±30 counts on DISPLAY A.

Note

If this test cannot be performed successfully, replace A2C4 in accordance with the instructions given in Table 5-2.

5-26. *INTERNAL DC BIAS ADJUSTMENT (OPTION 001 ONLY)*

PURPOSE:

Adjusts the output voltage of the internal dc bias voltage source.

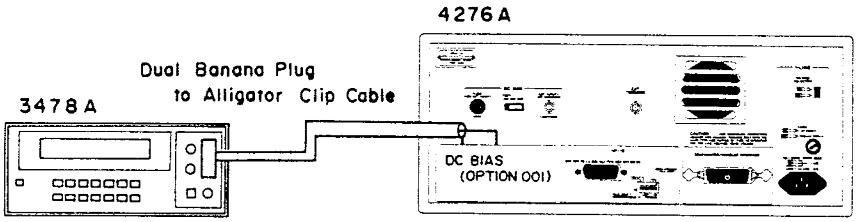


Figure 5-10. Internal DC Bias Adjustment Setup.

EQUIPMENT:

Digital Voltmeter	HP 3478A
Extender Board	HP P/N 04276-66562

PROCEDURE:

1. Extend the A22 DC BIAS board from the rear-panel with the extension board.
2. Set the DC BIAS select switch on the rear panel to INT.
3. Turn on the 4276A.
4. Set the DC BIAS switch on the front panel to ON.
5. Set the 3478A function to DCV.
6. Connect the 3478A HI and LOW inputs to A22TP2 and A22 GND, respectively.
7. Adjust A22R8 until the reading on the 3478A is 0V±0.05mV.
8. Connect the 3478A HI input to A22TP3.
9. Adjust A22R6 (ZERO) until the reading on the 3478A is 0V±0.2mV.
10. Connect the 3478A HI input to the center conductor of the EXT INPUT/INT MONITOR connector on the rear panel.
11. Set the dc bias voltage to +9.99V.
12. Adjust A22R7 (FS) until the reading on the 3478A is +9.99V±0.002V.

SECTION VI
REPLACEABLE PARTS

6-1. INTRODUCTION

6-2. This section contains information for ordering parts. Table 6-1 lists abbreviations used in the parts list and throughout the manual. Table 6-3 lists all replaceable parts in reference designator order. Table 6-2 contains the names and addresses that correspond to the manufacturer's code numbers.

6-3. ABBREVIATIONS

6-4. Table 6-1 lists abbreviations used in parts list, schematics and throughout the manual. In some cases, two forms of abbreviations are used, one in all capital letters, and one in partial capitals or no capitals. This occurs because the abbreviations in parts list are always all capitals. However, in the schematic and in other parts of the manual, other abbreviation forms with both lower case and upper case letters are used.

6-5. REPLACEABLE PARTS LIST

6-6. Table 6-3 is a list of replaceable parts and is organized as follows :

a. Electrical assemblies and their components in alphanumerical order by reference designation.
b. Chassis-mounted parts in alphanumerical order by reference designation.
c. Miscellaneous parts.
d. Illustrated parts breakdowns, if appropriate.

The information for each part includes :

a. The Hewlett-Packard part number.
b. The total quantity (Qty) in the instrument.
c. A description of the part.
d. A typical manufacturer of the part in a five-digit code.
e. The manufacturer's number for the part.

Table 6-1. List of Reference Designators and Abbreviations

REFERENCE DESIGNATORS

A = assembly
B = motor
BT = battery
C = capacitor
CP = coupler
CR = diode
DL = delay line
DS = device signaling (lamp)

E = misc electronic part
F = fuse
FL = filter
J = jack
K = relay
L = inductor
M = meter
MP = mechanical part

P = plug
Q = transistor
R = resistor
RT = thermistor
S = switch
T = transformer
TB = terminal board
TP = test point

U = integrated circuit
V = vacuum, tube, neon bulb, photocell, etc.
VR = voltage regulator
W = cable
X = socket
Y = crystal

ABBREVIATIONS

A = amperes
A. F. C. = automatic frequency control
AMPL = amplifier

B. F. O. = beat frequency oscillator
BE CU = beryllium copper
BH = binder head
BP = bandpass
BRS = brass
BWO = backward wave oscillator

CCW = counter-clockwise
CER = ceramic
CMO = cabinet mount only
COEF = coefficient
COM = common
COMP = composition
COMPL = complete
CONN = connector
CP = cadmium plate
CRT = cathode-ray tube
CW = clockwise

DEPC = deposited carbon
DR = drive

ELECT = electrolytic
ENCAP = encapsulated
EXT = external

F = farads
f = femto = 10^{-15}
FH = flat head
FIL H = fillister head
FXD = fixed

G = giga = 10^{9}
GE = germanium
GL = glass
GRD = ground(ed)

H = henries
HEX = hexagonal
HG = mercury
HR = hour(s)
Hz = hertz

IF = intermediate freq.
IMPG = impregnated
INCD = incandescent
INCL = include(s)
INS = insulation(ed)
INT = internal

k = kilo = 1000

LH = left hand
LIN = linear taper
LK WASH = lock washer
LOG = logarithmic taper
LPF = low pass filter

m = milli = 10^{-3}
M = meg = 10^{6}
MET FLM = metal film
MET OX = metallic oxide
MFR = manufacturer
MINAT = miniature
MOM = momentary
MTG = mounting
MY = "mylar"

n = nano = 10^{-9}
N/C = normally closed
NE = neon
NI PL = nickel plate
N/O = normally open
NPO = negative positive zero (zero temperature coefficient)

NPN = negative-positive-negative
NRFR = not recommended for field replacement
NSR = not separately replaceable

OBD = order by description
OH = oval head
OX = oxide

P = peak
PC = printed circuit
p = pico = 10^{-12}
PH BRZ = phosphor bronze
PHL = Phillips
PIV = peak inverse voltage
PNP = positive-negative-positive
P/O = part of
POLY = polystyrene
PORC = porcelain
POS = position(s)
POT = potentiometer
PP = peak-to-peak
PT = point
PWV = peak working voltage

RECT = rectifier
RF = radio frequency
RH = round head or right hand
RMO = rack mount only
RMS = root-mean square

RWV = reverse working voltage

S-B = slow-blow
SCR = screw
SE = selenium
SECT = section(s)
SEMICON = semiconductor
SI = silicon
SIL = silver
SL = slide
SPG = spring
SPL = special
SST = stainless steel
SR = split ring
STL = steel

TA = tantalum
TD = time delay
TGL = toggle
THD = thread
TI = titanium
TOL = tolerance
TRIM = trimmer
TWT = traveling wave tube

μ = micro = 10^{-6}

VAR = variable
VDCW = dc working volts

W/ = with
W = watts
WIV = working inverse voltage
WW = wirewound
W/O = without

0001-9700

The total quantity for each part is given only once--at the first appearance of the part number in the list.

6-7. ORDERING INFORMATION

6-8. To order a part listed in the replaceable parts table, give the Hewlett-Packard part number, indicate the quantity required, and address the order to the nearest Hewlett-Packard office.

6-9. To order a part that is not listed in the replaceable parts table, state the full instrument model and serial number, and description and function of the part, and the number of parts required. Address your order to the nearest Hewlett-Packard office.

6-10. DIRECT MAIL ORDER SYSTEM

6-11. Within the USA, Hewlett-Packard can supply parts through a direct mail order system. Advantages of using the system are :

a. Direct ordering and shipment from the HP Parts Center in Mountain View, California.

b. No maximum or minimum on any mail order (there is a minimum order amount for parts ordered through a local HP Office when the orders require billing and invoicing).

c. Prepaid transportation (there is a small handling charge for each order).

d. No invoices--to provide these advantages, a check or money order must accompany each order.

6-12. Mail order forms and specific ordering information are available through your local HP Office. Addresses and phone numbers are located at the back of this manual.

Table 6-2. Manufacturers Code Lists

MFR NO.	MANUFACTURER NAME	ADDRESS		ZIP CODE
00000	ANY SATISFACTORY SUPPLIER			
01121	ALLEN-BRADLEY CO	MILWAUKEE	WI	53204
01295	TEXAS INSTR INC SEMICOND CMPNT DIV	DALLAS	TX	75222
02111	SPECTROL ELECTRONICS CORP	CITY OF IND	CA	91745
03508	GE CO SEMICONDUCTOR PROD DEPT	AUBURN	NY	13201
03888	K D I PYROFILM CORP	WHIPPANY	NJ	07981
04713	MOTOROLA SEMICONDUCTOR PRODUCTS	PHOENIX	AZ	85008
05574	VIKING INDUSTRIES INC	CHATSWORTH	CA	91311
07263	FAIRCHILD SEMICONDUCTOR DIV	MOUNTAIN VIEW	CA	94042
14936	GENERAL INSTR CORP SEMICON PROD GP	HICKSVILLE	NY	11802
24355	ANALOG DEVICES INC	NORWOOD	MA	02062
24546	CORNING GLASS WORKS (BRADFORD)	BRADFORD	PA	16701
27014	NATIONAL SEMICONDUCTOR CORP	SANTA CLARA	CA	95051
27167	CORNING GLASS WORKS (WILMINGTON)	WILMINGTON	NC	28401
28480	HEWLETT-PACKARD CO CORPORATE HQ	PALO ALTO	CA	94304
3L585	RCA CORP SOLID STATE DIV	SOMERVILLE	NJ	
30983	MEPCO/ELECTRA CORP	SAN DIEGO	CA	92121
34649	INTEL CORP	MOUNTAIN VIEW	CA	95051
52763	STETTNER-TRUSH INC	CAZENOVIA	NY	13035
56289	SPRAGUE ELECTRIC CO	NORTH ADAMS	MA	01247
72136	ELECTRO MOTIVE CORP	FLORENCE	SC	06226
75042	TRW INC PHILADELPHIA DIV	PHILADELPHIA	PA	19108
75915	LITTELFUSE INC	DES PLAINES	IL	60016
98291	SEALECTRO CORP	MAMARONECK	NY	10544

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A 1	04276-66501	0	1	LOGIC BOARD ASSEMBLY	28480	04276-66501
A1C1	0180-1085	5	13	CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
C2	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
C3	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
C4	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
C5	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
C6	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
C7	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
C8	0180-0197	8	1	CAPACITOR-FXD 2.2UF+-10% 20VDC TA	56289	150D225X9020A2
C9	0160-4832	4	2	CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
C10	0180-3219	1	1	CAPACITOR-FXD 2.2 UF 63VDC	28480	0180-3219
C11	0160-4801	7	1	CAPACITOR-FXD 100PF +-5% 100VDC CER	28480	0160-4801
C12	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
C13	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
C14	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
C15	0180-2951	6	1	CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C16	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
C17	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
C18	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
C19	0160-4832	4		CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
C20	0180-3217	9	2	CAPACITOR-FXD 470UF	28480	0180-3217
C21	0180-3217	9		CAPACITOR-FXD 470UF	28480	0180-3217
A1CR1	1901-0539	3	2	DIODE-SM SIG SCHOTTKY	28490	1901-0539
CR2	1901-0539	3		DIODE-SM SIG SCHOTTKY	28480	1901-0539
A1J1	1200-0607	0	2	SOCKET-IC 16-CONT DIP DIP-SLDR	28480	1200-0607
J2	1200-0607	0		SOCKET-IC 16-CONT DIP DIP-SLDR	28480	1200-0607
J3	1200-0654	7	2	SOCKET-IC 40-CONT DIP DIP-SLDR	28480	1200-0654
J4	1200-0541	1	10	SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
J5	1200-0541	1		SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
J6	1200-0541	1		SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
J7	1200-0541	1		SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
J8	1200-0541	1		SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
J9	1200-0541	1		SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
J10	1200-0541	1		SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
J11	1200-0541	1		SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
J12	1200-0541	1		SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
J13	1200-0541	1		SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
J14	1200-0654	7		SOCKET-IC 40-CONT DIP DIP-SLDR	28480	1200-0654
A1Q1	1854-0810	2	3	TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
Q2	1854-0810	2		TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
Q3	1853-0281	9	1	TRANSISTOR PNP 2N2907A SI TO-18 PD=400MW	04713	2N2907A
Q4	1854-0810	2		TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
Q5	1853-0015	7	1	TRANSISTOR PNP SI PD=200MW FT=500MHZ	28480	1853-0015
A1R1	1810-0488	8	1	NETWORK-RES 8-SIP4.7K OHM X 4	28480	1810-0488
R2	0757-0199	3	1	RESISTOR 21.5K 1% .125W F TC=0+-100	24546	C4-1/8-T0-2152-F
R3	2100-3103	6	1	RESISTOR-TRMR 10K 10% C SIDE-ADJ 17-TRN	02111	43P103
R4	0757-0440	7	1	RESISTOR 7.5K 1% .125W F TC=0+-100	24546	C4-1/8-T0-7501-F
R5	0683-2215	1	1	RESISTOR 220 5% .25W FC TC=-400/+600	01121	CB2215
R6	0683-4715	0	1	RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
R7	1810-0607	3	1	RESISTIVE NETWORK- SIP	28480	1810-0607
R8	0683-1045	3	1	RESISTOR 100K 5% .25W FC TC=-400/+800	01121	CB1045
R9	0683-2245	7	1	RESISTOR 220K 5% .25W FC TC=-800/+900	01121	CB2245
R10	0683-1005	5	2	RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
R11	0683-1025	9	2	RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
R12	0683-5605	9	1	RESISTOR 56 5% .25W FC TC=-400/+500	01121	CB5605
R13	0683-0565	9	1	RESISTOR 5.6 5% .25W FC TC=-400/+500		
R14	0683-1025	9		RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
R15	1810-0305	8	5	NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
R16	1810-0305	8		NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
R17	1810-0269	3	1	NETWORK-RES 9-SIP10.0K OHM X 8	28480	1810-0269
R18	1810-0305	8		NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
R19	1810-0305	8		NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
R20	1810-0305	8		NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
R21	0683-4725	2	5	RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
R22	0683-4725	2		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
R23	0683-4725	2		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
R24	0683-3325	6	1	RESISTOR 3.3K 5% .25W FC TC=-400/+700	01121	CB3325
R25	0683-6825	7	1	RESISTOR 6.8K 5% .25W FC TC=-400/+700	01121	CB6825
R26	0683-4725	2		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
R27	0683-4725	2		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A1S1	3101-1973	7	1	SWITCH-SL 7-1A DIP-SLIDE-ASSY .1A 50VDC	28480	3101-1973

See introduction to this section for ordering information
*Indicates factory selected value

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A1U1	1813-0291	7	1	IC-CRYSTAL 11.52 M	28480	1813-0291
U2	1826-0978	4	1	IC- (MISC)	28480	1826-0978
U3	1826-0180	0	1	IC TIMER TTL MONO/ASTBL	01295	NE555P
U4	1820-2649	8	1	IC- Z80B-CPU	28480	1820-2649
U5	04276-85001	5	1	IC-PROM, PROGRAMMED	28480	04276-85001
U6	04276-85002	6	1	IC-PROM, PROGRAMMED	28480	04276-85002
U7	04276-85003	7	1	IC-PROM, PROGRAMMED	28480	04276-85003
U8	04276-85004	8	1	IC-PROM, PROGRAMMED	28480	04276-85004
U9	04276-85005	9	1	IC-PROM, PROGRAMMED	28480	04276-85005
U10	04276-85006	0	1	IC-PROM, PROGRAMMED	28480	04276-85006
U12	1818-1974	5	1	IC-MSM5128-15	28480	1818-1974
U13	1820-2024	3	2	IC DRVR TTL LS LINE DRVR OCTL	01295	SN74LS244N
U14	1820-2024	3		IC DRVR TTL LS LINE DRVR OCTL	01295	SN74LS244N
U15	1820-1730	6	1	IC FF TTL LS D-TYPE POS-EDGE-TRIG COM	01295	SN74LS273N
U16	1820-1217	4	1	IC MUXR/DATA-SEL TTL LS 8-TO-1-LINE	01295	SN74LS151N
U17	1820-1197	9	4	IC GATE TTL LS NAND QUAD 2-INP	01295	SN74LS00N
U18	1820-1112	8	5	IC FF TTL LS D-TYPE POS-EDGE-TRIG	01295	SN74LS74AN
U19	1820-1197	9		IC GATE TTL LS NAND QUAD 2-INP	01295	SN74LS00N
U20	1820-0682	5	1	IC GATE TTL S NAND QUAD 2-INP	01295	SN74S03N
U21	1820-1197	9		IC GATE TTL LS NAND QUAD 2-INP	01295	SN74LS00N
U22	1820-1216	3	4	IC DCDR TTL LS 3-TO-8-LINE 3-INP	01295	SN74LS138N
U23	1820-1199	1	3	IC INV TTL LS HEX 1-INP	01295	SN74LS04N
U24	1820-0681	4	1	IC GATE TTL S NAND QUAD 2-INP	01295	SN74S00N
U25	1820-2150	6	1	IC MICPROC-ACCESS NMOS	34649	D8279-5
U26	1820-1216	3		IC DCDR TTL LS 3-TO-8-LINE 3-INP	01295	SN74LS138N
U27	1820-1112	8		IC FF TTL LS D-TYPE POS-EDGE-TRIG	01295	SN74LS74AN
U28	1820-1112	8		IC FF TTL LS D-TYPE POS-EDGE-TRIG	01295	SN74LS74AN
U29	1820-1420	1	1	IC CNTR TTL LS DIV-X-12 ASYNCHRO	01295	SN74LS92N
U30	1820-1432	5	2	IC CNTR TTL LS BIN SYNCHRO POS-EDGE-TRIG	01295	SN74LS163AN
U31	1820-1432	5		IC CNTR TTL LS BIN SYNCHRO POS-EDGE-TRIG	01295	SN74LS163AN
U32	1820-1112	8		IC FF TTL LS D-TYPE POS-EDGE-TRIG	01295	SN74LS74AN
U33	1820-1199	1		IC INV TTL LS HEX 1-INP	01295	SN74LS04N
U34	1820-2075	4	1	IC MISC TTL LS	01295	SN74LS245N
U35	1820-1216	3		IC DCDR TTL LS 3-TO-8-LINE 3-INP	01295	SN74LS138N
U36	1820-1624	7	1	IC BFR TTL S OCTL 1-INP	01295	SN74S241N
U37	1820-1199	1		IC INV TTL LS HEX 1-INP	01295	SN74LS04N
U38	1820-1197	9		IC GATE TTL LS NAND QUAD 2-INP	01295	SN74LS00N
U39	1820-2873	0	2	IC-UPD8253-5	28480	1820-2873
U40	1820-2873	0		IC-UPD8253-5	28480	1820-2873
U41	1820-1216	3		IC DCDR TTL LS 3-TO-8-LINE 3-INP	01295	SN74LS138N
U42	1820-1112	8		IC FF TTL LS D-TYPE POS-EDGE-TRIG	01295	SN74LS74AN
U43	1820-1425	6	1	IC SCHMITT-TRIG TTL LS NAND QUAD 2-INP	01295	SN74LS132N
U44	1826-0122	0	1	IC 7805 V RGLTR TO-220	07263	7805UC
A1W1	1251-4822	6	3	CONNECTOR 3-PIN M POST TYPE	28480	1251-4822
W2	1251-4822	6		CONNECTOR 3-PIN M POST TYPE	28480	1251-4822
W3	1251-4822	6		CONNECTOR 3-PIN M POST TYPE	28480	1251-4822
W4	1251-4787	2	1	SHUNT-DIP 8-POSITION	28480	1251-4787
				MISCELLANEOUS PARTS		
	1258-0141	8	3	JUMPER-REM	28480	1258-0141

See introduction to this section for ordering information
*Indicates factory selected value

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A2						
	04276-66502	1	1	ANALOG BOARD ASSEMBLY	28480	04276-66502
A2C1	0160-5499	1	2	CAPACITOR- 0.22UF 100VDC F	28480	0160-5499
C2	0121-0036	0	3	CAPACITOR-V TRMR-CER 5.5-18PF 350V	52763	304324 5.5/18PF NPO
C3	0121-0036	0		CAPACITOR-V TRMR-CER 5.5-18PF 350V	52763	304324 5.5/18PF NPO
C4	0160-4791	4	1	CAPACITOR-FXD 10PF +-5% 100VDC CER 0+-30	28480	0160-4791
C5	0160-4788	9	1	CAPACITOR-FXD 18PF +-5% 100VDC CER 0+-30	28480	0160-4788
C6	0160-3402	2	2	CAPACITOR-FXD 1UF +-5% 50VDC MET-POLYC	28480	0160-3402
C7	0121-0105	4	3	CAPACITOR-V TRMR-CER 9-35PF 200V PC-MTG	52763	304324 9/35PF N650
C8	0160-4835	7	3	CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
C9	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
C10	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
C11	0160-4822	2	2	CAPACITOR-FXD 1000PF +-5% 100VDC CER	28480	0160-4822
C12	0121-0105	4		CAPACITOR-V TRMR-CER 9-35PF 200V PC-MTG	52763	304324 9/35PF N650
C13	0121-0105	4		CAPACITOR-V TRMR-CER 9-35PF 200V PC-MTG	52763	304324 9/35PF N650
C14	0160-2202	8	1	CAPACITOR-FXD 75PF +-5% 300VDC MICA	28480	0160-2202
C15	0160-4789	0	1	CAPACITOR-FXD 15PF +-5% 100VDC CER 0+-30	28480	0160-4789
C16	0140-0196	3	1	CAPACITOR-FXD 150PF +-5% 300VDC MICA	72136	DM15F151J0300WV1CR
C17	0160-4822	2		CAPACITOR-FXD 1000PF +-5% 100VDC CER	28480	0160-4822
C18	0121-0036	0		CAPACITOR-V TRMR-CER 5.5-18PF 350V	52763	304324 5.5/18PF NPO
C19	0160-0127	2	1	CAPACITOR-FXD 1UF +-20% 25VDC CER	28480	0160-0127
C20	0160-1674	6	1	CAPACITOR- .33UF 5% 200VDC	28480	0160-1674
C21	0180-2951	6	24	CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C22	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C23	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C24	0160-4806	2	1	CAPACITOR-FXD 39PF +-5% 100VDC CER 0+-30	28480	0160-4806
C25	0150-0121	5	1	CAPACITOR-FXD .1UF +80-20% 50VDC CER	28480	0150-0121
C26	0160-5499	1		CAPACITOR- 0.22UF 100VDC F	28480	0160-5499
C27	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C28	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C29	0160-5502	7	1	CAPACITOR- 1 UF 63 VDC F	28480	0160-5502
C30	0180-3223	7	2	CAPACITOR-FXD 22 UF 63VDC	28480	0180-3223
C31	0180-3223	7		CAPACITOR-FXD 22 UF 63VDC	28480	0180-3223
C32	0180-3233	9	6	CAPACITOR-FXD 22 UF 25VDCW	28480	0180-3233
C33	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C34	0180-3233	9		CAPACITOR-FXD 22 UF 25VDCW	28480	0180-3233
C35	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C36	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C37	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C38	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C39	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C40	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C41	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C42	0160-0194	3	1	CAPACITOR-FXD .015UF +-10% 200VDC POLYE	28480	0160-0194
C43	0180-0197	8	2	CAPACITOR-FXD 2.2UF+-10% 20VDC TA	56289	150D225X9020A2
C44	0180-0197	8		CAPACITOR-FXD 2.2UF+-10% 20VDC TA	56289	150D225X9020A2
C45	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C46	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C47	0160-4814	2	1	CAPACITOR-FXD 150PF +-5% 100VDC CER	28480	0160-4814
C48	0160-4803	9	2	CAPACITOR-FXD 68PF +-5% 100VDC CER 0+-30	28480	0160-4803
C49	0160-4786	7	1	CAPACITOR-FXD 27PF +-5% 100VDC CER 0+-30	28480	0160-4786
C50	0160-4792	5	1	CAPACITOR-FXD 8.2PF +-.5PF 100VDC CER	28480	0160-4792
C51	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C52	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C53	0180-3233	9		CAPACITOR-FXD 22 UF 25VDCW	28480	0180-3233
C54	0180-3233	9		CAPACITOR-FXD 22 UF 25VDCW	28480	0180-3233
C55	0160-4803	9		CAPACITOR-FXD 68PF +-5% 100VDC CER 0+-30	28480	0160-4803
C56	0160-1603	1	1	C:FXD MY 1 UF 10% 100VDCW	28480	0160-1603
C57	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C58	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C59	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C60	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C61	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C62	0160-5498	0	1	CAPACITOR- 0.01UF 50VDC F	28480	0160-5498
C63	0160-2009	3	1	CAPACITOR-FXD 820PF +-5% 300VDC MICA	28480	0160-2009
C64	0160-3901	6	3	CAPACITOR-FXD 2.2UF +-20% 25VDC CER	28480	0160-3901
C65	0160-3901	6		CAPACITOR-FXD 2.2UF +-20% 25VDC CER	28480	0160-3901
C66	0160-3901	6		CAPACITOR-FXD 2.2UF +-20% 25VDC CER	28480	0160-3901
C67	0180-3233	9		CAPACITOR-FXD 22 UF 25VDCW	28480	0180-3233
C68	0180-3233	9		CAPACITOR-FXD 22 UF 25VDCW	28480	0180-3233
C69	0160-5501	6	1	CAPACITOR- 0.1 UF 100VDC F	28480	0160-5501
C70	0160-5596	9	1	CAPACITOR- 3 PF +/- .5 PF	28480	0160-5596

See introduction to this section for ordering information
*Indicates factory selected value

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A2C71	0160-5594	7	1	CAPACITOR- 1 PF +/- .5 PF	28480	0160-5594
C72	0160-5597	0	1	CAPACITOR- 5 PF +/- .5 PF	28480	0160-5597
C73	0160-3402	2		CAPACITOR-FXD 1UF +-5% 50VDC MET-POLYC	28480	0160-3402
C74	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C75	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C76	0160-4830	2	1	CAPACITOR-FXD 2200PF +-10% 100VDC CER	28480	0160-4830
A2CR1	1901-0376	6	5	DIODE-GEN PRP 35V 50MA DO-35	28480	1901-0376
CR2	1901-0033	2	7	DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
CR3	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
CR4	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
CR5	1902-3059	0	2	DIODE-ZNR 3.83V 5% DO-35 PD=.4W	28480	1902-3059
CR6	1902-3059	0		DIODE-ZNR 3.83V 5% DO-35 PD=.4W	28480	1902-3059
CR7	1901-0040	1	2	DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
CR8	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
CR9	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
CR10	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
CR11	1901-1065	2	4	DIODE-PWR RECT 1N4936 400V 1A 200NS	14936	1N4936
CR12	1901-1065	2		DIODE-PWR RECT 1N4936 400V 1A 200NS	14936	1N4936
CR13	1901-1065	2		DIODE-PWR RECT 1N4936 400V 1A 200NS	14936	1N4936
CR14	1901-1065	2		DIODE-PWR RECT 1N4936 400V 1A 200NS	14936	1N4936
CR15	1901-0376	6		DIODE-GEN PRP 35V 50MA DO-35	28480	1901-0376
CR16	1901-0376	6		DIODE-GEN PRP 35V 50MA DO-35	28480	1901-0376
CR17	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
CR18	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
CR19	1901-0376	6		DIODE-GEN PRP 35V 50MA DO-35	28480	1901-0376
CR20	1901-0376	6		DIODE-GEN PRP 35V 50MA DO-35	28480	1901-0376
A2K1	0490-1269	4	3	RELAY 1C 12VDC-COIL .66A 30VDC	28480	0490-1269
K2	0490-1269	4		RELAY 1C 12VDC-COIL .66A 30VDC	28480	0490-1269
K3	0490-1269	4		RELAY 1C 12VDC-COIL .66A 30VDC	28480	0490-1269
A2Q1	1855-0119	6	4	TRANSISTOR-FET 2SK43	28480	1855-0119
Q2	1855-0119	6		TRANSISTOR-FET 2SK43	28480	1855-0119
Q3	1855-0119	6		TRANSISTOR-FET 2SK43	28480	1855-0119
Q4	1854-0810	2	1	TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
Q5	1853-0459	3	1	TRANSISTOR PNP SI PD=625MW FT=200MHZ	28480	1853-0459
Q6	1855-0119	6		TRANSISTOR-FET 2SK43	28480	1855-0119
A2R1	2100-3352	7	1	RESISTOR-TRMR 1K 10% C SIDE-ADJ 1-TRN	28480	2100-3352
R2	1810-0374	1	2	NETWORK-RES 8-SIP1.0K OHM X 4	01121	208B102
R3	0698-3157	3	1	RESISTOR 19.6K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1962-F
R4	2100-2520	9	1	RESISTOR-TRMR 50 20% C SIDE-ADJ 1-TRN	30983	ET50X500
R5	2100-2583	4	4	RESISTOR-TRMR 10 20% C SIDE-ADJ 1-TRN	30983	ET50X100
R6	2100-2489	9	2	RESISTOR-TRMR 5K 10% C SIDE-ADJ 1-TRN	30983	ET50X502
R7	2100-2574	3	1	RESISTOR-TRMR 500 10% C SIDE-ADJ 1-TRN	30983	ET50X501
R8	1810-0624	4	1	RESISTIVE NETWORK	28480	1810-0624
R9	0699-1018	3	1	RESISTOR-100.95 OHM 0.5W	28480	0699-1018
R10	0757-0346	2	2	RESISTOR 10 1% .125W F TC=0+-100	24546	C4-1/8-T0-10R0-F
R11	0683-5605	9	3	RESISTOR 56 5% .25W FC TC=-400/+500	01121	CB5605
R12	0683-1835	9	7	RESISTOR 18K 5% .25W FC TC=-400/+800	01121	CB1835
R13	2100-3274	2	7	RESISTOR-TRMR 10K 10% C SIDE-ADJ 1-TRN	28480	2100-3274
R14	2100-2514	1	1	RESISTOR-TRMR 20K 10% C SIDE-ADJ 1-TRN	30983	ET50W203
R15	2100-3274	2		RESISTOR-TRMR 10K 10% C SIDE-ADJ 1-TRN	28480	2100-3274
R16	2100-3274	2		RESISTOR-TRMR 10K 10% C SIDE-ADJ 1-TRN	28480	2100-3274
R17	2100-3274	2		RESISTOR-TRMR 10K 10% C SIDE-ADJ 1-TRN	28480	2100-3274
R18	0698-0084	9	2	RESISTOR 2.15K 1% .125W F TC=0+-100	24546	C4-1/8-T0-2151-F
R19	0757-0463	4	1	RESISTOR 82.5K 1% .125W F TC=0+-100	24546	C4-1/8-T0-8252-F
R20	0683-1835	9		RESISTOR 18K 5% .25W FC TC=-400/+800	01121	CB1835
R21	0683-1835	9		RESISTOR 18K 5% .25W FC TC=-400/+800	01121	CB1835
R22	0683-1835	9		RESISTOR 18K 5% .25W FC TC=-400/+800	01121	CB1835
R23	1810-0621	1	2	RESISTIVE NETWORK	28480	1810-0621
R24	0683-1835	9		RESISTOR 18K 5% .25W FC TC=-400/+800	01121	CB1835
R25	2100-3274	2		RESISTOR-TRMR 10K 10% C SIDE-ADJ 1-TRN	28480	2100-3274
R26	2100-2583	4		RESISTOR-TRMR 10 20% C SIDE-ADJ 1-TRN	30983	ET50X100
R27	2100-2583	4		RESISTOR-TRMR 10 20% C SIDE-ADJ 1-TRN	30983	ET50X100
R28	0698-4343	1	1	RESISTOR 100 .1% .125W F TC=0+-50	28480	0698-4343
R29	0698-5453	6	1	RESISTOR 900 .1% .125W F TC=0+-50	03888	PME55 T-2-900R-B
R30	0757-0278	9	1	RESISTOR 1.78K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1781-F
R31	1810-0623	3	1	RESISTIVE NETWORK	28480	1810-0623
R32	0698-3440	7	1	RESISTOR 196 1% .125W F TC=0+-100	24546	C4-1/8-T0-196R-F
R33	0683-1835	9		RESISTOR 18K 5% .25W FC TC=-400/+800	01121	CB1835
R34	0683-1835	9		RESISTOR 18K 5% .25W FC TC=-400/+800	01121	CB1835
R35	2100-2583	4		RESISTOR-TRMR 10 20% C SIDE-ADJ 1-TRN	30983	ET50X100
R36	0757-0280	3	7	RESISTOR 1K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1001-F
R37	0757-0416	7	2	RESISTOR 511 1% .125W F TC=0+-100	24546	C4-1/8-T0-511R-F
R38	0757-0416	7		RESISTOR 511 1% .125W F TC=0+-100	24546	C4-1/8-T0-511R-F
R39	2100-3274	2		RESISTOR-TRMR 10K 10% C SIDE-ADJ 1-TRN	28480	2100-3274
R40	2100-3274	2		RESISTOR-TRMR 10K 10% C SIDE-ADJ 1-TRN	28480	2100-3274

See introduction to this section for ordering information
*Indicates factory selected value

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A2R41	0757-0401	0	6	RESISTOR 100 1% .125W F TC=0+-100	24546	C4-1/8-T0-101-F
R42	1810-0622	2	1	RESISTIVE NETWORK	28480	1810-0622
R43	1810-0374	1		NETWORK-RES 8-SIP1.0K OHM X 4	01121	208B102
R44	1810-0607	3	1	RESISTIVE NETWORK- SIP	28480	1810-0607
R45	0698-3155	1	1	RESISTOR 4.64K 1% .125W F TC=0+-100	24546	C4-1/8-T0-4641-F
R46	0683-4715	0	1	RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
R47	0757-0279	0	1	RESISTOR 3.16K 1% .125W F TC=0+-100	24546	C4-1/8-T0-3161-F
R48	1810-0305	8	5	NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
R49	0683-3335	8	1	RESISTOR 33K 5% .25W FC TC=-400/+800	01121	CB3335
R50	0757-0346	2		RESISTOR 10 1% .125W F TC=0+-100	24546	C4-1/8-T0-10R0-F
R51	0757-1094	9	2	RESISTOR 1.47K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1471-F
R52	0757-0442	9	7	RESISTOR 10K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1002-F
R53	0757-0442	9		RESISTOR 10K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1002-F
R54	0698-3152	8	2	RESISTOR 3.48K 1% .125W F TC=0+-100	24546	C4-1/8-T0-3481-F
R55	0757-0444	1	1	RESISTOR 12.1K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1212-F
R56	0757-0442	9		RESISTOR 10K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1002-F
R57	0757-1094	9		RESISTOR 1.47K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1471-F
R58	0698-0084	9		RESISTOR 2.15K 1% .125W F TC=0+-100	24546	C4-1/8-T0-2151-F
R59	0757-0280	3		RESISTOR 1K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1001-F
R60	0757-0438	3	2	RESISTOR 5.11K 1% .125W F TC=0+-100	24546	C4-1/8-T0-5111-F
R61	1810-0478	6	1	NETWORK-RES 8-SIP22.0K OHM X 4	28480	1810-0478
R62	0683-2265	1	1	RESISTOR 22M 5% .25W FC TC=-900/+1200	01121	CB2265
R63	0698-3152	8		RESISTOR 3.48K 1% .125W F TC=0+-100	24546	C4-1/8-T0-3481-F
R64	0699-1022	9	1	RESISTOR FUSE-47 OHM 1/4W	28480	0699-1022
R65	0683-1005	5	1	RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
R66	0683-1025	9	1	RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
R67	0699-1020	7	1	RESISTOR-470 OHM 1W	28480	0699-1020
R68	1810-0305	8		NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
R69	0757-0401	0		RESISTOR 100 1% .125W F TC=0+-100	24546	C4-1/8-T0-101-F
R70	0757-0442	9		RESISTOR 10K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1002-F
R71	0757-0401	0		RESISTOR 100 1% .125W F TC=0+-100	24546	C4-1/8-T0-101-F
R72	0757-0442	9		RESISTOR 10K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1002-F
R73	0698-0083	8	1	RESISTOR 1.96K 1% .125W F TC=0+-100	24546	C4-1/8-TO-1961-F
R74	0698-0083	8	1	RESISTOR 1.96K 1% .125W F TC=0+-100	24546	C4-1/8-TO-1961-F
R75	0698-3161	9	1	RESISTOR 38.3K 1% .125W F TC=0+-100	24546	C4-1/8-T0-3832-F
R76	0757-0280	3		RESISTOR 1K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1001-F
R77	0757-0280	3		RESISTOR 1K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1001-F
R78	0757-0465	6	1	RESISTOR 100K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1003-F
R79	0683-5605	9		RESISTOR 56 5% .25W FC TC=-400/+500	01121	CB5605
R80	0683-5605	9		RESISTOR 56 5% .25W FC TC=-400/+500	01121	CB5605
R81	0757-0470	3	1	RESISTOR 162K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1623-F
R82	0698-3156	2	1	RESISTOR 14.7K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1472-F
R83	0757-0421	4	1	RESISTOR 825 1% .125W F TC=0+-100	24546	C4-1/8-T0-825R-F
R84	0757-0399	5	1	RESISTOR 82.5 1% .125W F TC=0+-100	24546	C4-1/8-T0-82R5-F
R85	0698-3153	9	1	RESISTOR 3.83K 1% .125W F TC=0+-100	24546	C4-1/8-T0-3831-F
R86	0757-0277	8	1	RESISTOR 49.9 1% .125W F TC=0+-100	24546	C4-1/8-T0-4992-F
R87	0757-0401	0		RESISTOR 100 1% .125W F TC=0+-100	24546	C4-1/8-T0-101-F
R88	0757-0442	9		RESISTOR 10K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1002-F
R89	1810-0305	8		NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
R90	1810-0305	8		NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
R91	1810-0305	8		NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
R92	0757-0280	3		RESISTOR 1K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1001-F
R93	0757-0464	5	1	RESISTOR 90.9K 1% .125W F TC=0+-100	24546	C4-1/8-T0-9092-F
R94	0757-0280	3		RESISTOR 1K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1001-F
R95	0699-1019	4	2	RESISTOR-7.071K OHM 0.1W	28480	0699-1019
R96	0757-0438	3		RESISTOR 5.11K 1% .125W F TC=0+-100	24546	C4-1/8-T0-5111-F
R97	0699-1019	4		RESISTOR-7.071K OHM 0.1W	28480	0699-1019
R98	1810-0621	1		RESISTIVE NETWORK	28480	1810-0621
R99	2100-2517	4	1	RESISTOR-TRMR 50K 10% C SIDE-ADJ 1-TRN	30983	ET50X503
R100	2100-2489	9		RESISTOR-TRMR 5K 10% C SIDE-ADJ 1-TRN	30983	ET50X502
R101	0757-0401	0		RESISTOR 100 1% .125W F TC=0+-100	24546	C4-1/8-T0-101-F
R102	0757-0280	3		RESISTOR 1K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1001-F
R103	0757-0439	4	1	RESISTOR 6.81K 1% .125W F TC=0+-100	24546	C4-1/8-T0-6811-F
R104	0757-0442	9		RESISTOR 10K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1002-F
R105	0698-3160	8	1	RESISTOR 31.6K 1% .125W F TC=0+-100	24546	C4-1/8-T0-3162-F
R106	0757-0401	0		RESISTOR 100 1% .125W F TC=0+-100	24546	C4-1/8-T0-101-F
R107	0683-3315	4	1	RESISTOR 330 5% .25W FC TC=-400/+600	01121	CB3315
A2T1	9100-4252	5	1	TRANSFORMER-PULSE	28480	9100-4252
A2U1	1813-0303	2	3	IC (MISC)	28480	1813-0303
U2	1813-0303	2		IC (MISC)	28480	1813-0303
U3	1813-0303	2		IC (MISC)	28480	1813-0303
U4	1813-0298	4	2	IC (MISC)	28480	1813-0298
U5	1826-0519	9	13	IC OP AMP LOW-BIAS-H-IMPD 8-DIP-P PKG	01295	TL071CP
U6	1820-1545	1	6	IC MULTIPLXR 2-CHAN-ANLG TRIPLE 16-DIP-C	3L585	CD4053BY
U7	1820-2111	9	1	IC DRVR TTL INV	01295	SN75468N
U8	1820-1546	2	3	IC MULTIPLXR 4-CHAN-ANLG DUAL 16-DIP-C	04713	MC14052BCL
U9	1826-0519	9		IC OP AMP LOW-BIAS-H-IMPD 8-DIP-P PKG	01295	TL071CP
U10	1826-0519	9		IC OP AMP LOW-BIAS-H-IMPD 8-DIP-P PKG	01295	TL071CP

See introduction to this section for ordering information
*Indicates factory selected value

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A2 U11	1820-1545	1		IC MULTIPLXR 2-CHAN-ANLG TRIPLE 16-DIP-C	3L585	CD4053BY
U12	1820-1546	2		IC MULTIPLXR 4-CHAN-ANLG DUAL 16-DIP-C	04713	MC14052BCL
U13	1826-0519	9		IC OP AMP LOW-BIAS-H-IMPD 8-DIP-P PKG	01295	TL071CP
U14	1826-0547	3	2	IC OP AMP LOW-BIAS-H-IMPD DUAL 8-DIP-P	01295	TL072ACP
U15	1826-0519	9		IC OP AMP LOW-BIAS-H-IMPD 8-DIP-P PKG	01295	TL071CP
U16	1820-1545	1		IC MULTIPLXR 2-CHAN-ANLG TRIPLE 16-DIP-C	3L585	CD4053BY
U17	1820-1546	2		IC MULTIPLXR 4-CHAN-ANLG DUAL 16-DIP-C	04713	MC14052BCL
U18	1820-1545	1		IC MULTIPLXR 2-CHAN-ANLG TRIPLE 16-DIP-C	3L585	CD4053BY
U19	1826-0519	9		IC OP AMP LOW-BIAS-H-IMPD 8-DIP-P PKG	01295	TL071CP
U20	1826-0519	9		IC OP AMP LOW-BIAS-H-IMPD 8-DIP-P PKG	01295	TL071CP
U21	1820-1545	1		IC MULTIPLXR 2-CHAN-ANLG TRIPLE 16-DIP-C	3L585	CD4053BY
U22	1826-0519	9		IC OP AMP LOW-BIAS-H-IMPD 8-DIP-P PKG	01295	TL071CP
U23	1826-0175	3	1	IC COMPARATOR GP DUAL 14-DIP-P PKG	27014	LM319N
U24	1820-1212	9	1	IC FF TTL LS J-K NEG-EDGE-TRIG	01295	SN74LS112AN
U25	1826-0138	8	1	IC COMPARATOR GP QUAD 14-DIP-P PKG	01295	LM339N
U26	1826-0519	9		IC OP AMP LOW-BIAS-H-IMPD 8-DIP-P PKG	01295	TL071CP
U27	1826-0248	1	1	IC CONV 8-B-D/A 16-DIP-C PKG	04713	MC1408L-6
U28	1813-0297	3	1	IC (MISC)	28480	1813-0297
U29	1816-1533	8	1	IC-MB7051	28480	1816-1533
U30	1820-1442	7	1	IC CNTR TTL LS DECD ASYNCHRO	01295	SN74LS290N
U31	1826-0547	3		IC OP AMP LOW-BIAS-H-IMPD DUAL 8-DIP-P	01295	TL072ACP
U32	1820-1443	8	1	IC CNTR TTL LS BIN ASYNCHRO	01295	SN74LS293N
U33	1820-0683	6	1	IC INV TTL S HEX 1-INP	01295	SN74S04N
U34	1820-0630	3	1	IC MISC TTL	04713	MC4044P
U35	1820-1730	6	4	IC FF TTL LS D-TYPE POS-EDGE-TRIG COM	01295	SN74LS273N
U36	1826-0147	9	5	IC 7812 V RGLTR TO-220	04713	MC7812CP
U37	1826-0221	0	5	IC V RGLTR TO-220	04713	MC7912CT
U38	1826-0122	0	4	IC 7805 V RGLTR TO-220	07263	7805UC
U39	1826-0122	0		IC 7805 V RGLTR TO-220	07263	7805UC
U40	1813-0298	4		IC (MISC)	28480	1813-0298
U41	1826-0519	9		IC OP AMP LOW-BIAS-H-IMPD 8-DIP-P PKG	01295	TL071CP
U42	1826-0519	9		IC OP AMP LOW-BIAS-H-IMPD 8-DIP-P PKG	01295	TL071CP
U43	1826-0519	9		IC OP AMP LOW-BIAS-H-IMPD 8-DIP-P PKG	01295	TL071CP
U44	1826-0147	9		IC 7812 V RGLTR TO-220	04713	MC7812CP
U45	1826-0221	0		IC V RGLTR TO-220	04713	MC7912CT
U46	1826-0221	0		IC V RGLTR TO-220	04713	MC7912CT
U47	1826-0147	9		IC 7812 V RGLTR TO-220	04713	MC7812CP
U48	1820-1545	1		IC MULTIPLXR 2-CHAN-ANLG TRIPLE 16-DIP-C	3L585	CD4053BY
U49	1826-0519	9		IC OP AMP LOW-BIAS-H-IMPD 8-DIP-P PKG	01295	TL071CP
U50	1820-1730	6		IC FF TTL LS D-TYPE POS-EDGE-TRIG COM	01295	SN74LS273N
U51	1820-1730	6		IC FF TTL LS D-TYPE POS-EDGE-TRIG COM	01295	SN74LS273N
U52	1820-1730	6		IC FF TTL LS D-TYPE POS-EDGE-TRIG COM	01295	SN74LS273N
U53	1826-0147	9		IC 7812 V RGLTR TO-220	04713	MC7812CP
U54	1826-0221	0		IC V RGLTR TO-220	04713	MC7912CT
U55	1826-0122	0		IC 7805 V RGLTR TO-220	07263	7805UC
U56	1826-0122	0		IC 7805 V RGLTR TO-220	07263	7805UC
U57	1820-1416	5	1	IC SCHMITT-TRIG TTL LS INV HEX 1-INP	01295	SN74LS14N
U58	1826-0522	4	1	IC OP AMP LOW-BIAS-H-IMPD QUAD 14-DIP-P	01295	TL074CN
U59	1813-0296	2	3	IC (MISC)	28480	1813-0296
U60	1813-0296	2		IC (MISC)	28480	1813-0296
U61	1813-0296	2		IC (MISC)	28480	1813-0296
U62	1820-1975	1	3	IC SHF-RGTR TTL LS NEG-EDGE-TRIG PRL-IN	01295	SN74LS165N
U63	1820-1975	1		IC SHF-RGTR TTL LS NEG-EDGE-TRIG PRL-IN	01295	SN74LS165N
U64	1820-1975	1		IC SHF-RGTR TTL LS NEG-EDGE-TRIG PRL-IN	01295	SN74LS165N
U65	1813-0302	1	1	IC (MISC)	28480	1813-0302
U66	1826-0221	0		IC V RGLTR TO-220	04713	MC7912CT
U67	1826-0147	9		IC 7812 V RGLTR TO-220	04713	MC7812CP
U68	1820-0475	4	1	IC COMPARATOR HS TO-99 PKG	27014	LM306H
A2 W1	8159-0005	0	10	RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
W2	8159-0005	0		RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
W3	8159-0005	0		RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
W4	8159-0005	0		RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
W5	8159-0005	0		RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
W6	8159-0005	0		RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
W7	8159-0005	0		RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
W8	8159-0005	0		RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
W9	8159-0005	0		RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
W10	8159-0005	0		RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
				MISCELLANEOUS PARTS		
	0340-0060	4	4	TERMINAL-STUD SPCL-FDTHRU PRESS-MTG	98291	011-6809 000 209
	0340-0092	2	7	TERMINAL-STUD SPCL-FDTHRU PRESS-MTG	28480	0340-0092
	0340-0220	8	28		28480	0340-0220
	0340-1049	1	14	SPACER-TO220	28480	0340-1049

See introduction to this section for ordering information
*Indicates factory selected value

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A4						
	04276-66504	3	1	POWER SUPPLY BOARD ASSEMBLY	28480	04276-66504
A4C1	0180-1075	3	3	CAPACITOR-FXD 2200 UF 16VDC AL	28480	0180-1075
C2	0180-2980	1	2	CAPACITOR-FXD 1000UF+-20% 35VDC AL	28480	0180-2980
C3	0180-2980	1		CAPACITOR-FXD 1000UF+-20% 35VDC AL	28480	0180-2980
C4	0180-1075	3		CAPACITOR-FXD 2200 UF 16VDC AL	28480	0180-1075
C5	0180-3221	5	6	CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
C6	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
C7	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
C8	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
C9	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
C10	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
C11	0180-1050	4	3	CAPACITOR-FXD 100UF 25VDC	28480	0180-1050
C12	0180-1050	4		CAPACITOR-FXD 100UF 25VDC	28480	0180-1050
C13	0180-1050	4		CAPACITOR-FXD 100UF 25VDC	28480	0180-1050
C14	0160-2055	9	1	CAPACITOR-FXD .01UF +80-20% 100VDC CER	28480	0160-2055
C15	0180-1075	3		CAPACITOR-FXD 2200 UF 16VDC AL	28480	0180-1075
C16	0160-3456	6	1	CAPACITOR-FXD 1000PF +-10% 1KVDC CER	28480	0160-3456
C17	0180-0197	8	1	CAPACITOR-FXD 2.2UF+-10% 20VDC TA	56289	150D225X9020A2
C18	0160-4822	2	1	CAPACITOR-FXD 1000PF +-5% 100VDC CER	28480	0160-4822
C19	0180-0291	3	1	CAPACITOR-FXD 1UF+-10% 35VDC TA	56289	150D105X9035A2
C20	0160-3094	8	1	CAPACITOR-FXD .1UF +-10% 100VDC CER	28480	0160-3094
C21	0180-1704	5	1	CAPACITOR-FXD 47UF+-10% 6VDC TA	56289	150D476X9006B2
C22	0180-0228	6	2	CAPACITOR-FXD 22UF+-10% 15VDC TA	56289	150D226X9015B2
C23	0160-0127	2	3	CAPACITOR-FXD 1UF +-20% 25VDC CER	28480	0160-0127
C24	0160-0127	2		CAPACITOR-FXD 1UF +-20% 25VDC CER	28480	0160-0127
C25	0160-4593	4	2	CAPACITOR-FXD 1.5UF +-20% 400VDC	28480	0160-4593
C26	0160-0127	2		CAPACITOR-FXD 1UF +-20% 25VDC CER	28480	0160-0127
C27	0180-1746	5	1	CAPACITOR-FXD 15UF+-10% 20VDC TA	56289	150D156X9020B2
C28	0160-4593	4		CAPACITOR-FXD 1.5UF +-20% 400VDC	28480	0160-4593
C29	0180-3231	7	4	CAPACITOR-FXD 4.7 UF 450VDC	28480	0180-3231
C30	0180-3231	7		CAPACITOR-FXD 4.7 UF 450VDC	28480	0180-3231
C31	0180-3231	7		CAPACITOR-FXD 4.7 UF 450VDC	28480	0180-3231
C32	0180-3231	7		CAPACITOR-FXD 4.7 UF 450VDC	28480	0180-3231
C33	0180-3253	6	2	CAPACITOR-FXD 470 UF 200VDC	28480	0180-3253
C34	0180-3253	6		CAPACITOR-FXD 470 UF 200VDC	28480	0180-3253
C35	0160-3969	6	2	CAPACITOR-FXD .015UF +-20PF 250VAC(RMS)	28480	0160-3969
C36	0160-3969	6		CAPACITOR-FXD .015UF +-20PF 250VAC(RMS)	28480	0160-3969
C37	0180-0228	6		CAPACITOR-FXD 22UF+-10% 15VDC TA	56289	150D226X9015B2
A4CR1	1902-1217	8	1	DIODE-ZNR 6.2V 5% DO-4 PD=10W TC=+.035%	28480	1902-1217
CR2	1902-3234	3	2	DIODE-ZNR 19.6V 5% DO-35 PD=.4W	28480	1902-3234
CR3	1902-3234	3		DIODE-ZNR 19.6V 5% DO-35 PD=.4W	28480	1902-3234
CR4	1901-0025	2	11	DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
CR5	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
CR6	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
CR7	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
CR8	1901-0691	8	6	DIODE-PWR RECT 100V 3A 200NS	03508	A115A
CR9	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
CR10	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
CR11	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
CR12	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
CR13	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
CR14	1901-0969	3	2	DIODE-POWER RECT.	28480	1901-0969
CR15	1901-0969	3		DIODE-POWER RECT.	28480	1901-0969
CR16	1902-3182	0	1	DIODE-ZNR 12.1V 5% DO-35 PD=.4W	28480	1902-3182
CR17	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
CR18	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
CR19	1902-3203	6	1	DIODE-ZNR 14.7V 5% DO-35 PD=.4W	28480	1902-3203
CR20	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
CR21	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
CR22	1902-0555	5	1	DIODE-ZNR 13V 5% PD=1W IR=5UA	28480	1902-0555
CR23	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
CR24	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
CR25	1901-1065	2	3	DIODE-PWR RECT 1N4936 400V 1A 200NS	14936	1N4936
CR26	1901-1065	2		DIODE-PWR RECT 1N4936 400V 1A 200NS	14936	1N4936
CR27	1901-1065	2		DIODE-PWR RECT 1N4936 400V 1A 200NS	14936	1N4936
CR28	1902-3191	1	1	DIODE-ZNR 13V 2% DO-35 PD=.4W TC=+.06%	28480	1902-3191
CR29	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
CR30	1906-0080	9	1	DIODE-FW BRDG 600V 10A	28480	1906-0080
A4F1	2110-0004	1	1	FUSE .25A 250V NTD 1.25X.25 UL	28480	2110-0004
F2	2110-0305	5	1	FUSE 1.25A 250V TD 1.25X.25 UL	75915	3131.25
F3	2110-0007	4	1	FUSE 1A 250V TD 1.25X.25 UL	75915	313001

See introduction to this section for ordering information
*Indicates factory selected value

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A4J1	1251-4938	5	1	CONNECTOR 3-PIN M METRIC POST TYPE	28480	1251-4938
J2	1251-3837	1	1	CONNECTOR 4-PIN M UTILITY	28480	1251-3837
A4L1	9100-3139	5	1	INDUCTOR 75UH 15% .5DX.875LG	28480	9100-3139
L2	9140-0758	3	1	INDUCTOR- 787 UH	28480	9140-0758
L3	9140-0171	3	4	INDUCTOR RF-CH-MLD 40UH 10% .296DX.968LG	28480	9140-0171
L4	9140-0171	3		INDUCTOR RF-CH-MLD 40UH 10% .296DX.968LG	28480	9140-0171
L5	9140-0462	5	1	INDUCTOR 355UH	28480	9140-0462
L6	9140-0757	0	1	INDUCTOR- 980 UH	28480	9140-0757
L7	9140-0171	3		INDUCTOR RF-CH-MLD 40UH 10% .296DX.968LG	28480	9140-0171
L8	9140-0463	6	1	INDUCTOR 10MH 6%	28480	9140-0463
L9	9140-0171	3		INDUCTOR RF-CH-MLD 40UH 10% .296DX.968LG	28480	9140-0171
L10	9140-0210	1	1	INDUCTOR RF-CH-MLD 100UH 5% .166DX.385LG	28480	9140-0210
A4Q1	1853-0281	9	3	TRANSISTOR PNP 2N2907A SI TO-18 PD=400MW	04713	2N2907A
Q2	1854-0477	7	5	TRANSISTOR NPN 2N2222A SI TO-18 PD=500MW	04713	2N2222A
Q3	1854-0477	7		TRANSISTOR NPN 2N2222A SI TO-18 PD=500MW	04713	2N2222A
Q4	1854-0477	7		TRANSISTOR NPN 2N2222A SI TO-18 PD=500MW	04713	2N2222A
Q5	1853-0281	9		TRANSISTOR PNP 2N2907A SI TO-18 PD=400MW	04713	2N2907A
Q6	1854-0477	7		TRANSISTOR NPN 2N2222A SI TO-18 PD=500MW	04713	2N2222A
Q7	1853-0281	9		TRANSISTOR PNP 2N2907A SI TO-18 PD=400MW	04713	2N2907A
Q8	1854-0624	6	2	TRANSISTOR NPN 2N6308 SI TO-3 PD=125W	04713	2N6308
Q9	1854-0624	6		TRANSISTOR NPN 2N6308 SI TO-3 PD=125W	04713	2N6308
Q10	1854-0935	2	1	TRANSISTOR-NPN	28480	1854-0935
Q11	1854-0936	3	1	TRANSISTOR-NPN	28480	1854-0936
Q12	1854-0477	7		TRANSISTOR NPN 2N2222A SI TO-18 PD=500MW	04713	2N2222A
A4R1	0683-2235	5	1	RESISTOR 22K 5% .25W FC TC=-400/+800	01121	CB2235
R2	0683-4705	8	3	RESISTOR 47 5% .25W FC TC=-400/+500	01121	CB4705
R3	0683-1005	5	3	RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
R4	0683-1515	2	1	RESISTOR 150 5% .25W FC TC=-400/+600	01121	CB1515
R5	0683-4715	0	3	RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
R6	0683-4715	0		RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
R7	0683-4735	4	2	RESISTOR 47K 5% .25W FC TC=-400/+800	01121	CB4735
R8	0683-4735	4		RESISTOR 47K 5% .25W FC TC=-400/+800	01121	CB4735
R9	0683-4715	0		RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
R10	0683-1525	4	2	RESISTOR 1.5K 5% .25W FC TC=-400/+700	01121	CB1525
R11	0683-1525	4		RESISTOR 1.5K 5% .25W FC TC=-400/+700	01121	CB1525
R12	0683-4705	8		RESISTOR 47 5% .25W FC TC=-400/+500	01121	CB4705
R13	0683-4705	8		RESISTOR 47 5% .25W FC TC=-400/+500	01121	CB4705
R14	2100-3352	7	1	RESISTOR-TRMR 1K 10% C SIDE-ADJ 1-TRN	28480	2100-3352
R15	2100-3274	2	1	RESISTOR-TRMR 10K 10% C SIDE-ADJ 1-TRN	28480	2100-3274
R16	0683-1025	9	1	RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
R17	0764-0015	7	1	RESISTOR 560 5% 2W MO TC=0+-200	28480	0764-0015
R18	0683-0335	2	2	RESISTOR 3.3 5% .25W FC TC=-400/+500	01121	CB33G5
R19	0683-1005	5		RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
R20	0683-0335	2		RESISTOR 3.3 5% .25W FC TC=-400/+500	01121	CB33G5
R21	0683-1005	5		RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
R22	0683-5615	1	1	RESISTOR 560 5% .25W FC TC=-400/+600	01121	CB5615
R23	0683-1035	1	1	RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
R24	0683-0275	9	4	RESISTOR 2.7 5% .25W FC TC=-400/+500	01121	CB27G5
R25	0683-0275	9		RESISTOR 2.7 5% .25W FC TC=-400/+500	01121	CB27G5
R26	0683-0275	9		RESISTOR 2.7 5% .25W FC TC=-400/+500	01121	CB27G5
R27	0683-0275	9		RESISTOR 2.7 5% .25W FC TC=-400/+500	01121	CB27G5
R28	0766-0033	3	1	RESISTOR 2K 2% 3W MO TC=0+-250	27167	FP3-3-250-2001-G
R29	0761-0004	8	1	RESISTOR 20K 5% 1W MO TC=0+-200	28480	0761-0004
R30	0699-1057	4	1	RESISTOR 15 10% 3W	28480	0699-1057
R31	0686-3945	2	1	RESISTOR 390K 5% .5W CC TC=0+882	01121	EB3945
R32	0683-5635	5	1	RESISTOR 56K 5% .25W FC TC=-400/+800	01121	CB5635
R33	0686-1055	1	1	RESISTOR 1M 5% .5W CC TC=0+1000	01121	EB1055
R34	0698-3657	8	2	RESISTOR 68K 5% 2W MO TC=0+-200	27167	FP42-2-T00-6802-J
R35	0698-3657	8		RESISTOR 68K 5% 2W MO TC=0+-200	27167	FP42-2-T00-6802-J
R36	0811-1670	3	1	RESISTOR 2.2 5% 2W PW TC=0+-400	75042	BWH2-2R2-J
A4RT1	0839-0006	5	1	THERMISTOR DISC	28480	0839-0006
A4RV1	0837-0237	0	1	VARISTOR	28480	0837-0237
RV2	0837-0106	2	1	VARISTOR	28480	0837-0106
A4T1	9100-4287	1	1	TRANSFORMER-POWER	28480	9100-4287
T2	9100-0857	8	1	TRANSFORMER-PULSE 114H1	28480	9100-0857
T3	9100-4293	2	1	TRANSFORMER-PULSE	28480	9100-4293
A4U1	1813-0255	3	1	IC-REGULATOR HYBRID	28480	1813-0255
A4W1	8159-0005	0	1	RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
				MISCELLANEOUS PARTS		
	0340-0060	4	1	TERMINAL-STUD SPCL-FDTHRU PRESS-MTG	98291	011-6809 000 209
	0340-0092	2	1	TERMINAL-STUD SPCL-FDTHRU PRESS-MTG	28480	0340-0092
	0340-0220	8	5		28480	0340-0220
	0380-0465	7	3	SPACER-RND .188-IN-LG .194-IN-ID	28480	0380-0465
	2110-0269	0	6	FUSEHOLDER-CLIP TYPE.25D-FUSE	28480	2110-0269

See introduction to this section for ordering information
*Indicates factory selected value

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
	2360-0115	4	6	SCREW-MACH 6-32 .312-IN-LG PAN-HD-POZI	00000	ORDER BY DESCRIPTION
	2740-0003	5	1	NUT-HEX-W/LKWR 10-32-THD .125-IN-THK	00000	ORDER BY DESCRIPTION
	04276-01204	4	1	ANGLE (HEATSINK)	28480	04276-01204

See introduction to this section for ordering information
*Indicates factory selected value

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A5						
	04276-66505	4	1	DISPLAY BOARD ASSEMBLY	28480	04276-66505
A5C1	0180-1085	5	4	CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
C2	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
C3	0180-3218	0	1	CAPACIOTOR-FXD 1 UF 63VDC AL	28480	0180-3218
C4	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
C5	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A5DS1	1990-0540	3	10	DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
DS2	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
DS3	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
DS4	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
DS5	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
DS6	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
DS7	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
DS8	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
DS9	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
DS10	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
DS11	1990-0531	2	4	DISPLAY-NUM-SEG 1-CHAR .3-H	28480	5082-7610
DS12	1990-0531	2		DISPLAY-NUM-SEG 1-CHAR .3-H	28480	5082-7610
DS13	1990-0531	2		DISPLAY-NUM-SEG 1-CHAR .3-H	28480	5082-7610
DS14	1990-0531	2		DISPLAY-NUM-SEG 1-CHAR .3-H	28480	5082-7610
DS15	1990-0486	6	51	LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS16	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS17	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS18	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS19	1990-0665	3	5	LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	1990-0665
DS20	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS21	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS22	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS23	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS24	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS25	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS26	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS27	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS28	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS29	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS30	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS31	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS32	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS33	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS34	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS35	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS36	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS37	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS38	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS39	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS40	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS41	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS42	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS43	1990-0665	3		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	1990-0665
DS44	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS45	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS46	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS47	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS48	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS49	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS50	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS51	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS52	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS53	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS54	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS55	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS56	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS57	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS58	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS59	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS60	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS61	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS62	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS63	1990-0665	3		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	1990-0665
DS64	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS65	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684

See introduction to this section for ordering information
*Indicates factory selected value

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A5DS66	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS67	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS68	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
DS69	1990-0665	3		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	1990-0665
DS70	1990-0665	3		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	1990-0665
A5J1 THRU J14	1200-0638	7	14	SOCKET-IC 14-CONT DIP DIP-SLDR	28480	1200-0638
A5R1	1810-0301	4	2	NETWORK-RES 16-DIP51.0 OHM X 8	01121	316B510
R2	1810-0627	7	3	RESISTIVE NETWORK	28480	1810-0627
R3	1810-0301	4		NETWORK-RES 16-DIP51.0 OHM X 8	01121	316B510
R4	1810-0627	7		RESISTIVE NETWORK	28480	1810-0627
R5	1810-0627	7		RESISTIVE NETWORK	28480	1810-0627
R7	0683-4725	2	1	RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A5S1	5060-9436	7	17	PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
S2	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
S3	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
S4	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
S5	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
S6	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
S7	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
S8	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
S9	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
S11	3101-1074	9	2	SWITCH-PUSHBUTTON SPST NO	28480	3101-1074
S12	3101-1074	9		SWITCH-PUSHBUTTON SPST NO	28480	3101-1074
S13	3101-2046	7	1	SWITCH-SLIDE DPDT-NS	28480	3101-2046
S14	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
S15	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
S16	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
S17	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
S18	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
S19	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
S20	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
S21	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5U1	1858-0038	4	4	TRANSISTOR ARRAY	28480	1858-0038
U2	1820-0495	8	1	IC DCDR TTL 4-TO-16-LINE 4-INP	01295	SN74154N
U3	1820-1624	7	2	IC BFR TTL S OCTL 1-INP	01295	SN74S241N
U4	1820-1624	7		IC BFR TTL S OCTL 1-INP	01295	SN74S241N
U5	1858-0038	4		TRANSISTOR ARRAY	28480	1858-0038
U6	1858-0038	4		TRANSISTOR ARRAY	28480	1858-0038
U7	1858-0038	4		TRANSISTOR ARRAY	28480	1858-0038
U8	1820-1216	3	1	IC DCDR TTL LS 3-TO-8-LINE 3-INP	01295	SN74LS138N
U9	1816-1533	8	1	IC-MB7051	28480	1816-1533
				MISCELLANEOUS PARTS		
	0360-1901	6	1	CABLE TRANSISTION	28480	0360-1901
	5041-0309	5	3	KEY CAP	28480	5041-0309
	5041-0318	6	3	KEY CAP	28480	5041-0318
	5041-0375	5	1	KEY CAP-QUARTER(SMOKE)	28480	5041-0375
	5041-0384	6	2	KEY CAP-QUARTER(SMOKE)	28480	5041-0384
	5041-0922	8	8	KEY CAP-QUARTER(EBY PEARL)	28480	5041-0922
	04191-40002	0	1	INSULATOR	28480	04191-40002
	04262-40001	5	6	INSULATOR	28480	04262-40001
	04274-40003	1	3	INSULATOR	28480	04274-40003
	04276-61641	9	1	CABLE ASSEMBLY-FLAT	28480	04276-61641
	5040-3323		1	INSULATOR		

See introduction to this section for ordering information
*Indicates factory selected value

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A6						
	04276-66506	5	1	MOTHER BOARD ASSEMBLY	28480	04276-66506
A6BT1	1420-0306	2	1	BATTERY- 2.4V	28480	1420-0306
A6J1	1251-7845	9	1	CONNECTOR- 6 PIN, MALE	28480	1251-7845
J2	1251-5382	5	1	CONNECTOR 4-PIN M METRIC POST TYPE	28480	1251-5382
J4	1251-0541	8	1	CONNECTOR 34-PIN M RECTANGULAR	28480	1251-0541
A6U1	1813-0304	3	1	IC (MISC) SIP	28480	1813-0304
A6XA1L	1251-2582	1	5	CONNECTOR-PC EDGE 24-CONT/ROW 2-ROWS	28480	1251-2582
XA1R	1251-2582	1		CONNECTOR-PC EDGE 24-CONT/ROW 2-ROWS	28480	1251-2582
XA2C	1251-2026	8	2	CONNECTOR-PC EDGE 18-CONT/ROW 2-ROWS	28480	1251-2026
XA2L	1251-2582	1		CONNECTOR-PC EDGE 24-CONT/ROW 2-ROWS	28480	1251-2582
XA2R	1251-2582	1		CONNECTOR-PC EDGE 24-CONT/ROW 2-ROWS	28480	1251-2582
XA4C	1251-2026	8		CONNECTOR-PC EDGE 18-CONT/ROW 2-ROWS	28480	1251-2026
XA4R	1251-2582	1		CONNECTOR-PC EDGE 24-CONT/ROW 2-ROWS	28480	1251-2582
XA21	1251-4978	3	3	CONNECTOR-PC EDGE 18-CONT/ROW 2-ROWS	05574	000231-3944
XA22	1251-4978	3		CONNECTOR-PC EDGE 18-CONT/ROW 2-ROWS	05574	000231-3944
XA23	1251-4978	3		CONNECTOR-PC EDGE 18-CONT/ROW 2-ROWS	05574	000231-3944
				MISCELLANEOUS PARTS		
	0360-1244	0	4	TERMINAL-SPECIAL-FEEDTHRU	28480	0360-1244

Table 6-3. Replaceable Parts

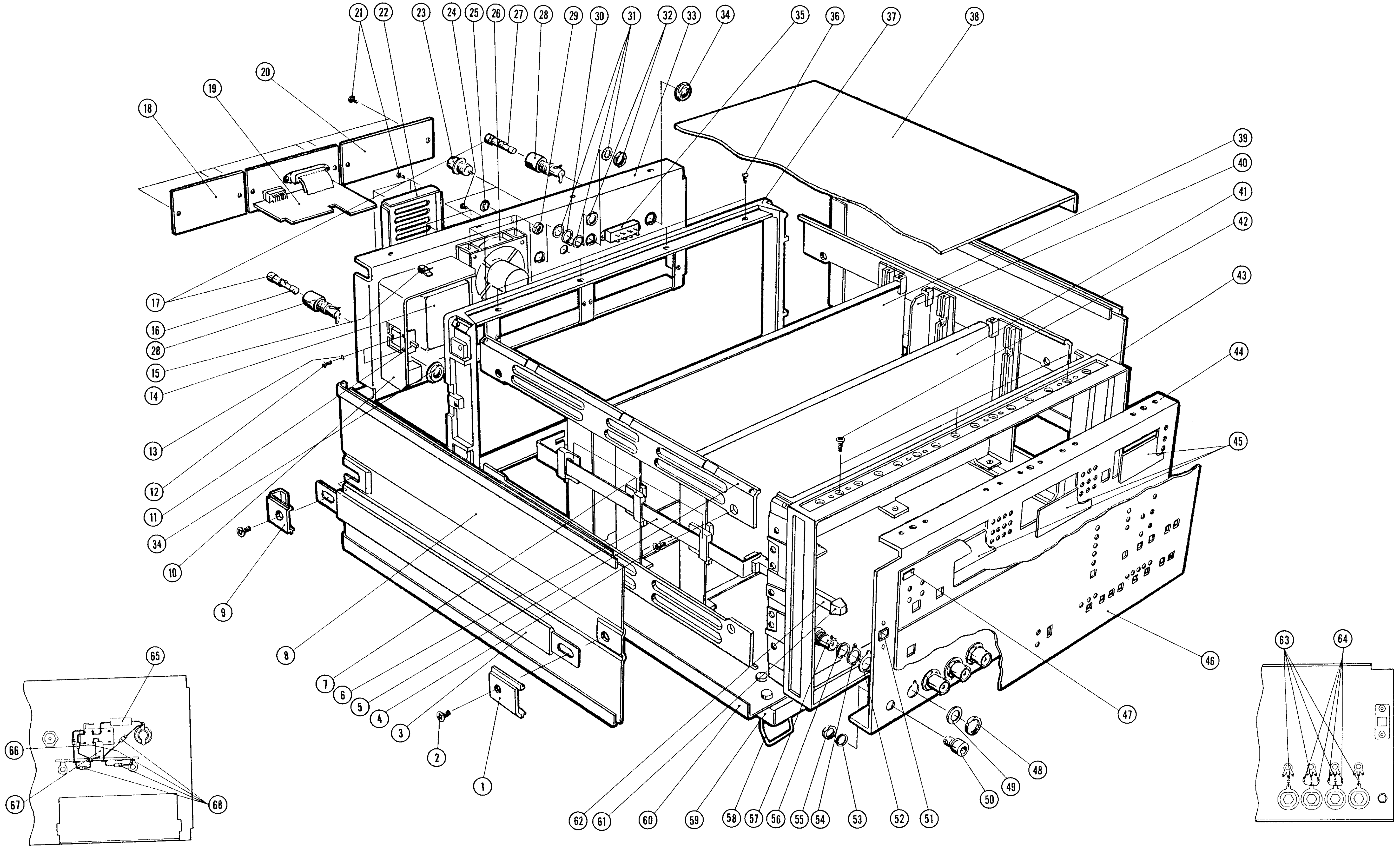
Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A21						
	04276-66521	4	1	HP-IB BOARD ASSEMBLY	28480	04276-66521
A21 C1	0180-2981	2	1	CAPACITOR-FXD 220UF+-20% 10VDC AL	28480	0180-2981
C2	0180-1085	5	1	CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A21 J1	1200-0485	2	1	SOCKET-IC 14-CONT DIP DIP-SLDR	28480	1200-0485
J2	1200-0654	7	1	SOCKET-IC 40-CONT DIP DIP-SLDR	28480	1200-0654
A21 R1	1810-0305	8	1	NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
R2	0683-4725	2	3	RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
R3	0683-4725	2		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
R4	0683-4725	2		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A21 S1	3101-1973	7	1	SWITCH-SL 7-1A DIP-SLIDE-ASSY .1A 50VDC	28480	3101-1973
A21 U1	1820-2024	3	1	IC DRVR TTL LS LINE DRVR OCTL	01295	SN74LS244N
U2	1820-2058	3	4	IC MISC TTL S QUAD	07263	MC3448AL
U3	1820-2058	3		IC MISC TTL S QUAD	07263	MC3448AL
U4	1820-2549	7	1	IC-8291A P HPIB	28480	1820-2549
U5	1820-1199	1	1	IC INV TTL LS HEX 1-INP	01295	SN74LS04N
U6	1820-2058	3		IC MISC TTL S QUAD	07263	MC3448AL
U7	1820-2058	3		IC MISC TTL S QUAD	07263	MC3448AL
U8	1820-2075	4	1	IC MISC TTL LS	01295	SN74LS245N
A21 W1	8159-0005	0	1	RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
				MISCELLANEOUS PARTS		
	2360-0113	2	2	SCREW-MACH 6-32 .25-IN-LG PAN-HD-POZI	00000	ORDER BY DESCRIPTION
	04276-00604	6	1	PLATE (HP-IB)	28480	04276-00604
	04276-61661	3	1	CABLE ASSEMBLY	28480	04276-61661
A22						
				OPTION 001		
	04276-66522	5	1	INTERNAL DC BIAS BOARD ASSEMBLY	28480	04276-66522
A22 C1	0180-2951	6	4	CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C2	0160-5498	9	1	CAPACITOR-FXD .01UF +80-20% 100VDC CER		
C3	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C4	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C5	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
C6	0180-3220	4	2	CAPACITOR-FXD 10 UF 63VDC AL	28480	0180-3220
C7	0180-3220	4		CAPACITOR-FXD 10 UF 63VDC AL	28480	0180-3220
C8	0150-5599	5	1	CAPACITOR-FXD .1UF +80-20% 50VDC CER		
C9	0160-5498	4	2	CAPACITOR-FXD .01UF +-10% 100VDC CER		
C10	0160-1631	6	1	CAPACITOR-FXD 1000PF +-10% 1KVDC CER		
C11	0160-5498	4		CAPACITOR-FXD .01UF +-10% 100VDC CER		
A22 CR1	1902-0692	1	1	DIODE-ZNR 6.3V 1% DO-7 PD=.4W TC=+.001%	28480	1902-0692
CR2	1901-0040	1	2	DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
CR3	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A22 Q1	1854-0358	3	2	TRANSISTOR NPN SI PD=310MW FT=60MHZ	28480	1854-0358
Q2	1853-0080	6	2	TRANSISTOR PNP SI PD=300MW FT=30MHZ	28480	1853-0080
Q3	1853-0080	6		TRANSISTOR PNP SI PD=300MW FT=30MHZ	28480	1853-0080
Q4	1854-0358	3		TRANSISTOR NPN SI PD=310MW FT=60MHZ	28480	1854-0358
Q5	1854-0523	4	1	TRANSISTOR NPN SI TO-39 PD=1W FT=150MHZ	28480	1854-0523
Q6	1853-0037	3	1	TRANSISTOR PNP SI TO-39 PD=1W FT=100MHZ	28480	1853-0037
A22 R1	1810-0629	9	1	RESISTIVE NETWORK- DIP	28480	1810-0629
R2	1810-0625	5	1	RESISTIVE NETWORK- DIP	28480	1810-0625
R3	1810-0302	5	1	NETWORK-RES 8-SIP47.0 OHM X 4	01121	208B470
R4	0699-1020	7	1	RESISTOR- 470 OHM 1%	28480	0699-1020
R5	0683-2255	9	1	RESISTOR 2.2M 5% .25W FC TC=-900/+1100	01121	CB2255
R6	2100-3214	0	2	RESISTOR-TRMR 100K 10% C TOP-ADJ 1-TRN	28480	2100-3214
R7	2100-0567	0	1	RESISTOR-TRMR 2K 10% C TOP-ADJ 1-TRN	28480	2100-0567
R8	2100-3214	0		RESISTOR-TRMR 100K 10% C TOP-ADJ 1-TRN	28480	2100-3214
R9	0683-3355	2	1	RESISTOR 3.3M 5% .25W FC TC=-900/+1100	01121	CB3355
R10	0683-1035	1	1	RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A22 U1	1820-1730	6	2	IC FF TTL LS D-TYPE POS-EDGE-TRIG COM	01295	SN74LS273N
U2	1820-1730	6		IC FF TTL LS D-TYPE POS-EDGE-TRIG COM	01295	SN74LS273N
U3	1826-0485	8	1	IC CONV 10-B-D/A 16-DIP-P PKG	24355	AD7530LN
U4	1826-0416	5	1	IC SWITCH ANLG QUAD 16-DIP-C PKG	27014	LF13331D
U5	1826-0522	4	1	IC OP AMP LOW-BIAS-H-IMPD QUAD 14-DIP-P	01295	TL074CN
U6	1826-0275	4	1	IC 78L12A V RGLTR TO-92	04713	MC78L12ACP
U7	1826-0282	3	1	IC V RGLTR TO-92	04713	MC79L12ACP
				MISCELLANEOUS PARTS		
	2360-0113	2	2	SCREW-MACH 6-32 .25-IN-LG PAN-HD-POZI	00000	ORDER BY DESCRIPTION
	04276-00605	7	1	PLATE (DC BIAS)	28480	04276-00605

See introduction to this section for ordering information
*Indicates factory selected value

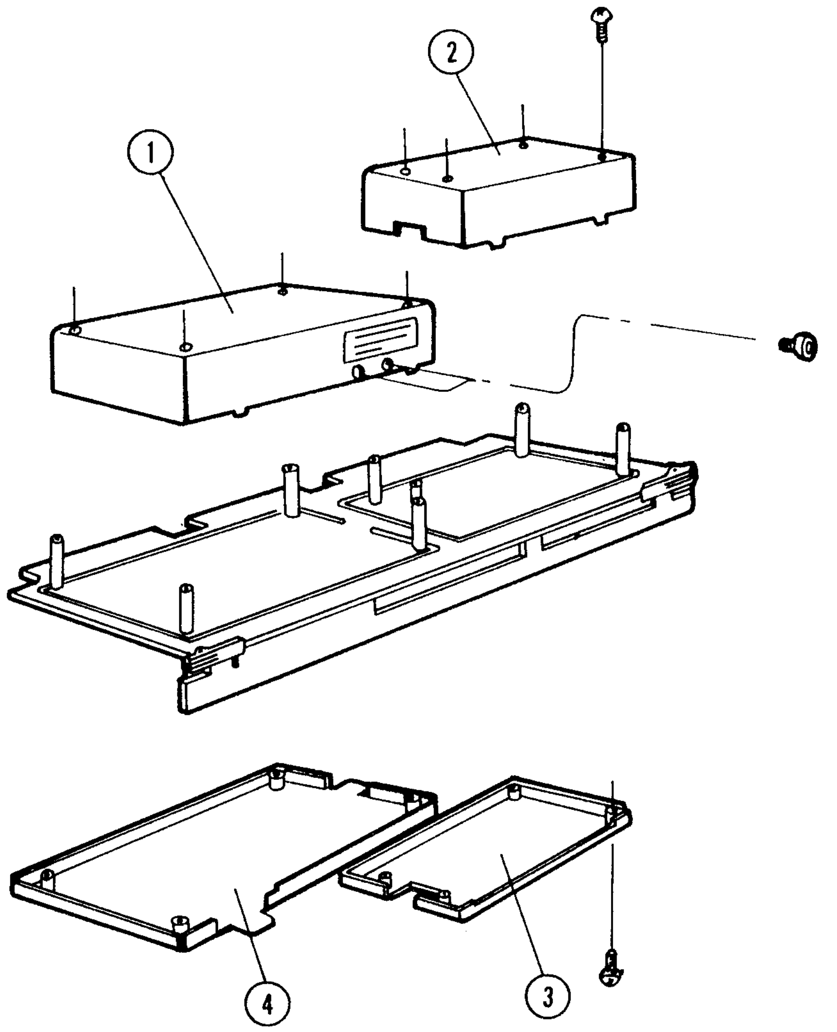
Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
1	5040-7219		2	STRAP HANDLE CAP (FRONT)		
2	2680-0172		4	SCREW		
3	5060-9803		2	STRAP HANDLE		
4	2510-0192		16	SCREW		
5	5020-8836		4	STRUT		
6	04276-01202		1	ANGLE (POWER SWITCH)		
7	04274-40002		3	GUIDE (ANGLE)		
8	5060-9941		2	SIDE COVER		
9	5040-7220		2	STRAP HANDLE CAP (REAR)		
10	04276-01201		1	ANGLE		
11	3101-2216		1	LINE SWITCH		
12	0515-0150		2	SCREW		
13	3050-0235		2	WASHER		
14	9135-0084		1	LINE FILTER		
15	1400-0866		1	CABLE CLAMP		
16	2110-0360		1	FUSE .75A 250V (220/240V) SLOW BLOW		
	2100-0007		1	FUSE 1A 250V (100/120V) SLOW BLOW		
17	2110-0565		2	FUSEHOLDER CAP		
18	04276-00603		1	BLANK PANEL (COMPARATOR/HANDLER INTERFACE)		
19	04276-66521		1	HP-IB BOARD		
20	04276-00602		1	BLANK PANEL (INTERNAL DC BIAS)		
21	2360-0113		10	SCREW		
22	04276-04001		1	FAN COVER		
23	1250-0118		2	CONNECTOR-BNC		
24	2200-0105		4	SCREW		
25	6960-0001		1	CAP		
26	3160-0266		1	FAN		
27	2110-0011		1	FUSE 1/16A 250V		
28	2110-0564		2	FUSEHOLDER BODY		
29	2260-0009		4	NUT		
30	0360-1190		1	SOLDER TERMINAL		
31	2190-0016		3	WASHER		
32	2950-0001		2	NUT		
33	04276-00204		1	REAR PANEL		
34	2110-0569		2	FUSEHOLDER NUT		
35	3101-1877		1	DC BIAS SELECT SWITCH		
36	2360-0113		8	SCREW		
37	5020-8806		1	REAR FRAME		
38	5060-9834		1	TOP COVER		
39	04276-00102		1	CHASSIS (YELLOW)		
40	04276-00103		1	CHASSIS (RED)		
41	04276-00101		1	CHASSIS (BROWN)		
42	2360-0333		6	SCREW		
43	5020-8805		1	FRONT FRAME		
44	04276-00203		1	SUB PANEL		
45	04276-25001		3	WINDOW		
46	04276-00201		1	FRONT PANEL (HP)		
	04276-00202		1	FRONT PANEL (YHP)		
47	7120-1254		1	NAME PLATE (HP)		
	7120-0478		1	NAME PLATE (YHP)		
48	2950-0035		4	NUT		
49	5040-3324		4	INSULATOR-BNC		
50	1510-0038		1	BINDING POST		
51	04191-40001		1	GUIDE		
52	5040-3325		4	INSULATOR-BNC		
53	2190-0084		1	WASHER		
54	5000-4212		4	SOLDER TERMINAL		
55	2950-0006		1	NUT		
56	2190-0054		4	WASHER		
57	1250-0252		4	CONNECTOR-BNC		
58	1460-1345		2	STAND		
59	5040-7201		4	FOOT (BOTTOM)		
60	5060-9846		1	BOTTOM COVER		
61	5041-0564		1	KEY CAP		
62	04274-40001		1	ROD (POWER SWITCH)		
63	0160-4297		4	CAPACITOR 0.022µF		
64	1901-1065		4	DIODE		
55	0698-3634		1	RESISTOR 470Ω		
66	0683-2245		1	RESISTOR 220kΩ		
67	0764-0016		1	RESISTOR 1kΩ		
68	1902-0657		4	DIODE		

See introduction to this section for ordering information



21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
18
19
20
17
16
28
15
14
13
12
11
34
10
9
8
7
6
5
4
3
2
1
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
65
66
67
68
63
64



Reference No.	HP Part No.	Description
1	04276-00613	Shield Box
2	04276-00615	Shield Box
3	04276-00616	Shield Box
4	04276-00614	Shield Box

Figure 6-1. Shields on the A4 Board.

