Errata

Title & Document Type: 4277A LCZ Meter Operating and Service Manual

Manual Part Number: 04277-90000

Revision Date: March 1984

HP References in this Manual

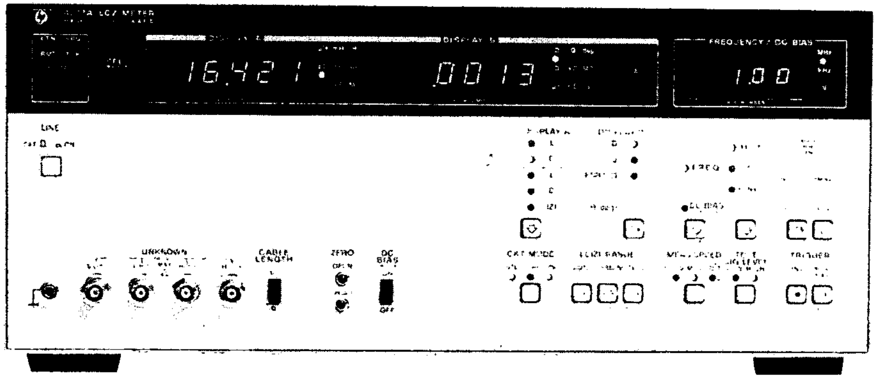
About this Manual

Support for Your Product

Agilent Technologies

OPERATION AND SERVICE MANUAL

4277A
LCZ METER



HEWLETT
PACKARD

HP 4277A

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MANUAL CHANGES

HP 4277A
LCZ Meter

Operation and Service Manual

MANUAL IDENTIFICATION

Model Number: HP 4277A
Date Printed: January 1984
Part Number: 04277-90000

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

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

SERIAL PREFIX OR NUMBER	MAKE MANUAL CHANGES
All	1
2515J02256 and above	2
2515J02255 and below	3

SERIAL PREFIX OR NUMBER	MAKE MANUAL CHANGES

▸ New Item

Preliminary

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

Date/Div: July,19XX/33

HEWLETT PACKARD

PRINTED IN JAPAN

▸CHANGE 1

Page X-X, Section 1 Title, Section 2 Title, Section 3 Title

Change Information

Change	Page	Note	Reference Designator	HP Part Number	Description
1		►C			
	6-15		A5U1	1858-0149	TRANSISTOR ARRAY
			A5U5	1858-0149	TRANSISTOR ARRAY
			A5U6	1858-0149	TRANSISTOR ARRAY
			A5U7	1858-0149	TRANSISTOR ARRAY
	6-16		14	04276-61801	LINE FILTER ASSY
2	6-16	►C	A6BT1	1420-0362	Ni-Cd Battery
	6-3	►C	A1R6	0757-0280	
3	6-16	►C	A6BT1	1420-0362	Ni-Cd Battery
		►A		1400-0757	Battery Clamp (see Service Note 4276A-05)

►: New Item C: Change D: Delete A: Add

Change part numbers as following table.

Change	Former Part Number	New Part Number	Description	Parent Assembly	Qty.
1	0180-1077	0180-4402		04275-66501	5
				04275-66503	7

MANUAL CHANGES

4277A

LCZ METER

MANUAL IDENTIFICATION

Model Number: 4277A
Date Printed: JAN. 1984
Part Number: 04277-90000

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
2517J01271 and above	1		
2228J01030 and above	2		
2515J01618 and above	3		

► NEW ITEM

ERRATA

Page 3-49, Figure 3-22, External Trigger Pulse:
Change the Input Level limits to read as follows.

Input Levels: $V_{IL} \leq 0.4V$
$2.4V \leq V_{IH} \leq 5V$

Page 3-74, Figure 3-32, Internal DC Bias Voltage Monitor (Sheet 1 of 2):
In item 1. (i), change the equation for R to read as follows.

$$R_{\ell}=(V_K-V_H)\cdot R_0/(V_H-V_L)$$

Page 4-A, Table 4-1, Recommended Equipment (Sheet 1 of 2):
Change the Recommended Model for the 61cm test cable from HP 11170B to PN 8120-1839.

Change the Recommended Model for the 30cm test cable from HP 11170A to PN 8220-1838.

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Date/Div: Aug. 14, 1986/33
Page 1 of 3

HEWLETT PACKARD

Printed in Japan

Pages 4-6 and 4-7, Paragraphs 4-9, Test Frequency Accuracy Test, and 4-11, Test Signal Level Accuracy Test:
Under EQUIPMENT, change the model number of the BNC-to-BNC cable from HP 11170A to PN 8120-1838.

Page 5-8, Paragraph 5-21, Test Signal Level Adjustment:
Under EQUIPMENT, change the model number of the BNC-to-BNC cable from HP 11170B to PN 8120-1839.

Page 6-7, Table 6-3, Replaceable Parts:
Change the part numbers and descriptions of A2Q6 through Q10 to read as follows.

Q6 and Q10: 1854-1041, TRANSISTOR NPN
Q2, Q3, and Q4: 1855-0571, TRANSISTOR FET

Page 6-18, Table 6-3, Replaceable Parts:
Change the part number of item 50 to 1510-0130.

Page 8-65, Figure 8-41, A1 LOGIC Board Troubleshooting Flow Diagram:
Delete pin 23 and the associated signature from Signature Set 8-1.

Page 8-67, Figure 8-41, A1 LOGIC Board Troubleshooting Flow Diagram:
In Signature Set 9-2, change the signature of A22U2 pin 15 to 810P.

CHANGE 1

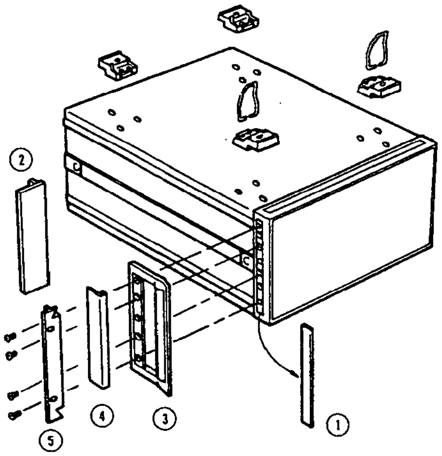
Page 2-5, Figure 2-3;

Change the Figure as shown on the next page.

CHANGE	Page	NOTE	Reference Designation	HP Part Number	Description
2	6-6	▶ C	A2C97	0160-4833	CAPACITOR-FXD .022μF 10%
3	6-6	▶ C	A2C100	0160-5493	CAPACITOR-FXD .1μF 10% 63V

▶: New Item A: Add D: Delete C: Change

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.

MANUAL CHANGES

HP 4277A

LCZ Meter

MANUAL IDENTIFICATION

Model Number: HP 4277A
Date Printed: Not Specified
Part Number: 04277-90000

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To use this supplement
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SERIAL PREFIX OR NUMBER	MAKE MANUAL CHANGES
All	1

SERIAL PREFIX OR NUMBER	MAKE MANUAL CHANGES

► New Item

► Some LCR components used in the HP 4277A have been standardized to decrease the number of similar components. For example, if a single model uses both 6.8kΩ 5% and 6.81kΩ 1% resistors, the standard resistor will be 6.81kΩ 1%.

Change the part numbers in the Replaceable Parts List of Section 6 as given in the table on the next page.

NOTE

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HEWLETT PACKARD

Date/Div: April 1, 1987/33
Page: 1 of 2

PRINTED IN JAPAN

Table 1. Parts Standardization Change

Old Part		New Part	
Part Number	Description	Part Number	Description
0683-1005	Resistor 10Ω 5%	0757-0346	Resistor 10Ω 1%
0683-1015	Resistor 100Ω 5%	0757-0401	Resistor 100Ω 1%
0683-1025	Resistor 1kΩ 5%	0757-0280	Resistor 1kΩ 1%
0683-1035	Resistor 10kΩ 5%	0757-0442	Resistor 10kΩ 1%
0683-1045	Resistor 100kΩ 5%	0757-0465	Resistor 100kΩ 1%
0683-1055	Resistor 1MΩ 5%	0698-8827	Resistor 1MΩ 1%
0683-1515	Resistor 150Ω 5%	0698-3438	Resistor 147Ω 1%
0683-1525	Resistor 1.5kΩ 5%	0757-1094	Resistor 1.47kΩ 1%
0683-1835	Resistor 18kΩ 5%	0698-3136	Resistor 17.8kΩ 1%
0683-2215	Resistor 220Ω 5%	0698-3441	Resistor 215Ω 1%
0683-2225	Resistor 2.2kΩ 5%	0698-0084	Resistor 2.15kΩ 1%
0683-2235	Resistor 22kΩ 5%	0757-0199	Resistor 21.5kΩ 1%
0683-2245	Resistor 220kΩ 5%	0698-3454	Resistor 215kΩ 1%
0683-2715	Resistor 270Ω 5%	0698-3132	Resistor 261Ω 1%
0683-2725	Resistor 2.7kΩ 5%	0698-0085	Resistor 2.61kΩ 1%
0683-2735	Resistor 27kΩ 5%	0698-3159	Resistor 26.1kΩ 1%
0683-3305	Resistor 33Ω 5%	0757-0180	Resistor 31.6Ω 1%
0683-3315	Resistor 330Ω 5%	0698-3444	Resistor 316Ω 1%
0683-3325	Resistor 3.3kΩ 5%	0757-0279	Resistor 3.16kΩ 1%
0683-3335	Resistor 33kΩ 5%	0698-3160	Resistor 31.6kΩ 1%
0683-4705	Resistor 47Ω 5%	0698-4037	Resistor 46.4Ω 1%
0683-4715	Resistor 470Ω 5%	0698-0082	Resistor 464Ω 1%
0683-4725	Resistor 4.7kΩ 5%	0698-3155	Resistor 4.64kΩ 1%
0683-4735	Resistor 47kΩ 5%	0698-3162	Resistor 46.4kΩ 1%
0683-4745	Resistor 470kΩ 5%	0698-3260	Resistor 464kΩ 1%
0683-5605	Resistor 56Ω 5%	0698-0395	Resistor 56.2Ω 1%
0683-5615	Resistor 560Ω 5%	0698-0417	Resistor 562Ω 1%
0683-5635	Resistor 56kΩ 5%	0698-0459	Resistor 56.2kΩ 1%
0683-6805	Resistor 68Ω 5%	0757-0397	Resistor 68.1Ω 1%
0683-6825	Resistor 6.8kΩ 5%	0757-0439	Resistor 6.81kΩ 1%

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.

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.

Herstellerbescheinigung

Hiermit wird bescheinigt, daß das Gerät HP 4277A (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.

Aum: 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 4277A 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.

HEWLETT
PACKARD

OPERATION AND SERVICE MANUAL

MODEL 4277A

LCZ METER

(Including Options 001 and 002)

SERIAL NUMBERS

This manual applies directly to instruments with serial numbers prefixed 2228J.

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

MANUAL PART NO. 04277-90000
Microfiche Part No. 04277-90050

Printed: JAN. 1984

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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 4277A 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 4277A 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 10kHz to 1MHz and provides 701 spot frequencies. Test frequency resolution is 100Hz (maximum), and frequency accuracy is ±0.01% of the selected spot frequency. Frequently used spot frequencies--10kHz, 100kHz, and 1MHz--can be quickly selected by the SPOT key. Test signal level is selectable at 1Vrms (HIGH) or 20mVrms (LOW). The instrument's state-of-the-art 4-terminal pair configuration provides a basic measurement accuracy of 0.1% over a wide measurement range.

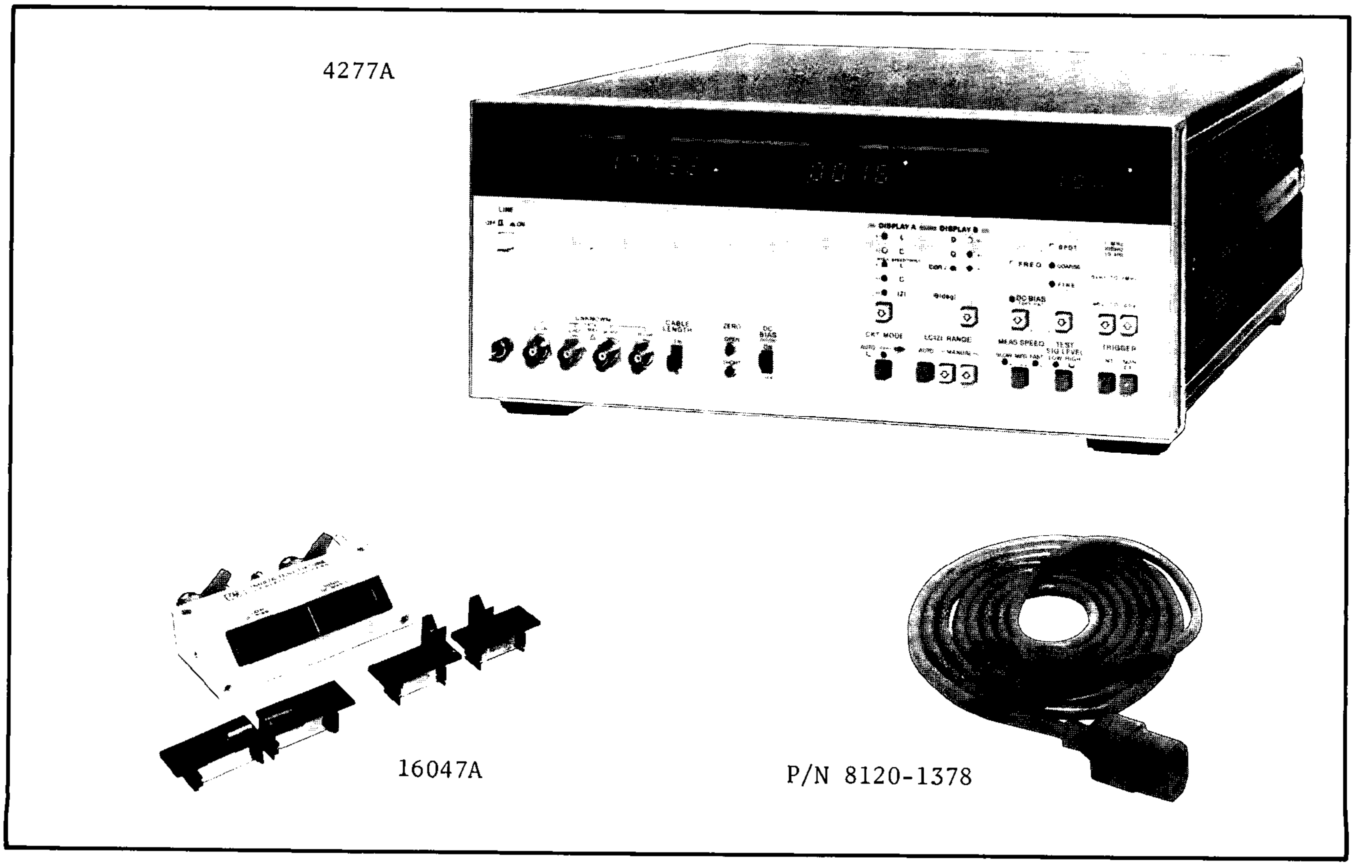


Figure 1-1. Model 4277A and Accessories.

1-6. The 4277A 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 70ms (at 1MHz). FAST mode measurement time is approximately 25 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 35ms (HIGH SPEED C or L, FAST mode, at 1MHz). The 4277A is equipped with a Δ (delta) measurement function to permit temperature dependency or dc bias dependency measurements.

1-7. All instrument operations--measurement, front panel control settings, ranging, triggering, HP-IB, displays, 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 4277A 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 4277A. 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 4277A can send measurement data to an external device (a printer, for example) without a controller.

1-9. The 4277A 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 avaialable. All accessories are useable with HP's other four-terminal-pair type instruments. 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 4277A 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 4277A is shipped from the factory, it meets the specifications listed in Table 1-1.

1-13. SAFETY CONSIDERATIONS

1-14. The Model 4277A 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.

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.

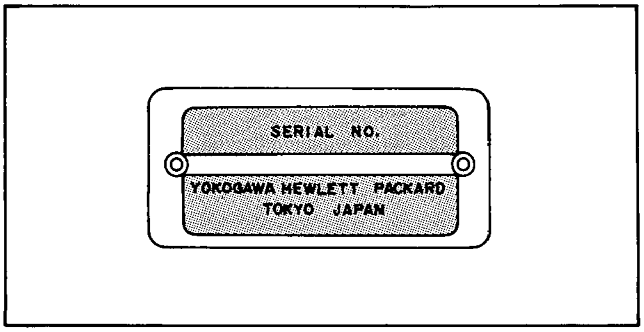


Figure 1-2. Serial Number Plate.

1-21. OPTIONS

1-22. Options are modifications to the standard instrument that implement the user's special requirements for minor functional changes. The 4277A has two options:

Option 001 : Internal DC Bias Supply (0 -- ±40V)

Option 002 : Comparator/Handler Interface

1-23. OPTION 001

1-24. Option 001 equips the standard 4277A 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 4277A 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 open collector (TTL level voltages) 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.

Table 1-1. Specifications (Sheet 1 of 17)

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 (at 1MHz only), HIGH SPEED L (at 1MHz only), Δ (deviation).

Measurement Circuit Modes:
Auto, Series (), and Parallel ()

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 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:
4-terminal-pair configuration with guard terminal

Ranging Modes:
Auto and Manual (UP/DOWN keys)

Test Frequencies:

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

Frequency Control Modes:
SPOT (10kHz, 100kHz, 1MHz)
COARSE (10 freq. points/decade)
FINE (maximum resolution)

Frequency Accuracy: ±0.01%

Test Signal Level:
HIGH (1Vrms) or LOW (20mVrsm)

Level Accuracy:

Test Signal Level	Test Frequency	
	1MHz	10kHz to 995kHz
HIGH	±10%	±10%
LOW		±15%

Output Impedance: 100Ω ±10%

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

Self Test:
Checks the 4277A'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.

Table 1-1. Specifications (Sheet 2 of 17)

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:

10k, 20.2k, 50.5k, 100k, 202k, 505k, 700k, 900k, and 1MHz

Compensation at other frequencies is automatically done by secondary interpolation.

Maximum Offset Values:

C: Up to 20pF } (open)
G: Up to 2 μs
L: up to 2 μH } (short)
R: up to 2Ω

CABLE LENGTH:

1m or 0m. Use 0m for direct attachment type test fixtures; use 1m for test leads.

Trigger:

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

External DC Bias:

Up to ±40V dc can be applied to the DUT from an external voltage source connected to the EXT INT/INT MONITOR BNC connector on the rear panel. Output impedance is 1040Ω±10%.

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, DC BIAS (ON/OFF switch, and CABLE LENGTH switch) and all 16064A Comparator/Handler-Interface settings (option 002).

Data Output:

Parameter measured
Equivalent circuit mode
Display status
Measured values
Comparator output

Output Format:

ASCII format or Binary format

Continuous Memory:

Memorizes all front panel control settings (except DC BIAS voltage setting), zero offset adjustment data, Δ 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:

Minimum 30 minutes

Ambient Temperature:

23 °C±5 °C (at 0 °C to 55 °C, error doubles)

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:

75VA max. with any option

Dimensions:

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

Weight: Approximately 8.5kg

Table 1-1. Specifications (Sheet 3 of 17)

Capacitance Measurement Accuracy

C-D Measurement Accuracy:

C Accuracy: ±[(% of reading) + (error in farads) + (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 10kHz, 100kHz, or 1MHz. Use Table A-2 for all other frequencies.

Note: Accuracies obtained from Tables A-1 and A-2 are valid only for measurements made with the CABLE LENGTH switch set to 0m. When the CABLE LENGTH switch is set to 1m, add the errors listed in Table A-3 to the accuracies obtained from Tables A-1 and A-2.

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

Capacitance Range	Test Frequency		
	10kHz	100kHz	1MHz
10μF		▨	▨
1μF		(1 + α)% + $\underline{3}$ 1% + .03 + $\underline{2}$	▨
100nF	.1% + 30pF + $\underline{5}$ .5% + .0005/α + .0006 + $\underline{5}$	(.3 + .5α)% + $\underline{3}$ .3% + .003α + .002 + $\underline{3}$	
10nF	.1% + 3pF + $\underline{5}$ .5% + .0005/α + .0006 + $\underline{5}$	.1% + 3pF + $\underline{5}$ .3% + .0005/α + .0006 + $\underline{5}$	(.3 + .5α)% + $\underline{3}$ .3% + .003α + .002 + $\underline{3}$
1nF	.1% + .3pF + $\underline{5}$ .5% + .0005/α + .0006 + $\underline{5}$	.1% + .3pF + $\underline{5}$ .3% + .0005/α + .0006 + $\underline{5}$	.1% + $\underline{5}$* .3% + .0005/α + .0006 + $\underline{5}$
100pF	.3% + 30fF + $\underline{10}$ .5% + .0005/α + .003 + $\underline{5}$	.1% + 30fF + $\underline{5}$ .3% + .0005/α + .0006 + $\underline{5}$	
10pF	▨	.3% + 3fF + $\underline{10}$ .5% + .0005/α + .003 + $\underline{5}$	
1pF	▨	▨	.3% + .3fF + $\underline{10}$ .5% + .0005/α + .003 + $\underline{5}$

*: When LOW test signal level (20mVrms) is used, C accuracy is as follows:

.1% + $\underline{10}$

Table 1-1. Specifications (Sheet 4 of 17)

Table A-2. C-D Accuracies

Capacitance Range	Test Frequency Range					
	10.1kHz to 20kHz	20.2kHz to 50kHz	50.5kHz to 99.5kHz	101kHz to 200kHz	202kHz to 500kHz	505kHz to 995kHz
10µF		▨	▨	▨	▨	▨
1µF		(1 + α)% + $\underline{3}$ 1% + .03 + $\underline{2}$			▨	▨
100nF	.1% + 80pF + $\underline{5}$ .3% + .0005/α + .0016 + $\underline{5}$	(.3 + .5α)% + $\underline{3}$ .3% + .003α + .002 + $\underline{3}$				
10nF	.1% + 8pF + 5 .3% + .0005/α + .0016 + $\underline{5}$	.1% + 12pF + $\underline{5}$ .3% + .0005/α + .0024 + $\underline{5}$	.1% + 6pF + $\underline{5}$ .3% + .0005/α + .0012 + $\underline{5}$	.1% + 8pF + $\underline{5}$ .3% + .0005/α + .0016 + $\underline{5}$		
1nF	.1% +.8pF + $\underline{5}$ .3% + .0005/α + .0016 + $\underline{5}$	.1% + 1.2pF + $\underline{5}$ .3% + .0005/α + .0024 + $\underline{5}$	.1% + .6pF + $\underline{5}$ .3% + .0005/α + .0012 + $\underline{5}$	.1% + .8pF + $\underline{5}$ .3% + .0005/α + .0016 + $\underline{5}$	.1% + 1.2pF + $\underline{5}$ .3% + .0005/α + .0024 + $\underline{5}$	.1% + .6pF + $\underline{5}$ .3% + .0005/α + .0012 + $\underline{5}$
100pF	.3% + 80fF + $\underline{10}$ .5% + .0005/α + .003 + $\underline{5}$	.1% + .12pF + $\underline{5}$ .3% + .0005/α + .0024 + $\underline{5}$	.1% + 60fF + $\underline{5}$ .3% + .0005/α + .0012 + $\underline{5}$	.1% + 80fF + $\underline{5}$ .3% + .0005/α + .0016 + $\underline{5}$	.1% + .12pF + 5 .3% + .0005/α + .0024 + $\underline{5}$	.1% + 60fF + $\underline{5}$ .3% + .0005/α + .0012 + $\underline{5}$
10pF	▨	.3% + 12fF + $\underline{10}$ .5% + .0005/α + .003 + $\underline{5}$	.3% + 6fF + $\underline{10}$ .5% + .0005/α + .003 + $\underline{5}$	.3% + 8fF + $\underline{10}$ .5% + .0005/α + .003 + $\underline{5}$	.1% + 12fF + $\underline{5}$ .3% + .0005/α + .0024 + $\underline{5}$	.1% + 6fF + $\underline{5}$ .3% + .0005/α + .0012 + $\underline{5}$
1pF	▨	▨	▨	▨	.3% + 1.2fF + $\underline{10}$ .5% + .0005/α + .003 + $\underline{5}$	.3% + .6fF + $\underline{10}$ .5% + .0005/α + .003 + $\underline{5}$

10kHz 20kHz 50kHz 100kHz 200kHz 500kHz 1MHz

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.

Table A-3. Additional Measurement Error for C-D at 1MHz

C Range	1MHz
100nF	.1% of reading .001/α
10nF	
1nF	.06% of reading .0003α
100pF	.03% of reading .0002α
10pF	.05% of reading .0003α
1pF	.4% of reading .001α

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

(1) CABLE LENGTH: 0m

(2) Test Signal Level: HIGH (1Vrms)

(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 (20mVrms) is used.

Note 1: Table A-3 is applicable under the following conditions:

(1) Test Frequency: 1MHz

(2) CABLE LENGTH: 1m

(3) Test Signal Level: HIGH (1Vrms)

(4) Sample's D Value: ≤0.1

(5) Test Leads: Model 16048A or 16048B

(6) 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 (20mVrms) is used.

Table 1-1. Specifications (Sheet 5 of 17)

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 3-19.

HIGH SPEED C Measurement Accuracy:

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

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

Note: Table A-1 is applicable under the following condition:

(1) Sample's D Value: ≤0.01

C-ESR/G Measurement Accuracy:

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

ESR Accuracy: ±[(% of reading) + (ESR error in ohms) + (number of counts)], 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 10kHz, 100kHz, or 1MHz. 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-7.

Note: Accuracies obtained from Tables A-4 and A-5 are valid only for measurements made with the CABLE LENGTH switch set to 0m. When the CABLE LENGTH switch is set to 1m, add the errors listed in Table A-6 to the accuracies obtained from Tables A-4 and A-5.