SECTION VII
MANUAL CHANGES

7-1. INTRODUCTION

7-2. This section contains information for adapting this manual to instruments for which the content does not directly apply. The following paragraphs explain how to adapt this manual to apply to an older instrument with a serial prefix lower than that given on the title page.

7-3. MANUAL CHANGES

7-4. To adapt this manual to your instrument, refer to Table 7-1 and make all of the manual changes listed opposite your instrument serial number. Perform these changes in the sequence listed.

7-5. If your instrument serial number is not listed on the title page of this manual or in Table 7-1, it may be documented in a yellow MANUAL CHANGES supplement. For additional information about serial number coverage, refer to INSTRUMENTS COVERED BY MANUAL in Section I.

Table 7-1. Manual Changes by Serial Number

Serial Prefix or Number	Make Manual Changes
2227J00101 thru 2227J00155	1

CHANGE 1

Section VIII, Troubleshooting Flow Diagram A1-5:
Change Signature Sets 5-4, 5-6, and 5-11 as follows:

Signature Set 5-4

A1J1 pin 9	3388
pin 10	A9FP
pin 11	3190
pin 12	AF81
pin 13	50A4
pin 14	4H45
pin 15	A07C
pin 16	6UC0

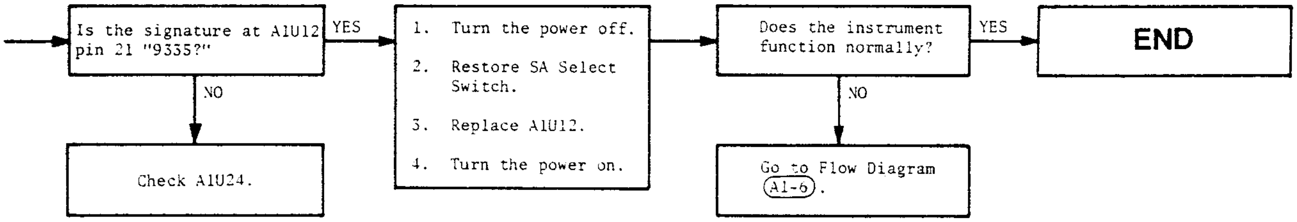
Signature Set 5-11

A1U10 pin 9	8415
pin 10	5193
pin 11	U083
pin 13	2H2F
pin 14	7A72
pin 15	3PU8
pin 16	62A2
pin 17	CFF2

Signature Set 5-6

A1U5 pin 9	0512
pin 10	5UA2
pin 11	AU44
pin 13	9693
pin 14	U762
pin 15	9911
pin 16	F79P
pin 17	U0P0

Partially change the flow diagram as follows :



SECTION VIII
SERVICE

8-1. INTRODUCTION

8-2. This section provides the information and instructions required to service the Model 4276A LCZ Meter. Included are Theory of Operation and Troubleshooting Guide with Circuit Schematics. The Theory of Operation describes fundamental principles and circuit operating theory of the 4276A with block diagrams. Circuit schematics, locator illustrations, troubleshooting guide and other technical data necessary for repairs are integrated into the service sheet foldouts. An illustration of the instrument interior is shown in Figure 8- 27.

8-3. SAFETY CONSIDERATIONS

8-4. This section contains warnings and cautions that must be followed for your protection and to avoid damage to the instrument.

WARNING

MAINTENANCE DESCRIBED HEREIN IS PERFORMED WITH POWER SUPPLIED TO THE INSTRUMENT AND PROTECTIVE COVERS REMOVED. SUCH MAINTENANCE SHOULD BE PERFORMED ONLY BY SERVICE-TRAINED PERSONNEL AWARE OF THE HAZARDS INVOLVED (FOR EXAMPLE, FIRE AND ELECTRICAL SHOCK). WHERE MAINTENANCE CAN BE PERFORMED WITHOUT POWER APPLIED, THE POWER SHOULD BE REMOVED. BEFORE ANY REPAIR IS COMPLETED, ENSURE THAT ALL SAFETY FEATURES ARE INTACT AND FUNCTIONING AND THAT ALL NECESSARY PARTS ARE CONNECTED TO THEIR MEANS OF PROTECTIVE GROUNDING.

8-5. THEORY OF OPERATION

8-6. The theory of operation discussion is organized into two sections : basic theory and block diagram discussion. The basic theory, beginning with paragraph 8-13, explains the concepts and fundamental theory of the 4276A adapted for accurately measuring the DUT and for achieving automated measurements. The block diagram discussion describes the overall circuit operating theory of the 4276A with block-to-block signal flow. Also included are block and timing diagrams.

8-7. RECOMMENDED TEST EQUIPMENT

8-8. The test equipment required to the perform operations outlined in this section is listed in Table 4-1. The table includes type of instrument required, critical specifications, use, and recommended model. If the recommended model is not available, equipment which meets or exceeds the critical specifications listed may be substituted.

8-9. TROUBLESHOOTING

8-10. The troubleshooting guide provides instructions and information for locating a faulty circuit component. All instructions consider the safety of service personnel performing the procedures. The diagnostic guides are in the form flow diagrams. The board level troubleshooting diagrams are used to isolate failures to an individual malfunctioning circuit board assembly. The guides for locating a defective component are given on the individual board service-sheets and integrate service support data—test point locations, waveform illustrations, voltage data, timing diagrams, and other technical information in addition to providing schematic diagrams for each board. To facilitate troubleshooting of the 4276A Digital Section, the troubleshooting guide for the logic circuits uses signature analysis.

8-11. REPAIR

8-12. Repair explanations tell how to replace defective circuit components. The recommended replacement procedures for components and parts which require special repair, replacement tools, or test equipment should be observed. To prevent damage resulting from improper repair procedure, refer to the appropriate manual section before proceeding with repair.

8-13. BASIC THEORY

8-14. The 4276A applies a sinusoidal voltage to the device under test and detects the resulting complex voltage, $\dot{V}$, and complex current, $\dot{I}$. The instrument then converts $\dot{V}$ and $\dot{I}$ into their individual orthogonal components to obtain the DUT's resistance, R, and reactance, X.

$$\dot{V} = a + jb$$

$$\dot{I} = c + jd$$

$$R = \frac{ac + bd}{c^2 + d^2}$$

$$X = \frac{bc - ad}{c^2 + d^2}$$

Once the values of R and X are known, all other impedance parameters--C, L, D, Q, ESR, G, | Z |, and θ can be calculated. Refer to Table 8-1.

8-15. A simplified drawing of the circuit used to detect $\dot{V}$ and $\dot{I}$ is shown in Figure 8-1. In the figure, $\dot{V} = e_{DUT}$ and $\dot{I} = e_{RR}/- R_{RR}$, where e_{DUT} is the voltage across the DUT, e_{RR} the output voltage from the I/V converter, and R_{RR} is the value of the range resistor.

All measurement parameters are calculated from the two vector voltages e_{DUT} and e_{RR}.

Table 8-1. Impedance Parameter Conversion Equations

Parameter	Equation
C	$-1/2\pi fX$
L	$X/2\pi f$
D	R/X
Q	X/R
ESR	R
G	$R/(R^2 + X^2)$
$\|Z\|$	$R^2 + X^2$
θ	$\tan^{-1}(X/R)$

f = test frequency

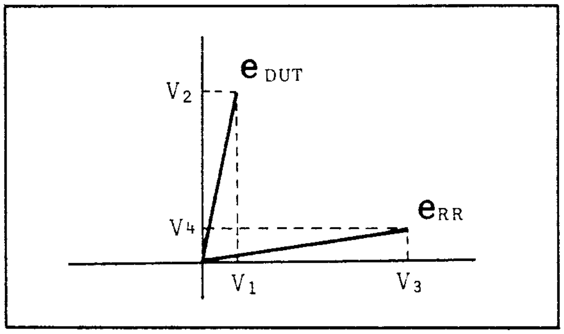


Figure 8-2. Vector Voltages.

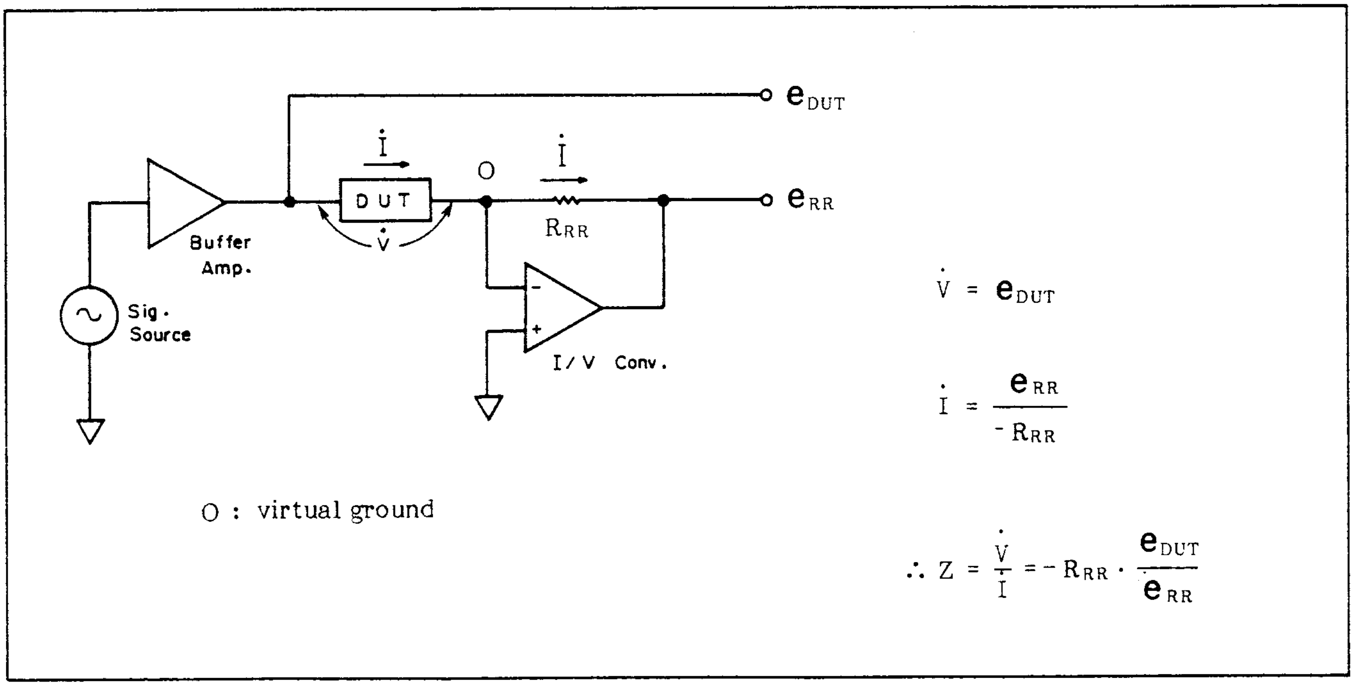


Figure 8-1. e_{DUT} and e_{RR} Detection.

8-16. The 4276A alternately detects e_{DUT} and e_{RR} , and converts them into their orthogonal (real and imaginary) voltage components.

$$e_{DUT} = V_1 + jV_2$$
$$e_{RR} = V_3 + jV_4$$

To obtain R and X, the 4276A measures three voltage ratios: α , β, and γ. Refer to Table 8-2. R and X, the primary impedance parameters, are calculated from α, β, and γ using the equations listed in Table 8-3.

Table 8-2. Voltage Ratios

Voltage Ratio	e_{DUT} / e_{RR} Component
α	V_4/V_3
β	V_2/V_3
γ	V_1/V_2*

* For ESR and G measurements, γ is V_1/V_3.

8-17. As long as the DUT's D value, which nearly equals γ, is less than 0.01, the product of α and γ will be approximately zero, $\alpha\gamma \simeq 0$, because α is always small. Thus, reactance, X, can be obtained by measuring β only. All three voltage ratios—α, β, and γ--are measured when the 4276A is set to C, L, or $|Z|$ measurement mode. When HIGH SPEED C or HIGH SPEED L is selected, however, α and γ are not measured, thereby shortening the time required for measurement.

8-18. The voltage ratios are measured using dual-slope integration. Refer to Figure 8-3. The integrator is charged by voltage V_A for a constant time T_A ($= \simeq$ 5ms), and is then discharged by voltage V_B. The ratio V_A/V_B is obtained by measuring the time required to discharge the integrator. In this example, voltages V_A and V_B can be any of the orthogonal voltages of e_{RR} or e_{DUT}; that is, V_1, V_2, V_3, or V_4.

8-19. When measurement is made on the high impedance ranges—those ranges enclosed by the bold line in Figure 8-4--the 4276A measures admittance parameters G and B instead of R and X in order to provide optimum accuracy.

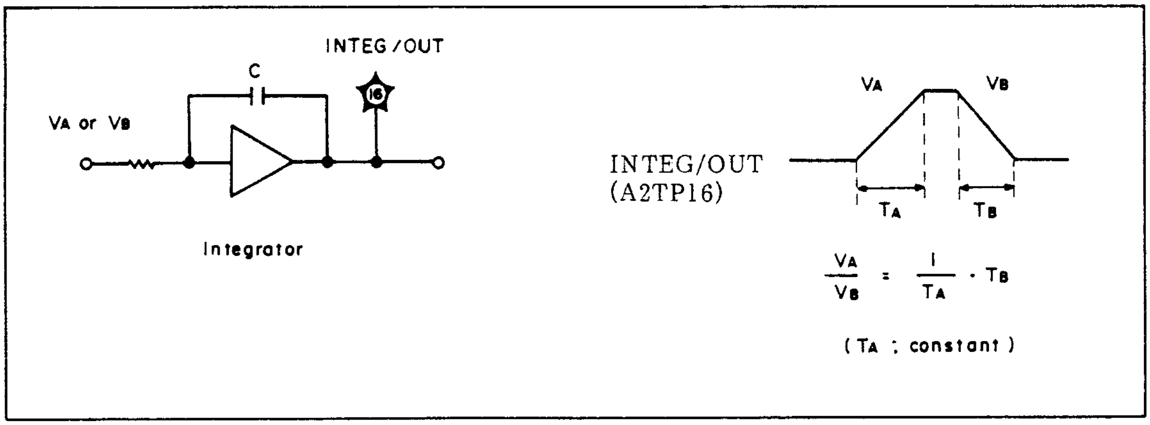


Figure 8-3. Voltage Ratio Detection

Table 8-3. Voltage Ratio Equations

DISPLAY A Function	DISPLAY B Function	Impedance Parameter	Voltage Ratio Equation
C, L	D, Q	X	$- R_{RR} \cdot \beta\,(1 - \alpha\gamma)/(1 + \alpha^2)$
		R/X (= D)	$(\alpha + \gamma)/(1 - \alpha\gamma)$
C, L, $\|Z\|$	ESR, G, θ	X	$- R_{RR} \cdot (\beta - \alpha\gamma)/(1 + \alpha^2)$
		R	$- R_{RR} \cdot (\alpha\beta + \gamma)/(1 + \alpha^2)$

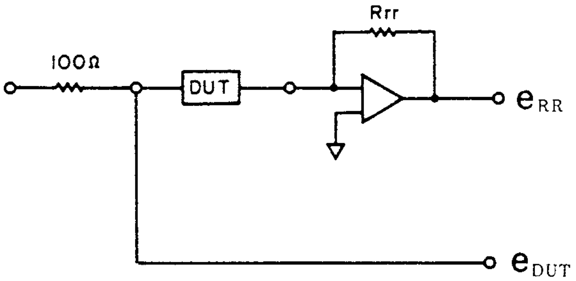
e_{RR} and e_{DUT}

e_{RR} and e_{DUT} are voltages across the range resistor and the DUT, respectively. Each voltage is calculated from the following equations:

$$e_{DUT} = \frac{|Z|}{100 + |Z|} \cdot 1\mathrm{Vrms}$$

$$e_{RR} = \frac{e_{DUT}}{|Z|} \cdot R_{RR} = \frac{R_{RR}}{100 + |Z|} \cdot 1\mathrm{Vrms}$$

where, $|Z|$ and R_{RR} are the DUT's impedance value and the range resistor value, respectively. It is obvious that both e_{DUT} and e_{RR} depend on the DUT's impedance value. The instrument amplifies the voltage which is smaller, e_{RR} or e_{DUT}, so as to input an appropriate level signal to the VRD. This is necessary because a small signal cannot be detected in the VRD with high accuracy and resolution.



DUT Impedance	e_{RR}	e_{DUT}
$\|Z\|$ 100Ω		
$\|Z\|$ 100Ω		

When the DUT's impedance is less than 100Ω, e_{DUT} is smaller than e_{RR}, which is amplified by the AM1 and AM2 circuits in the Process Amplifier. Conversely, when the DUT's impedance is more than 100Ω, e_{RR} is smaller than e_{DUT}, which is amplified in the range resistor circuit by changing the range resistor value, and also in the AM1 and AM2 circuits if necessary.

Figure 8-4. e_{RR} and e_{DUT}.

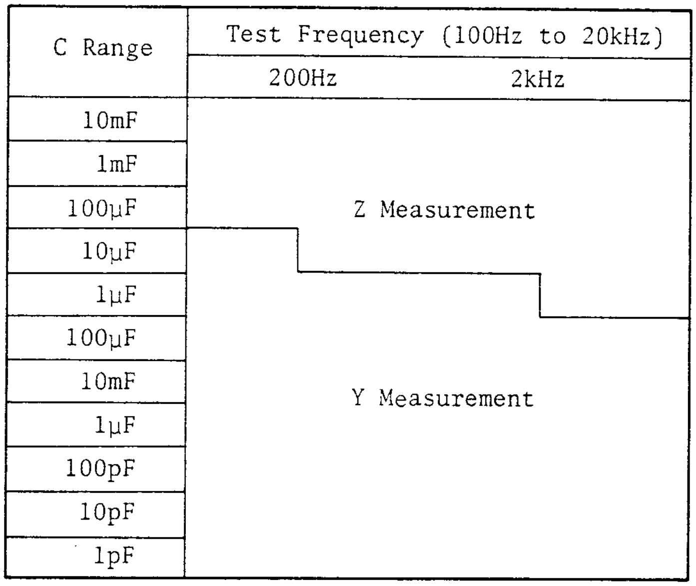
Z/Y Measurement Modes

When the measurement range is set to a range suitable for measuring a DUT whose impedance value is less than 100Ω, the instrument measures the impedance parameters R and X (Z measurement mode). When the measurement range is set to a higher range, however, the instrument measures the admittance parameters G and B (Y measurement mode). Refer to Figure A. In either measurement mode, the instrument calculates the selected measurement parameter, C, L, etc., from the measured parameter values.

Note

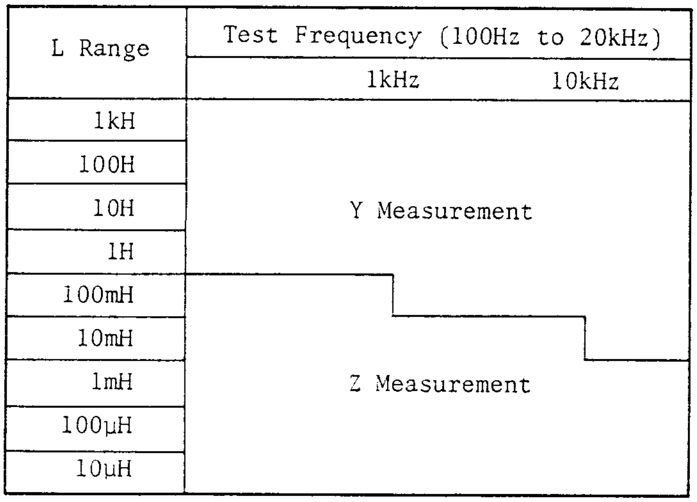
A DUT whose impedance is 100Ω is measured in Y measurement mode on some ranges.

Table A. Capacitance Measurement



C Range	Test Frequency (100Hz to 20kHz)	
	200Hz	2kHz
10mF		
1mF		
100µF	Z Measurement	
10µF		
1µF		
100µF		
10mF	Y Measurement	
1µF		
100pF		
10pF		
1pF		

Table B. Inductance Measurement



L Range	Test Frequency (100Hz to 20kHz)	
	1kHz	10kHz
1kH		
100H		
10H	Y Measurement	
1H		
100mH		
10mH		
1mH	Z Measurement	
100µH		
10µH		

Figure 8-5. Z/Y Measurement Modes (Sheet 1 of 4).

Table C. Impedance Measurement

Z Range	Test Frequency
	100Hz to 20kHz
10MΩ	Y Measurement
1MΩ	
100kΩ	
10kΩ	
1kΩ	
100Ω	Z Measurement
10Ω	
1Ω	
100mΩ	

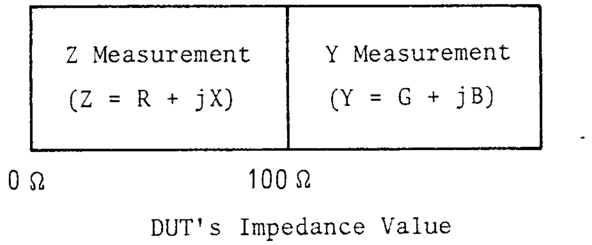
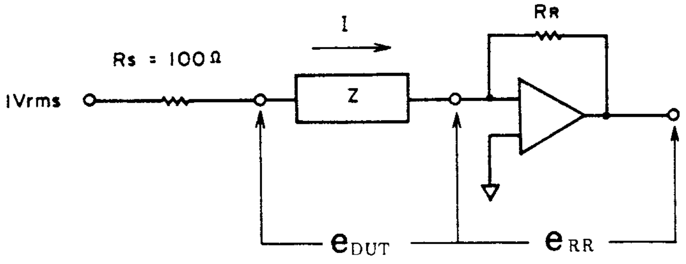


Figure A



$$e_{DUT} = \frac{Z}{100\Omega + Z} \text{ (Vrms)}$$

$$I = \frac{1\text{Vrms}}{100\Omega + Z}$$

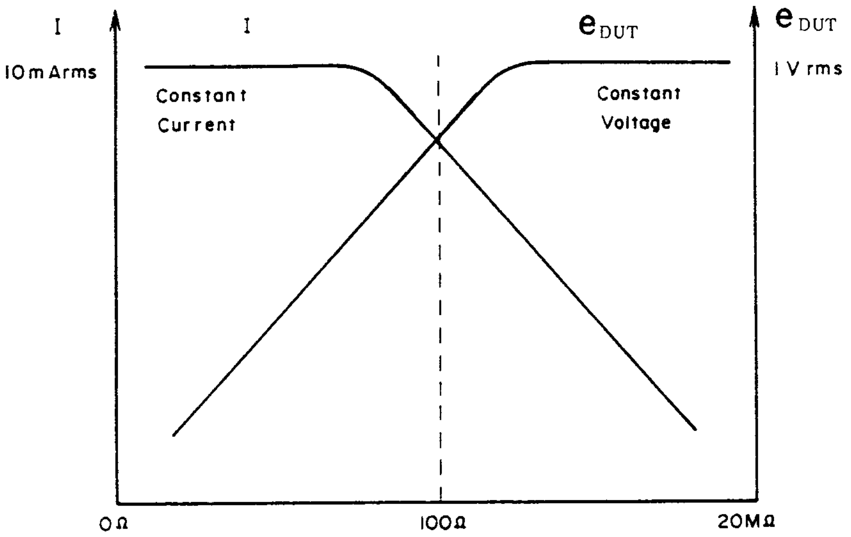


Figure B

Figure 8-5. Z/Y Measurement Modes (Sheet 2 of 4).

(1) Z Measurement Mode

When the DUT's impedance value is lower than 100Ω, the current through the DUT, I in Figure B, is approximately constant. Thus, the voltage, e_{RR}, across the range resistor, is also approximately constant because e_{RR} is the product of R_{RR} and I.

In this case, impedance parameter measurement is more accurate than admittance parameter measurement. Therefore, the instrument measures R and X.

$$Z = e_{DUT}/I = R_{RR} \cdot (e_{DUT}/ e_{RR})$$

In D or Q measurement mode, the instrument measures D (= R/X) directly.

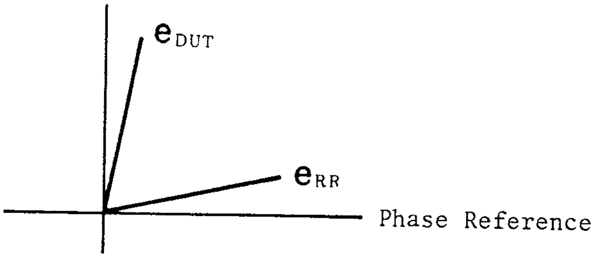


Table D. Measurement Parameters Relation in Z Mode

Measurement Functions	CKT MODE	DISPLAY A Value	DISPLAY B Value	Measured Parameters
L-D		L = X/2πf	D = D	X, D
		L = X $(1 + D^2)/2\pi f$	D = D	X, D
L-Q		L = X/2πf	Q = 1/D	X, D
		L = X $(1 + D^2)/2\pi f$	Q = 1/D	X, D
L-ESR/G		L = X/2πf	ESR = R	X, R
		L = $(X^2 + R^2)/2\pi fX$	G = $R/(R^2 + X^2)$	X, R
C-D		C = -1/2πfX	D = -D	X, D
		C = $-1/2\pi fX\ (1 + D^2)$	D = -D	X, D
C-Q		C = -1/2πfX	Q = -1/D	X, D
		C = $-1/2\pi fX\ (1 + D^2)$	Q = -1/D	X, D
C-ESR/G		C = -1/2πfX	ESR = R	X, R
		C = $-X/2\pi f\ (R^2 + X^2)$	G = $R/(R^2 + X^2)$	X, R
|Z| - θ	 	$\|Z\| = \sqrt{R^2 + X^2}$	$\theta = \tan^{-1}(X/R)$	X, R

Figure 8-5. Z/Y Measurement Modes (Sheet 3 of 4).

(2) Y Measurement Mode

When the DUT's impedance value is higher than 100Ω, the voltage across the DUT, e_{DUT}, is approximately constant, as shown in Figure B.

In this case, admittance parameter measurement is more accurate than impedance parameter measurement. Therefore, the instrument measures G and B.

$$Y = I/e_{DUT} = (1/R_{RR}) \cdot (e_{RR}/e_{DUT})$$

In D or Q measurement mode, the instrument measures D (= R/X) directly.

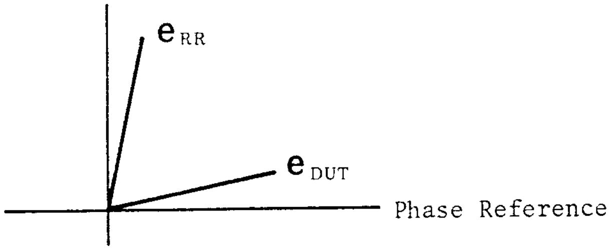


Table E Measurement Parameters Relation in Y Mode

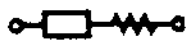
Measurement Functions	CKT MODE	DISPLAY A Value	DISPLAY B Value	Measured Parameters
L-D		$L = -1/2\pi fB\ (1 + D^2)$	D = D	B, D
		$L = -1/2\pi fB$	D = D	B, D
L-Q		$L = -1/2\pi fB\ (1 + D^2)$	Q = 1/D	B, D
		$L = -1/2\pi fB$	Q = 1/D	B, D
L-ESR/G		$L = -B/2\pi f\ (G^2 + B^2)$	$ESR = G/(G^2 + B^2)$	B, G
		$L = -1/2\pi fB$	G = G	B, G
C-D		$C = B\ (1 + D^2)/2\pi f$	D = D	B, D
		$C = B/2\pi f$	D = D	B, D
C-Q		$C = B\ (1 + D^2)/2\pi f$	Q = 1/D	B, D
		$C = B/2\pi f$	Q = 1/D	B, D
C-ESR/G		$C = (G^2 + B^2)/2\pi fB$	$ESR = G/(G^2 + B^2)$	B, G
		$C = B/2\pi f$	G = G	B, G
|Z| - θ		$\|Z\| = 1/\sqrt{G^2 + B^2}$	$\theta = \tan^{-1}\ (-B/G)$	B, G
				

Figure 8-5. Z/Y Measurement Modes (Sheet 4 of 4).

e_{ref} and e_{test}

The instrument measures the ratio between two vector voltages: e_{DUT} (voltage across the DUT) and e_{RR} (voltage across the range resistor). In Z measurement mode, the vector voltage ratio is e_{DUT}/e_{RR}, and in Y measurement mode, e_{RR}/e_{DUT}.

e_{test} and e_{ref} are defined as the numerator and the denominator of the detected ratio, respectively. The relations among e_{test}, e_{ref}, e_{DUT}, and e_{RR} are described in Table A.

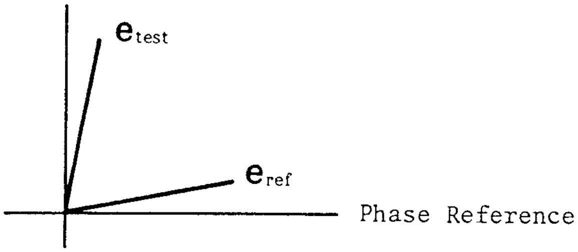


Table A.

Measurement Mode	e_{test}	e_{ref}
Z	e_{DUT}	e_{RR}
Y	e_{RR}	e_{DUT}

Figure 8-6. e_{ref} and e_{test}.

HIGH SPEED C/L MEASUREMENT PRINCIPLE

The instrument measures the selected impedance parameters--C, L, D, Q, etc.--by detecting three voltage ratios-- α, β, and γ --and calculating each parameter from the equations listed in Table A of Figure 8-7. Voltage ratio α is always close to zero because the phase reference signal used by the phase detector is nearly in-phase with or 90° out of phase with e_{ref}. Also, when γ is much smaller than 1, only β is necessary to obtain C or L. Therefore, if the dissipation factor, D, of the DUT is much lower than 1, voltage ratios α and γ need not be detected to obtain C or L, significantly reducing total measurement time. In HIGH SPEED C or HIGH SPEED L measurement mode, the instrument detects only β.

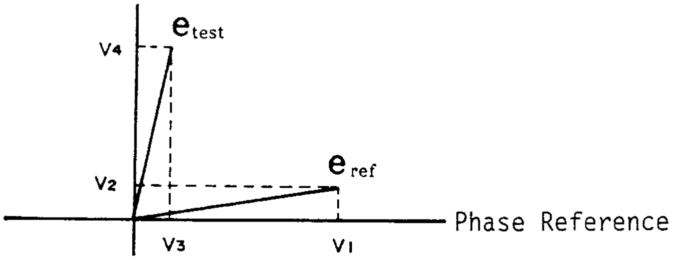


Table A.

Measurement Mode	Measured Parameters	Parameter Equation	Voltage Ratio		
			α	β	γ
Z	X, D	$X = -R_{RR}\cdot\beta\ (1 - \alpha\gamma)/(1 + \alpha^2)$ $D = (\alpha + \gamma)/(1 - \alpha\gamma)$	V_2/V_1	V_4/V_1	V_3/V_4
	X, R	$X = -R_{RR}\cdot(\beta - \alpha\gamma)/(1 + \alpha^2)$ $R = -R_{RR}\cdot(\alpha\beta + \gamma)/(1 + \alpha^2)$	V_2/V_1	V_4/V_1	V_3/V_1
Y	B, D	$B = -G_{RR}\cdot\beta\ (1 - \alpha\gamma)/(1 + \alpha^2)$ $D = -(\alpha + \gamma)/(1 - \alpha\gamma)$	V_2/V_1	V_4/V_1	V_3/V_4
	B, G	$B = -G_{RR}\cdot(\beta - \alpha\gamma)/(1 + \alpha^2)$ $G = -G_{RR}\cdot(\alpha\beta + \gamma)/(1 + \alpha^2)$	V_2/V_1	V_4/V_1	V_3/V_1

$(\dot{Y} = 1/\dot{Z},\ \dot{Z} = R + jX,\ \dot{Y} = B + jX,\ D = R/X,\ D = -G/B)$

Figure 8-7. HIGH SPEED C/L Measurement Principle

8-20. ANALOG SECTION BLOCK LEVEL THEORY

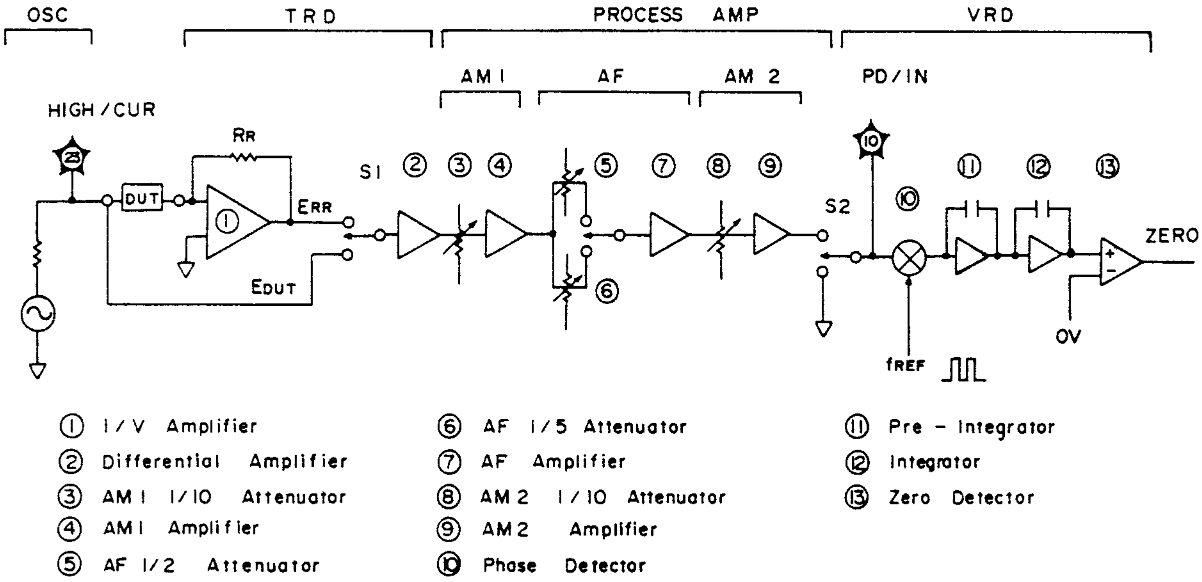
8-21. The following paragraphs describe the structure and operation of the 4276A's Analog Section. The Analog Section consists of the Signal Source, the Transducer, the Process Amplifier, and the Vector Ratio Detector (VRD). The block diagram of the Analog Section is shown in Figure 8-8. The simplified block diagram of the Analog Section is shown in Figure 8-8.

8-22. SIGNAL SOURCE

8-23. The block diagram of the Signal Source is shown in Figure 8-9 . The Signal Source consists of a crystal oscillator, a phase-locked loop (PLL), a quasi-sinewave oscillator, low-pass filters, and an attenuator.

8-24. The crystal oscillator (located on the A1 board) outputs a precise 11.5200MHz signal which is divided down to provide an 8kHz reference signal for the phase detector in the PLL, a 5.760MHz clock signal for the Z80 microprocessor, and other clock signals for the various digital operations performed by the instrument.

8-25. The voltage-controlled oscillator (VCO) in the PLL outputs an 8MHz to 20MHz signal, which is divided down to a 16F signal for test frequency generation. The output frequency of the VCO is determined by the phase detector, the loop filter, and the ÷N divider. If the frequency of the signal output from the ÷N divider is different from the 8kHz of the reference signal from the crystal oscillator, the phase detector will output an "unlock" signal to the loop filter, which will then adjust the VCO



①: Converts the current through the DUT into a voltage (e_{RR}).

⑤, ⑥, ⑧: Precision attenuators

⑪: Converts the phase detector's output signal to the dc voltage.

⑬: Compares the integrator's output voltage to the shifted reference zero voltage.

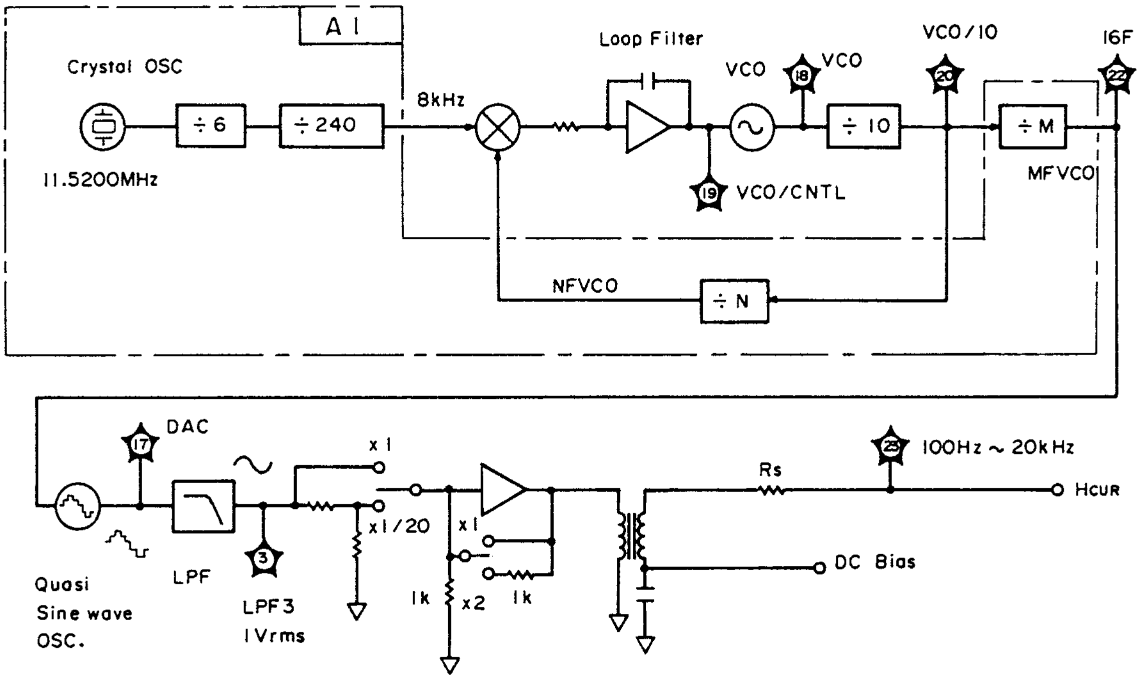
R_{RR}: Range resistor (from 100Ω to 100kΩ)

Figure 8-8 . Simplified Analog Section Block Diagram.

control voltage up or down until the PLL is locked. The VCO control voltage is between -10V and +10V; the N divisor is from 100 to 250. The PLL is locked when NFVCO is 8kHz.

8-26. The quasi-sinewave oscillator generates a digital sinewave whose fundamental frequency is the same as the test frequency. This oscillator consists of a 16-bit counter, a ROM, and a DA converter. The 16-bit counter counts the pulses of the 16F signal sent from the PLL. The counter's outputs are connected to the address-select lines of the ROM. The ROM contains digital data which determines the output from the DA converter. The digital data and the addresses are arranged so that, as the ROM is addressed by the 16-bit counter, the output from the DA converter will be a rising and falling staircase waveform. The DA converter's output is filtered by a low-pass filter, leaving a clean 1Vrms sinewave. Signal level is controlled by an attenuator and a buffer amplifier. When HIGH SIG LEVEL is selected on the front panel, the 1Vrms signal is not attenuated; when LOW SIG LEVEL is selected, the test signal level is attenuated to 50mVrms. On certain measurement ranges, the 1Vrms signal level is amplified to 2Vrms.

8-27. The source resistor, Rs in Figure 8-9 , is a 47Ω fuse resistor which protects the instrument from damage if a charged capacitor is connected to the UNKNOWN terminals.



Frequency Band	Test Frequency Range	Step Frequency	VCO Frequency Range	N Value Range	M Value
1	100Hz to 200Hz	1Hz	8MHz to 16MHz	100 to 200	500
2	202Hz to 500Hz	2Hz	8.08MHz to 20MHz	101 to 250	250
3	505Hz to 1kHz	5Hz	8.08MHz to 16MHz	101 to 200	100
4	1.01kHz to 2kHz	10Hz	8.08MHz to 16MHz	101 to 200	50
5	2.02kHz to 5kHz	20Hz	8.08MHz to 20MHz	101 to 250	25
6	5.05kHz to 10kHz	50Hz	8.08MHz to 16MHz	101 to 200	10
7	10.1kHz to 20kHz	100Hz	8.08MHz to 16MHz	101 to 200	5

Figure 8-9 . Signal Source Block Diagram.

Quasi-Sinewave Oscillator

The quasi-sinewave oscillator consists of a modulo-16 counter, a ROM, and a digital-to-analog converter, as shown in Figure A. The oscillator outputs a digital sinewave, which, once filtered, becomes the instrument's test signal. The circuit works as follows.

The counter, A2U32, counts the pulses of a 16F squarewave sent from the phase-locked loop. The counter's outputs are connected directly to the ROM's lower-four address control lines. As the counts changes, a different address is selected and the binary number at the selected address is output to the digital-to-analog converter. Output from the digital-to-analog converter is a dc voltage proportional to the binary number output from the ROM. The address sequence and the data stored in the ROM are such that the output from the digital-to-analog resembles a sine wave. The relationships among the ROM addresses, stored data, and output voltage are listed in Table A. Figure B shows the timing diagram of the circuit.

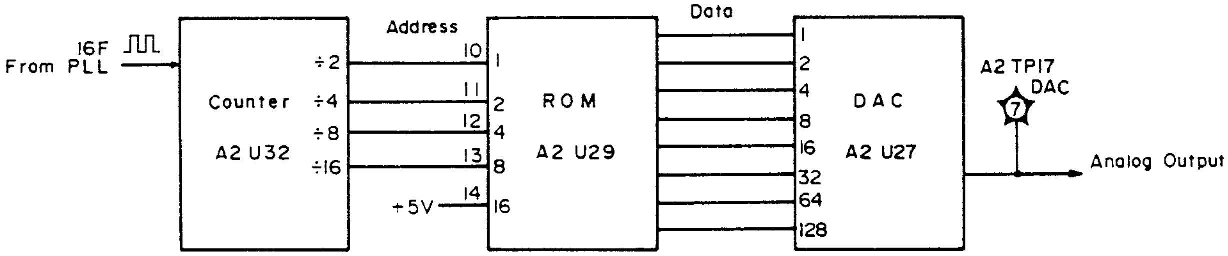


Figure A. Quasi-Sinewave Oscillator Circuit.

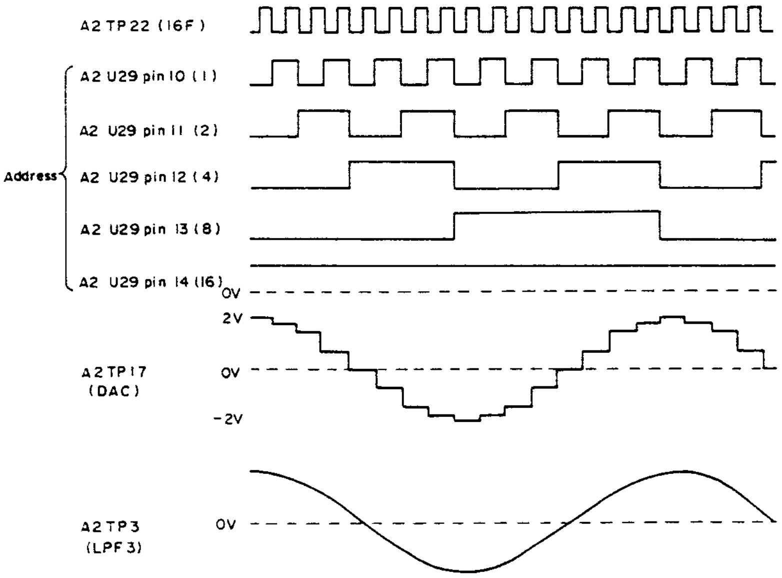


Figure B. Timing Diagram.

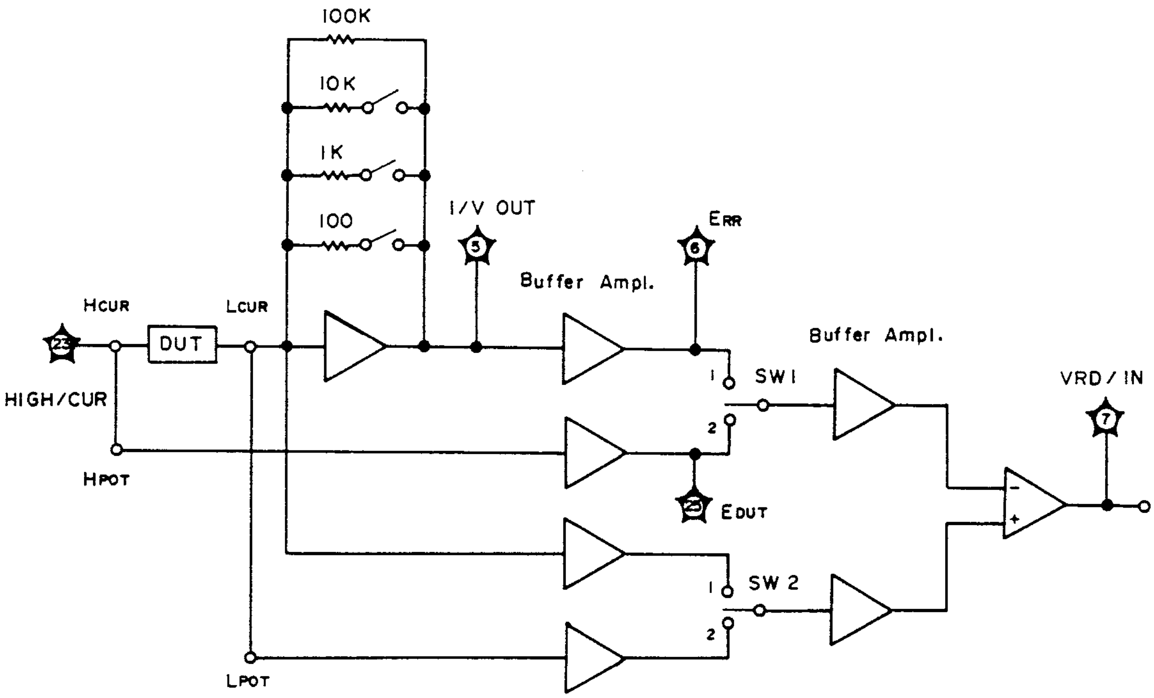
Table A. ROM Data

Address	Data	A2TP17
16	255	2V
17	245	1.92V
18	218	1.71V
19	176	1.38V
20	128	0V
21	79	-1.38V
22	38	-1.71V
23	10	-1.92V
24	0	-2V
25	10	-1.92V
26	38	-1.71V
27	79	-1.38V
28	128	0V
29	176	1.38V
30	218	1.71V
31	245	1.92V

Figure 8-10. Quasi-Sinewave Oscillator.

8-28. TRANSDUCER

8-29. A simplified schematic of the Transducer is shown in Figure 8-11. The transducer detects two vector voltage, e_{DUT} and e_{RR} , and alternately selects each for output to the voltage ratio detector (VRD) through the process amplifier. e_{DUT} is the voltage across the DUT. e_{RR} is the voltage across the range resistor in the feedback loop of the I/V converter amplifier. Since the current flowing through the DUT must also flow through the range resistor, e_{RR} is proportional to the current. There are four range resistors: 100Ω, 1kΩ, 10kΩ, and 100kΩ. Measurement range is determined by the range resistor and the gain of the AM circuit in the process amplifier. e_{DUT} and e_{RR} are both detected by a precision differential amplifier.



SW1	SW2	A2TP7
1	1	E_{RR}
2	2	E_{DUT}

Figure 8-11. Transducer Block Diagram.

8-30. PROCESS AMPLIFIER

8-31. When the DUT's impedance is much lower than 100Ω, the level of the e_{DUT} signal is much lower than that of the e_{RR} signal ($\simeq$ 1Vrms). When the DUT's impedance is much higher than 100Ω, the level of the e_{RR} signal is much lower than that of the e_{DUT} signal ($\simeq$1Vrms).

The process amplifier controls the signal levels of e_{DUT} and e_{RR} so that they are roughly equal; thereby improving resolution in the VRD section. The process amplifier consists of three stages--AM1, AF, and AM2--as shown in Figure 8-12. The AM1 and AM2 stages compensate for signal level differences between e_{DUT} and e_{RR} caused by measurement range selection. The AF stage compensates for signal level differences caused by test frequency selection. Each stage contains an amplifier to roughly magnify the signal level and an attenuator to precisely attenuate the signal. In one measurement cycle, the amplifiers magnify both e_{DUT} and e_{RR} by the same gain factor. On the other hand, however, the attenuators attenuate e_{DUT} and e_{RR} by different attenuation factors, depending on the DUT's impedance. Therefore, the difference of amplitudes for e_{DUT} and e_{RR} is determined by the precise attenuators contained in AM1/AF/AM2 circuits. It is important that the common amplification of e_{DUT} and e_{RR} have no effect on voltage detection because the instrument detects the voltage ratios of the quadrature components of e_{DUT} and e_{RR} in the VRD section.

8-32. Figures 8-13 and 8-14 show the AM and the AF controls, respectively.

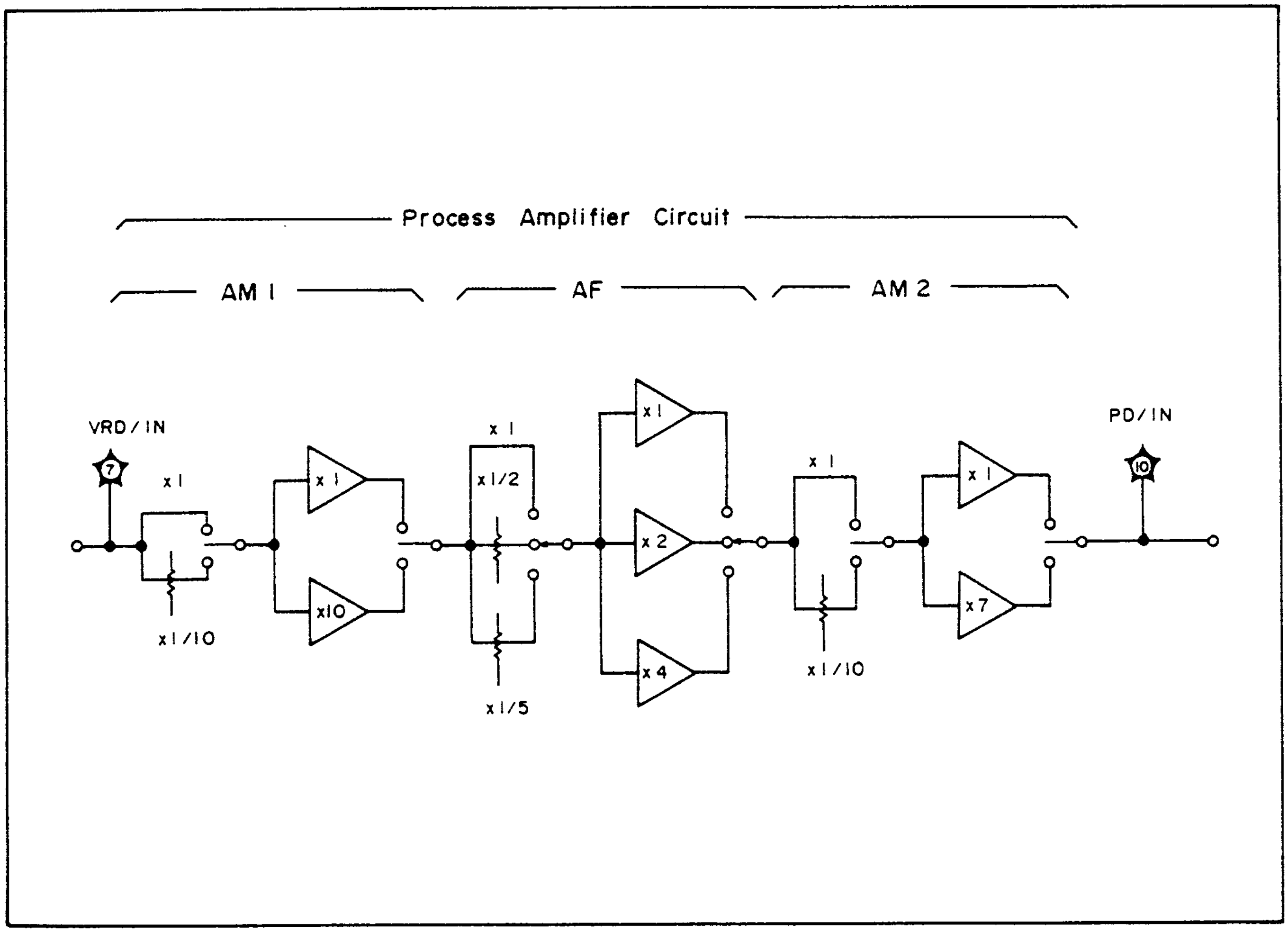


Figure 8-12. Process Amplifier Block Diagram

Table AM Control (L Measurement)

L Range	Test Frequency Range		
	100Hz to 995Hz	1kHz to 9.95kHz	10kHz to 20kHz
1kH		▨	▨
100H		Y, 100kΩ, M2	▨
10H		Y, 10kΩ, M2	
1H		Y, 1kΩ, M2	
100mH		Y, 100Ω, M2	
10mH		Z, 100Ω, M2	
1mH	▨	Z, 100Ω, M3	
100μH	▨	▨	

Table AM Control (Z Measurement)

Z Range	Test Frequency Range
	100Hz to 20kHz
10MΩ	Y, 100kΩ, M3
1MΩ	Y, 100kΩ, M2
100kΩ	Y, 10kΩ, M2
10kΩ	Y, 1kΩ, M2
1kΩ	Y, 100Ω, M2
100Ω	Z, 100Ω, M2
10Ω	Z, 100Ω, M3
1Ω	Z, 100Ω, M4

Table AM Control (C Measurement)

C Range	Test Frequency Range		
	100Hz to 199Hz	200Hz to 1.99kHz	2kHz to 20kHz
10mF		▨	▨
1mF		Z, 100Ω, M0	▨
100μF		Z, 100Ω, M1	
10μF		Z, 100Ω, M2	
1μF		Y, 100Ω, M2	
100nF		Y, 1kΩ, M2	
10nF		Y, 10kΩ, M2	
1nF	Y, 100kΩ, M3	Y, 100kΩ, M2	
100pF	▨	▨ Y, 100kΩ, M3	
10pF	▨	▨	▨ Y, 100kΩ, M3

500Hz 5kHz

Note: Each description represents

Measurement, Range Resistor Value, AM Code .

Table AM Gain

AM Code	(Gt)				(Gr)				Gain Ratio (Gt/Gr)
	AM1		AM2		AM1		AM2		
	ATT	AMP	ATT	AMP	ATT	AMP	ATT	AMP	
M0	x 1	x 1	x 1	x 10	x 1/10	x 1	x 1/10	x 10	100
M1	x 1/10	x 1	x 1	x 10	x 1/10	x 1	x 1/10	x 10	10
M2	x 1	x 1	x 1	x 1	x 1	x 1	x 1	x 1	1
M3	x 1	x 1	x 1	x 10	x 1	x 1	x 1/10	x 10	10
M4	x 1	x 10	x 1	x 10	x 1/10	x 10	x 1/10	x 10	100
M5	x 1	x 1	x 1/10	x 10	x 1	x 1	x 1	x 10	.1
M6	x 1/10	x 1	x 1	x 10	x 1	x 1	x 1	x 10	.1
M7	x 1	x 1	x 1/10	x 1	x 1	x 1	x 1/10	x 1	1

Figure 8-13. AM Control.

Table AF Control

Test Frequency Range [Hz]	C Measurement		L Measurement		Z Measurement	
	Z Mode	Y Mode	Z Mode	Y Mode	Z Mode	Y Mode
100 to 199	F0	F0	F0	F0	F0	F0
200 to 498	F5	F2	F4	F1		
500 to 995	F4	F1	F5	F2		
1k to 1.99k	F0	F0	F0	F0		
2k to 4.98k	F5	F2	F4	F1		
5k to 9.95k	F4	F1	F5	F2		
10k to 20k	F0	F0	F0	F0		

Table AF Gain

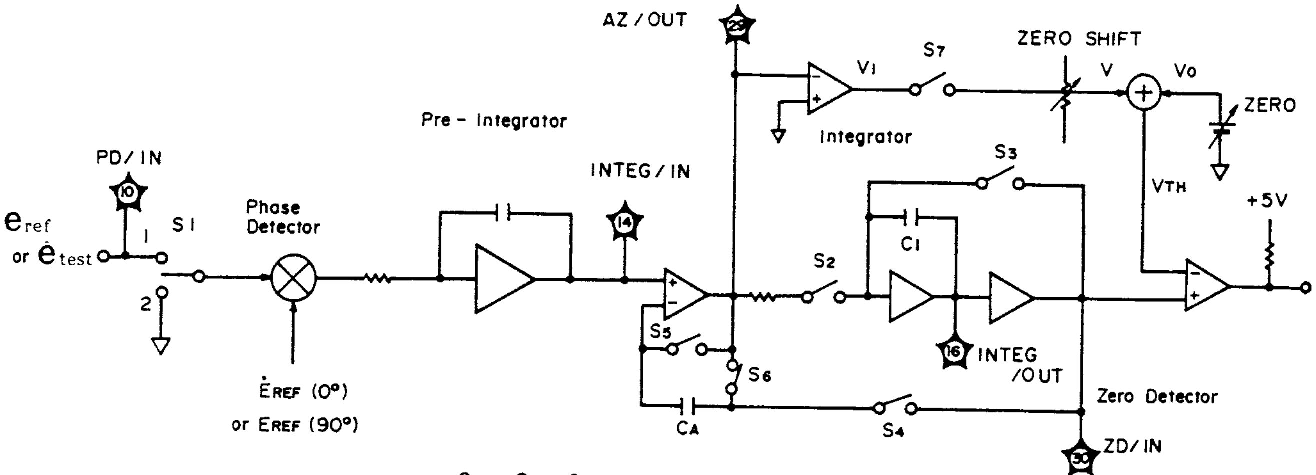
AF Code	(Gt)		(Gr)		Gain Ratio (Gt/Gr)
	ATT	AMP	ATT	AMP	
F0	x 1	x 1	x 1	x 1	1
F1	x 1	x 2	x 1/2	x 2	2
F2	x 1	x 4	x 1/5	x 4	5
F3	x 1	x 4	x 1	x 4	1
F4	x 1/2	x 1	x 1	x 1	1/2
F5	x 1/5	x 1	x 1	x 1	1/5
F6	x 1/5	x 2	x 1/2	x 2	2/5
F7	x 1	x 1	x 1/5	x 1	5

Figure 8-14. AF Control.

8-33. VECTOR RATIO DETECTOR (VRD)

8-34. A simplified circuit diagram of the VRD is shown in Figure 8-15. The VRD consists of a phase detector, a pre-integrator, an integrator, and a zero detector. The VRD's function is to measure the three voltage ratios—α, β, and γ—from which all measurement parameters are derived.

8-35. The phase detector is switched by two signals-- e_{ref} (0 °) and e_{ref} (90 °)--which convert the input signals-- e_{ref} and e_{test} --into their orthogonal components. Thus, the phase detector outputs four voltages: e_{ref} (0 °), e_{ref} (90 °), e_{test} (0 °), and e_{test} (90 °). The pre-integrator integrates the phase detector output voltage for 5ms at test frequencies of 200Hz and above, or for one test signal period up to 10ms at frequencies below 200Hz. The dc voltage output from the pre-integrator charges the integrator for 5ms. The next dc voltage output from the pre-integrator discharges the integrator. When the integrator is completely discharged, the output from the zero detector goes HIGH (+5V) or LOW (0V) depending on the polarity of the integrator output voltage. During the discharge period, a counter on the A1 board counts the pulses of a 3.84MHz clock signal. The number of pulses counted represents the ratio of the charge and discharge voltages.



	S1	S2	S3	S4	S5	S6
Auto Zero	2	OFF	ON	ON	ON	OFF
Measuring	1	ON	OFF	OFF	OFF	ON

Figure 8-15. Vector Ratio Detector Block Diagram.

Reference Detection Signal (REFDET)

The phase relationship between e_{ref} and the main phase reference signal, X, must be a precise 0 ° when the real vector components of e_{ref} and e_{test} are measured. When the imaginary vector components of e_{ref} and e_{test} are measured, however, X must be phase shifted 90 ° in reference to e_{ref} . Refer to Figure A.

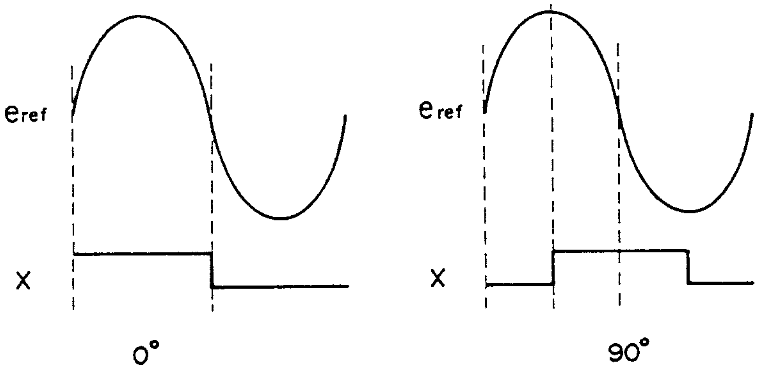


Figure A.

To establish the 0 ° phase relationship, the instrument detects the negative-to-positive zero crossover of the e_{ref} signal. Refer to Figure B. At the zero crossover, the REFDET signal goes HIGH, starting the 8flck signal and enabling three shift registers—A2U62, U63, and U64. These shift registers generate the X, Y, and Z phase reference signals shown in Figure C. To shift the X phase reference signal 90 ° in reference to e_{ref} , the instrument adds two narrow pulses to the 8flck signal, as shown in Figure D. The phase relationships among X, Y, and Z are constant.

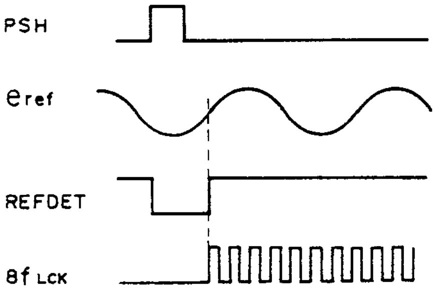


Figure B

Figure 8-16. REFDET (Sheet 1 of 2).

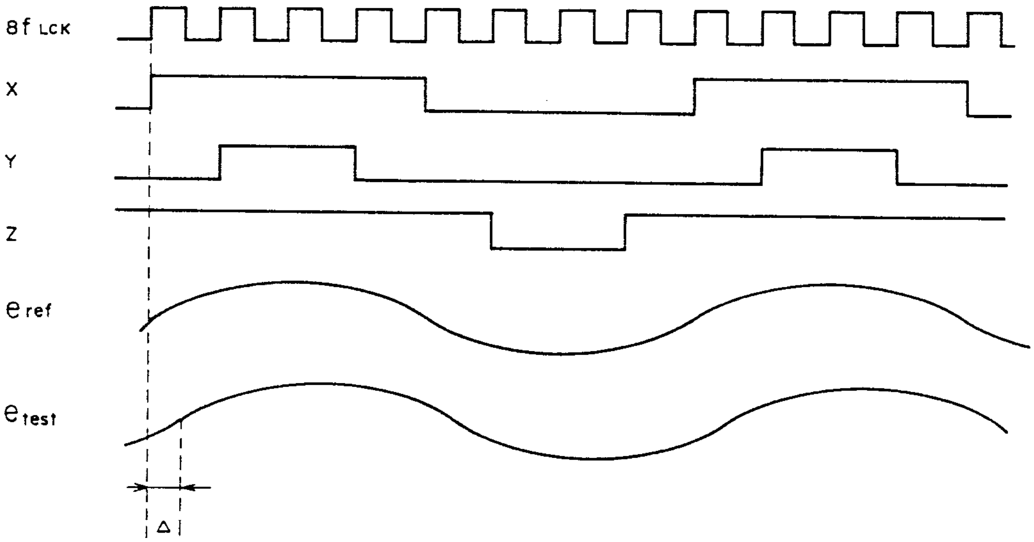


Figure C

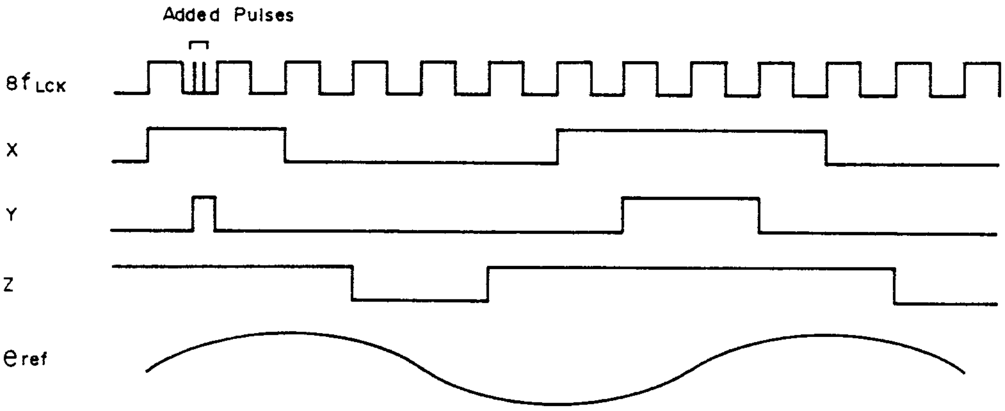
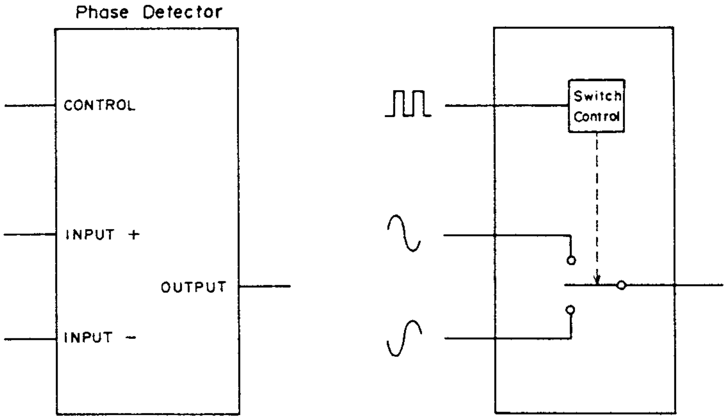


Figure D

Figure 8-16. REFDET (Sheet 2 of 2).

Phase Detector

The phase detector is basically an analog switch controlled by a square wave signal. Refer to Figure A. The square wave is the phase reference signal, and it is either in-phase with or 90° out of phase with the e_{ref} signal. When the phase reference signal is HIGH, the signal applied to the INPUT- terminal is selected for output; when the phase reference signal is LOW, the signal applied to the INPUT+ terminal is selected for output. The signals applied to the INPUT+ and INPUT- terminals are e_{ref} (or e_{test}) and an inverted (shifted 180°) e_{ref} (or e_{test}), respectively.



CONTROL	OUTPUT
HIGH	INPUT −
LOW	INPUT +

Figure A.

The function of the phase detector is to resolve e_{ref} and e_{test} into their orthogonal (real and imaginary) components. See Figure B.

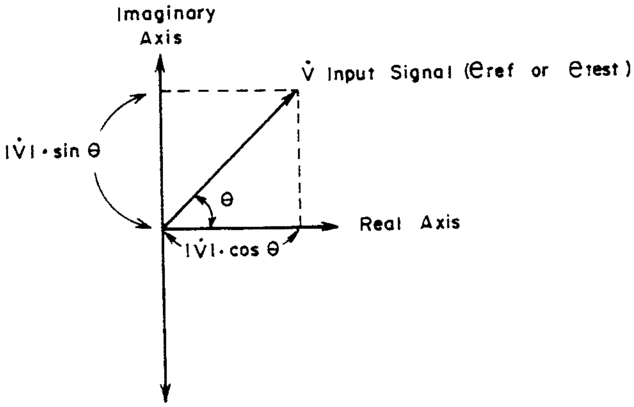


Figure B.

Figure 8-17. Phase Detector (Sheet 1 of 2)

To obtain the real component of e_{ref} or e_{test}, the phase reference signal, which controls switching of the phase detector, must be in-phase with e_{ref} (see Figure C). Similarly, to obtain the imaginary component of e_{ref} or e_{test}, the phase reference signal must be 90 ° out of phase with e_{ref} (see Figure D).

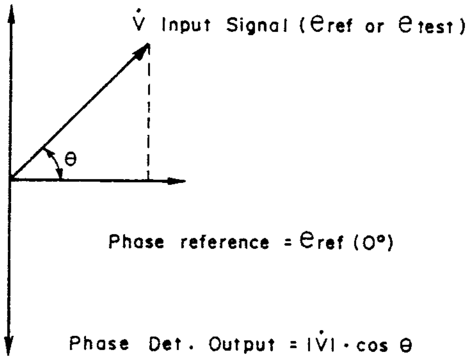


Figure C.

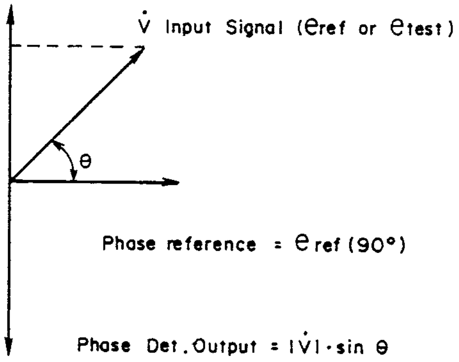


Figure D.

To minimize phase detection errors caused by low order odd harmonics which may be present at the output, three parallel-connected phase detectors (A2U59, U60, and U61) are used in the 4276A, as shown in the simplified circuit schematic of Figure E. Figure F shows the phase reference signals for the three phase detectors.

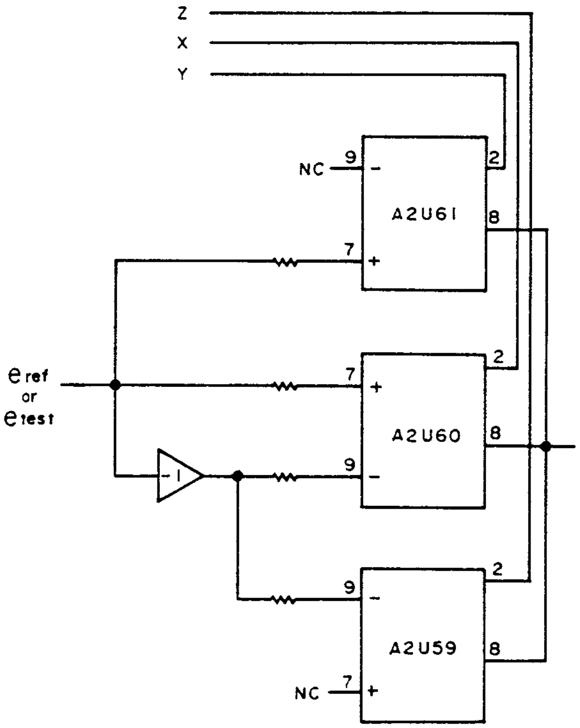


Figure E.

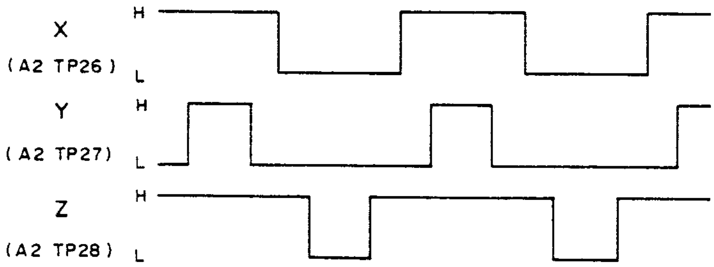


Figure F.

Figure 8-17. Phase Detector (Sheet 2 of 2)

Phase Detection

The phase detector is basically a network of analog switches which are controlled by the square waves shown in Figure A. When the switches are closed, the current through each switch charges the integrator. The integrator output voltage is given as:

$$V_{OUT}= \frac{6a}{CR} \cos \Delta \propto |V_{IN}| \cdot \cos \Delta \qquad (\because |V_{IN}| = a)$$

When the control signals X, Y, and Z are phase-shifted by 90 degrees, however, the integrator output voltage is as:

$$V_{OUT} = \frac{6a}{CR} \sin \Delta \propto |V_{IN}| \cdot \sin \Delta$$

$|V_{IN}| \cos\Delta$ and $|V_{IN}| \sin\Delta$ are the in-phase and the 90° out of phase component of the input vector voltage V_{IN} with X,respectively, where X is the phase reference signal.

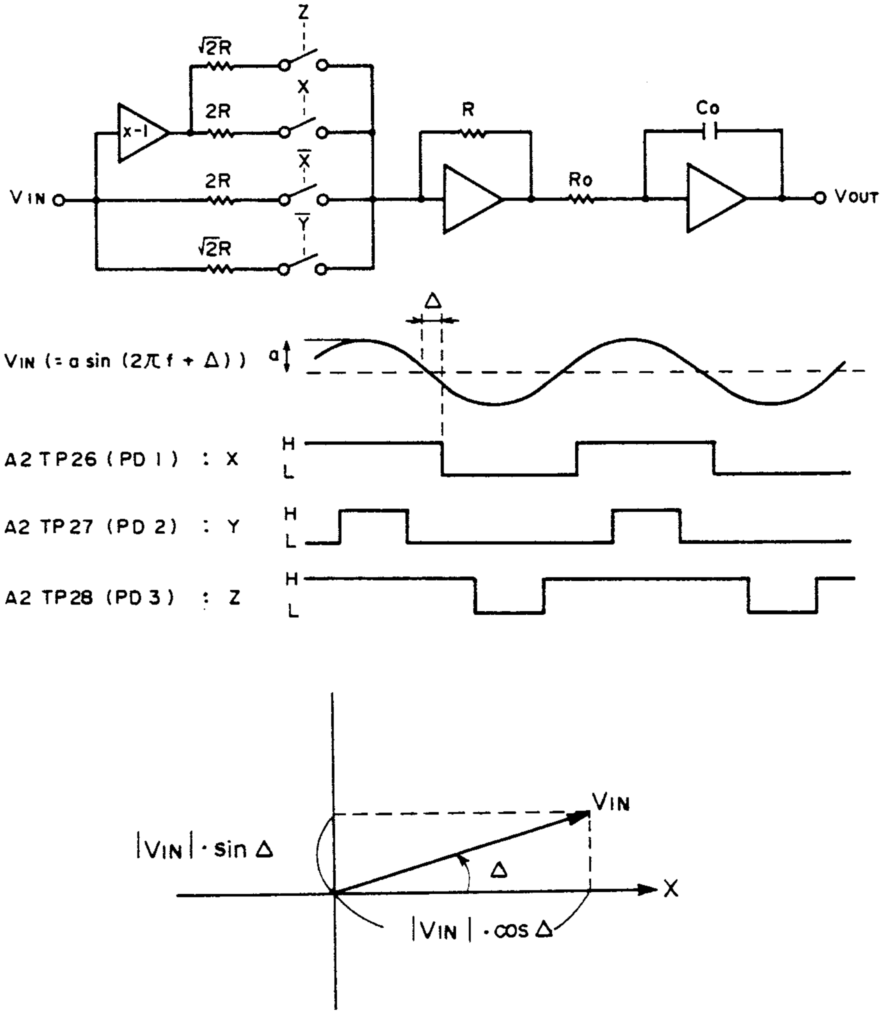


Figure A

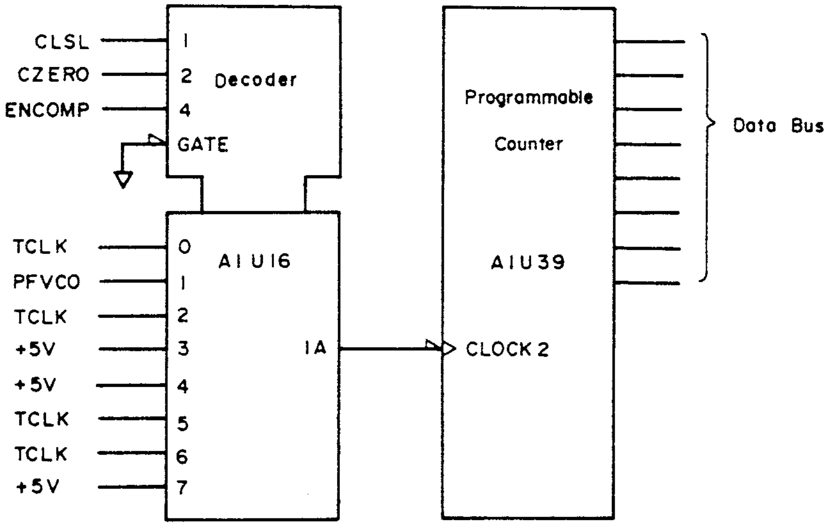
Figure 8-18. Phase Detector (Sheet 2 of 2)

Voltage Ratio Detection

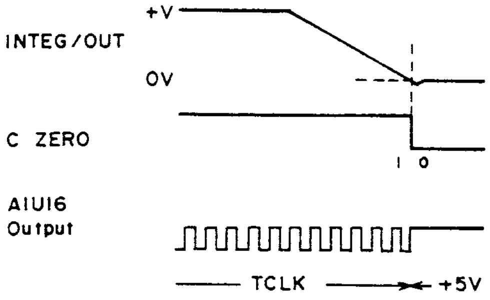
The voltage ratio is easily measured by an integrator and a counter. Refer to Figure A. The integrator is first charged by voltage Ea for a known time, T_0 (determined by the instrument). It is then discharged by voltage Eb. At the start of the discharge cycle, a counter (not shown) is enabled and begins counting the pulses of a reference clock signal. The counter is disabled when the integrator's output reaches 0V. The number of pulses counted by the counter represents the integrator discharge time, T. The voltage ratio Ea/Eb is represented by the following equation:

$$Ea/Eb = (1/T_0) \cdot T \quad (\because Ea \cdot T_0 = Eb \cdot T)$$

where T_0 is a known constant.

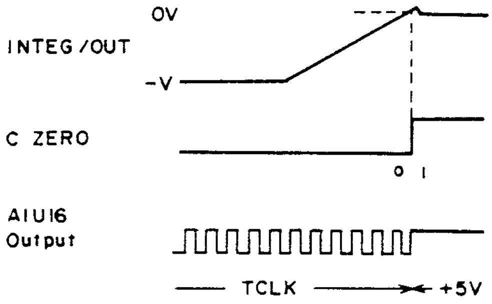


Select Input			A1U16 Output (1A)
4	2	1	
0	0	0	TCLK
0	0	1	PFVCO
0	1	0	TCLK
0	1	1	+5V
1	0	0	+5V
1	0	1	TCLK
1	1	0	TCLK
1	1	1	+5V



Downward Discharge

ENCOMP	CZERO	CLSL	Output
1	1	0	TCLK
1	0	0	+5V



Upward Discharge

ENCOMP	CZERO	CLSL	Output
1	0	1	TCLK
1	1	1	+5V

Figure A

Figure 8-19. Voltage Ratio Detection.

ZERO SHIFT

The zero reference input to the Zero Detector (A2U68) is slightly shifted from zero volts so as to measure the discharge time of the Integrator (A2U65) accurately even when the discharge time is very short. The additional time required for the zero shift operation, T , is compensated for in the digital section.

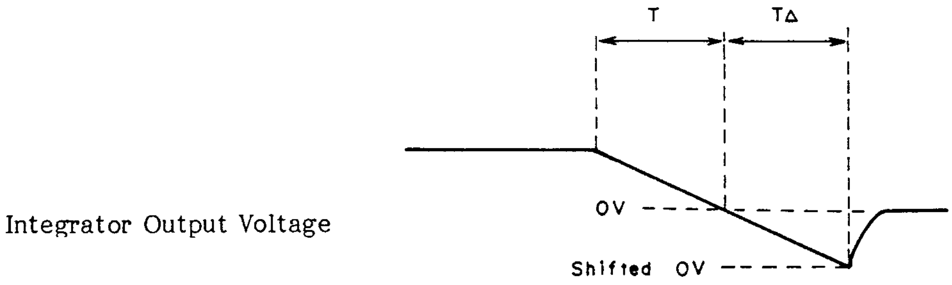


Figure 8-20. ZERO SHIFT.

8-36. DIGITAL SECTION THEORY

8-37. Digital section block diagram is shown in Figure 8-30. A simplified digital section block diagram, including an analog section block diagram, is shown in Figure 8-21.

8-38. Overall instrument operation is controlled by a high speed Z80 microprocessor driven by a 5.76MHz clock. A1U22 controls selection of the required ROM (U5 through U11) by decoding four address lines--A12 through A15—into seven ROM gate signals—ROMG1 through ROMG7. U11 and ROM gate signal ROMG7 are not used in normal operation. The correspondence between address lines A12 through A15 and ROMs U5 through U10 is given in Table 8- 4 . Addressing of data stored in the selected ROM is handled by the remaining address lines--A0 through A11. Data read from the selected ROM is sent to the microprocessor via data bus lines D0 through D7. The

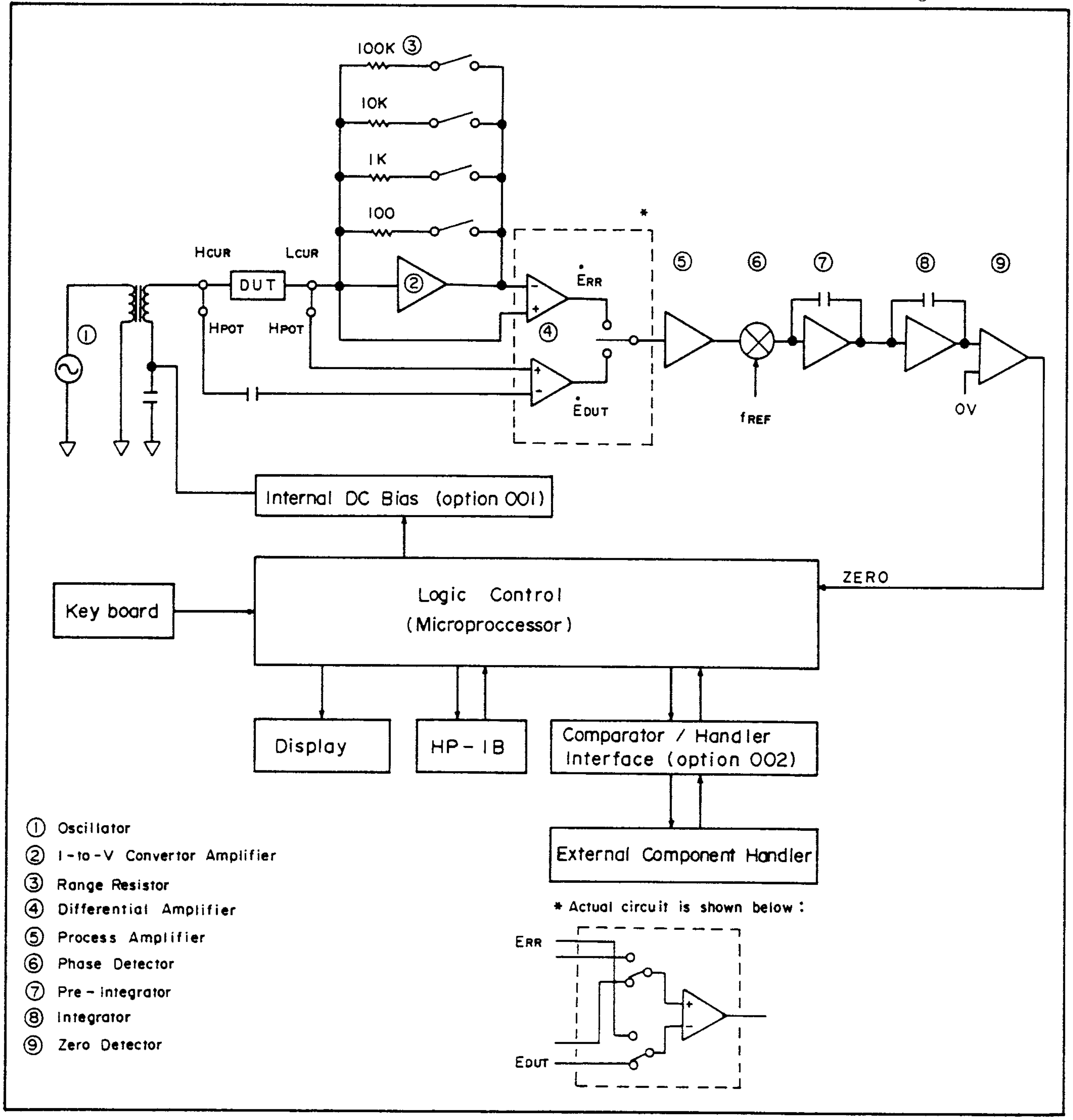


Figure 8-21. Digital Section Block Diagram.

microprocessor operates in accordance with the instructions and data stored in the ROMs.

A1U35 provides five signallines—ANACTL1 through ANACTL5--which control the data latches in the analog circuits. Similarly, A1U41 provides six signal lines—$\overline{\text{IOEN0}}$ through $\overline{\text{IOEN5}}$--which control data transfer to and from other boards via the data bus. For example, when the $\overline{\text{IOEN0}}$ line is LOW, data is transmitted between the microprocessor and the HP-IB circuits on the A21 board. Refer to Table 8- 5 for the correspondence between address lines A3 through A5 and I/O lines $\overline{\text{IOEN0}}$ through $\overline{\text{IOEN5}}$.

8- 39. Operation of the microprocessor is interrupted by any one of three interrupt signals: $\overline{\text{IBINT}}$, $\overline{\text{TRIGINT}}$ and KEYINT. The $\overline{\text{IBINT}}$ line is active (LOW) when an interrupt request is on theHP-IB: $\overline{\text{TRIGINT}}$ is active (LOW) when the instrument is externally triggered; KEYINT is active (HIGH) when a key on the front panel is pressed. These interrupts are detected at the beginning of a measurement cycle or before each voltage-ratio measurement period.

8- 40. The microprocessor, the HP-IB circuits on the A21 board, and the data latches on the A22 board (option 001) are reset each time the $\overline{\text{RESET}}$ signal goes LOW. $\overline{\text{RESET}}$ goes LOW if the +5V supply on the A1 board drops below +4.8V. Refer to Figure 8- 22. The active (LOW) time for the $\overline{\text{RESET}}$ signal is approximately 500ms.

8-41. Perhaps the most important function of the section is to measure the time required for the main integrator on the A2 board to discharge during each voltage-ratio measurement. This is done by a counter, A1U39. At the start of the integrator discharge period, A1U39 is enabled and begins counting the pulses of a 3.84MHz clock signal (TCLK) output from A1U16. When the integrator is completely discharged (output reaches zero volts), the ZERO DETECTOR on the A2 board sends the ZERO signal, which stops the clock. The time required for the integrator to discharge is indicated by the number in A1U39. See Figures 8- 19 and 8- 20.

8- 42. The A1 board contains an 11.5200MHz crystal oscillator, A1U1. Output from the oscillator is counted down to provide the 5.76MHz clock signal for the microprocessor, the 3.84MHz clock signal for voltage-ratio measurement, and the 8kHz reference signal for the phase-locked loop on the A2 board.

8-43. Figure 8-23 shows the flow diagram for the measurement sequence.

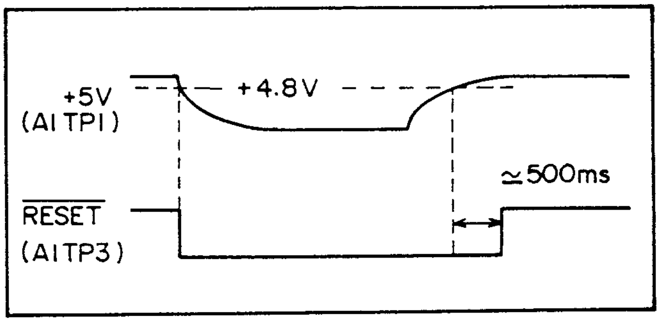


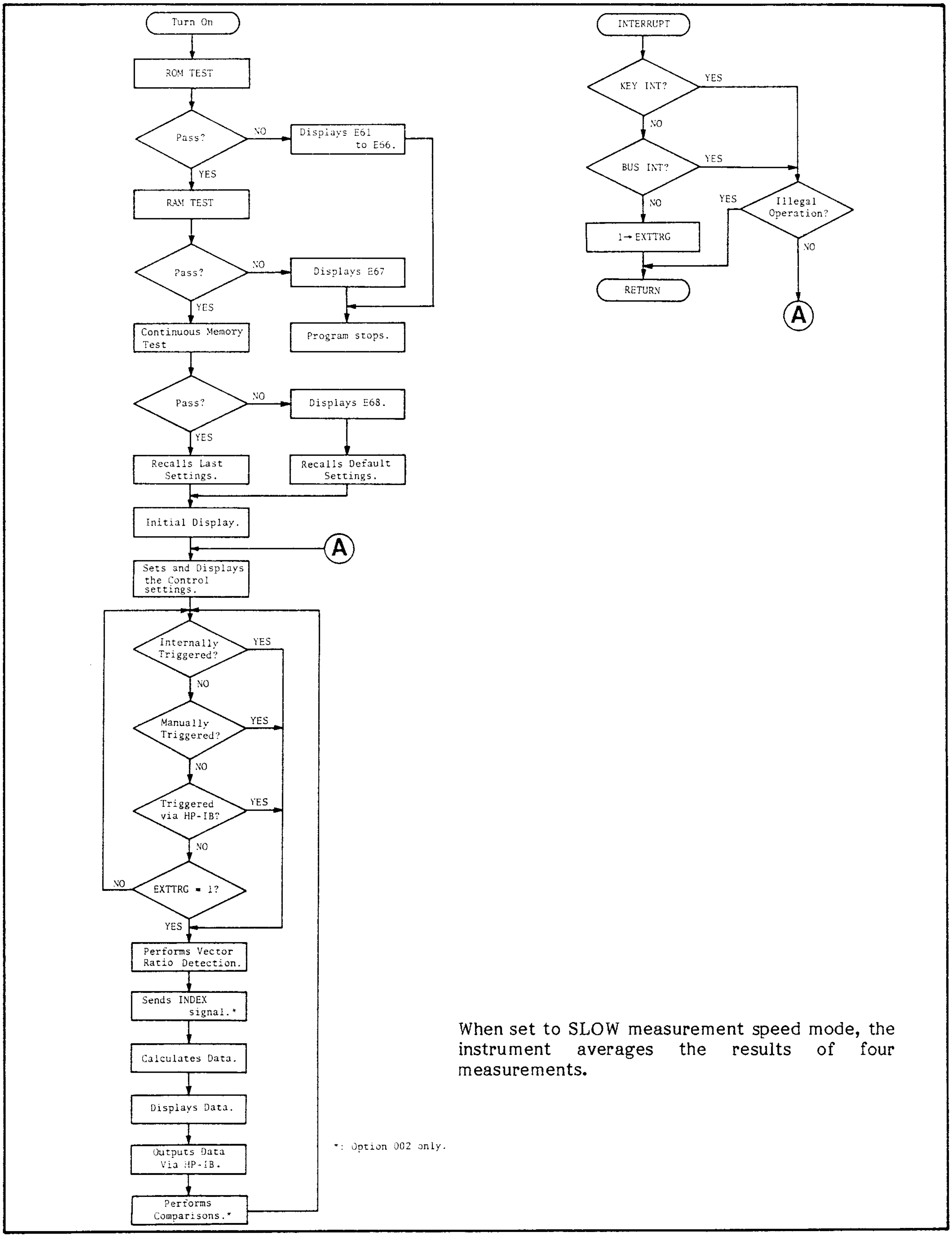
Figure 8- 22. Reset Signal.

Table 8- 5 . I/O Enable Signals

Address Lines			I/O Enable Signal
5	4	3	
0	0	0	$\overline{\text{IOEN0}}$
0	0	1	$\overline{\text{IOEN1}}$
0	1	0	$\overline{\text{IOEN2}}$
0	1	1	$\overline{\text{IOEN3}}$
1	0	0	$\overline{\text{IOEN4}}$
1	0	1	$\overline{\text{IOEN5}}$

Table 8- 4 . ROM Addresses

Address Lines																Addressed ROM
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	ROM0 (A1U5)
0	0	0	1	-	-	-	-	-	-	-	-	-	-	-	-	ROM1 (A1U6)
0	0	1	0	-	-	-	-	-	-	-	-	-	-	-	-	ROM2 (A1U7)
0	0	1	1	-	-	-	-	-	-	-	-	-	-	-	-	ROM3 (A1U8)
0	1	0	0	-	-	-	-	-	-	-	-	-	-	-	-	ROM4 (A1U9)
0	1	0	1	-	-	-	-	-	-	-	-	-	-	-	-	ROM5 (A1U10)



*: Option 002 only.

When set to SLOW measurement speed mode, the instrument averages the results of four measurements.

Figure 8-23. Flow Diagram.

8-44. OPTIONS

8-45. The theory of operation for the 4276A's optional circuits is outlined in the following paragraphs.

8-46. OPTION 001 INTERNAL DC BIAS (A22)

8-47. The A22 board primarily contains a DAC (A22U3) and an output amplifier, as shown in Figure 8-24. The DAC outputs a dc voltage whose polarity and magnitude are determined by the reference voltage, V_{ref} , and the digital is determined by the digital data sent from the microprocessor and stored in latches U1 and U2. Output voltage is calculated as follows:

$$V_{OUT} = -V_{ref} \cdot \sum_{n=1}^{10} Bn \cdot 2^{-n}$$

(Bn: 0 or 1)

where V_{ref} is determined as follows:

Internal DC Bias Voltage Range	Vref
40.0V to .00V	-6.3V
-.01V to -40.0V	+6.3V

The output voltage of DAC is shown in Figure A.

V_{ref} is switched by an analog switch controlled by Data Bus lines BD6 and BD7 via the latch A22U2. The two latches, A22U1 and U2, are successively enabled by clock signals $\overline{IOEN1}$ and $\overline{IOEN2}$ to output digital data to the DAC and to control the analog switches. Another analog switch selects the attenuation factor — x1 or x1/5 — in accordance with the internal dc bias voltage setting as follows:

Internal DC Bias Voltage Range	Attenuator
±(.00V to 9.99V)	x 1/5
±(10.0V to 40.0V)	x 1

The DAC output voltage shown in Figure A is attenuated by a x1 or x1/5 attenuator to obtain the linear characteristic shown in Figure B. This attenuated voltage is amplified by the x8 output amplifier.

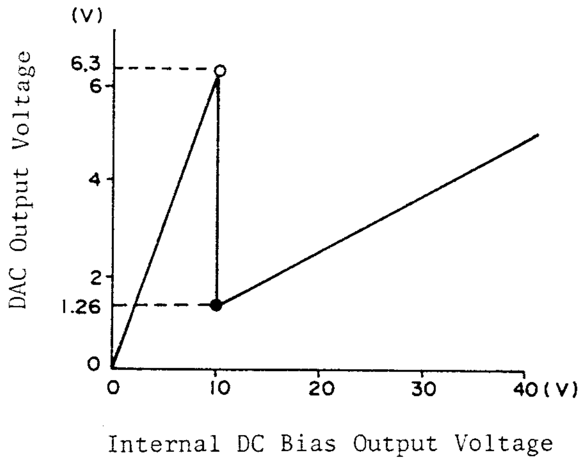


Figure A

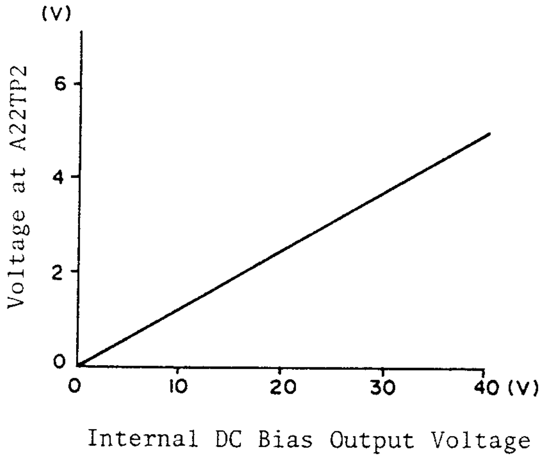


Figure B

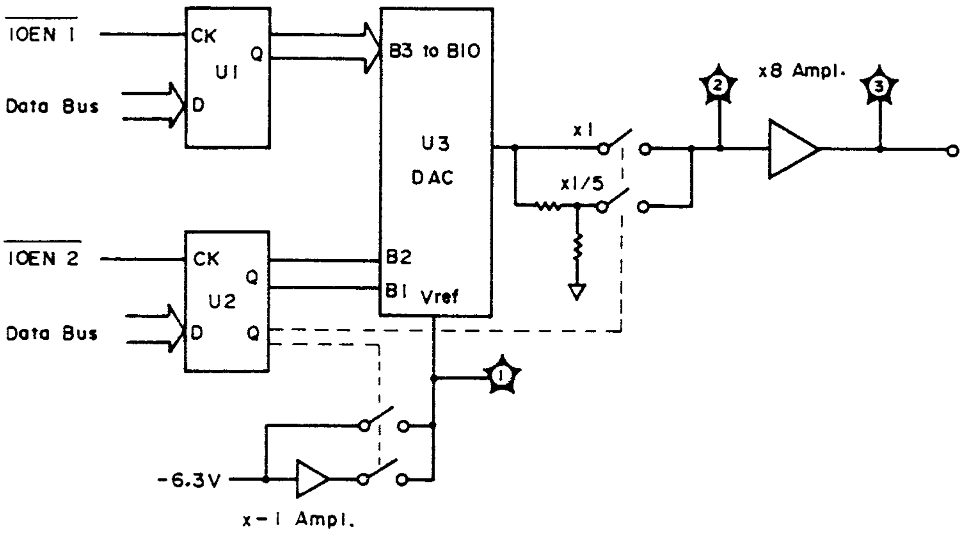


Figure 8-24. A22 Board Block Diagram.

8-48. TIMING DIAGRAM DISCUSSION

8-49. Figure 8-26 shows the timing diagram for the various signals necessary for VRD operation. In the figure, the REFDET signal goes HIGH when the e_{ref} signal crosses zero volts in a negative voltage-to-positive voltage direction after the PSH signal goes LOW. The REFDET signal provides the start timing for the 8F , which is the source of the phase reference signals used by the phase detector. Refer to Figure 8-25.

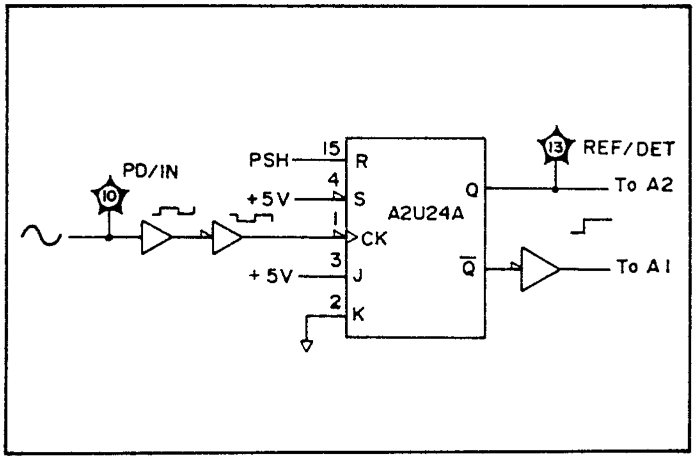


Figure 8-25. REFDET Circuit.

8-50. In each voltage ratio detection period — , , and — the integrator charge time, T_0, is constant for the selected measurement speed, as listed in Table 8-6.

Table 8-6. Integrator Charge Time

Measurement Speed	To
MED, SLOW	5ms
FAST	1.25ms

The discharge times T_α, T_β, and T_γ are measured by a programmable counter, A1U39, which counts the pulses of a 3.84MHz clock signal.

8-51. For accurate dual-slope analog-to-digital conversion, the VRD contains a pre-integrator which converts the phase detector's output signal into a dc voltage for integration by the main integrator. The pre-integrator charge time, T_1, depends on the test frequency and the measurement speed. Refer to Table 8-7.

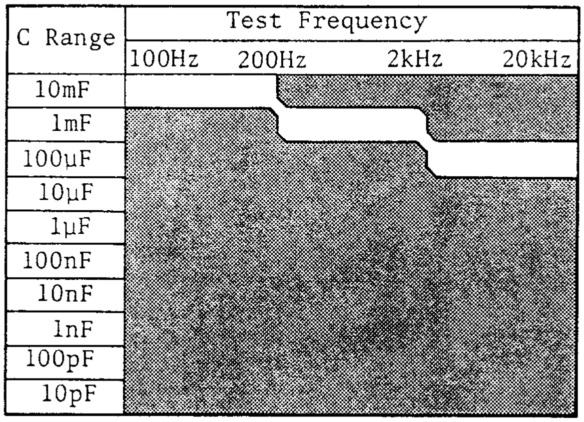
Table 8-7. Pre-Integrator Charge Time

Test Frequency	Measurement Speed	
	MED, SLOW	FAST
100Hz to 199Hz	1/f [s]	1/f [s]
200Hz to 498Hz	5ms	
500Hz to 20kHz		2ms

f: Test Frequency

Note

On the ranges shown in the table below, pre-integrator charge time, T_1, is 10 times longer than those listed in Table 8-7.



Capacitance Measurement

8-52. For the reference convenience, abbreviated signal names are listed in Table 8-8.

Table 8-8. Signal Abbreviations

Abbreviation	Description
PSH	Phase Search
PS1, PS2, PS3	Phase Signals 1 through 3
REFDET	Reference Detection
AZT	Auto Zero Time
PC	Polarity Check
ZST	Zero Shift
IRST	Integrator Reset
PRST	Pre-Integrator Reset
IOFF	Integration Off
IOFS	Integration Off Switch

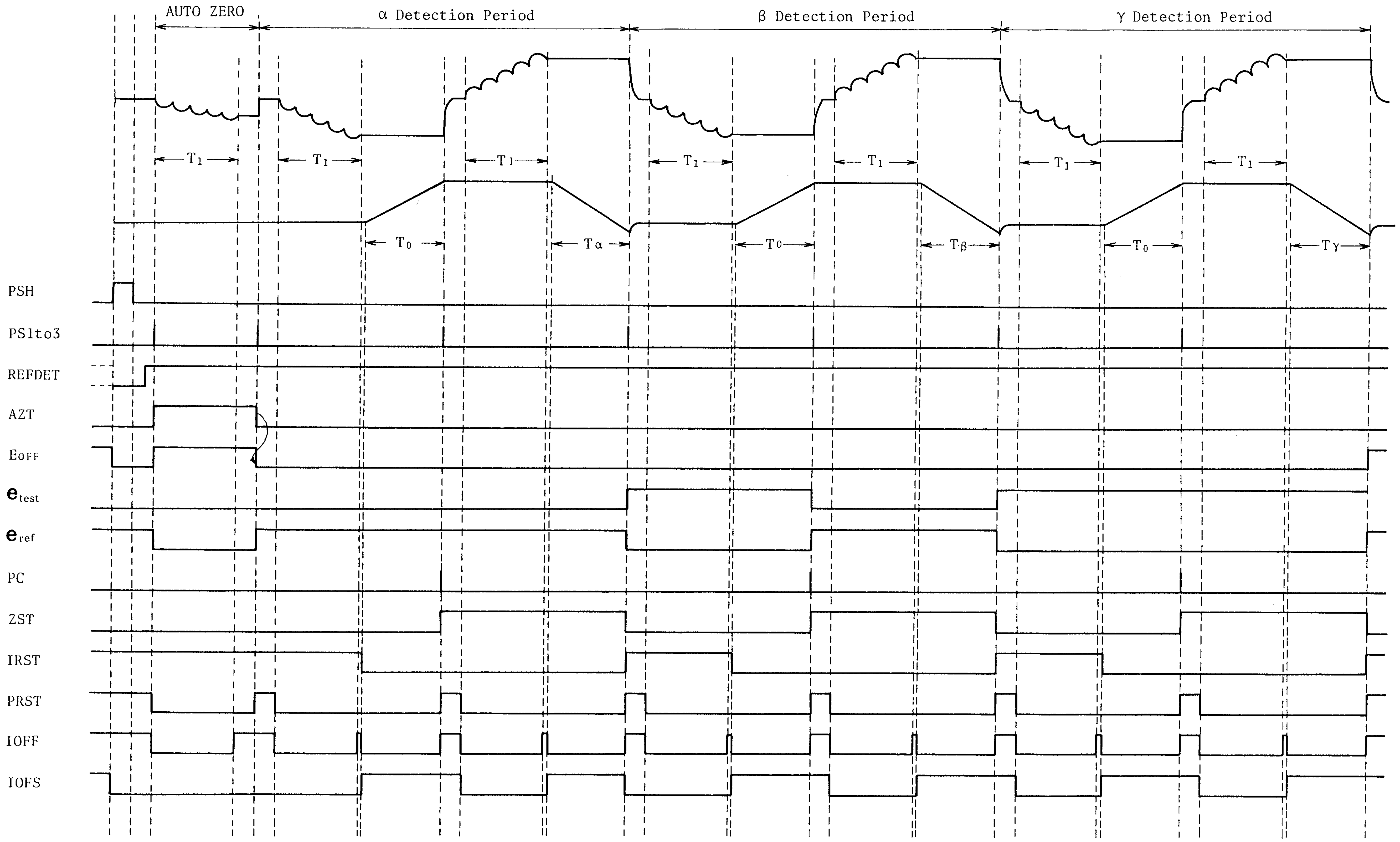
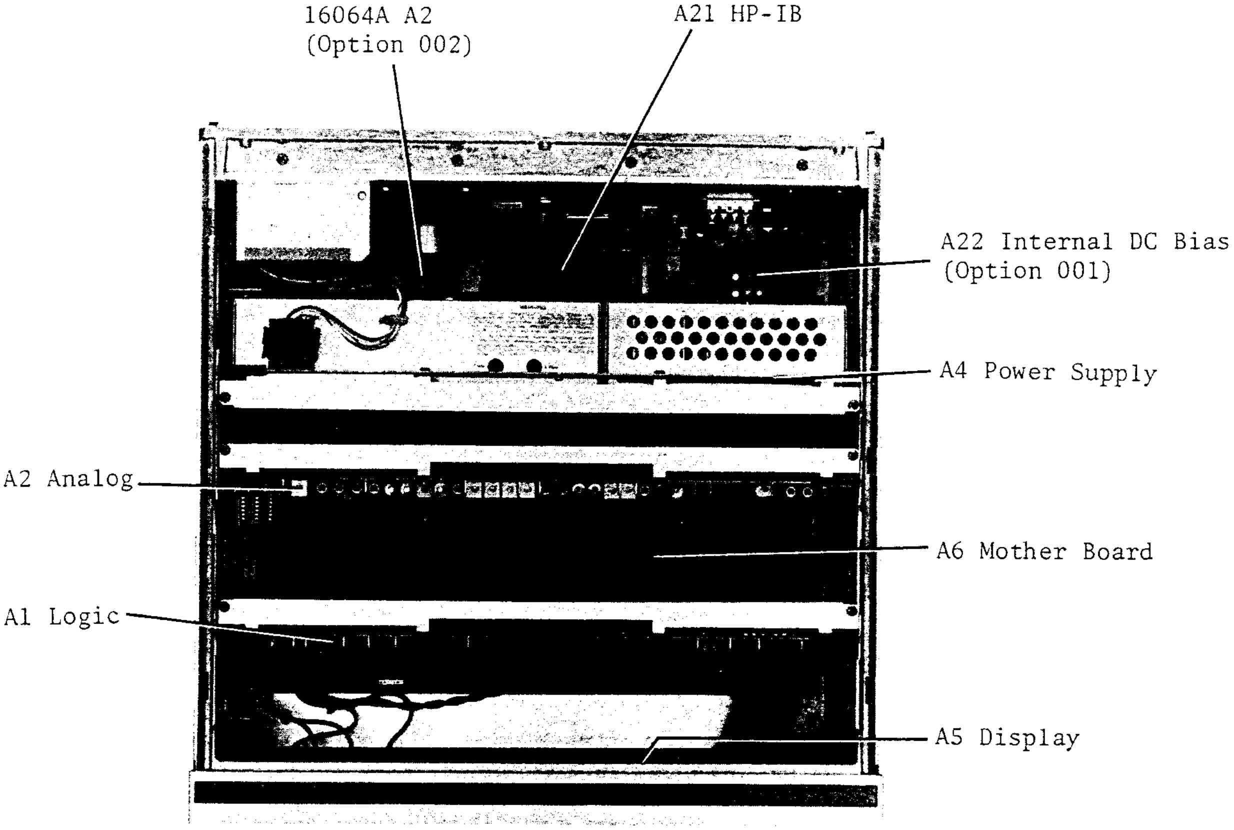


Figure 8-26. Timing Diagram.

8-53. Repair.

8-54. Board assembly locations are shown in Figure 8-27. Graphic symbols and abbreviated signal names used in schematic diagrams are explained in Figure 8-28 and Table 8-9, respectively.



A1 Logic Board: P/N 04276-66501
A2 Analog Board: P/N 04276-66502
A4 Power Supply Board: P/N 04276-66504
A5 Display Boar: P/N 04276-66505
A6 Mother Board: P/N 04276-66506
A21 HP-IB Board: P/N 04276-66521
A22 Internal DC Bias: P/N 04276-66522
16064A A2 Board: P/N 16064-66502

P/N: Part Number

Figure 8-27. Assembly Locations (Top View).

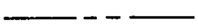
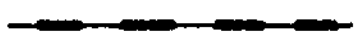
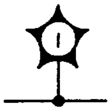
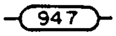
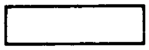
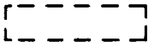
P/O	Part of.
○	Knob control.
	Screwdriver adjustment.
	Circuit assembly boarderline.
*	Asterisk denotes a factory selected value. Value shown is typical, part may be omitted.
	Bead inductance.
	Circuit board pattern inductance.
	Heavy line indicates main signal path.
	Heavy dashed line indicates main feedback path.
	Wiper moves towards CW with clockwise rotation of control (as viewed from shaft or knob).
	Numbered test point. Measurement aid provided.
	Denotes wire color code. Code used is the same as the resistor color code (e.g., 9.4.7 denotes white/yellow/violet).
	Encloses front panel designations.
	Shielded area.
⏚	Indicates direct conducting connection to earth.
⊥	Indicates conducting connection to chassis or frame.
	Indicates circuit common connection.

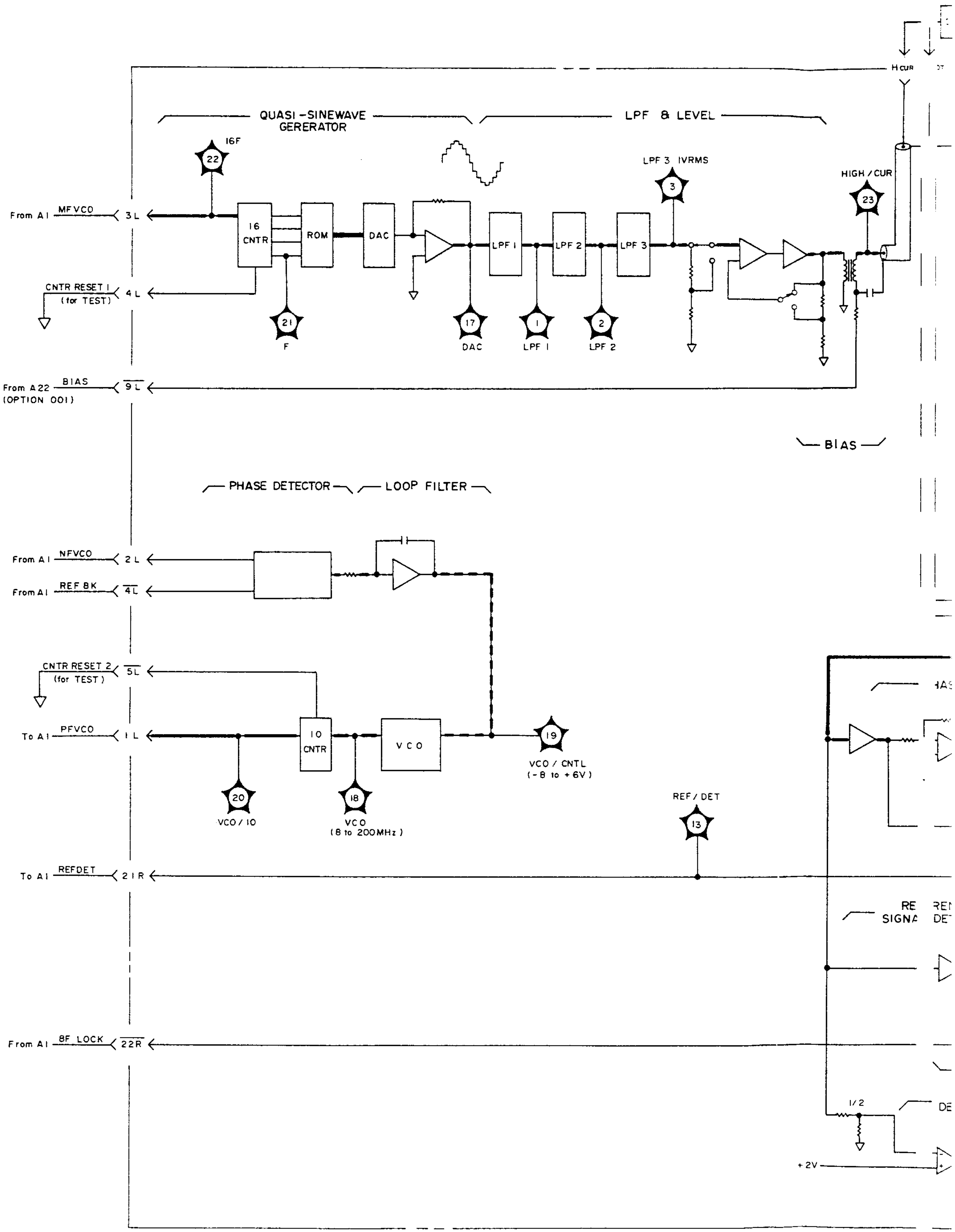
Figure 8-28. Schematic Diagram Notes.

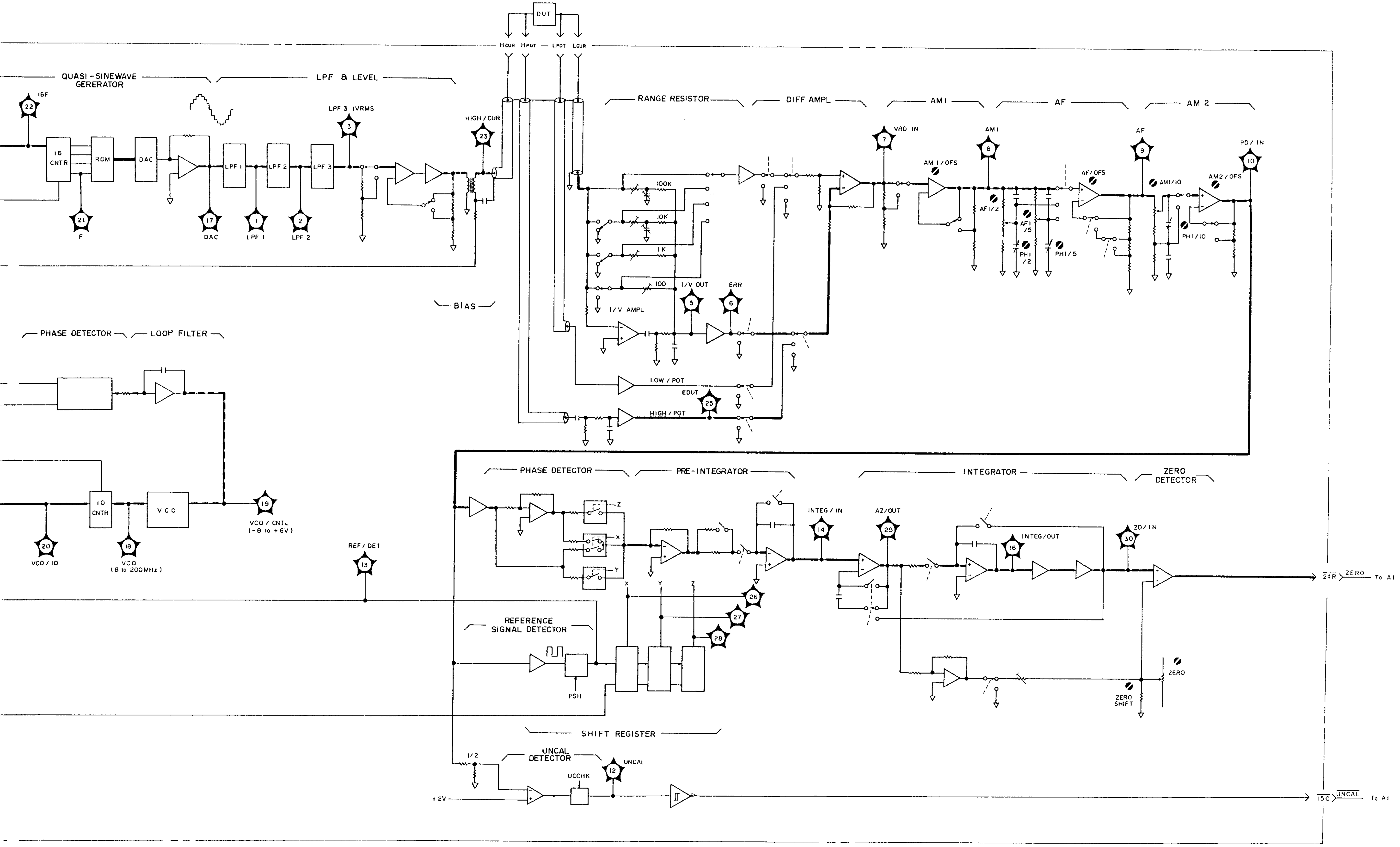
Table 8 9 . Mnemonic Information (Sheet 1 of 2)

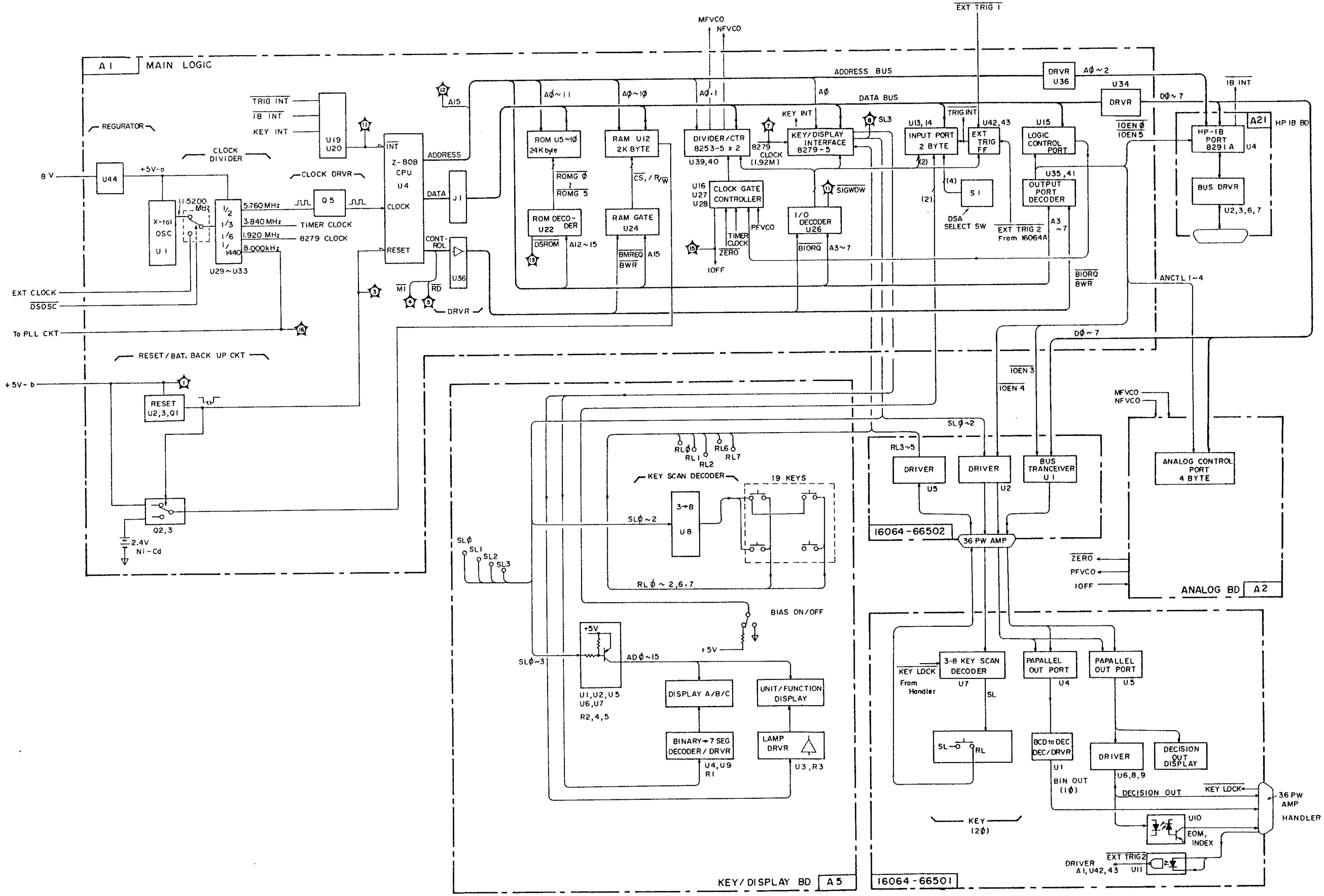
Mnemonic	DESCRIPTION
AF	Amplifier-Frequency
AM1	Amplifier-Magnitude 1
AM2	Amplifier-Magnitude 2
$\overline{\mathrm{ANACTL\ 1\ -\ 5}}$	Analog section control lines
BA0-2	Buffered address bus lines to the A21 HP-IB board
BATTERY	Continuous Memory battery supply and charge line
BCLK	Buffered master clock (5.760MHz)
BD0-7	Buffered data bus lines
$\overline{\mathrm{BEXT\ TRIG\ 2}}$	Buffered external trigger signal from the 16064A
BIAS	Output from the internal dc bias source (0 to ±40V)
BIASG	Internal dc bias source common
$\overline{\mathrm{BIAS}}$	A22 DC BIAS board is installed.
$\overline{\mathrm{BIAS\ ON}}$	Front panel DC BIAS switch status
$\overline{\mathrm{BIN1}}$ - $\overline{9}$	Comparison results output to an external component handler
$\overline{\mathrm{BIOEN3}}$ - $\overline{4}$	Buffered I/O enable lines from the 16064A A2 board to the A1 board.
$\overline{\mathrm{BIORD}}$	Buffered I/O read line from the 16064A A2 board to the A1 board.
$\overline{\mathrm{BIOWR}}$	Buffered I/O write line from the 16064A A2 board to the A1 board.
BLANK	Display blanking signal
BRL3-5	Buffered return line from the 16064A keyboard
BSL0- 2	Buffered send line to the 16064A keyboard
$\overline{\mathrm{CPWT}}$	Comparator wait signal
DA 0 - 3	Front panel display data lines
DB 0 - 3	Front panel display data lines
$\overline{\mathrm{DQ\ HI}}$, $\overline{\mathrm{IN}}$, $\overline{\mathrm{LO}}$	Comparison results output to an external component handler.
DUT	Device under test
$\overline{\mathrm{EOM}}$	End of measurement. Informs an external component handler that the comparison has been made.
EXT DCV1	External DC supply input to HANDLER INTERFACE for open collector outputs.
EXT DCV2	External DC supply. Input from an external component handler.
EXT DCV2 COM	EXT DCV2 return line to an external component handler.
EXT TRIG	External trigger input from an external component handler.
EXT TRIG 1	External trigger signal from the rear panel.
EXT TRIG 2	External trigger signal from 16064A.
Hc	Center conductor of high current terminal

Table 8- 9 . Mnemonic Information (Sheet 2 of 2)

Mnemonic	DESCRIPTION
Hcg	Outer conductor of high current terminal
Hp	Center conductor of high potential terminal
$\overline{\text{IB INT}}$	HP-IB interrupt
$\overline{\text{INDEX}}$	Signal which informs an external component handler that the instrument has finished analog measurement.
$\overline{\text{IOEN0}}$ - $\overline{\text{5}}$	I/O enable lines
IOFF	Integrator off
$\overline{\text{IORD}}$	I/O read
$\overline{\text{IOWR}}$	I/O write
$\overline{\text{KEY LOCK}}$	16064A keyboard disable. Input from an external component handler.
Lc	Center conductor of low current terminal
Lcg	Outer conductor of low current terminal
$\overline{\text{LC HI}}$, $\overline{\text{IN}}$, $\overline{\text{LO}}$	Comparison results output to an external component handler
Lp	Center conductor of low potential terminal
MF VCO	Divided VCO output (16 times the test frequency)
NF VCO	Divided VCO output (8kHz)
$\overline{\text{OUT OF BIN}}$	Comparison result output to an external component handler
PD	Phase detector
PF VCO	Divided VCO output (fvco ÷ 10)
PWF	Power failure
$\overline{\text{REF DET}}$	Reference phase detect
REF8K	VCO reference frequency, 8kHz
$\overline{\text{RESET}}$	Reset signal for A21 HP-IB and A22 DC BIAS boards
RL0 - 2, 6-7	Return lines from the A5 DISPLAY board.
SL0 - 3	Send lines to the A5 DISPLAY board.
$\overline{\text{UNCAL}}$	Uncalibration detect
ZERO	Integrator zero detect
8FLCK	Signal for phase detector (8 times of test frequency)

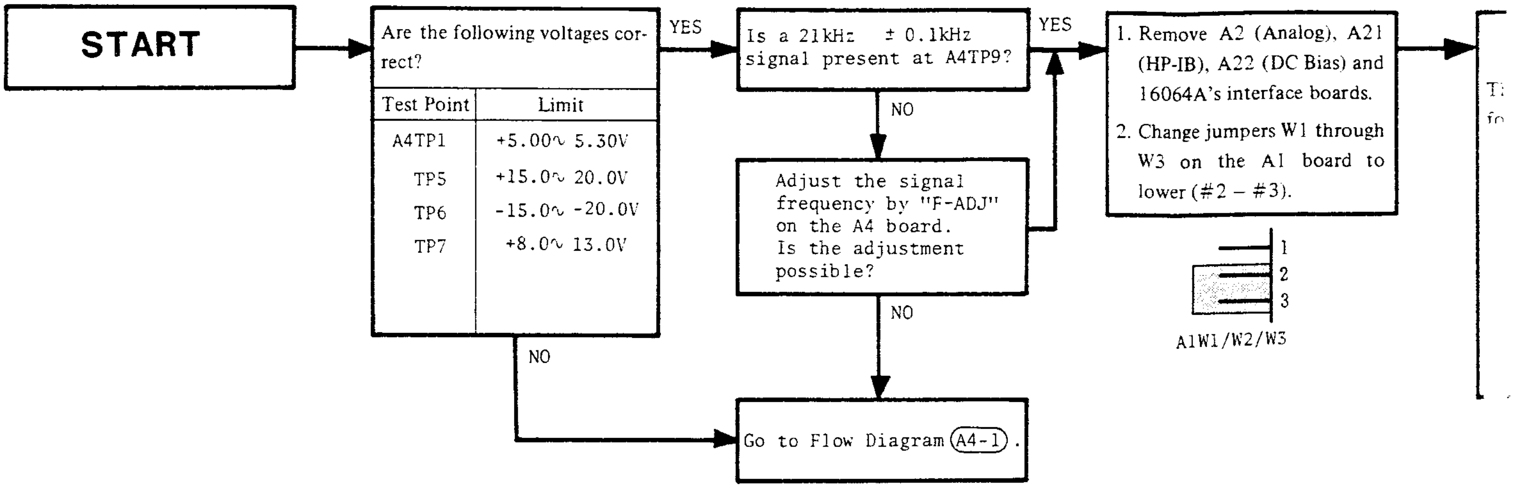

QUASI -SINEWAVE GERERATOR
LPF & LEVEL
16F
22
From A1
MFVCO
3L
16 CNTR
ROM
DAC
LPF 3 1VRMS
3
HIGH / CUR
23
H CUR
LPF 1
LPF 2
LPF 3
CNTR RESET 1 (for TEST)
4L
21
F
17
DAC
1
LPF 1
2
LPF 2
From A22 (OPTION 001)
BIAS
9L
BIAS
PHASE DETECTOR
LOOP FILTER
From A1
NFVCO
2L
From A1
REF 8K
4L
CNTR RESET 2 (for TEST)
5L
To A1
PFVCO
1L
10 CNTR
VCO
19
VCO / CNTL (-8 to +6V)
20
VCO / 10
18
VCO (8 to 200MHz)
REF / DET
13
To A1
REFDET
21R
RE SIGNA
RE DE
From A1
8F LOCK
22R
1/2
DE
+2V


DUT
HCUR
HPOT
LPOT
LCUR
QUASI-SINEWAVE GERERATOR
LPF & LEVEL
16F
22
16 CNTR
ROM
DAC
LPF 1
LPF 2
LPF 3
LPF 3 1VRMS
3
HIGH/CUR
23
21
F
17
DAC
1
LPF 1
2
LPF 2
BIAS
RANGE RESISTOR
DIFF AMPL
AM 1
AF
AM 2
100K
10K
1K
100
I/V AMPL
I/V OUT
5
ERR
6
VRD IN
7
AM 1
8
AF
9
PD/IN
10
AM 1/OFS
AF1/2
AF1/5
PH1/2
PH1/5
AF/OFS
AM1/10
AM2/OFS
PH1/10
LOW/POT
EDUT
25
HIGH/POT
PHASE DETECTOR
LOOP FILTER
10 CNTR
VCO
19
VCO/CNTL (-8 to +6V)
20
VCO/10
18
VCO (8 to 200MHz)
REF/DET
13
PHASE DETECTOR
PRE-INTEGRATOR
INTEGRATOR
ZERO DETECTOR
Z
X
Y
INTEG/IN
14
AZ/OUT
29
INTEG/OUT
16
ZD/IN
30
26
27
28
REFERENCE SIGNAL DETECTOR
PSH
SHIFT REGISTER
ZERO
ZERO SHIFT
24R
ZERO
To A1
1/2
UNCAL DETECTOR
UCCHK
12
UNCAL
+2V
15C
UNCAL
To A1



A1 MAIN LOGIC
REGURATOR
8 V
U44
+5V-a
CLOCK DIVIDER
X-tal OSC U1
11.5200 MHz
1/2 1/3 1/6 1/1440
U29~U33
5.760 MHz
3.840 MHz TIMER CLOCK
1.920 MHz 8279 CLOCK
8.000 kHz
CLOCK DRVR
Q5
TRIG INT
IB INT
KEY INT
U19 U20
INT
Z-80B CPU U4
CLOCK
RESET
ADDRESS
DATA
J1
CONT-ROL
U36
M1
RD
DRVR
A15
EXT CLOCK
DSOSC
To PLL CKT
RESET/BAT. BACK UP CKT
+5V-b
RESET U2,3,Q1
Q2,3
2.4V Ni-Cd
ADDRESS BUS
DATA BUS
A0~11
A0~10
A0·1
A0
ROM U5~10 24K byte
ROMG 0 ~ ROMG 5
ROM DECODER U22
DSROM
A12~15
RAM U12 2K BYTE
CS, R/W
RAM GATE U24
BMREQ A15
BWR
MFVCO
NFVCO
DIVIDER/CTR 8253-5 x 2
U39,40
8279 CLOCK (1.92M)
U16 U27 U28
CLOCK GATE CONTROLLER
TIMER CLOCK
ZERO
PFVCO
IOFF
KEY INT
KEY/DISPLAY INTERFACE 8279-5
SL3
SIGWDW
I/O DECODER U26
BIORQ
A3~7
EXT TRIG 1
TRIG INT
U13, 14
INPUT PORT 2 BYTE
U42,43
EXT TRIG FF
S1
DSA SELECT SW
EXT TRIG 2 From 16064A
U15
LOGIC CONTROL PORT
U35,41
OUTPUT PORT DECODER
A3~7
DRVR U36
A0~2
U34
DRVR
D0~7
IB INT
IOEN 0
IOEN 5
A21 HP IB BD
HP-IB PORT 8291A U4
BUS DRVR U2,3,6,7
BIORQ
BWR
ANCTL 1~4
D0~7
IOEN 3
IOEN 4
SL0~2
RL3~5
DRIVER U5
DRIVER U2
BUS TRANCEIVER U1
16064-66502
36 PW AMP
MFVCO
NFVCO
ANALOG CONTROL PORT 4 BYTE
ZERO
PFVCO
IOFF
ANALOG BD A2
RL0 RL1 RL2 RL6 RL7
KEY SCAN DECODER
19 KEYS
SL0~2
3→8 U8
RL0~2,6,7
SL0 SL1 SL2 SL3
BIAS ON/OFF
+5V
SL0~3
U1,U2,U5 U6,U7 R2,4,5
AD0~15
DISPLAY A/B/C
UNIT/FUNCTION DISPLAY
BINARY→7 SEG DECODER/DRVR U4,U9 R1
LAMP DRVR U3,R3
KEY/DISPLAY BD A5
KEY LOCK From Handler
3-8 KEY SCAN DECODER U7
SL
SL RL
KEY (20)
PAPALLEL OUT PORT U4
PAPALLEL OUT PORT U5
BCD to DEC DEC/DRVR U1
BIN OUT (10)
DRIVER U6,8,9
DECISION OUT DISPLAY
DECISION OUT
KEY LOCK
36 PW AMP
HANDLER
U10
EOM, INDEX
EXT TRIG2
DRIVER A1,U42,43
U11
16064-66501

Board Isolation Flow Diagram



Are the following voltages correct?

Test Point	Limit
A4TP1	+5.00∿ 5.30V
TP5	+15.0∿ 20.0V
TP6	-15.0∿ -20.0V
TP7	+8.0∿ 13.0V

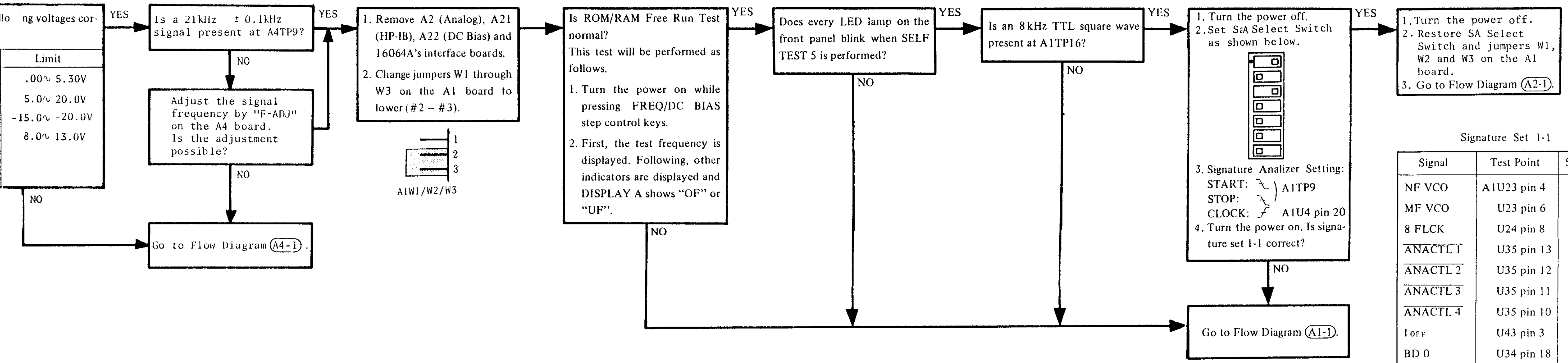
Is a 21kHz ± 0.1kHz signal present at A4TP9?

Adjust the signal frequency by "F-ADJ" on the A4 board. Is the adjustment possible?

Go to Flow Diagram (A4-1).

1. Remove A2 (Analog), A21 (HP-IB), A22 (DC Bias) and 16064A's interface boards.
2. Change jumpers W1 through W3 on the A1 board to lower (#2 – #3).