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

Table 1-1. Specifications (Sheet 6 of 17)

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

ESR/G Range		Test Frequency		
		10kHz	100kHz	1MHz
ESR	1MΩ	ESR: See Note 1.		
G	10μS	G : .3% + 4αnS + 20nS + $\underline{5}$		
ESR	100kΩ	ESR: See Note 1.		
G	100μS	G : .1% + 60αnS + 20nS + $\underline{5}$		
ESR	10kΩ	ESR: See Note 1.		
G	1mS	G : .1% + .6αμS + 0.2μS + $\underline{5}$		
ESR	1kΩ	ESR: See Note 1.		
G	10mS	G : .1% + 6αμS + 2μS + $\underline{5}$		
ESR	100Ω	ESR: .2% + 30αmΩ + 20mΩ + $\underline{5}$		
G	100mS	G : See Note 2.		
ESR	10Ω	ESR: .5% + 5αmΩ + 6mΩ + $\underline{5}$		
G	1S	G : See Note 2.		

Table A-5. C-ESR/G Accuracies

ESR/G Range		Test Frequency Range			
		10.1kHz to 20kHz	20.2kHz to 99.5kHz	101kHz to 200kHz	202kHz to 995kHz
ESR	1MΩ	See Note 1.	See Note 1.	See Note 1.	See Note 1.
G	10μS	.3% + 12αnS + 60nS + $\underline{5}$	.3% + 6αnS + 30nS + $\underline{5}$	.3% + 12αnS + 60nS + $\underline{5}$	.3% + 6αnS + 30nS + $\underline{5}$
ESR	100kΩ	See Note 1.	See Note 1.	See Note 1.	See Note 1.
G	100μS	.1% + .18αμS + 60nS + $\underline{5}$	.1% + 90αnS + 30nS + $\underline{5}$	.1% + .18αμS + 60nS + $\underline{5}$	.1% + 90αnS + 30nS + $\underline{5}$
ESR	10kΩ	See Note 1.	See Note 1.	See Note 1.	See Note 1.
G	1mS	.1% + 1.8αμS +.6 μS + $\underline{5}$	.1% + .9αμS + .3μS + $\underline{5}$	.1% + 1.8αμS +.6μS + $\underline{5}$	.1% +.9αμS + .3μS + $\underline{5}$
ESR	1kΩ	See Note 1.	See Note 1.	See Note 1.	See Note 1.
G	10mS	.1% + 18αμS + 6μS + $\underline{5}$	.1% + 9αμS + 3μS + $\underline{5}$	.1% + 18αμS + 6μS + $\underline{5}$	.1% + 9αμS + 3μS + $\underline{5}$
ESR	100Ω	.2% + 30αmΩ + 60mΩ + $\underline{5}$	.2% + 30αmΩ + 30mΩ + $\underline{5}$	.2% + 30αmΩ + 60mΩ + $\underline{5}$	.2% + 30αmΩ + 30mΩ + $\underline{5}$
G	100mS	See Note 2.	See Note 2.	See Note 2.	See Note 2.
ESR	10Ω	.5% + 5αmΩ + 18mΩ + $\underline{5}$	.5% + 5αmΩ + 18mΩ + $\underline{5}$	.5% + 5αmΩ + 18mΩ + $\underline{5}$	.5% + 5αmΩ + 9mΩ + $\underline{5}$
G	1S	See Note 2.	See Note 2.	See Note 2.	See Note 2.

10kHz 20kHz 100kHz 200kHz 1MHz

Table 1-1. Specifications (Sheet 7 of 17)

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) CABLE LENGTH: 0m

(2) Test Signal Level: HIGH (1Vrms)

(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 (20mVrms) is used.

Table A-6. Additional Measurement Error for ESR and G at 1MHz

ESR/G Range	1MHz
10Ω	.1% of reading
100Ω	.06% of reading
10mS	.06% of reading + 3αµS
1mS	.04% of reading of .2αµS
100µS	.05% of reading + 30αnS
10µS	.4% of reading + 10αnS

Note 1: Table A-6 is applicable under the following conditions:

(1) Test Frequency: 1MHz

(2) CABLE LENGTH: 1m

(3) Test Signal Level: HIGH (1Vrms)

(4) Sample's D Value: ≤0.1

(5) Test Lead: Model 16048A or 16048B

(6) 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 (20mVrms) is used.

Table 1-1. Specifications (Sheet 8 of 17)

Table A-7. ESR/G Range Selection

Capacitance Range		Test Frequency Range		
		10kHz to 20kHz	20.2kHz to 200kHz	202kHz to 1MHz
10μF	ESR		▨	▨
	G		▨	▨
1μF	ESR		10Ω 1S	▨
	G			▨
100nF	ESR		100Ω 100mS	
	G			
10nF	ESR		1kΩ 10mS	
	G			
1nF	ESR		10kΩ 1mS	
	G			
100pF	ESR		100kΩ 100μS	
	G			
10pF	ESR	▨	1MΩ 10μS	
	G	▨		
1PF	ESR	▨	▨	
	G	▨	▨	

Table 1-1. Specifications (Sheet 9 of 17)

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 10kHz, 100kHz, or 1MHz. Use Tables B-2 for all other frequencies.

Note: Accuracies obtained from Tables B-1 and B-2 are valid only for measurements made with the CABLE LENGTH switch set to 0m. When the CABLE LENGTH switch is set to 1m, add the errors listed in Table B-3 to the accuracies obtained from Tables B-1 and B-2.

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

Inductance Range	Test Frequency		
	10kHz	100kHz	1MHz
1H	1% + 5 1% + .02 + 3	▨	▨
100mH			▨
10mH			
1mH	.2% + .4µH + 5 .3% + .0005/α + .0008 + 5	.5% + 5 .5% + .005α + .005 + 5	
100µH	.3% + 40nH + 10 .5% + .0005/α + .005 + 5	.2% + 40nH + 5 .3% + .0005/α + .0008 + 5	
10µH	▨	.3% + 4nH + 10 .5% + .0005/α + .005 + 5	.2% + 4nH + 5 .3% + .0005/α + .0008 + 5
1µH	▨	▨	.3% + .4nH + 10 .5% + .0005/α + .005 + 5

Table 1-1. Specifications (Sheet 10 of 17)

Table B-2. L-D Accuracies

<table>
<tr><th rowspan="2">Inductance Range</th><th colspan="6">Test Frequency Range</th></tr>
<tr><th>10.1kHz to 20kHz</th><th>20.2kHz to 50kHz</th><th>50.5kHz to 99.5kHz</th><th>101kHz to 200kHz</th><th>202kHz to 500kHz</th><th>505kHz to 995kHz</th></tr>
<tr><td>1H</td><td>▨</td><td>▨</td><td>▨</td><td>▨</td><td>▨</td><td>▨</td></tr>
<tr><td>100mH</td><td colspan="3" rowspan="2">1% + 5
1% + .02 + 3</td><td>▨</td><td>▨</td><td>▨</td></tr>
<tr><td>10mH</td><td colspan="3" rowspan="2">1% + 5
1% + .02 + 3</td></tr>
<tr><td>1mH</td><td colspan="3">.5% + 5
.5% + .005α + .005 + 5</td></tr>
<tr><td>100µH</td><td>.2% + .12µH + 5
.3% + .0005/α + .0024 + 5</td><td>.2% + 80nH + 5
.3% + .0005/α + .0016 + 5</td><td>.2% + 60nH + 5
.3% + .0005/α + .0012 + 5</td><td colspan="3">.5% + 5
.5% + .005α + .005 + 5</td></tr>
<tr><td>10µH</td><td>.3% + 12nF + 10
.5% + .0005/α + .005 + 5</td><td>.3% + 8nH + 10
.5% + .0005/α + .005 + 5</td><td>.3% + 6nH + 10
.5% + .0005/α + .005 + 5</td><td>.2% + 12nH + 5
.3% + .0005/α + .0024 + 5</td><td>.2% + 8nH + 5
.3% + .0005/α + 0.0016 + 5</td><td>.2% + 6nH + 5
.3% + .0005/α + .0012 + 5</td></tr>
<tr><td>1µH</td><td>▨</td><td>▨</td><td>▨</td><td>.3% + 1.2nH + 10
.5% + .0005/α + .005 + 5</td><td>.3% + .8nH + 10
.5% + .0005/α + .005 + 5</td><td>.3% + .6nH + 10
.5% + .0005/α + .005 + 5</td></tr>
</table>

10kHz 20kHz 50kHz 100kHz 200kHz 500kHz 1MHz

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 L value 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) CABLE LENGTH: 0m

(2) Test Signal Level: HIGH (1Vrms)

(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 (20mVrms) is used.

Table B-3. Additional Measurement Error for L and D at 1MHz

L Range	1MHz
10mH	.1% of reading .001/α
1mH	
100µH	
10µH	.06% of reading .0003α
1µH	.1% of reading .001α

Note 1: Table B-3 is applicable under the following conditions:

(1) Test Frequency: 1MHz

(2) CABLE LENGTH: 1m

(3) Test Signal Level: HIGH (1Vrms)

(4) Sample's D Value: ≤ 0.1

(5) Test Lead: Model 16048A and 16048B

(6) 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 (20mVrms) is used.

Table 1-1. Specifications (Sheet 11 of 17)

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 3-19.

HIGH SPEED L Measurement Accuracy:

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

Note: HIGH SPEED L accuracy is specified in the range enclosed in the dotted line in Table B-1.

Note: Table B-1 is applicable under the following condition:

(1) Sample's D Value: ≤ 0.01

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 10kHz, 100kHz, or 1MHz. 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-7.

Note: Accuracies obtained from Tables B-4 and B-5 are valid only for measurements made with the CABLE LENGTH switch set to 0m. When the CABLE LENGTH switch is set to 1m, add the errors listed in Table B-6 to the accuracies obtained from Tables B-4 and B-5.

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

Table 1-1. Specifications (Sheet 12 of 17)

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

ESR/G Range		Test Frequency		
		10kHz	100kHz	1MHz
ESR	100kΩ	ESR: See Note 1.		
G	100µS	G : 1% + 50αnS + 40nS + $\underline{5}$		
ESR	10kΩ	ESR: See Note 1.		
G	1mS	G : 1% + .5αµS + .4µS + $\underline{5}$		
ESR	1kΩ	ESR: See Note 1.		
G	10mS	G : .3% + 5αµS + 2µS + $\underline{5}$		
ESR	100Ω	ESR: .1% + .05αΩ + $\underline{5}$		
G	100mS	G : See Note 2.		
ESR	10Ω	ESR: .3% + .5αΩ + $\underline{5}$		
G	1S	G : See Note 2.		

Table B-5. L-ESR/G Accuracies

ESR/G Range		Test Frequency Range	
		10.1kHz to 99.5kHz	101kHz to 995kHz
ESR	100kΩ	ESR: See Note 1.	
G	100µS	G : 1% + 50αnS + 60nS + $\underline{5}$	
ESR	10kΩ	ESR: See Note 1.	
G	1mS	G : 1% + .5αµS + .6µS + $\underline{5}$	
ESR	1kΩ	ESR: See Note 1.	
G	10mS	G : .3% + 5αµS + 3µS + $\underline{5}$	
ESR	100Ω	ESR: .1% + 50αmΩ + 30mΩ + $\underline{5}$	
G	100mS	G : See Note 2.	
ESR	10Ω	ESR: .3% + 5αmΩ + 6mΩ + $\underline{5}$	
G	1S	G : See Note 2.	

Table 1-1. Specifications (Sheet 13 of 17)

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 ±[2 (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) CABLE LENGTH: 1m

(2) Test Signal Level: HIGH (1Vrms)

(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 (20mVrms) is used.

Table B-6. Additional Measurement Error for ESR and G at 1MHz

ESR/G	1MHz
10Ω	.1% of reading + 10αmΩ
100Ω	.06% of reading + 30αmΩ
10mS	.1% of reading
1mS	
100μS	

Note 1: Table B-6 is applicable under the followig conditions:

(1) Test Frequency: 1MHz

(2) CABLE LENGTH: 1m

(3) Test Signal Level: HIGH (1Vrms)

(4) Sample's D Value: ≤ 0.1

(5) Test Lead: Model 16048A or 16048B

(6) 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 (20mVrms) is used.

Table 1-1. Specifications (Sheet 14 of 17)

Table B-7. ESR/G Range Selection

Inductance Range		Test Frequency Range		
		10kHz	10.1kHz to 100kHz	101kHz to 1MHz
1H	ESR		▨	▨
	G		▨	▨
100mH	ESR		100kΩ	▨
	G		100μS	▨
10mH	ESR		10kΩ	
	G		1mS	
1mH	ESR		1kΩ	
	G		10mS	
100μH	ESR		100Ω	
	G		100mS	
10μH	ESR	▨	10Ω	
	G	▨	1S	
1μH	ESR	▨	▨	
	G	▨	▨	

Table 1-1. Specifications (Sheet 15 of 17)

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 10kHz, 100kHz, or 1MHz. Use Table C-2 for all other frequencies.

Note: Accuracies obtained from Tables C-1 and C-2 are valid only for measurements made with the CABLE LENGTH switch set to 0m. When the CABLE LENGTH switch is set to 1m, add the errors listed in Table C-3 to the accuracies obtained from Tables C-1 and C-2.

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

|Z| Range	Test Frequency		
	10kHz	100kHz	1MHz
1MΩ	2% + 3 3° + 3α° + 2		
100kΩ	.1% + .2α% + 3 .3° + .3α° + 2		
10kΩ			
1kΩ			
100Ω	.1% + 5 .1° + .1/α° + 2		
10Ω	.3% + 10 .3° + .2/α° + 2		

Table C-2. |Z| - θ Accuracies

|Z| Range	Test Frequency Range	
	10.1kHz to 99.5kHz	101kHz to 995kHz
1MΩ	2% + 3 3° + 3α° + 2	
100kΩ	.1% + .2α% + 3 .3° + .3α° + 2	
10kΩ		
1kΩ		
100Ω	.1% + 5 .1° + .1/α° + 2	
10Ω	.3% + 10 .3° + .2/α° + 2	

Table 1-1. Specifications (Sheet 16 of 17)

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

|Z| Accuracy
θ Accuracy

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 applicable under the following conditions:

(1) CABLE LENGTH: 0m

(2) Test Signal Level: HIGH (1Vrms)

(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 (20mVrms) is used.

Table C-3. Additional Measurement Error for |Z| and θ at 1MHz

|Z| Range	1MHz
1MΩ	.5% .1/α°
100kΩ	.1% .1/α°
10kΩ	
1kΩ	
100Ω	.06% .03α°
10Ω	.1% .1α°

Note 1: Table C-3 is applicable under the following conditions:

(1) Test Frequency: 1MHz

(2) CABLE LENGTH: 0m

(3) Test Signal Level: HIGH (1Vrms)

(4) Sample's D Value: ≤ 0.1

(5) Test Lead: Model 16048A and 16048B

(6) 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 (20mVrms) is used.

Table 1-1. Specifications (Sheet 17 of 17)

OPTIONS

Option 001:

Internal DC Bias. Equips the standard 4277A 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 - 40.0V	100mV	23°C±5°C	±(0.5% of rdg + 35mV)
		0°C - 55°C	±(1% of rdg + 70mV)
.00 - 9.99V	10mV	23°C±5°C	±(0.3% of rdg + 10mV)
		0°C - 55°C	±(1% of rdg + 20mV)
-9.99 - -.01V	10mV	23°C±5°C	±(1% of rdg + 10mV)
		0°C - 55°C	±(2% of rdg + 20mV)
-40.0 - -10.0V	100mV	23°C±5°C	±(1% of rdg + 35mV)
		0°C - 55°C	±(2% of rdg + 70mV)

Output Impedance: 1040Ω±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:

Voltage Range	Output Current
0 - ±25V	5mAmax.
±25 - ±40V	1mAmax.

Note: Measurement accuracies are guaranteed when output current is maximum.

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 (open-collectors, TTL). 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

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.

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

Supplemental Performance Characteristics

Measurement Accuracies:

Applicable at all test frequencies except 1MHz

Additional Error for 1m CABLE LENGTH Mode:

Add the errors listed in Table 1.

Table 1.

Measurement Function	Additional Error
L, C, $\|Z\|$	$.05f^2$% of reading
D	$.0005\alpha f$
θ	$.05\alpha f°$
ESR, G	$5\alpha f \times 10^{\beta-4}$ counts

where,

α : Full-scale factor
β : Number of display digits
f : Test frequency in MHz

Note: Error doubles when LOW test signal level (20mVrms) is used.

Use Table 2 for C measurements on the 1pF range.

Table 2.

Measurement Parameter	Additional Error
C	$.4f^2$% of reading
D	$\alpha f \times 10^{-3}$
ESR, G	$10\alpha f$ counts

α : Full-scale factor
β : Number of display digits
f: Test frequency in MHz

Note: Table 2 does not apply when LOW test signal level (20mVrms) is used.

Use Table 3 for $|Z|$ measurements on the 1MΩ range.

Table 3.

Measurement Function	Additional Error
$\|Z\|$	f^2% of reading
θ	$.1\alpha f°$

α : Full-scale factor
f: Test frequency in MHz

Note: Table 2 does not apply when LOW test signal level (20mVrms) is used.

Use Table 4 when 2-meter cables are used to connect the DUT to the UNKNOWN terminals.

Table 4.

Measurement Function	Additional Error
L, C, $\|Z\|$	$.2f^2$% of reading
D	$.002\alpha f$
θ	$.2\alpha f°$
ESR, G	$20\alpha f \times 10^{\beta-4}$ counts

α : Full-scale factor
β : Number of display digits
f: Test frequency in MHz

Note: Table 4 does not apply when

(1) C measurement is made on the 1pF range.

(2) C measurement is made on the 10pF range and LOW test signal level is used.

(3) $|Z|$ measurement is made on the 1MΩ range.

Note: Error doubles when LOW test signal level (20mVrms) is used.

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

Additional Measurement Error of Test Fixtures:
Maximum additional errors attributable to the test fixtures:

Model	Residual Impedance
16047A, 16047C, 16048A, 16048B, 16048D, 16065A	-
16048C	C<App. 5pF L<App. 200nH R<App. 10mΩ
16034B	C<App. 0.02pF L<App. 30nH R<App. 50mΩ

Additional Measurement Error when D>0.01:
Add 5D% (when LOW test signal level is used, 10D%) to the accuracies for HIGH SPEED C and HIGH SPEED L.

Additional Measurement Error when D > 0.1:
Multiply C, L, or D accuracy by $(1 + D^2)$

Settling Time after measurement range change:
Approximately 60ms

Settling Time after frequency change:
Approximately 300ms

Settling Time after Test Signal Level Change:
Approximately 60ms

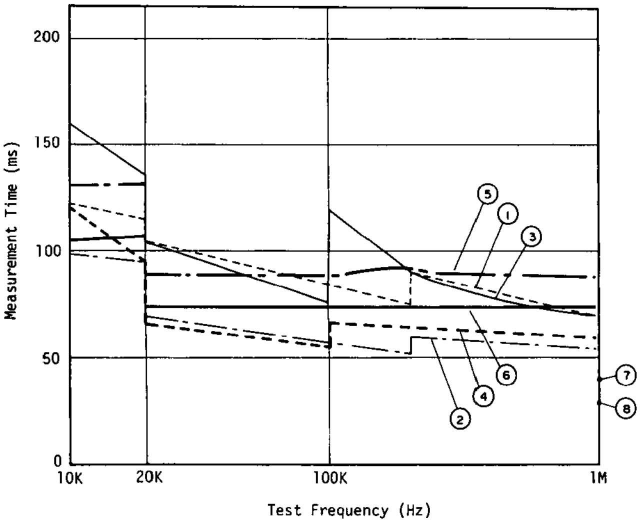
Test Signal Settling Time in DC Bias applications:
The same as dc bias voltage settling time

DC Bias Voltage Settling Time:
Typical value for C measurement (C < 2000pF)

Bias Voltage	Settling Time
99% of setting	7.5ms
99.9% of setting	25ms
99.99% of setting	40ms

Continuous Memory: Approximately 2 weeks (at 23 °C±5 °C)

Measurement Time:
Typical characteristics are shown in the figure below:



Number	Measurement Function	Measurement Speed Mode
1	C	MED
2	C	FAST
3	L	MED
4	L	FAST
5	Z	MED
6	Z	FAST
7	HIGH SPEED C HIGH SPEED L	MED
8	HIGH SPEED C HIGH SPEED L	FAST

1-30. ACCESSORIES SUPPLIED

1-31. The standard HP Model 4277A 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

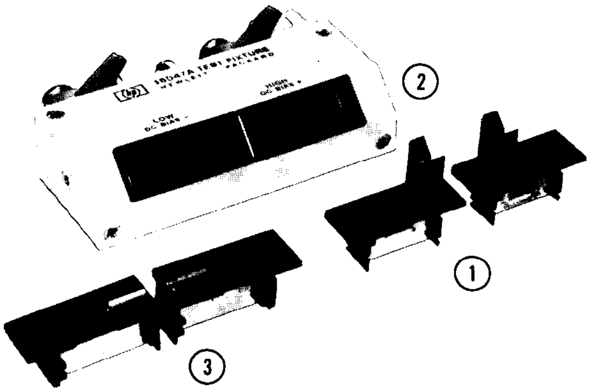
1-32. ACCESSORIES AVAILABLE

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

<table>
<tr><th>Model</th><th>Description</th></tr>
<tr><td>

16047A (furnished)



</td><td>

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)

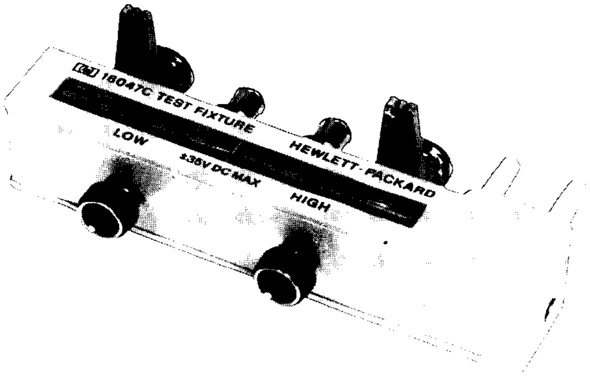
② For general radial-lead components,
(HP P/N: 16061-70021)

③ For radial short-lead components,
(HP P/N: 16047-65001)

DC bias up to ±40V* can be applied.

</td></tr>
<tr><td>

16047C



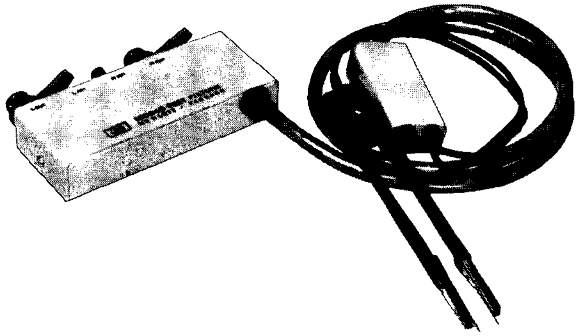
</td><td>

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.

</td></tr>
<tr><td>

16034B



</td><td>

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

</td></tr>
</table>

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

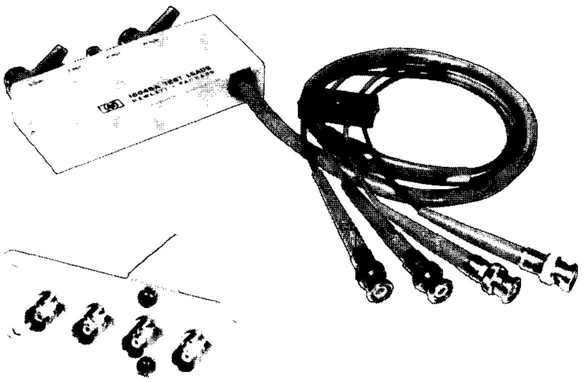
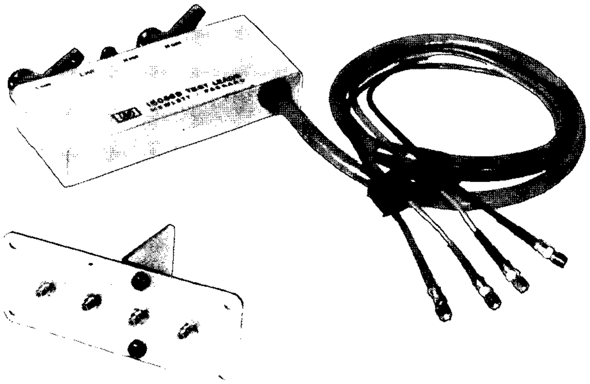
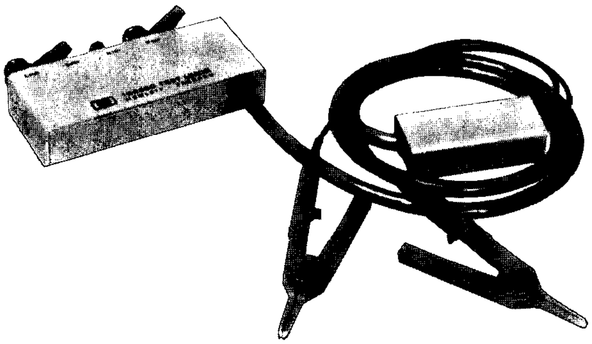
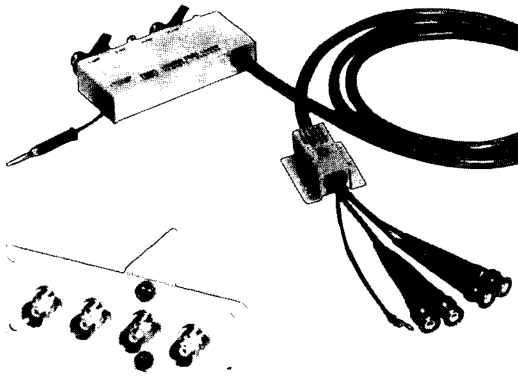
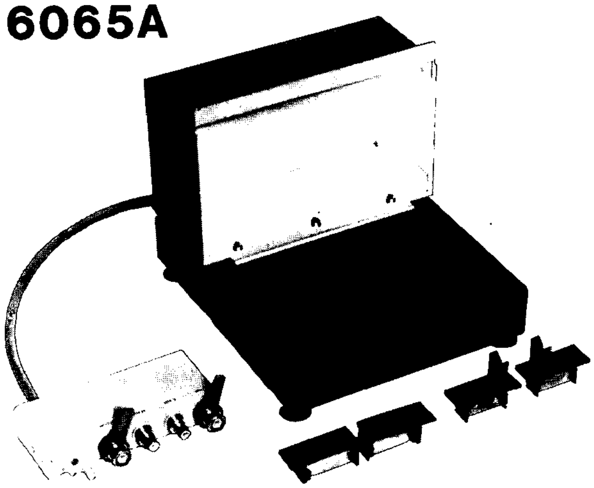
Model	Description
16048A 	Test Leads (four terminal pair) with BNC connectors for connecting user-fabricated test fixtures. DC bias up to ±40V* can be applied. Cable length: 1m
16048B 	Test Leads (four terminal pair) with miniature RF connectors suitable for connecting user-fabricated test fixtures in 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 4277A.