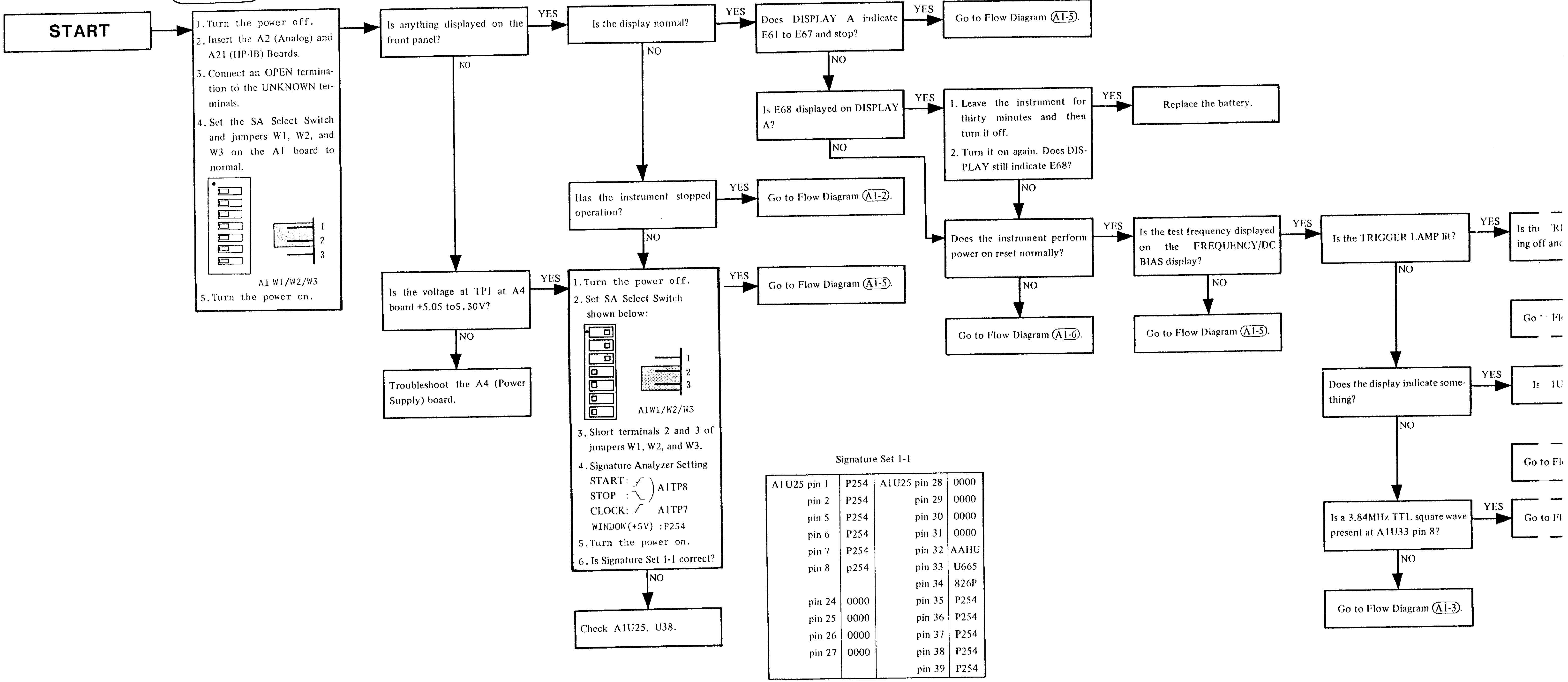
D agram



Signature Set 1-1

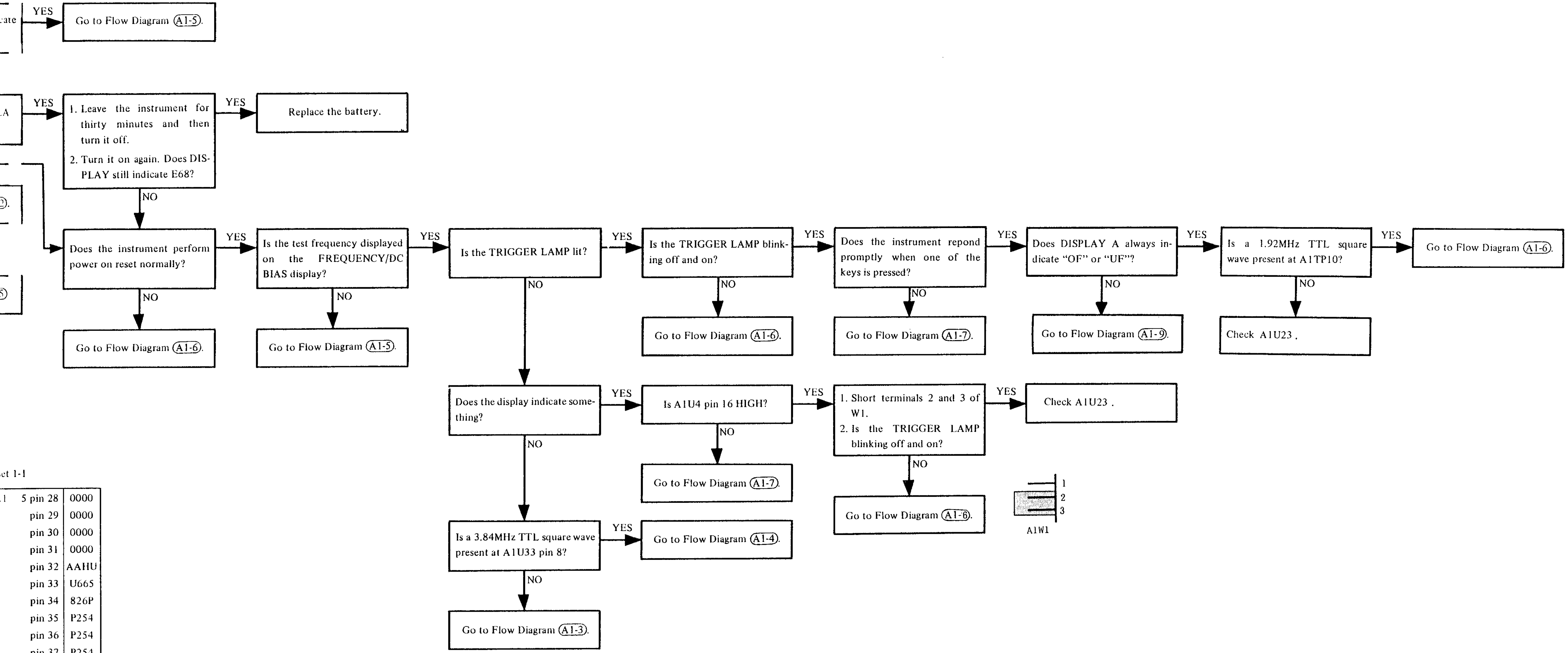
Signal	Test Point	Signature
NF VCO	A1U23 pin 4	CF47
MF VCO	U23 pin 6	F3C8
8 FLCK	U24 pin 8	7F1U
$\overline{\text{ANACTL 1}}$	U35 pin 13	84U4
$\overline{\text{ANACTL 2}}$	U35 pin 12	P4P5
$\overline{\text{ANACTL 3}}$	U35 pin 11	7FP4
$\overline{\text{ANACTL 4}}$	U35 pin 10	44A6
I_{OFF}	U43 pin 3	4625
BD 0	U34 pin 18	6UAC
BD 1	U34 pin 17	2P3P
BD 2	U34 pin 16	708A
BD 3	U34 pin 15	05PF
BD 4	U34 pin 14	491U
BD 5	U34 pin 13	239P
BD 6	U34 pin 12	F019
BD 7	U34 pin 11	H19P
$\overline{\text{IOEN 0}}$	U41 pin 15	C65F
$\overline{\text{IOEN 1}}$	U41 pin 14	195C
$\overline{\text{IOEN 2}}$	U41 pin 13	PPA0
$\overline{\text{IOEN 3}}$	U41 pin 12	955H
$\overline{\text{IOEN 4}}$	U41 pin 11	A8A3
$\overline{\text{IOEN 5}}$	U41 pin 10	C923

Flow Diagram (A1 - 1)



Signature Set 1-1

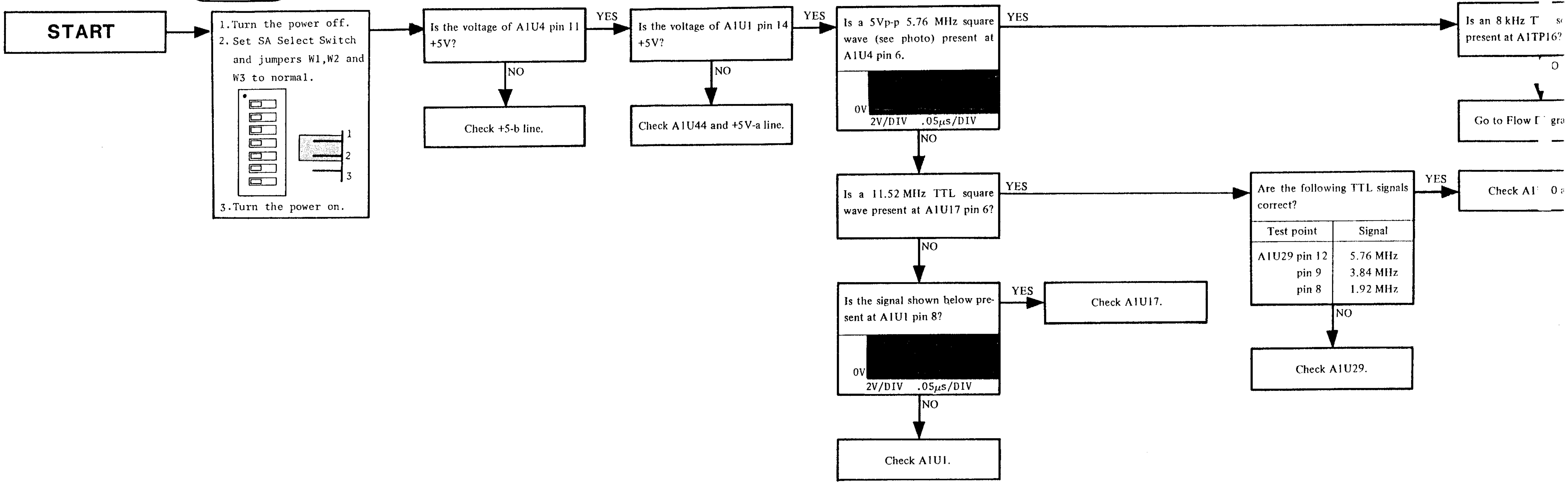
A1U25 pin 1	P254	A1U25 pin 28	0000
pin 2	P254	pin 29	0000
pin 5	P254	pin 30	0000
pin 6	P254	pin 31	0000
pin 7	P254	pin 32	AAHU
pin 8	p254	pin 33	U665
		pin 34	826P
pin 24	0000	pin 35	P254
pin 25	0000	pin 36	P254
pin 26	0000	pin 37	P254
pin 27	0000	pin 38	P254
		pin 39	P254

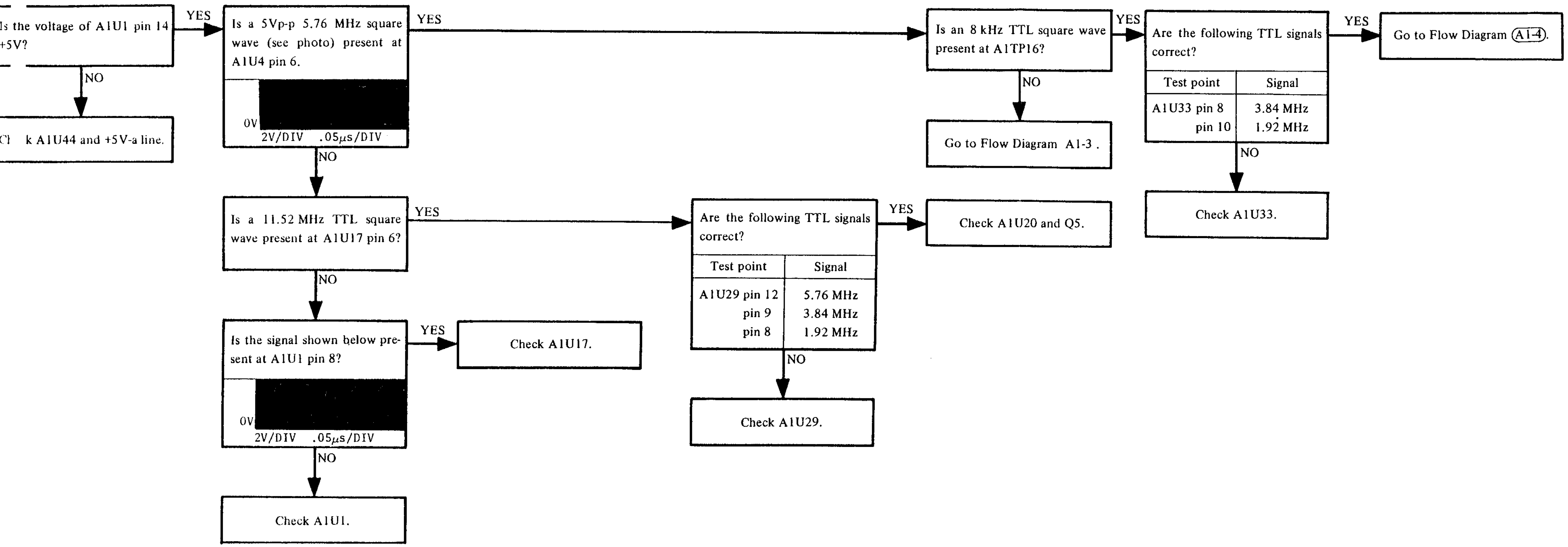


...et 1-1

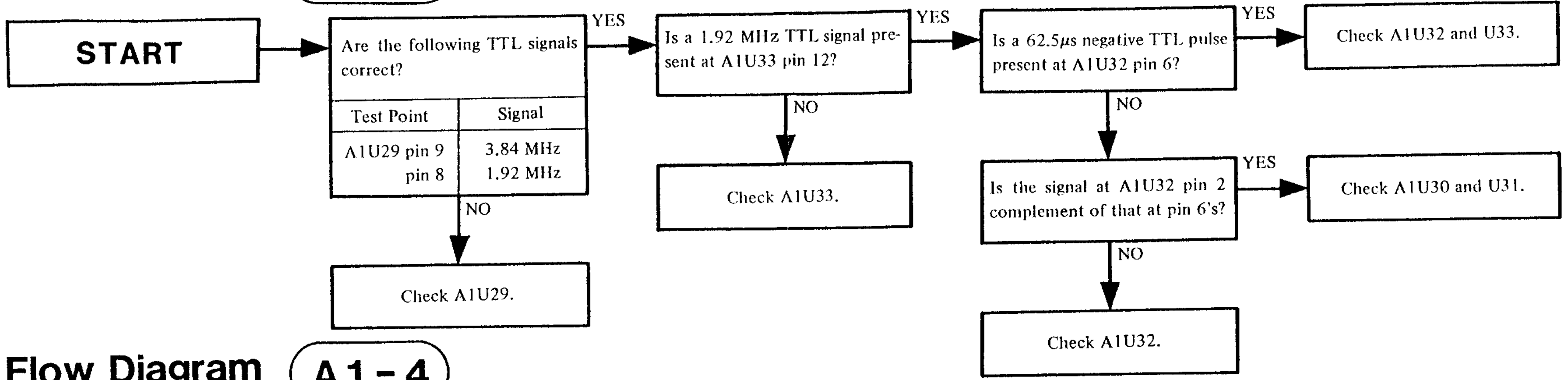
...1 5 pin 28	0000
pin 29	0000
pin 30	0000
pin 31	0000
pin 32	AAHU
pin 33	U665
pin 34	826P
pin 35	P254
pin 36	P254
pin 37	P254
pin 38	P254
pin 39	P254

Flow Diagram A1 - 2

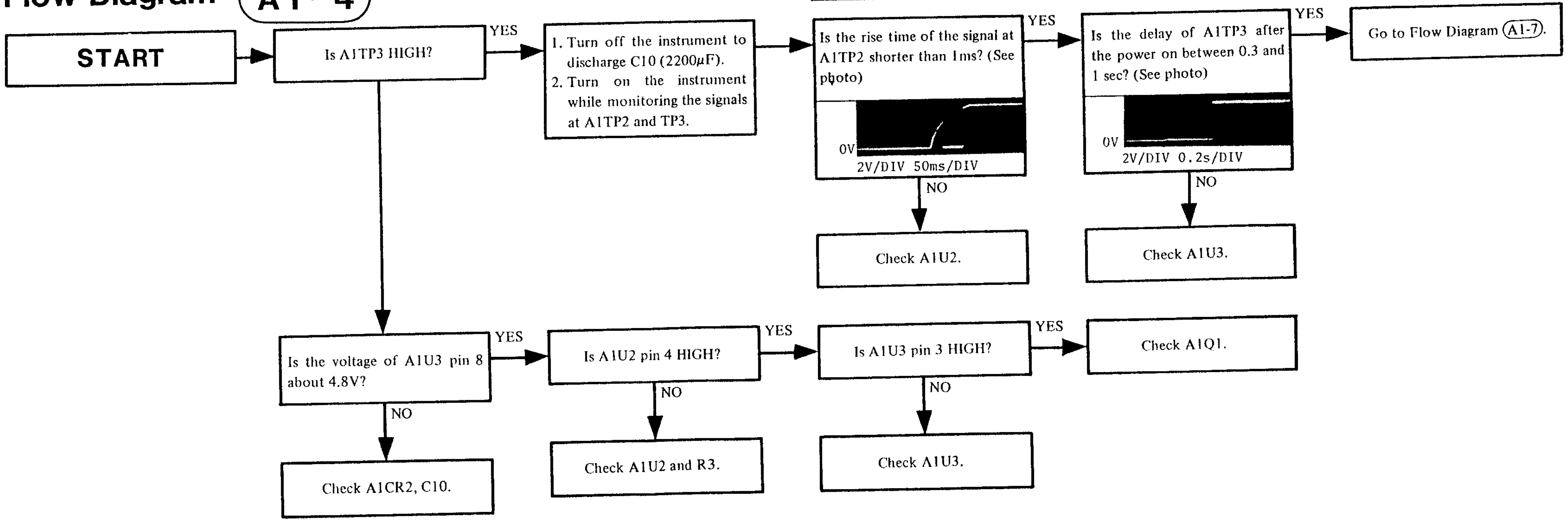



Is the voltage of A1U1 pin 14 +5V?
YES
NO
Cl k A1U44 and +5V-a line.
Is a 5Vp-p 5.76 MHz square wave (see photo) present at A1U4 pin 6.
0V
2V/DIV .05μs/DIV
YES
NO
Is a 11.52 MHz TTL square wave present at A1U17 pin 6?
YES
NO
Is the signal shown below present at A1U1 pin 8?
0V
2V/DIV .05μs/DIV
YES
NO
Check A1U17.
Check A1U1.
Are the following TTL signals correct?
Test point
Signal
A1U29 pin 12
pin 9
pin 8
5.76 MHz
3.84 MHz
1.92 MHz
YES
NO
Check A1U29.
Check A1U20 and Q5.
Is an 8 kHz TTL square wave present at A1TP16?
YES
NO
Go to Flow Diagram A1-3 .
Are the following TTL signals correct?
Test point
Signal
A1U33 pin 8
pin 10
3.84 MHz
1.92 MHz
YES
NO
Check A1U33.
Go to Flow Diagram (A1-4).

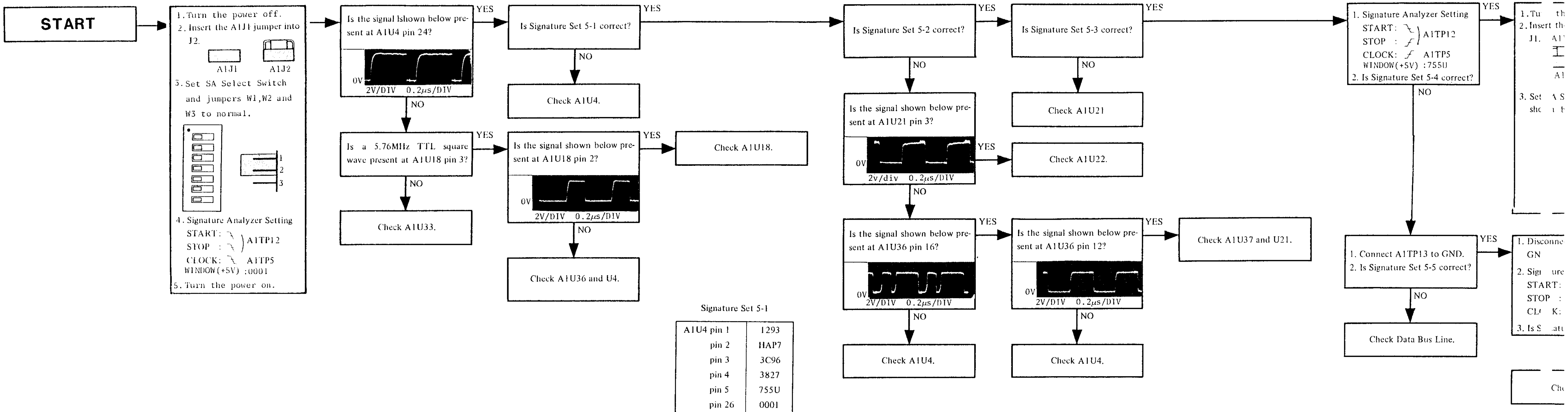
Flow Diagram (A1 - 3)



Flow Diagram (A1-4)



Flow Diagram A1 - 5



Signature Set 5-1

A1U4 pin 1	1293
pin 2	HAP7
pin 3	3C96
pin 4	3827
pin 5	755U
pin 26	0001
pin 30	UUUU
pin 31	5555
pin 32	CCCC
pin 33	7F7F
pin 34	5H21
pin 35	0AFA
pin 36	UPFH
pin 37	52F8
pin 38	HC89
pin 39	2H70
pin 40	HPP0

Signature Set 5-2

A1U22 pin 9	96F8
pin 10	57HH
pin 11	CFHH
pin 12	04UH
pin 13	160U
pin 14	7631
pin 15	383A

Signature Set 5-3

A1U21 pin 6 (BIORQ)	0001
pin 8 (IORD)	0001
pin 11 (IOWR)	0001

Signature Set 5-4

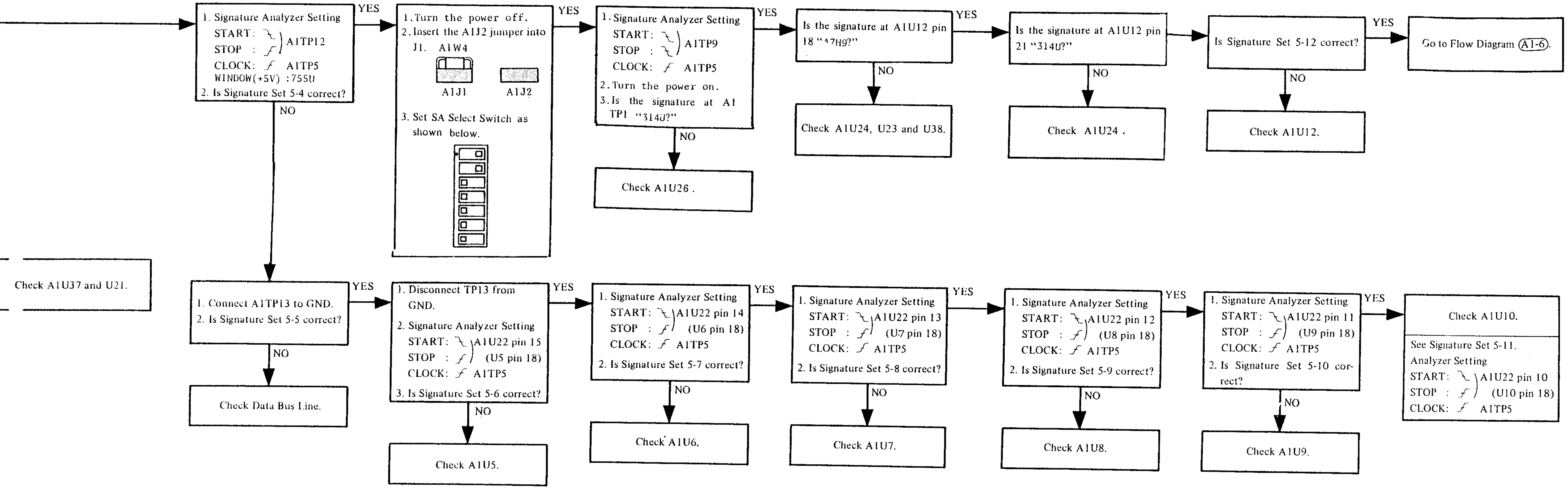
A1J1 pin 9	58UU
pin 10	5P82
pin 11	FPAC
pin 12	15CC
pin 13	PU8H
pin 14	9F0U
pin 15	490F
pin 16	HA04

Signature Set 5-5

A1J1 pin 9	755U
pin 10	755U
pin 11	755U
pin 12	755U
pin 13	755U
pin 14	755U
pin 15	755U
pin 16	755U

gna

A1 pin	
pin	
pin	
pin	
pin	
pin	
pin	
pin	



Signature Set 5-4

I1 pin 9	58UU
pin 10	5P82
pin 11	FPAC
pin 12	15CC
pin 13	PU8H
pin 14	9F0U
pin 15	490F
pin 16	HA04

Signature Set 5-5

A1J1 pin 9	755U
pin 10	755U
pin 11	755U
pin 12	755U
pin 13	755U
pin 14	755U
pin 15	755U
pin 16	755U

Signature Set 5-6

A1U5 pin 9	1U9C
pin 10	F42C
pin 11	3273
pin 13	CPCU
pin 14	6093
pin 15	5H49
pin 16	3438
pin 17	1258

Signature Set 5-7

A1U6 pin 9	4C82
pin 10	6C80
pin 11	8HH8
pin 13	90HP
pin 14	9838
pin 15	A970
pin 16	H78U
pin 17	45P9

Signature Set 5-8

A1U7 pin 9	8598
pin 10	5U8A
pin 11	5568
pin 13	F22C
pin 14	7UUP
pin 15	22HC
pin 16	5811
pin 17	6884

Signature Set 5-9

A1U8 pin 9	1532
pin 10	FPUC
pin 11	4P0P
pin 13	9CP5
pin 14	H633
pin 15	106H
pin 16	51C2
pin 17	168P

Signature Set 5-10

A1U9 pin 9	F30A
pin 10	6A47
pin 11	2498
pin 13	1F6A
pin 14	0U3U
pin 15	0A40
pin 16	6PFP
pin 17	8UFF

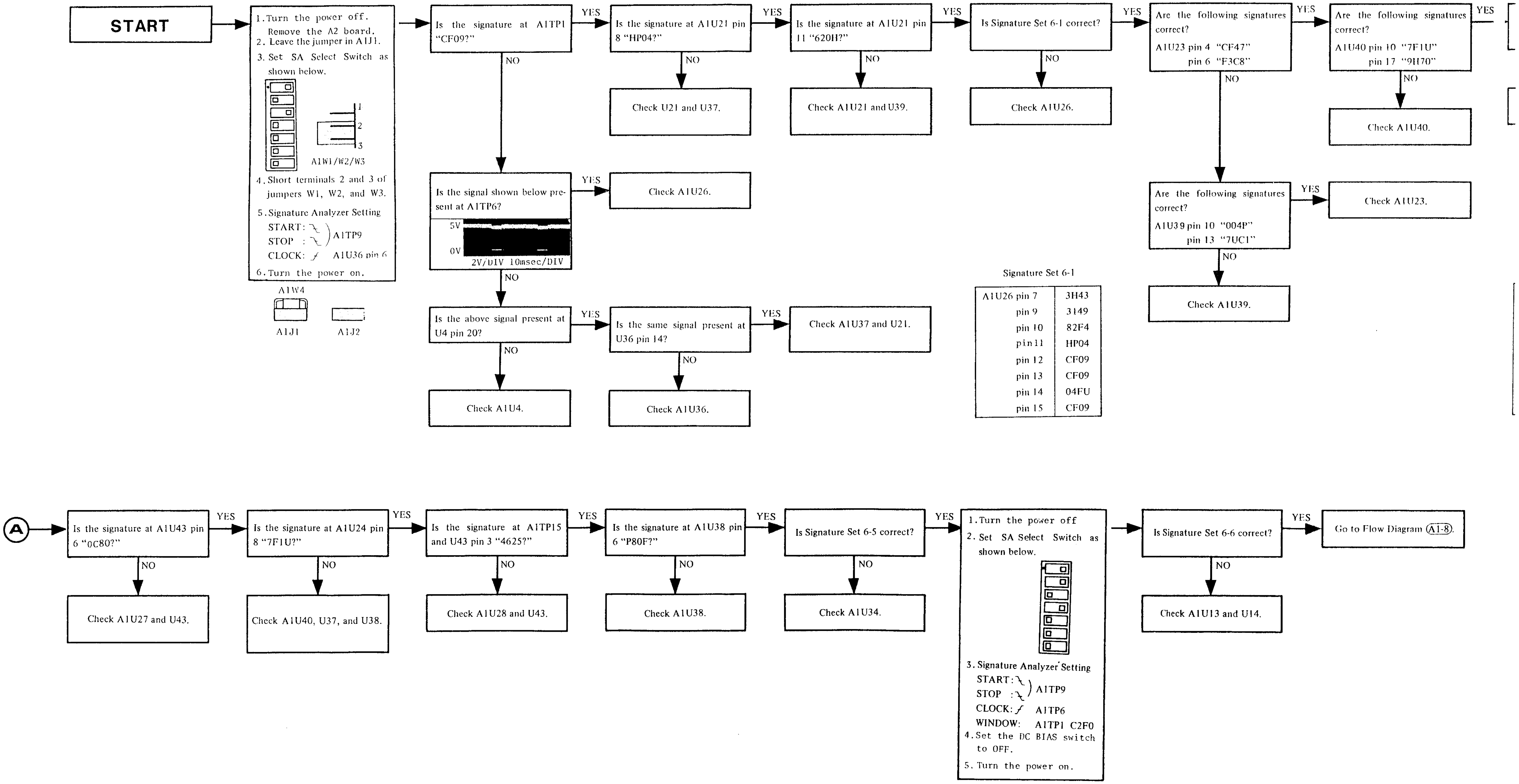
Signature Set 5-11

A1U10 pin 9	7A36
pin 10	7A38
pin 11	ACF6
pin 13	3F2U
pin 14	AH7A
pin 15	27U8
pin 16	C1U2
pin 17	A6F1

Signature Set 5-12

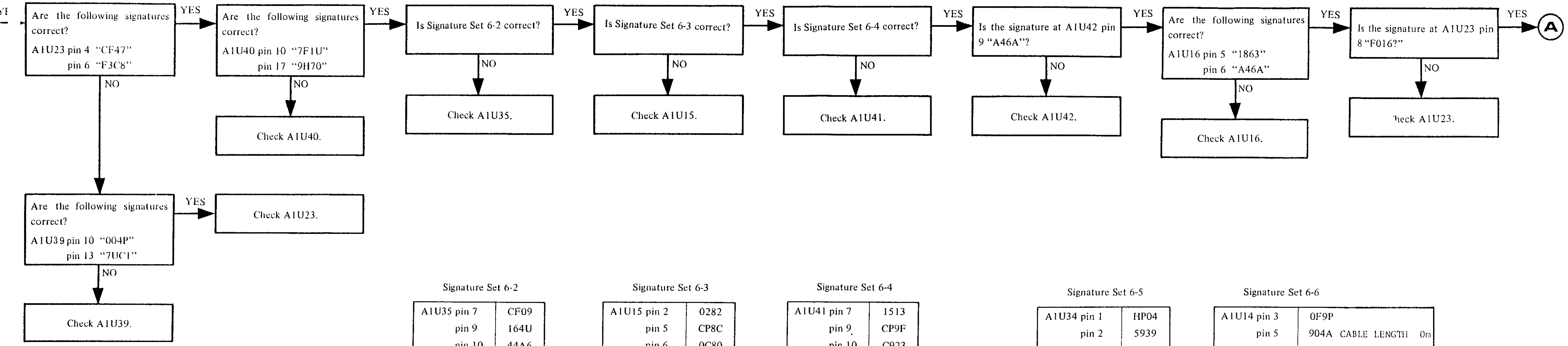
A1U12 pin 9	UC96
pin 10	2P21
pin 11	7528
pin 13	4H31
pin 14	251U
pin 15	35C0
pin 16	2H57
pin 17	90H2

Flow Diagram (A1 - 6)



Signature Set 6-1

A1U26 pin 7	3H43
pin 9	3149
pin 10	82F4
pin 11	HP04
pin 12	CF09
pin 13	CF09
pin 14	04FU
pin 15	CF09



Signature Set 6-2

A1U35 pin 7	CF09
pin 9	164U
pin 10	44A6
pin 11	7FP4
pin 12	P4P5
pin 13	84U4
pin 14	P884
pin 15	2061

Signature Set 6-3

A1U15 pin 2	0282
pin 5	CP8C
pin 6	0C80
pin 9	0F73
pin 12	07U3
pin 15	F793
pin 16	A46A
pin 19	AH21

Signature Set 6-4

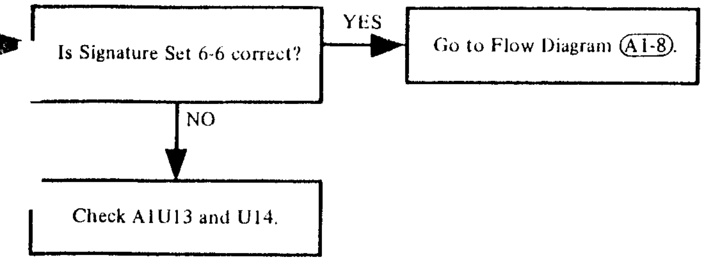
A1U41 pin 7	1513
pin 9	CP9F
pin 10	C923
pin 11	A8A3
pin 12	955H
pin 13	PPA0
pin 14	195C
pin 15	C65F

Signature Set 6-5

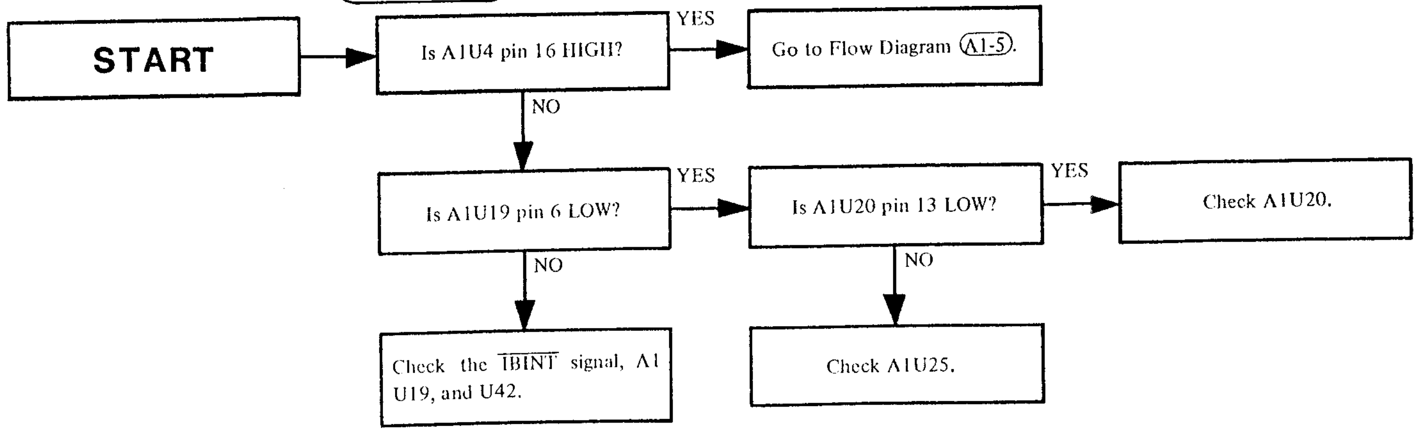
A1U34 pin 1	HP04
pin 2	5939
pin 3	PF6C
pin 4	6H6F
pin 5	C5HH
pin 6	2104
pin 7	U3A4
pin 8	277U
pin 9	8741
pin 11	H19P
pin 12	F019
pin 13	239P
pin 14	491U
pin 15	05PF
pin 16	708A
pin 17	2P3P
pin 18	6UAC
pin 19	P80F

Signature Set 6-6

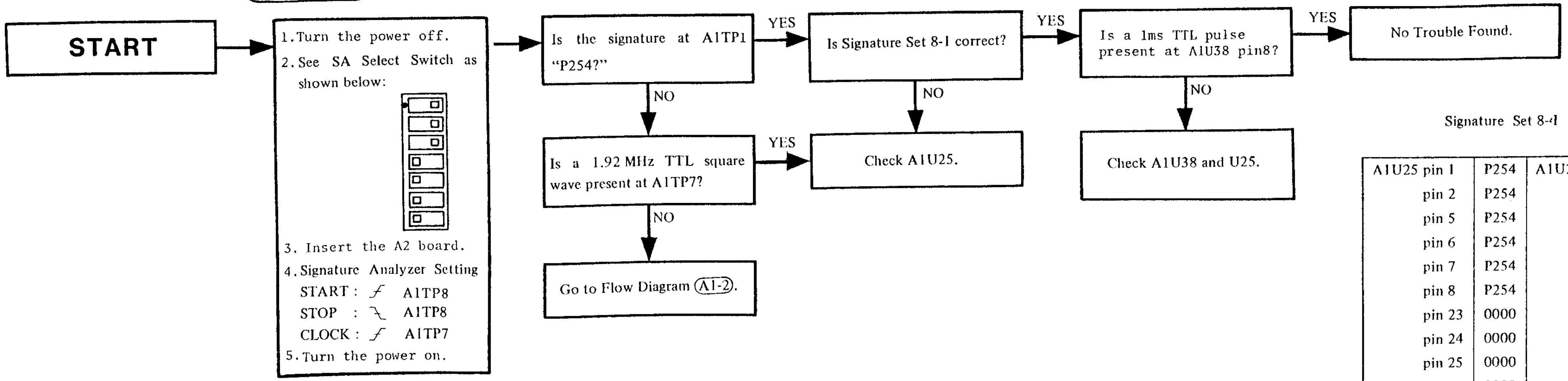
A1U14 pin 3	0F9P
pin 5	904A CABLE LENGTH 0m
pin 7	FPU9
pin 9	C215 DC BIAS OFF
pin 12	0463
pin 14	U857
pin 16	C786
pin 18	0UFH



Flow Diagram (A1 - 7)



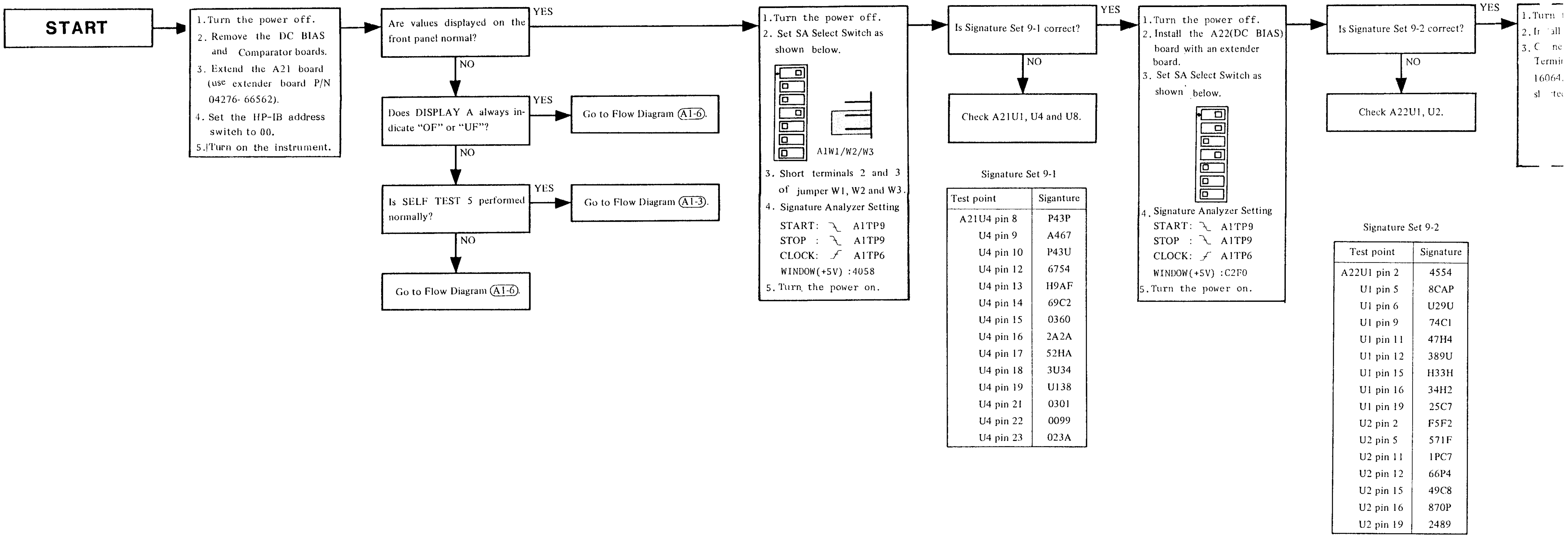
Flow Diagram (A1 - 8)



Signature Set 8-4

A1U25 pin 1	P254	A1U25 pin 28	0000
pin 2	P254	pin 29	0000
pin 5	P254	pin 30	0000
pin 6	P254	pin 31	0000
pin 7	P254	pin 32	AAHU
pin 8	P254	pin 33	U665
pin 23	0000	pin 34	826P
pin 24	0000	pin 35	P254
pin 25	0000	pin 36	P254
pin 26	0000	pin 37	P254
pin 27	0000	pin 38	P254
		pin 39	P254

Flow Diagram (A1 - 9)



1. Turn the power off.
2. Remove the DC BIAS and Comparator boards.
3. Extend the A21 board (use extender board P/N 04276- 66562).
4. Set the HP-IB address switch to 00.
5. Turn on the instrument.

Are values displayed on the front panel normal?

Does DISPLAY A always indicate "OF" or "UF"?

Go to Flow Diagram (A1-6).

Is SELF TEST 5 performed normally?

Go to Flow Diagram (A1-3).

Go to Flow Diagram (A1-6).

1. Turn the power off.
2. Set SA Select Switch as shown below.
3. Short terminals 2 and 3 of jumper W1, W2 and W3.
4. Signature Analyzer Setting

   START: ⌙ A1TP9
   STOP : ⌙ A1TP9
   CLOCK: ⌐ A1TP6
   WINDOW(+5V) :4058
5. Turn the power on.

Is Signature Set 9-1 correct?

Check A21U1, U4 and U8.

Signature Set 9-1

Test point	Siganture
A21U4 pin 8	P43P
U4 pin 9	A467
U4 pin 10	P43U
U4 pin 12	6754
U4 pin 13	H9AF
U4 pin 14	69C2
U4 pin 15	0360
U4 pin 16	2A2A
U4 pin 17	52HA
U4 pin 18	3U34
U4 pin 19	U138
U4 pin 21	0301
U4 pin 22	0099
U4 pin 23	023A

1. Turn the power off.
2. Install the A22(DC BIAS) board with an extender board.
3. Set SA Select Switch as shown below.
4. Signature Analyzer Setting

   START: ⌙ A1TP9
   STOP : ⌙ A1TP9
   CLOCK: ⌐ A1TP6
   WINDOW(+5V) :C2F0
5. Turn the power on.

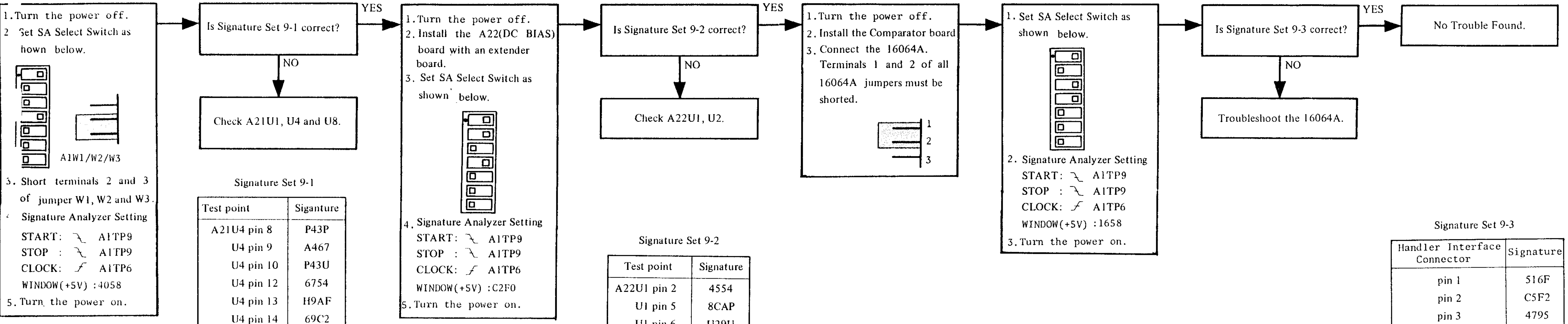
Is Signature Set 9-2 correct?

Check A22U1, U2.

Signature Set 9-2

Test point	Signature
A22U1 pin 2	4554
U1 pin 5	8CAP
U1 pin 6	U29U
U1 pin 9	74C1
U1 pin 11	47H4
U1 pin 12	389U
U1 pin 15	H33H
U1 pin 16	34H2
U1 pin 19	25C7
U2 pin 2	F5F2
U2 pin 5	571F
U2 pin 11	1PC7
U2 pin 12	66P4
U2 pin 15	49C8
U2 pin 16	870P
U2 pin 19	2489

1. Turn
2. I all
3. C ne
Termi
16064.
sl te



1. Turn the power off.
2. Set SA Select Switch as hown below.
3. Short terminals 2 and 3 of jumper W1, W2 and W3.
4. Signature Analyzer Setting
   START: ⌝_ A1TP9
   STOP : ⌝_ A1TP9
   CLOCK: _/ A1TP6
   WINDOW(+5V) :4058
5. Turn the power on.

Is Signature Set 9-1 correct?

NO: Check A21U1, U4 and U8.

YES:

1. Turn the power off.
2. Install the A22(DC BIAS) board with an extender board.
3. Set SA Select Switch as shown below.
4. Signature Analyzer Setting
   START: ⌝_ A1TP9
   STOP : ⌝_ A1TP9
   CLOCK: _/ A1TP6
   WINDOW(+5V) :C2F0
5. Turn the power on.

Is Signature Set 9-2 correct?

NO: Check A22U1, U2.

YES:

1. Turn the power off.
2. Install the Comparator board
3. Connect the 16064A. Terminals 1 and 2 of all 16064A jumpers must be shorted.

1. Set SA Select Switch as shown below.
2. Signature Analyzer Setting
   START: ⌝_ A1TP9
   STOP : ⌝_ A1TP9
   CLOCK: _/ A1TP6
   WINDOW(+5V) :1658
3. Turn the power on.

Is Signature Set 9-3 correct?

NO: Troubleshoot the 16064A.

YES: No Trouble Found.

Signature Set 9-1

Test point	Siganture
A21U4 pin 8	P43P
U4 pin 9	A467
U4 pin 10	P43U
U4 pin 12	6754
U4 pin 13	H9AF
U4 pin 14	69C2
U4 pin 15	0360
U4 pin 16	2A2A
U4 pin 17	52HA
U4 pin 18	3U34
U4 pin 19	U138
U4 pin 21	0301
U4 pin 22	0099
U4 pin 23	023A

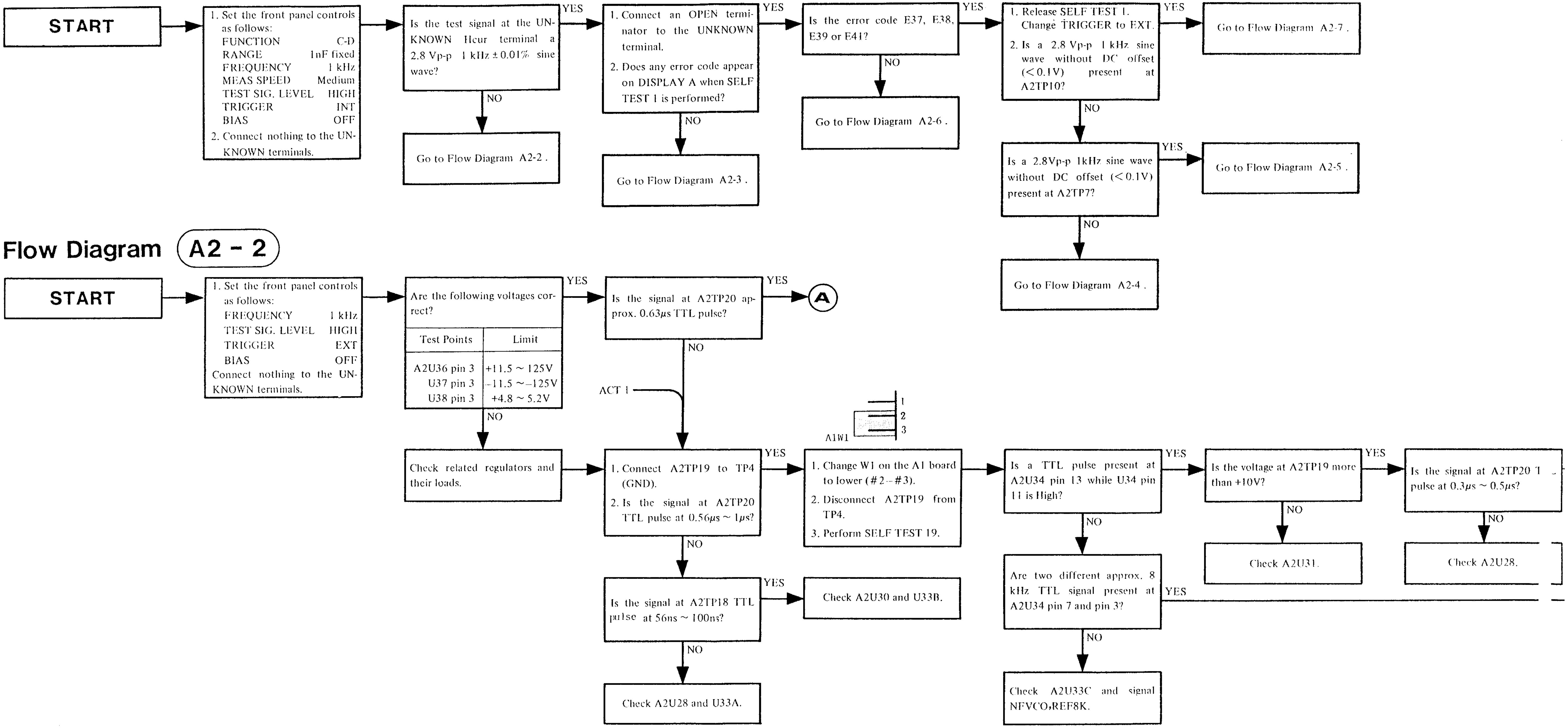
Signature Set 9-2

Test point	Signature
A22U1 pin 2	4554
U1 pin 5	8CAP
U1 pin 6	U29U
U1 pin 9	74C1
U1 pin 11	47H4
U1 pin 12	389U
U1 pin 15	H33H
U1 pin 16	34H2
U1 pin 19	25C7
U2 pin 2	F5F2
U2 pin 5	571F
U2 pin 11	1PC7
U2 pin 12	66P4
U2 pin 15	49C8
U2 pin 16	870P
U2 pin 19	2489

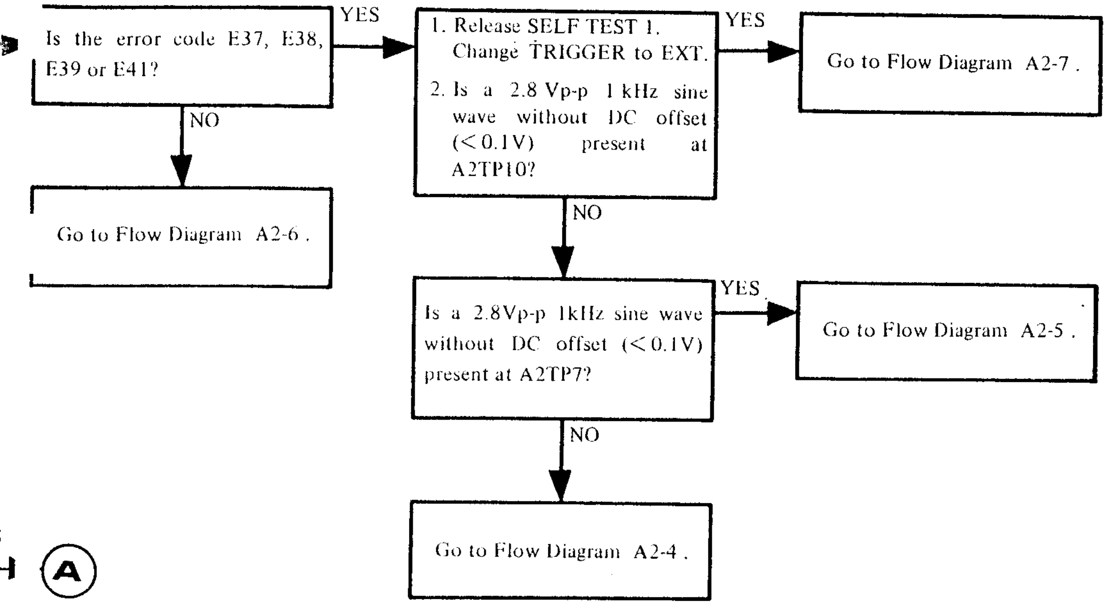
Signature Set 9-3

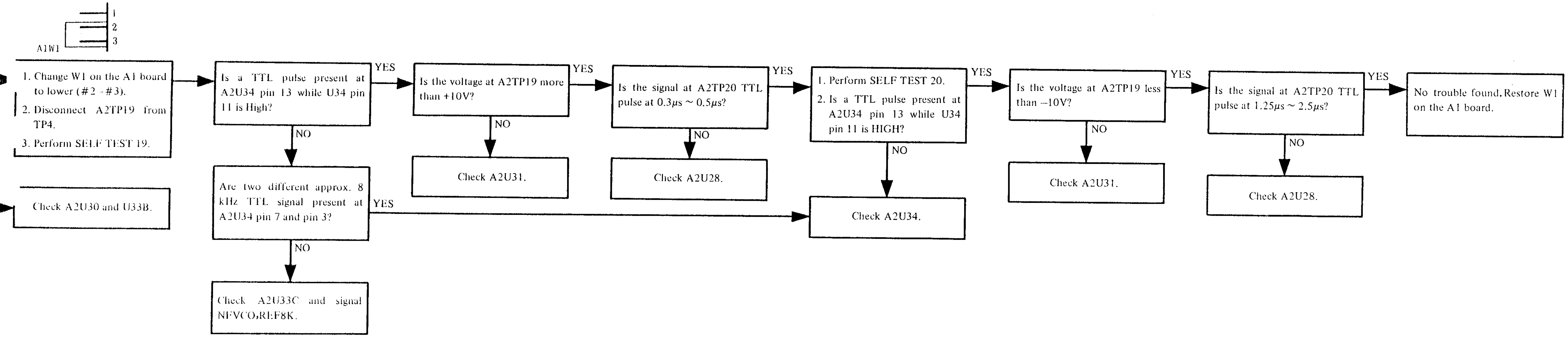
Handler Interface Connector	Signature
pin 1	516F
pin 2	C5F2
pin 3	4795
pin 4	CPCP
pin 5	F22C
pin 6	7F61
pin 7	2344
pin 8	8FH6
pin 9	HC1U
pin 10	9831
pin 19	3C80
pin 20	HU37
pin 21	4881
pin 22	U68F
pin 23	H349
pin 24	2886

Flow Diagram A2 - 1

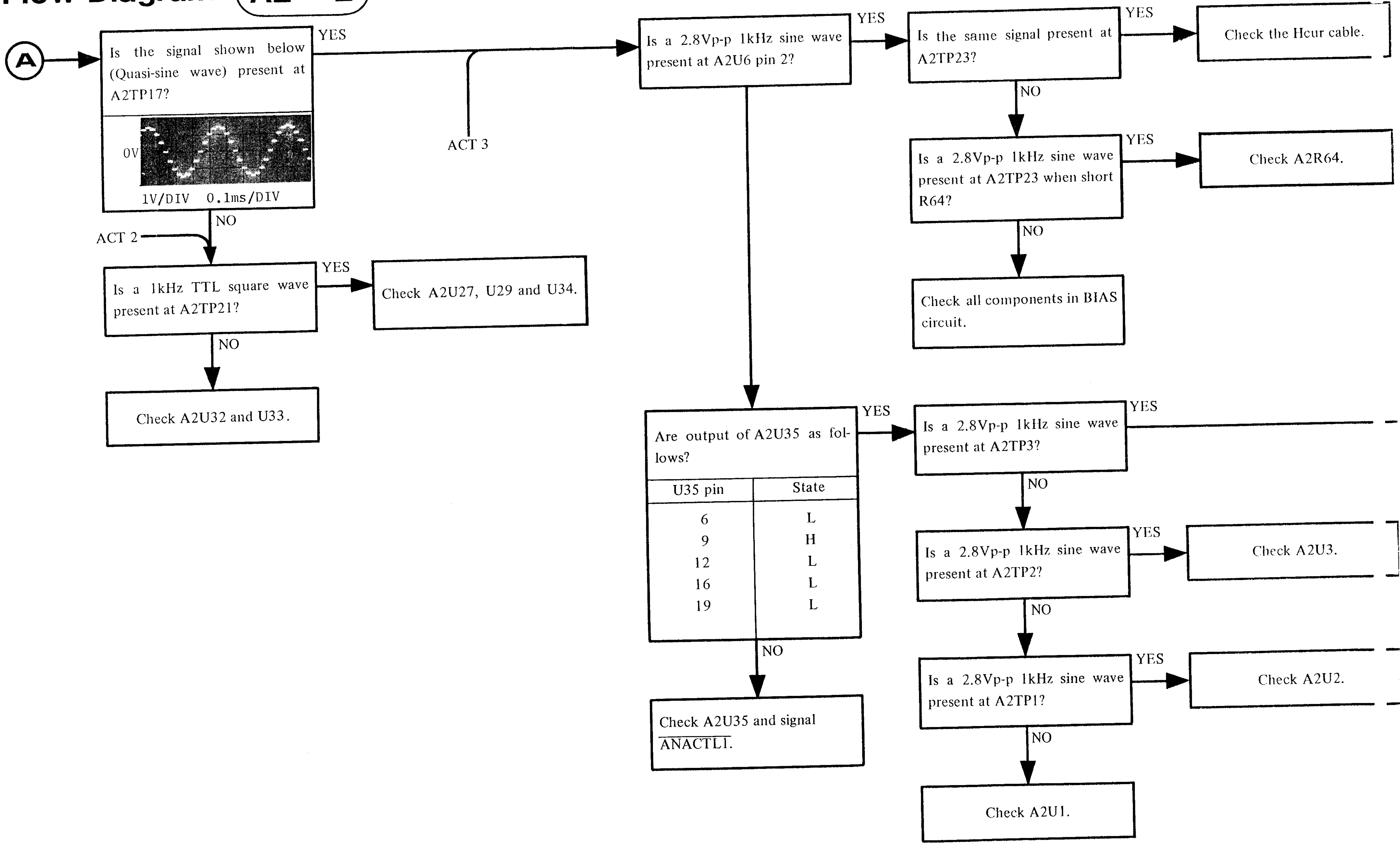


Flow Diagram A2 - 2

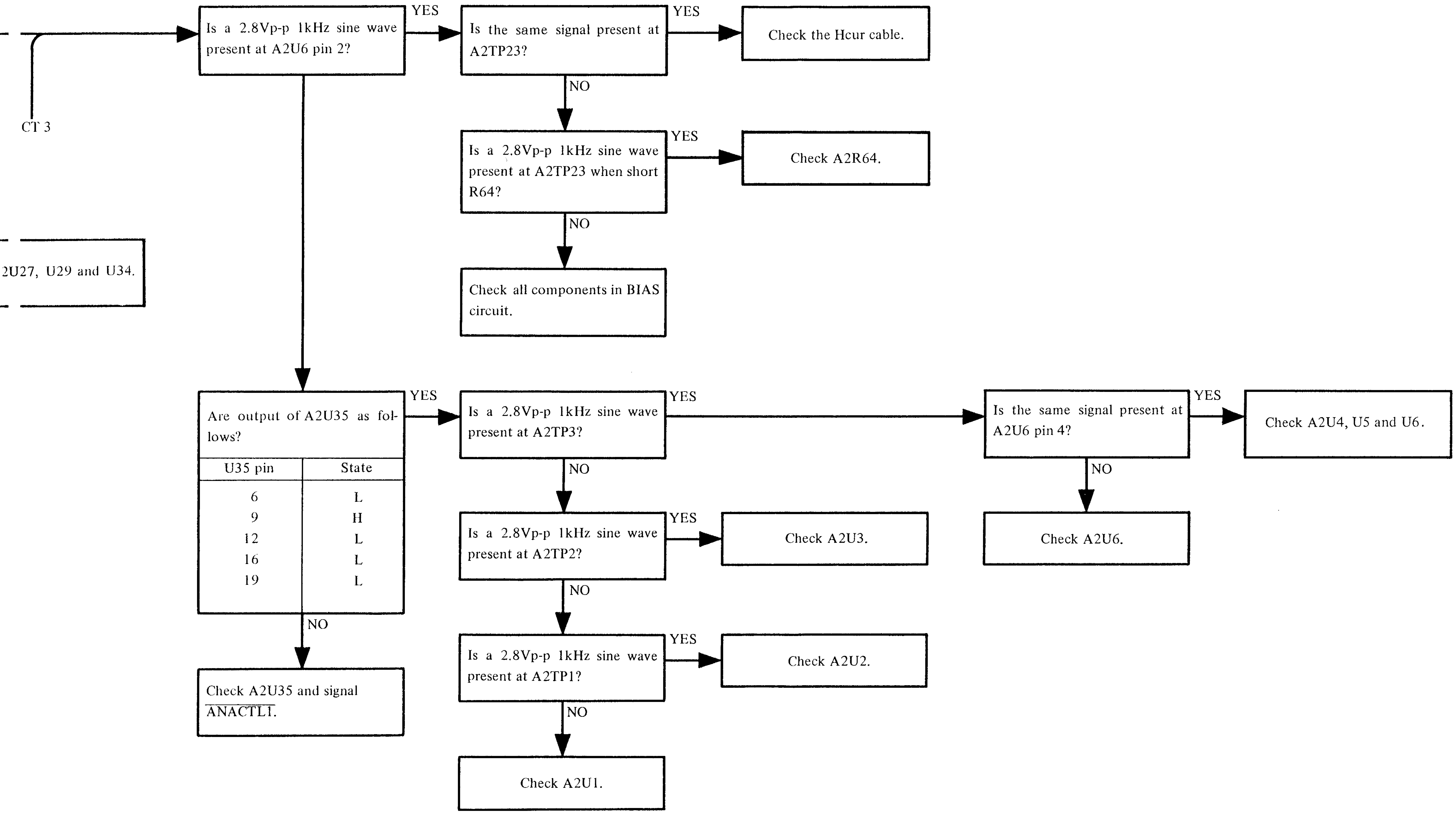

Is the error code E37, E38, E39 or E41?
YES
NO
1. Release SELF TEST 1. Change TRIGGER to EXT.
2. Is a 2.8 Vp-p 1 kHz sine wave without DC offset (< 0.1V) present at A2TP10?
YES
Go to Flow Diagram A2-7 .
NO
Go to Flow Diagram A2-6 .
Is a 2.8Vp-p 1kHz sine wave without DC offset (< 0.1V) present at A2TP7?
YES
Go to Flow Diagram A2-5 .
NO
Go to Flow Diagram A2-4 .
A


A1W1
1
2
3
1. Change W1 on the A1 board to lower (#2 - #3).
2. Disconnect A2TP19 from TP4.
3. Perform SELF TEST 19.
Is a TTL pulse present at A2U34 pin 13 while U34 pin 11 is High?
YES
NO
Is the voltage at A2TP19 more than +10V?
YES
NO
Check A2U31.
Is the signal at A2TP20 TTL pulse at 0.3μs ~ 0.5μs?
YES
NO
Check A2U28.
1. Perform SELF TEST 20.
2. Is a TTL pulse present at A2U34 pin 13 while U34 pin 11 is HIGH?
YES
NO
Check A2U34.
Is the voltage at A2TP19 less than −10V?
YES
NO
Check A2U31.
Is the signal at A2TP20 TTL pulse at 1.25μs ~ 2.5μs?
YES
NO
Check A2U28.
No trouble found. Restore W1 on the A1 board.
Check A2U30 and U33B.
Are two different approx. 8 kHz TTL signal present at A2U34 pin 7 and pin 3?
YES
NO
Check A2U33C and signal NFVCO,REF8K.

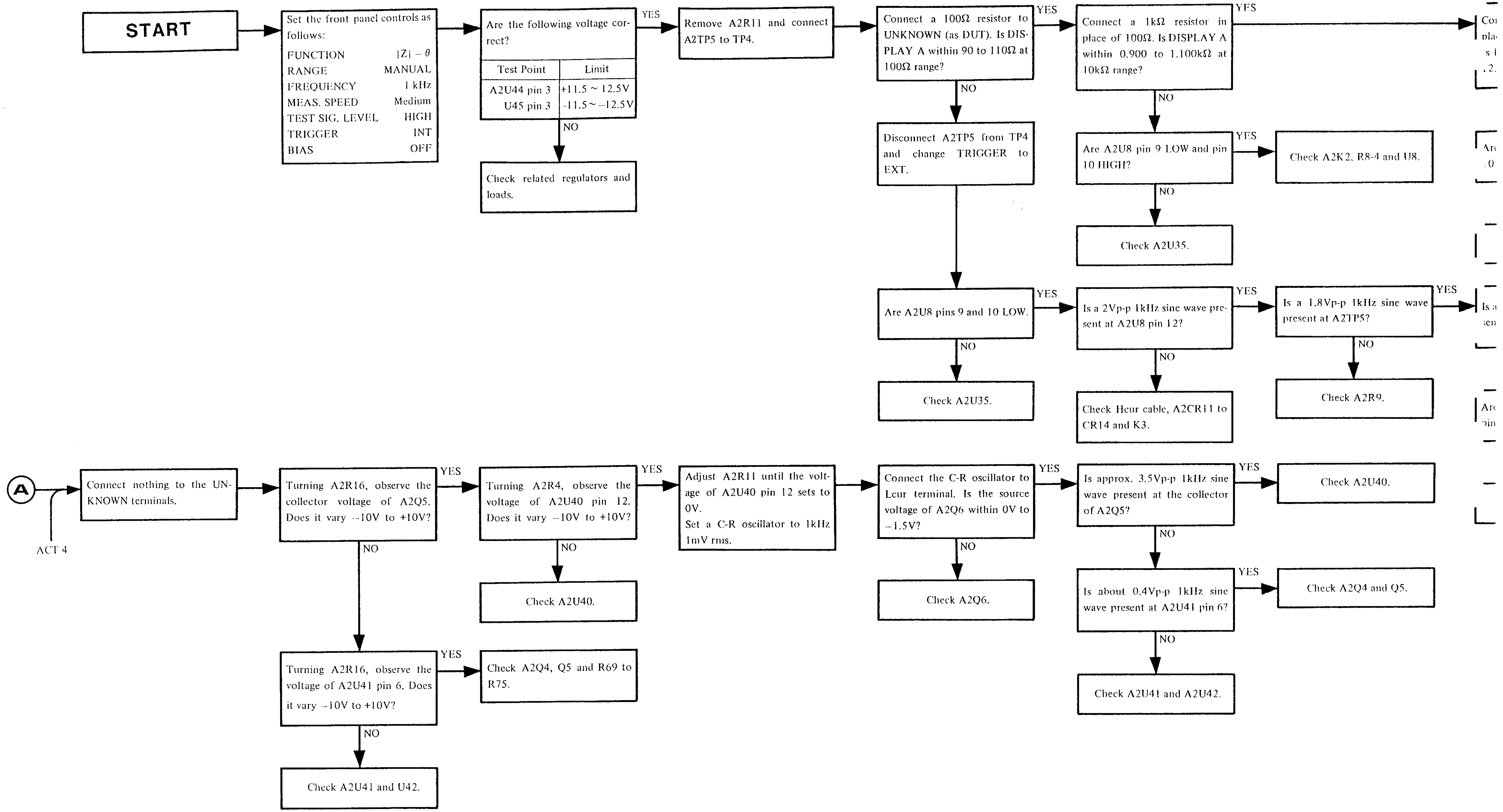
Flow Diagram A2 - 2

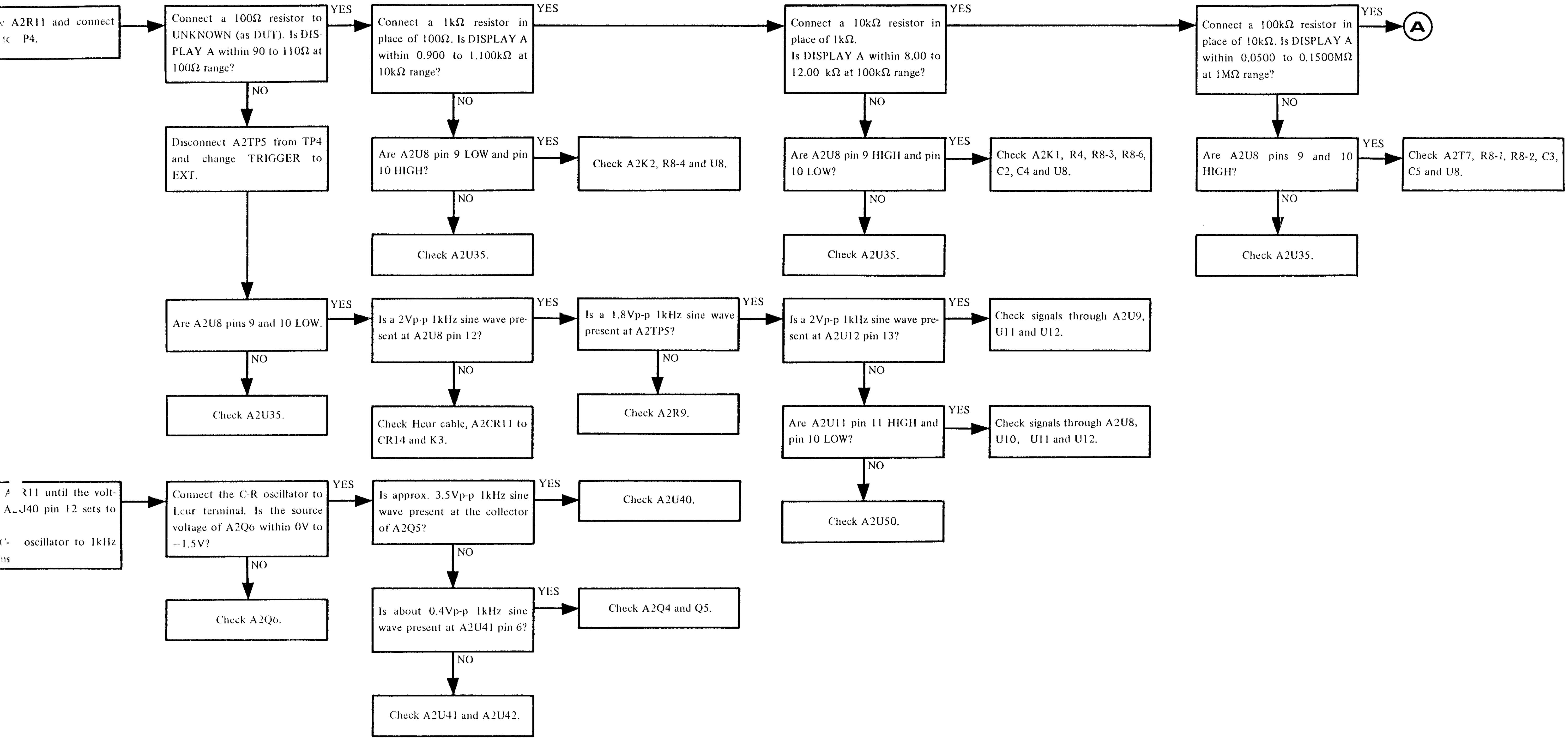


U35 pin	State
6	L
9	H
12	L
16	L
19	L

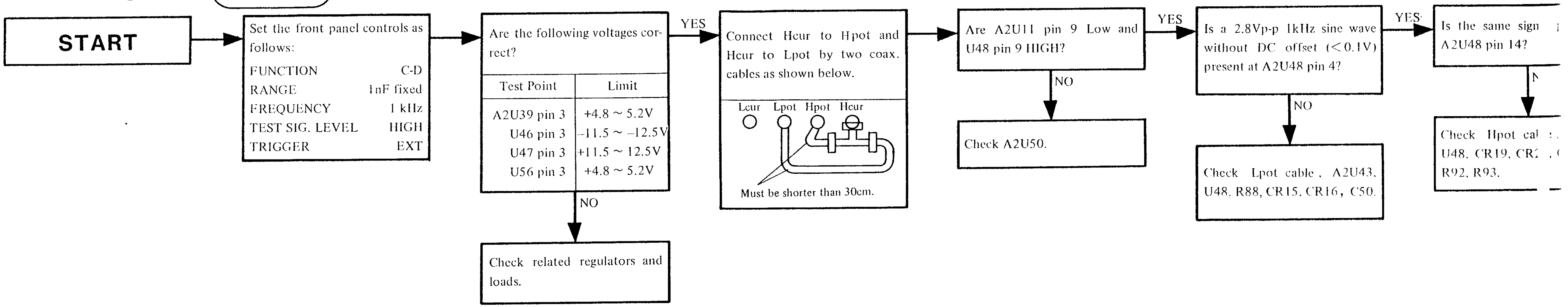

CT 3
2U27, U29 and U34.
Is a 2.8Vp-p 1kHz sine wave present at A2U6 pin 2?
YES
Is the same signal present at A2TP23?
YES
Check the Hcur cable.
NO
Is a 2.8Vp-p 1kHz sine wave present at A2TP23 when short R64?
YES
Check A2R64.
NO
Check all components in BIAS circuit.
Are output of A2U35 as follows?
U35 pin
State
6 L
9 H
12 L
16 L
19 L
NO
Check A2U35 and signal $\overline{\text{ANACTL1}}$.
YES
Is a 2.8Vp-p 1kHz sine wave present at A2TP3?
YES
Is the same signal present at A2U6 pin 4?
YES
Check A2U4, U5 and U6.
NO
Check A2U6.
NO
Is a 2.8Vp-p 1kHz sine wave present at A2TP2?
YES
Check A2U3.
NO
Is a 2.8Vp-p 1kHz sine wave present at A2TP1?
YES
Check A2U2.
NO
Check A2U1.

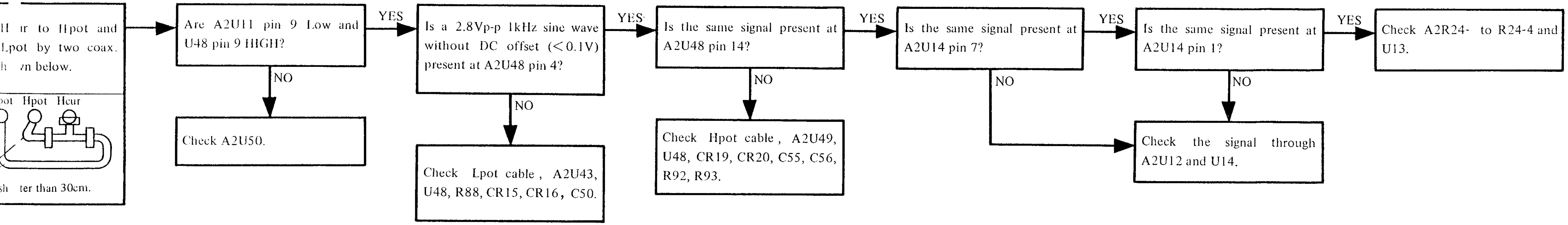
Flow Diagram A2 - 3




A2R11 and connect
P4.
Connect a 100Ω resistor to UNKNOWN (as DUT). Is DISPLAY A within 90 to 110Ω at 100Ω range?
YES
NO
Connect a 1kΩ resistor in place of 100Ω. Is DISPLAY A within 0.900 to 1.100kΩ at 10kΩ range?
YES
NO
Connect a 10kΩ resistor in place of 1kΩ. Is DISPLAY A within 8.00 to 12.00 kΩ at 100kΩ range?
YES
NO
Connect a 100kΩ resistor in place of 10kΩ. Is DISPLAY A within 0.0500 to 0.1500MΩ at 1MΩ range?
YES
A
NO
Disconnect A2TP5 from TP4 and change TRIGGER to EXT.
Are A2U8 pin 9 LOW and pin 10 HIGH?
YES
Check A2K2, R8-4 and U8.
NO
Check A2U35.
Are A2U8 pin 9 HIGH and pin 10 LOW?
YES
Check A2K1, R4, R8-3, R8-6, C2, C4 and U8.
NO
Check A2U35.
Are A2U8 pins 9 and 10 HIGH?
YES
Check A2T7, R8-1, R8-2, C3, C5 and U8.
NO
Check A2U35.
Are A2U8 pins 9 and 10 LOW.
YES
NO
Check A2U35.
Is a 2Vp-p 1kHz sine wave present at A2U8 pin 12?
YES
NO
Check Hcur cable, A2CR11 to CR14 and K3.
Is a 1.8Vp-p 1kHz sine wave present at A2TP5?
YES
NO
Check A2R9.
Is a 2Vp-p 1kHz sine wave present at A2U12 pin 13?
YES
Check signals through A2U9, U11 and U12.
NO
Are A2U11 pin 11 HIGH and pin 10 LOW?
YES
Check signals through A2U8, U10, U11 and U12.
NO
Check A2U50.
R11 until the volt-
J40 pin 12 sets to
oscillator to 1kHz
ns
Connect the C-R oscillator to Lcur terminal. Is the source voltage of A2Q6 within 0V to −1.5V?
YES
NO
Check A2Q6.
Is approx. 3.5Vp-p 1kHz sine wave present at the collector of A2Q5?
YES
Check A2U40.
NO
Is about 0.4Vp-p 1kHz sine wave present at A2U41 pin 6?
YES
Check A2Q4 and Q5.
NO
Check A2U41 and A2U42.

Flow Diagram A2 - 4




H ır to Hpot and Lpot by two coax. h ⁄n below.

sh ter than 30cm.

Are A2U11 pin 9 Low and U48 pin 9 HIGH?

Check A2U50.

Is a 2.8Vp-p 1kHz sine wave without DC offset (<0.1V) present at A2U48 pin 4?

Check Lpot cable, A2U43, U48, R88, CR15, CR16, C50.

Is the same signal present at A2U48 pin 14?

Check Hpot cable, A2U49, U48, CR19, CR20, C55, C56, R92, R93.

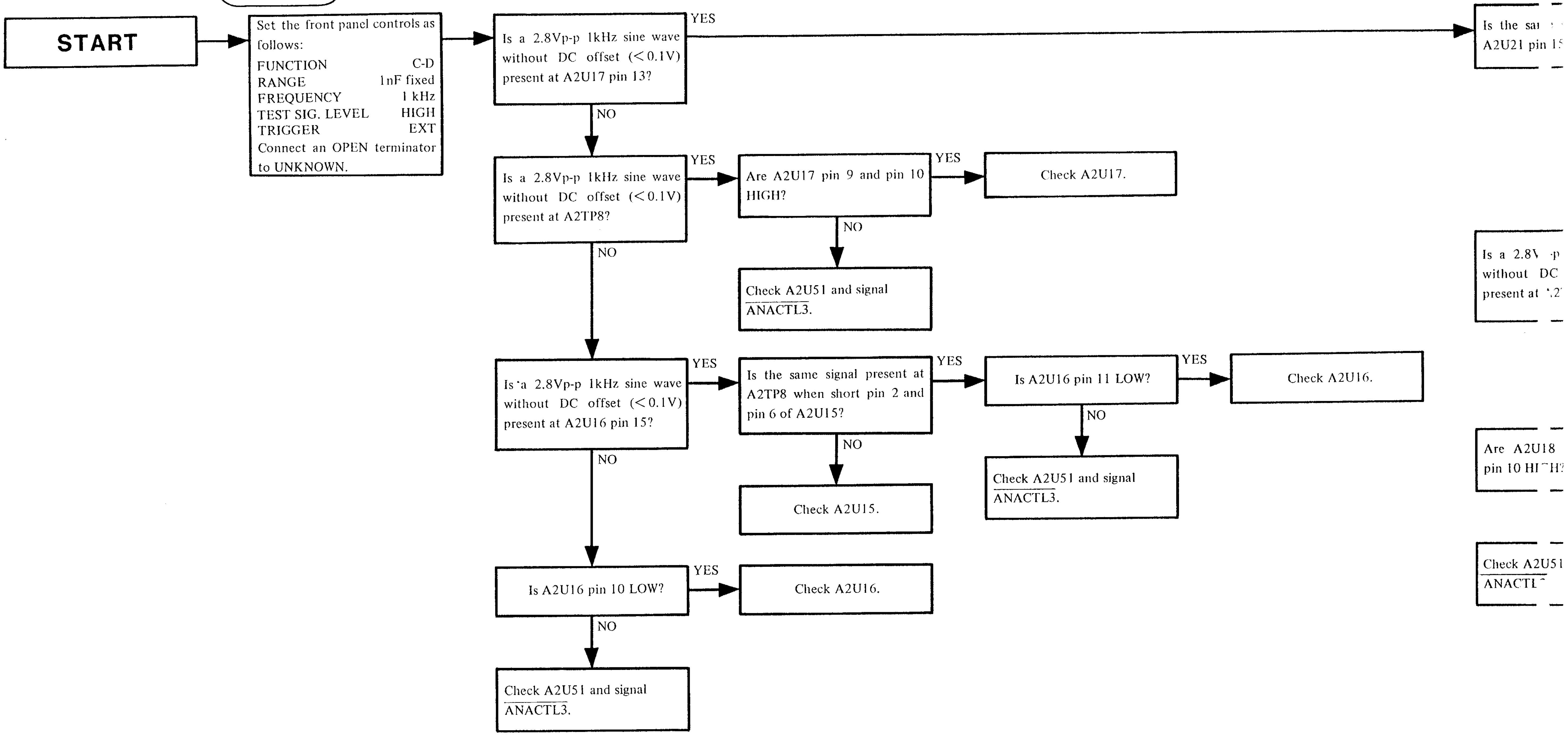
Is the same signal present at A2U14 pin 7?