SECTION II
INSTALLATION

2-1. INTRODUCTION

2-2. This section provides installation instructions for the Model 4277A LCZ Meter. It also includes information on initial inspection and damage claims, preparation for using the 4277A, and packaging, storage, and shipment.

2-3. INITIAL INSPECTION

2-4. The 4277A 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 4277A LCZ Meter against its specifications are given in Section IV. First, do the self test. If the 4277A is electrically questionable, then do the Performance Tests to determine whether the 4277A 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 4277A 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 75VA 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 4277A 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 FUSE-HOLDERS 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 4277A 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. 1251-8196) 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.

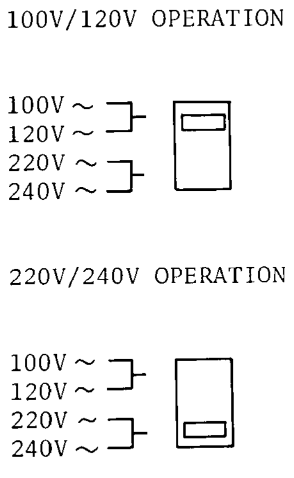
2-16. OPERATING ENVIRONMENT

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 4277A can be operated on the bench or in a rack mount. The 4277A 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.

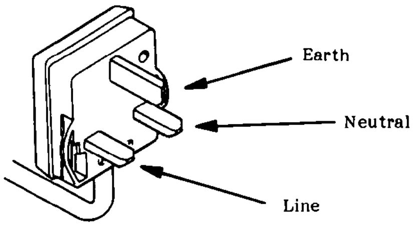


FUSE SELECTION

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

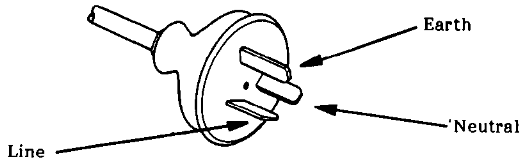
Figure 2-1. Voltage and Fuse Selection.

OPTION 900 United Kingdom



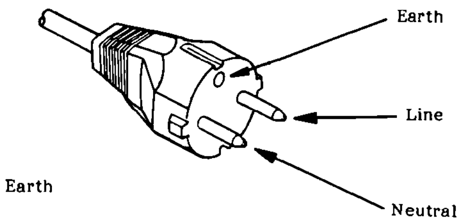
Plug : BS 1363A, 250V
Cable : HP 8120-1703

OPTION 901 Australia/New Zealand



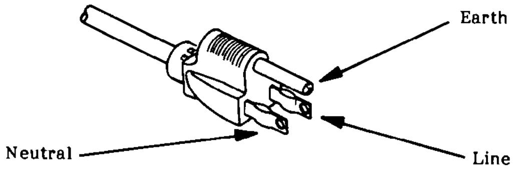
Plug : NZSS 198/AS C112, 250V
Cable : HP 8120-0696

OPTION 902 European Continent



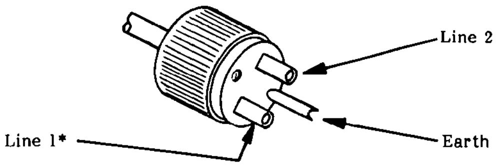
Plug : CEE-VII, 250V
Cable : HP 8120-1692

OPTION 903 U.S./Canada



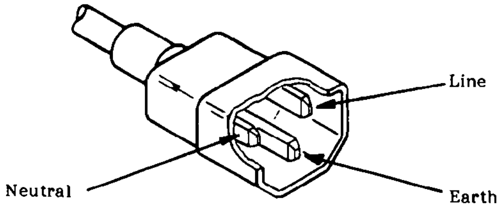
Plug : NEMA 5-15P, 125V, 15A
Cable : HP 8120-1521

OPTION 904 U.S./Canada



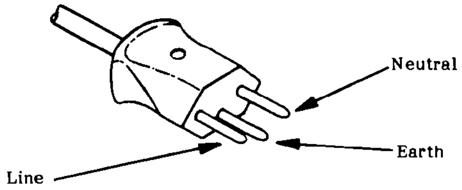
Plug : NEMA 6-15P, 250V, 6A
Cable : HP 8120-0698

OPTION 905** Any country



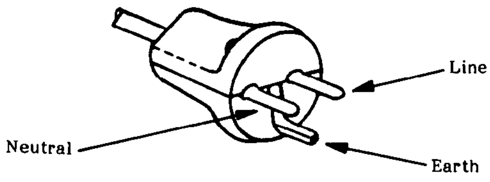
Plug : CEE 22-VI, 250V
Cable : HP 8120-1860

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

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

* In the U.S.A. a 230-volt mains might not include a neutral conductor. In this case it is recommended that the blue conductor of the standard power cord be connected to the terminal normally used for neutral (line 1).

Figure 2-2. Power Cables Supplied.

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

2-22. The 4277A can be installed in a rack and be operated as a component of a measurement system. Rack mounting information for the 4277A 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.

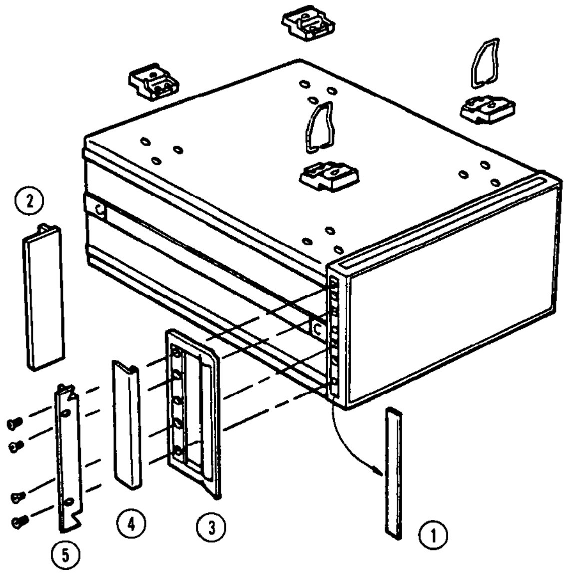
2-31. POWER FAILURE MONITOR INSTALLATION

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 2-114 for a description of the power failure monitor signal.

Procedure:

1. Turn off the 4277A.
2. Disconnect the 4277A 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.

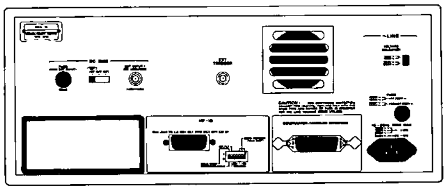
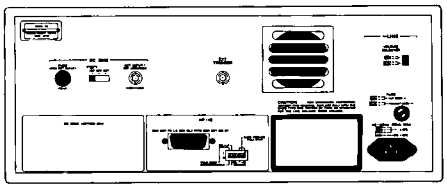
	OPTION 001 DC BIAS SUPPLY (0 to ±40V)	OPTION 002 COMPARATOR/ HANDLER INTERFACE
Option Parts	Board Assembly A22 04276-66522	Comparator 16064A Includes: Interface Board Assembly 16064-66502 and 36-pin male Amphenol connector 1251-0084
Installation Procedure (after removing top cover)	1. Remove the rear 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 4277A 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 4277A 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 4277A 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.

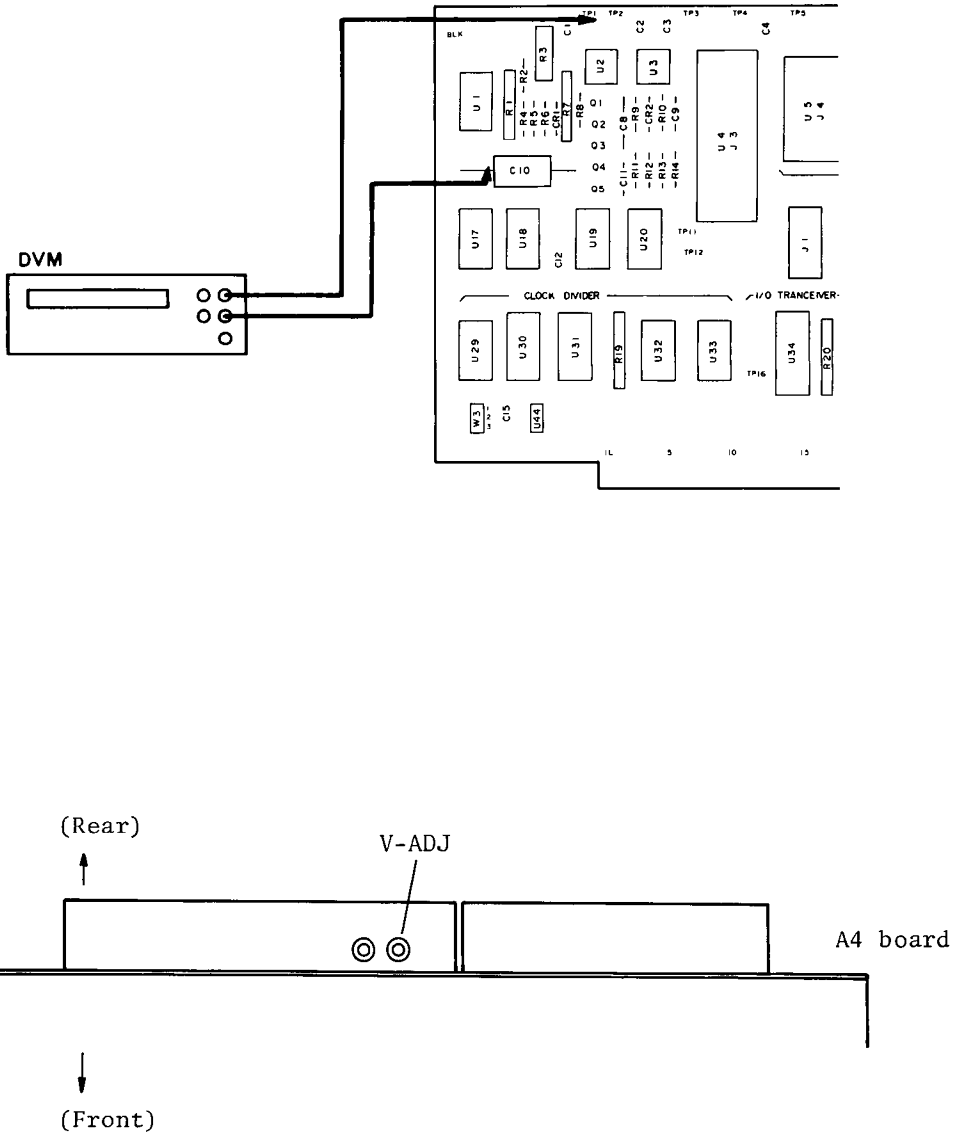
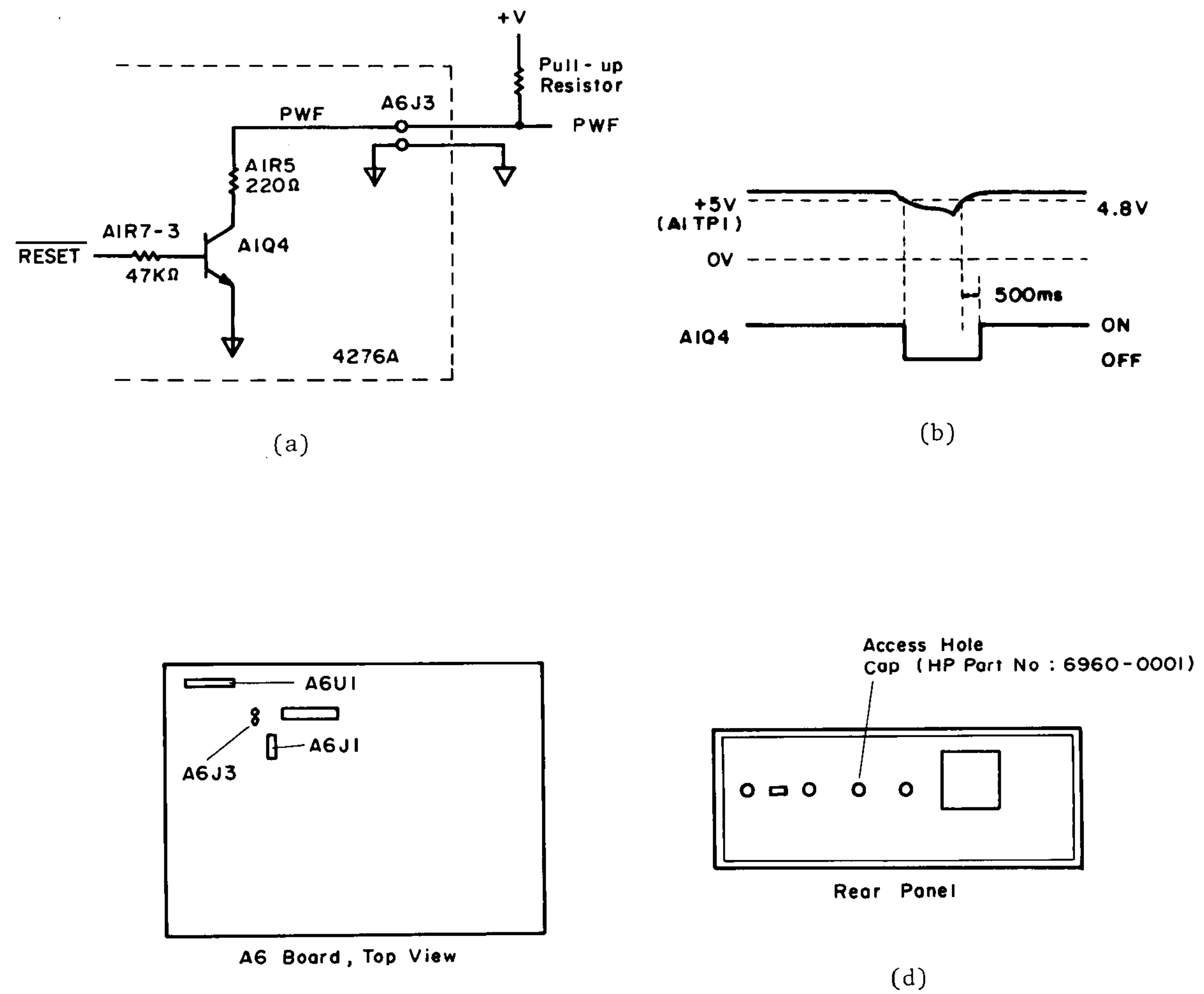


Figure 2-5. Power Supply Adjustment After Installing Option 002.



(a) (b)

(c) (d)

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 4277A 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

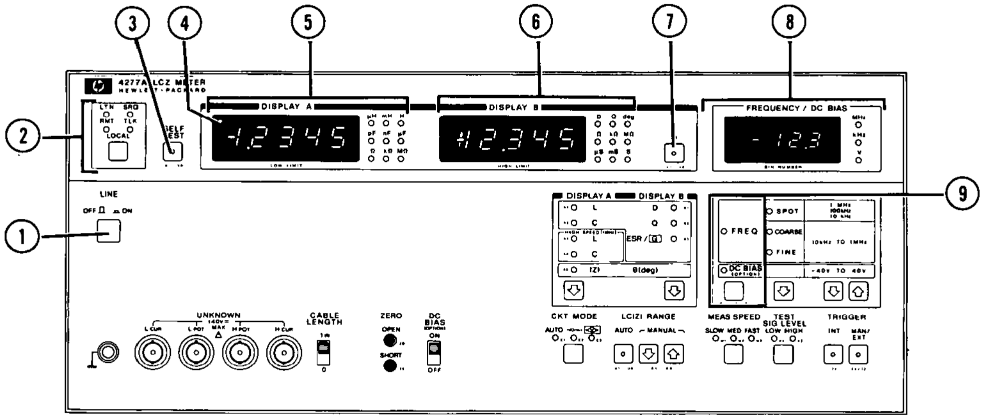
If a ROM/RAM test error code, E61 through E68, appears on DISPLAY A when the instrument is turned on, contact the nearest Hewlett-Packard Sales or Service Office for repairs.

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.

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.



① LINE OFF/ON Switch:

Applies 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 4277A 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.

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

⑥ DISPLAY 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.

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.

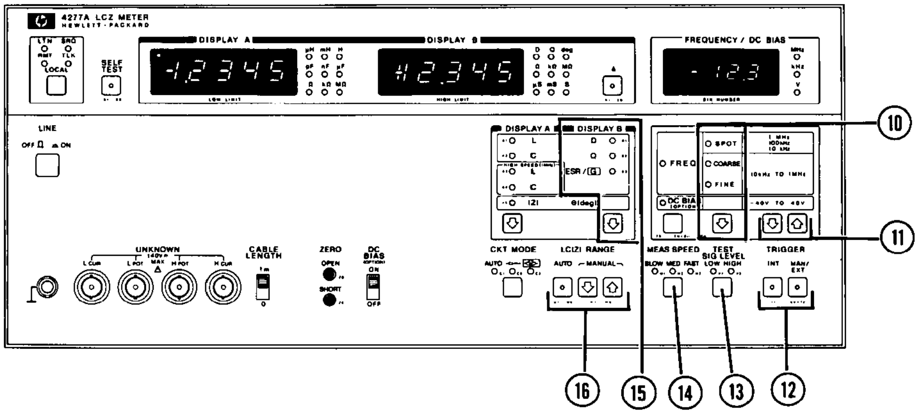
⑨ FREQUENCY/DC BIAS Select Key and Indicators :

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

Note

When the DISPLAY A Function ⑱ is set to HIGH SPEED L or HIGH SPEED C, or 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.

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

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 (④in Figure 3-2).

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 20mVrms. The selected test signal level is indicated by the corresponding LED lamp.

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 14 measurements per second in C-G measurement mode.
FAST:	Measurement speed is approximately one and a half 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 o-□-ww-o; G is selected when CIRCUIT MODE ⑰ is set to o-[□ ww]-o.

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.

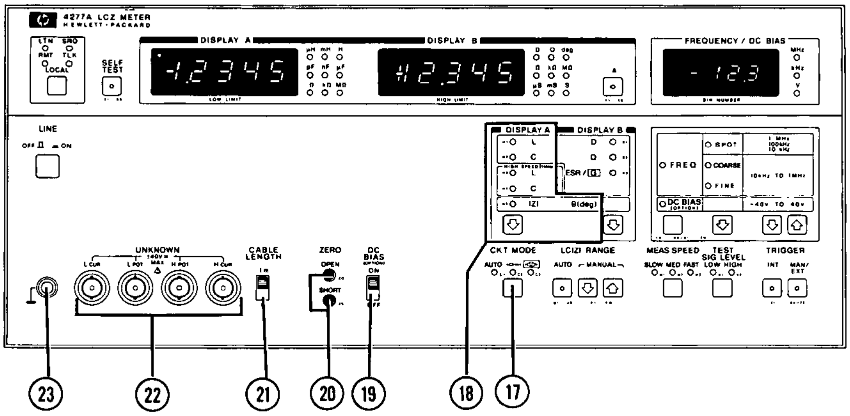
MANUAL (when indicator is not lit):

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.

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



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 o–□–ʌʌʌ–o . When LC | Z | RANGE ⑯ is set to the 1kΩ range or higher, circuit mode is set to o–[□‖ʌʌʌ]–o.

o–□–ʌʌʌ–o : Selects equivalent series circuit.

o–[□‖ʌʌʌ]–o : 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).

HIGH SPEED L (1MHz):
Measures only inductance at 1MHz, which is set automatically when this function is selected.

HIGH SPEED C (1MHz):
Measures only capacitance at 1MHz, which is set automatically when this function is selected.

| 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 | ∠ θ) of the DUT's impedance.

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

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 ㉒. When set to OFF, this switch turns off the internal DC bias source; no DC voltage is output from the H_{CUR} UNKNOWN terminal ㉒, 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:

1MHz, 900kHz, 700kHz, 505kHz, 202kHz, 100kHz, 50.5kHz, 20.2kHz, and 10kHz.

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 CABLE LENGTH Switch:

This switch facilitates balancing of the measuring bridge circuit and minimizes measurement errors when the standard 1 meter test leads are used.

1m : Set the switch to this position when using the standard 1 meter test leads. Appropriate compensation is made for propagation delay and phase error caused by the test leads in high frequency measurements.

0 : Set the switch to this position when using a direct attachment type test fixture, such as the 16047A (connects to the UNKNOWN terminals ㉒).

Note

This switch is not HP-IB programmable.

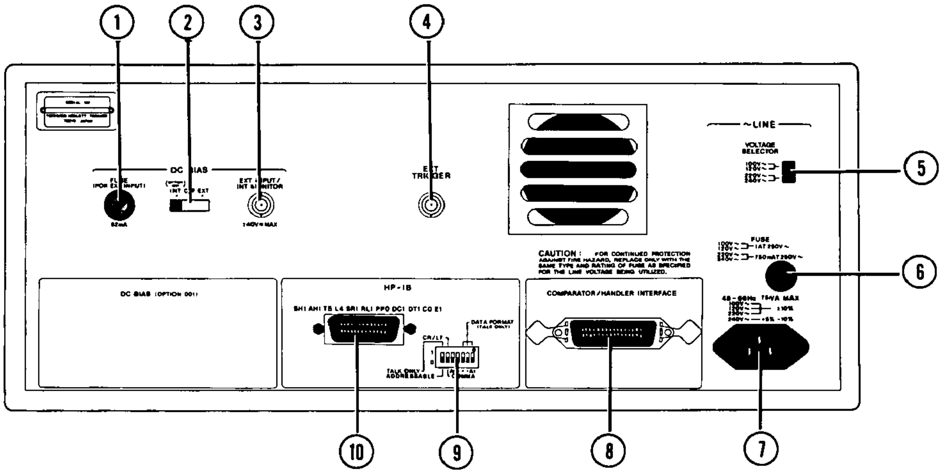
㉒ UNKNOWN Terminals:

These four BNC connectors provide the means to connect DUT's in a four-terminal pair 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.

㉓ 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 3-74.

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).

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

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)

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 3-86.

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).

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 4277A has three front panel displays: DISPLAY A, DISPLAY B, and FREQUENCY/DC BIAS. Each is described in paragraphs 3-17 through 3-19, respectively.

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.

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. 10oo.o
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 displayed 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. 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 3-6. 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 3-5 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
E61	A1U5 ROM is faulty.
E62	A1U6 ROM is faulty.
E63	A1U7 ROM is faulty.
E64	A1U8 ROM is faulty.
E65	A1U9 ROM is faulty.
E66	A1U10 ROM is faulty.
E67	A1U12 RAM is faulty.
E68	A1U12 RAM or A6BT1 is faulty.

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

Display	Meaning
E36 ~ E43	Analog Circuit is not functioning properly.

Table 3-5. Operation Error Codes Displayed on FREQUENCY/DC BIAS Display

DISPLAY A	DISPLAY B	FREQ/DC BIAS	Meanings	Treatment
12345 (any reading)	12345 (any reading)	OFF	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 3-6. Operation Error Codes Displayed on DISPLAY A/B (Sheet 1 of 3)

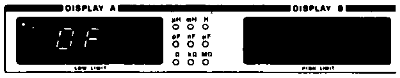
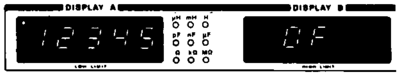
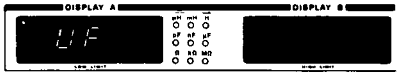
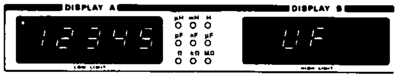
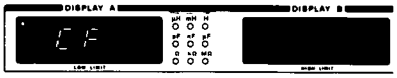
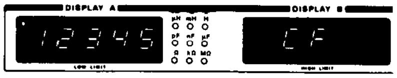
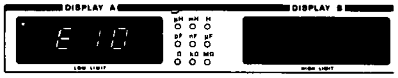
ERROR CODE	Meaning	Treatment
	Overflow - The inductance, capacitance, or impedance of the DUT is too high to be measured on the selected LC|Z| RANGE.	Select a higher LC|Z| RANGE.
 (any reading)	Overflow - The dissipation factor, quality factor, ESR, or conductance of the DUT is too high.	Change the DISPLAY 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 3-50 for details on Zero Offset Adjustments.