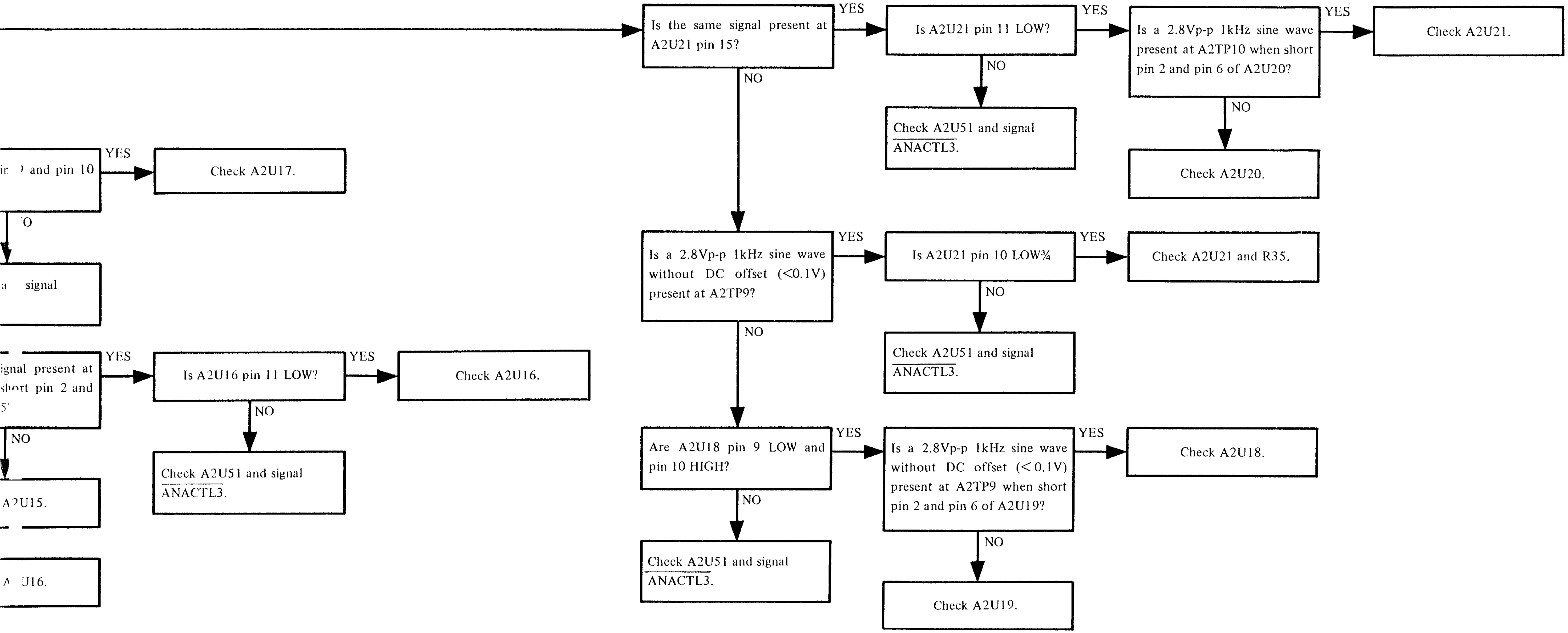
Is the same signal present at A2U14 pin 1?

Check the signal through A2U12 and U14.

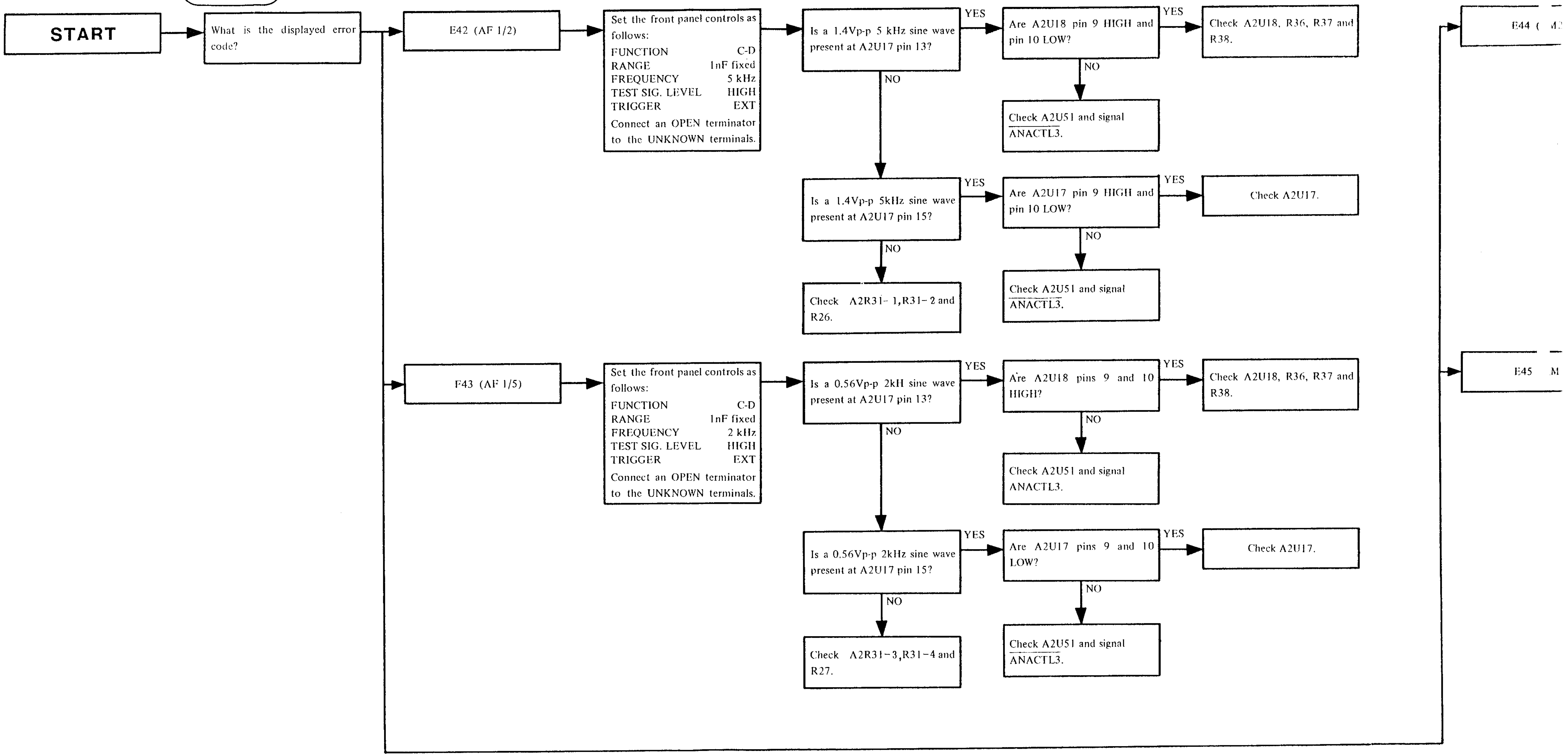
Check A2R24- to R24-4 and U13.

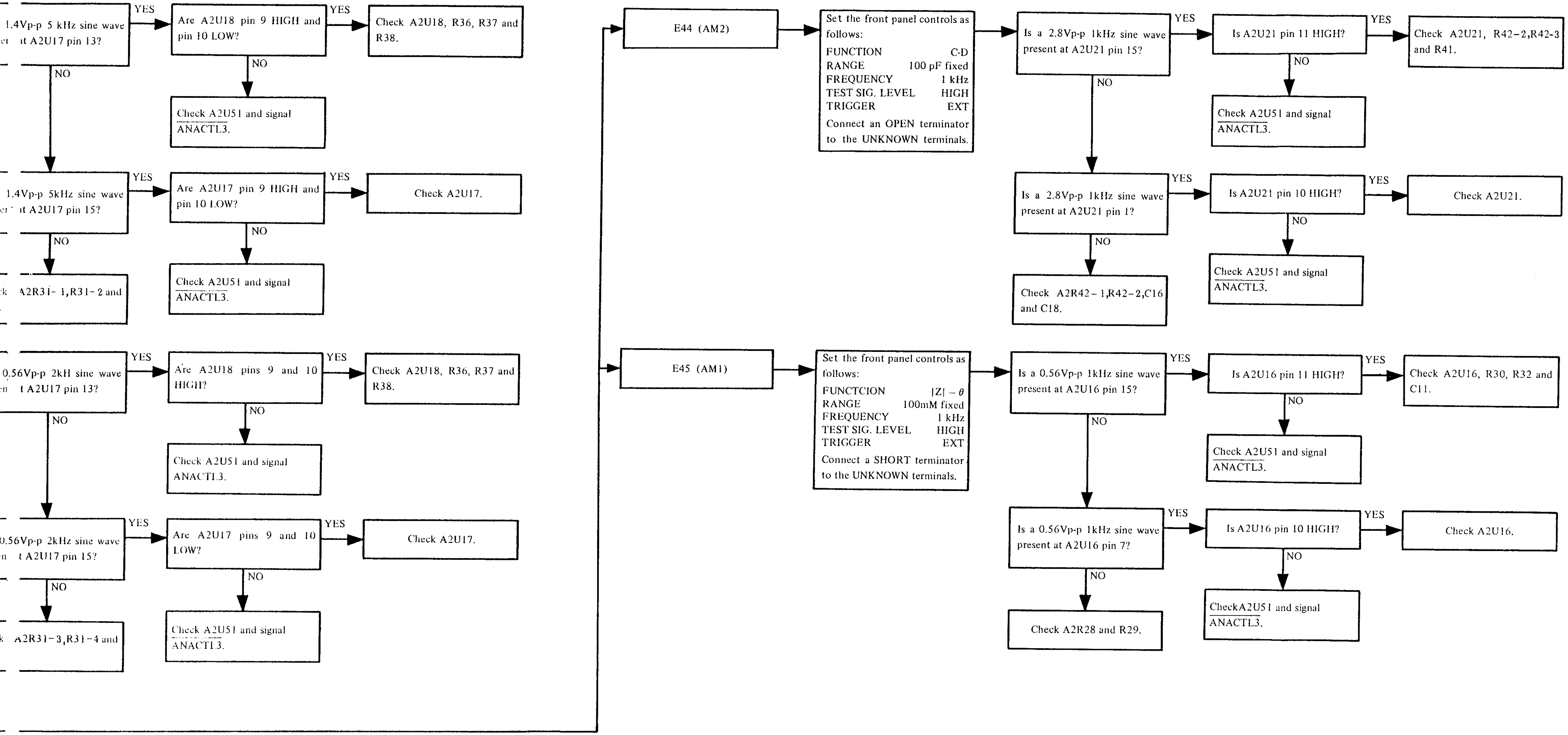
Flow Diagram (A2 - 5)



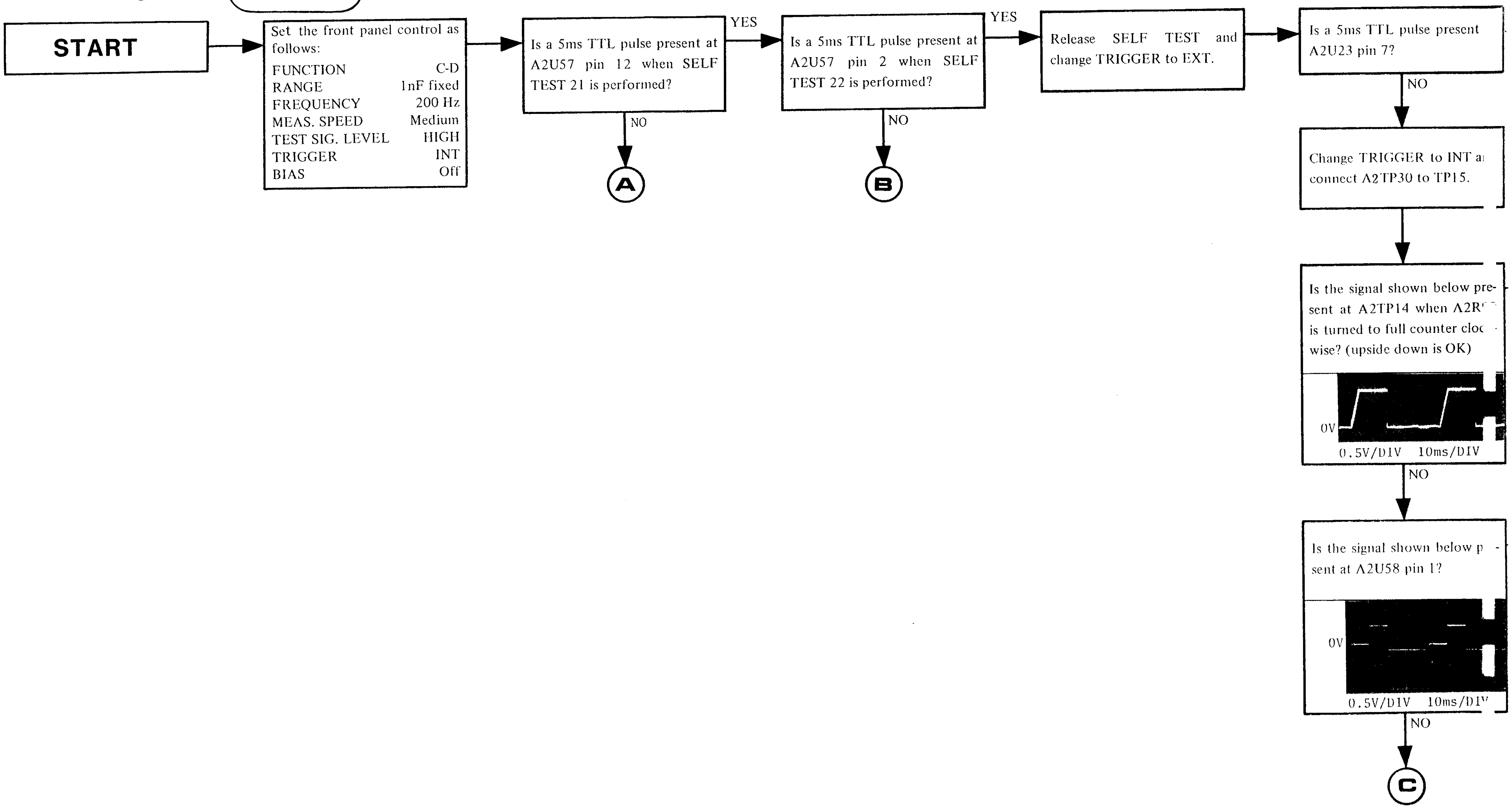

Is the same signal present at A2U21 pin 15?
YES
NO
Is A2U21 pin 11 LOW?
YES
NO
Check A2U51 and signal ANACTL3.
Is a 2.8Vp-p 1kHz sine wave present at A2TP10 when short pin 2 and pin 6 of A2U20?
YES
NO
Check A2U21.
Check A2U20.
in) and pin 10
YES
Check A2U17.
O
a signal
Is a 2.8Vp-p 1kHz sine wave without DC offset (<0.1V) present at A2TP9?
YES
NO
Is A2U21 pin 10 LOW¾
YES
NO
Check A2U21 and R35.
Check A2U51 and signal ANACTL3.
ignal present at short pin 2 and 5'
YES
NO
Is A2U16 pin 11 LOW?
YES
NO
Check A2U16.
Check A2U51 and signal ANACTL3.
A?U15.
A U16.
Are A2U18 pin 9 LOW and pin 10 HIGH?
YES
NO
Check A2U51 and signal ANACTL3.
Is a 2.8Vp-p 1kHz sine wave without DC offset (<0.1V) present at A2TP9 when short pin 2 and pin 6 of A2U19?
YES
NO
Check A2U18.
Check A2U19.

Flow Diagram A2 - 6




1.4Vp-p 5 kHz sine wave
t A2U17 pin 13?
YES
NO
Are A2U18 pin 9 HIGH and pin 10 LOW?
YES
NO
Check A2U18, R36, R37 and R38.
Check A2U51 and signal ANACTL3.
1.4Vp-p 5kHz sine wave
t A2U17 pin 15?
YES
NO
Are A2U17 pin 9 HIGH and pin 10 LOW?
YES
NO
Check A2U17.
Check A2U51 and signal ANACTL3.
A2R31-1,R31-2 and
0.56Vp-p 2kH sine wave
t A2U17 pin 13?
YES
NO
Are A2U18 pins 9 and 10 HIGH?
YES
NO
Check A2U18, R36, R37 and R38.
Check A2U51 and signal ANACTL3.
0.56Vp-p 2kHz sine wave
t A2U17 pin 15?
YES
NO
Are A2U17 pins 9 and 10 LOW?
YES
NO
Check A2U17.
Check A2U51 and signal ANACTL3.
A2R31-3,R31-4 and
E44 (AM2)
Set the front panel controls as follows:
FUNCTION C-D
RANGE 100 pF fixed
FREQUENCY 1 kHz
TEST SIG. LEVEL HIGH
TRIGGER EXT
Connect an OPEN terminator to the UNKNOWN terminals.
Is a 2.8Vp-p 1kHz sine wave present at A2U21 pin 15?
YES
NO
Is A2U21 pin 11 HIGH?
YES
NO
Check A2U21, R42-2,R42-3 and R41.
Check A2U51 and signal ANACTL3.
Is a 2.8Vp-p 1kHz sine wave present at A2U21 pin 1?
YES
NO
Is A2U21 pin 10 HIGH?
YES
NO
Check A2U21.
Check A2U51 and signal ANACTL3.
Check A2R42-1,R42-2,C16 and C18.
E45 (AM1)
Set the front panel controls as follows:
FUNCTCION |Z| - θ
RANGE 100mM fixed
FREQUENCY 1 kHz
TEST SIG. LEVEL HIGH
TRIGGER EXT
Connect a SHORT terminator to the UNKNOWN terminals.
Is a 0.56Vp-p 1kHz sine wave present at A2U16 pin 15?
YES
NO
Is A2U16 pin 11 HIGH?
YES
NO
Check A2U16, R30, R32 and C11.
Check A2U51 and signal ANACTL3.
Is a 0.56Vp-p 1kHz sine wave present at A2U16 pin 7?
YES
NO
Is A2U16 pin 10 HIGH?
YES
NO
Check A2U16.
CheckA2U51 and signal ANACTL3.
Check A2R28 and R29.

Flow Diagram A2 - 7



Set the front panel control as follows:

FUNCTION	C-D
RANGE	1nF fixed
FREQUENCY	200 Hz
MEAS. SPEED	Medium
TEST SIG. LEVEL	HIGH
TRIGGER	INT
BIAS	Off

Is a 5ms TTL pulse present at A2U57 pin 12 when SELF TEST 21 is performed?

Is a 5ms TTL pulse present at A2U57 pin 2 when SELF TEST 22 is performed?

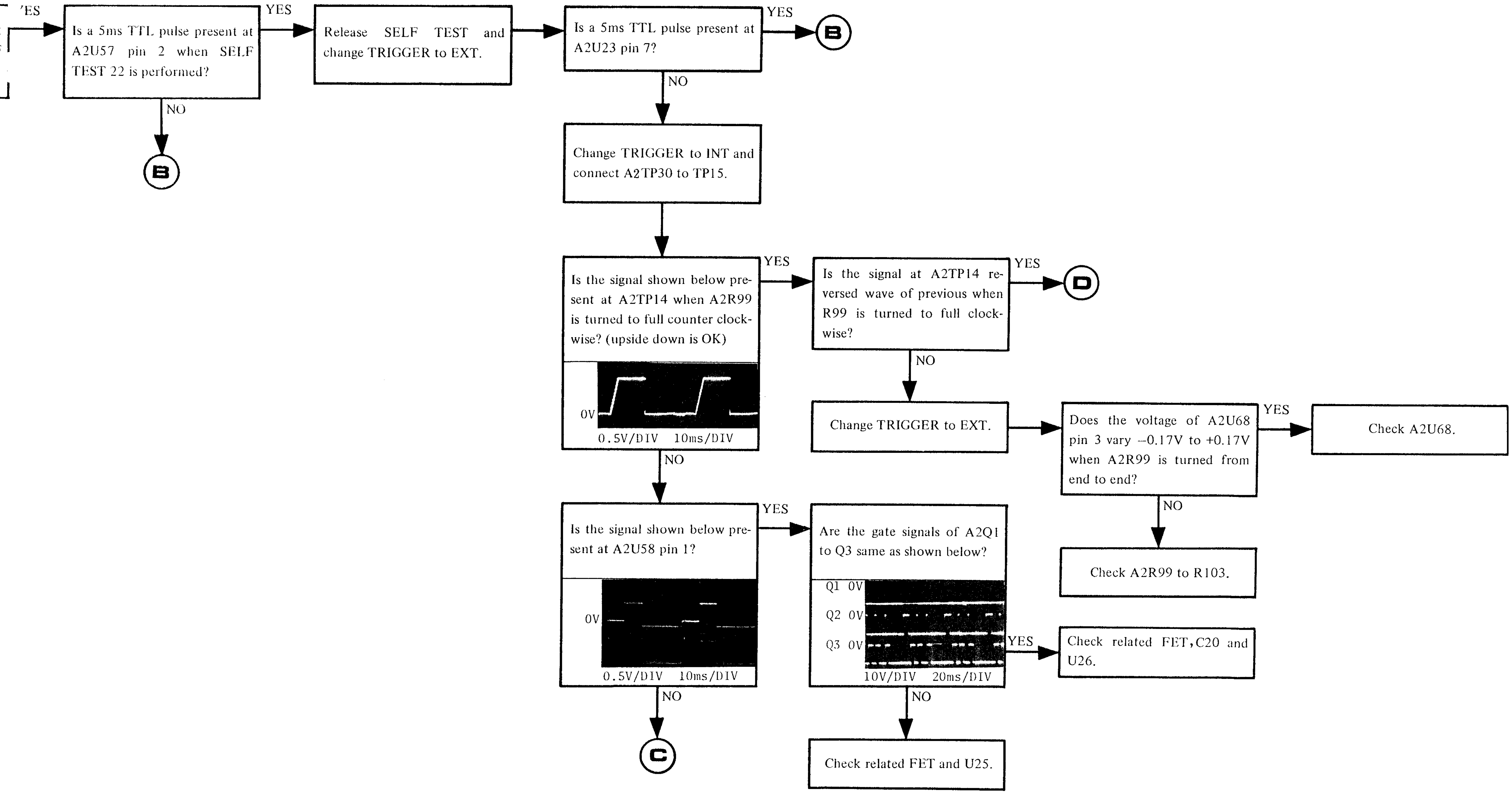
Release SELF TEST and change TRIGGER to EXT.

Is a 5ms TTL pulse present A2U23 pin 7?

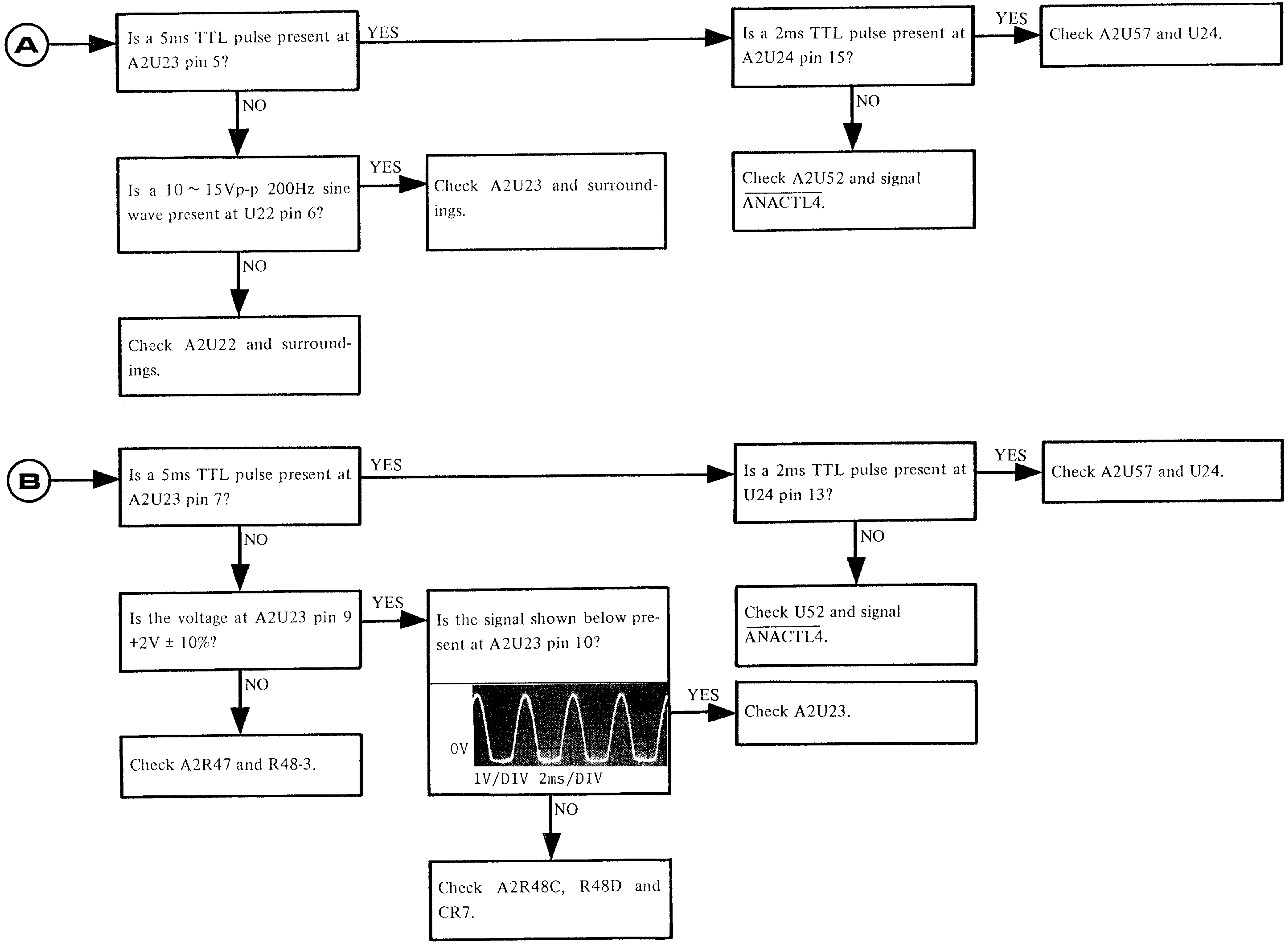
Change TRIGGER to INT a connect A2TP30 to TP15.

Is the signal shown below present at A2TP14 when A2R is turned to full counter cloc wise? (upside down is OK)

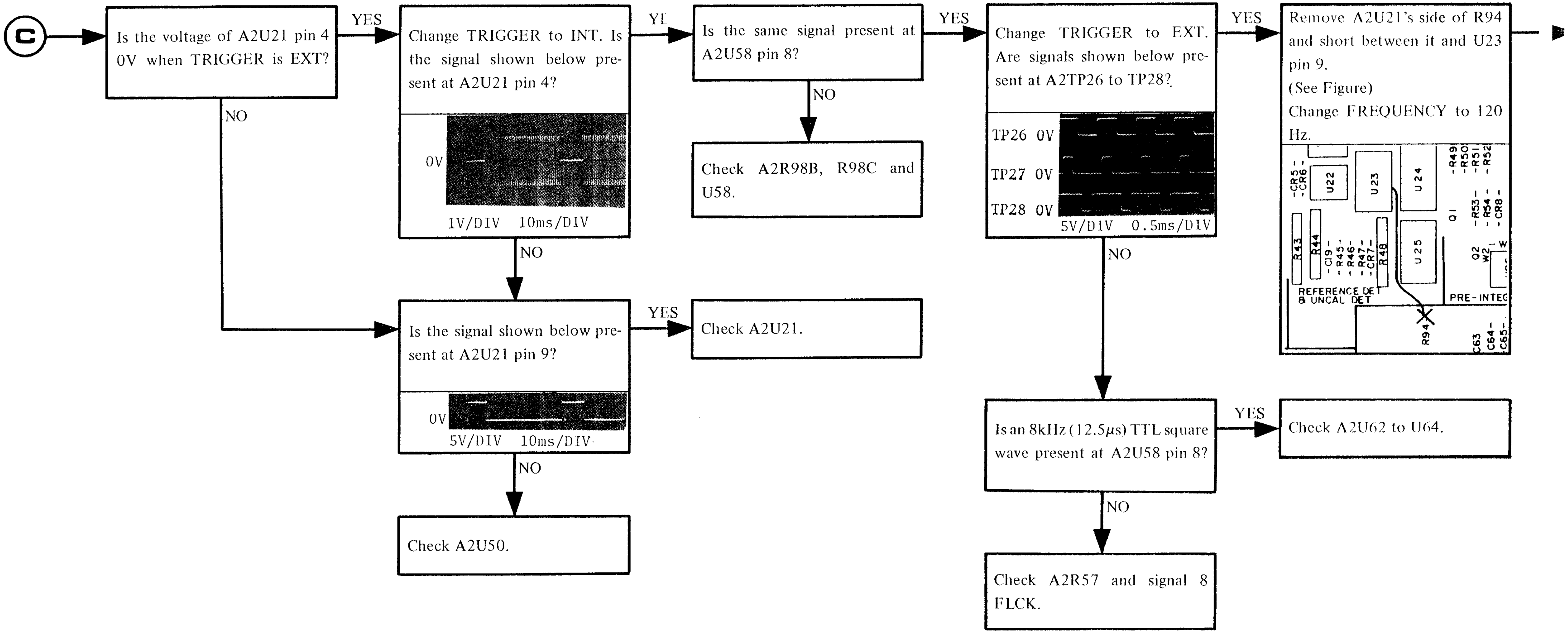
Is the signal shown below p- sent at A2U58 pin 1?


'ES
Is a 5ms TTL pulse present at A2U57 pin 2 when SELF TEST 22 is performed?
YES
NO
B
Release SELF TEST and change TRIGGER to EXT.
Is a 5ms TTL pulse present at A2U23 pin 7?
YES
B
NO
Change TRIGGER to INT and connect A2TP30 to TP15.
Is the signal shown below present at A2TP14 when A2R99 is turned to full counter clockwise? (upside down is OK)
0V
0.5V/DIV 10ms/DIV
YES
Is the signal at A2TP14 reversed wave of previous when R99 is turned to full clockwise?
YES
D
NO
Change TRIGGER to EXT.
Does the voltage of A2U68 pin 3 vary –0.17V to +0.17V when A2R99 is turned from end to end?
YES
Check A2U68.
NO
Check A2R99 to R103.
NO
Is the signal shown below present at A2U58 pin 1?
0V
0.5V/DIV 10ms/DIV
YES
Are the gate signals of A2Q1 to Q3 same as shown below?
Q1 0V
Q2 0V
Q3 0V
10V/DIV 20ms/DIV
YES
Check related FET, C20 and U26.
NO
Check related FET and U25.
NO
C

Flow Diagram A2 - 7



Flow Diagram A2 - 7



Is the voltage of A2U21 pin 4 0V when TRIGGER is EXT?

Change TRIGGER to INT. Is the signal shown below present at A2U21 pin 4?

Is the same signal present at A2U58 pin 8?

Check A2R98B, R98C and U58.

Change TRIGGER to EXT. Are signals shown below present at A2TP26 to TP28?

Remove A2U21's side of R94 and short between it and U23 pin 9.
(See Figure)
Change FREQUENCY to 120 Hz.

Is the signal shown below present at A2U21 pin 9?

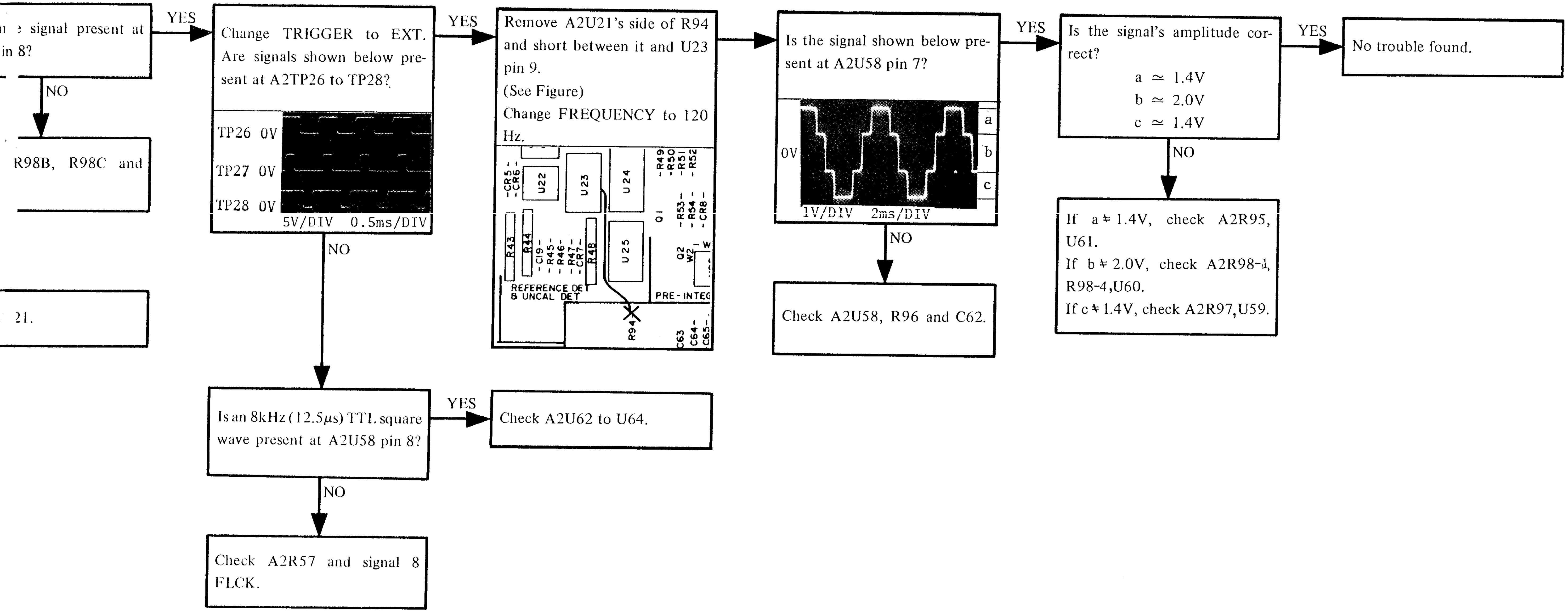
Check A2U21.

Check A2U50.

Is an 8kHz (12.5μs) TTL square wave present at A2U58 pin 8?

Check A2U62 to U64.

Check A2R57 and signal 8 FLCK.



signal present at in 8?

YES

NO

R98B, R98C and

21.

Change TRIGGER to EXT. Are signals shown below present at A2TP26 to TP28?

YES

Remove A2U21's side of R94 and short between it and U23 pin 9.
(See Figure)
Change FREQUENCY to 120 Hz.

NO

Is an 8kHz (12.5μs) TTL square wave present at A2U58 pin 8?

YES

Check A2U62 to U64.

NO

Check A2R57 and signal 8 FLCK.

Is the signal shown below present at A2U58 pin 7?

NO

Check A2U58, R96 and C62.

YES

Is the signal's amplitude correct?

a ≃ 1.4V
b ≃ 2.0V
c ≃ 1.4V

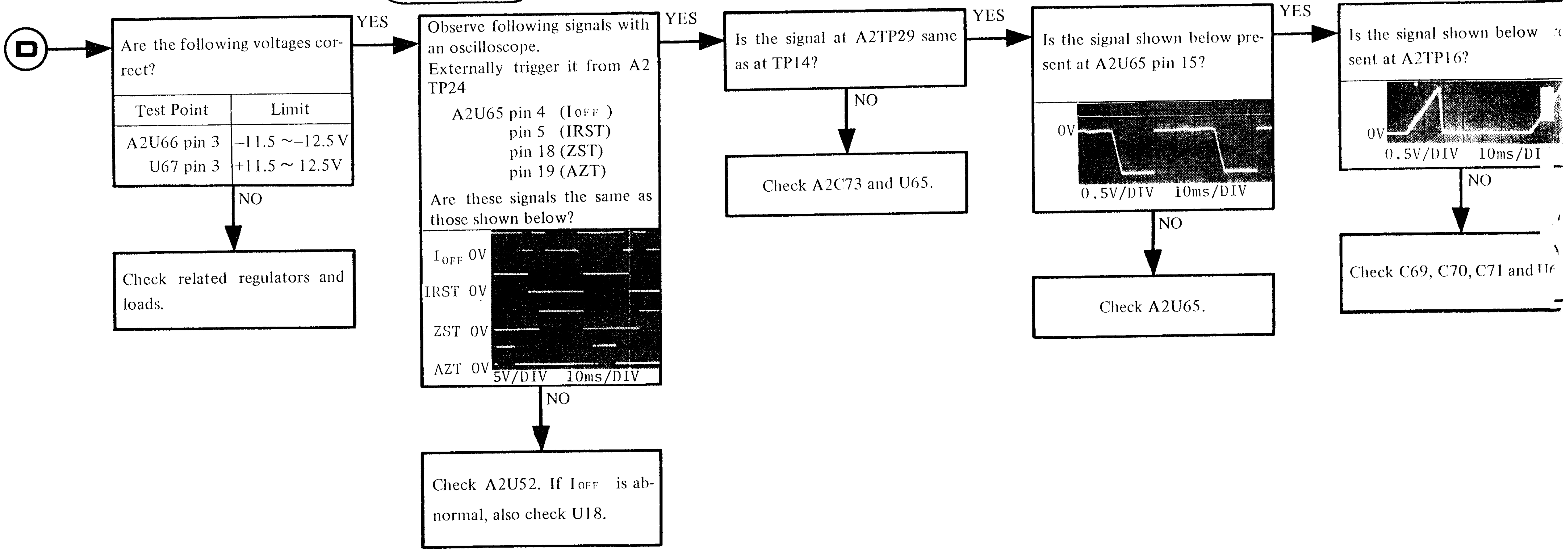
YES

No trouble found.

NO

If a ≠ 1.4V, check A2R95, U61.
If b ≠ 2.0V, check A2R98-1, R98-4,U60.
If c ≠ 1.4V, check A2R97,U59.

Flow Diagram A2 - 7



Are the following voltages correct?

Test Point	Limit
A2U66 pin 3	−11.5 ~ −12.5 V
U67 pin 3	+11.5 ~ 12.5V

Check related regulators and loads.

Observe following signals with an oscilloscope.
Externally trigger it from A2 TP24

A2U65 pin 4 (I_{OFF})
pin 5 (IRST)
pin 18 (ZST)
pin 19 (AZT)

Are these signals the same as those shown below?

Check A2U52. If I_{OFF} is abnormal, also check U18.

Is the signal at A2TP29 same as at TP14?

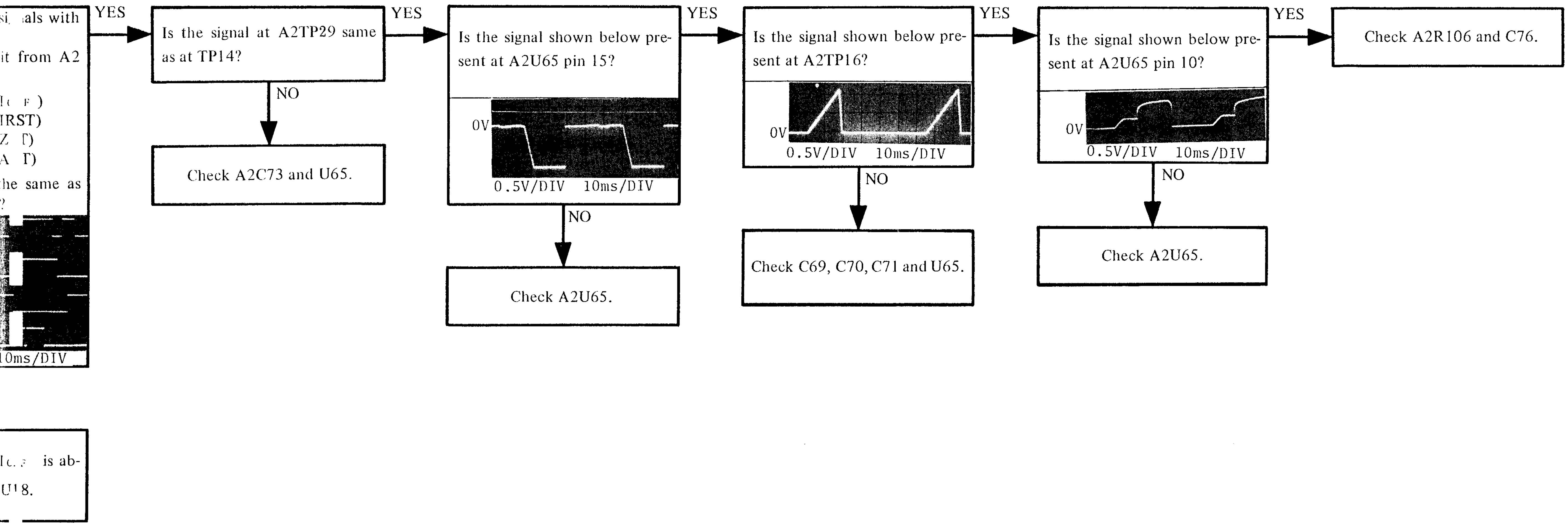
Check A2C73 and U65.

Is the signal shown below present at A2U65 pin 15?

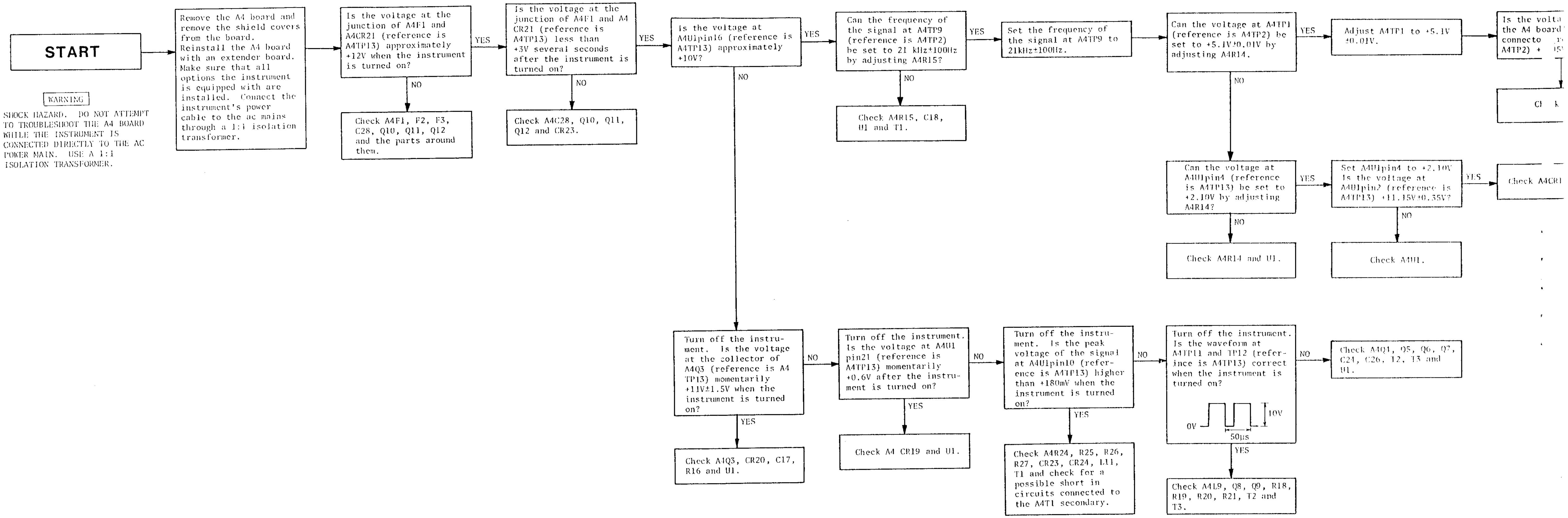
Check A2U65.

Is the signal shown below
sent at A2TP16?

Check C69, C70, C71 and


als with
it from A2
IRST)
he same as
0ms/DIV
is ab-
8.
YES
Is the signal at A2TP29 same as at TP14?
NO
Check A2C73 and U65.
YES
Is the signal shown below present at A2U65 pin 15?
0V
0.5V/DIV 10ms/DIV
NO
Check A2U65.
YES
Is the signal shown below present at A2TP16?
0V
0.5V/DIV 10ms/DIV
NO
Check C69, C70, C71 and U65.
YES
Is the signal shown below present at A2U65 pin 10?
0V
0.5V/DIV 10ms/DIV
NO
Check A2U65.
YES
Check A2R106 and C76.

Flow Diagram (A4- 1)



WARNING

SHOCK HAZARD. DO NOT ATTEMPT TO TROUBLESHOOT THE A4 BOARD WHILE THE INSTRUMENT IS CONNECTED DIRECTLY TO THE AC POWER MAIN. USE A 1:1 ISOLATION TRANSFORMER.

Remove the A4 board and remove the shield covers from the board. Reinstall the A4 board with an extender board. Make sure that all options the instrument is equipped with are installed. Connect the instrument's power cable to the ac mains through a 1:1 isolation transformer.

Is the voltage at the junction of A4F1 and A4CR21 (reference is A4TP13) approximately +12V when the instrument is turned on?

Check A4F1, F2, F3, C28, Q10, Q11, Q12 and the parts around them.

Is the voltage at the junction of A4F1 and A4 CR21 (reference is A4TP13) less than +3V several seconds after the instrument is turned on?

Check A4C28, Q10, Q11, Q12 and CR23.

Is the voltage at A4U1pin16 (reference is A4TP13) approximately +10V?

Can the frequency of the signal at A4TP9 (reference is A4TP2) be set to 21 kHz±100Hz by adjusting A4R15?

Check A4R15, C18, U1 and T1.

Set the frequency of the signal at A4TP9 to 21kHz±100Hz.

Can the voltage at A4TP1 (reference is A4TP2) be set to +5.1V±0.01V by adjusting A4R14.

Adjust A4TP1 to +5.1V ±0.01V.

Is the volta
the A4 board
connecto
A4TP2) +

Cl k

Can the voltage at A4U1pin4 (reference is A4TP13) be set to +2.10V by adjusting A4R14?

Check A4R14 and U1.

Set A4U1pin4 to +2.10V Is the voltage at A4U1pin2 (reference is A4TP13) +11.15V±0.35V?

Check A4U1.

Check A4CR1

Turn off the instrument. Is the voltage at the collector of A4Q3 (reference is A4 TP13) momentarily +11V±1.5V when the instrument is turned on?

Check A4Q3, CR20, C17, R16 and U1.

Turn off the instrument. Is the voltage at A4U1 pin21 (reference is A4TP13) momentarily +0.6V after the instrument is turned on?

Check A4 CR19 and U1.

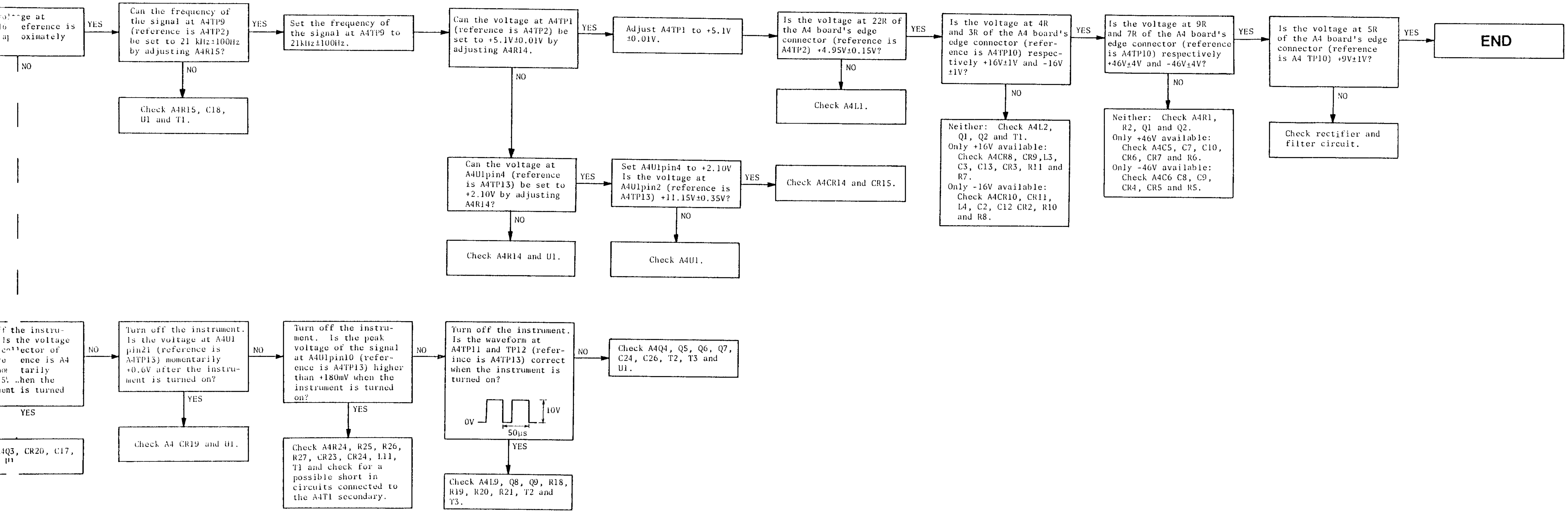
Turn off the instrument. Is the peak voltage of the signal at A4U1pin10 (reference is A4TP13) higher than +180mV when the instrument is turned on?

Check A4R24, R25, R26, R27, CR23, CR24, L11, T1 and check for a possible short in circuits connected to the A4T1 secondary.

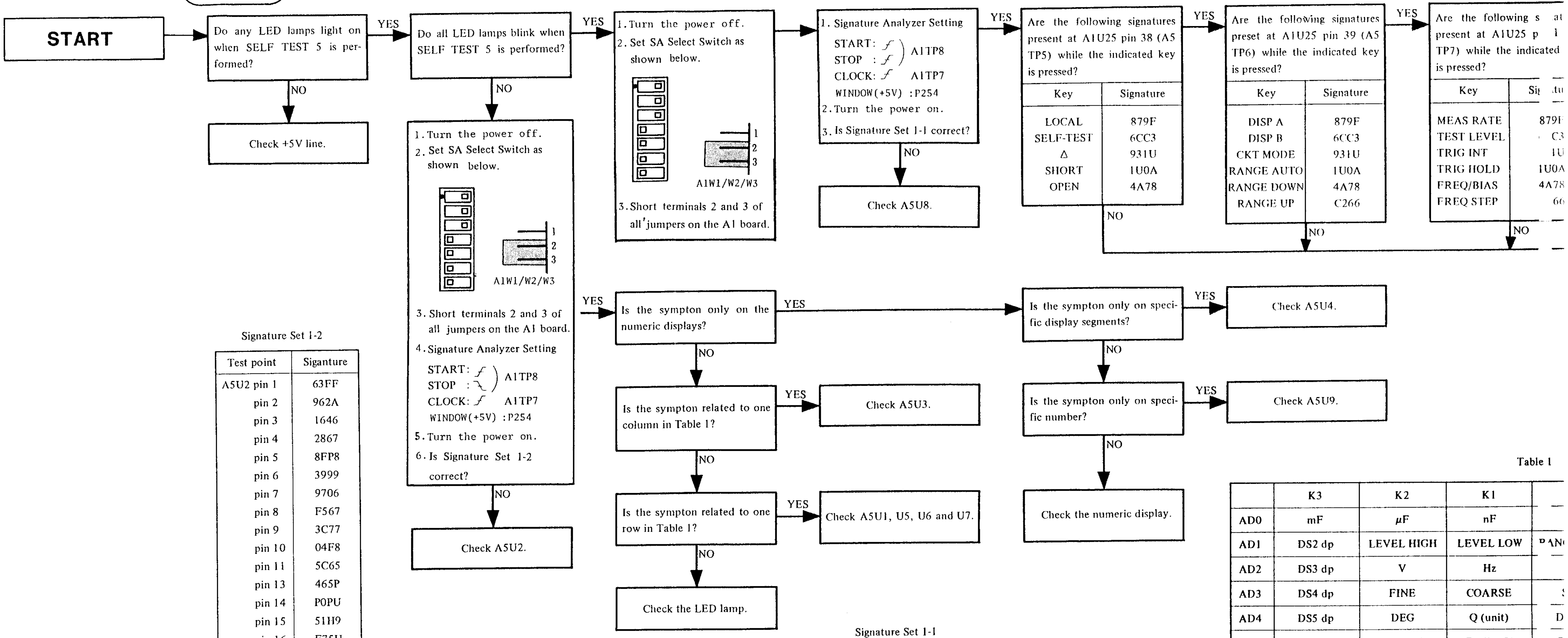
Turn off the instrument. Is the waveform at A4TP11 and TP12 (refer-ince is A4TP13) correct when the instrument is turned on?

Check A4L9, Q8, Q9, R18, R19, R20, R21, T2 and T3.

Check A4Q4, Q5, Q6, Q7, C24, C26, T2, T3 and U1.


ge at
eference is
oximately
YES
NO
Can the frequency of the signal at A4TP9 (reference is A4TP2) be set to 21 kHz±100Hz by adjusting A4R15?
YES
NO
Check A4R15, C18, U1 and T1.
Set the frequency of the signal at A4TP9 to 21kHz±100Hz.
Can the voltage at A4TP1 (reference is A4TP2) be set to +5.1V±0.01V by adjusting A4R14.
YES
NO
Adjust A4TP1 to +5.1V ±0.01V.
Is the voltage at 22R of the A4 board's edge connector (reference is A4TP2) +4.95V±0.15V?
YES
NO
Check A4L1.
Is the voltage at 4R and 3R of the A4 board's edge connector (reference is A4TP10) respectively +16V±1V and -16V ±1V?
YES
NO
Neither: Check A4L2, Q1, Q2 and T1.
Only +16V available: Check A4CR8, CR9,L3, C3, C13, CR3, R11 and R7.
Only -16V available: Check A4CR10, CR11, L4, C2, C12 CR2, R10 and R8.
Is the voltage at 9R and 7R of the A4 board's edge connector (reference is A4TP10) respectively +46V±4V and -46V±4V?
YES
NO
Neither: Check A4R1, R2, Q1 and Q2.
Only +46V available: Check A4C5, C7, C10, CR6, CR7 and R6.
Only -46V available: Check A4C6 C8, C9, CR4, CR5 and R5.
Is the voltage at 5R of the A4 board's edge connector (reference is A4 TP10) +9V±1V?
YES
NO
Check rectifier and filter circuit.
END
Can the voltage at A4U1pin4 (reference is A4TP13) be set to +2.10V by adjusting A4R14?
YES
NO
Check A4R14 and U1.
Set A4U1pin4 to +2.10V Is the voltage at A4U1pin2 (reference is A4TP13) +11.15V±0.35V?
YES
NO
Check A4U1.
Check A4CR14 and CR15.
f the instru-
Is the voltage
collector of
ence is A4
tarily
hen the
ent is turned
NO
YES
4Q3, CR20, C17,
Turn off the instrument. Is the voltage at A4U1 pin21 (reference is A4TP13) momentarily +0.6V after the instrument is turned on?
NO
YES
Check A4 CR19 and U1.
Turn off the instrument. Is the peak voltage of the signal at A4U1pin10 (reference is A4TP13) higher than +180mV when the instrument is turned on?
NO
YES
Check A4R24, R25, R26, R27, CR23, CR24, L11, T1 and check for a possible short in circuits connected to the A4T1 secondary.
Turn off the instrument. Is the waveform at A4TP11 and TP12 (referince is A4TP13) correct when the instrument is turned on?
0V
10V
50μs
NO
YES
Check A4Q4, Q5, Q6, Q7, C24, C26, T2, T3 and U1.
Check A4L9, Q8, Q9, R18, R19, R20, R21, T2 and T3.

Flow Diagram (A5 - 1)



START

Do any LED lamps light on when SELF TEST 5 is performed?

Check +5V line.

Do all LED lamps blink when SELF TEST 5 is performed?

1. Turn the power off.
2. Set SA Select Switch as shown below.
3. Short terminals 2 and 3 of all jumpers on the A1 board.
4. Signature Analyzer Setting
   START: ⨍) A1TP8
   STOP : ⌝)
   CLOCK: ⨍ A1TP7
   WINDOW(+5V) :P254
5. Turn the power on.
6. Is Signature Set 1-2 correct?

Check A5U2.

1. Turn the power off.
2. Set SA Select Switch as shown below.
3. Short terminals 2 and 3 of all jumpers on the A1 board.

1. Signature Analyzer Setting
   START: ⨍) A1TP8
   STOP : ⨍)
   CLOCK: ⨍ A1TP7
   WINDOW(+5V) :P254
2. Turn the power on.
3. Is Signature Set 1-1 correct?

Check A5U8.

Are the following signatures present at A1U25 pin 38 (A5 TP5) while the indicated key is pressed?

Key	Signature
LOCAL	879F
SELF-TEST	6CC3
Δ	931U
SHORT	1U0A
OPEN	4A78

Are the following signatures preset at A1U25 pin 39 (A5 TP6) while the indicated key is pressed?

Key	Signature
DISP A	879F
DISP B	6CC3
CKT MODE	931U
RANGE AUTO	1U0A
RANGE DOWN	4A78
RANGE UP	C266

Are the following s at
present at A1U25 p 1
TP7) while the indicated
is pressed?

Key	Si tu
MEAS RATE	879F
TEST LEVEL	C3
TRIG INT	1U
TRIG HOLD	1U0A
FREQ/BIAS	4A78
FREQ STEP	66

Is the sympton only on the numeric displays?

Is the sympton only on specific display segments?

Check A5U4.

Is the sympton only on specific number?

Check A5U9.

Check the numeric display.

Is the sympton related to one column in Table 1?

Check A5U3.

Is the sympton related to one row in Table 1?

Check A5U1, U5, U6 and U7.

Check the LED lamp.

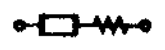
Signature Set 1-2

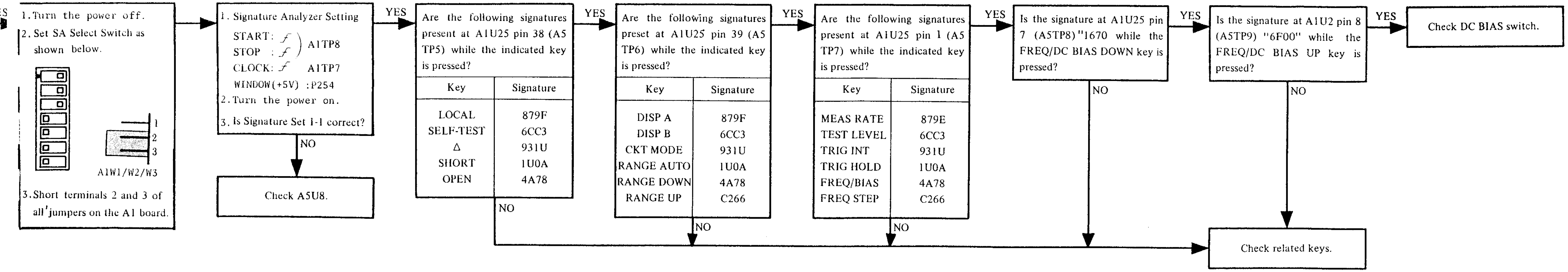
Test point	Siganture
A5U2 pin 1	63FF
pin 2	962A
pin 3	1646
pin 4	2867
pin 5	8FP8
pin 6	3999
pin 7	9706
pin 8	F567
pin 9	3C77
pin 10	04F8
pin 11	5C65
pin 13	465P
pin 14	P0PU
pin 15	51H9
pin 16	F75U
pin 17	9F2A

Signature Set 1-1

Test point	Signature
A5U8 pin 7	6F00
pin 9	1670
pin 10	C266
pin 11	4A78
pin 12	1U0A
pin 13	931U
pin 14	6CC3
pin 15	879F

Table 1

	K3	K2	K1	
AD0	mF	μF	nF	
AD1	DS2 dp	LEVEL HIGH	LEVEL LOW	AN
AD2	DS3 dp	V	Hz	
AD3	DS4 dp	FINE	COARSE	
AD4	DS5 dp	DEG	Q (unit)	D
AD5	MΩ (disp B)	kΩ (disp B)	Ω (disp B)	mΩ
AD6	DS7 dp	|Z|	C	
AD7	DS8 dp	G/ESR	Q (FUNC)	D
AD8	DS9 dp			CK
AD9	DS10 dp	MEAS FAST	MEAS MED	IE
AD10	kH	H	mH	
AD11	DS12 dp	L ONLY	TRIG HOLD	TF
AD12	DS13 dp	C ONLY	BIAS	I
AD13	DS14 dp	Δ	TRIG LAMP	SE
AD14		S	mS	
AD15	MΩ (disp A)	kΩ (disp A)	Ω (disp A)	mΩ



1. Turn the power off.
2. Set SA Select Switch as shown below.
3. Short terminals 2 and 3 of all jumpers on the A1 board.

1. Signature Analyzer Setting
   START: ⨍ A1TP8
   STOP : ⨍ A1TP8
   CLOCK: ⨍ A1TP7
   WINDOW(+5V) :P254
2. Turn the power on.
3. Is Signature Set 1-1 correct?

Check A5U8.

Are the following signatures present at A1U25 pin 38 (A5 TP5) while the indicated key is pressed?

Key	Signature
LOCAL	879F
SELF-TEST	6CC3
Δ	931U
SHORT	1U0A
OPEN	4A78

Are the following signatures preset at A1U25 pin 39 (A5 TP6) while the indicated key is pressed?

Key	Signature
DISP A	879F
DISP B	6CC3
CKT MODE	931U
RANGE AUTO	1U0A
RANGE DOWN	4A78
RANGE UP	C266

Are the following signatures present at A1U25 pin 1 (A5 TP7) while the indicated key is pressed?

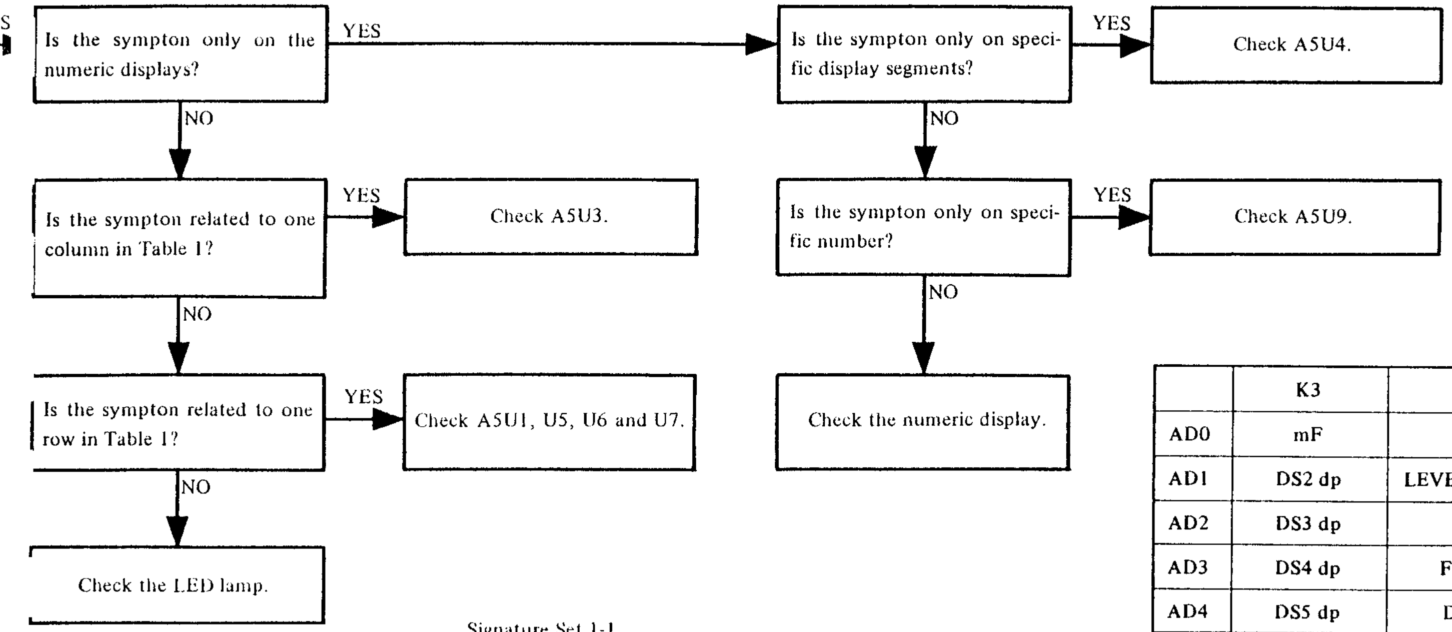
Key	Signature
MEAS RATE	879E
TEST LEVEL	6CC3
TRIG INT	931U
TRIG HOLD	1U0A
FREQ/BIAS	4A78
FREQ STEP	C266

Is the signature at A1U25 pin 7 (A5TP8) "1670 while the FREQ/DC BIAS DOWN key is pressed?

Is the signature at A1U2 pin 8 (A5TP9) "6F00" while the FREQ/DC BIAS UP key is pressed?

Check DC BIAS switch.

Check related keys.



Is the sympton only on the numeric displays?

Is the sympton only on specific display segments?

Check A5U4.

Is the sympton related to one column in Table 1?

Check A5U3.

Is the sympton only on specific number?

Check A5U9.

Is the sympton related to one row in Table 1?

Check A5U1, U5, U6 and U7.

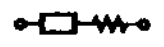
Check the numeric display.

Check the LED lamp.

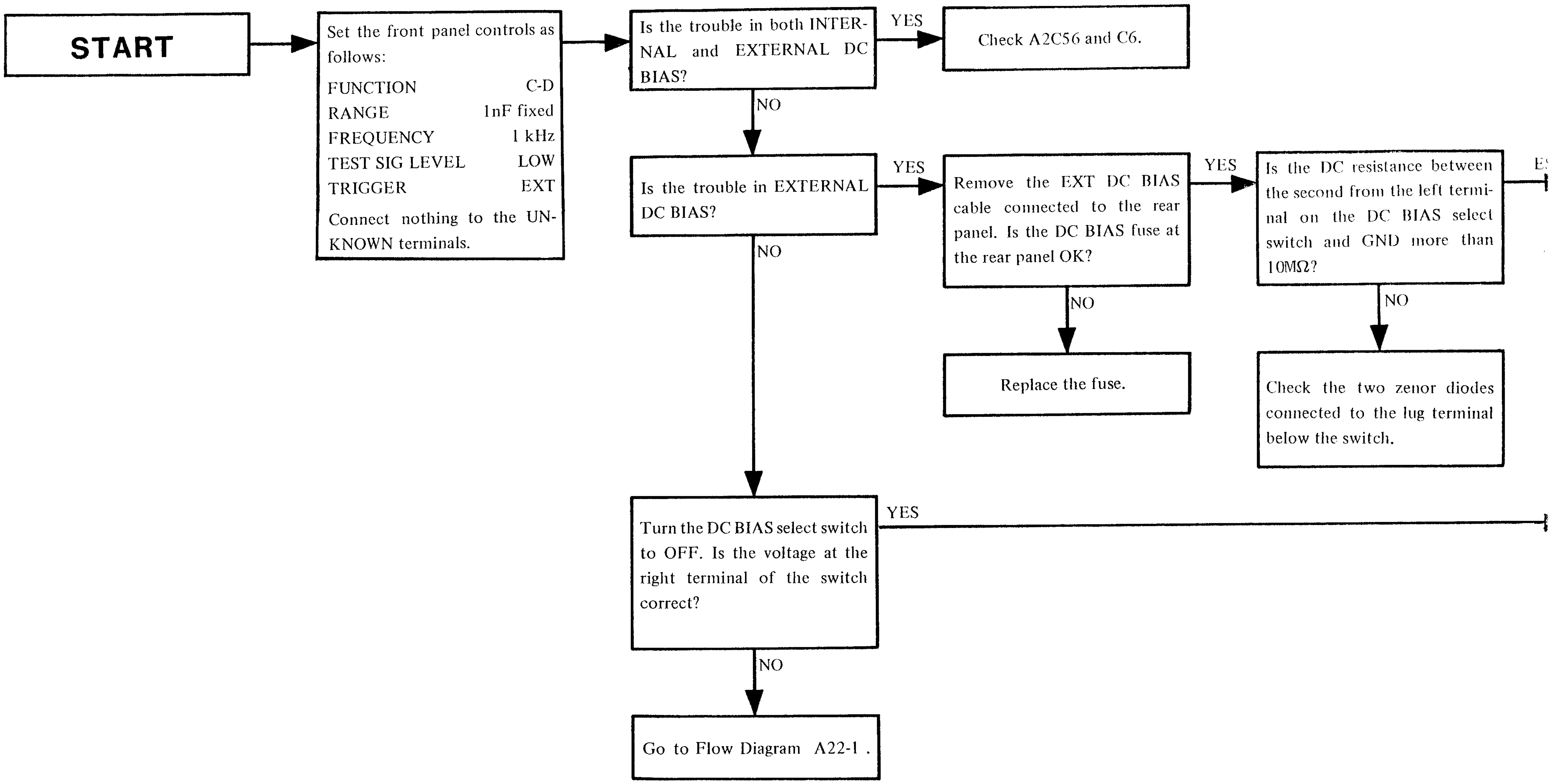
Signature Set 1-1

Test point	Signature
A5U8 pin 7	6F00
pin 9	1670
pin 10	C266
pin 11	4A78
pin 12	1U0A
pin 13	931U
pin 14	6CC3
pin 15	879F

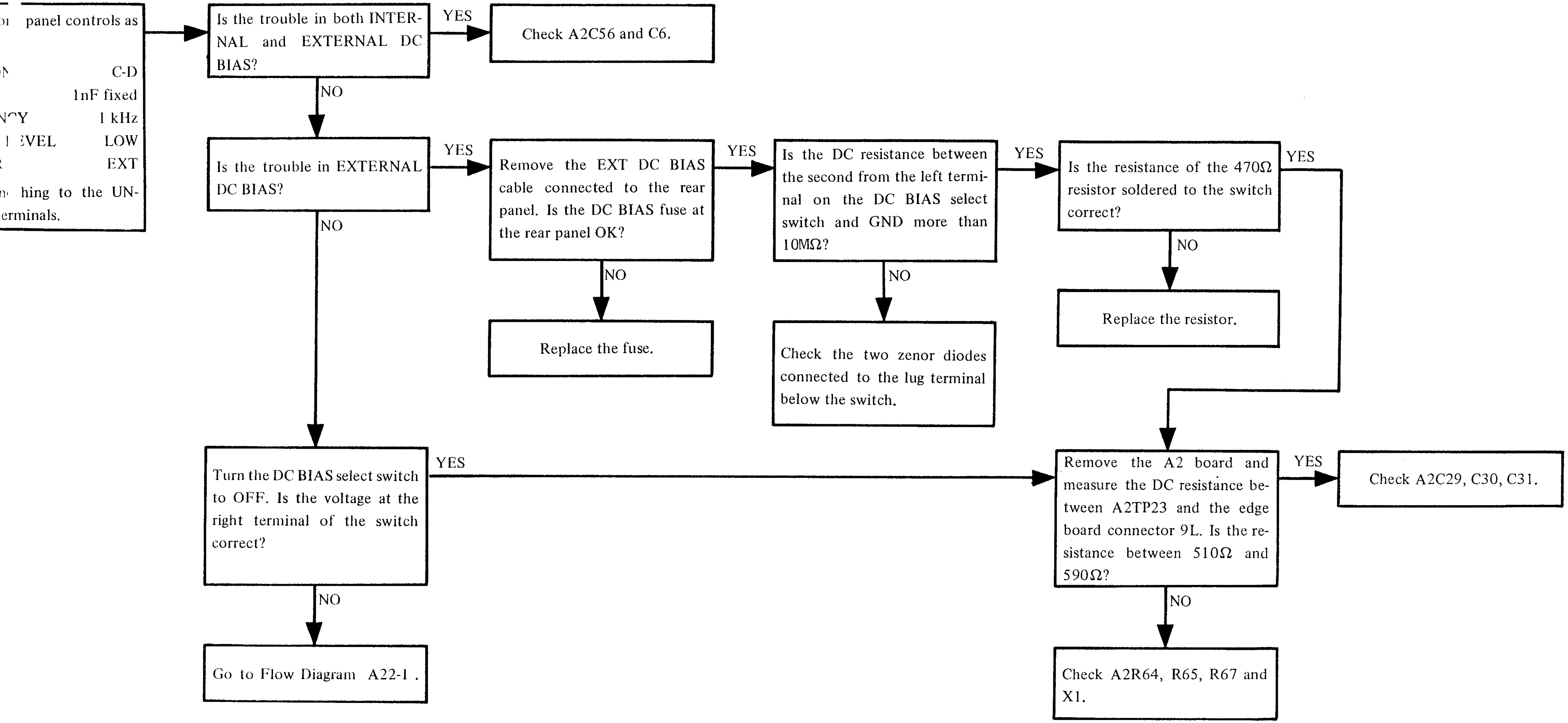
Table 1

	K3	K2	K1	K0	KB3	KB2	KB1	KB0
AD0	mF	μF	nF	pF	DS1 2^3	DS1 2^2	DS1 2^1	DS1 2^0
AD1	DS2 dp	LEVEL HIGH	LEVEL LOW	RANGE AUTO	DS2 2^3	DS2 2^2	DS2 2^1	DS2 2^0
AD2	DS3 dp	V	Hz	kHz	DS3 2^3	DS3 2^2	DS3 2^1	DS3 2^0
AD3	DS4 dp	FINE	COARSE	SPOT	DS4 2^3	DS4 2^2	DS4 2^1	DS4 2^0
AD4	DS5 dp	DEG	Q (unit)	D (unit)	DS5 2^3	DS5 2^2	DS5 2^1	DS5 2^0
AD5	MΩ (disp B)	kΩ (disp B)	Ω (disp B)	mΩ (disp B)	DS6 2^3	DS6 2^2	DS6 2^1	DS6 2^0
AD6	DS7 dp	|Z|	C	L	DS7 2^3	DS7 2^2	DS7 2^1	DS7 2^0
AD7	DS8 dp	G/ESR	Q (FUNC)	D (FUNC)	DS8 2^3	DS8 2^2	DS8 2^1	DS8 2^0
AD8	DS9 dp			CKT AUTO	DS9 2^3	DS9 2^2	DS9 2^1	DS9 2^0
AD9	DS10 dp	MEAS FAST	MEAS MED	MEAS SLOW	DS10 2^3	DS10 2^2	DS10 2^1	DS10 2^0
AD10	kH	H	mH	μH	DS11 2^3	DS11 2^2	DS11 2^1	DS11 2^0
AD11	DS12 dp	L ONLY	TRIG HOLD	TRIG INT	DS12 2^3	DS12 2^2	DS12 2^1	DS12 2^0
AD12	DS13 dp	C ONLY	BIAS	FREQ	DS13 2^3	DS13 2^2	DS13 2^1	DS13 2^0
AD13	DS14 dp	Δ	TRIG LAMP	SELF TEST	DS14 2^3	DS14 2^2	DS14 2^1	DS14 2^0
AD14		S	mS	μS				
AD15	MΩ (disp A)	kΩ (disp A)	Ω (disp A)	mΩ (disp A)	REMOTE	SRQ	TALK	LISTEN

DC BIAS Flow Diagram



m



panel controls as
C-D
1nF fixed
1 kHz
LOW
EXT
hing to the UN-
erminals.

Is the trouble in both INTERNAL and EXTERNAL DC BIAS?

Check A2C56 and C6.

Is the trouble in EXTERNAL DC BIAS?

Remove the EXT DC BIAS cable connected to the rear panel. Is the DC BIAS fuse at the rear panel OK?

Replace the fuse.

Is the DC resistance between the second from the left terminal on the DC BIAS select switch and GND more than 10MΩ?

Check the two zenor diodes connected to the lug terminal below the switch.

Is the resistance of the 470Ω resistor soldered to the switch correct?

Replace the resistor.

Turn the DC BIAS select switch to OFF. Is the voltage at the right terminal of the switch correct?

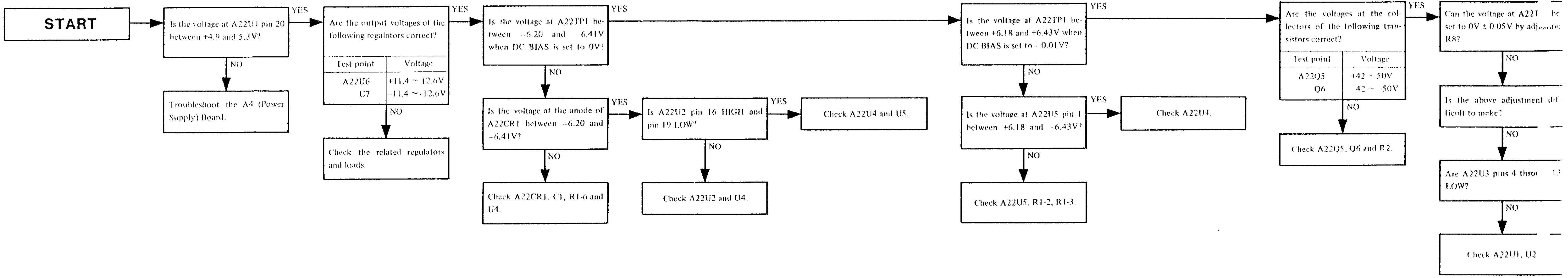
Go to Flow Diagram A22-1 .

Remove the A2 board and measure the DC resistance between A2TP23 and the edge board connector 9L. Is the resistance between 510Ω and 590Ω?

Check A2C29, C30, C31.

Check A2R64, R65, R67 and X1.

Flow Diagram A22 - 1



START

Is the voltage at A22U1 pin 20 between +4.9 and 5.3V?

Troubleshoot the A4 (Power Supply) Board.

Are the output voltages of the following regulators correct?

Test point	Voltage
A22U6	+11.4 ~ 12.6V
U7	-11.4 ~ -12.6V

Check the related regulators and loads.

Is the voltage at A22TP1 between -6.20 and -6.41V when DC BIAS is set to 0V?

Is the voltage at the anode of A22CR1 between -6.20 and -6.41V?

Check A22CR1, C1, R1-6 and U4.

Is A22U2 pin 16 HIGH and pin 19 LOW?

Check A22U2 and U4.

Check A22U4 and U5.

Is the voltage at A22TP1 between +6.18 and +6.43V when DC BIAS is set to - 0.01V?

Is the voltage at A22U5 pin 1 between +6.18 and -6.43V?

Check A22U5, R1-2, R1-3.

Check A22U4.

Are the voltages at the collectors of the following transistors correct?

Test point	Voltage
A22Q5	+42 ~ 50V
Q6	42 ~ -50V

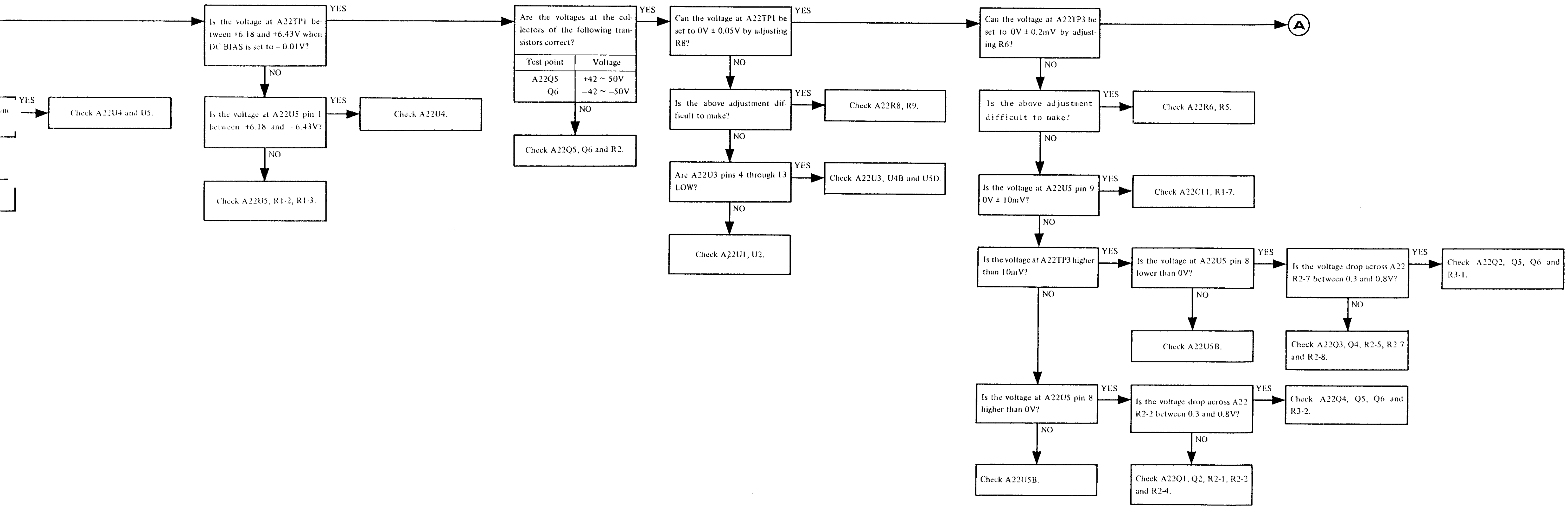
Check A22Q5, Q6 and R2.

Can the voltage at A221 be set to 0V ± 0.05V by adj R8?

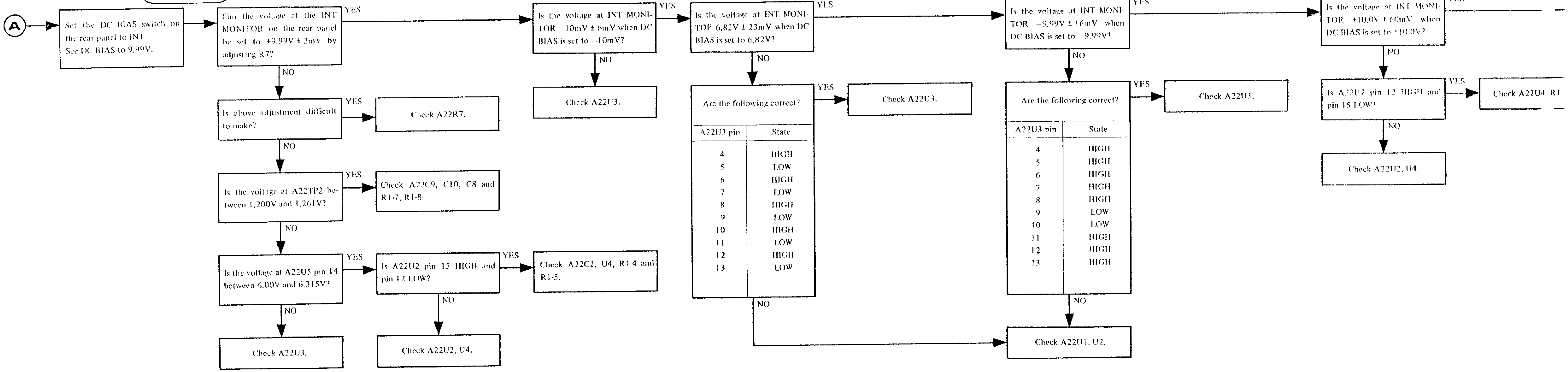
Is the above adjustment dif ficult to make?

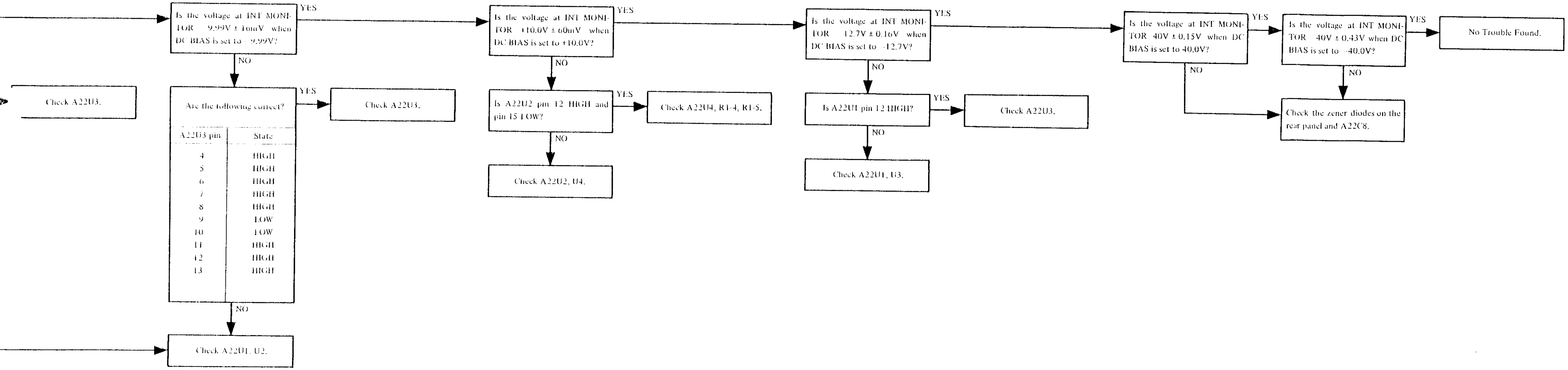
Are A22U3 pins 4 throu 13 LOW?

Check A22U1, U2

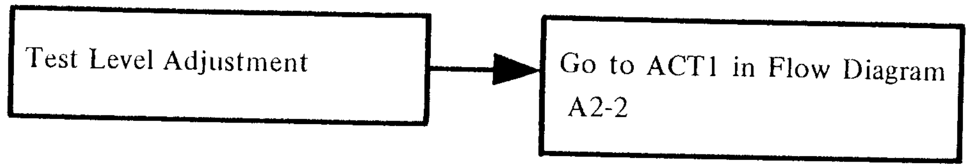

YES
Check A22U4 and U5.
Is the voltage at A22TP1 between +6.18 and +6.43V when DC BIAS is set to – 0.01V?
YES
NO
Is the voltage at A22U5 pin 1 between +6.18 and –6.43V?
YES
Check A22U4.
NO
Check A22U5, R1-2, R1-3.
Are the voltages at the collectors of the following transistors correct?
Test point
Voltage
A22Q5
+42 ~ 50V
Q6
–42 ~ –50V
YES
NO
Check A22Q5, Q6 and R2.
Can the voltage at A22TP1 be set to 0V ± 0.05V by adjusting R8?
YES
NO
Is the above adjustment difficult to make?
YES
Check A22R8, R9.
NO
Are A22U3 pins 4 through 13 LOW?
YES
Check A22U3, U4B and U5D.
NO
Check A22U1, U2.
Can the voltage at A22TP3 be set to 0V ± 0.2mV by adjusting R6?
YES
A
NO
Is the above adjustment difficult to make?
YES
Check A22R6, R5.
NO
Is the voltage at A22U5 pin 9 0V ± 10mV?
YES
Check A22C11, R1-7.
NO
Is the voltage at A22TP3 higher than 10mV?
YES
Is the voltage at A22U5 pin 8 lower than 0V?
YES
Is the voltage drop across A22 R2-7 between 0.3 and 0.8V?
YES
Check A22Q2, Q5, Q6 and R3-1.
NO
Check A22U5B.
NO
Check A22Q3, Q4, R2-5, R2-7 and R2-8.
NO
Is the voltage at A22U5 pin 8 higher than 0V?
YES
Is the voltage drop across A22 R2-2 between 0.3 and 0.8V?
YES
Check A22Q4, Q5, Q6 and R3-2.
NO
Check A22U5B.
NO
Check A22Q1, Q2, R2-1, R2-2 and R2-4.

Flow Diagram (A22 - 1)

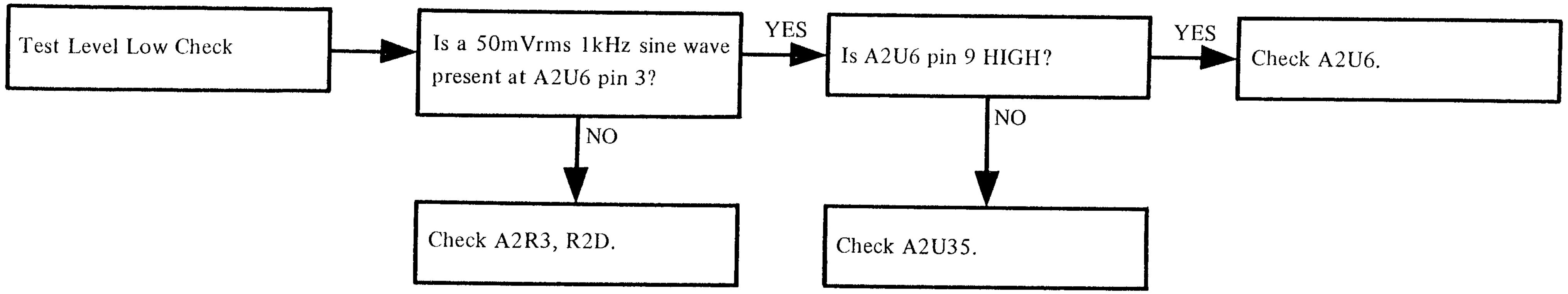



Is the voltage at INT MONITOR 9.99V ± 10mV when DC BIAS is set to -9.99V?
YES
NO
Check A22U3.
Are the following correct?
YES
Check A22U3.
A22U3 pin
State
4
HIGH
5
HIGH
6
HIGH
7
HIGH
8
HIGH
9
LOW
10
LOW
11
HIGH
12
HIGH
13
HIGH
NO
Check A22U1, U2.
Is the voltage at INT MONITOR +10.0V ± 60mV when DC BIAS is set to +10.0V?
YES
NO
Is A22U2 pin 12 HIGH and pin 15 LOW?
YES
Check A22U4, R1-4, R1-5.
NO
Check A22U2, U4.
Is the voltage at INT MONITOR 12.7V ± 0.16V when DC BIAS is set to -12.7V?
YES
NO
Is A22U1 pin 12 HIGH?
YES
Check A22U3.
NO
Check A22U1, U3.
Is the voltage at INT MONITOR 40V ± 0.15V when DC BIAS is set to 40.0V?
YES
NO
Is the voltage at INT MONITOR 40V ± 0.43V when DC BIAS is set to -40.0V?
YES
No Trouble Found.
NO
Check the zener diodes on the rear panel and A22C8.

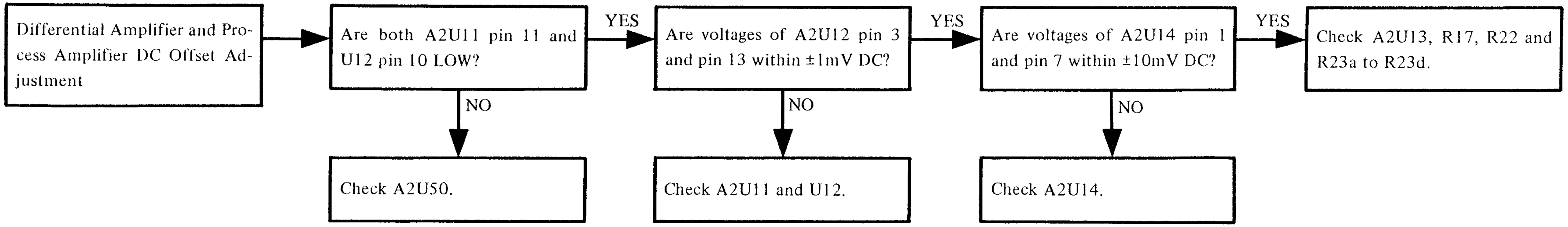
Flow Diagram ADJ-1



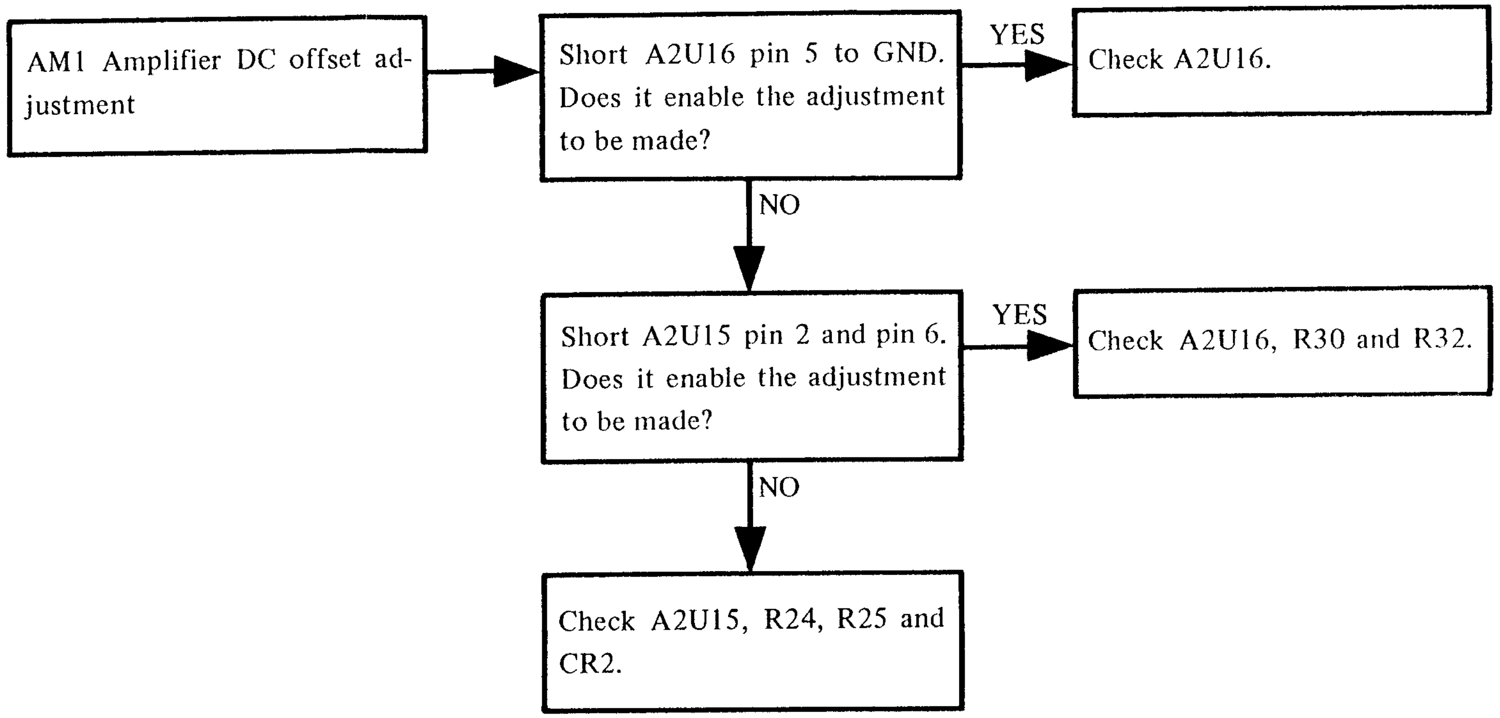
Flow Diagram ADJ-2



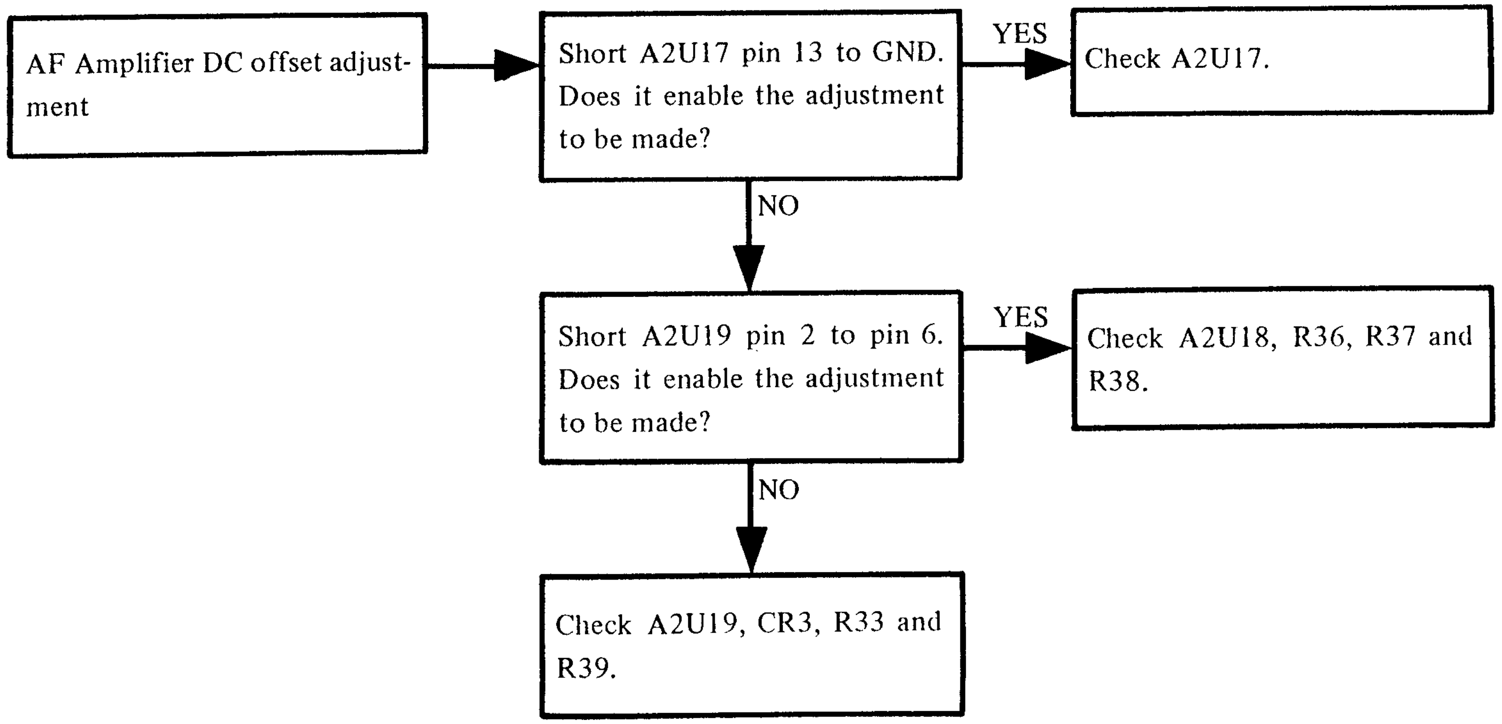
Flow Diagram ADJ-3



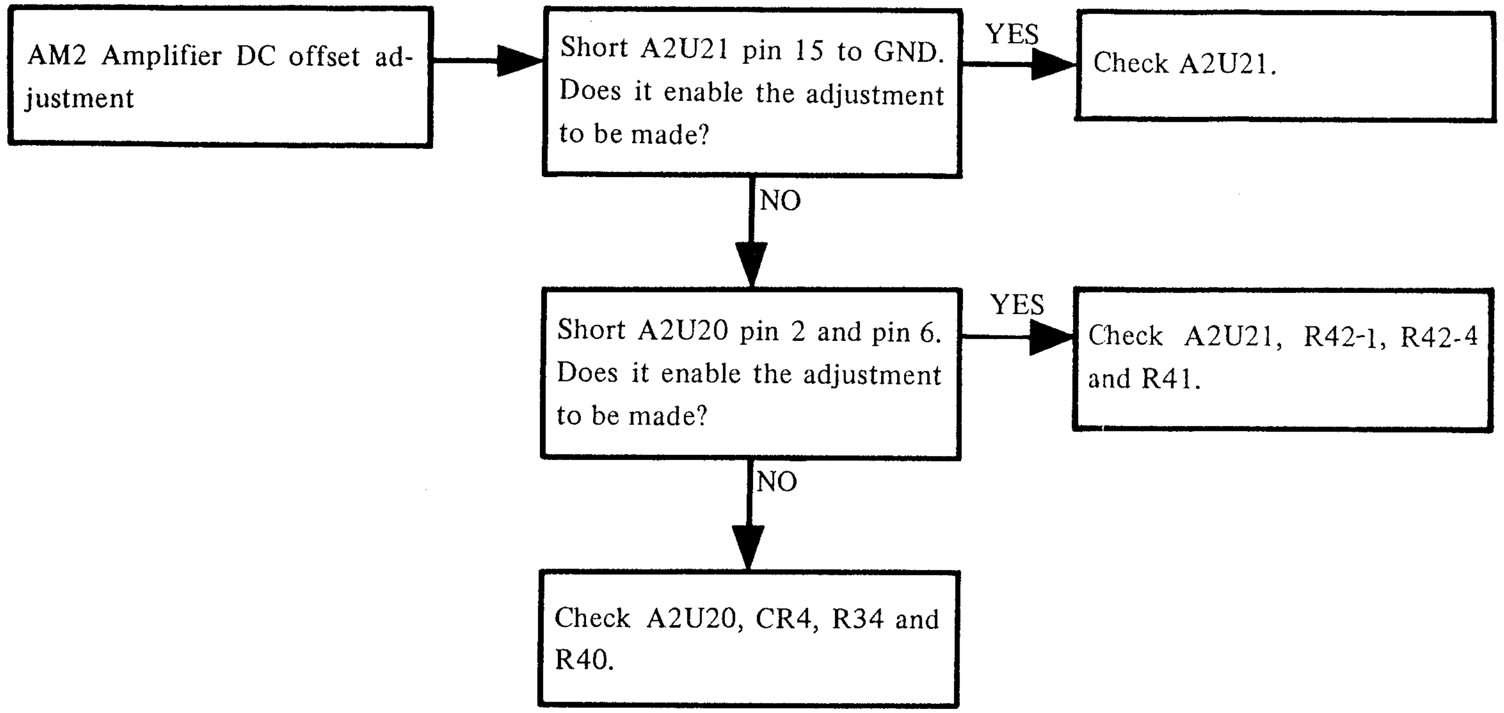
Flow Diagram ADJ-4



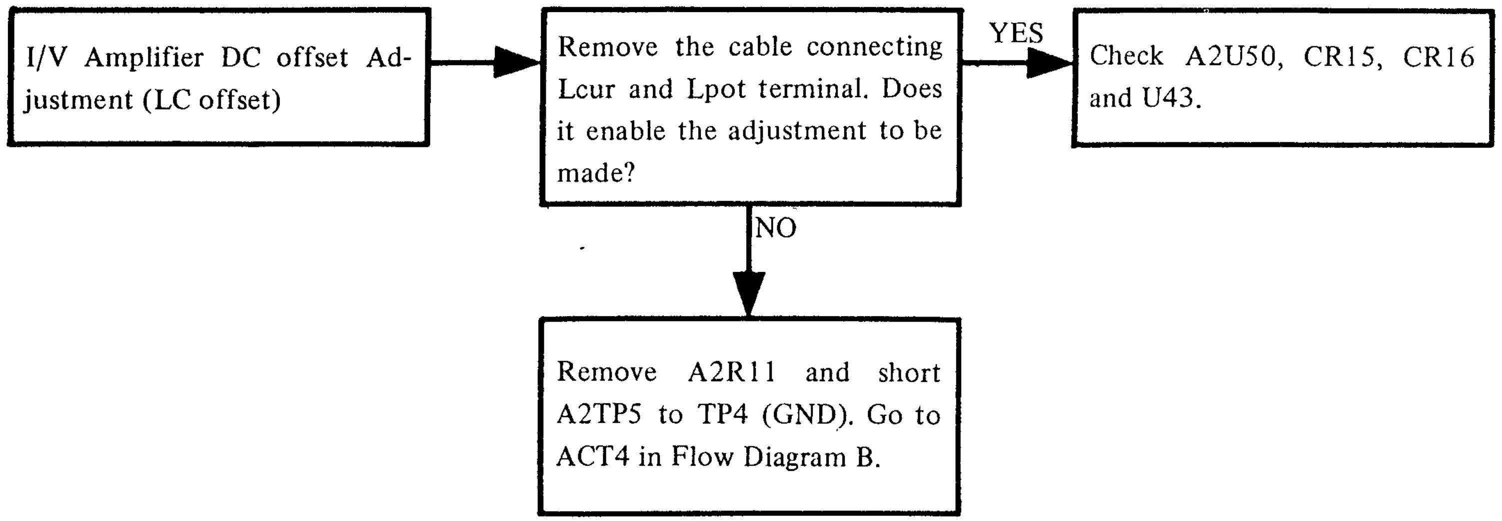
Flow Diagram ADJ-5



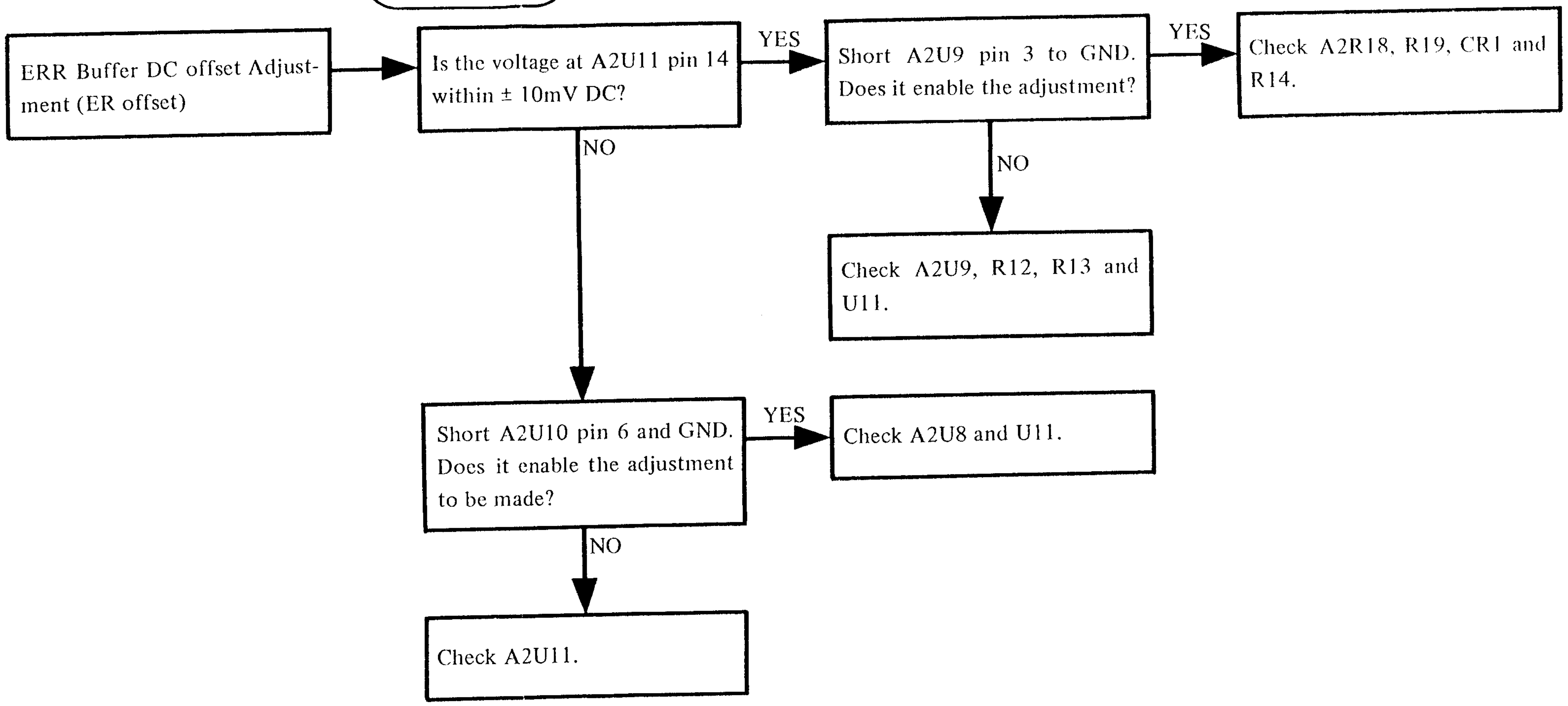
Flow Diagram ADJ-6



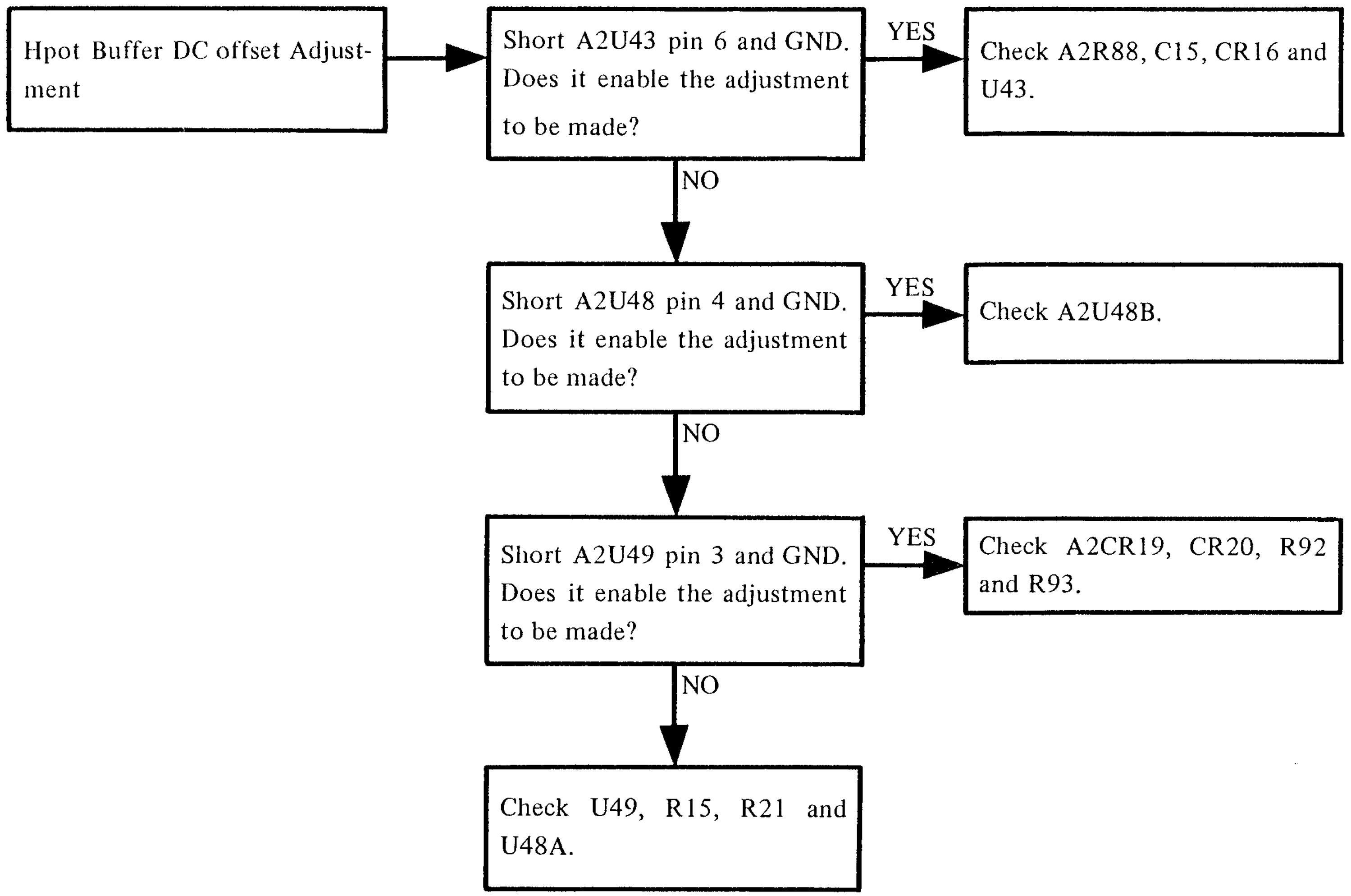
Flow Diagram ADJ-7



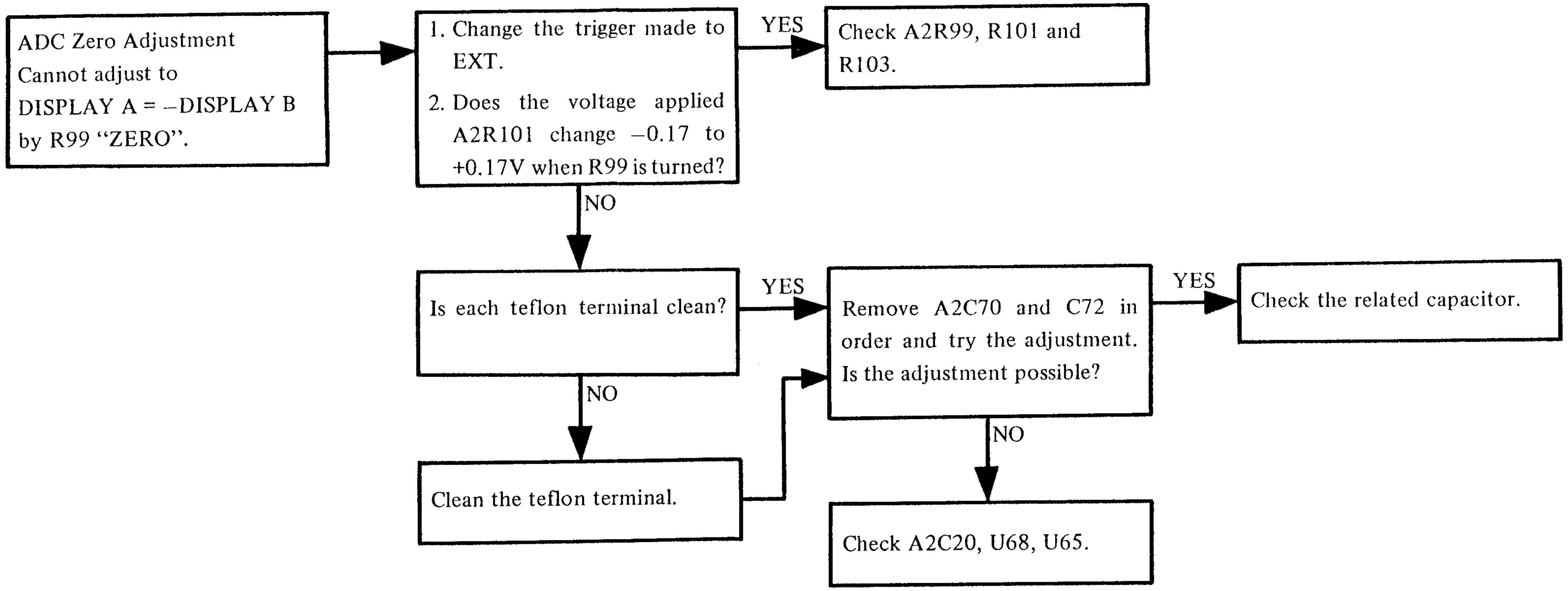
Flow Diagram ADJ-8



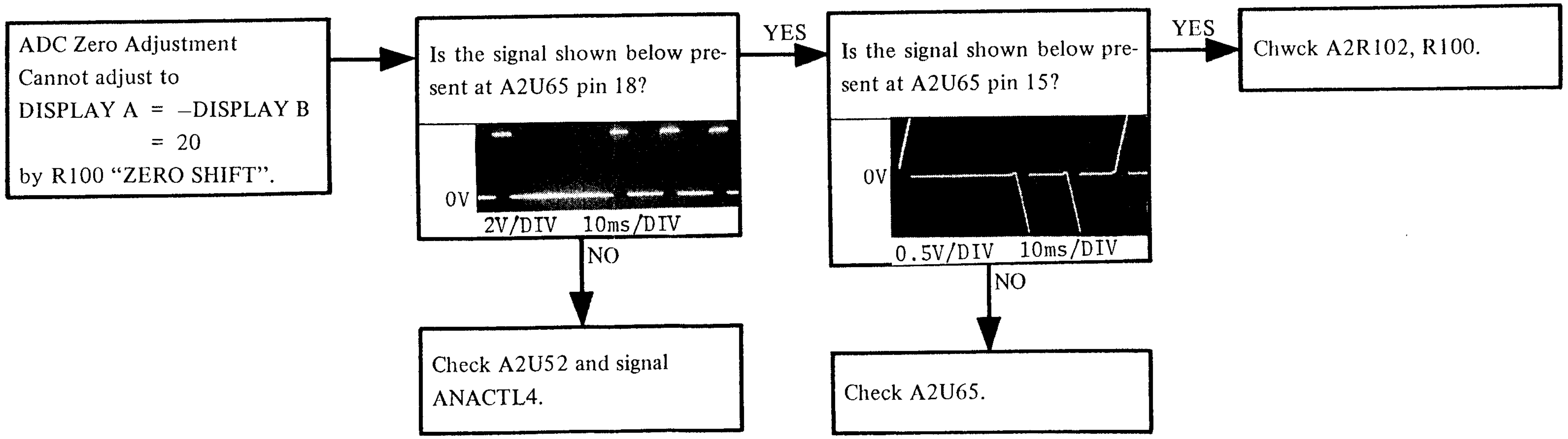
Flow Diagram ADJ-9



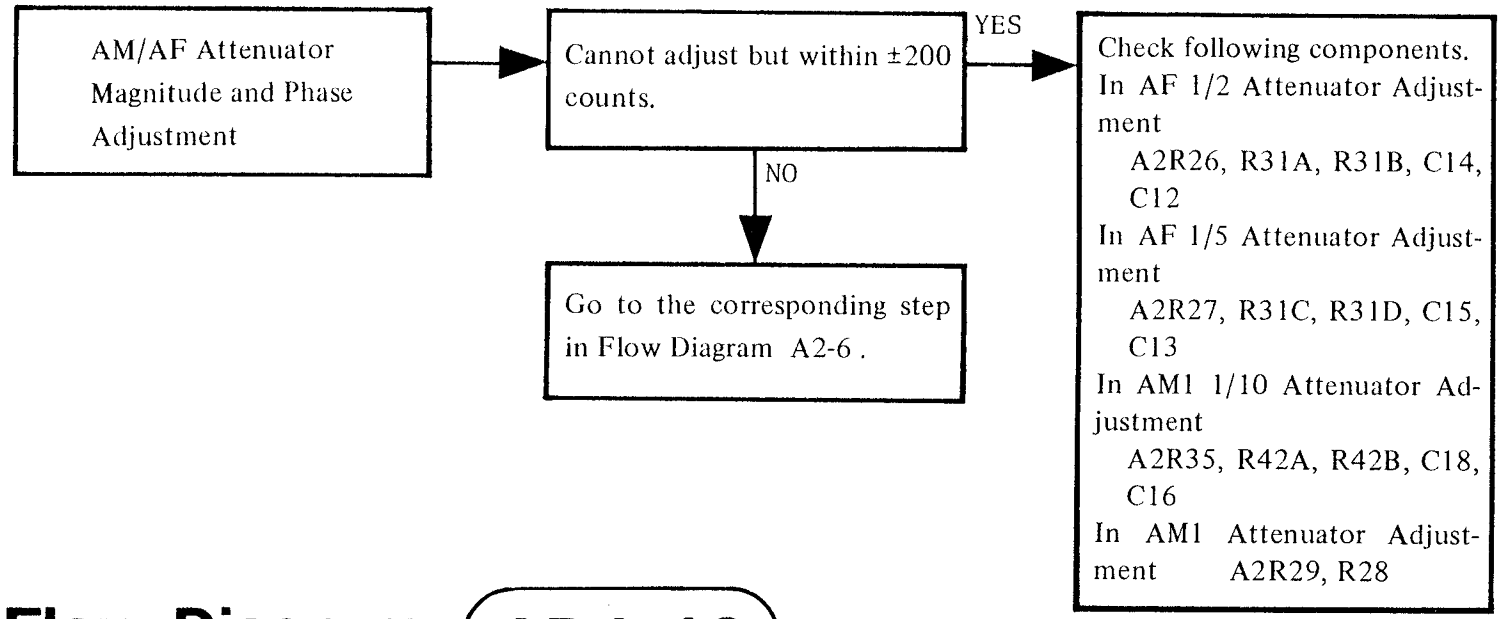
Flow Diagram ADJ-10



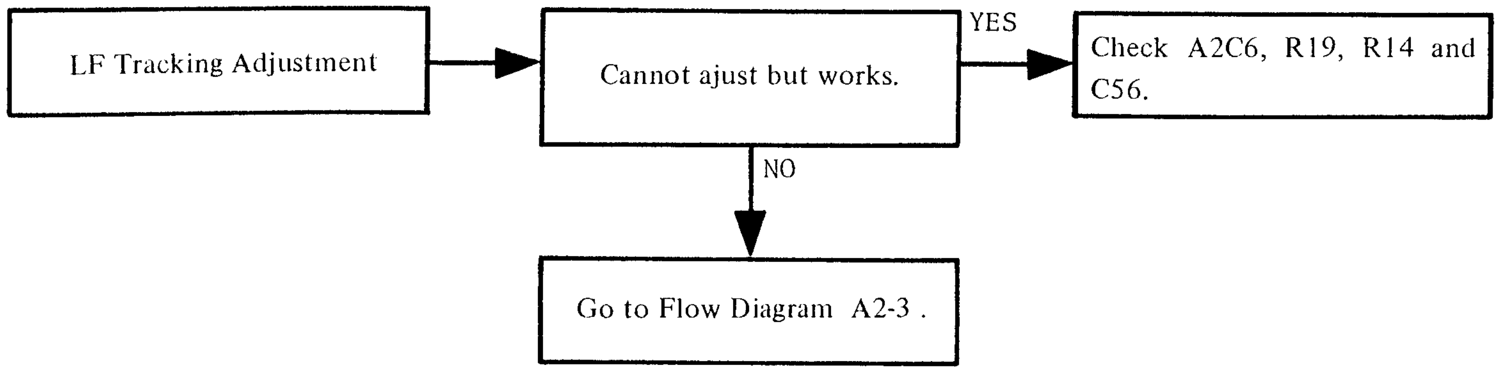
Flow Diagram ADJ-11



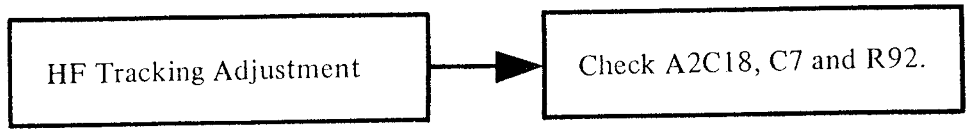
Flow Diagram ADJ-12



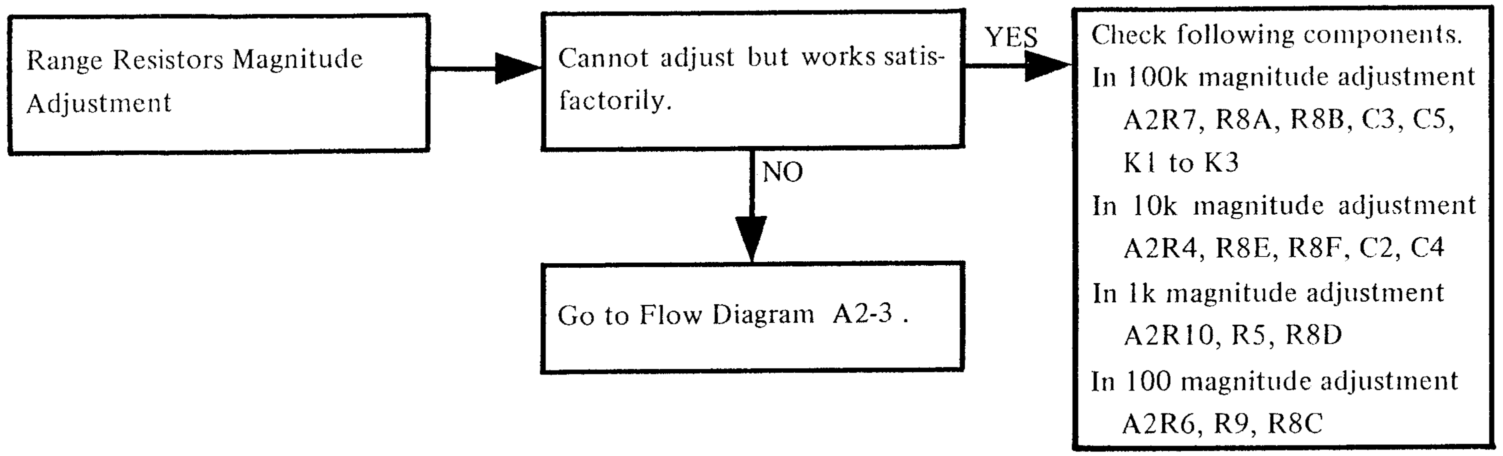
Flow Diagram ADJ-13



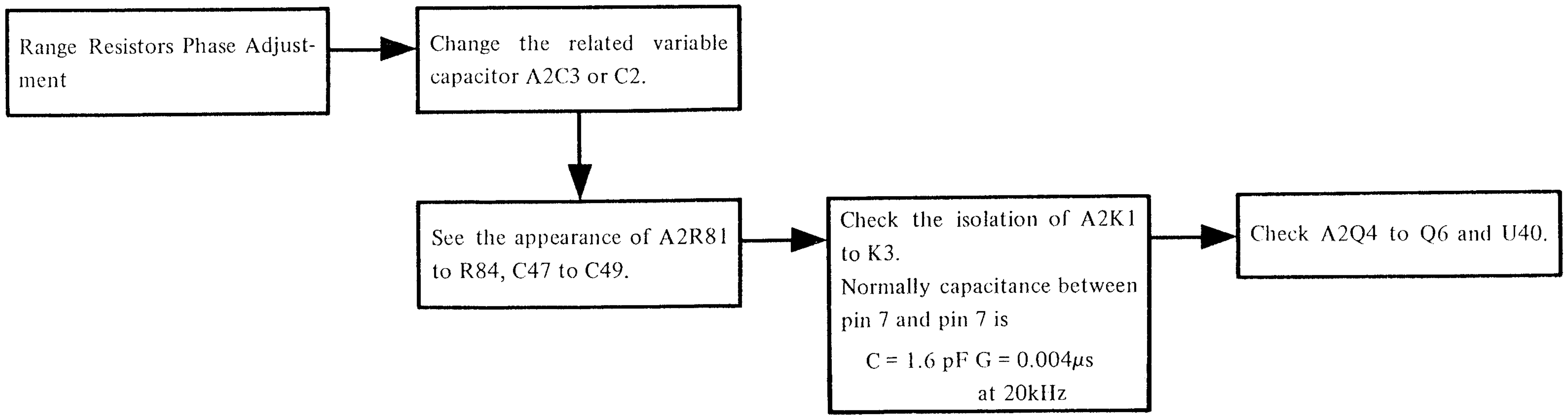
Flow Diagram ADJ-14



Flow Diagram ADJ-15



Flow Diagram ADJ-16



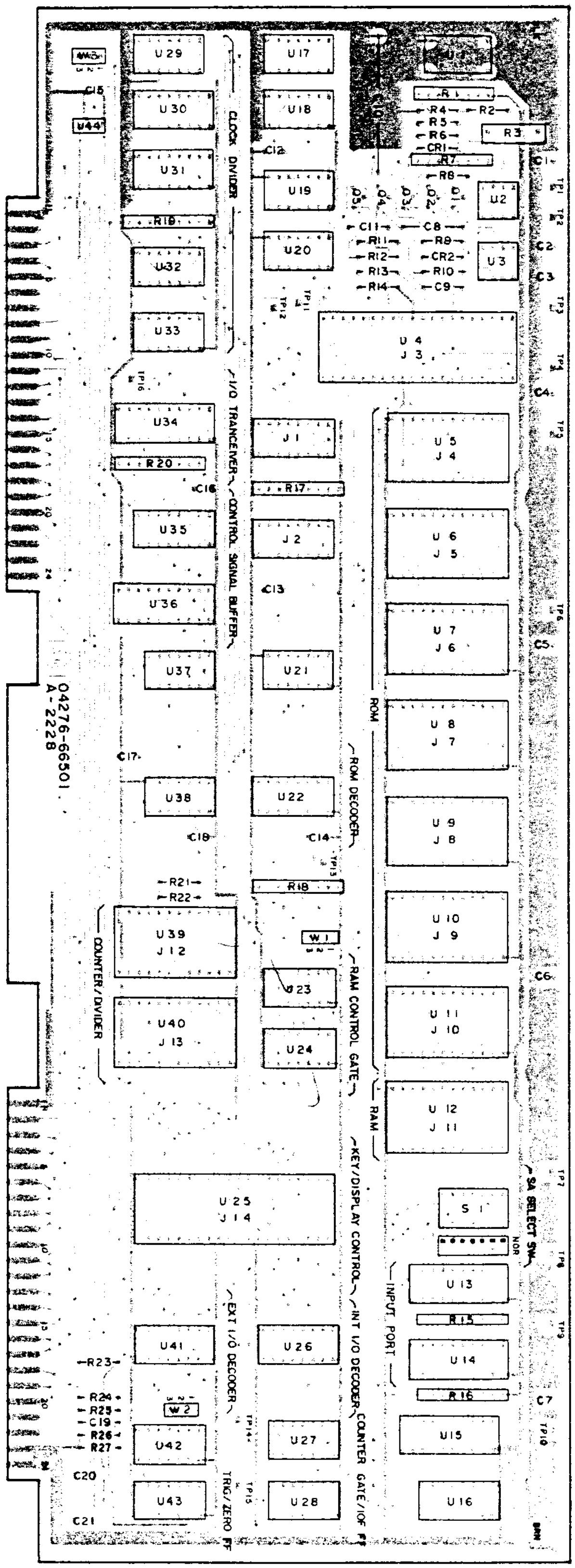
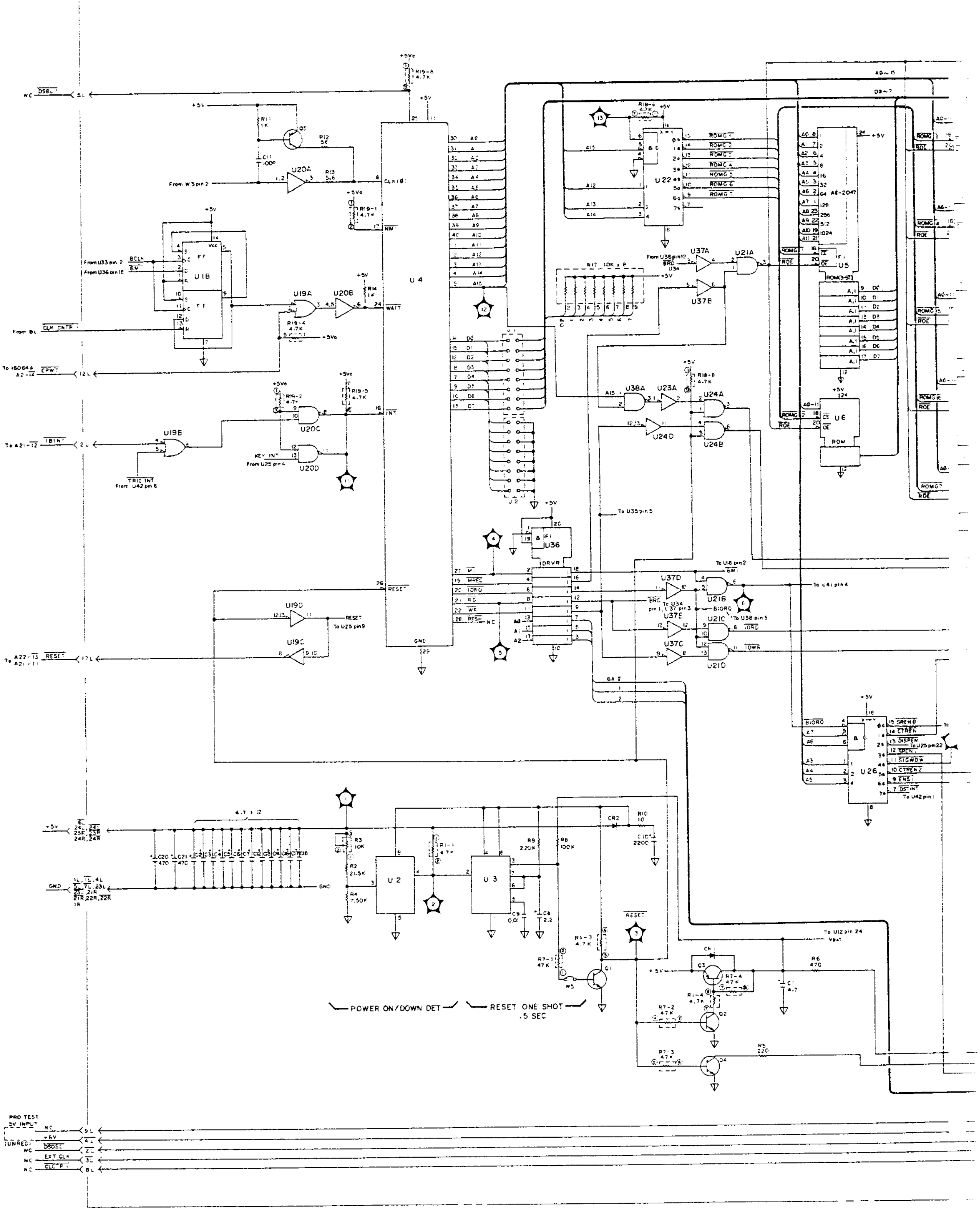
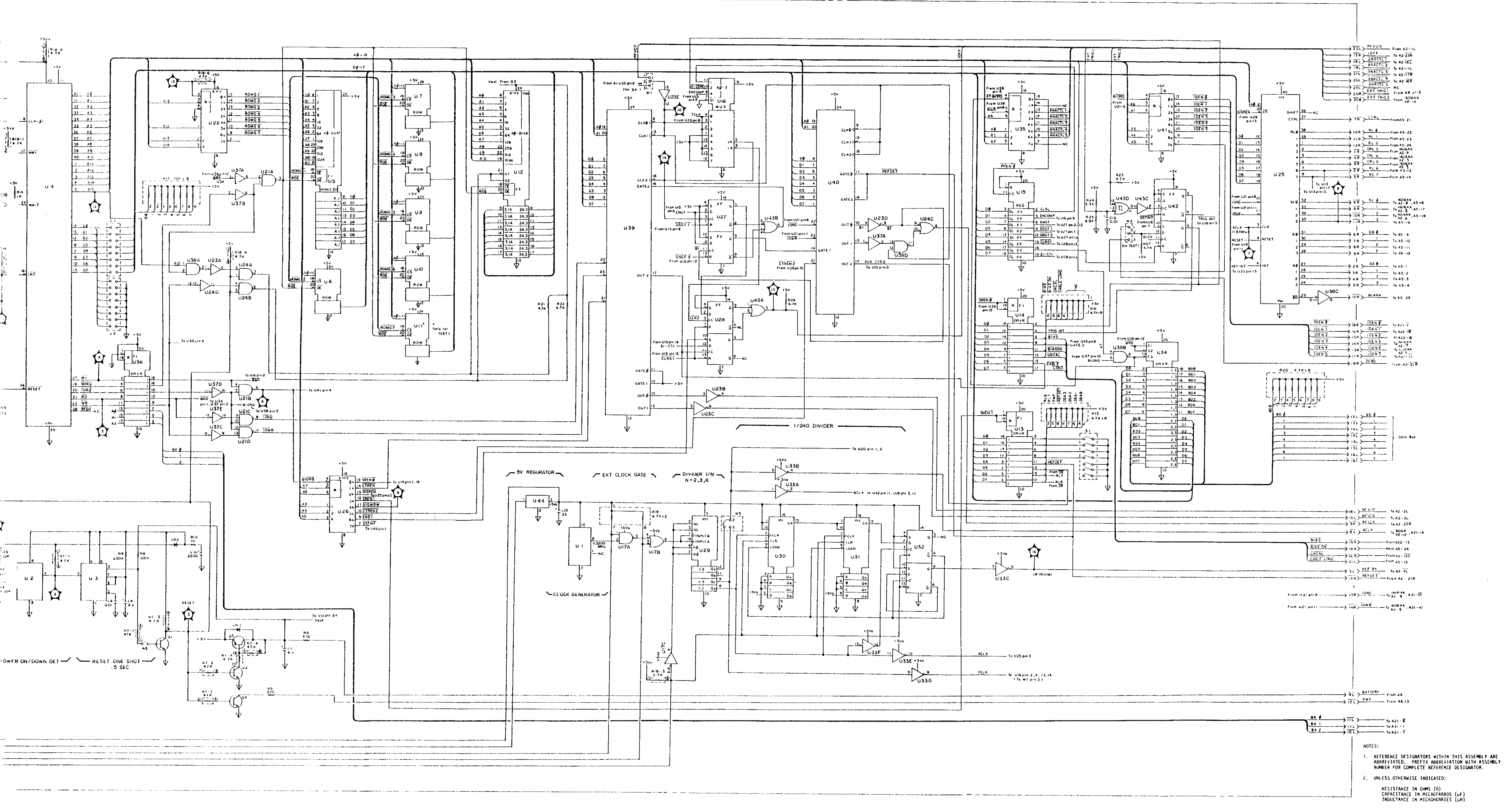


Figure 8-XX. A1 LOGIC Board Assembly Component Locations.

A1 LOGIC (P/N:04276-66501)





NOTES:

1. REFERENCE DESIGNATORS WITHIN THIS ASSEMBLY ARE ABBREVIATED. PREFIX ABBREVIATION WITH ASSEMBLY NUMBER FOR COMPLETE REFERENCE DESIGNATOR.

2. UNLESS OTHERWISE INDICATED:

RESISTANCE IN OHMS (Ω)
CAPACITANCE IN MICROFARADS (µF)
INDUCTANCE IN MICROHENRIES (µH)

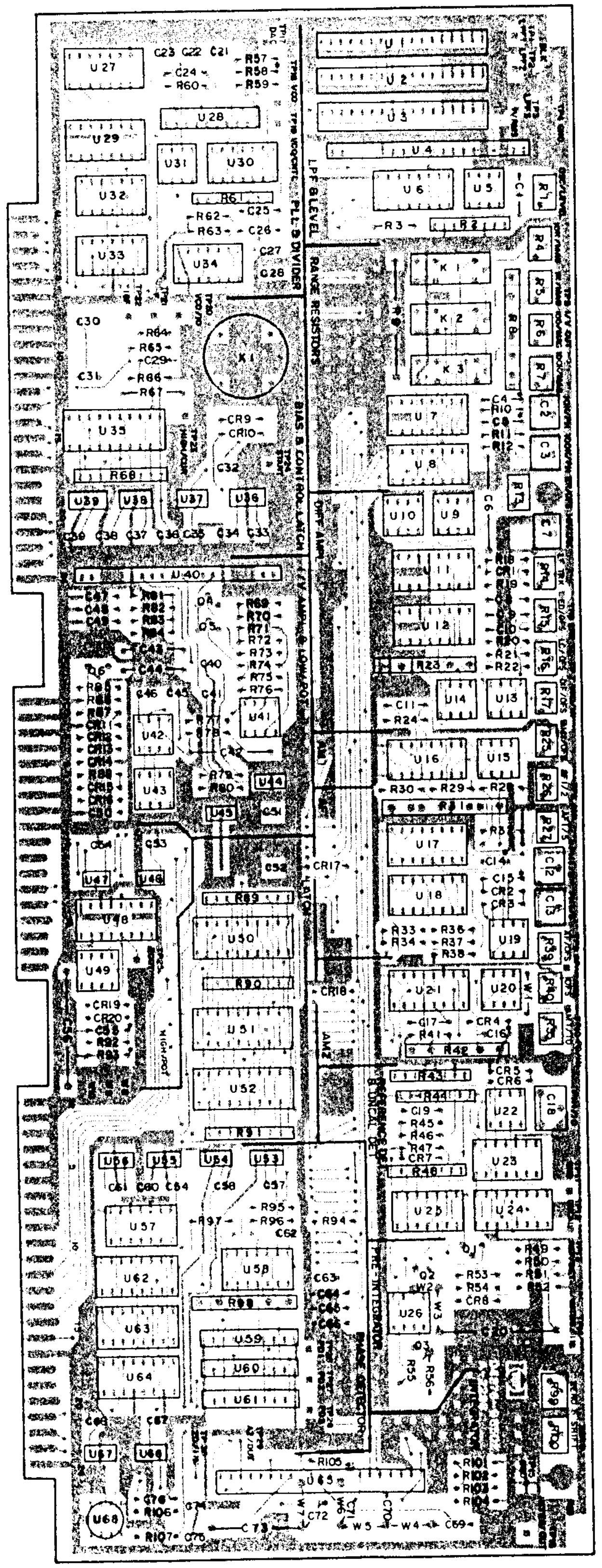
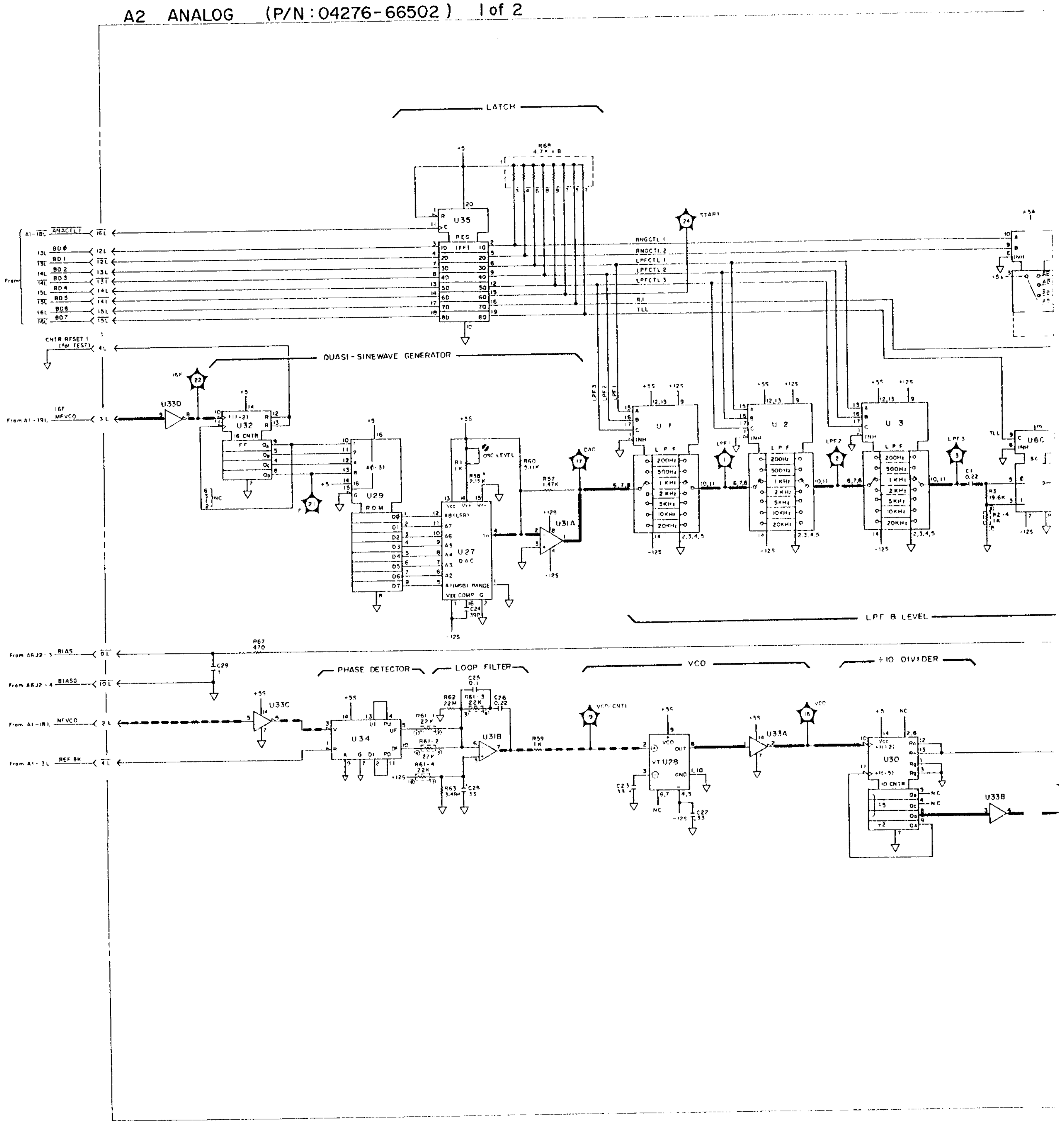
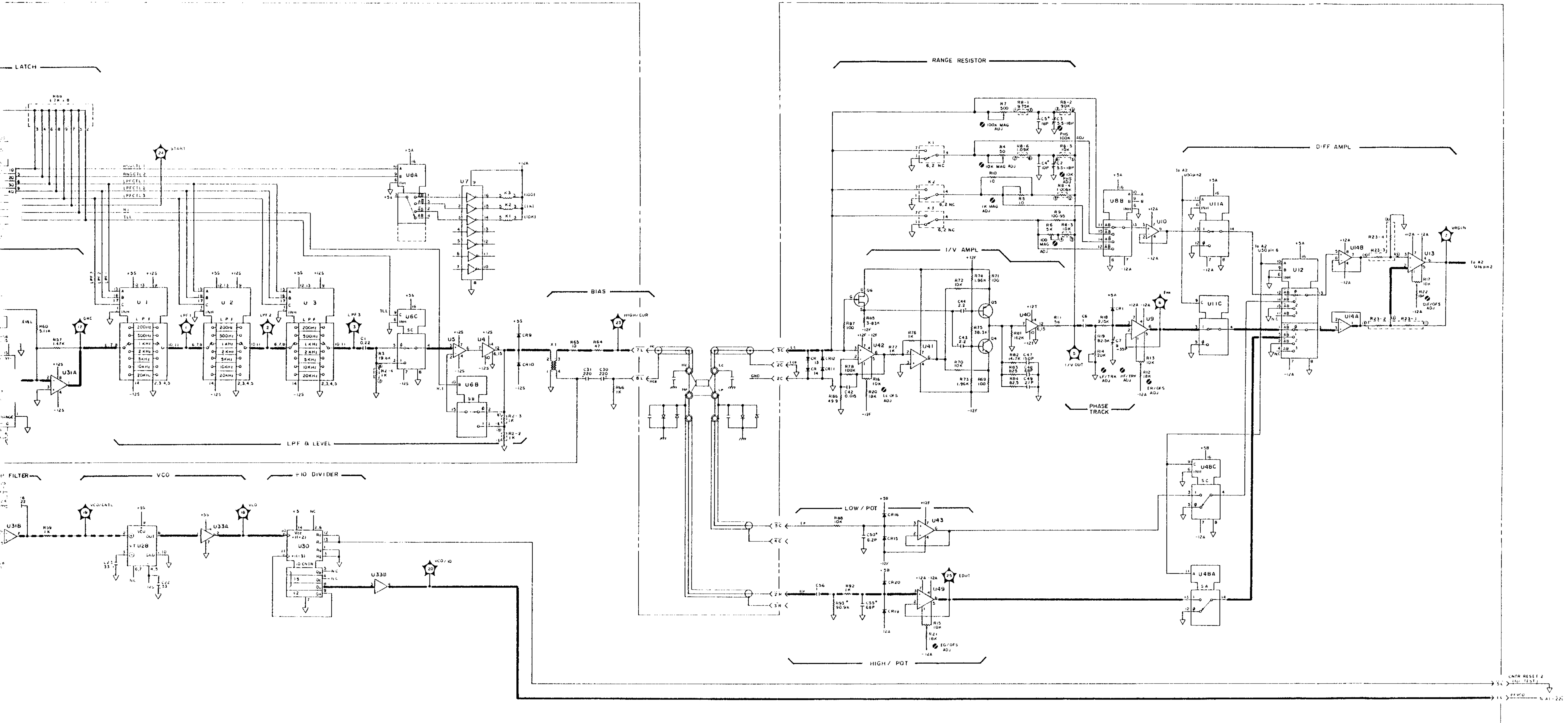


Figure 8-XX. A2 ANALOG Board Assembly Component Locations.



A2 ANALOG (P/N: 04276-66502) 1 of 2

1 of 2



NOTES:

1. REFERENCE DESIGNATORS WITHIN THIS ASSEMBLY ARE ABBREVIATED. PREFIX ABBREVIATION WITH ASSEMBLY NUMBER FOR COMPLETE REFERENCE DESIGNATOR.