Table 3-6. Operation Error Codes Displayed on DISPLAY A/B (Sheet 2 of 3)

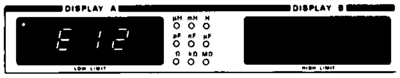
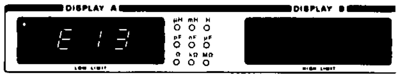
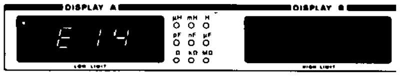
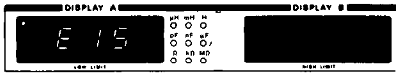
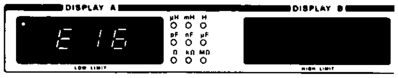
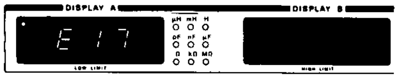
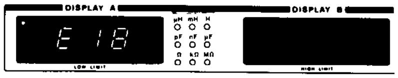
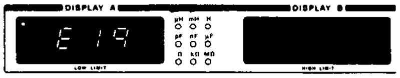
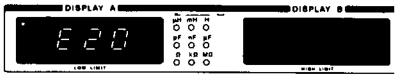
ERROR CODE	Meaning	Treatment
	Illegal LC|Z| RANGE, DISPLAY A, FREQ, or TEST SIG LEVEL setting.	The instrument will automatically select the correct setting.
	Illegal DC BIAS or COMPARATOR operation. Internal dc bias voltage was set via the HP-IB, but the instrument is not equipped with Option 001; or 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 4277A'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 4277A, 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 3-6. Operation Error Codes Displayed on DISPLAY A/B (Sheet 3 of 3)

ERROR CODE	Meaning	Treatment
	Illegal COMPARATOR operation. The 4277A'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 six 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 Ranges and Resolution

Test Frequency Range	Resolution
10.0kHz - 20.0kHz	100Hz
20.0kHz - 50.0kHz	200Hz
50.0kHz - 100kHz	500Hz
100kHz - 200kHz	1kHz
200kHz - 500kHz	2kHz
500kHz - 1.00MHz	5kHz

3-28. TEST SIGNAL LEVEL

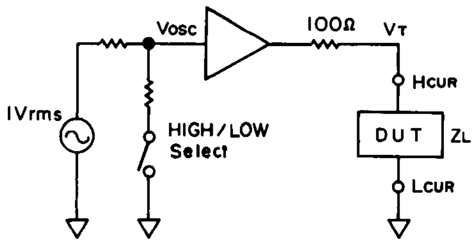
3-29. The 4277A has two test signal levels: HIGH (1Vrms) and LOW (20mVrms). Accuracy for each level is listed in Table 3-8. The output impedance of the test signal source is 100Ω±10%, so the voltage across the DUT depends on the DUT's impedance. Refer to Figure 3-3.

Table 3-8. Test Signal Level Accuracy

Freq. Level	1MHz	Other Frequencies
HIGH	±10%	±10%
LOW		±15%

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 3-5. Each range allows a 100% overrange of the 10000 full scale counts (maximum 19999 counts). Figure 3-4 shows the number of display digits for each measurement functions. 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.



$$V_T = \left| \frac{Z_L}{100 + Z_L} \right| \cdot V_{osc}$$

where,

V_{OSC}: Oscillator Level (1 Vrms or 20m Vrms)

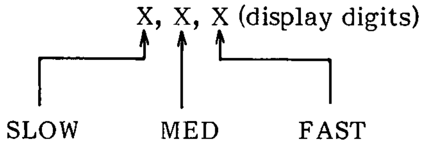
V_T: Test Signal Level

Z_L: DUT Impedance

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

NUMBER OF DISPLAY DIGITS

Tables 1 through 12 show the number of significant digits displayed for each of the 4277A's measurement parameters. The three-number combinations given in the tables indicate the number of display digits for the respective measurement range and test frequency for each measurement speed. For example, if MED measurement speed is selected, use the middle number; if FAST is selected, use the right most number.



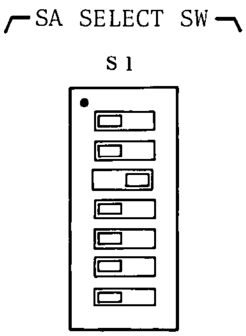
The number of display digits is defined as follows:

4 digits	0000	to	19999
3 digits	000	to	1999
2 digits	00o	to	199o
1 digits	0oo	to	19oo

A full-scale factor is used in Figure A through Figure N. It is defined as follows:

Full-scale factor = (measured value ÷ full-scale value) of C, L, or $|Z|$

For example, when the measured C value is 9.5nF on the 10nF range, full-scale factor is 0.95.



Note

To obtain more display digits on ranges where the number of display digits is less than 3-1/2, set the SA SELECT switch (S1) on the A1 (logic) board as shown in the figure. However, display fluctuation will be more than that in normal operation. The setting of this switch can be changed only when the instrument is turned off.

Figure 3-4. Measurement Ranges and Number of Display Digits (Sheet 1 of 16).

NUMBER OF DISPLAY DIGITS FOR CAPACITANCE

1 Test Signal Level: HIGH

Capacitance Range	Test Frequency (Hz)		
	10.0k to 20.0k	20.2k to 200k	202k to 1.00M
10µF	See Figure B	▨	▨
1µF	See Figure A	See Figure B	▨
100nF	4·4·3	See Figure A	See Figure B
10nF	4·4·3	4·4·3	See Figure A
1nF	4·4·3	4·4·3	4·4·3
100pF	4·4·3	4·4·3	4·4·3
10pF	▨	4·4·3	4·4·3
1pF	▨	▨	4·4·3

Note: Shaded areas indicate that measurement cannot be performed.

2 Test Signal Level: LOW

Capacitance Range	Test Frequency (Hz)								
	10.0k	10.1k to 18.0k	18.1k to 19.9k	20.0k	20.2k to 99.5k	100k	101k to 200k	202k to 995k	1.00M
10µF	See Figure B	See Figure B	See Figure B	See Figure B	▨	▨	▨	▨	▨
1µF	See Figure A	See Figure A	See Figure A	See Figure A	See Figure B	See Figure B	See Figure B	▨	▨
100nF	4·4·3	4·3·3	3·3·3	4·3·3	See Figure A	See Figure A	See Figure A	See Figure B	See Figure B
10nF	4·4·3	4·3·3	3·3·3	4·3·3	4·3·3	4·4·3	4·3·3	See Figure A	See Figure A
1nF	4·4·3	4·3·3	3·3·3	4·3·3	4·3·3	4·4·3	4·3·3	4·3·3	4·4·3
100pF	3·3·2	3·2·2	3·2·2	3·2·2	4·3·3	4·4·3	4·3·3	4·3·3	4·4·3
10pF	▨	▨	▨	▨	3·2·2	3·3·2	3·2·2	4·3·3	4·4·3
1pF	▨	▨	▨	▨	▨	▨	▨	3·2·2	3·3·2

Note: Shaded areas indicate that measurement cannot be performed.

Figure 3-4. Measurement Ranges and Number of Display Digits (Sheet 2 of 16).

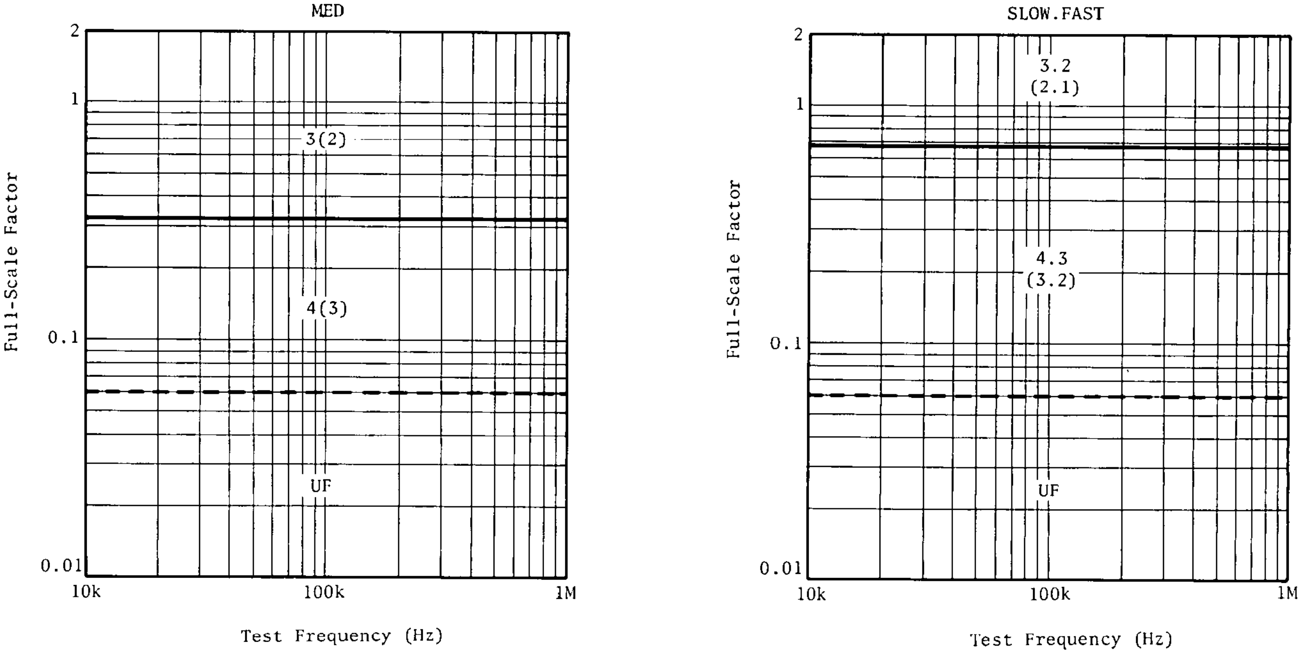


Figure A

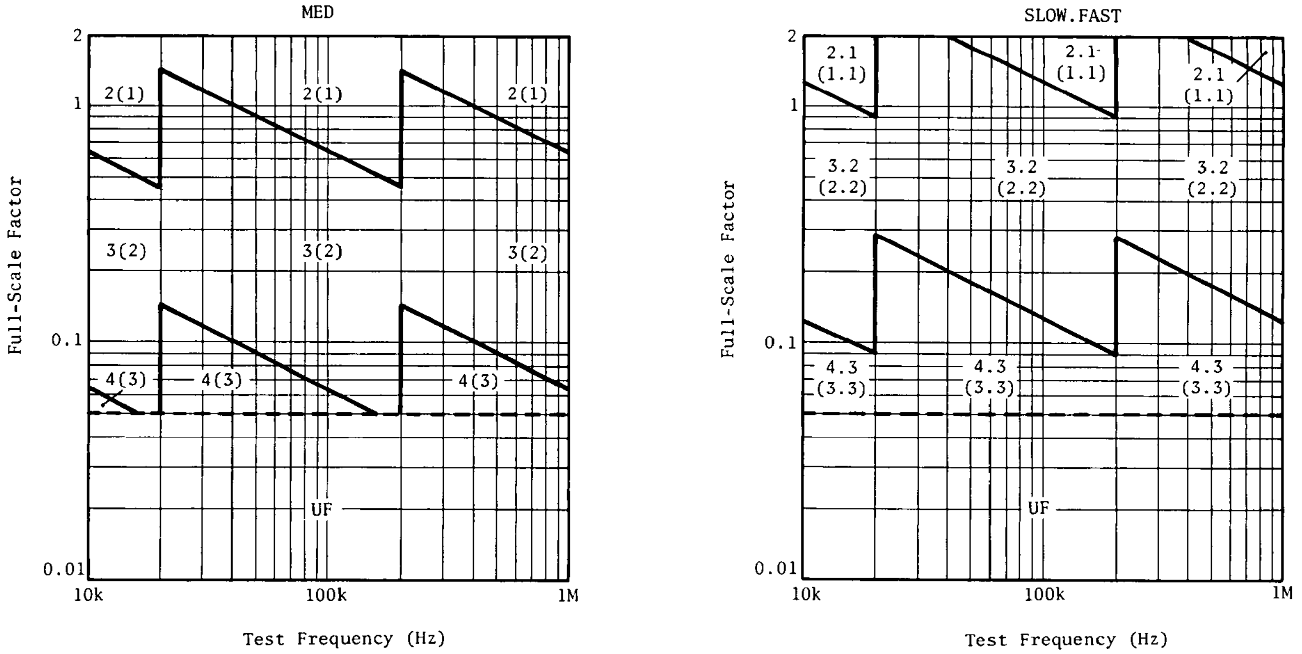


Figure B

Note: Numbers not enclosed in parentheses apply when Test Signal Level is HIGH; numbers enclosed in parentheses apply when Test Signal Level is LOW.

Figure 3-4. Measurement Ranges and Number of Display Digits (Sheet 3 of 16).

NUMBER OF DISPLAY DIGITS FOR DISSIPATION FACTOR IN C-D MEASUREMENT

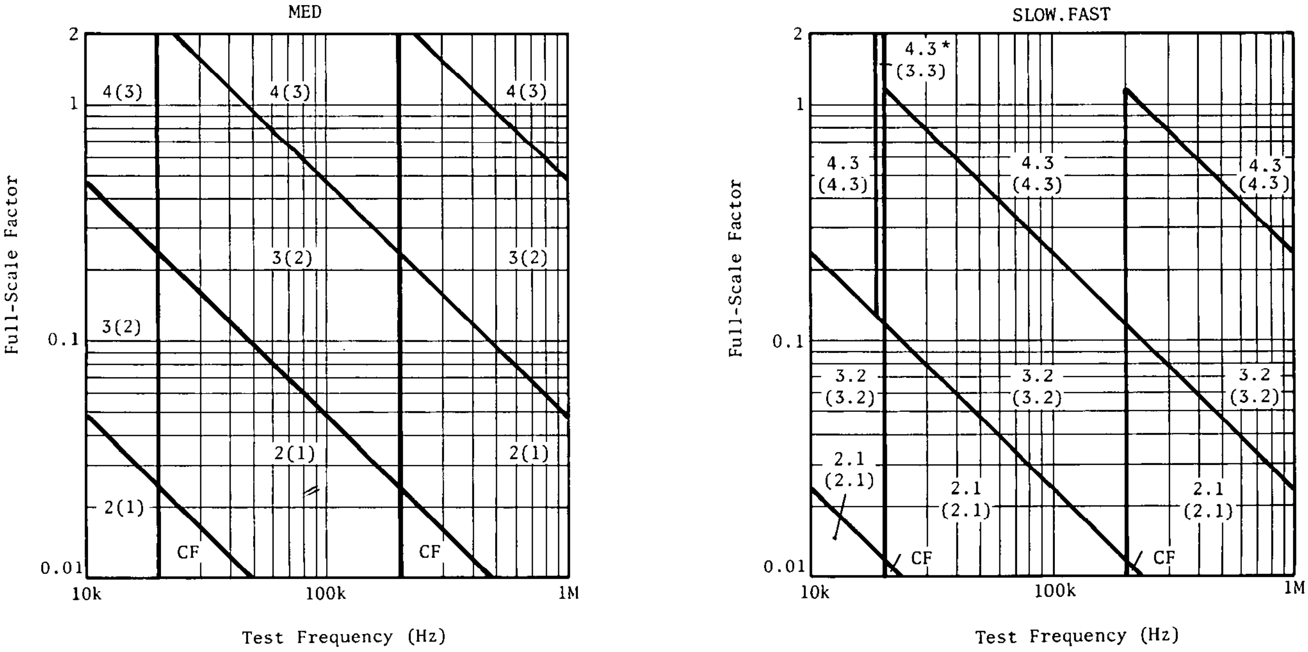
3

Capacitance Range	Test Frequency (Hz)		
	10.0k to 20.0k	20.2k to 200k	202k to 1.00M
10μF	See Figure E	▨	▨
1μF	3·3·2 (2·2·2)*	See Figure E	▨
100nF	See Figure C	3·3·2 (2·2·2)*	See Figure E
10nF			3·3·2 (2·2·2)*
1nF			
100pF	See Figure D		
10pF	▨	See Figure D	
1pF	▨	▨	See Figure D

Note: 1) Numbers not enclosed in parentheses apply when Test Signal Level is HIGH; numbers enclosed in parentheses apply when Test Signal Level is LOW.

2) Shaded areas indicate that measurement cannot be performed.

3) *When the measured C value is less than 5% of full scale, D measurement cannot be performed.



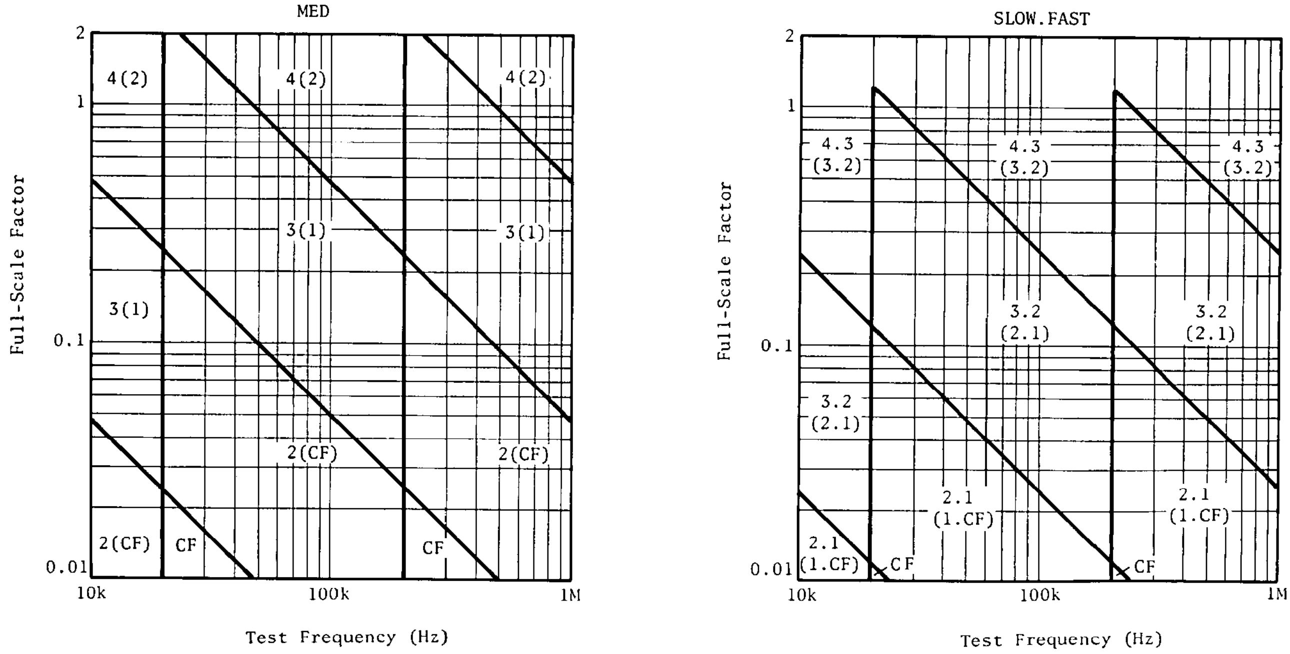
Note: 1) Add one digit at 10k, 100k, and 1MHz when Test Signal Level is LOW.

2) *Frequency range is 18.1kHz to 19.9kHz.

3) Numbers not enclosed in parentheses apply when Test Signal Level is HIGH; numbers enclosed in parentheses apply when Test Signal Level is LOW.

Figure C

Figure 3-4. Measurement Ranges and Number of Display Digits (Sheet 4 of 16).



Note: Add one digit at 10k, 100k, and 1MHz when Test Signal Level is LOW.

Figure D

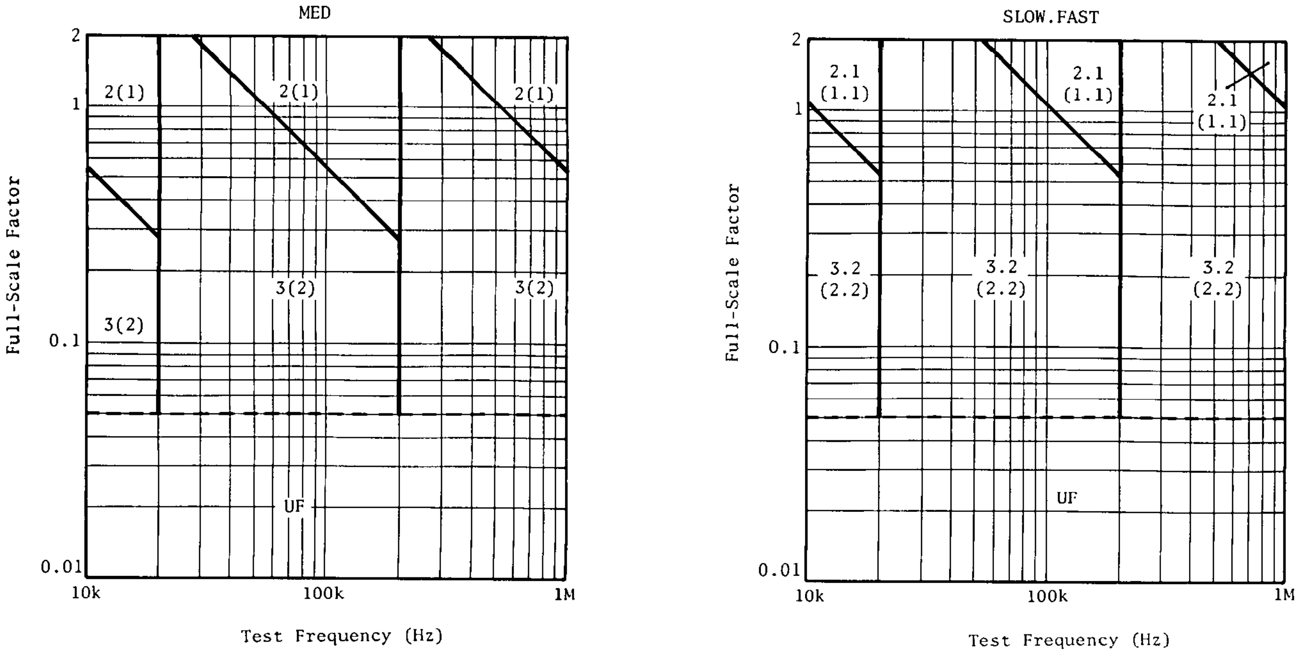


Figure E

Note: In Figures D and E numbers not enclosed in parentheses apply when Test Signal Level is HIGH; numbers enclosed in parentheses apply when Test Signal Level is LOW.

Figure 3-4. Measurement Ranges and Number of Display Digits (Sheet 5 of 16).

NUMBER OF DISPLAY DIGITS FOR INDUCTANCE

4 Test Signal Level: HIGH

Inductance Range	Test Frequency (Hz)						
	10.0k	10.1k to 20.0k	202.k to 99.5k	100k	101k to 200k	202k to 995k	1.00M
1H	See Figure G_1	▨	▨	▨	▨	▨	▨
100mH		See Figure G_2		See Figure G_1	▨	▨	▨
10mH	See Figure F				See Figure G_2		See Figure G_1
1mH	4·4·3	See Figure F					
100µH		4·3·3	4·4·3		See Figure F		
10µH	▨				4·3·3	4·4·3	
1µH	▨	▨	▨	▨			

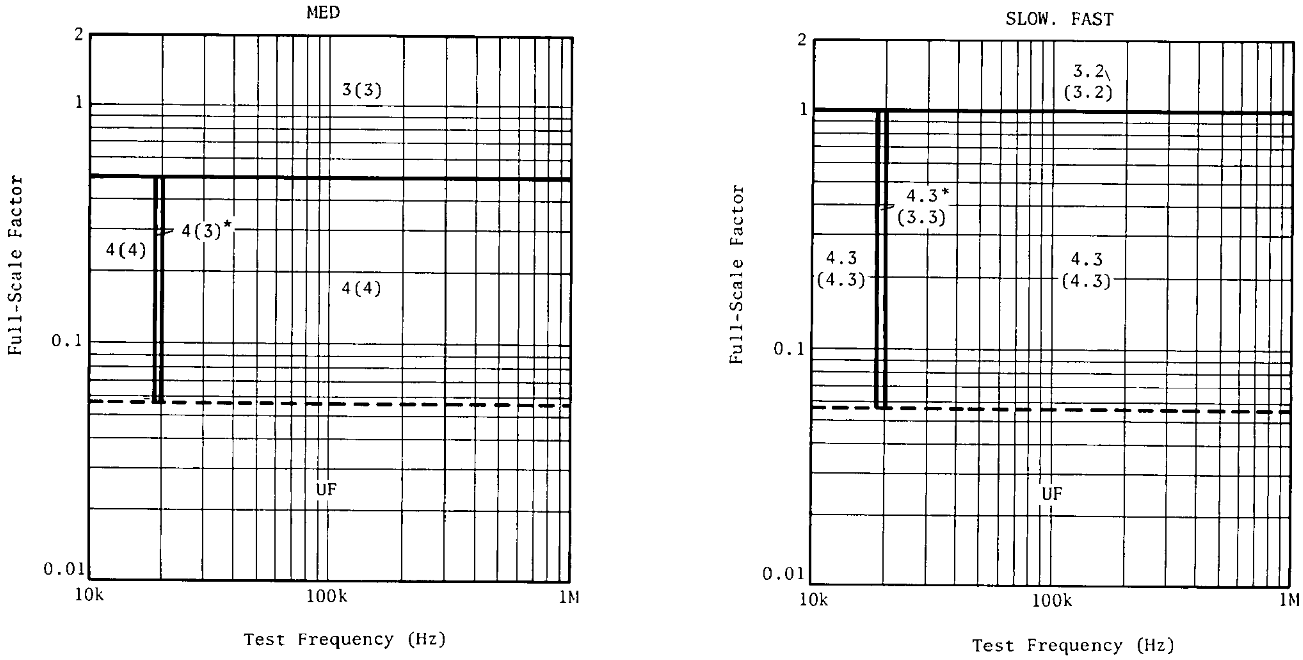
Note: Shaded areas indicate that measurement cannot be performed.

5 Test Signal Level: LOW

Inductance Range	Test Frequency (Hz)						
	10.0k	10.1k to 20.0k	20.2k to 99.5k	100k	101k to 200k	202k to 995k	1.00M
1H	See Figure G_1	▨	▨	▨	▨	▨	▨
100mH		See Figure G_2		See Figure G_1	▨	▨	▨
10mH	See Figure F				See Figure G_2		See Figure G_1
1mH	4·4·3	See Figure F					
100µH	3·3·2	3·3·3	4·3·3	4·4·3	See Figure F		
10µH	▨	2·2·2	3·2·2	3·3·2	3·3·3	4·3·3	4·4·3
1µH	▨	▨	▨	▨	2·2·2	3·2·2	3·3·2

Note: Shaded areas indicate that measurement cannot be performed.

Figure 3-4. Measurement Ranges and Number of Display Digits (Sheet 6 of 16).



Note: * Frequency range is 18.1kHz to 19.9kHz.

Figure F

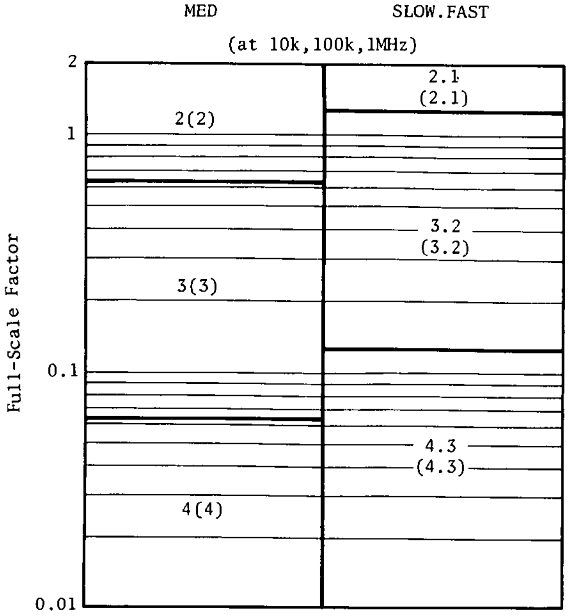
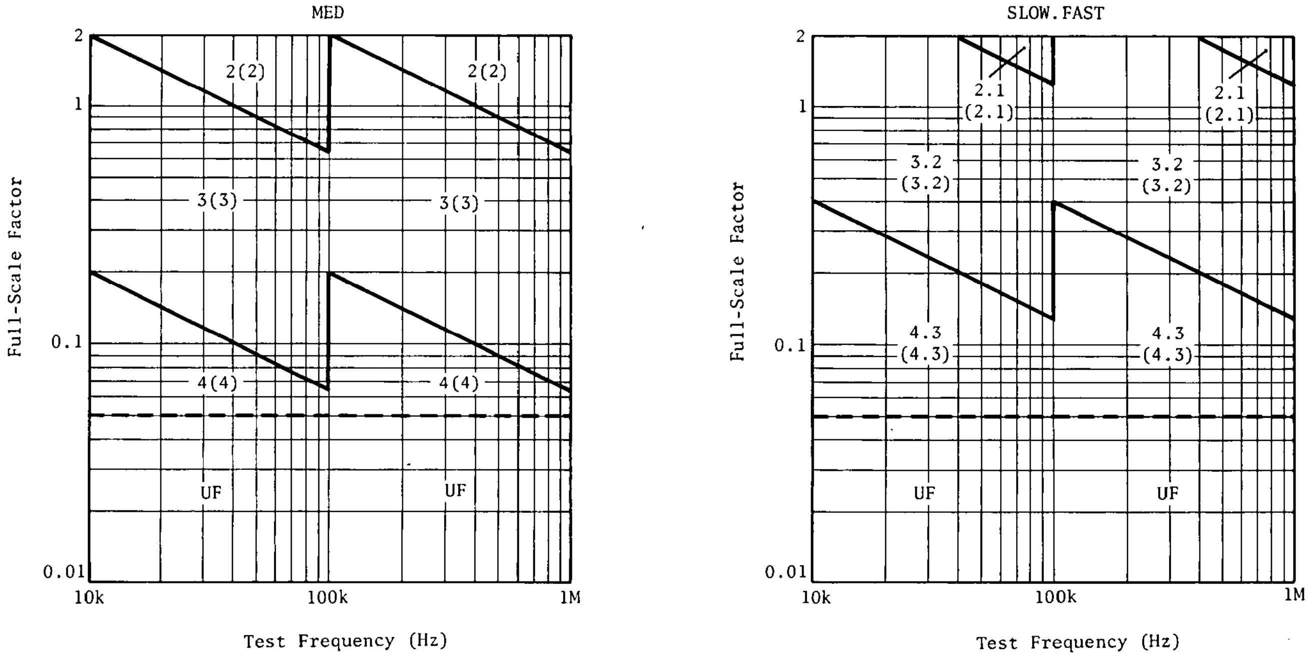


Figure G1

Figure G1

Note: In Figures F and G1 numbers not enclosed in parentheses apply when Test Signal Level is HIGH; numbers enclosed in parentheses apply when Test Signal Level is LOW.

Figure 3-4. Measurement Ranges and Number of Display Digits (Sheet 7 of 16).



Note: Numbers not enclosed in parentheses apply when Test Signal Level is HIGH; numbers enclosed in parentheses apply when Test Signal Level is LOW.

Figure G_2

Figure 3-4. Measurement Ranges and Number of Display Digits (Sheet 8 of 16).

NUMBER OF DISPLAY DIGITS FOR DISSIPATION FACTOR IN L-D MEASUREMENT

6

Inductance Range	Test Frequency (Hz)				
	10.0k	10.1k to 99.5k	100k	101k to 995k	1.00M
1H	See Figure J	▨	▨	▨	▨
100mH				▨	▨
10mH	3·3·2 (3·3·2)*				
1mH	See Figure I_1 → See Figure H_1	3·3·2 (3·3·2)*			
100μH	See Figure I_1	See Figure H_2	See Figure H_1	3·3·2 (3·3·2)*	
10μH	▨	See Figure I_2	See Figure I_1	See Figure H_2	See Figure H_1
1μH	▨	▨	▨	See Figure I_2	See Figure I_1

Note: 1) Numbers not enclosed in parentheses apply when Test Signal Level is HIGH; numbers enclosed in parentheses apply when Test Signal Level is LOW.

2) Shaded areas indicate that measurement cannot be performed.

3) *When the measured L value is less than 5.6% of full scale, D measurement cannot be performed.

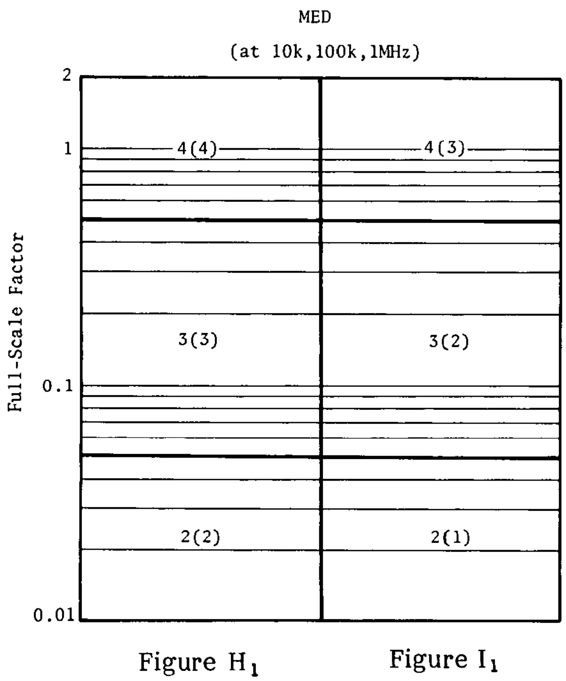


Figure H_1 Figure I_1

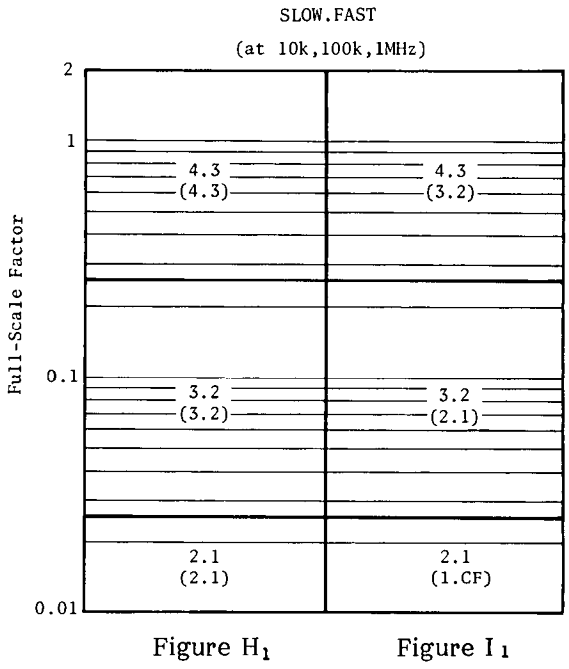


Figure H_1 Figure I_1

Note: Numbers not enclosed in parentheses apply when Test Signal Level is HIGH; numbers enclosed in parentheses apply when Test Signal Level is LOW.

Figure 3-4. Measurement Ranges and Number of Display Digits (Sheet 9 of 16).

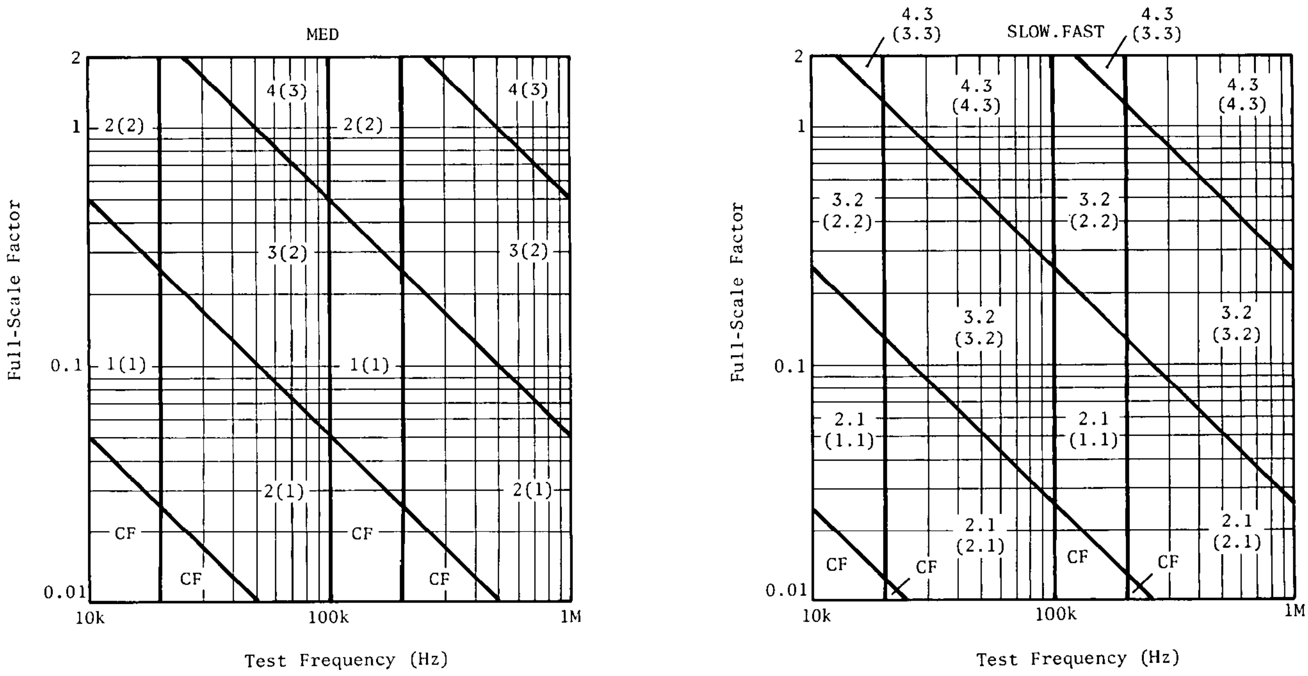


Figure H2

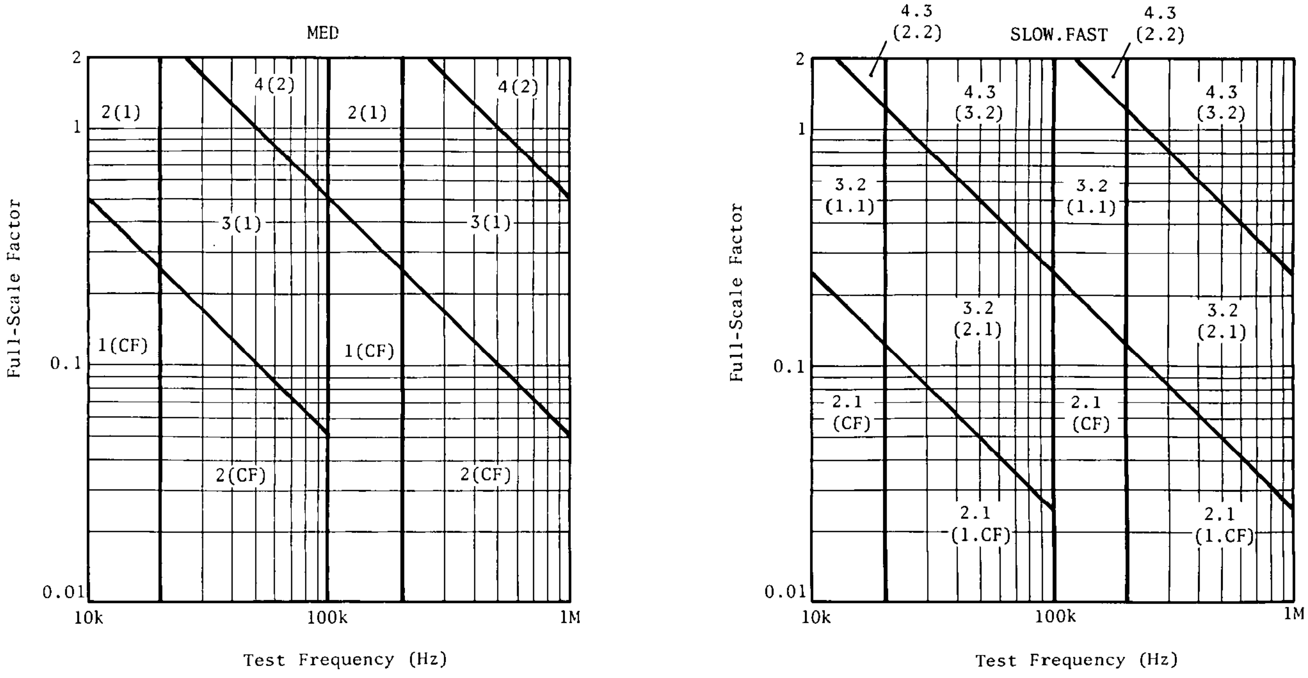
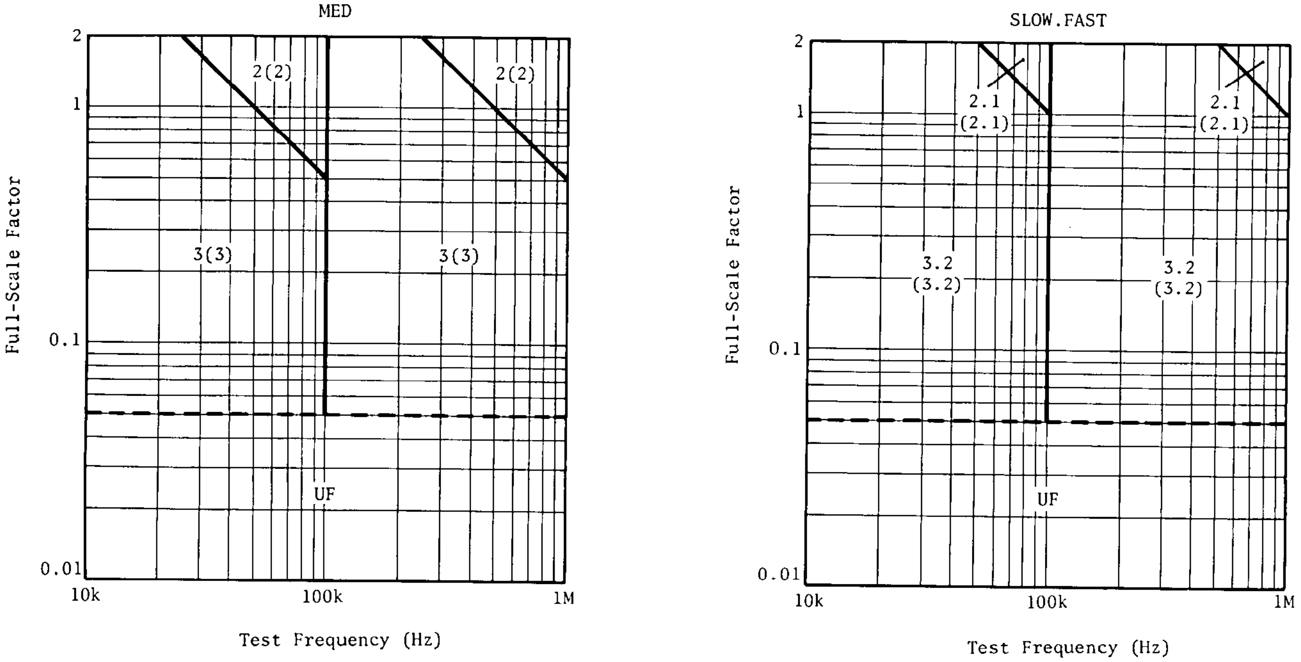


Figure I2

Note: Numbers not enclosed in parentheses apply when Test Signal Level is HIGH; numbers enclosed in parentheses apply when Test Signal Level is LOW.

Figure 3-4. Measurement Ranges and Number of Display Digits (Sheet 10 of 16).



Note: Numbers not enclosed in parentheses apply when Test Signal Level is HIGH; numbers enclosed in parentheses apply when Test Signal Level is LOW.

Figure J

Figure 3-4. Measurement Ranges and Number of Display Digits (Sheet 11 of 16).

NUMBER OF DISPLAY DIGITS FOR ESR AND G IN C-ESR/G MEASUREMENT

7

<table>
<tr><th rowspan="2">ESR/G Range</th><th colspan="3">Test Frequency (Hz)</th></tr>
<tr><th>10.0k to 18.0k</th><th>18.1k to 19.9k</th><th>20.0k to 1.00M</th></tr>
<tr><td>1MΩ/10μS</td><td colspan="3">4·4·3 (3·3·2)</td></tr>
<tr><td>100kΩ/100μS</td><td rowspan="3">4·4·3 (4·4·3)</td><td rowspan="3">4·4·3 (3·3·3)</td><td rowspan="3">4·4·3 (4·4·3)</td></tr>
<tr><td>10kΩ/1mS</td></tr>
<tr><td>1kΩ/10mS</td></tr>
<tr><td>100Ω/100mS</td><td colspan="3" rowspan="2">3·3·2 (3·3·2)</td></tr>
<tr><td>10Ω/1S</td></tr>
</table>

Note: 1) ESR and G ranges depend on the selected C range.

2) Numbers not enclosed in parentheses apply when Test Signal Level is HIGH; numbers enclosed in parentheses apply when Test Signal Level is LOW.

NUMBER OF DISPLAY DIGITS FOR ESR AND G IN L-ESR/G MEASUREMENT

8

<table>
<tr><th rowspan="2">ESR/G Range</th><th colspan="3">Test Frequency (Hz)</th></tr>
<tr><th>10.0k to 18.0k</th><th>18.1k to 19.9k</th><th>20.0k to 1.00M</th></tr>
<tr><td>100kΩ/100μS</td><td colspan="3" rowspan="3">3·3·2 (3·3·2)</td></tr>
<tr><td>10kΩ/1mS</td></tr>
<tr><td>1kΩ/10mS</td></tr>
<tr><td>100Ω/100mS</td><td>4·4·3 (4·4·3)</td><td>4·4·3 (3·3·3)</td><td>4·4·3 (4·4·3)</td></tr>
<tr><td>10Ω/1S</td><td colspan="3">4·4·3 (3·3·2)</td></tr>
</table>

Note: 1) ESR and G ranges depend on the selected L range.

2) Numbers not enclosed in parentheses apply when Test Signal Level is HIGH; numbers enclosed in parentheses apply when Test Signal Level is LOW.

Figure 3-4. Measurement Ranges and Number of Display Digits (Sheet 12 of 16).

DISPLAY INDICATION FOR QUALITY FACTOR

9 D: 4 digits

D	Q	Display
.0001 to .0009	10000 to 1111	0F
.0010 to .0033	1000 to 303	10oo. to 3oo.
.0034 to .0099	294 to 101	29o. to 10o.
.0100 to .0333	100 to 30	100. to 30.
.0334 to 1.9999	29.9 to 0.5	29.9 to .5

Note: Q is the reciprocal of D.

10 D: 3 digits

D	Q	Display
.001 to .003	1000 to 333	0F
.004 to .010	250 to 100	3oo. to 1oo.
.011 to .033	90.9 to 30.3	9o. to 3o.
.034 to 1.999	29.4 to 0.5	30. to 1.

Note: Q is the reciprocal of D.

Figure 3-4. Measurement Ranges and Number of Display Digits (Sheet 13 of 16).

NUMBER OF DISPLAY DIGITS FOR IMPEDANCE

11

|Z| Range	Test Frequency (Hz)			
	10.0k to 18.0k	18.1k to 19.9k	20.0k to 99.5k	100k to 1.00M
1MΩ	See Figure L			
100kΩ	See Figure K			
10kΩ				
1kΩ				
100Ω	4·4·3 (4·3·3)	4·4·3 (3·3·3)	4·4·3 (4·3·3)	4·4·3 (4·4·3)
10Ω	4·4·3 (3·3·2)			

Note: Numbers not enclosed in parentheses apply when Test Signal Level is HIGH; numbers enclosed in parentheses apply when Test Signal Level is LOW.

NUMBER OF DISPLAY DIGITS FOR PHASE ANGLE

12

|Z| Range	Test Frequency (Hz)
	10.0k to 1.00M
1MΩ	See Figure L
100kΩ	See Figure K
10kΩ	
1kΩ	
100Ω	See Figure M
10Ω	See Figure N

Figure 3-4. Measurement Ranges and Number of Display Digits (Sheet 14 of 16).