2. UNLESS OTHERWISE INDICATED:

RESISTANCE IN OHMS (Ω)
CAPACITANCE IN MICROFARADS (μF)
INDUCTANCE IN MICROHENRIES (μH)

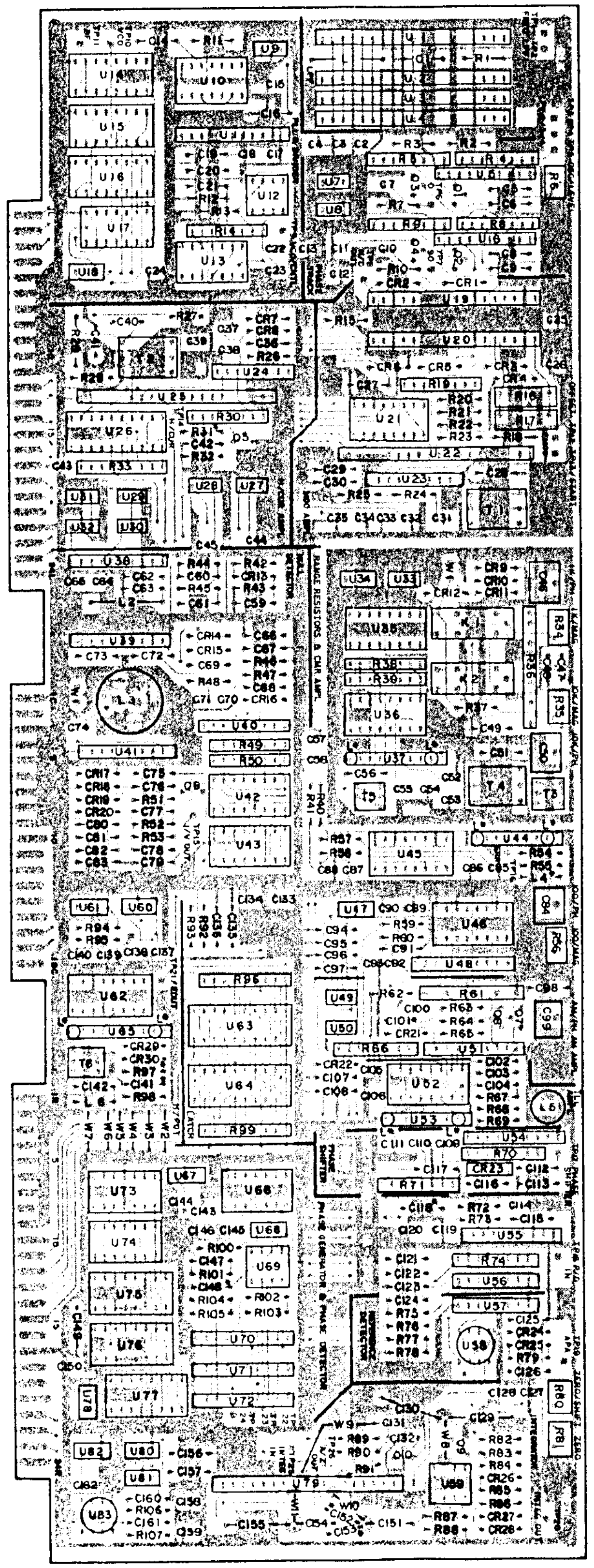
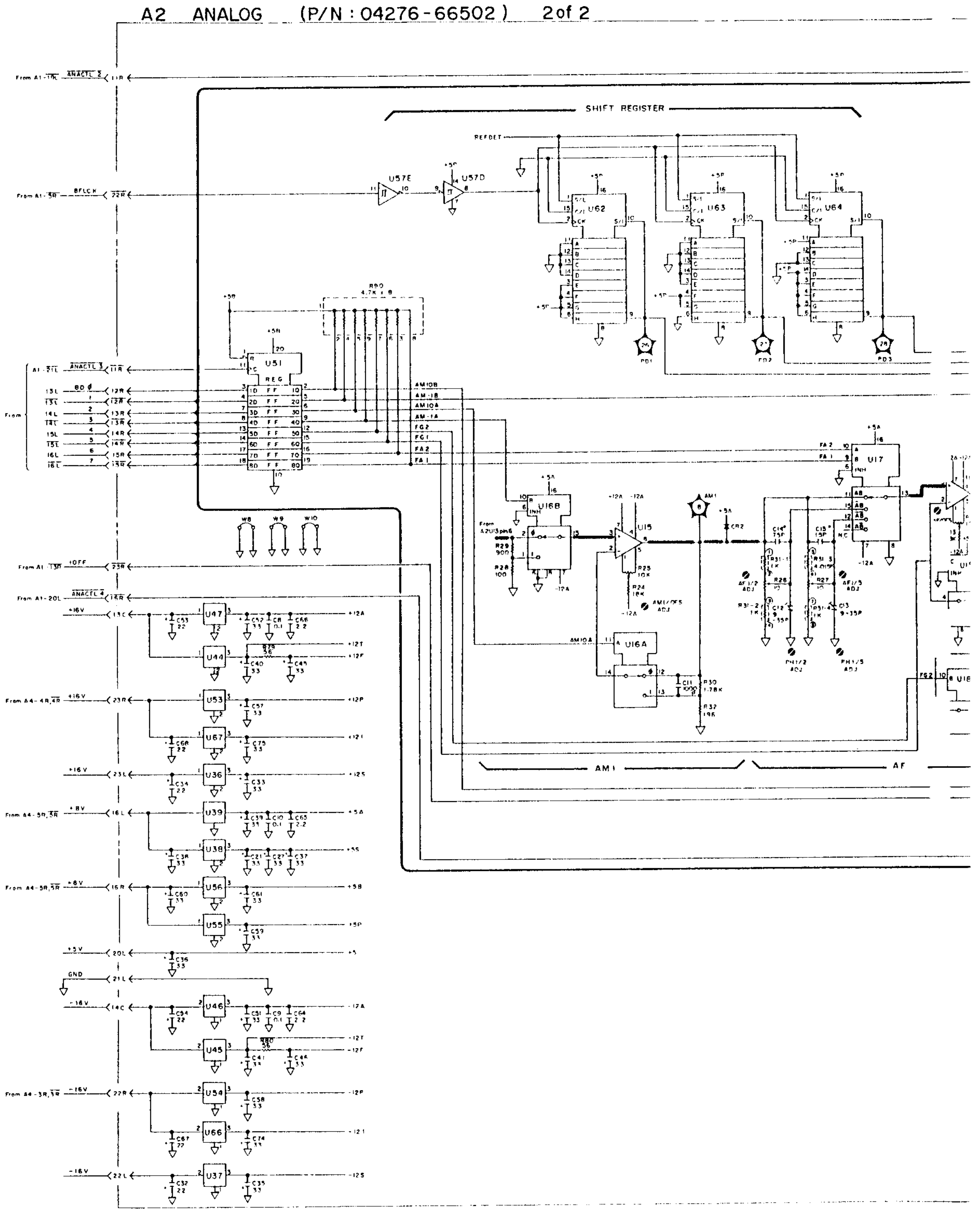
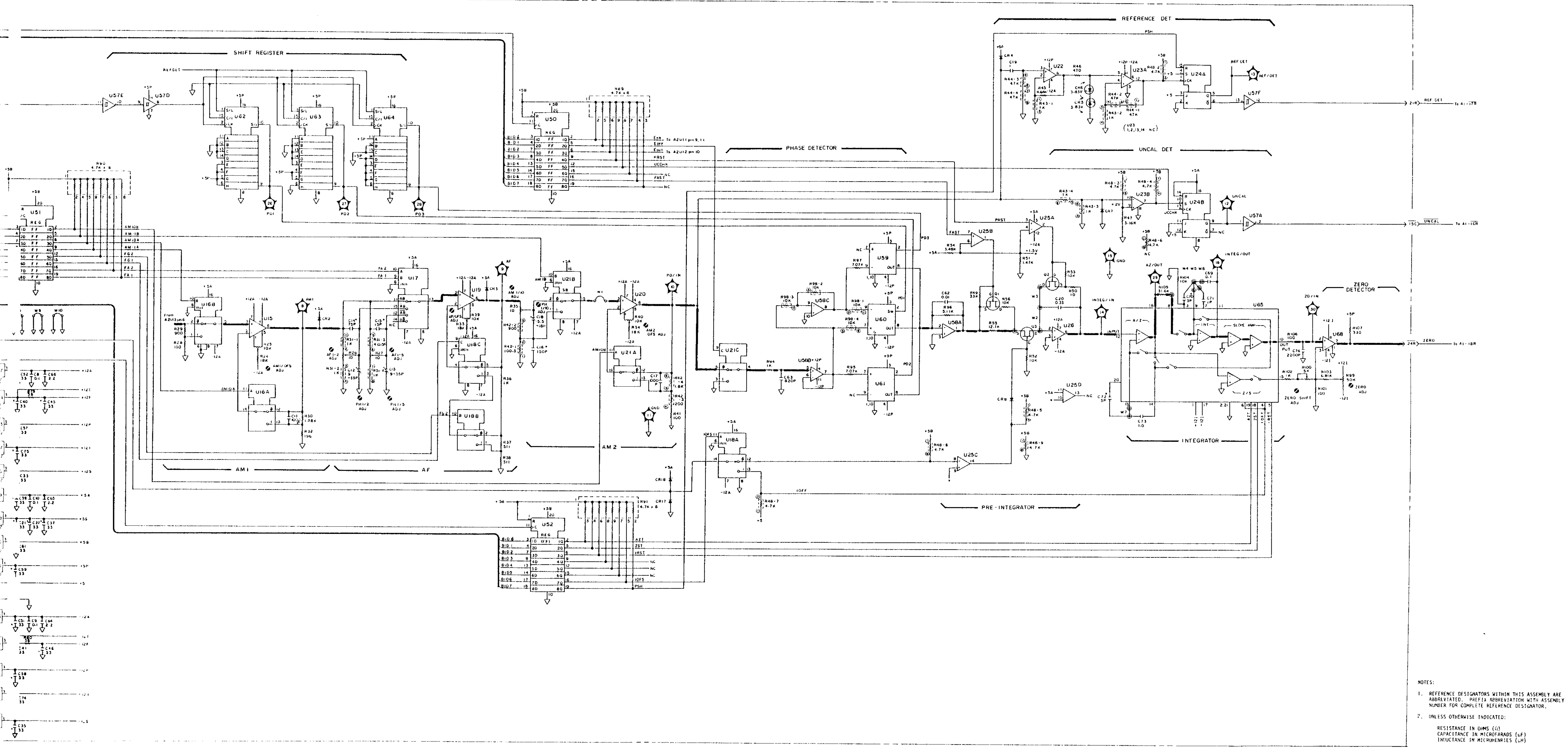


Figure 8-XX. A2 ANALOG Board Assembly Component Locations.



A)G (P/N : 04276-66502) 2of 2



NOTES:

1. REFERENCE DESIGNATORS WITHIN THIS ASSEMBLY ARE ABBREVIATED. PREFIX ABBREVIATION WITH ASSEMBLY NUMBER FOR COMPLETE REFERENCE DESIGNATOR.

2. UNLESS OTHERWISE INDICATED:

RESISTANCE IN OHMS (Ω)
CAPACITANCE IN MICROFARADS (μF)
INDUCTANCE IN MICROHENRIES (μH)

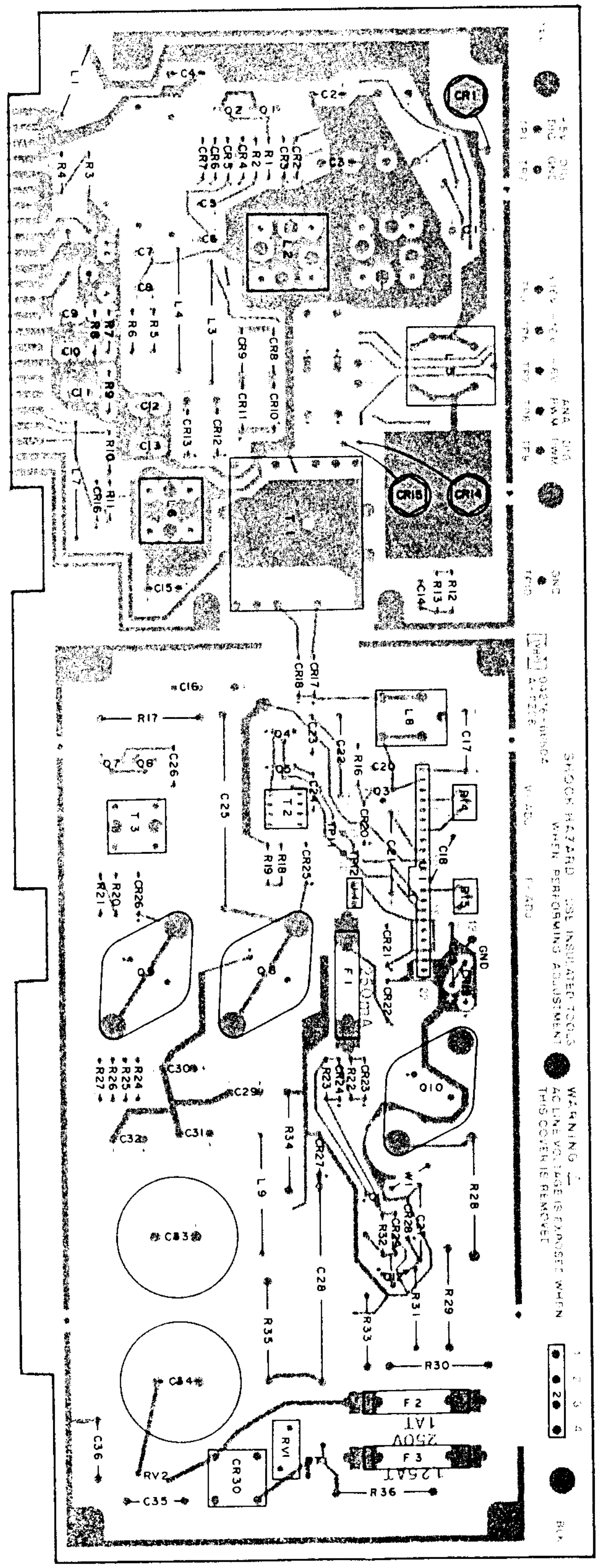
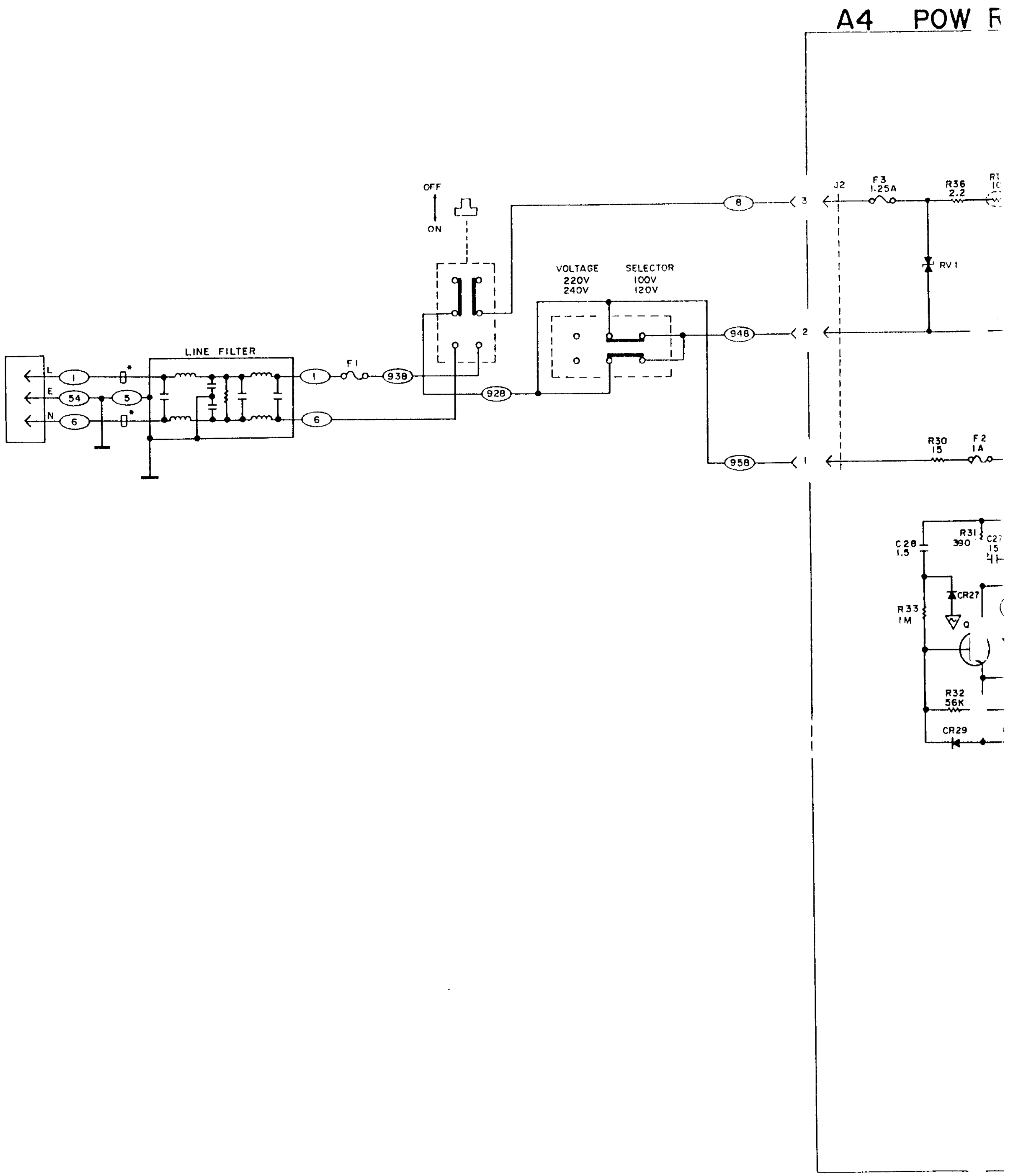
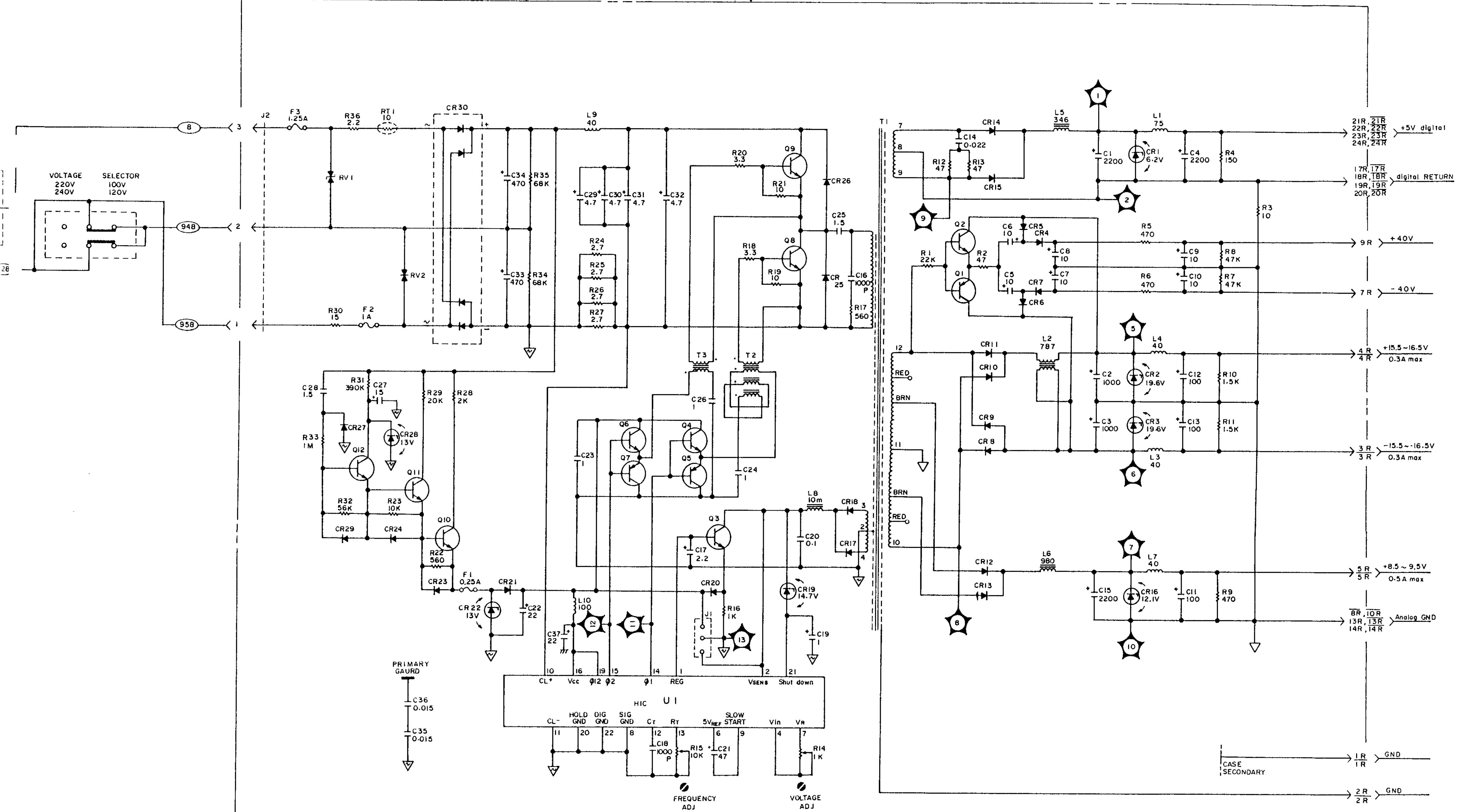


Figure 8-XX. A4 POWER SUPPLY Board Assembly Component Locations.



A4 POWER SUPPLY (P/N:04276-66504)



NOTES:

1. REFERENCE DESIGNATORS WITHIN THIS ASSEMBLY ARE ABBREVIATED. PREFIX ABBREVIATION WITH ASSEMBLY NUMBER FOR COMPLETE REFERENCE DESIGNATOR.

2. UNLESS OTHERWISE INDICATED:

   RESISTANCE IN OHMS (Ω)
   CAPACITANCE IN MICROFARADS (μF)
   INDUCTANCE IN MICROHENRIES (μH)

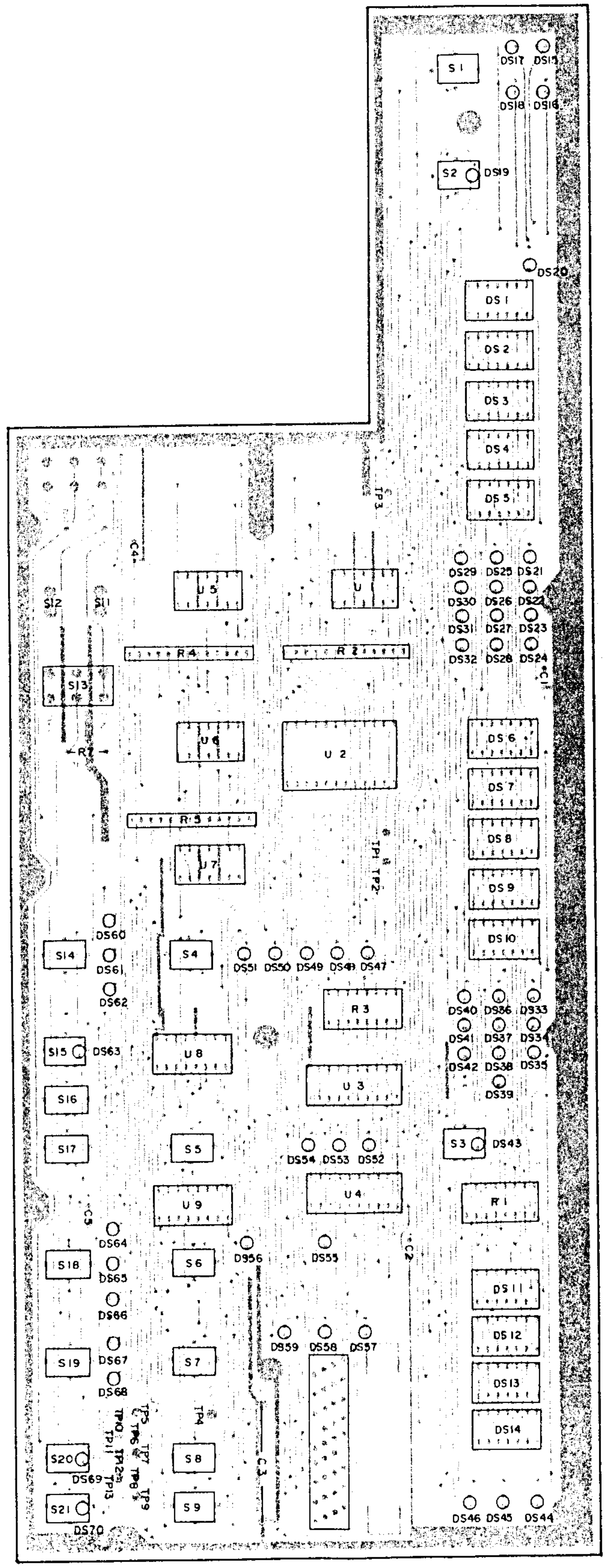
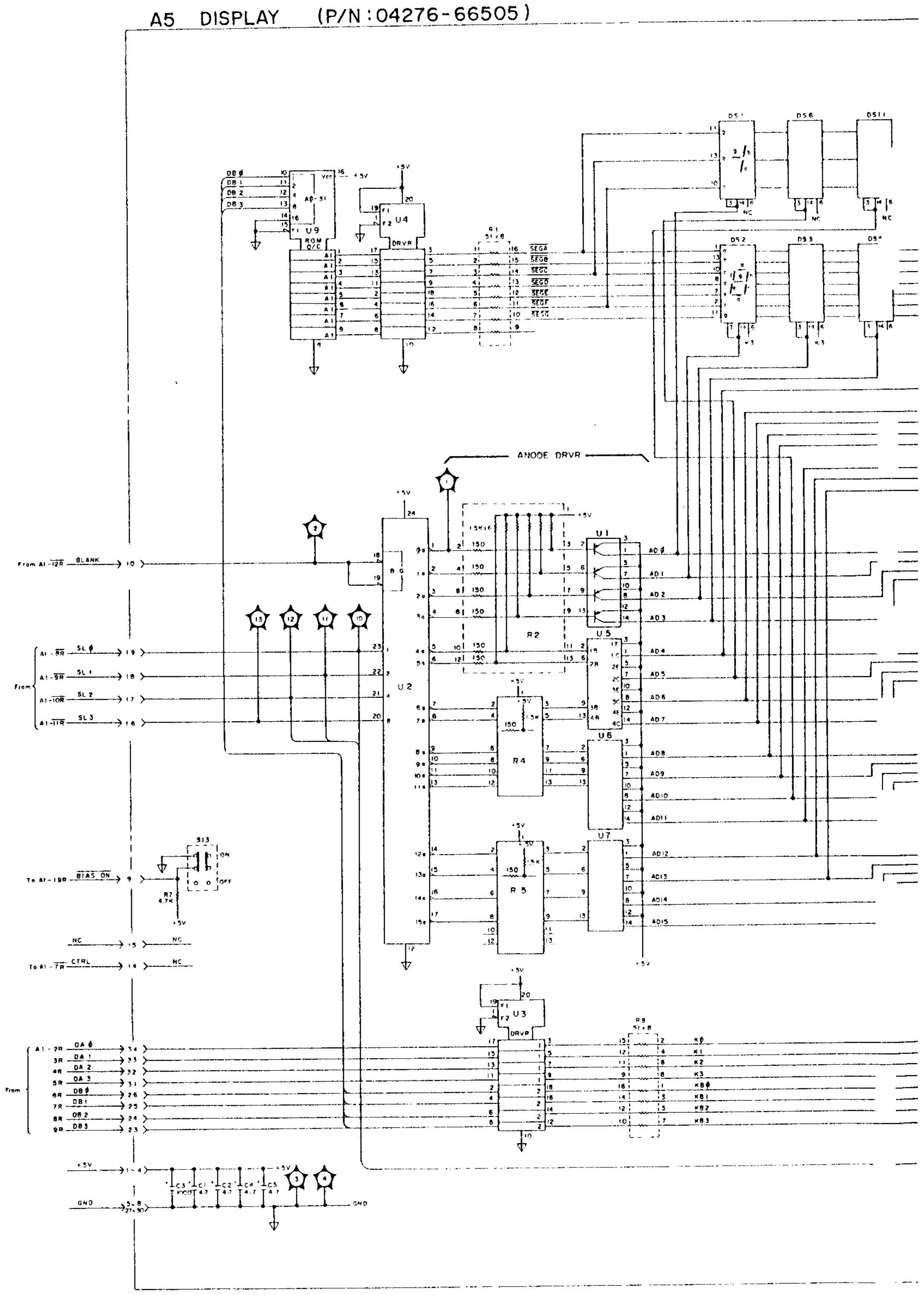
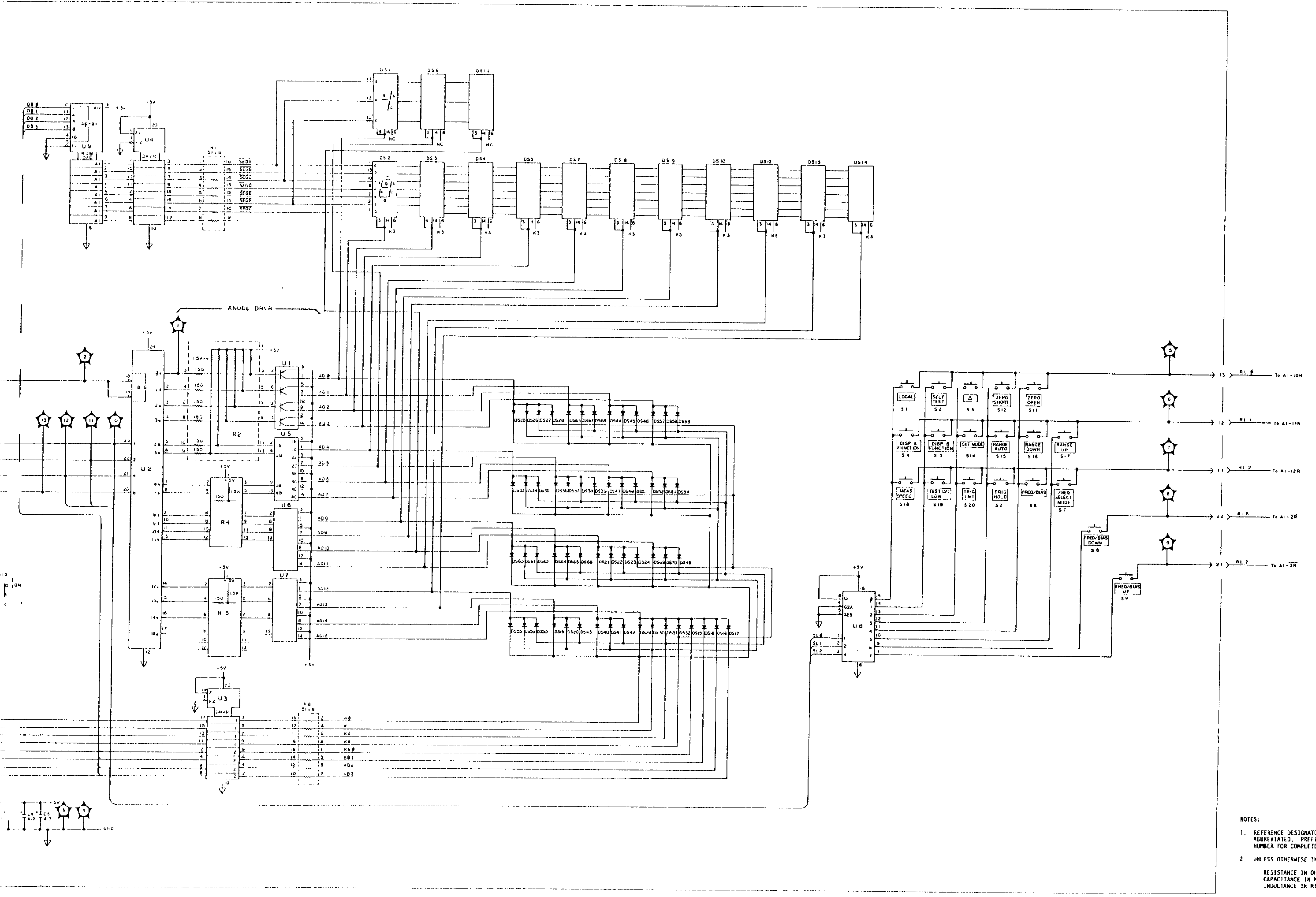


Figure 8-XX. A5 DISPLAY Board Assembly Component Locations.



DISPLAY (P/N:04276-66505)



NOTES:

1. REFERENCE DESIGNATORS WITHIN THIS ASSEMBLY ARE ABBREVIATED. PREFIX ABBREVIATION WITH ASSEMBLY NUMBER FOR COMPLETE REFERENCE DESIGNATOR.

2. UNLESS OTHERWISE INDICATED:

   RESISTANCE IN OHMS (Ω)
   CAPACITANCE IN MICROFARADS (μF)
   INDUCTANCE IN MICROHENRIES (μH)

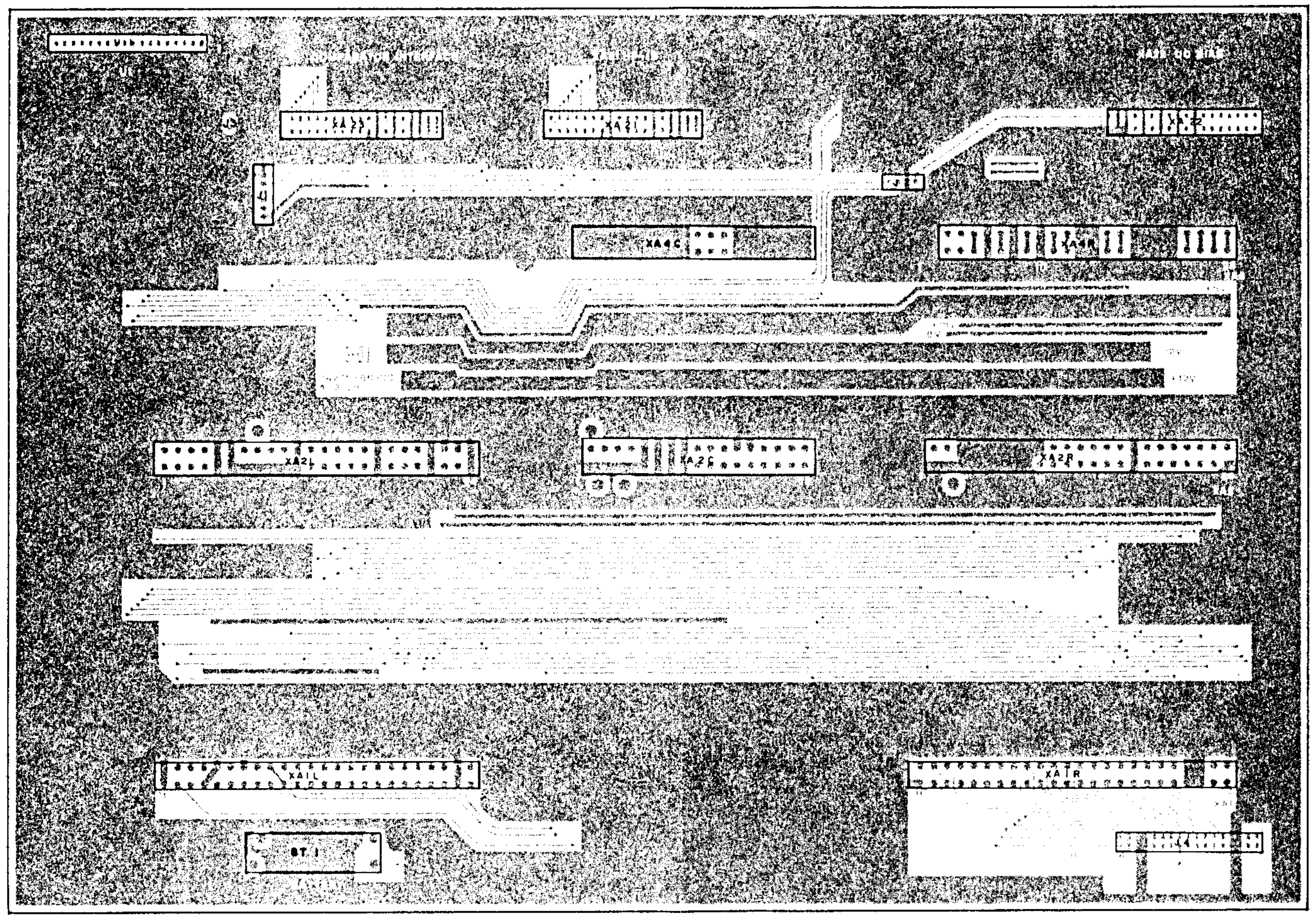
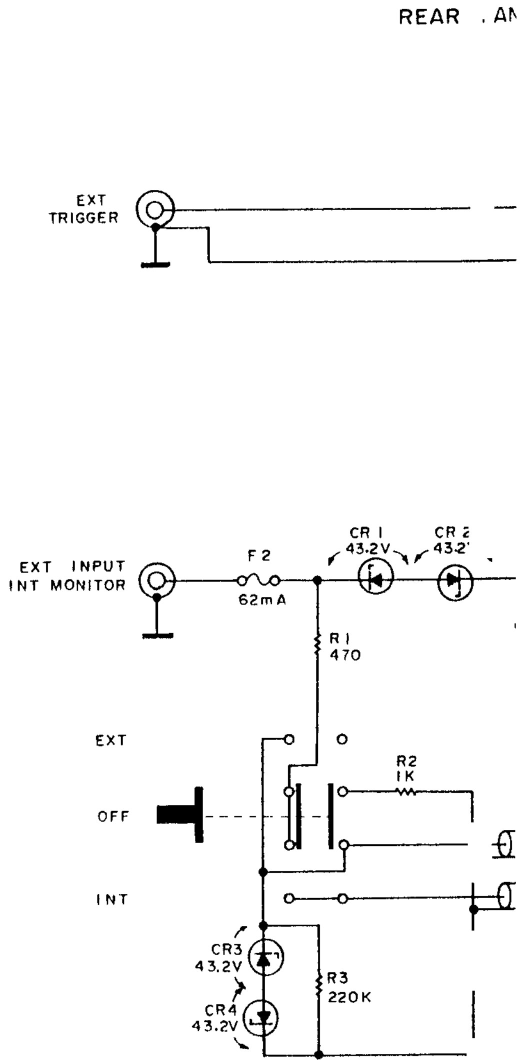
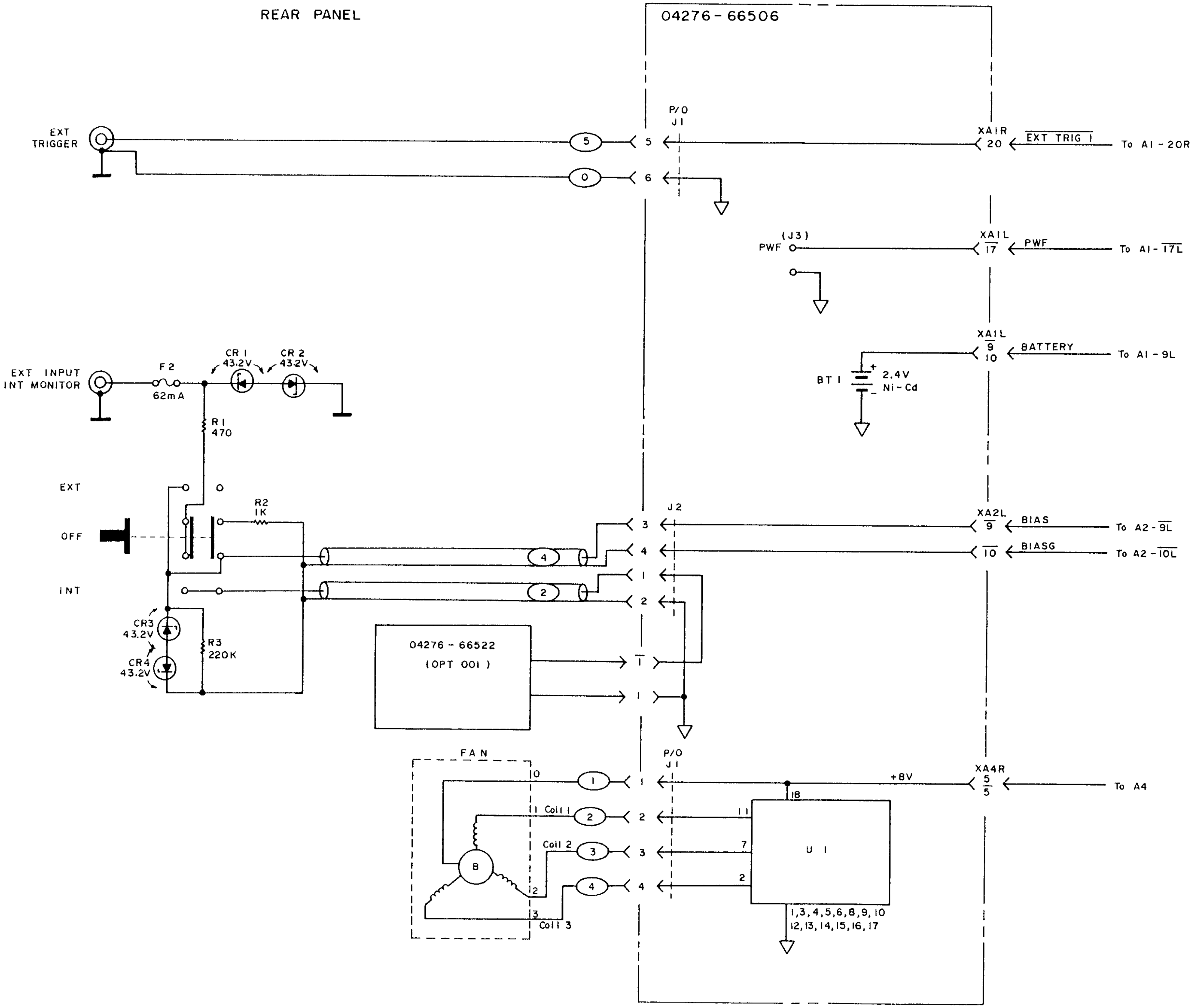


Figure 8-XX. A6 MOTHER Board Assembly Component Locations.



A6 MOTHER (P/N : 04276-66506)



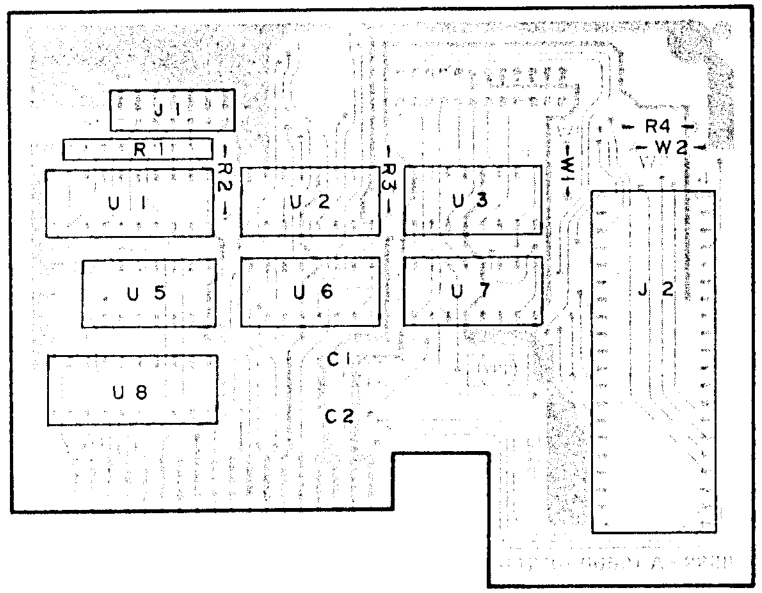
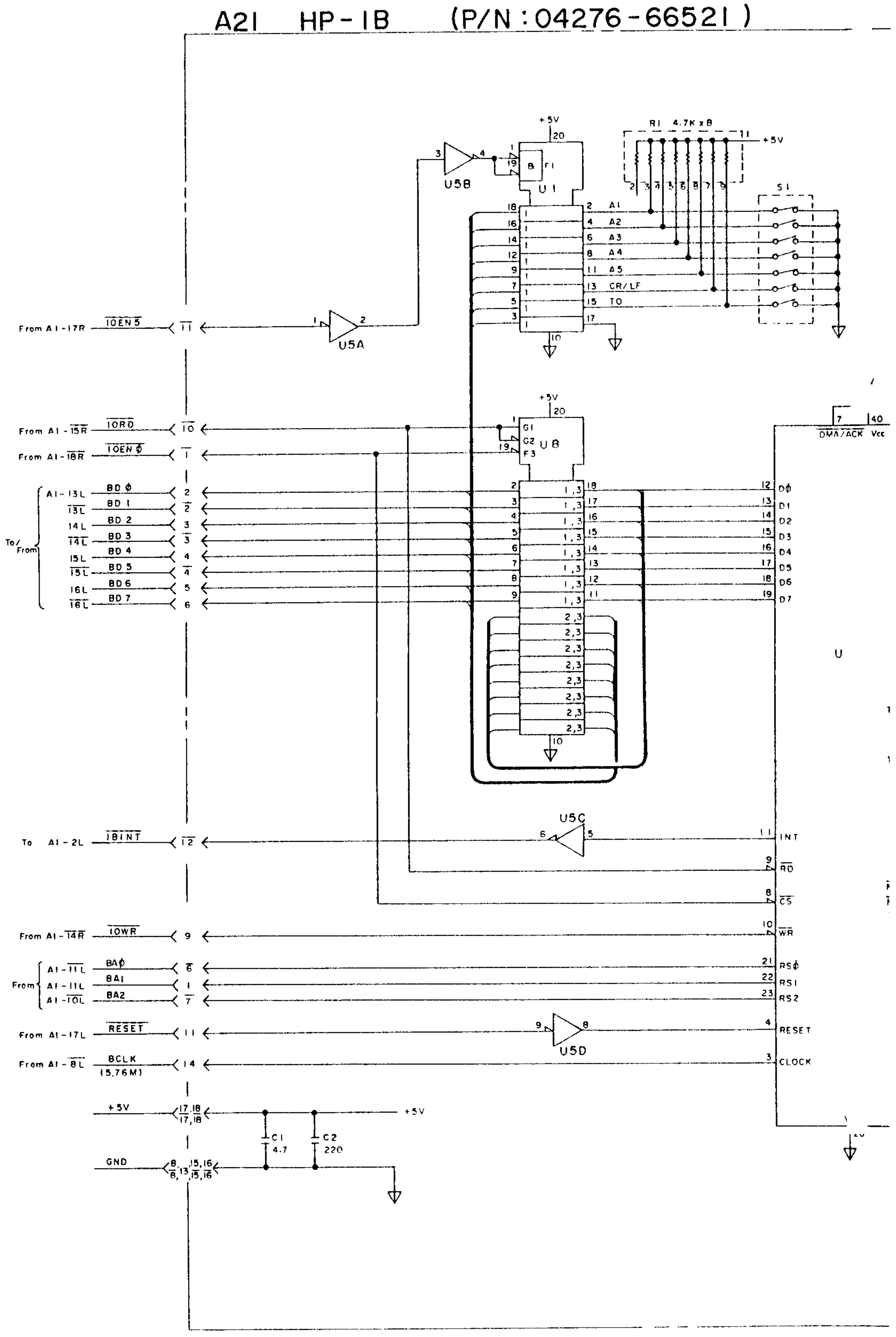
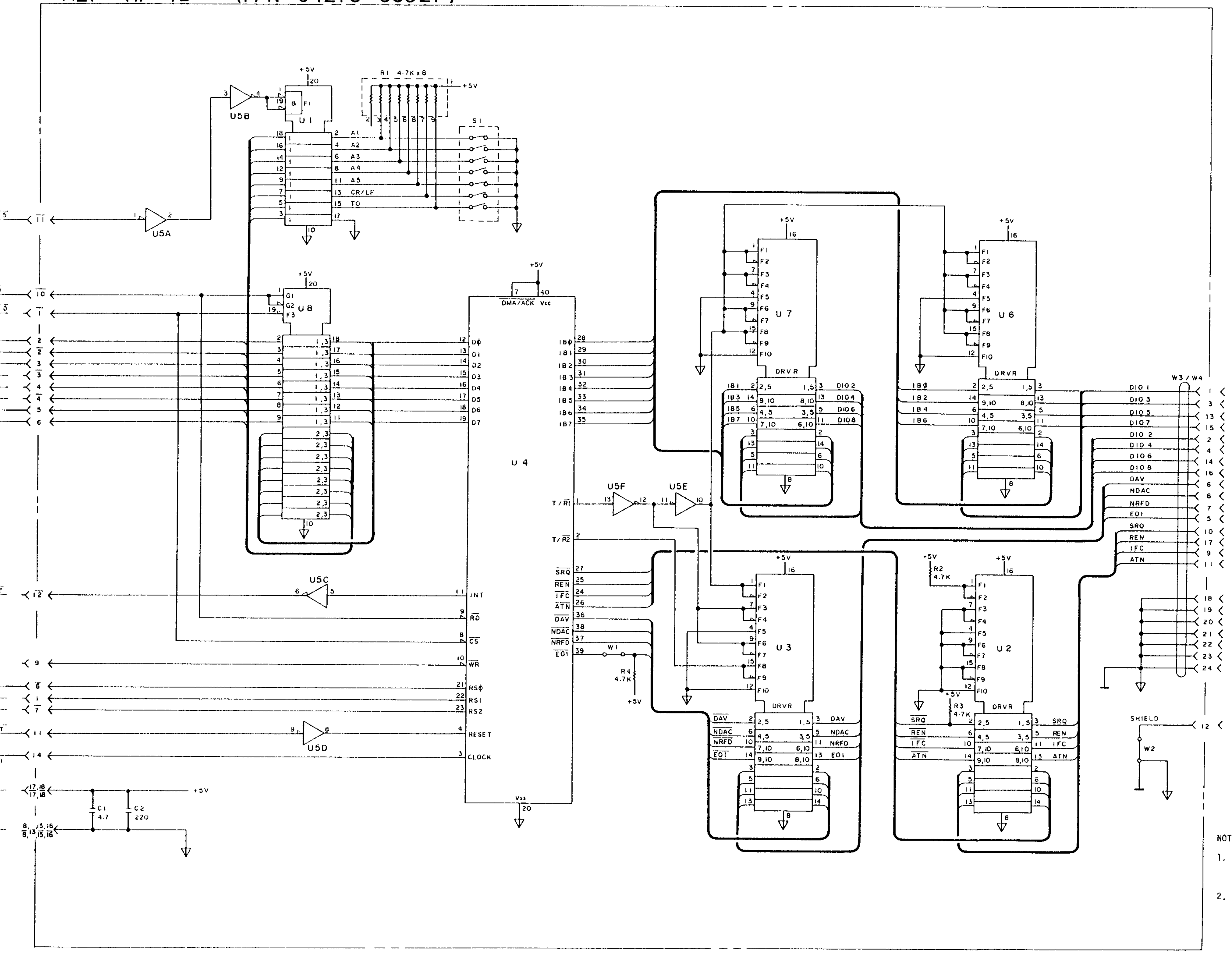


Figure 8-XX. A21 HP-IB Board Assembly Component Locations.



A21 HP-IB (P/N:04276-66521)



NOTES:

1. REFERENCE DESIGNATORS WITHIN THIS ASSEMBLY ARE ABBREVIATED. PREFIX ABBREVIATION WITH ASSEMBLY NUMBER FOR COMPLETE REFERENCE DESIGNATOR.

2. UNLESS OTHERWISE INDICATED:

   RESISTANCE IN OHMS (Ω)
   CAPACITANCE IN MICROFARADS (μF)
   INDUCTANCE IN MICROHENRIES (μH)

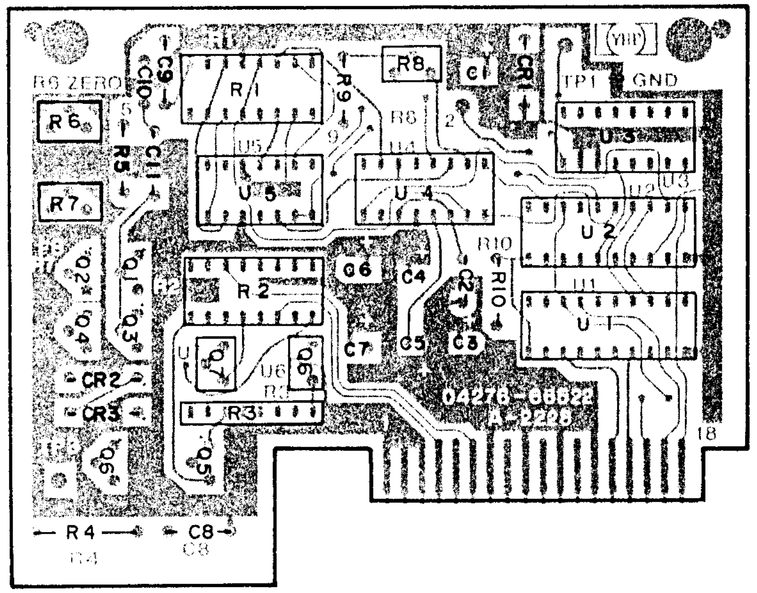
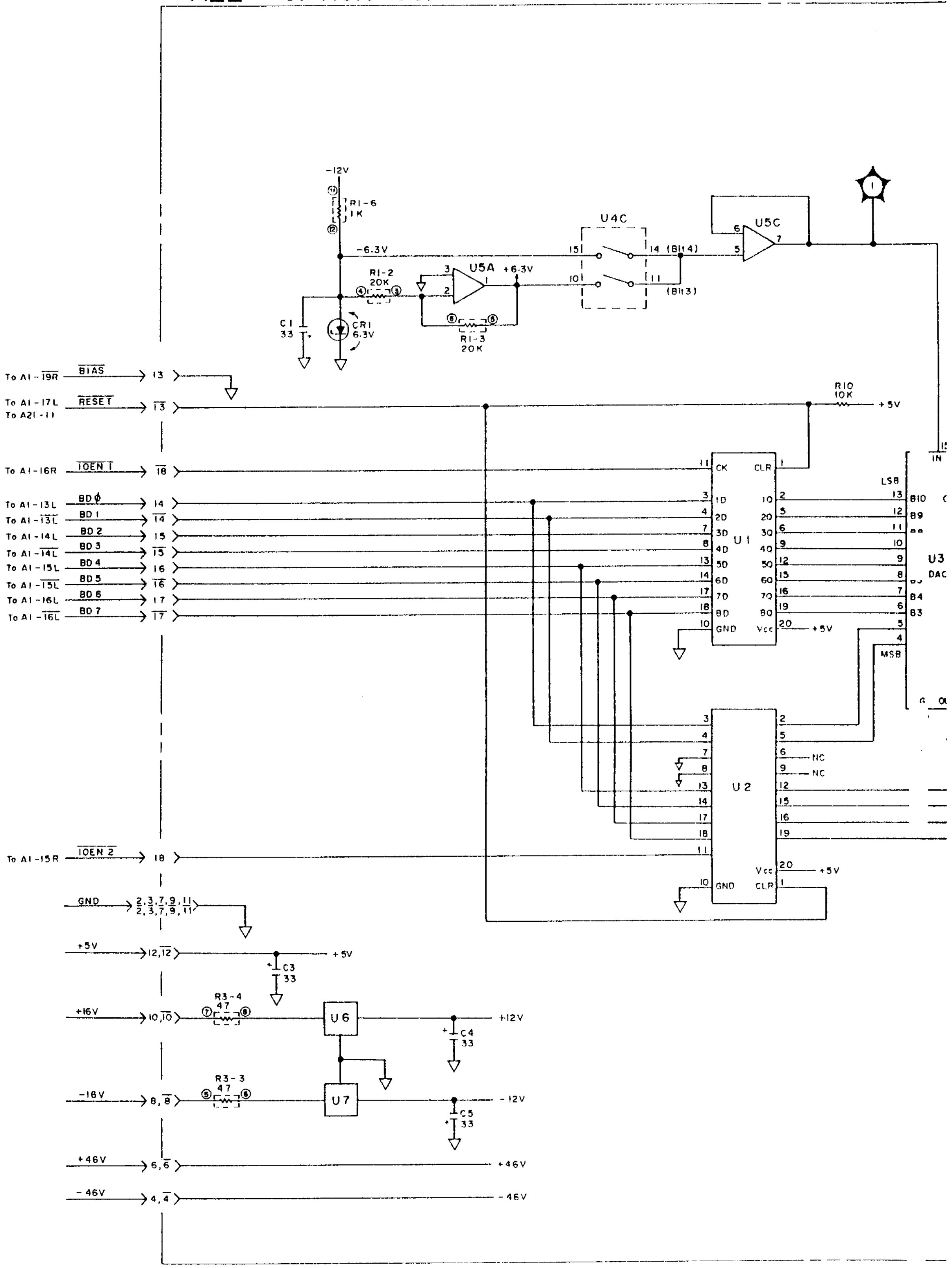
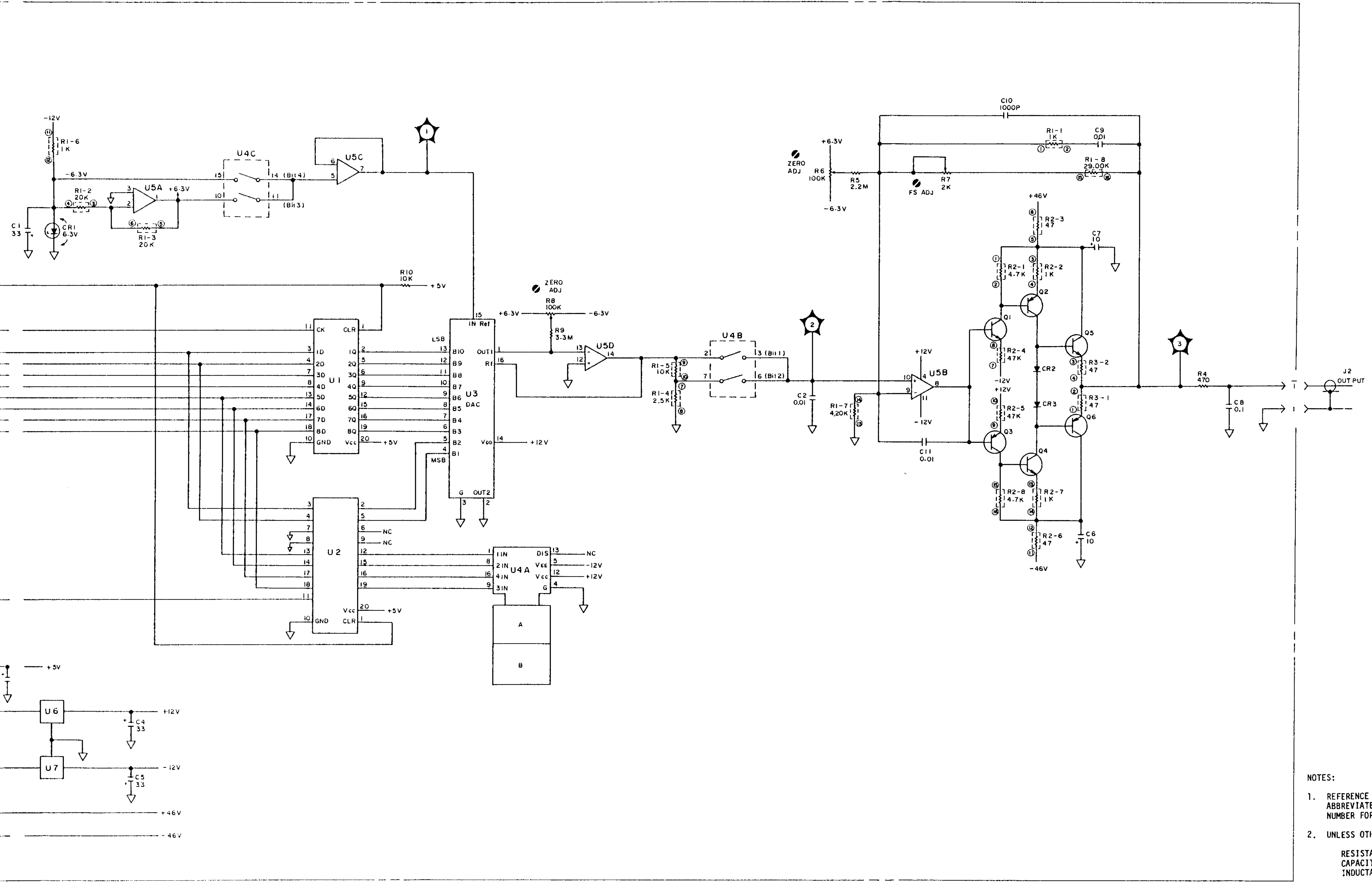


Figure 8-XX. A22 OPTION 001 INTERNAL DC BIAS Board Assembly Component Locations.

A22 OPTION 001 INTERNAL DC BIAS (P/N:0427



OPTION 001 INTERNAL DC BIAS (P/N:04276-66522)



NOTES:

1. REFERENCE DESIGNATORS WITHIN THIS ASSEMBLY ARE ABBREVIATED. PREFIX ABBREVIATION WITH ASSEMBLY NUMBER FOR COMPLETE REFERENCE DESIGNATOR.

2. UNLESS OTHERWISE INDICATED:

   RESISTANCE IN OHMS (Ω)
   CAPACITANCE IN MICROFARADS (μF)
   INDUCTANCE IN MICROHENRIES (μH)

SALES & SUPPORT OFFICES

Arranged alphabetically by country

1

NORTH/CENTRAL AFRICA
Hewlett Packard S.A.
7, rue du Bois-du-Lan
CH-1217 **MEYRIN** 1, Switzerland
Tel (022) 83 12 12
Telex 27835 hmea
Cable HEWPACKSA Geneve

ASIA
Hewlett Packard Asia Ltd
47/F, 26 Harbour Rd
Wanchai, **HONG KONG**
G.P.O. Box 863, Hong Kong
Tel 5-8330833
Telex 76793 HPA HX
Cable HPASIAL TD

CANADA
Hewlett Packard (Canada) Ltd
6877 Goreway Drive
MISSISSAUGA, Ontario L4V 1M8
Tel (416) 678 9430
Telex 610 492 4246

EASTERN EUROPE
Hewlett Packard Ges.m.b.h.
Lieblgasse 1
P.O. Box 72
A-1222 **VIENNA**, Austria
Tel (222) 2500-0
Telex 1 3 4425 HEPA A

NORTHERN EUROPE
Hewlett Packard S.A.
Uilenstede 475
P.O. Box 999
NL-1183 AG **AMSTELVEEN**
The Netherlands
Tel 20 437771
Telex 18 919 hpner nl

SOUTH EAST EUROPE
Hewlett Packard S.A.
World Trade Center
110 Avenue Louis Casai
1215 Cointrin, **GENEVA**, Switzerland
Tel (022) 98 96 51
Telex 27225 hpser

MEDITERRANEAN AND MIDDLE EAST
Hewlett Packard S.A.
Mediterranean and Middle East Operations
Atrina Centre
32 Kifissias Ave
Paradissos Amarousion, **ATHENS**
Greece
Tel 682 88 11
Telex 21-6588 HPAT GR
Cable HEWPACKSA Athens

UNITED KINGDOM
Hewlett Packard Ltd
Nine Mile Ride
Easthampstead, **WOKINGHAM**
Berkshire, RG11 3LL
Tel 0344 773100
Telex 848805

EASTERN USA
Hewlett-Packard Co
4 Choke Cherry Road
ROCKVILLE, MD 20850
Tel (301) 258 2000

MIDWESTERN USA
Hewlett Packard Co
5201 Tollview Drive
ROLLING MEADOWS, IL 60008
Tel (312) 255-9800

SOUTHERN USA
Hewlett Packard Co
2000 South Park Place
P.O. Box 105005
ATLANTA, GA 30348
Tel (404) 955 1500

WESTERN USA
Hewlett-Packard Co
3939 Lankershim Blvd
P.O. Box 3919
LOS ANGELES, CA 91604
Tel (213) 506 3700

OTHER INTERNATIONAL AREAS
Hewlett Packard Co
Intercontinental Headquarters
3495 Deer Creek Road
PALO ALTO, CA 94304
Tel (415) 857-1501
Telex 034 8300
Cable HEWPACK

ANGOLA
Telectra Angola LDA
Empresa Técnica de Equipamentos
Rua Conselheiro Júlio de Vilhena, 16
Caixa Postal 6487
LUANDA
Tel 35515, 35516
Telex 3134
E.P.

ARGENTINA
Hewlett Packard Argentina S.A.
Montañeses 2140/50
1428 **BUENOS AIRES**
Tel 783 4886/4836/4730
Cable HEWPACKARG
A.C.CM.E.P.

Biotron S.A.C.I.e.I.
Av. Paso Colon 221, Piso 9
1399 **BUENOS AIRES**
CM

Laboratorio Rodriguez
Corswant S.R.L.
Misiones, 1156 - 1876
Bernal, Oeste
BUENOS AIRES
Tel 252-3958, 252-4991
A

Argentina Esanco S.R.L.
A/ASCO 2328
1416 **BUENOS AIRES**
Tel 541-58-1981, 541-59-2767
A

AUSTRALIA

Adelaide, South Australia Office
Hewlett Packard Australia Ltd
153 Greenhill Road
PARKSIDE, S.A. 5063
Tel 272-5911
Telex 82536
Cable HEWPARD Adelaide
A*.C.CM.E.M.P

Brisbane, Queensland Office
Hewlett Packard Australia Ltd
10 Payne Road
THE GAP, Queensland 4061
Tel 30-4133
Telex 42133
Cable HEWPARD Brisbane
A.C.CM.E.M.P

Canberra, Australia Capital Territory Office
Hewlett Packard Australia Ltd
121 Wollongong Street
FYSHWICK, A.C.T. 2609
Tel 80 4244
Telex 62650
Cable HEWPARD Canberra
C.CM.E.P

Melbourne, Victoria Office
Hewlett Packard Australia Ltd
31-41 Joseph Street
BLACKBURN, Victoria 3130
Tel 895-2895
Telex 31-024
Cable HEWPARD Melbourne
A.C.CM.E.M.P

Perth, Western Australia Office
Hewlett Packard Australia Ltd
261 Stirling Highway
CLAREMONT, W.A. 6010
Tel 383-2188
Telex 93859
Cable HEWPARD Perth
A.C.CM.E.M.P

Sydney, New South Wales Office
Hewlett Packard Australia Ltd
17-23 Talavera Road
P.O. Box 308
NORTH RYDE, N.S.W. 2113
Tel 888 4444
Telex 21561
Cable HEWPARD Sydney
A.C.CM.E.M.P

AUSTRIA
Hewlett-Packard Ges.m.b.h.
Verkaufsbüro Graz
Grottenhofstrasse 94
A-8052 **GRAZ**
Tel (0316) 291 56 60
Telex 32375
C.E

Hewlett-Packard Ges.m.b.h.
Lieblgasse 1
P.O. Box 72
A-1222 **VIENNA**
Tel (0222) 2500-0
Telex 134425 HEPA A
A.C.CM.E.M.P

BAHRAIN
Green Salon
P.O. Box 557
MANAMA
Tel 255503-255950
Telex 8441
P

Wael Pharmacy
P.O. Box 648
MANAMA
Tel 256123
Telex 8550 WAEL BN
E.M

Zayani Computer Systems
218 Shaik Mubarak Building
Government Avenue
P.O. Box 5918
MANAMA
Tel 276278
Telex 9015
P

BELGIUM
Hewlett Packard Belgium S.A./N.V.
Blvd de la Woluwe, 100
Woluwedal
B-1200 **BRUSSELS**
Tel (02) 762-32-00
Telex 23-494 paloben bru
A.C.CM.E.M.P

BERMUDA
Applied Computer Technologies
Atlantic House Building
Par-La-Ville Road
Hamilton 5
Tel 295-1616
P

BRAZIL
Hewlett Packard do Brasil
I.e.C. Ltda
Alameda Rio Negro, 750
Alphaville
06400 **BARUERI SP**
Tel (011) 421-1311
Telex (011) 33872 HPBR BR
Cable HEWPACK Sao Paulo
A.C.CM.E.M.P

Hewlett Packard do Brasil
I.e.C. Ltda
Praia de Botafogo, 228
6° Andar-conj 614
Edificio Argentina - Ala A
22250 **RIO DE JANEIRO**
Tel (021) 552-6422
Telex 21905 HPBR BR
Cable HEWPACK Rio de Janeiro
A.C.CM.E.P*

Convex/van Den
Rua Jose Bonifacio
458 Todos Os Santos
CEP 20771
RIO DE JANEIRO, RJ
Tel 591-0197
Telex 33487 EGLB BR
A

ANAMED I.C.E.I. Ltda
Rua Bage, 103
04012 **SAO PAULO**, SP
Tel (011) 572-6537
Telex 24720 HPBR BR
M

Datatronix Electronica Ltda
Av. Pacaembu 746-C11
SAO PAULO, SP
Tel (118) 260111
CM

CAMEROON
Beriac
B.P. 23
DOUALA
Tel 420153
Telex 5351
C.P

CANADA

Alberta
Hewlett Packard (Canada) Ltd
3030 3rd Avenue N.E.
CALGARY, Alberta T2A 6T7
Tel (403) 235-3100
A.C.CM.E*.M.P*

Hewlett Packard (Canada) Ltd
11120-178th Street
EDMONTON, Alberta T5S 1P2
Tel (403) 486-6666
A.C.CM.E.M.P

British Columbia
Hewlett Packard (Canada) Ltd
10691 Shellbridge Way
RICHMOND
British Columbia V6X 2W7
Tel (604) 270-2277
Telex 610-922-5059
A.C.CM.E*.M.P*

Hewlett Packard (Canada) Ltd
121 - 3150 Douglas Street
VICTORIA, British Columbia V8Z 3K3
Tel (604) 381-6616
C

Manitoba
Hewlett Packard (Canada) Ltd
1825 Inkster Blvd
WINNIPEG, Manitoba R2X 1R3
Tel (204) 694-2777
A.C.CM.E.M.P*

New Brunswick
Hewlett Packard (Canada) Ltd
814 Main Street
MONCTON, New Brunswick E1C 1E6
Tel (506) 855-2841
C

Nova Scotia
Hewlett Packard (Canada) Ltd
Suite 111
900 Windmill Road
DARTMOUTH, Nova Scotia B3B 1P7
Tel (902) 469-7820
C.CM.E*.M.P*

Ontario
Hewlett-Packard (Canada) Ltd
3325 N. Service Rd., Unit 3
BURLINGTON, Ontario L7N 3G2
Tel (416) 335-8644
C.M*

Hewlett Packard (Canada) Ltd
496 Days Road
KINGSTON, Ontario K7M 5R4
Tel (613) 384-2088
C

Hewlett Packard (Canada) Ltd
552 Newbold Street
LONDON, Ontario N6E 2S5
Tel (519) 686-9181
A.C.CM.E*.M.P*

Hewlett-Packard (Canada) Ltd
6877 Goreway Drive
MISSISSAUGA, Ontario L4V 1M8
Tel (416) 678-9430
A.C.CM.E.M.P

Hewlett Packard (Canada) Ltd
2670 Queensview Dr
OTTAWA, Ontario K2B 8K1
Tel (613) 820-6483
A.C.CM.E*.M.P*

Hewlett-Packard (Canada) Ltd
The Oaks Plaza, Unit #9
2140 Regent Street
SUDBURY, Ontario P3E 5S8
Tel (705) 522-0202
C

Hewlett Packard (Canada) Ltd
3790 Victoria Park Ave
WILLOWDALE, Ontario M2H 3H7
Tel (416) 499-2550
C

Quebec
Hewlett Packard (Canada) Ltd
17500 Trans Canada Highway
South Service Road
KIRKLAND, Quebec H9J 2X8
Tel (514) 697-4232
A.C.CM.E.M.P*

Hewlett Packard (Canada) Ltd
1150 rue Claire Fontaine
QUEBEC CITY, Quebec G1R 5G4
Tel (418) 648-0726
C

Hewlett-Packard (Canada) Ltd
130 Robin Crescent
SASKATOON, Saskatchewan S7L 6M7
Tel (306) 242-3702
C

CHILE
ASC Ltda
Austria 2041
SANTIAGO
Tel 223-5946, 223-6148
Telex 340192 ASC CK
C.P

Jorge Calcagni y Cia
Av. Italia 634 Santiago
Casilla 16475
SANTIAGO 9
Tel 222-0222
Telex 440283 JCYCL CZ
CM.E.M

Metrolab S.A.
Monjitas 454 of. 206
SANTIAGO
Tel 395752, 398296
Telex 340866 METLAB CK
A

Olympia (Chile) Ltda
Av. Rodrigo de Araya 1045
Casilla 256-V
SANTIAGO 21
Tel 225-5044
Telex 340892 OLYMP
Cable Olympiachile Santiagochile
C.P

CHINA, People's Republic of
China Hewlett Packard, Ltd
47/F China Resources Bldg
26 Harbour Road
HONG KONG
Tel 5-8330833
Telex 76793 HPA HX
Cable HP ASIA LTD
A*.M*

China Hewlett Packard, Ltd
P.O. Box 9610, Beijing
4th Floor, 2nd Watch Factory Main Bldg
Shuang Yu Shu, Bei San Huan Rd
Hai Dian District
BEIJING
Tel 28-2561
Telex 22601 CTSHP CN
Cable 1920 Beijing
A.C.CM.E.M.P

COLOMBIA
Instrumentación
H. A. Langebaek & Kier S.A.
Carrera 4A No. 52A-26
Apartado Aereo 6287
BOGOTA 1, D.E.
Tel 212-1466
Telex 44400 INST CO
Cable AARIS Bogota
CM.E.M

Nefromedicas Ltda
Calle 123 No. 9B-31
Apartado Aereo 100-958
BOGOTA D.E. 10
Tel 213-5267, 213-1615
Telex 43415 HEGAS CO
A

Compumundo
Avenida 15 # 107-80
BOGOTA D.E.
Tel 214-4458
Telex 45466 MARICO
E

Carvajal, S.A.
Calle 29 Norte No. 6A-40
Apartado Aereo 46
CALI
Tel 368-1111
Telex 55650
C.E.P

CONGO
Seric-Congo
B.P. 2105
BRAZZAVILLE
Tel 815034
Telex 5262

COSTA RICA
Cientifica Costarricense S.A.
Avenida 2, Calle 5
San Pedro de Montes de Oca
Apartado 10159
SAN JOSÉ
Tel 24-38-20, 24-08-19
Telex 2367 GALGUR CR
CM.E.M

CYPRUS
Telerexa Ltd
P.O. Box 4809
14C Stassinos Avenue
NICOSIA
Tel 62698
Telex 2894 LEVIDO CY
E.M.P

DENMARK
Hewlett Packard A/S
Datavej 52
DK-3460 **BIRKEROD**
Tel (02) 81-66-40
Telex 37409 hpas dk
A.C.CM.E.M.P

Hewlett-Packard A/S
Rolighedsvej 32
DK-8240 **RISSKOV**, Aarhus
Tel (06) 17-60-00
Telex 37409 hpas dk
C.E

DOMINICAN REPUBLIC
Microprog S.A.
Juan Tomás Mejía y Cotes No. 60
Arroyo Hondo
SANTO DOMINGO
Tel 565-6268
Telex 4510 ARENTA DR (RCA)
P

ECUADOR
CYEDE Cia. Ltda
Avenida Eloy Alfaro 1749
y Belgica
Casilla 6423 CCI
QUITO
Tel 450-975, 243-052
Telex 22548 CYEDE ED
CM.E.P

Medtronics
Valladolid 524 Madrid
P.O. 9171, **QUITO**
Tel 223-8951
Telex 2298 ECKAME ED
A

Hospitalar S.A.
Robles 625
Casilla 3590
QUITO
Tel 545-250, 545-122
Telex 2485 HOSPTL ED
Cable HOSPITALAR-Quito
M

Ecuador Overseas Agencies C.A.
Calle 9 de Octubre #818
P.O. Box 1296, Guayaquil
QUITO
Tel 306022
Telex 3361 PBCGYE ED
M

EGYPT
Sakrco Enterprises
70, Mossadak Str.
Dokki, Giza
CAIRO
Tel 706440
Telex 93146
C

International Engineering Associates
24 Hussein Hegazi Street
Kasr-el-Aini
CAIRO
Tel 23829, 21641
Telex 93830 IEA UN
Cable INTEGASSO
E.M*

S.S.C. Medical
40 Gezerat El Arab Street
Mohandessin
CAIRO
Tel 803844, 805998, 810263
Telex 20503 SSC UN
M*

EL SALVADOR
IPESA de El Salvador S.A.
29 Avenida Norte 1223
SAN SALVADOR
Tel 26-6858, 26-6868
Telex 20539 IPESA SAL
A.C.CM.E.P

ETHIOPIA
Seric-Ethiopia
P.O. Box 2764
ADDIS ABABA
Tel 185114
Telex 21150
C.P

FINLAND
Hewlett Packard Oy
Piispankalliontie 17
02200 **ESPOO**
Tel 00358-0-88721
Telex 121563 HEWPA SF
A.C.CM.E.M.P

FRANCE
Hewlett Packard France
Z.I. Mercure B
Rue Berthelot
13763 Les Milles Cedex
AIX-EN-PROVENCE
Tel (42) 59-41-02
Telex 410770F
A.C.E.M.P*

Hewlett Packard France
64, rue Marchand Saillant
61000 **ALENCON**
Tel (33) 29 04 42

Hewlett-Packard France
28, rue de la République
Boite Postale 503
25026 **BESANCON** Cedex
Tel (81) 83-16-22
Telex 361157
C.M

Hewlett Packard France
Chemin des Mouilles
Boite Postale 162
69130 **ECULLY** Cedex (Lyon)
Tel (78) 833-81-25
Telex 310617F
A.C.E.M

Hewlett Packard France
Parc d'activités du Bois Briard
2, avenue du Lac
91040 **EVRY** Cedex
Tel 6 077-96-60
Telex 692315F
E

Hewlett Packard France
5, avenue Raymond Chanas
38320 **EYBENS** (Grenoble)
Tel (76) 62-57-98
Telex 980124 HP GRENOB EYBE
C

Hewlett-Packard France
Rue Fernand Forest
Z.A. Kergaradec
29239 **GOUESNOU**
Tel (98) 41-87-90

Hewlett Packard France
Centre d'affaires Paris-Nord
Bâtiment Ampère
Rue de la Commune de Paris
Boite Postale 300
93153 **LE BLANC MESNIL**
Tel (1) 865-44-52
Telex 211032F
C.E.M

Hewlett-Packard France
Parc d'activités Cadera
Quartier Jean Mermoz
Avenue du Président JF Kennedy
F-33700 **MÉRIGNAC** (Bordeaux)
Tel (56) 34-00-84
Telex 550105F
C.E.M

Hewlett-Packard France
Immeuble "Les 3 B"
Nouveau chemin de la Garde
ZAC du Bois Briand
44085 **NANTES** Cedex
Tel (40) 50-32-22
Telex 711085F
C**

Hewlett-Packard France
125, rue du Faubourg Bannier
45000 **ORLEANS**
Tel (38) 68 01 63

Hewlett Packard France
Zone industrielle de Courtaboeuf
Avenue des Tropiques
91947 Les Ulis Cedex **ORSAY**
Tel (6) 907-78-25
Telex 600048F
A.C.CM.E.M.P

Hewlett Packard France
Paris Porte-Maillot
15, boulevard de L'Amiral-Bruix
75782 **PARIS** Cedex 16
Tel (1) 502-12-20
Telex 613663F
C.M.P

Hewlett Packard France
124, Boulevard Tourasse
64000 **PAU**
Tel (59) 80 38 02

Hewlett Packard France
2 Allée de la Bourgonnette
35100 **RENNES**
Tel (99) 51-42-44
Telex 740912F
C.CM.E.M.P*

Hewlett Packard France
98 avenue de Bretagne
76100 **ROUEN**
Tel (35) 63-57-66
Telex 770035F
C

Hewlett Packard France
4, rue Thomas Mann
Boite Postale 56
67033 **STRASBOURG** Cedex
Tel (88) 28-56-46
Telex 890141F
C.E.M.P*

Hewlett Packard France
La Péripole III
20, chemin du Pigeonnier de la Cépière
F-31083 **TOULOUSE** Cedex
Tel (61) 40-11-12
Telex 531639F
A.C.E.P*

Hewlett-Packard France
9, rue Baudin
26000 **VALENCE**
Tel (75) 42 76 16

Hewlett Packard France
Carolor
ZAC de Bois Briand
57640 **VIGY** (Metz)
Tel (8) 771 20 22
C

Hewlett Packard France
Parc d'activité des Prés
1, rue Papin
59658 **VILLENEUVE D'ASCQ** Cedex
Tel (20) 47 78 78
Telex 160124F
C.E.M.P*

GABON
Sho Gabon
P.O. Box 89
LIBREVILLE
Tel 721 484
Telex 5230

GERMAN FEDERAL REPUBLIC
Hewlett Packard GmbH
Geschäftsstelle
Keithstrasse 2-4
D-1000 **BERLIN** 30
Tel (030) 21 99 04-0
Telex 018 3405 hpbln d
A.C.E.M.P

Hewlett Packard GmbH
Vertriebszentrum Südwest
Schickardstrasse 2
D-7030 **BÖBLINGEN**
Tel (07031) 645-0
Telex 7265 743 hep
A.C.CM.E.M.P

Hewlett Packard GmbH
Vertriebszentrum West
Berliner Strasse 111
D-4030 **RATINGEN** 3
Tel (02102) 494-0
Telex 589 070 hprad
A.C.E.M.P

Hewlett Packard GmbH
Geschäftsstelle
Schleefstr. 28a
D-4600 **DORTMUND** 41
Tel (0231) 45001
Telex 822858 hepdod
A.C.E

Hewlett Packard GmbH
Vertriebszentrum Mitte
Hewlett Packard Strasse
D-6380 **BAD HOMBURG**
Tel (06172) 400-0
Telex 410 844 hpbhg
A.C.E.M.P

Hewlett Packard GmbH
Vertriebszentrum Nord
Kapstadtring 5
D-2000 **HAMBURG** 60
Tel (040) 63804-1
Telex 021 63 032 hphh d
A.C.E.M.P

Hewlett Packard GmbH
Geschäftsstelle
Heidering 37-39
D-3000 **HANNOVER** 61
Tel (0511) 5706-0
Telex 092 3259
A.C.CM.E.M.P

Hewlett Packard GmbH
Geschäftsstelle
Rosslauer Weg 2-4
D-6800 **MANNHEIM**
Tel (0621) 70 05-0
Telex 0462105
A.C.E

Hewlett-Packard GmbH
Geschäftsstelle
Messerschmittstrasse 7
D-7910 **NEU ULM**
Tel (0731) 70 73-0
Telex 0712816 HP ULM-D
A.C.E*

Hewlett Packard GmbH
Geschäftsstelle
Emmericher Strasse 13
D-8500 **NÜRNBERG** 10
Tel (0911) 5205-0
Telex 0623 860 hpnbg
C.CM.E.M.P

Hewlett-Packard GmbH
Vertriebszentrum Süd
Eschenstrasse 5
D-8028 **TAUFKIRCHEN**
Tel (089) 61 20 7-0
Telex 0524985
A.C.CM.E.M.P

Hewlett Packard GmbH
Geschäftsstelle
Ermlisallee
7517 **WALDBRONN** 2
Tel (07243) 602-0
Telex 782 838 hepk
A.C.E

GREAT BRITAIN
See United Kingdom

GREECE
Hewlett-Packard A.E.
178, Kifissias Avenue
6th Floor
Halandri-**ATHENS**
Greece
Tel 6471543, 6471673, 6472971
Telex 221 286 HPHLGR
A.C.CM**.E.M.P

Kostas Karaynnis S.A.
8, Omirou Street
ATHENS 133
Tel 32 30 303, 32 37 371
Telex 215962 RKAR GR
A.C*.CM.E

Impexin
Intelect Div.
209 Mesogion
11525 **ATHENS**
Tel 6474481/2
Telex 216286
P

Haril Company
38, Mihalakopoulou
ATHENS 612
Tel 7236071
Telex 218767
M*

Hellamco
P.O. Box 87528
18507 **PIRAEUS**
Tel 4827049
Telex 241441
A

GUATEMALA
IPESA
Avenida Reforma 3-48, Zona 9
GUATEMALA CITY
Tel 316627, 314786
Telex 3055765 IPESA GU
A.C.CM.E.M.P

HONG KONG
Hewlett Packard Hong Kong, Ltd
G.P.O. Box 795
5th Floor, Sun Hung Kai Centre
30 Harbour Road
HONG KONG
Tel 5-8323211
Telex 66678 HEWPA HX
Cable HEWPACK Hong Kong
E.C.P

CET Ltd
10th Floor, Hua Asia Bldg
64-66 Gloucester Road
HONG KONG
Tel (5) 200922
Telex 85148 CET HX
CM

Schmidt & Co. (Hong Kong) Ltd
18th Floor, Great Eagle Centre
23 Harbour Road
HONG KONG
Tel 5-8330222
Telex 74766 SCHMC HX
A.M

ICELAND
Hewlett Packard Iceland
Hoefdabakka 9
110 **Reykjavik**
Tel (1) 67 1000
A.C.CM.E.M.P

INDIA
Computer products are sold through Blue Star Ltd. All computer repairs and maintenance service is done through Computer Maintenance Corp.