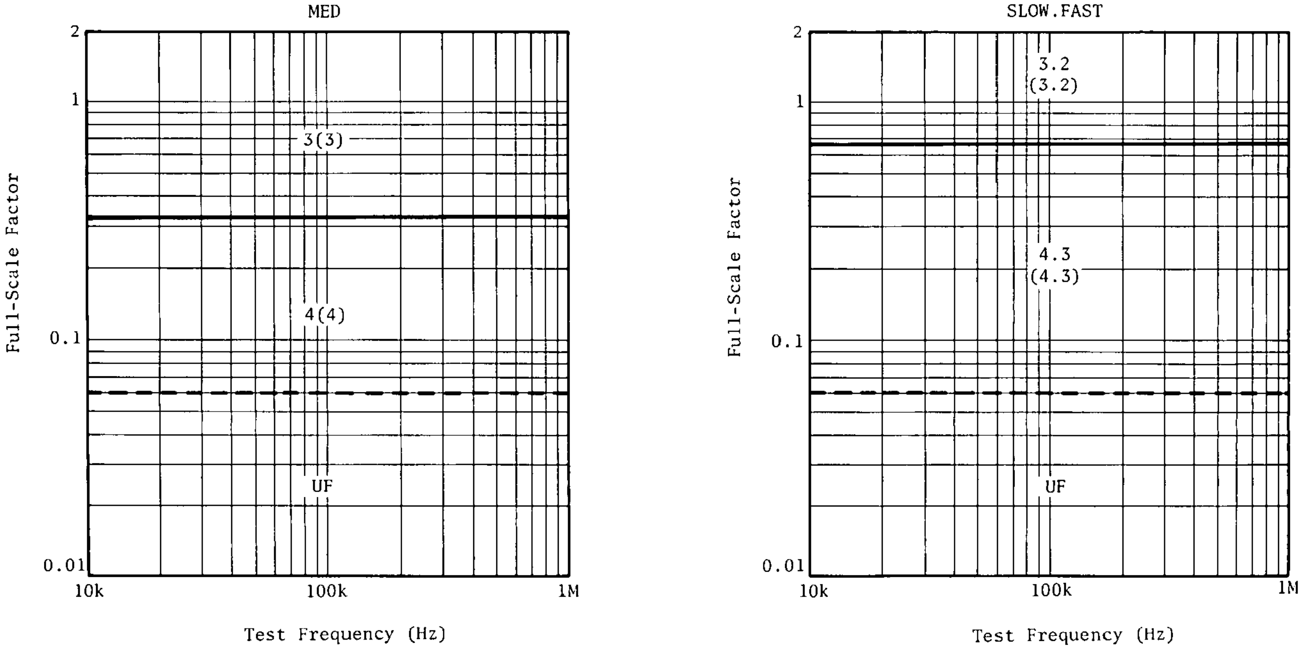


Figure K

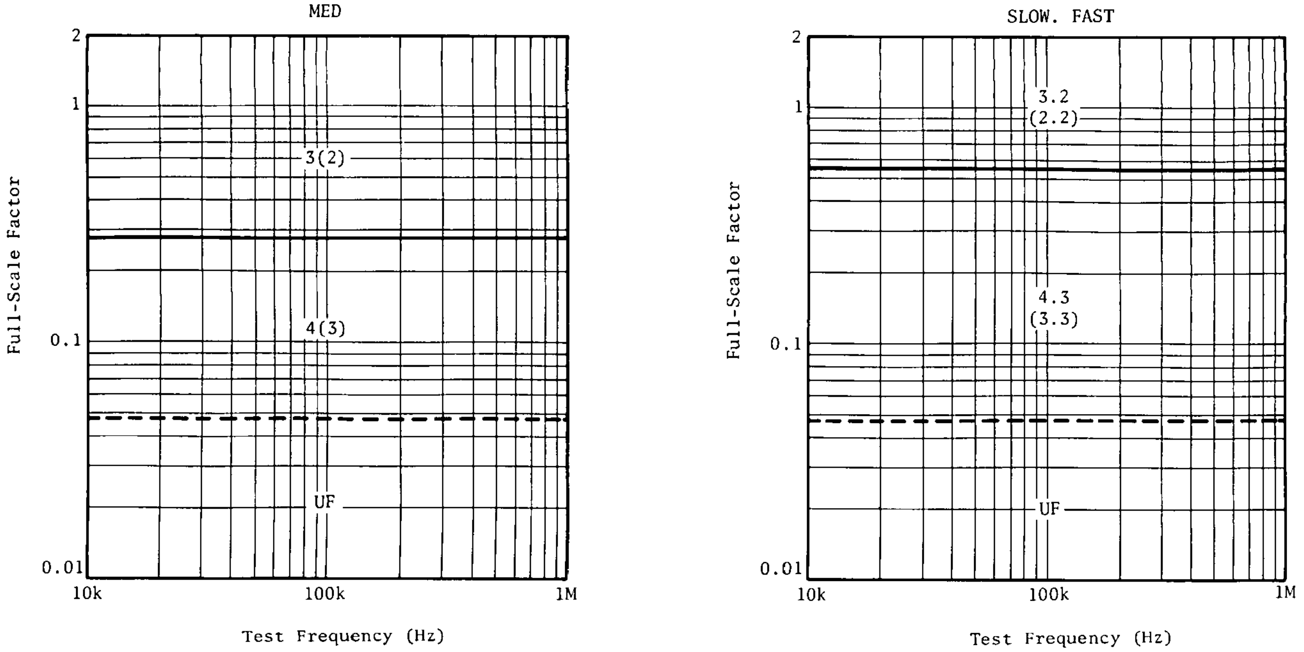
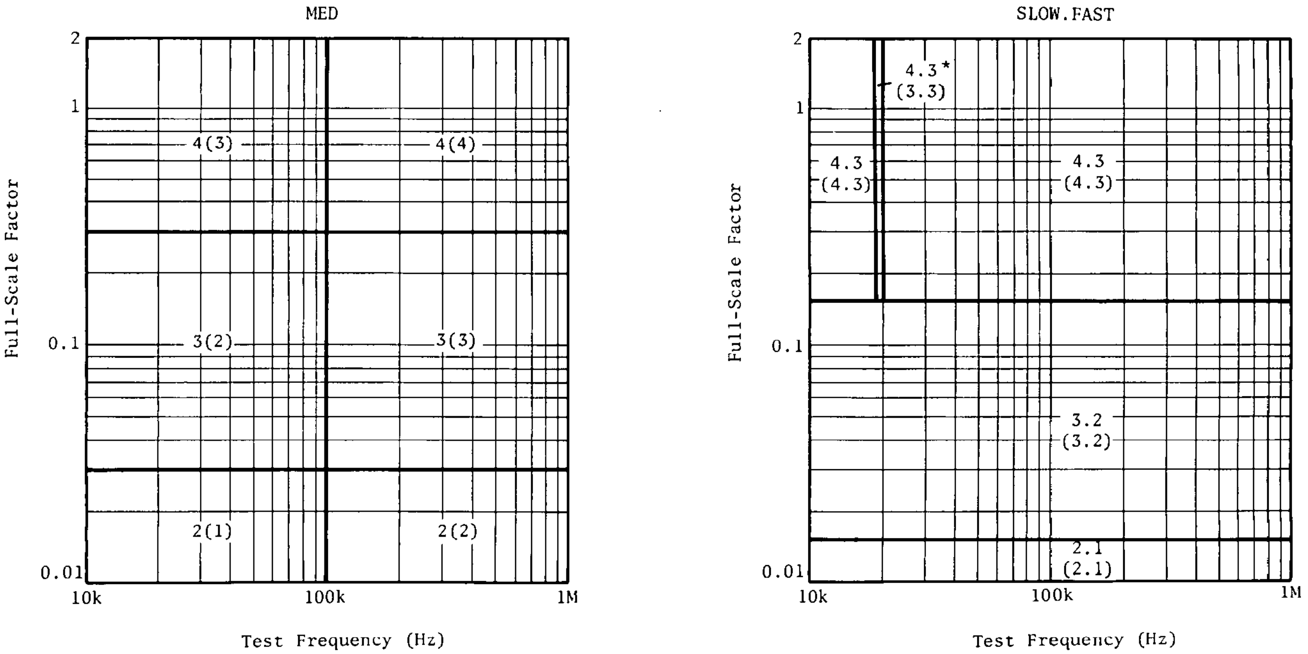


Figure L

Note: Numbers not enclosed in parentheses apply when Test Signal Level is HIGH; numbers enclosed in parentheses apply when Test Signal Level is LOW.

Figure 3-4. Measurement Ranges and Number of Display Digits (Sheet 15 of 16).



Note: * Frequency range is 18.1kHz to 19.9kHz.

Figure M

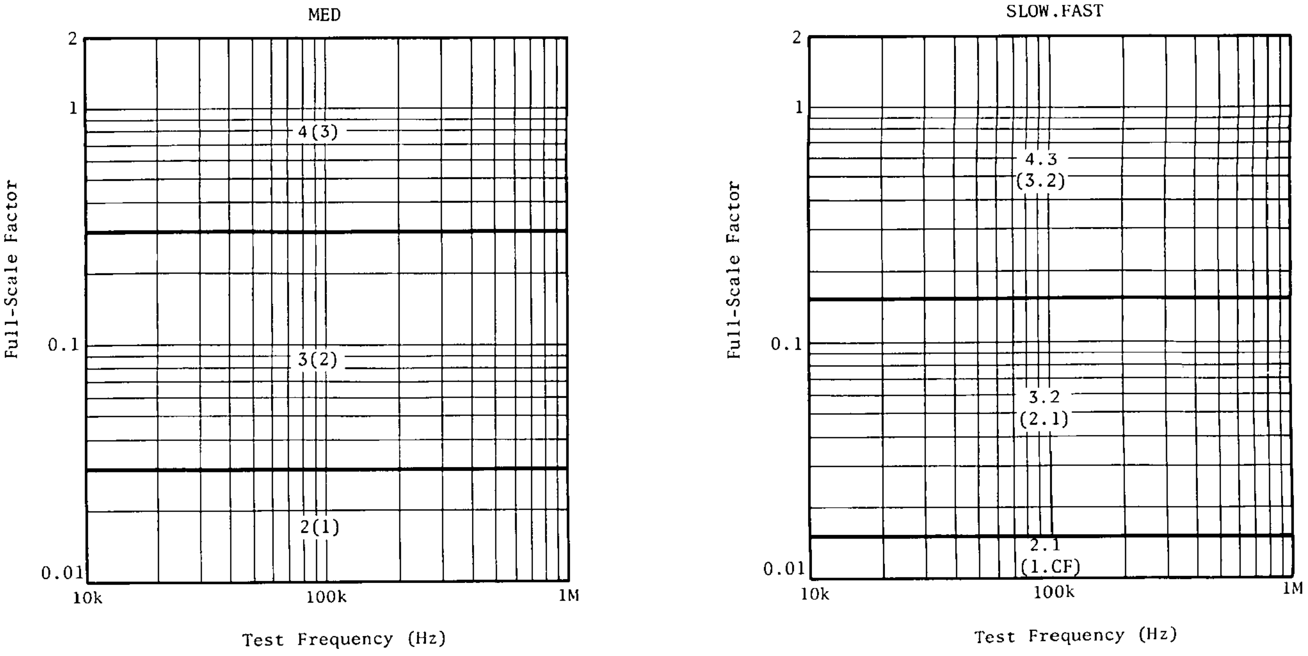


Figure N

Note: In Figures M and N numbers not enclosed in parentheses apply when Test Signal Level is HIGH; numbers enclosed in parentheses apply when Test Signal Level is LOW.

Figure 3-4. Measurement Ranges and Number of Display Digits (Sheet 16 of 16).

C-D Measurement

C Range	Test Frequency (Hz)		
	10.0k to 20.0k	20.2k to 200k	202k to 1.00M
10µF	100Ω	▨	▨
1µF	100Ω	100Ω	▨
100nF	100Ω	100Ω	100Ω
10nF	1kΩ	100Ω	100Ω
1nF	10kΩ	1kΩ	100Ω
100pF	10kΩ	10kΩ	1kΩ
10pF	▨	10kΩ	10kΩ
1pF	▨	▨	10kΩ

C-ESR/G Measurement

ESR/G Range	Test Frequency (Hz)
	10.0k to 1.00M
1MΩ/10µS	10kΩ
100kΩ/100µS	
10kΩ/1mS	1kΩ
1kΩ/10mS	100Ω
100Ω/100mS	
10Ω/1S	

L-D Measurement

L Range	Test Frequency (Hz)		
	10.0k	10.1k to 100k	101k to 1.00M
1H	1kΩ	▨	▨
100mH	100Ω	1kΩ	▨
10mH	100Ω	100Ω	1kΩ
1mH	100Ω	100Ω	100Ω
100µH	100Ω	100Ω	100Ω
10µH	▨	100Ω	100Ω
1µH	▨	▨	100Ω

L-ESR/G Measurement

ESR/G Range	Test Frequency (Hz)
	10.0k to 1.00M
100kΩ/100µS	1kΩ
10kΩ/1mS	100Ω
1kΩ/10mS	
100Ω/100mS	
10Ω/1S	

|Z|-θ Measurement

|Z| Range	Test Frequency (Hz)
	10.0k to 1.00M
1MΩ	10kΩ
100kΩ	
10kΩ	1kΩ
1kΩ	100Ω
100Ω	
10Ω	

Figure 3-5. Measurement Ranges and Range Resistors.

Note

When a C-D measurement is made with the instrument controls set as follows, the number of display counts depends on frequency, as shown in Figure 3-6.

CIRCUIT MODE······AUTO ()
LC | Z | RANGE·····MANUAL
Test Frequency ········15.9kHz - 20.0kHz
or 159kHz - 200kHz

As an example, suppose you're measuring a 180pF capacitor on the 100pF range at 17kHz, and the measured value is 175.62pF. If the test frequency is increased to 19kHz, OF will be displayed on DISPLAY A because the maximum number of counts at this higher frequency is only 17000, as shown in Figure 3-6.

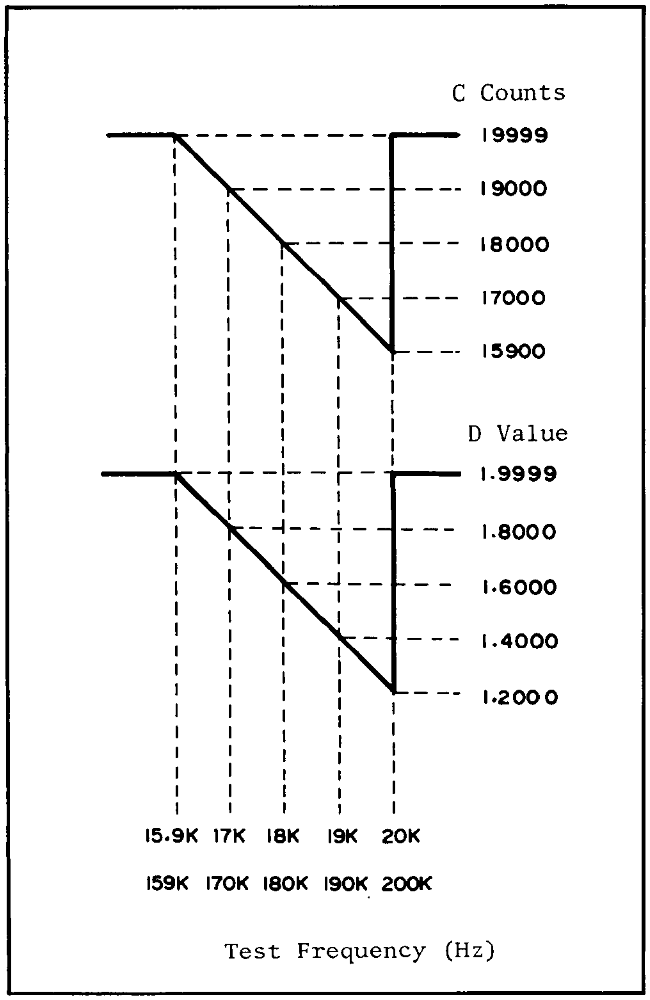
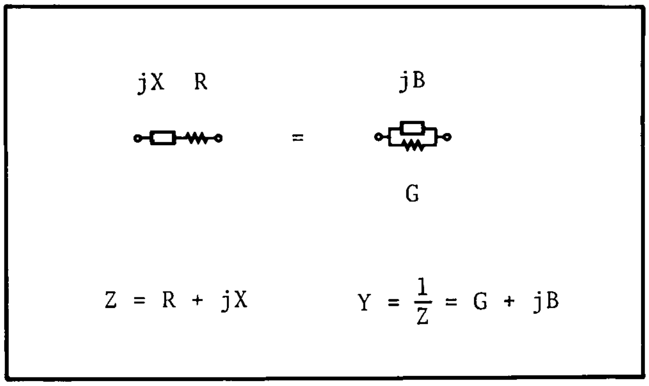


Figure 3-6. Number of Counts vs Frequency.

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 4277A 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 100Ω or below. Equivalent parallel circuit mode is automatically selected when the measurement range is 1kΩ or above. 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 considers the effect of dissipation factor. See Table 3-9. Figure 3-7 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 3-7, 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.

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 4277A, 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.

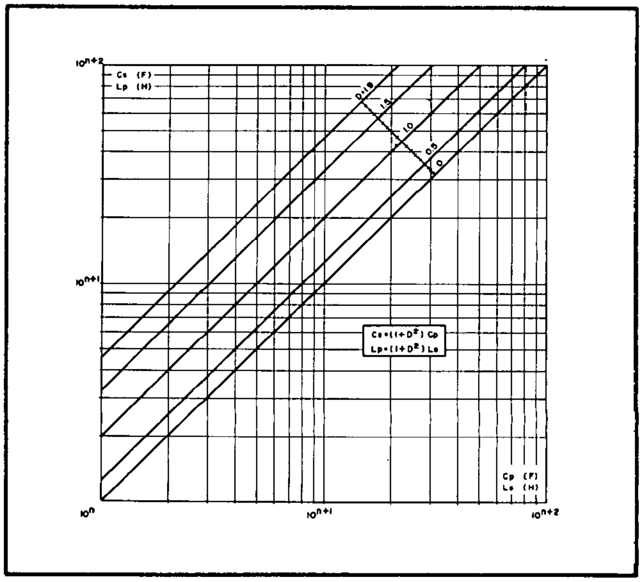
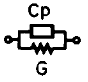
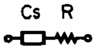
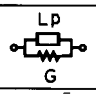


Figure 3-7. Parallel and Series Parameter Relationship.

Table 3-9. 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		$D = \omega LpG = \frac{1}{Q}$	$Ls = \frac{1}{1 + D^2}\ Lp,\ R = \frac{D^2}{1 + D^2} \cdot \frac{1}{G}$
		$D = \frac{R}{\omega Ls} = \frac{1}{Q}$	$Lp = (1 + D^2)\ Ls,\ G = \frac{D^2}{1 + D^2} \cdot \frac{1}{R}$

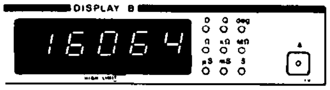
3-35. INITIAL DISPLAY AND INDICATIONS

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 3-76.

Note

If the instrument is set to TALK ONLY mode, the output data format number (see paragraph 3-90) will appear on DISPLAY A instead of the HP-IB address.

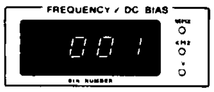
The following option code is displayed on DISPLAY B if the instrument is equipped with Option 002, Comparator/Handler Interface.



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.



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 4277A 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 3-43.

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 4277A 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 4277A is turned on.

Note

When turned on, the 4277A 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).

3-42. OPEN and SHORT Zero Offset values (refer to paragraph 3-51) and reference values for deviation measurements (refer to paragraph 3-60) 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.

3-43. RESETTING CONTINUOUS MEMORY

3-44. To reset, or clear, continuous memory, proceed as follows:

(1) Turn off the 4277A.

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

(3) Turn on the 4277A.

3-45. UNKNOWN TERMINALS

3-46. Generally, the mutual inductance between test leads, noise from nearby equipment,and the residuals and strays of conventional connection methods significantly affect the accuracy of impedance measurements made at high frequencies. To minimize these error sources and thereby ensure optimum measurement accuracy, the 4277A employs a four-terminal pair connection method. The UNKNOWN terminals consist of four BNC female connectors: H_{CUR} (high current), H_{POT} (high potential), L_{POT} (low potential), and L_{CUR} (low current). The current terminals (H_{CUR} and L_{CUR}) provide the test signal current, and the potential terminals (H_{POT} and L_{POT}) detect the voltage across the DUT (device under test). To connect a sample, the four-terminal pair configuration must be converted to a two-terminal configuration. This is done by connecting the outer conductors of the terminals to each other and then H_{CUR} to H_{POT} and L_{CUR} to L_{POT}, as shown in Figure 3-8. The principle of the four-terminal pair measurement is illustrated in Figure 3-9. At first glance, the arrangement appears to be an expanded four terminal method with a built-in guard structure. This is true. Thus, the four-terminal pair method combines the advantages of the four terminal method in low impedance measurements while providing the shielding required for high impedance measurements. The distinctive feature of the four-terminal pair configuration is that the outer shield works as the return path for the test signal current. The same current flows through both the center conductors and the outer shield conductors (in opposite directions), yet no external magnetic fields are generated around the conductors (the magnetic fields produced by the currents through the inner and outer conductors completely cancel each other). Because the measurement signal current does not develop an inductive magnetic field, the test leads do not contribute additional measurement errors due to mutual-inductance between the individual leads. Hence, the four-terminal pair method provides best measurement accuracy while minimizing the effects of stray capacitance and residual inductance inherent in the test leads or test fixture.

Note

Because test leads have residual inductance, the resultant additional measurement error increases in capacitance measurements in proportion to the square of the test frequency.

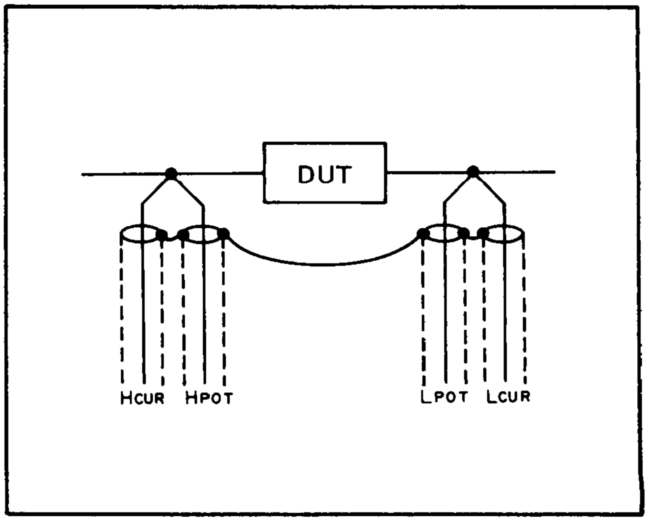


Figure 3-8. Four Terminal Pair DUT Connections.

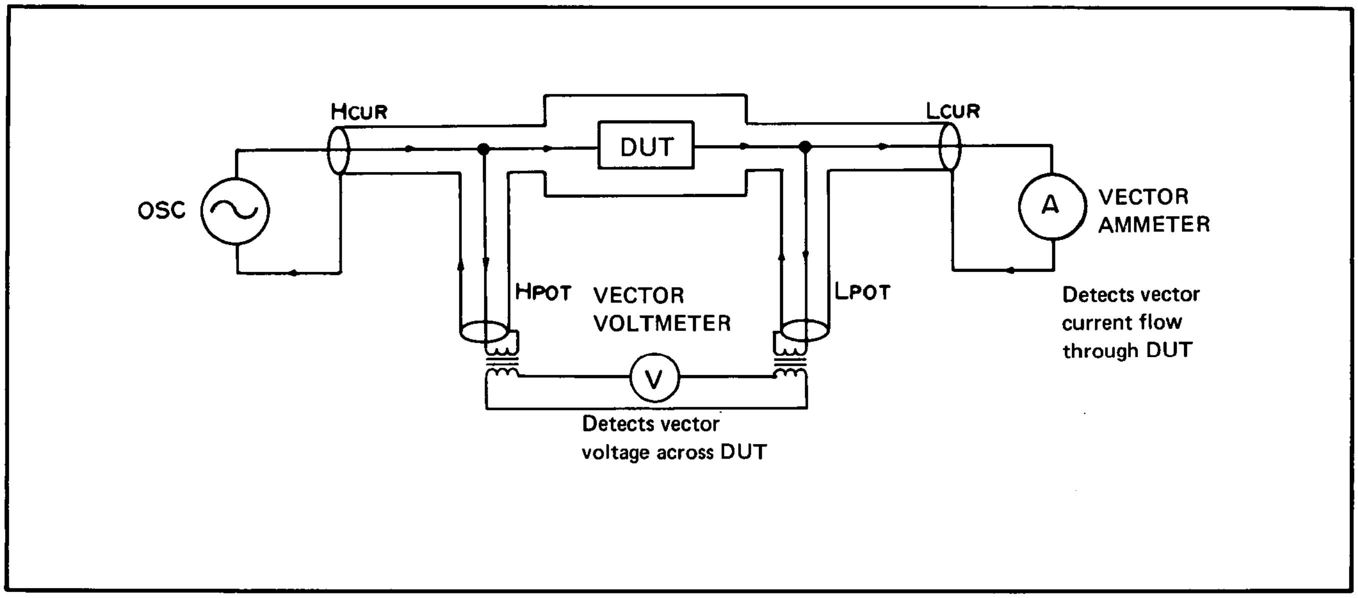


Figure 3-9. Four Terminal Pair Measurement Principle.

3-47. MEASUREMENT OF GROUNDED SAMPLES

3-48. Samples which have one terminal (except GROUND terminal) grounded to earth cannot normally be measured by the 4277A. 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 4277A may display a measurement error message or incorrect measurement results. This is because the bridge section cannot achieve a balance with any measurement terminal grounded and, additionally, any grounding modifies the four terminal pair measurement architecture (other than an internal connection of the shield conductor to instrument chassis at one point).

Note

If one terminal is grounded, a signal current of equal magnitude (an operating condition of the four terminal pair configuration measurement) will not flow in the inner and outer conductors of the measurement cable.

3-49. SELECTION OF TEST CABLE LENGTH

3-50. The propagation signal in a transmission line will develop a change in phase between two points on the line as illustrated in Figure 3-10. The difference in phase corresponds to the ratio of the distance between the two points to the wavelength of the propagating signal. Consequently, owing to their length, test cables used to connect a sample to the UNKNOWN terminals will cause a phase shift and a propagation loss of the test signal. For example, the wavelength of a 1MHz test signal is 300 meters which is 300 times as long as the 1m standard test cables. Here, the phase of the test signal at the end of the test cable will be shifted by about 1.2 degrees (360 ° ÷ 300) in reference to the phase at the other end of the cable. Since the effect of test cables on measurements and the resultant measurement error increase in proportion to the test frequency, cable length must be taken into consideration when making high frequency measurements. The CABLE LENGTH switch must be selected so as to provide the correct phase compensation for measurements made with the 1m standard test cables or for a test fixture attached directly to the UNKNOWN terminals. When standard test cables (1m or 2m) are used, the CABLE LENGTH switch must be set to the 1m position to minimize additional measurement errors. The 0 position is for direct attachment type test fixtures.

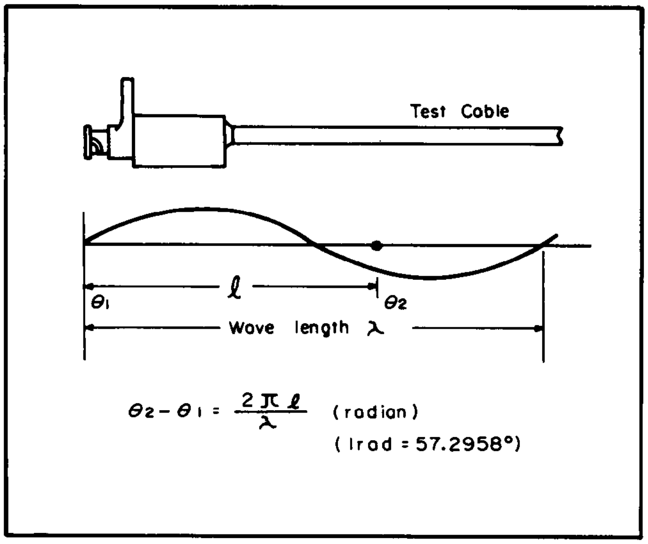


Figure 3-10. Test Signal Phase on Test Cables.

Note

When the HP 16065A, EXT Voltage Bias Fixture, is used with the 4277A, set the CABLE LENGTH switch to the 1m position.

Note

When the HP 16048D Test Leads (standard 2m test cable) is used with the 4277A, the CABLE LENGTH switch must be set to the 1m position and the SA SELECT switch (S1) on the A1 (Logic) board must be set as shown in Figure 3-11. The setting of this switch can be changed only when the instrument is turned off.