Blue Star Ltd
Sabri Complex 2nd Floor
24 Residency Rd
BANGALORE 560 025
Tel 55660, 578881
Telex 0845-430
Cable BLUESTAR
A.C*.CM.E

Blue Star Ltd
Band Box House
Prabhadevi
BOMBAY 400 025
Tel 4933101, 4933222
Telex 011-71051
Cable BLUESTAR
A.M

Blue Star Ltd
Sahas
414/2 Vir Savarkar Marg
Prabhadevi
BOMBAY 400 025
Tel 422-6155, 422-6556
Telex 011-71193 BSSS IN
Cable FROSTBLUE
A.C*.CM.E.M

Blue Star Ltd
Kalyan, 19 Vishwas Colony
Alkapuri, **BORODA**, 390 005
Tel 65235, 65236
Cable BLUE STAR
A

Blue Star Ltd
7 Hare Street
CALCUTTA 700 001
Tel 230131, 230132
Telex 021-7655
Cable BLUESTAR
A.M

Blue Star Ltd
133 Kodambakkam High Road
MADRAS 600 034
Tel 472056, 470238
Telex 041-379
Cable BLUESTAR
A.M

Blue Star Ltd.
13 Community Center
New Friends Colony
NEW DELHI 110 065
Tel 633773, 634473
Telex 031-61120
Cable BLUEFROST
A.C*.CM.E.M

Blue Star Ltd
15/16 C Wellesley Rd
PUNE 411 011
Tel 22775
Cable BLUE STAR
A

Blue Star Ltd
2-2-47/1108 Bolerum Rd
SECUNDERABAD 500 003
Tel 72057, 72058
Telex 0155645
Cable BLUEFROST
A.E

Blue Star Ltd
T.C. 7/603 Poornima
Maruthunkuzhi
TRIVANDRUM 695 013
Tel 65799, 65820
Telex 0884-259
Cable BLUESTAR
E

Computer Maintenance Corporation Ltd
115, Sarojini Devi Road
SECUNDERABAD 500 003
Tel 310-184, 345-774
Telex 031-2960
C**

INDONESIA
BERCA Indonesia P.T.
P.O. Box 496/Jkt
Jl. Abdul Muis 62
JAKARTA
Tel 21-373009
Telex 46748 BERSAL IA
Cable BERSAL JAKARTA
P

BERCA Indonesia P.T.
P.O. Box 2497/Jkt
Antara Bldg., 12th Floor
Jl. Medan Merdeka Selatan 17
JAKARTA-PUSAT
Tel 21-340417, 341445
Telex 46748 BERSAL IA
A.C.E.M

BERCA Indonesia P.T.
Jalan Kutai 24
SURABAYA
Tel 67118
Telex 31146 BERSAL SB
Cable BERSAL-SURABAYA
A*.E.M.P

IRAQ
Hewlett Packard Trading S.A.
Service Operation
Al Mansoor City 9B/3/7
BAGHDAD
Tel 551-49-73
Telex 212-455 HEPAIRAQ IK
C

IRELAND
Hewlett Packard Ireland Ltd
82/83 Lower Leeson Street
DUBLIN 2
Tel 0001 608800
Telex 30439
A.C.CM.E.M.P

Cardiac Services Ltd
Kilmore Road
Artane
DUBLIN 5
Tel (01) 351820
Telex 30439
M

ISRAEL
Eldan Electronic Instrument Ltd
P.O. Box 1270
JERUSALEM 91000
16, Ohaliav St.
JERUSALEM 94467
Tel 533 221, 553 242
Telex 25231 AB/PAKRD IL
A.M

Computation and Measurement Systems (CMS) Ltd
11 Masad Street
67060
TEL-AVIV
Tel 388 388
Telex 33569 Motil IL
C.CM.E.P

ITALY
Hewlett Packard Italiana S.p.A.
Traversa 99C
Via Giulio Petroni, 19
I-70124 **BARI**
Tel (080) 41-07-44
C.M

Hewlett Packard Italiana S.p.A.
Via Emilia, 51/C
I-40011 **BOLOGNA** Anzola Dell'Emilia
Tel (051) 731061
Telex 511630
C.E.M

Hewlett Packard Italiana S.p.A.
Via Principe Nicola 43G/C
I-95126 **CATANIA**
Tel (095) 37-10-87
Telex 970291
C

Hewlett Packard Italiana S.p.A.
Via G. Di Vittorio 9
I-20063 **CERNUSCO SUL NAVIGLIO**
(Milano)
Tel (02) 4459041
Telex 334632
A.C.CM.E.M.P

Hewlett Packard Italiana S.p.A.
Via C. Colombo 49
I-20090 **TREZZANO SUL NAVIGLIO**
(Milano)
Tel (02) 4459041
Telex 322116
C

Hewlett Packard Italiana S.p.A.
Via Nuova San Rocco a Capodimonte, 62/A
I-80131 **NAPOLI**
Tel (081) 7413544
Telex 710698
A**.C.E.M

Hewlett Packard Italiana S.p.A.
Viale G. Modugno 33
I-16156 **GENOVA PEGLI**
Tel (010) 68-37-07
Telex 215238
C.E

Hewlett-Packard Italiana S.p.A.
Via Pelizzo 15
I-35128 **PADOVA**
Tel (049) 664888
Telex 430315
A.C.E.M

Hewlett-Packard Italiana S.p.A.
Viale C. Pavese 340
I-00144 **ROMA EUR**
Tel (06) 54831
Telex 610514
A.C.E.M.P*

Hewlett-Packard Italiana S.p.A.
Via di Casellina 57/C
I-50018 **SCANDICCI-FIRENZE**
Tel (055) 753863
C.E.M

Hewlett Packard Italiana S.p.A.
Corso Svizzera, 185
I-10144 **TORINO**
Tel (011) 74 4044
Telex 221079
A*.C.E

IVORY COAST
S.I.T.E.L.
Societe Ivoirienne de Telecommunications
Bd. Giscard d'Estaing
Carrefour Marcory
Zone 4.A.
Boite postale 2580
ABIDJAN 01
Tel 353600
Telex 43175
E

S.I.T.I.
Immeuble "Le General"
Av. du General de Gaulle
01 BP 161
ABIDJAN 01
Tel 321227
C.P

JAPAN
Yokogawa-Hewlett-Packard Ltd
152-1, Onna
ATSUGI, Kanagawa, 243
Tel (0462) 25-0031
C.CM.E

Yokogawa-Hewlett-Packard Ltd
Meiji Seimei Bldg. 6F
3-1 Hon Chiba-Cho
CHIBA, 280
Tel 472 25 7701
C.E

Yokogawa-Hewlett-Packard Ltd
Yasuda-Seimei Hiroshima Bldg
6-11, Hon-dori, Naka-ku
HIROSHIMA, 730
Tel 82-241-0611

Yokogawa-Hewlett-Packard Ltd
Towa Building
2-3, Kaigan-dori, 2 Chome Chuo-ku
KOBE, 650
Tel (078) 392-4791
C.E

Yokogawa-Hewlett-Packard Ltd
Kumagaya Asahi 82 Bldg
3-4 Tsukuba
KUMAGAYA, Saitama 360
Tel (0485) 24-6563
C.CM.E

Yokogawa-Hewlett-Packard Ltd
Asahi Shinbun Daiichi Seimei Bldg
4-7, Hanabata-cho
KUMAMOTO, 860
Tel (096) 354-7311
C.E

Yokogawa-Hewlett-Packard Ltd
Shin-Kyoto Center Bldg
614, Higashi-Shiokoji-cho
Karasuma-Nishiiru
Shiokoji-dori, Shimogyo-ku
KYOTO, 600
Tel 075-343-0921
C.E

Yokogawa-Hewlett-Packard Ltd
Mito Mitsui Bldg
4-73, Sanno-maru, 1 Chome
MITO, Ibaraki 310
Tel (0292) 25-7470
C.CM.E

Yokogawa-Hewlett-Packard Ltd
Meiji Seimei Kokubun Bldg. 7-8
Kokubun, 1 Chome, Sendai
MIYAGI, 980
Tel (0222) 25-1011
C.E

Yokogawa-Hewlett-Packard Ltd
Nagoya Kokusai Center Building
47-1, Nagono, 1 Chome
Nakamura-ku
NAGOYA, 450
Tel (052) 571-5171
C.CM.E.M

Yokogawa-Hewlett-Packard Ltd
Saikyoren Building
1-2, Dote-machi, **OHMIYA**
Saitama 330
Tel (0486) 45-8031

Yokogawa-Hewlett-Packard Ltd
Chuo Bldg.,
4-20 Nishinakajima, 5 Chome
Yodogawa-ku
OSAKA, 532
Tel (06) 304-6021
Telex YHPOSA 523-3624
A.C.CM.E.M.P*

Yokogawa-Hewlett-Packard Ltd
27-15, Yabe, 1 Chome
SAGAMIHARA Kanagawa, 229
Tel 0427 59-1311

Yokogawa-Hewlett-Packard Ltd
Daiichi Seimei Bldg
7-1, Nishi Shinjuku, 2 Chome
Shinjuku-ku, **TOKYO** 160
Tel 03-348-4611
C.E

Yokogawa-Hewlett-Packard Ltd
29-21 Takaido-Higashi, 3 Chome
Suginami-ku, **TOKYO** 168
Tel (03) 331-6111
Telex 232-2024 YHPTOK
A.C.CM.E.M.P*

Yokogawa-Hokushin Electric Corp
9-32 Nokacho 2 Chome
2 Chome Musashino-shi
TOKYO, 180
Tel (0422) 54-1111
Telex 02822-421 YEW MTK J
A

Yokogawa-Hewlett-Packard Ltd
Meiji Seimei Utsunomiya Odori Building
1-5 Odori, 2 Chome
UTSUNOMIYA, Tochigi 320
Tel (0286) 33-1153
C.E

Yokogawa-Hewlett-Packard Ltd
Yasuda Seimei Yokohama Nishiguchi Bldg
30-4 Tsuruya-cho, 3 Chome
YOKOHAMA 221
Tel (045) 312-1252
C.E

JORDAN
Scientific and Medical Supplies Co
P.O. Box 1387
AMMAN
Tel 24907, 39907
Telex 21456 SABCO JO
C.E.M.P

KENYA
ADCOM Ltd., Inc., Kenya
P.O. Box 30070
NAIROBI
Tel 331955
Telex 22639
E.M

KOREA
Samsung Hewlett-Packard Co. Ltd
Dongbang Yeoeuido Building
12-16th Floors
36-1 Yeoeuido-dong
Yongdeungpo-ku
SEOUL
Tel 784-2666, 784-4666
Telex 25166 SAMSAN K
A.C.CM.E.M.P

Young In Scientific Co., Ltd
Youngwha Building
547 Shinsa Dong, Kangnam-ku
SEOUL 135
Tel 5467771
Telex K23457 GINSCO
A

KUWAIT
Al-Khaldiya Trading & Contracting
P.O. Box 830
SAFAT
Tel 424910, 411726
Telex 22481 AREEG KT
Cable VISCOUNT
E.M.A

Gulf Computing Systems
P.O. Box 25125
SAFAT
Tel 435969
Telex 23648
P

Photo & Cine Equipment
P.O. Box 270
SAFAT
Tel 2445111
Telex 22247 MATIN KT
Cable MATIN KUWAIT
P

W.J. Towell Computer Services
P.O. Box 5897
SAFAT
Tel 2462640
Telex 30336 TOWELL KT
C

LEBANON
Computer Information Systems S.A.L.
Chammas Building
P.O. Box 11-6274 Dora
BEIRUT
Tel 89 40 73
Telex 42309
C.E.M.P

LIBERIA
Unichemicals Inc.
P.O. Box 4509
MONROVIA
Tel 224282
Telex 4509
E

MADAGASCAR
Technique et Precision
12, rue de Nice
P.O. Box 1227
101 **ANTANANARIVO**
Tel 22090
Telex 22255
P

LUXEMBOURG
Hewlett Packard Belgium S.A./N.V.
Blvd de la Woluwe, 100
Woluwedal
B-1200 **BRUSSELS**
Tel (02) 762-32-00
Telex 23-494 paloben bru
A.C.CM.E.M.P

MALAYSIA
Hewlett Packard Sales (Malaysia) Sdn. Bhd.
9th Floor
Chung Khiaw Bank Building
46, Jalan Raja Laut
KUALA LUMPUR
Tel 03-986555
Telex 31011 HPSM MA
A.C.E.M.P*

Protel Engineering
P.O. Box 1917
Lot 6624, Section 64
23/4 Pending Road
Kuching, **SARAWAK**
Tel 36299
Telex 70904 PROMAL MA
Cable PROTELENG
A.E.M

MALTA
Philip Toledo Ltd
Birkirkara P.O. Box 11
Notabile Rd
MRIEHEL
Tel 447 47, 455 66
Telex 1649
E.M.P

MAURITIUS
Blanche Birger Co. Ltd
18, Jules Koenig Street
PORT LOUIS
Tel 20828
Telex 4296
P

MEXICO
Hewlett Packard de Mexico, S.A.
Francisco J. Allen #30
Colonia Nueva
Los Angeles 27140
COAHUILA, Torreon
Tel 37220
P

Hewlett Packard de Mexico, S.A.
Monti Morelos 299
Fraccionamiento Loma Bonita 45060
GUADALAJARA, Jalisco
Tel 316630/314600
Telex 0684 186 ECOME
P

Microcomputadoras Hewlett-Packard, S.A.
Monti Pelvoux 115
LOS LOMAS, Mexico, D.F.
Tel 520-9127
P

Hewlett-Packard Mexicana, S.A. de C.V.
Av. Periferico Sur No. 6501
Tepepan, Xochimilco
16020 **MEXICO D.F.**
Tel 6-76-46-00
Telex 17-74-507 HEWPACK MEX
A.C.CM.E.M.P

Hewlett Packard De Mexico (Polanco)
Avenida Ejercito Nacional #579
2da y 3er piso
Colonia Granada 11560
MEXICO D.F.
Tel 254-4433
P

Hewlett Packard De Mexico, S.A. de C.V.
Czda. del Valle
409 Ote. 4th Piso
Colonia del Valle
Municipio de Garza Garciá
66220 **MONTERREY**, Nuevo León
Tel 78 42 41
Telex 038 410
P

MOROCCO
Etablissement Hubert Dolbeau & Fils
81 rue Karatchi
B.P. 11133
CASABLANCA
Tel 3041-82, 3068-38
Telex 23051, 22822
E

Gerep
2, rue Agadir
Boite Postale 156
CASABLANCA 01
Tel 272093, 272095
Telex 23 739
P

Sema-Maroc
Dept. Seric
6, rue Lapebie
CASABLANCA
Tel 260980
Telex 21641
C.P

NETHERLANDS
Hewlett-Packard Nederland B.V.
Startbaan 16
1187 XR **AMSTELVEEN**
P.O. Box 667
NL 1180 AR **AMSTELVEEN**
Tel (020) 547-6911
Telex 13 216 HEPA NL
A.C.CM.E.M.P

Hewlett Packard Nederland B.V.
Bongerd 2
NL 2906VK **CAPELLE A/D IJSSEL**
P.O. Box 41
NL 2900AA **CAPELLE A/D IJSSEL**
Tel (10) 51-64-44
Telex 21261 HEPAC NL
C.E

Hewlett-Packard Nederland B.V.
Pastoor Petersstraat 134-136
NL 5612 LV **EINDHOVEN**
P.O. Box 2342
NL 5600 CH **EINDHOVEN**
Tel (040) 326911
Telex 51484 hepae nl
A.C.E.M.P

NEW ZEALAND
Hewlett-Packard (N.Z.) Ltd
5 Owens Road
P.O. Box 26-189
Epsom, **AUCKLAND**
Tel 687-159
Cable HEWPAK Auckland
C.CM.E.P*

Hewlett Packard (N.Z.) Ltd
4-12 Cruickshank Street
Kilbirnie, **WELLINGTON** 3
P.O. Box 9443
Courtenay Place, **WELLINGTON** 3
Tel 877-199
Cable HEWPACK Wellington
C.CM.E.P

Northrop Instruments & Systems Ltd
369 Khyber Pass Road
P.O. Box 8602
AUCKLAND
Tel 794-091
Telex 60605
A.M

Northrop Instruments & Systems Ltd
110 Mandeville St
P.O. Box 8388
CHRISTCHURCH
Tel 488-873
Telex 4203
A.M

Northrop Instruments & Systems Ltd
Sturdee House
85-87 Ghuznee Street
P.O. Box 2406
WELLINGTON
Tel 850-091
Telex NZ 3380
A.M

NIGERIA
Elmeco Nigeria Ltd
45 Calcutta Crescent Apapa
P.O. Box 244and
LAGOS
E

NORTHERN IRELAND
See United Kingdom

NORWAY
Hewlett-Packard Norge A/S
Folke Bernadottes vei 50
P.O. Box 3558
N-5033 **FYLLINGSDALEN** (Bergen)
Tel 0047/5/16 55 40
Telex 76621 hpnas n
C.E.M

Hewlett-Packard Norge A/S
Osterndalen 16-18
P.O. Box 34
N-1345 **ØSTERÅS**
Tel 0047/2/17 11 80
Telex 76621 hpnas n
A.C.CM.E.M.P

OMAN
Khimjil Ramdas
P.O. Box 19
MUSCAT/SULTANATE OF OMAN
Tel 745601
Telex 5289 BROKER MB MUSCAT
P

Suhail & Saud Bahwan
P.O. Box 169
MUSCAT/SULTANATE OF OMAN
Tel 734201
Telex 5274 BAHWAN MB
E

Imtac LLC
P.O. Box 8676
MUTRAH/SULTANATE OF OMAN
Tel 601695
Telex 5741 Tawoos On
A.C.M

PAKISTAN
Mushko & Company Ltd
House No. 16, Street No. 16
Sector F-6/3
ISLAMABAD
Tel 824545
Cable FEMUS Islamabad
A.E.M.P*

Mushko & Company Ltd
Oosman Chambers
Abdullah Haroon Road
KARACHI 0302
Tel 524131, 524132
Telex 2894 MUSKO PK
Cable COOPERATOR Karachi
A.E.M.P*

PANAMA
Electronico Balboa, S.A.
Calle Samuel Lewis, Ed. Alfa
Apartado 4929
PANAMA 5
Tel 64-2700
Telex 3483 ELECTRON PG
A.CM.E.M.P

PERU
Cía Electro Médica S.A.
Los Flamencos 145, Ofc. 301/2
San Isidro
Casilla 1030
LIMA 1
Tel 41-4325, 41-3705
Telex Pub. Booth 25306 PEC PISIDR
CM.E.M.P

SAMS
Arenida Republica de Panama 3534
San Isidro, LIMA
Tel 419928/417108
Telex 20450 PE LIBERTAD
A.C.P

PHILIPPINES
The Online Advanced Systems Corp
2nd Floor, Electra House
115-117 Esteban Street
Legaspi Village, Makati
P.O. Box 1510
Metro **MANILA**
Tel 815-38-10 (up to 16)
Telex 63274 ONLINE PN
A.C.E.M.P

PORTUGAL
Mundinter Intercambio
Mundial de Comércio S.A.R.L.
Av. Antonio Augusto Aguiar 138
Apartado 2761
LISBON
Tel (19) 53-21-31, 53-21-37
Telex 16691 munter p
M

Soquimica
Av. da Liberdade, 220-2
1298 **LISBOA** Codex
Tel 56-21-82
Telex 13316 SABASA
A

Telectra-Empresa Técnica de Equipmentos Eléctricos S.A.R.L.
Rua Rodrigo da Fonseca 103
P.O. Box 2531
LISBON 1
Tel (19) 68-60-72
Telex 12598
CM.E

C.P.C.S.I.
Rua de Costa Cabral 575
4200 **PORTO**
Tel 499174/495173
Telex 26054
C.P

PUERTO RICO
Hewlett-Packard Puerto Rico
101 Muñoz Rivera Av
Esu. Calle Ochoa
HATO REY, Puerto Rico 00918
Tel (809) 754-7800
A.C.CM.M.E.P

QATAR
Computer Arabia
P.O. Box 2750
DOHA
Tel 428555
Telex 4806 CHPARB
P

Nasser Trading & Contracting
P.O. Box 1563
DOHA
Tel 422170
Telex 4439 NASSER DH
M

SAUDI ARABIA
Modern Electronics Establishment
Hewlett-Packard Division
P.O. Box 281
Thoughbah
AL-KHOBAR 31952
Tel 895-1760, 895-1764
Telex 671 106 HPMEEK SJ
Cable ELECTA AL-KHOBAR
C.E.M

Modern Electronics Establishment
Hewlett-Packard Division
P.O. Box 1228
JEDDAH
Tel 644 96 28
Telex 4027 12 FARNAS SJ
Cable ELECTA JEDDAH
A.C.CM.E.M.P

Modern Electronics Establishment
Hewlett-Packard Division
P.O. Box 22015
RIYADH 11495
Tel 476-3030
Telex 202049 MEERYD SJ
A.C.CM.E.M.P

Abdul Ghani El Ajou Corp.
P.O. Box 78
RIYADH
Tel 40 41 717
Telex 200 931 EL AJOU
P

SCOTLAND
See United Kingdom

SENEGAL
Societe Hussein Ayad & Cie
76, Avenue Georges Pompidou
B.P. 305
DAKAR
Tel 32339
Cable AYAD-Dakar
E

Moneger Distribution S.A.
1, Rue Parent
B.P. 148
DAKAR
Tel 215 671
Telex 587
P

Systeme Service Conseil (SSC)
14, Avenue du Parachute
DAKAR ETOILE
Tel 219976
Telex 577
C.P

SINGAPORE
Hewlett-Packard Singapore (Sales) Pte. Ltd
08-00 Inchcape House
450-2 Alexandra Road
Alexandra P.O. Box 58
SINGAPORE, 9115
Tel 4731788
Telex 34209 HPSGSO RS
Cable HEWPACK, Singapore
A.C.E.M.P

Dynamar International Ltd
Unit 05-11 Block 6
Kolam Ayer Industrial Estate
SINGAPORE 1334
Tel 747-6188
Telex 26283 RS
CM

SOUTH AFRICA
Hewlett-Packard So Africa (Pty.) Ltd
P.O. Box 120
Howard Place, **CAPE PROVINCE** 7450
Pine Park Center, Forest Drive, Pinelands
CAPE PROVINCE 7405
Tel (021) 53 7954
Telex 57-20006
A.C.CM.E.M.P

Hewlett Packard So Africa (Pty.) Ltd
2nd Floor Juniper House
92 Overport Drive
DURBAN 4067
Tel (031) 28-4178
Telex 6-22954
C

Hewlett-Packard So Africa (Pty.) Ltd
6 Linton Arcade
511 Cape Road
Linton Grange
PORT ELIZABETH 6001
Tel 041-301201
Telex 24-2916
C

SOUTH AFRICA (Cont'd)
Hewlett-Packard So Africa (Pty.) Ltd
Fountain Center
Kalkden Str.
Monument Park Ext 2
PRETORIA 0105
Tel (012) 45 5725
Telex 3-21063
C.E

Hewlett-Packard So Africa (Pty.) Ltd
Private Bag Wendywood
SANDTON 2144
Tel 802-5111, 802-5125
Telex 4-20877 SA
Cable HEWPACK Johannesburg
A.C.CM.E.M.P

SPAIN
Hewlett-Packard Española S.A.
Calle Entenza, 321
08029 **BARCELONA**
Tel 3/322 24 51, 321 73 54
Telex 52603 hpbee
A.C.E.M.P

Hewlett-Packard Española S.A.
Calle San Vicente S/N
Edificio Albia II 7B
48001 **BILBAO**
Tel 4/423 83 06
A.C.E.M

Hewlett-Packard Española S.A.
Crta. de la Coruña, Km. 16, 400
Las Rozas
E-**MADRID**
Tel (1) 637.00.11
Telex 23515 HPE
C.M

Hewlett-Packard Española S.A.
Avda. S. Francisco Javier, S/N
Planta 10. Edificio Sevilla 2
41005 **SEVILLA**
Tel 54/64 44 54
Telex 72933
A.C.M.P

Hewlett-Packard Española S.A.
Isabel La Catolica, 8
46004 **VALENCIA**
Tel 0034/6/351 59 44
C.P

SWEDEN
Hewlett-Packard Sverige AB
Östra Tullgatan 3
S-21128 **MALMÖ**
Tel (040) 70270
Telex (854) 17886 (via Spånga office)
C.P

Hewlett-Packard Sverige AB
Skalholtsgatan 9, Kista
Box 19
S-16393 **SPÅNGA**
Tel (08) 750-2000
Telex (854) 17886
Telefax (08) 7527781
A.C.CM.E.M.P

Hewlett-Packard Sverige AB
Frötallisgatan 30
S-42132 **VÄSTRA-FRÖLUNDA** (Gothenburg)
Tel (031) 49-09-50
Telex (854) 17886 (via Spånga office)
A.C.CM.E.M.P

SUDAN
Mediterranean Engineering & Trading Co. Ltd
P.O. Box 1025
KHARTOUM
Tel 41184
Telex 24052
C.P

SWITZERLAND
Hewlett-Packard (Schweiz) AG
Clarastrasse 12
CH-4058 **BASEL**
Tel (61) 33-59-20
A

Hewlett-Packard (Schweiz) AG
7, rue du Bois-du-Lan
Case postale 365
CH-1217 **MEYRIN** 1
Tel (0041) 22-83-11-11
Telex 27333 HPAG CH
C.CM

Hewlett-Packard (Schweiz) AG
Allmend 2
CH-8967 **WIDEN**
Tel (0041) 57 31 21 11
Telex 53933 hpag ch
Cable HPAG CH
A.C.CM.E.M.P

SYRIA
General Electronic Inc.
Nuri Basha Ahnaf Ebn Kays Street
P.O. Box 5781
DAMASCUS
Tel 33-24-87
Telex 411 215
Cable ELECTROBOR DAMASCUS
E

Middle East Electronics
P.O. Box 2308
Abu Rumaneh
DAMASCUS
Tel 33 45 92
Telex 411 771
M

TAIWAN
Hewlett-Packard Taiwan
Kaohsiung Office
11/F, 456, Chung Hsiao 1st Road
KAOHSIUNG
Tel (07) 2412318
C.E

Hewlett-Packard Taiwan
8th Floor, Hewlett-Packard Building
337 Fu Hsing North Road
TAIPEI
Tel (02) 712-0404
Telex 24439 HEWPACK
Cable HEWPACK Taipei
A.C.CM.E.M.P

Ing Lih Trading Co
3rd Floor, 7 Jen-Ai Road, Sec. 2
TAIPEI 100
Tel (02) 3948191
Cable INGLIH Taipei
A

THAILAND
Unimesa Co. Ltd
30 Patpong Ave., Suriwong
BANGKOK 5
Tel 235-5727
Telex 84439 Simonco TH
Cable UNIMESA Bangkok
A.C.E.M

Bangkok Business Equipment Ltd
5/5-6 Dejo Road
BANGKOK
Tel 234-8670, 234-8671
Telex 87699-BEQUIPT TH
Cable BUSIQUIPT Bangkok
P

TOGO
Societe Africaine De Promotion
Immeuble Sagap
22, Rue d'Atakpame
B.P. 4150
LOME
Tel 21-62-88
Telex 5304
P

TRINIDAD & TOBAGO
Caribbean Telecoms Ltd
Corner McAllister Street & Eastern Main Road, Laventille
P.O. Box 732
PORT-OF-SPAIN
Tel 624-4213
Telex 22561 CARTEL WG
Cable CARTEL, PORT OF SPAIN
CM.E.M.P

Computer and Controls Ltd
P.O. Box 51
66 Independence Square
PORT-OF-SPAIN
Tel 62-279-85
Telex 3000 POSTLX WG ACCT
LOOGO AGENCY 1264
A.P

Feral Assoc.
8 Fitzgerald Lane
PORT-OF-SPAIN
Tel 62-36864, 62-39255
Telex 22432 FERALCO
Cable FERALCO
M

TUNISIA
Precision Electronique S.A.R.L.
31 Avenue de la Liberte
TUNIS
Tel 893937
Telex 13238
P

Tunisie Electronique S.A.R.L.
94, Av. Jugurtha, Mutuelleville
1002 **TUNIS-BELVEDERE**
Tel 280144
Telex 13238
C.E.P

Corema S.A.
23, bis Rue de Marseille
TUNIS
Tel 253-821
Telex 14812 CABAM TN
M

TURKEY
E.M.A.
Medina Eldem Sokak No. 41/6
Yenisehir
ANKARA
Tel 319175
Telex 46912 KTX TR
Cable EMATRADE ANKARA
M

Teknim Company Ltd
Iran Caddesi No. 7
Kavaklidere
ANKARA
Tel 275800
Telex 42155 TKNM TR
E.CM

Saniva Bilgisayar Sistemleri A.S.
Buyukdere Caddesi 103/6
Gayrettepe
ISTANBUL
Tel 1727030
Telex 26345 SANI TR
C.P

Best Inc.
Esentepe, Gazeteciler Sitesi
Keskin Kalem
Sokak 6/3, Gayrettepe
ISTANBUL
Tel 1721328
Telex 42490
A

UNITED ARAB EMIRATES
Emitac Ltd
P.O. Box 1641
SHARJAH
Tel 591181
Telex 68136 EMITAC EM
Cable EMITAC SHARJAH
E.C.M.P.A

Emitac Ltd
P.O. Box 2711
ABU DHABI
Tel 820419-20
Cable EMITACH ABUDHABI

Emitac Ltd
P.O. Box 8391
DUBAI
Tel 377591

Emitac Ltd
P.O. Box 473
RAS AL KHAIMAH
Tel 28133, 21270

UNITED KINGDOM

GREAT BRITAIN
Hewlett-Packard Ltd
Trafalgar House
Navigation Road
ALTRINCHAM
Cheshire WA14 1NU
Tel 061 928 6422
Telex 668068
A.C.E.M.P

Hewlett-Packard Ltd
Miller House
The Ring, **BRACKNELL**
Berks RG12 1XN
Tel 0344 424898
Telex 848733
E

Hewlett-Packard Ltd
Elstree House, Elstree Way
BOREHAMWOOD, Herts WD6 1SG
Tel 01 207 5000
Telex 8952716
C.E

Hewlett-Packard Ltd
Oakfield House, Oakfield Grove
Clifton **BRISTOL**, Avon BS8 2BN
Tel 0272 736806
Telex 444302
C.E.P

Hewlett-Packard Ltd
Bridewell House
9 Bridewell Place
LONDON EC4V 6BS
Tel 01 583 6565
Telex 298163
C.P

Hewlett-Packard Ltd
Pontefract Road
NORMANTON, West Yorkshire WF6 1RN
Tel 0924 895566
Telex 557355
C.P

Hewlett-Packard Ltd
The Quadrangle
106-118 Station Road
REDHILL, Surrey RH1 1PS
Tel 0737 68655
Telex 947234
C.E.P

Hewlett-Packard Ltd
Avon House
435 Stratford Road
Shirley, **SOLIHULL**, West Midlands B90 4BL
Tel 021 745 8800
Telex 339105
C.E.P

Hewlett Packard Ltd
West End House
41 High Street, West End
SOUTHAMPTON
Hampshire S03 3DQ
Tel 0703 476767
Telex 477138
C.P

Hewlett Packard Ltd
Harrison House
No. 1 George Street
UXBRIDGE, Middlesex UX8 1YH
Tel 895 720 20
Telex 893134/5
C.CM.E.M.P

Hewlett Packard Ltd
King Street Lane
Winnersh, **WOKINGHAM**
Berkshire RG11 5AR
Tel 0734 784774
Telex 847178
A.C.E.M.P

IRELAND

NORTHERN IRELAND
Hewlett Packard (Ireland) Ltd
Carrickfergus Industrial Centre
75 Belfast Road, Carrickfergus
BELFAST BT38 8PH
Tel 09603 67333
Telex 747626
C.E

SCOTLAND
Hewlett Packard Ltd
8 Woodside Place
GLASGOW, G3 7QF
Tel 041 332 6232
Telex 779615
C.E

Hewlett-Packard Ltd
SOUTH QUEENSFERRY
West Lothian, EH30 9TG
Tel 031 331 1188
Telex 72682
C.CM.E.M.P

UNITED STATES

Alabama
Hewlett Packard Co
700 Century Park South, Suite 128
BIRMINGHAM, AL 35226
Tel (205) 822-6802
A.C.M.P*

Hewlett Packard Co
420 Wynn Drive
HUNTSVILLE, AL 35805
Tel (205) 830-2000
C.CM.E.M*

Alaska
Hewlett Packard Co
3601 C St., Suite 1416
ANCHORAGE, AK 99503
Tel (907) 563-8855
C.E

Arizona
Hewlett Packard Co
8080 Pointe Parkway West
PHOENIX, AZ 85044
Tel (602) 273-8000
A.C.CM.E.M.P

Hewlett Packard Co
3400 East Britannia Dr
Bldg. C, Suite 124
TUCSON, AZ 85706
Tel (602) 573-7400
C.E.M**

California
Hewlett Packard Co
99 South Hill Dr
BRISBANE, CA 94005
Tel (415) 330-2500
C

Hewlett Packard Co
5060 E. Clinton Avenue, Suite 102
FRESNO, CA 93727
Tel (209) 252-9652
C.M

Hewlett-Packard Co
1421 S. Manhattan Av
FULLERTON, CA 92631
Tel (714) 999-6700
C.CM.E.M

Hewlett-Packard Co
7408 Hollister Ave. #A
GOLETA, CA 93117
Tel (805) 685-6100
C.E

Hewlett Packard Co
5400 W. Rosecrans Blvd
LAWNDALE, CA 90260
Tel (213) 643-7500
Telex 910-325-6608
C.M

Hewlett-Packard Co
2525 Grand Avenue
Long Beach, CA 90815
Tel (213) 498-1111
C

Hewlett-Packard Co
3155 Porter Drive
PALO ALTO, CA 94304
Tel (415) 857-8000
C.E

Hewlett-Packard Co
4244 So. Market Court, Suite A
SACRAMENTO, CA 95834
Tel (916) 929-7222
A*.C.E.M

Hewlett Packard Co
9606 Aero Drive
SAN DIEGO, CA 92123
Tel (619) 279-3200
C.CM.E.M

Hewlett-Packard Co
5725 W. Las Positas Blvd
Pleasanton, CA 94566
Tel (415) 460-0282
C

Hewlett Packard Co
3003 Scott Boulevard
SANTA CLARA, CA 95054
Tel (408) 988-7000
Telex 910-338-0586
A.C.CM.E

Hewlett Packard Co
2150 W. Hillcrest Dr
THOUSAND OAKS, CA 91320
(805) 373-7000
C.CM.E

Colorado
Hewlett Packard Co
2945 Center Green Court South
Suite A
BOULDER, CO 80301
Tel (303) 938-3005
A.C.E

Hewlett-Packard Co
24 Inverness Place, East
ENGLEWOOD, CO 80112
Tel (303) 649-5000
A.C.CM.E.M

Connecticut
Hewlett Packard Co
500 Sylvan Av
BRIDGEPORT, CT 06606
Tel (203) 371-6454
C.E

Hewlett Packard Co
47 Barnes Industrial Road South
WALLINGFORD, CT 06492
Tel (203) 265-7801
A.C.CM.E.M

Florida
Hewlett Packard Co
2901 N.W. 62nd Street
FORT LAUDERDALE, FL 33309
Tel (305) 973-2600
C.E.M.P*

Hewlett Packard Co
6800 South Point Parkway
Suite 301
JACKSONVILLE, FL 32216
Tel (904) 398-0663
C*.M**

Hewlett-Packard Co
6177 Lake Ellenor Drive
ORLANDO, FL 32809
Tel (305) 859-2900
A.C.CM.E.P*

Hewlett-Packard Co
4700 Bayou Blvd
Building 5
PENSACOLA, FL 32503
Tel (904) 476-8422
A.C.M

Hewlett-Packard Co
5550 W. Idlewild, 150
TAMPA, FL 33614
Tel (813) 884-3282
C.E.M.P

Georgia
Hewlett Packard Co
2000 South Park Place
ATLANTA, GA 30339
Tel (404) 955-1500
Telex 810-766-4890
A.C.CM.E.M.P*

Hewlett-Packard Co
3607 Parkway Lane
Suite 300
NORCROSS, GA 30092
Tel (404) 448-1894
C.E.P

Hawaii
Hewlett-Packard Co
Kawaiahao Plaza, Suite 190
567 South King Street
HONOLULU, HI 96813
Tel (808) 526-1555
A.C.E.M

Idaho
Hewlett-Packard Co
11309 Chinden Blvd
BOISE, ID 83707
Tel (208) 323-2700
C

Illinois
Hewlett Packard Co
304 Eldorado Road
P.O. Box 1607
BLOOMINGTON, IL 61701
Tel (309) 662-9411
C.M**

Hewlett Packard Co
525 W. Monroe, 1308
CHICAGO, IL 60606
Tel (312) 930-0010
C

Hewlett Packard Co
1200 East Diehl Road
NAPERVILLE, IL 60566
Tel (312) 357-8800
C

Hewlett Packard Co
5201 Tollview Drive
ROLLING MEADOWS, IL 60008
Tel (312) 255-9800
Telex 910-687-1066
A.C.CM.E.M

Indiana
Hewlett Packard Co
11911 N. Meridian St
CARMEL, IN 46032
Tel (317) 844-4100
A.C.CM.E.M

Hewlett Packard Co
3702 Rupp Drive
FT. WAYNE, IN 46815
Tel (219) 482-4283
C.E

Iowa
Hewlett Packard Co
4070 22nd Av. SW
CEDAR RAPIDS, IA 52404
Tel (319) 390-4250
C.E.M

Hewlett-Packard Co
4201 Corporate Dr
WEST DES MOINES, IA 50265
Tel (515) 224-1435
A**.C.M**

Kansas
Hewlett Packard Co
7804 East Funston Road, 203
WICHITA, KS 67207
Tel (316) 684-8491
C.E

Kentucky
Hewlett Packard Co
10300 Linn Station Road, 100
LOUISVILLE, KY 40223
Tel (502) 426-0100
A.C.M

Louisiana
Hewlett-Packard Co
160 James Drive East
ST. ROSE, LA 70087
P.O. Box 1449
KENNER, LA 70063
Tel (504) 467-4100
A.C.E.M.P

Maryland
Hewlett Packard Co
3701 Koppers Street
BALTIMORE, MD 21227
Tel (301) 644-5800
Telex 710-862-1943
A.C.CM.E.M

Hewlett Packard Co
2 Choke Cherry Road
ROCKVILLE, MD 20850
Tel (301) 948-6370
A.C.CM.E.M

Massachusetts
Hewlett-Packard Co
1775 Minuteman Road
ANDOVER, MA 01810
Tel (617) 682-1500
A.C.CM.E.M.P*

Hewlett-Packard Co
32 Hartwell Avenue
LEXINGTON, MA 02173
Tel (617) 861-8960
C.E

Michigan
Hewlett-Packard Co
4326 Cascade Road S.E.
GRAND RAPIDS, MI 49506
Tel (616) 957-1970
C.M

Hewlett Packard Co
39550 Orchard Hill Place Drive
NOVI, MI 48020
Tel (313) 349-9200
A.C.E.M

Hewlett Packard Co
1771 W. Big Beaver Road
TROY, MI 48084
Tel (313) 643-6474
C

Minnesota
Hewlett Packard Co
2025 W. Larpenteur Ave
ST. PAUL, MN 55113
Tel (612) 644-1100
A.C.CM.E.M

Missouri
Hewlett Packard Co
1001 E. 101st Terrace Suite 120
KANSAS CITY, MO 64131-3368
Tel (816) 941-0411
A.C.CM.E.M

Hewlett Packard Co
13001 Hollenberg Drive
BRIDGETON, MO 63044
Tel (314) 344-5100
A.C.E.M

Nebraska
Hewlett Packard
10824 Old Mill Rd., Suite 3
OMAHA, NE 68154
Tel (402) 334-1813
C.E.M

New Jersey
Hewlett Packard Co
120 W. Century Road
PARAMUS, NJ 07653
Tel (201) 265-5000
A.C.CM.E.M

Hewlett Packard Co
20 New England Av. West
PISCATAWAY, NJ 08854
Tel (201) 562-6100
A.C.CM.E

New Mexico
Hewlett Packard Co
7801 Jefferson N.E.
ALBUQUERQUE, NM 87109
Tel (505) 292-1330
C.E.M

New York
Hewlett Packard Co
5 Computer Drive South
ALBANY, NY 12205
Tel (518) 458-1550
A.C.E.M

Hewlett Packard Co
9600 Main Street
CLARENCE, NY 14031
Tel (716) 759-8621
C.E

Hewlett Packard Co
200 Cross Keys Office Park
FAIRPORT, NY 14450
Tel (716) 223-9950
A.C.CM.E.M

Hewlett Packard Co
7641 Henry Clay Blvd
LIVERPOOL, NY 13088
Tel (315) 451-1820
A.C.CM.E.M

Hewlett Packard Co
No. 1 Pennsylvania Plaza
55th Floor
34th Street & 8th Avenue
MANHATTAN NY 10119
Tel (212) 971-0800
C.M*

Hewlett Packard Co
15 Myers Corner Rd
Hollowbrook Park, Suite 20
WAPPINGER FALLS, NY 12590
CM.E

Hewlett Packard Co
250 Westchester Avenue
WHITE PLAINS, NY 10604
Tel (914) 684-6100
C.CM.E

Hewlett Packard Co
3 Crossways Park West
WOODBURY, NY 11797
Tel (516) 682-7800
A.C.CM.E.M

North Carolina
Hewlett Packard Co
305 Gregson Dr
CARY, NC 27511
Tel (919) 467-6600
C.CM.E.M.P*

Hewlett Packard Co
9600-H Southern Pine Blvd
CHARLOTTE, NC 28210
Tel (704) 527-8780
C*

Hewlett-Packard Co
5605 Roanne Way
GREENSBORO, NC 27420
Tel (919) 852-1800
A.C.CM.E.M.P*

Ohio
Hewlett Packard Co
2717 S. Arlington Road
AKRON, OH 44312
Tel (216) 644-2270
C.E

Hewlett-Packard Co
23200 Chagrin Blvd #100
BEACHWOOD, OH 44122
Tel (216) 292-4677
C.P

Hewlett Packard Co
9920 Carver Road
CINCINNATI, OH 45242
Tel (513) 891-9870
C.M

Hewlett Packard Co
16500 Sprague Road
CLEVELAND, OH 44130
Tel (216) 243-7300
A.C.CM.E.M

Hewlett Packard Co
9080 Springboro Pike
MIAMISBURG, OH 45342
Tel (513) 433-2223
A.C.CM.E*.M

Hewlett Packard Co
One Maritime Plaza, 5th Floor
720 Water Street
TOLEDO, OH 43604
Tel (419) 242-2200
C

Hewlett-Packard Co
675 Brooksedge Blvd
WESTERVILLE, OH 43081
Tel (614) 891-3344
C.CM.E*

Oklahoma
Hewlett Packard Co
3525 N.W. 56th St
Suite C-100
OKLAHOMA CITY, OK 73112
Tel (405) 946-9499
C.E*.M

Hewlett Packard Co
3840 S. 103rd E. Ave., 100
TULSA, OK 74146
Tel (918) 665-3300
A**.C.E.M*.P*

Oregon
Hewlett Packard Co
9255 S. W. Pioneer Court
WILSONVILLE, OR 97070
Tel (503) 682-8000
A.C.E*.M

Pennsylvania
Hewlett Packard Co
50 Dorchester Rd
HARRISBURG, PA 17112
Tel (717) 657-5900
C

Hewlett Packard Co
111 Zeta Drive
PITTSBURGH, PA 15238
Tel (412) 782-0400
A.C.E.M

Hewlett Packard Co
2750 Monroe Boulevard
VALLEY FORGE, PA 19482
Tel (215) 666-9000
A.C.CM.E.M

South Carolina
Hewlett Packard Co
Brookside Park, Suite 122
1 Harbison Way
COLUMBIA, SC 29210
Tel (803) 732-0400
C.M

Hewlett Packard Co
555 N. Pleasantburg Dr
Suite 107
GREENVILLE, SC 29607
Tel (803) 232-8002
C

Tennessee
Hewlett Packard Co
One Energy Centr. 200
Pellissippi Pkwy
KNOXVILLE, TN 37932
Tel (615) 966-4747
A.C.M

Hewlett-Packard Co
3070 Directors Row
Directors Square
MEMPHIS, TN 38131
Tel (901) 346-8370
A.C.M

Hewlett Packard Co
220 Great Circle Road, Suite 116
NASHVILLE, TN 37228
Tel (615) 255-1271
C.M.P*

Texas
Hewlett Packard Co
1826-P Kramer Lane
AUSTIN, TX 78758
Tel (512) 835-6771
C.E.P*

Hewlett Packard Co
5730 Cromo Dr
EL PASO, TX 79912
Tel (915) 833-4400
C.E*.M**

Hewlett Packard Co
3952 Sandshell Drive
FORT WORTH, TX 76137
Tel (817) 232-9500
C

Hewlett Packard Co
10535 Harwin Drive
HOUSTON, TX 77036
Tel (713) 776-6400
A.C.E.M.P*

Hewlett Packard Co
511 E. John W. Carpenter Fwy
Royal Tech. Center 100
IRVING, TX 75062
Tel (214) 556-1950
C.E

Hewlett Packard Co
109 E. Toronto, Suite 100
McALLEN, TX 78503
Tel (512) 630-3030
C

Hewlett Packard Co
930 E. Campbell Rd
RICHARDSON, TX 75081
Tel (214) 231-6101
A.C.CM.E.M.P*

Hewlett Packard Co
1020 Central Parkway South
SAN ANTONIO, TX 78216
Tel (512) 494-9336
A.C.E.M.P*

Utah
Hewlett Packard Co
3530 W. 2100 South
SALT LAKE CITY, UT 84119
Tel (801) 974-1700
A.C.E.M

Virginia
Hewlett Packard Co
4305 Cox Road
GLEN ALLEN, VA 23060
Tel (804) 747-7750
A.C.E.M.P*

Hewlett Packard Co
Tanglewood West Bldg
Suite 240
3959 Electric Road
ROANOKE, VA 24018
Tel (703) 774-3444
C.E.P

Washington
Hewlett Packard Co
15815 S.E. 37th Street
BELLEVUE, WA 98006
Tel (206) 643-4000
A.C.CM.E.M

Hewlett Packard Co
708 North Argonne Road
SPOKANE, WA 99212-2793
Tel (509) 922-7000
C

West Virginia
Hewlett Packard Co
501 56th St
CHARLESTON, WV 25304
Tel (304) 925-0492
A.C.M

Wisconsin
Hewlett Packard Co
275 N. Corporate Dr
BROOKFIELD, WI 53005
Tel (414) 784-8800
A.C.E*.M

URUGUAY
Pablo Ferrando S.A.C. e I.
Avenida Italia 2877
Casilla de Correo 370
MONTEVIDEO
Tel 80-2586
Telex 802586
A.CM.E.M

Olympia de Uruguay S.A.
Maquinas de Oficina
Avda. del Libertador 1997
Casilla de Correos 6644
MONTEVIDEO
Tel 91-1809, 98-3807
Telex 6342 OROU UY
P

VENEZUELA
Hewlett Packard de Venezuela C.A.
3A Transversal Los Ruices Norte
Edificio Segre 2 & 3
Apartado 50933
CARACAS 1071
Tel 239-4133
Telex 251046 HEWPACK
A.C.CM.E.M.P

Hewlett Packard de Venezuela, C.A.
Centro Ciudad Comercial Tamanaco
Nivel C-2 (Nueva Etapa)
Local 53H05
Chuao, **CARACAS**
Tel 928291
P

Albis Venezolana S.R.L.
Av. Las Marias, Ota. Albis
El Pedregal
Apartado 81025
CARACAS 1080A
Tel 747984, 742146
Telex 24009 ALBIS VC
A

Tecnologica Medica del Caribe, C.A.
Multicentro Empresarial del Este
Ave. Libertador
Edif. Libertador
Nucleo "C" - Oficina 51-52
CARACAS
Tel 339867/333780
M

Hewlett Packard de Venezuela C.A.
Residencias Tia Betty Local 1
Avenida 3 y con Calle 75
MARACAIBO, Estado Zulia
Apartado 2646
Tel (061) 75801-75805-75806
80304
Telex 62464 HPMAR
C.E*

Hewlett Packard de Venezuela C.A.
Urb. Lomas de Este
Torre Trebol — Piso 11
VALENCIA, Estado Carabobo
Apartado 3347
Tel (041) 222992/223024
C.P

YUGOSLAVIA
Do Hermes
General Zdanova 4
YU-11000 **BEOGRAD**
Tel 340 327, 342 641
Telex 11433
A.C.E.P

Hermes
Titova 50
YU-61000 **LJUBLJANA**
Tel 324 856, 324 858
Telex 31583
C.E.M.P

Elektrotehna
Titova 51
YU-61000 **LJUBLJANA**
CM

ZAIRE
Computer & Industrial Engineering
25, Avenue de la Justice
B.P. 12797
KINSHASA, Gombe
Tel 32063
Telex 21552
C.P

ZAMBIA
R.J. Tilbury (Zambia) Ltd
P.O. Box 32792
LUSAKA
Tel 215590
Telex 40128
E

ZIMBABWE
Field Technical Sales (Private) Limited
45, Kelvin Road North
P.O. Box 3458
HARARE
Tel 705 231
Telex 4-122 RH
E.P

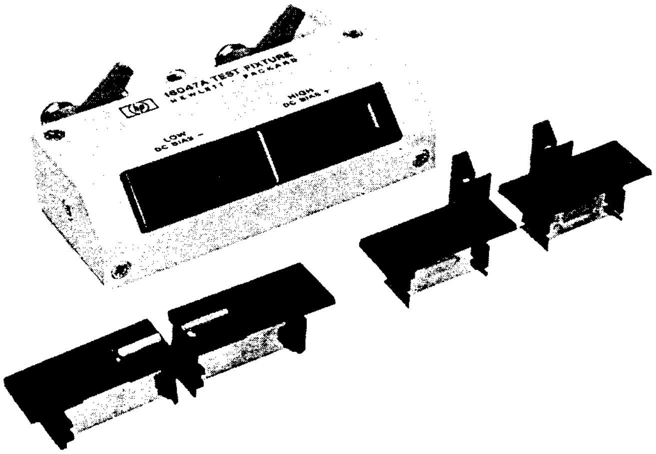
SEPT. 1985

HP 16047A

OPERATING NOTE

TEST FIXTURE

16047A



APR. 1984

HEWLETT
PACKARD

HP 16047A

WARRANTY AND ASSISTANCE

All Hewlett-Packard products are warranted against defects in materials and workmanship. This warranty applies for one year from the date of delivery, or, in the case of certain major components listed in the operating manual, for the specified period. We will repair or replace products which prove to be defective during the warranty period provided they are returned to Hewlett-Packard. No other warranty is expressed or implied. We are not liable for consequential damages.

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

1. INTRODUCTION

This operating note provides complete information on the Hewlett-Packard Model 16047A Test Fixture. The 16047A is shown pictorially on the front-cover, its phyical dimensions are given in Table 1, and typical characteristics related to offset error are given in Table 2. To order additional copies of this operating note, use the part number listsed on the rear cover.

Table 1. Specifications.

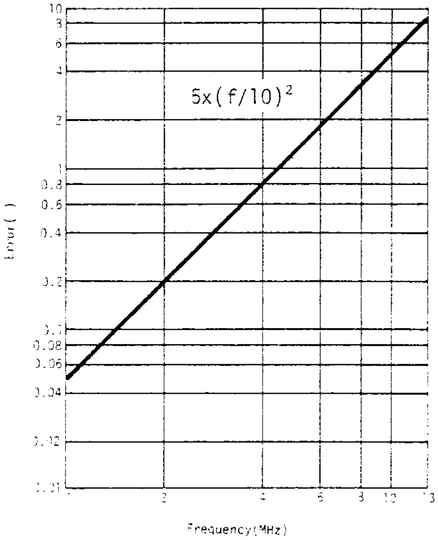
Function:	For use with Hewlett-Packard Models 4274A, 4275A, 4276A, 4277A, and 4192A. Permits connecting axial and radial lead components to the UNKNOWN terminals (4-terminal pair configuration) of the 4274A, 4275A, 4276A, 4277A, or 4192A.
Contact Inserts:	Three kinds: one for axial lead components, one for radial lead components, and one for radial short lead components.
Dimensions in mm (inches):	124(4.9) x 31(1.2) x 62(2.4)
Weight in grams (lbs):	205(0.45)

Table 2. Typical Characteristics.

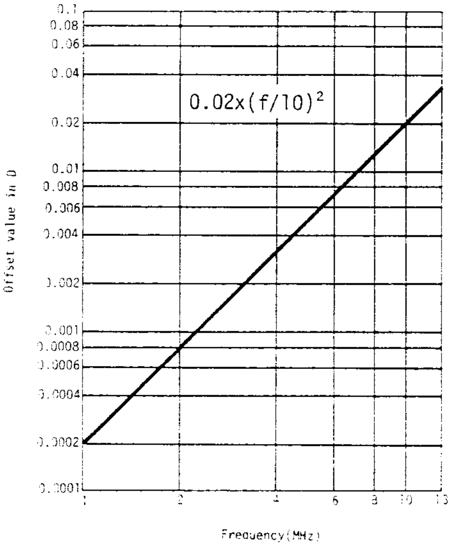
Model	Applicable Measurement Ranges		Incremental error at freq. ≥ 1MHz	
	Parameter value	Measurement frequency	Parameter reading error	Offset value for D
4274A*	Full range	Full range		
4275A			$\pm 5 \times \left(\frac{f}{10}\right)^2 \%$	$\pm 0.02 \times \left(\frac{f}{10}\right)^2$
4192A				

Note: f is the measurement frequency in megahertz. The incremental errors calculated from the equation in the table for measurements at frequencies above 1MHz are additive.

*: The maximum frequency of the 4274A is 100kHz.



Parameter reading error vs frequency.



Offset value in D vs frequency.

Table 2. Typical Characteristics (cont'd).

Model	Applicable Measurement Ranges		Incremental error at 1MHz	
	Parameter value	Measurement frequency	Parameter reading error	Offset value for D
4276A**	Full range	Full range		
4277A			±0.05%	±0.0002

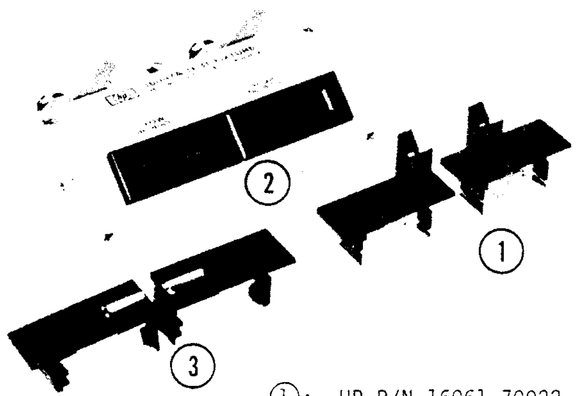
**: The maximum frequency of the 4276A is 20kHz.

2. DESCRIPTION

The Model 16047A Test Fixture is designed for use with the following instruments:

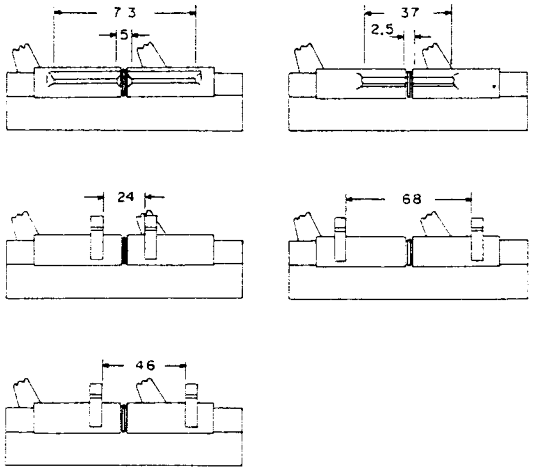
Model 4192A LF Impedance Analyzer
Model 4274A Multi-Frequency LCR Meter
Model 4275A Multi-Frequency LCR Meter
Model 4276A LCZ Meter
Model 4277A LCZ Meter

It is a direct attachment, 4-terminal pair configuration type test fixture for measurements on both axial and radial lead components. Three contact inserts — labelled ①,②, and ③ in Figure 1 — are available: one,①, for measurements on axial components and two, ② and ③, for measurements on radial lead components. DC bias levels up to ±35V can be applied to the device under test (DUT) through this test fixture. When used with the 4276A or 4277A, however, the 16047A can handle dc bias voltages up to ±40V. The dimensions of the contact inserts are given in Figure 2.



①: HP P/N 16061-70022
②: HP P/N 16061-70021
③: HP P/N 16047-65001

Figure 1. 16047A Test Fixture.



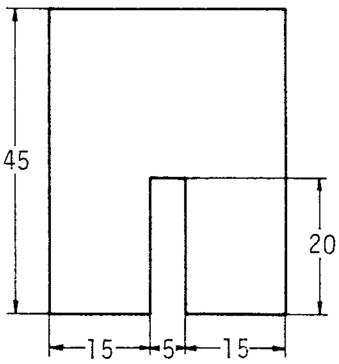
(Unit : mm)

Figure 2. Dimensions of Test Fixture Contacts.

3. ZERO OFFSET ADJUSTMENT

The 16047A has inherent stray capacitance, residual inductance, and residual resistance that affect the accuracy of measured values. To compensate for, or negate, these residuals to minimize measurement error, the instrument's zero offset adjustment procedure should be performed. The procedure is given in Section III of the instrument's operating manual. For SHORT zero offset adjustments a low impedance copper or phosphor bronze shorting bar such as the one shown in Figure 3 is recommended.

(Unit : mm)



Indicated values are in mm.
Thickness is 0.4mm.

Figure 3. Shorting-bar dimensions.

4. OPERATION

Setup and measurement procedure is as follows:

a. Set the CABLE LENGTH switch (4275A, 4277A and 4192A only) on the instrument's front-panel to 0m.

b. Connect the 16047A directly to the UNKNOWN terminals of the instrument.

c. Perform ZERO OFFSET ADJUSTMENT as described in Section III of the instrument's operating manual.

d. Insert the DUT into the test fixture.

5. MAINTENANCE

The internal wiring of the 16047A is shown in Figure 4 and an exploded view — for parts identification — in Figure 5. Do not disassemble any further than shown. Maintenance consists principally of cleaning contacts and replacing worn or damaged parts. Take special care when cleaning contacts. To order parts, use the Hewlett-Packard part numbers listed in Figure 5. If a faulty part is located in an assembly that cannot be disassembled, order the next higher assembly or return the whole device to the nearest Hewlett-Packard Sales/Service Office for repair or replacement.

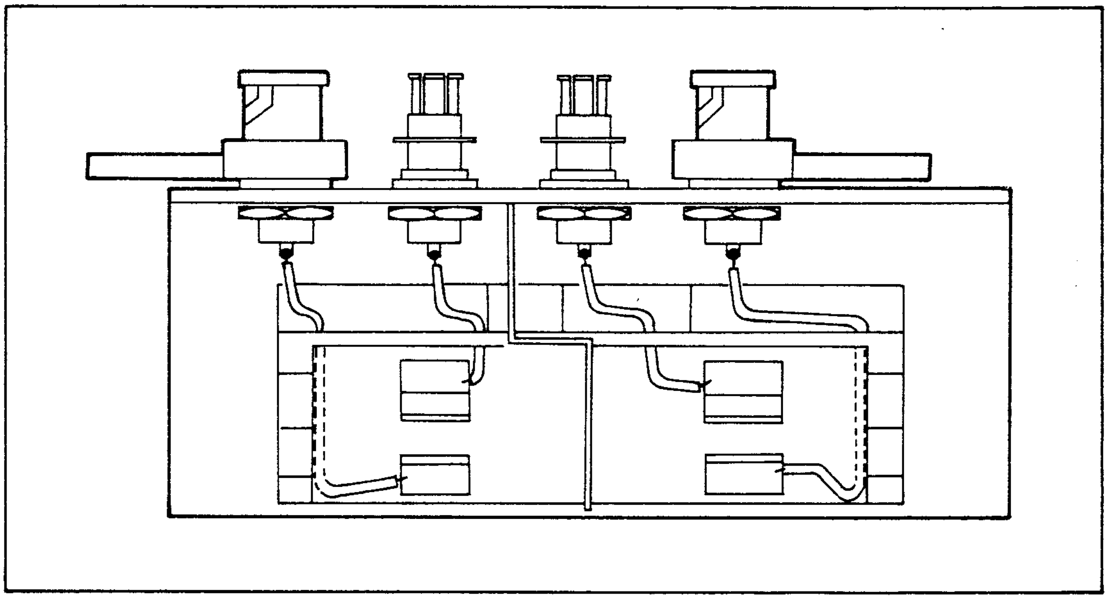


Figure 4. Internal Wiring of 16047A.

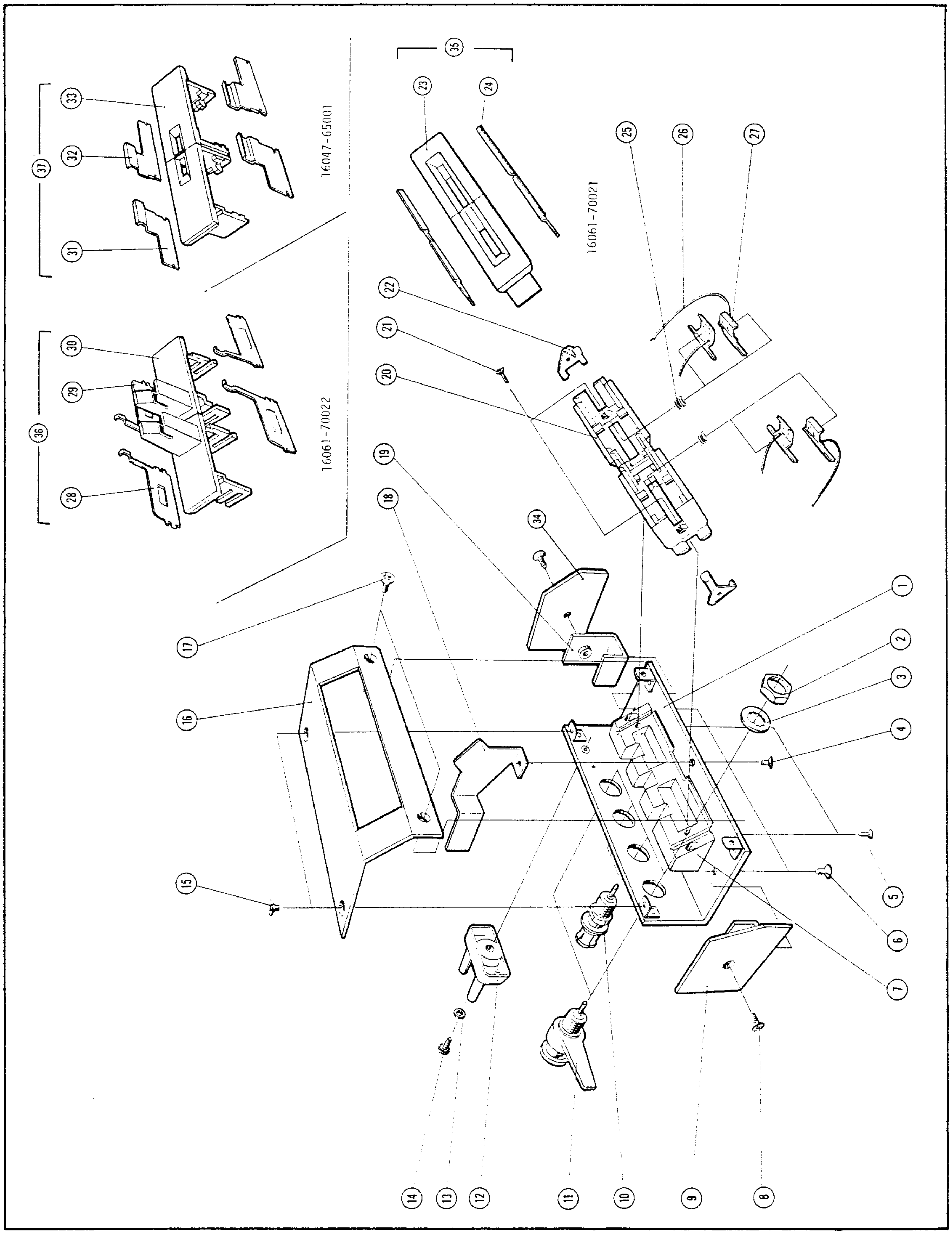


Figure 5. Parts Identification for 16047A (Sheet 1 of 2).

Reference	HP Part No.	Qty	Description
1	16047-04001	1	COVER-BOTTOM
2	2950-0043	4	NUT
3	2190-0016	4	WASHER
4	2200-0140	1	SCREW
5	0624-0203	2	SCREW
6	2360-0192	2	SCREW
7	16061-50022	1	BASE
8	2360-0192	2	SCREW
9	16047-00603	1	SIDE PLATE (LEFT)
10	1250-1798	2	CONNECTOR-BNC
11	16012-7122	2	CONNECTOR-BNC
12	16047-40000	1	STOPPER
13	3050-0229	1	WASHER
14	2200-0105	1	SCREW
15	2360-0192	2	SCREW
16	16047-04000	1	COVER-TOP
17	2360-0192	2	SCREW
18	16047-00600	1	SHIELD PLATE
19	16047-01200	2	ANGLE
20	16061-50023	1	SOCKET
21	0624-0202	2	SCREW
22	16061-10027	2	SPRING
23	16061-50031	1	SOCKET-RADIAL
24	16061-10031	4	CONTACT-RADIAL
25	1460-0343	2	SPRING
26	8150-0447	4	WIRE
27	16061-10026	4	CONTACT
28	16061-10033	2	CONTACT-AXIAL
29	16061-10032	2	CONTACT-AXIAL
30	16061-50032	1	SOCKET-AXIAL
31	16047-00604	2	CONTACT
32	16047-00605	2	CONTACT
33	16047-40001	2	SOCKET
34	16047-00602	1	SIDE PLATE (RIGHT)
35	16061-70021	2	SOCKET ASSEMBLY (㉓ and ㉔)
36	16061-70022	2	SOCKET ASSEMBLY (㉘ , ㉙ and ㉚)
37	16047-65001	2	SOCKET ASSEMBLY (㉛ , ㉜ and ㉝)

Figure 5. Parts Identification for 16047A (Sheet 2 of 2).

M A N U A L   C H A N G E S

4276A

LCZ METER

MANUAL IDENTIFICATION

Model Number: 4276A
Date Printed: JUL. 1983
Part Number: 04276-90000

This supplement contains important information for correcting manual errors and for adapting the manual to instruments containing improvements made after the printing of the manual.

To use this supplement:
Make all ERRATA corrections.
Make all appropriate serial number related changes indicated in the tables below.

SERIAL PREFIX OR NUMBER	MAKE MANUAL CHANGES	SERIAL PREFIX OR NUMBER	MAKE MANUAL CHANGES
2517J01681 and above	1		

► NEW ITEM

► CHANGE 1

Page 2-5, Figure 2-3;

Change the Figure as shown on the next page.

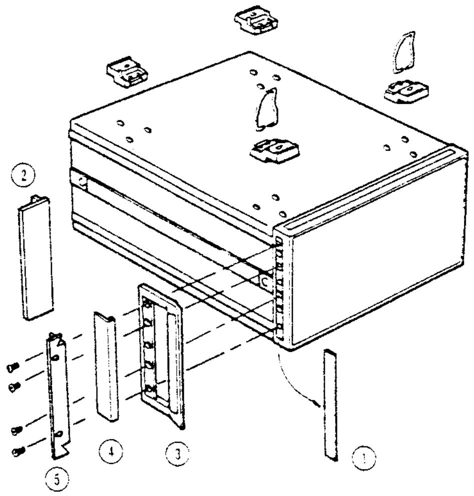
NOTE

Date/Div: May 17, 1985/33

HEWLETT PACKARD

Printed in Japan

Option	Description	Kit Part Number
907	Handle Kit	5061-9690
908	Rack Flange Kit	5061-9678
909	Rack Flange & Handle Kit	5061-9684



1. Remove adhesive-backed trim strips ① from side at right and left front of instrument.

2. HANDLE INSTALLATION : Attach front handle ③ to sides at right and left front of instrument with screws provided and attach trim ④ to handle.

3. RACK MOUNTING : Attach rack mount flange ② to sides at right and left front of instrument with screws provided.

4. HANDLE AND RACK MOUNTING : Attach front handle ③ and rack mount flange ⑤ together to sides at right and left front of instrument with screws provided.

5. When rack mounting (3 and 4 above), remove all four feet (lift bar at inner side of foot, and slide foot toward the bar).

Figure 2-3. Rack Mount Kit.