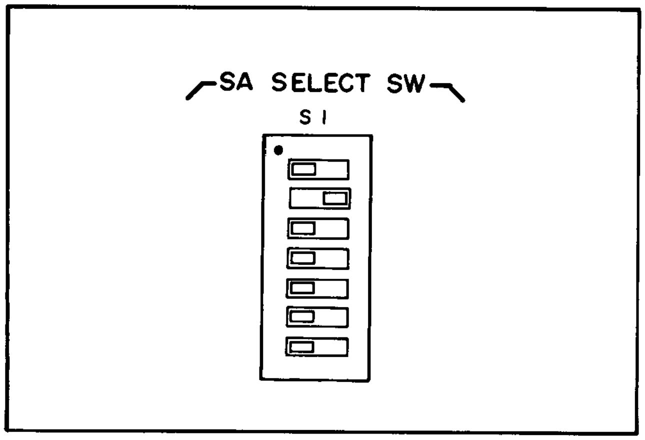


Figure 3-11. SA SELECT Switch Settings for 2m Test Leads.

Note

If test leads longer or shorter than the standard 1m or 2m test leads are used, the additional error is proportional to the square of the frequency. As the characteristic impedance of the test leads is also a factor in the propagation loss and phase shift (and of resultant measurement error), use of different type test leads must be avoided. Use only the standard test leads available from Hewlett-Packard.

3-51. ZERO OFFSET ADJUSTMENT

3-52. 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 4277A 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:

1MHz 900kHz 700kHz 505kHz 202kHz
100kHz 50.5Hz 20.2Hz 10kHz

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 four-terminal pair configuration to a two-terminal configuration. Refer to paragraph 3-45 and Figure 3-8.

(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 stray 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 3-12 (a), consists of G_0 and C_0. (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 3-12 (a)—is negligibly low and therefore does not affect the accuracy of 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

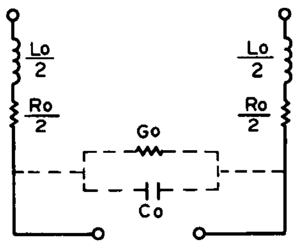
> If test leads are used, you must convert the four-terminal configuration to a two-terminal configuration. Refer to paragraph 3-45 and Figure 3-8.

(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.

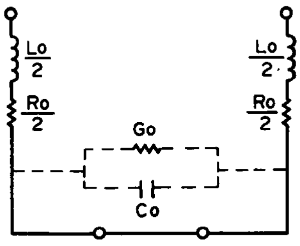
(3) Press the ZERO SHORT button.

When the ZERO SHORT button is pressed, the instrument will be automatically set to L-ESR 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 3-12 (b), 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 3-12 (b)-- 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.



OPEN
(a)



SHORT
(b)

Figure 3-12. Equivalent Circuits for Zero Offset Adjustment.

Capacitance:	Up to 20pF	OPEN
Conductance:	Up to 2µS	
Inductance:	Up to 2µH	SHORT
Resistance:	Up to 2Ω	

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.

3-53. ACTUAL MEASUREMENT EQUIVALENT CIRCUIT

3-54. 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 four-terminal pair configuration employed in the 4277A minimizes residual impedance circuit. The residual impedance, inherent in the test fixture or test leads, can be eliminated by the 4277A's ZERO offset function (refer to paragraph 3-51).

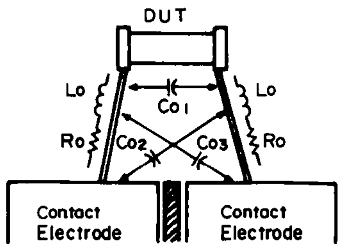
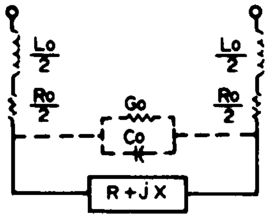


Figure 3-13. Parasitic Impedances Incident to DUT Connections.

However, the four-terminal pair 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 3-13 illustrates lead impedance and the stray capacitances between the component's leads.

3-55. 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 3-14 shows the equivalent circuit of the samples parasitic elements (R + jX is the sample's impedance). In Figure 3-14, 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 3-13. Reactive factors in the residual impedance and susceptive factors in the stray admittance have a greater effect on measurements made at higher frequencies.



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 3-14. Equivalent Circuit Including Residual Impedance.

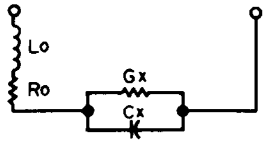
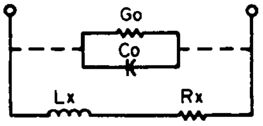
	Effect of residual impedance on C-G measurement: $Cm \approx Cx\ (1 + \omega^2 LoCx - 2RoGx - LoGx^2/Cx)$ $Gm \approx Gx\ (1 + 2\omega^2 LoCx - RoGx + \omega^2 RoCx^2/Gx)$
	Effect of stray admittance on L - ESR measurement: $Lm \approx Lx\ (1 - 2GoRx + \omega^2 CoLx - CoRx^2/Lx)$ $Rm \approx Rx\ (1 - GoRx + 2\omega^2 CoLx + \omega^2 Lx^2 Go/Rx)$

Figure 3-15. Effects of Residual Impedance.

3-56. Figure 3-15 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 3-16. 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:

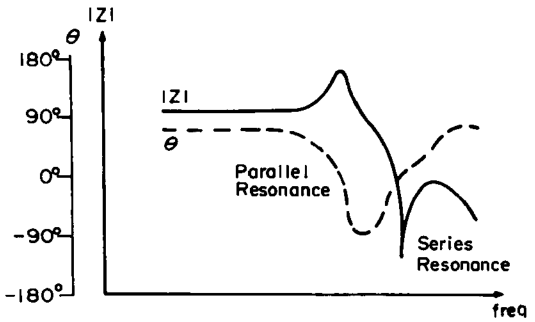


Figure 3-16. Effect of Resonance in Sample (Example).

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

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.

3-57. MEASURED VALUES AND BEHAVIOR OF COMPONENTS

3-58. 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, we'll discuss only the effects which result from the interaction of the reactive elements (L, C, etc.) of a component.

3-59. The impedance of a component can be graphically represented in vector form as shown in Figure 3-17. 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 3-18 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.

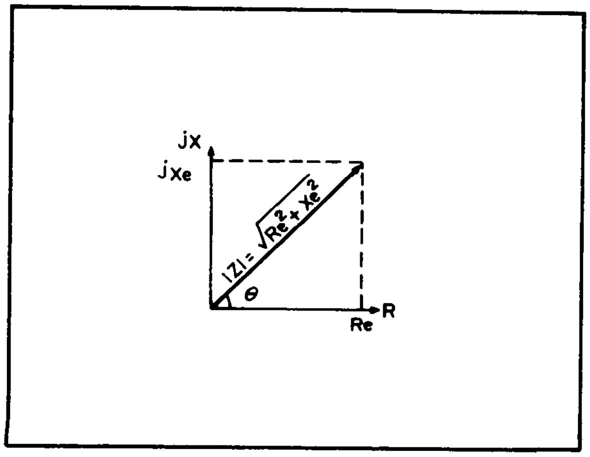


Figure 3-17. Impedance Vector Representation.

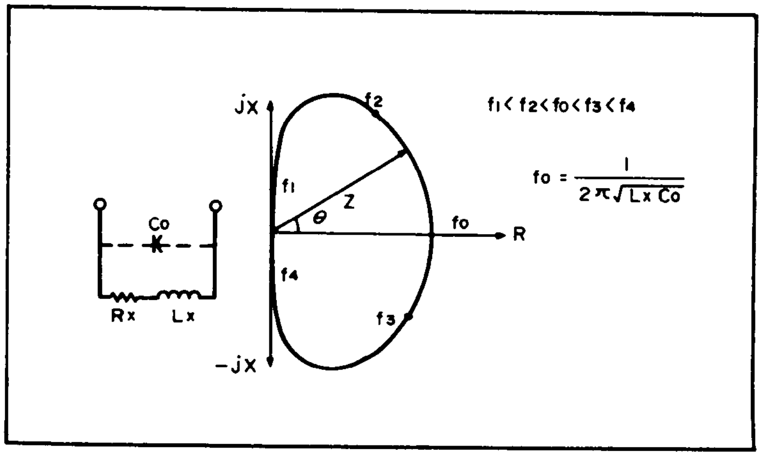


Figure 3-18. Typical Impedance Locus of an Inductor.

3-60. DEVIATION MEASUREMENT FUNCTION

3-61. 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.

3-62. When the Δ 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 4277A'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.

3-63. CHARACTERISTICS OF TEST FIXTURES

3-64. Characteristics and applicable measurement ranges of the HP test fixtures and test leads for the 4277A are summarized in Table 3-10. 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 3-10. Typical Characteristics of Test Fixtures and Leads

Model	Applicable Measurement Ranges		Reading Error at 1MHz	
	Parameter Value	Measurement Frequency	Parameter Reading Error	D Offset Value
16047A	Full range	Full range	±0.05%	±0.0002
16047C	Full range	Full range	±0.01%	±0.0001
16048A 16048B	Full range	Full range	±0.05%	±0.0005
16048C	$C>1000pF$ $L>100\mu H$	Below 100kHz	Residual Parameter Values: $C<5pF$, $L<200nH$, $R<10m\Omega$	
16048D	Full range	Full range	±0.20%	±0.0020
16034B	Ranges satisfied $\lvert Z\rvert>50\Omega$	Full range	±0.05%	±0.0005
			Residual Parameter Values: $C<0.02pF$, $L<30nH$, $R<50m\Omega$	
16065A	Full range	50Hz to 2MHz	———	———

3-65. MEASUREMENT ACCURACY

3-66. The measurement reference plane for the accuracies specified in Section I is the UNKNOWN terminals. The measurement accuracy of the 4277A 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 3-19.

3-67. GENERAL COMPONENT MEASUREMENT

3-68. The procedures for measuring general components--inductors, capacitors, resistors--are given in Figure 3-20. 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, 16048B, 16034B, etc., or by using specially designed user-built fixtures instead of the 16047A Test Fixture.

3-69. SEMICONDUCTOR DEVICE MEASUREMENT

3-70. As an example of a typical semiconductor measurement, the procedures for measuring the base-collector junction capacitance (C_{ob}) of an NPN transistor are given in Figure 3-21.

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

Front Panel Settings:

Test Frequency: 1MHz
LC | Z | RANGE: 100pF
TEST SIG LEVEL: HIGH
MEAS SPEED: MED

Measured Values:

C: 148.97pF
D: .0005
Q: OF (Assume a value of Qm)

Accuracies (Refer to Table 1-1):

C: ±.1% of reading + 5 counts
148.97pF x (.1/100) + .05pF
= (±) 0.199pF
D: ±.3% of reading + .0005/α + .0006 + 5 counts
.0005 x (.3/100) + .0005/1.4897 + .0006 + .0005
= (±) .00144
Q: Q_M x (.00144/.0005) + .1
= ± (Q_M x 2.88 + .1)

Note

In this case, Q accuracy (2.88 times Q) has no meaning, because Q 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

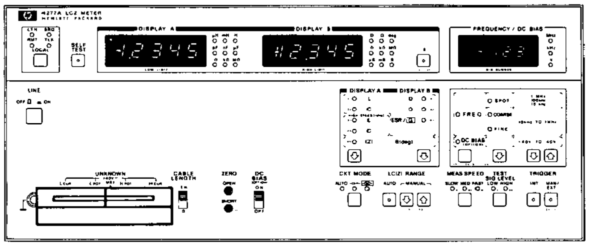
Measured Values:

C: .905μF
ESR: .3Ω
G: 1.0mS

Accuracies:

C: (.3 + .5α)% of reading + 3 counts
.905μF x (.3 + .5 x .905)/100 + .003
= (±) 0.0180μF
ESR: .2% of reading + 30αmΩ + 20mΩ + 5 counts
.3Ω x .2/100 + 30 x .905mΩ + 20mΩ + .5Ω
= (±) 550mΩ
G: 1mS x (550/300)
= (±) 1.83mS

Figure 3-19. How to Calculate Measurement Accuracies.



1. Connect the 16047A Test Fixture to the UNKNOWN terminals.
2. Turn on the 4277A.
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 3-51.
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

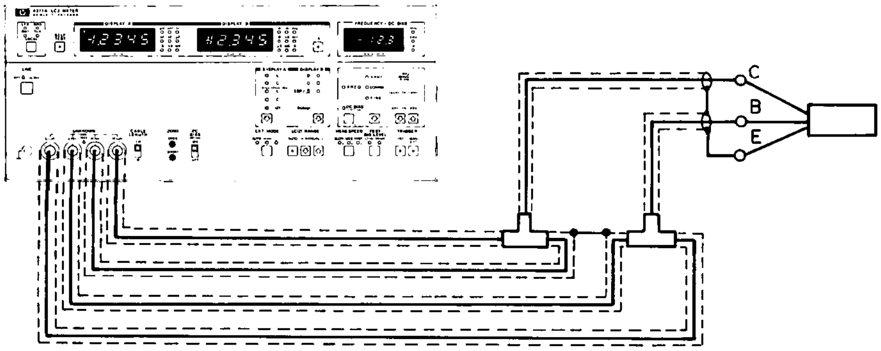
When the instrument is set to C-D or C-Q measurement mode and nothing is connected to the measurement terminals, CF and .0000 may be alternately displayed on DISPLAY A. This is not a malfunction, however.

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 3-20. General Component Measurements.

Parameters of semiconductor devices have a strong dependency on the applied voltage and device temperature. Because of the non-linear impedance chanracteristics 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 4277A 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 4277A.
2. Turn on the 4277A.
3. Set the 4277A's front panel controls as follows:

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

4. Perform OPEN and SHORT Zero Offset adjustments as described in paragraph 3-51.
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.

Figure 3-21. Semiconductor Device Measurement (Sheet 1 of 2).

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 ON/OFF switch on the front panel to ON, and set the desired bias voltage.

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 3-21. Semiconductor Device Measurement (Sheet 2 of 2).

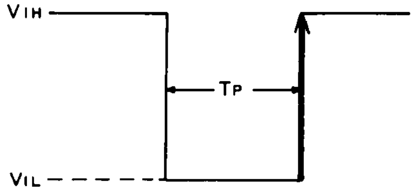
3-71. EXTERNAL DC BIAS

3-72. The special biasing circuits and procedures for using external voltage or current bias (required for certain capacitance or inductance measurements) are given in Figure 3-23. The figures show sample circuits appropriate for 4277A 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_{POT} and H_{CUR} terminals.

3-73. Bias Voltage Settling Time: When a measurement with dc bias voltage superposed is performed, it takes some time for the voltage across sample to reach a certain percentage of the applied (desired) voltage. Typical values of dc bias voltage settling time are listed in Table 1-2 as reference data.

3-74. EXTERNAL TRIGGERING

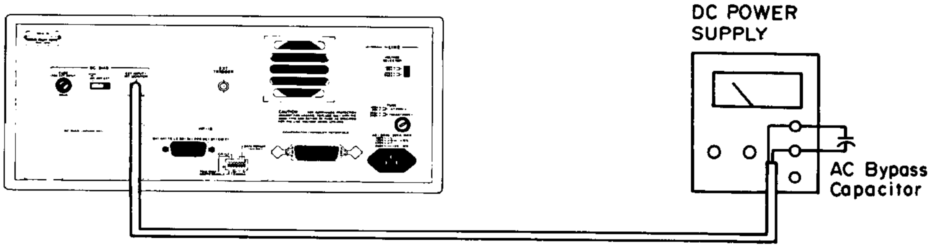
3-75. The 4277A can be externally triggered by connecting an external triggering device to the EXT TRIGGER connector on the rear panel and setting the TRIGGER control on the front panel to MAN/EXT on front panel. The instrument is triggered (measurement is made) each time a positive-going TTL level pulse is applied to this connector (refer to Figure 3-22). External triggering can be also done by alternately shorting and opening the center conductor of the EXT TRIGGER connector to ground (chassis).



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

Figure 3-22. External Trigger Pulse.

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 4277A'S EXT INPUT/INT MONITOR CONNECTOR. IF THE APPLIED VOLTAGE EXCEEDS ±40V, THE 4277A 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 4277A.
3. Turn on the instruments.
4. Set the 4277A's controls as described in steps 5 through 7 of Figure 3-20. Set the DISPLAY A function to "C" measurement mode.
5. Perform OPEN and SHORT Zero Offset Adjustments as described in paragraph 3-51.
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

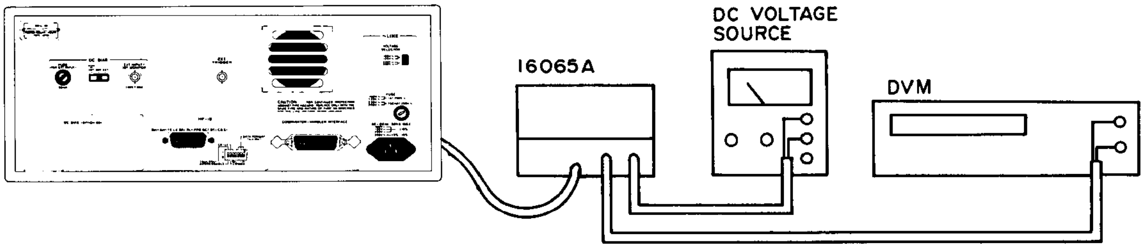
Use a stable dc voltage source.

Note

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

Figure 3-23. External DC Bias (Sheet 1 of 4).

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 4277A'S EXT INPUT/INT MONITOR CONNECTOR. IF THE APPLIED VOLTAGE EXCEEDS ±40V, THE 4277A MAY BE DAMAGED.

PROCEDURE:

1. Set DC BIAS select switch on rear panel to OFF.
2. Set CABLE LENGTH switch on the front panel to 1m.
3. Connect the 16065A to the UNKNOWN terminals of the 4277A.
4. Connect the dc voltage source to DC BIAS INPUT connector of the 16065A.
5. Connect a DVM or an oscilloscope to the DC BIAS MONITOR connector of the 16065A.
6. Turn on the instruments.
7. Set the 4277A's controls as described in steps 5 through 7 of Figure 3-20. Set the DISPLAY A function to "C" measurement mode.
8. Perform OPEN and SHORT Zero Offset Adjustments.
9. 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.

10. Set the external dc voltage source to the desired output voltage and close the cover of the 16065A.
11. Read the measured values. Wait until the monitored voltage becomes stable.
12. 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.

Figure 3-23. External DC Bias (Sheet 2 of 4).

13. Remove the sample from the 16065A.

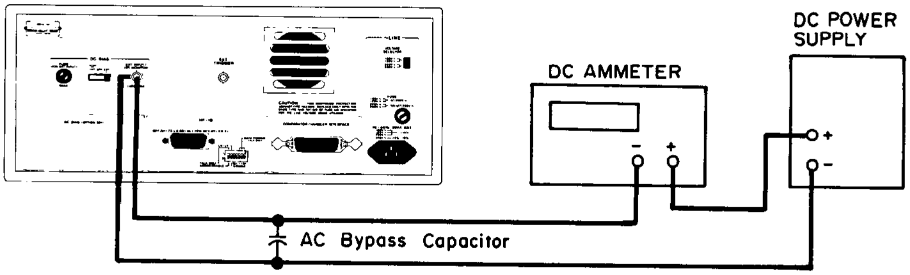
Note

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.

EXTERNAL DC CURRENT BIAS OPERATION (≤35mA)



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 a 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 4277A.
4. Turn on the instruments.
5. Set the 4277A's controls as described in steps 5 through 7 of Figure 3-20. 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:

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

Figure 3-23. External DC Bias (Sheet 3 of 4).

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 bridge circuit's range resistor, as listed in the table below.

Range Resistor	Maximum Output Current
100Ω	35mA
1kΩ and 10kΩ	10mA

Refer to Figure 3-5 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 3-23. External DC Bias (Sheet 4 of 4).

3-76. HP-IB INTERFACE

3-77. The 4277A 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."

3-78. HP-IB INTERFACE CAPABILITIES

3-79. The 4277A has eight HP-IB interface functions, as listed in Table 3-11.

Table 3-11. 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.

3-80. CONNECTION TO HP-IB

3-81. The 4277A 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 3-86).

3-82. HP-IB STATUS INDICATORS

3-83. The HP-IB Status Indicators are four LED lamps located on the front panel. When lit, these lamps show the existing status of the 4277A in the HP-IB system as follows:

SRQ:	SRQ signal from the 4277A to the controller is on the HP-IB line. Refer to paragraph 3-104.
LISTEN:	The 4277A is set to listener.
TALK:	The 4277A is set to talker.
REMOTE:	The 4277A is under remote control.

3-84. LOCAL KEY

3-85. The LOCAL key releases the 4277A 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 4277A is set to "local lockout" status by the controller.

3-86. HP-IB CONTROL SWITCH

3-87. The HP-IB Control Switch, located on the rear panel, has seven bit switches. See Figure 3-24. 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.

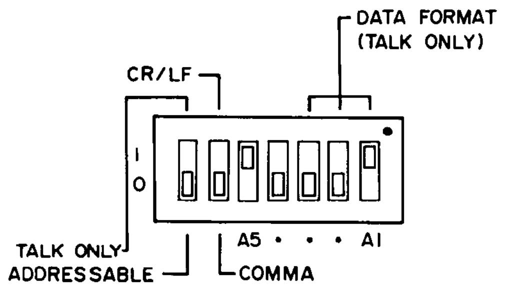


Figure 3-24. HP-IB Control Switch.

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, as set at the factory, is shown in Figure 3-24.

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.

3-88. ADDRESSABLE MODE

3-89. 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.

3-90. TALK ONLY MODE

3-91. 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 3-12. Refer to paragraph 3-98 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 F3, the number displayed on DISPLAY A at turn on will be 53.

Note

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

Table 3-12. Output Data Formats Selectable in TALK ONLY Mode

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 3-98 for details.

3-92. REMOTE PROGRAM CODES

3-93. Remoe program codes for the 4277A are listed in Table 3-13.

Table 3-13. 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>B / A</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>1μH/1pF
10μH/10pF
100μH/100pF/10Ω
1mH/1nF/100Ω
10mH/10nF/1kΩ
100mH/100nF/10kΩ
1H/1μF/100kΩ
10μF/1MΩ</td><td>R1
R2
R3
R4
R5
R6
R7
R8</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 3-13. Remote Program Codes (Sheet 2 of 2)

Item	Control	Program Code	Description
Data Ready	OFF ON	D0• D1	If Data Ready is set to ON, an SRQ signal is output when the measurement is completed.
Comparator Enable	OFF ON	E0• E1	If the instrument is not equipped with Option 002, an error will result if E1 is sent via the HP-IB.
Comparator Run	OFF ON	G0• G1	
Comparator Limit	L/C/Z input D/Q/ESR/G input	L1• L2	
Comparator Bin Number	BIN1 BIN2 BIN3 BIN4 BIN5 BIN6 BIN7 BIN8 BIN9	N1• N2 N3 N4 N5 N6 N7 N8 N9	These codes are used when setting L/C/|Z| limits.
Comparator Limit Recall		LR	Refer to paragraph 3-102.
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 Displays A/B/Comparator Display A or Comparator Display A/Comparator	F1• F2 F3 F4	Refer to paragraph 3-98 and Table 3-16.
Learn Mode		LN	Refer to paragraph 3-100.
Output Data Mode	ASCII BINARY	P0• P1	

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

3-94. DATA OUTPUT

3-95. 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 binary word. 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 3-25.

3-96. PARAMETER SETTING

3-97. Test frequency, DC bias (Option 001), and bin limits (Option 002) can be set via remote programming.

[1] Test Frequency Setting

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

(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:

"FR75.9EN": 75.5kHz displayed on FREQUENCY/DC BIAS DISPLAY

[2] DC Bias Setting (Option 001 only)

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

(1) Setting value, in volts.

Note

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

[3] Comparator Limit Setting (Option 002 only)

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

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

(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.

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

① DISPLAY A/B

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

$$\underset{(7)}{\underline{\text{X}}}\ \underset{(8)}{\underline{\text{X}}}\ \underset{(9)}{\underline{\pm\text{N.NNNN}}}\ \underset{(10)}{\underline{\text{E}\pm\text{NN}}}\ \underset{(11)}{\underline{\text{CR LF}}}$$

(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) Comma (data delimiter)

(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)

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

(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	+00000E-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 EOI signal is output with the LF signal.

Figure 3-25. Data Output Format for the 4277A (Sheet 1 of 2).

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

① DISPLAY A/B

$$\overset{\text{1st byte}}{\underset{(1)}{\underline{BB}}\ \underset{(2)}{\underline{BB}}\ \underset{(3)}{\underline{BBBB}}}\ \ \underset{(4)}{\underline{\overset{\text{2nd byte}}{BBBBBBBB}\ \overset{\text{3rd byte}}{BBBBBBBB}}}$$

$$\underset{(5)}{\underline{\overset{\text{4th byte}}{BBBBBBBB}\ \overset{\text{5th byte}}{BBBBBBBB}}}$$

(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.

$$\underbrace{01}_{1}\ \ \underbrace{11}_{3}\ \ \underbrace{0101}_{5}$$

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

② COMPARATOR (Option 002 only)

$$\underset{(1)}{\underline{BB}}\ \underset{(2)}{\underline{BB}}\ \underset{(3)}{\underline{BBBB}}$$

(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

The EOI signal is output with the last data byte.

Figure 3-25. Data Output Format for the 4277A (Sheet 2 of 2).

Table 3-14. 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 3-15. Data Output Codes for PACKED BINARY Mode

Item	Information	Code
Data Status of DISPLAY A/B	Normal Overflow Underflow Change Function or Blank	0 1 2 3
Measurement Range	1μH/1pF 10μH/10pF 100μH/100pF/10Ω 1mH/1nF/100Ω 10mH/10nF/1kΩ 100mH/100nF/10kΩ 1H/1μF/100kΩ 10μF/1MΩ	1 2 3 4 5 6 7 8
Data Status of L/C/|Z| for Comparator	Bin IN HIGH LOW Embedded or Undefined	0 1 2 3
Data Status of D/Q/ESR/G for Comparator	Bin IN HIGH LOW Undefine	0 1 2 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

3-98. OUTPUT DATA FORMAT

3-99. The 4277A 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 3-16.

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 PACKED BINARY 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.

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 F3, the number displayed on DISPLAY A at turn on will be 53.

Table 3-16. Output Data Formats

Format	Output Data				Output Mode	
		Display A	Display B	Comparator	ASCII	PACKED BINARY
F1	I	Yes	Yes	No	Yes	Yes
	II	No	No	Yes		
F2	I	Yes	Yes	No	Yes	Yes
	II	Yes	Yes	Yes		
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		

3-100. LEARN MODE DATA

3-101. All front panel settings and comparator key settings are output from the 4277A when the program code "LN" is used (refer to Figure 3-28). The data is output in the following format:

FRnnnnEN	An	Bn	Cn	Dn	Fn	Mn	Pn
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

Rn	Sn	Tn	Un	Vn	Xn
(9)	(10)	(11)	(12)	(13)	(14)

BI±nnnnEN	En	Gn	Ln	Nn	CR LF
(15)	(16)	(17)	(18)	(19)	(20)

(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 - R8: 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.

3-102. RECALL COMPARATOR LIMIT DATA

3-103. Low and high bin limits can be output from the 4277A when the program code "LR" is used (refer to Figure 3-30). The L/C/ | Z | limits for the designated bin are output when program code "L1" is used. When program code "L2" is used, D/Q/ESR/G limits are output. The data is output in the following format:

LLXX.XXXEN	LHXX.XXXEN	CR LF
(1)	(2)	(3)

(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

3-104. SERVICE REQUEST STATUS BYTE

3-105. The 4277A outputs an RQS (Request Service) signal whenever it is set to one of the five possible service request states. Figure 3-26 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 4277A:

(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 4277A is externally triggered before the measurement has been completed.

(5) Bit 5: ① This bit is set when the 4277A has one of the following operation errors:

OFF, E10, E13, E14, E15, E16, E17, E18, E20

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

Error Codes: E36 - E43

Figure 3-26. Status Byte for the 4277A.

3-106. PROGRAMMING GUIDE FOR 4277A

3-107. Sample programs that can be run on the HP-85, 9835A/B, 9845B, 9826A, or 9836A are given in Figures 3-27 through 3-30. These programs are listed in Table 3-17.

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) 4277A 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) 9845B Desktop Computer 98412A I/O ROM

(3) 98034A HP-IB INTERFACE CARD

or

(2) 9826A Desktop Computer

or

(2) 9836A Desktop Computer

Table 3-17. Sample Programs

Sample Program	Figure	Description
1	3-27	Remote control and data output program
2	3-28	How to use remote program code "LN."
3	3-29	How to input low and high bin limits for the Comparator.
4	3-30	How to use remote program code "LR."

Sample Program 1

Description:

This program has three capabilities:

(1) Control of the 4277A via the HP-IB

(2) Trigger of the 4277A via the HP-IB

(3) Data output from the 4277A via the HP-IB

Program:

```
 10  REMOTE 717
 20  CLEAR 717
 30  DIM A$[50]
 40  OUTPUT 717;"A2B1T2P0F1"
           (1)(2)     (3)
 50  OUTPUT 717;"FR100 EN"
                   (4)
 60  OUTPUT 717;"EX"
            (5)
 70  ENTER 717;A$
 80  DISP A$
 90  PRINT A$
100  END
```

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

(2) HP-IB Address of the 4277A

(3) Program codes for the 4277A (refer to Table 3-13)

(4) Program codes for parameter setting of the 4277A (refer to paragraph 3-96)

(5) This is equivalent to: TRIGGER 717

Figure 3-27. 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 3-27. 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 3-28. 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$[50]
 40 OUTPUT 717;"A2B1R4T2P0F2"
                     (1)
 50 OUTRUT 717;"FR100EN"
 60 OUTPUT 717;"E1G0ER"
                  (2)
 70 OUTPUT 717;"L1N1LL.995ENLH.998EN"
                 (2)      (3)
 80 OUTPUT 717;"N2LL1ENLH1.1EN"
 90 OUTPUT 717;"N3LL1.0001ENLH1.2EN"
100 OUTPUT 717;"L2LL0ENLH.001EN"
110 OUTPUT 717;"G1"
120 OUTPUT 717;"EX"
130 ENTER 717; A$
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 3-29. 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 3-30. Sample Program 4.

3-108. OPTIONS

3-109. Options are standard modificaions to the instrument that implement user's special requirements for minor functional changes. Operating instructions for the 4277A's options (except rack mount and handle installation kit options) and associated information are described in the following paragraphs.

3-110. Two options are available, as listed in the following tables:

Option No.	Option Name
001	Internal DC Bias
002	Comparator/Handler Interface

Option contents are as follows:

Option No.	Contents
001	A22 Internal DC Bias Board Assembly
002	Comparator/Handler Interface Kit

3-111. OPTION 001 INTERNAL DC BIAS (-40V to +40V)

3-112. 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 front-panel or remotely via the HP-IB. Manual control and dc bias applications under HP-IB control are described in Figure 3-31. The internal dc bias source has two ranges and a maximum resolution of 10mV. Refer to Table 3-18. 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 ON/OFF switch on the front panel is set to ON. If the DC BIAS ON/OFF 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 3-32.

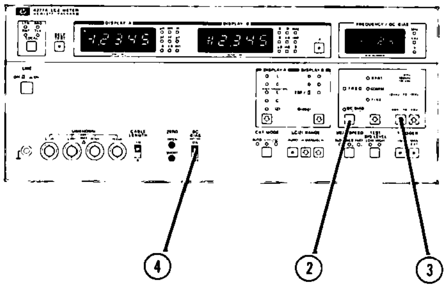
Table 3-18. Bias Voltage Resolution

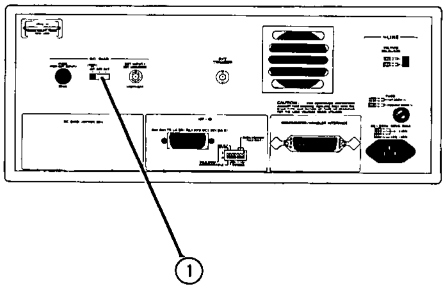
Bias Voltage Range	Resolution
0V to ±9.99V	10mV
±10.0V to ±40.0V	100mV

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 ① 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 4277A.
4. Perform OPEN and SHORT Zero Offset adjustments as described in paragraph 3-51.
5. Set the instrument's front panel controls as appropriate for the desired measurement.
6. Press the FREQ/DC BIAS select key ②. The DC BIAS lamp will come on.
7. Set the desired voltage by pressing the appropriate FREQ/DC BIAS control key ③. 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 ④ 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 ON/OFF switch ④ to ON.
10. If you're measuring a capacitive DUT, all 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 ON/OFF switch ④ to OFF.
13. Wait until the voltage across the DUT return to 0V.
14. Remove the DUT from the test fixture.

Note

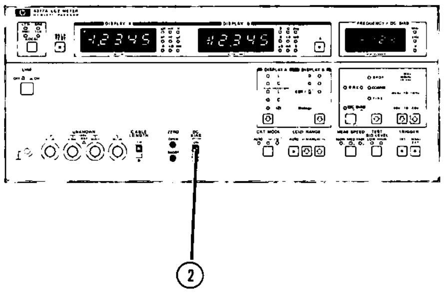
For reasons of safety and measurement accuracy, the voltage actually applied to the DUT should be monitored. Refer to Figure 3-32.

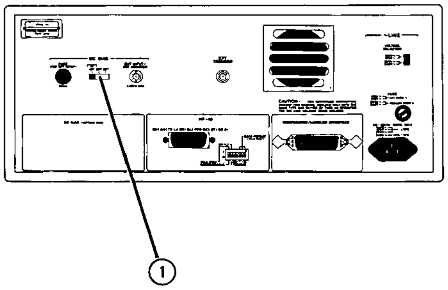
Note

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 Table 1-2 Supplemental Performance Characteristics.

Figure 3-31. Option 001 Internal DC Bias (Sheet 1 of 3).

[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 ① 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 4277A.
4. Perform OPEN and SHORT Zero Offset adjustments as described in paragraph 3-51.
5. Set the DC BIAS ON/OFF switch ② 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.

```
REMOTE 717
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 10ms wait.

```
WAIT 10
```

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
```

Figure 3-31. Option 001 Internal DC Bias (Sheet 2 of 3).

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

```
OUTPUT 717; "BI0EN"
```

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

    * Example of programming a 10ms wait.

```
WAIT 10
```

14. Remove the DUT from the test fixture.

Note

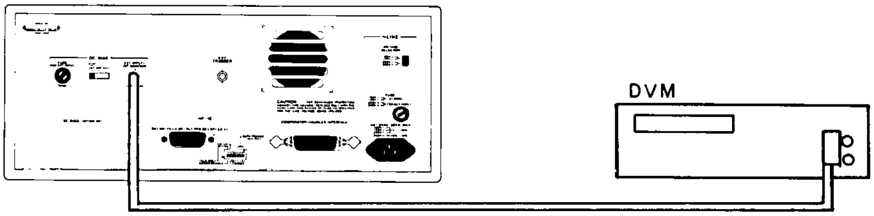
The above remote programming examples can be used on the HP Model 85 (with 00085-15003 I/O ROM), Model 9835A, Model 9845B/C, Model 9826A, and Model 9836A.

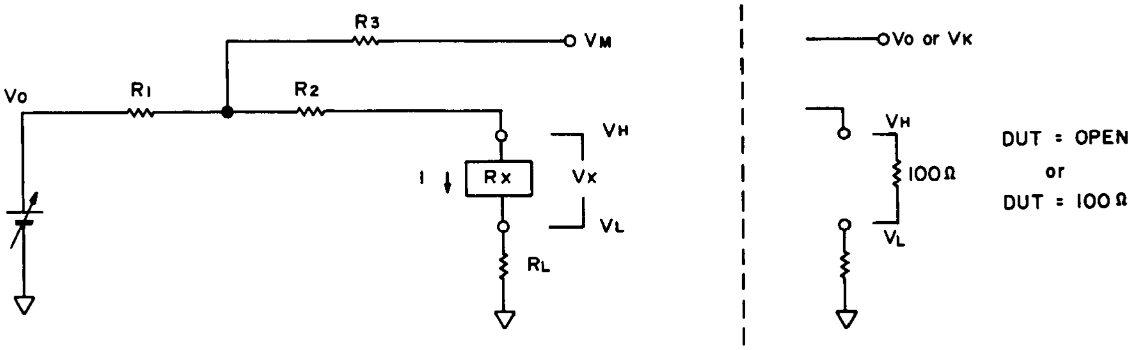
Note

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

Figure 3-31. Option 001 Internal DC Bias (Sheet 3 of 3).

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

   (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 3-5.

   (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:

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

Figure 3-32. Internal DC Bias Voltage Monitor (Sheet 1 of 2).

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 3-32. Internal DC Bias Voltage Monitor (Sheet 2 of 2).

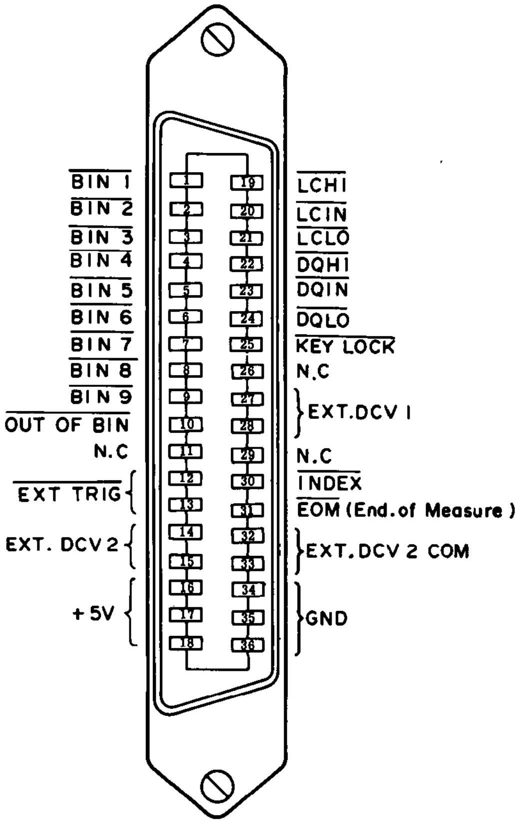
3-113. OPTION 002 COMPARATOR/HANDLER INTERFACE

3-114. Option 002 equips the standard 4277A 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.

3-115. 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 3-34.

3-116. 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 3-33. For complete information, refer to the 16064A Operation Note.

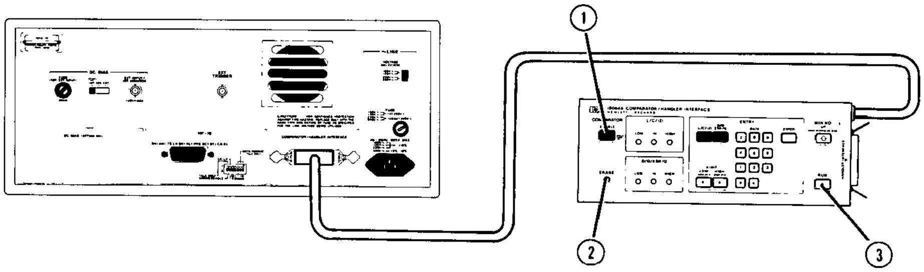
Pin No.	Signal Name	Pin No.	Signal Name
1	$\overline{\text{BIN 1}}$	19	$\overline{\text{LCHI}}$
2	$\overline{\text{BIN 2}}$	20	$\overline{\text{LCIN}}$
3	$\overline{\text{BIN 3}}$	21	$\overline{\text{LCLO}}$
4	$\overline{\text{BIN 4}}$	22	$\overline{\text{DQHI}}$
5	$\overline{\text{BIN 5}}$	23	$\overline{\text{DQIN}}$
6	$\overline{\text{BIN 6}}$	24	$\overline{\text{DQLO}}$
7	$\overline{\text{BIN 7}}$	25	$\overline{\text{KEY LOCK}}$*
8	$\overline{\text{BIN 8}}$	26	NC
9	$\overline{\text{BIN 9}}$	27	$\overline{\text{EXT DCV 1}}$*
10	$\overline{\text{OUT OF BINS}}$	28	$\overline{\text{EXT DCV 1}}$*
11	NC	29	NC
12	$\overline{\text{EXT TRIG}}$*	30	$\overline{\text{INDEX}}$
13	$\overline{\text{EXT TRIG}}$*	31	$\overline{\text{EOM}}$
14	EXT DCV 2*	32	EXT DCV COM*
15	EXT DCV 2*	33	EXT DCV COM*
16	+5V	34	GROUND
17	+5V	35	GROUND
18	+5V	36	GROUND



*: Externally Applied Signals

Figure 3-33. Pin Assignments for the Handler Interface Connector (HP 16064A).

OPTION 002 COMPARATOR OPERATION



1. Connect the Model 16064A COMPARATOR/HANDLER INTERFACE to the COMPARATOR/HANDLER INTERFACE connector on the 4277A'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 3-51.

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

6. Press the ENABLE key ① on the 16064A. The LED lamp at the center of the key should come on.

   Note

   If E16 is displayed or DISPLAY A, press the ERASE button ② on the 16064A to erase previously stored limits.

7. Enter the high/low limits for L/C/ | Z | or D/Q/ESR/G.

8. Press the RUN key ③ on the 16064A. The comparator will then begin comparing all measured values with the high/low limits entered in step 6. 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.

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 3-34. Option 002 Comparator (Sheet 1 of 7).

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

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

LOW Limit	HIGH Limit
.01	.05

Table C. Measured Values

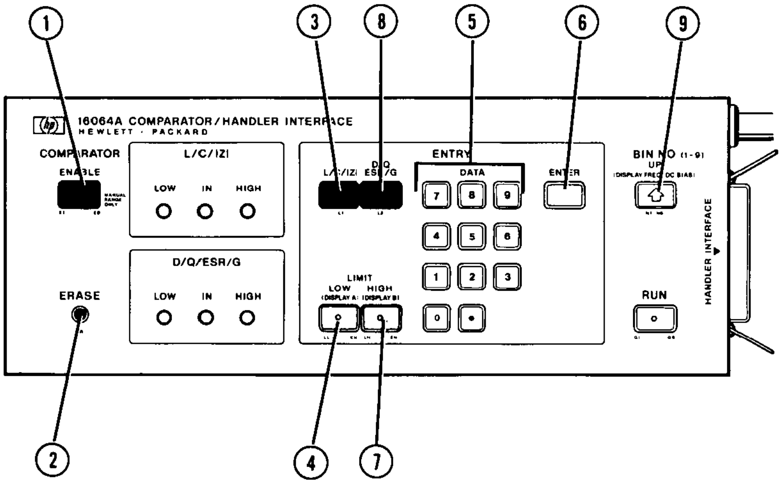
Sample No.	Measured Data	Sample No.	Measured Data
1	C 1.22 nF	6	C 1.1 nF
	D .013		D .02
2	C 1.08 nF	7	C 1.18 nF
	D .005		D .071
3	C .8 nF	8	C 4.1 nF
	D .025		D .033
4	C 2.75 nF	9	C 1.5 nF
	D .06		D .029
5	C .95 nF	10	C 1.72 nF
	D .055		D .025

Table D. Comparison Results

Sample No.	L/C/|Z| Lamp LOW IN HIGH	D/Q/ESR/ G Lamp LOW IN HIGH	FREQUENCY /DC BIAS Display
1	● ☼ ●	● ☼ ●	3
2	● ☼ ●	☼ ● ●	0
3	☼ ● ●	● ☼ ●	0
4	● ☼ ●	● ● ☼	0
5	☼ ● ●	● ● ☼	0
6	● ☼ ●	● ☼ ●	1
7	● ☼ ●	● ● ☼	0
8	● ● ☼	● ☼ ●	0
9	● ☼ ●	● ☼ ●	5
10	☼ ● ☼	● ☼ ●	0

Figure 3-34. Option 002 Comparator (Sheet 2 of 7).

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.

Figure 3-34. Option 002 Comparator (Sheet 3 of 7).

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.

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.

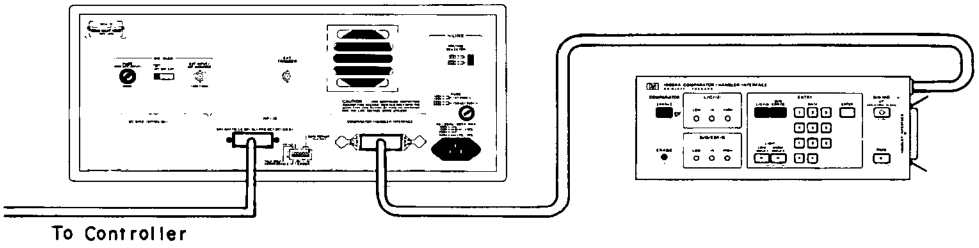
18. Key in the desired HIGH limit using the DATA keys ⑤. The HIGH limit value will be displayed on DISPLAY B.

19. Press the ENTER Key ⑥.

Note

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

[HP-IB OPERATION]



1. Connect the Model 16064A COMPARATOR/HANDLER INTERFACE to the COMPARATOR/HANDLER INTERFACE connector on the 4277A'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 100kHz test frequency

```
REMOTE717
CLEAR 717
OUTPUT 717;"A2B1FR100ENR4T2"
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).

Figure 3-34. Option 002 Comparator (Sheet 4 of 7).

* 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.

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.

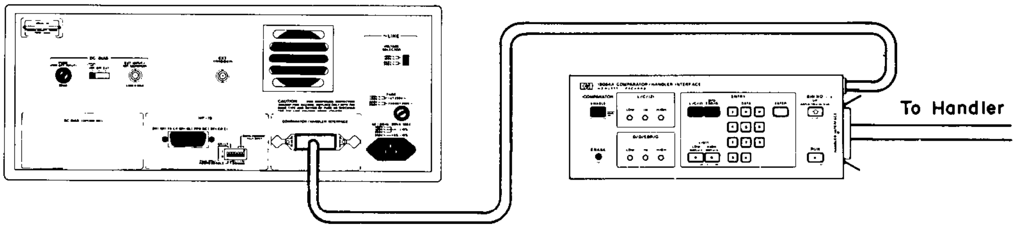
```
ENTER 717;A$
PRINT A$
```

Note

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

Figure 3-34. Option 002 Comparator (Sheet 5 of 7).

OPTION 002 HANDLER INTERFACE OPERATION



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

(1) Comparison result signals ($\overline{\text{LCHI}}$, $\overline{\text{LCIN}}$, $\overline{\text{LCLO}}$, $\overline{\text{DQHI}}$, $\overline{\text{DQIN}}$, $\overline{\text{DQLO}}$)

(2) Bin number signals ($\overline{\text{BIN1}}$ ... $\overline{\text{BIN9}}$, $\overline{\text{OUT-OF-BIN}}$)

(3) DUT change signal ($\overline{\text{INDEX}}$)

(4) Comparison complete signal ($\overline{\text{EOM}}$)

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, $\overline{\text{INDEX}}$, goes LOW when the 4277A 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, $\overline{\text{EOM}}$, goes LOW when the 4277A 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 ($\overline{\text{EXT TRIG}}$) that starts measurement and a key lock signal ($\overline{\text{KEY LOCK}}$) that disables all control keys during comparator operation. To trigger the 4277A, apply a LOW signal (at least 100μs duration) to the $\overline{\text{EXT TRIG}}$ line. To disable the control keys of the 4277A and 16064A, apply a LOW signal to the $\overline{\text{KEY LOCK}}$ line.

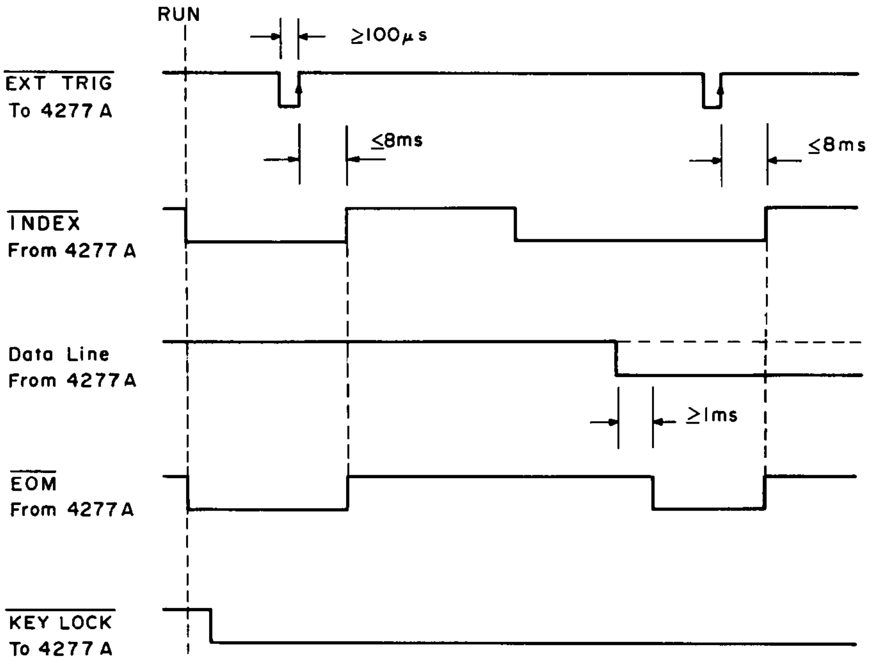
Note

The $\overline{\text{INDEX}}$ and $\overline{\text{KEY LOCK}}$ 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.

Figure 3-34. Option 002 Comparator (Sheet 6 of 7).



Timing Diagram

Figure 3-34. Option 002 Comparator (Sheet 7 of 7).

Table 4-1. Recommended Equipment (Sheet 1 of 2)

Equipment	Critical Specifications	Recommended Model/Note	Use*
Digital Voltmeter	Voltage range: 10mV to 100Vf.s. Resolution: 0.1mV Accuracy: 0.05% Input impedance: >10MΩ	HP 3478A	P, A, T
RF Voltmeter	Voltage range: 10mV to 3Vrms f.s. Bandwidth: 10kHz to 1MHz Accuracy: 1%	HP 400E and HP 3403C	P, A
Frequency Counter	Maximum frequency: >1MHz Accuracy: 0.001% Trigger level: Adjustable	HP 5314A	P, A, T
DC Power Supply	Maximum output voltage: >50V Resolution: <100mV	HP 6206B	P
Oscilloscope	Bandwidth: 100MHz Sensitivity: 5mV/DIV	HP 1740A	A, T
Oscillator	Frequency: 1kHz Output voltage: 1mV	HP 652A	T
Signature Analyzer		HP 5004A	T
Test Cables	BNC (m)-to-BNC (m), 61cm long, 1 ea.	HP 11170B	P, A
	BNC (m)-to-BNC (m), 10cm long, 1 ea.		A, T
	BNC (m)-to-BNC (m), 30cm long, 2 ea.	HP 11170A	T
	BNC (m)-to-Dual Banana Plug, 1 ea.	HP 11001A	P, A
	Dual Banana Plug-to-Alligator Clip, 1 ea.	HP 11002A	P, A, T
	BNC (m)-to-Dual Alligator Clip,10cm long, 2 ea.	Refer to the troubleshooting diagram A2-17.	T
	Alligator Clip-to-Alligator Clip,20cm long,1 ea.		T
Adaptors	BNC (f)-to-BNC (f), 5 ea.	HP P/N 1250-0080	P, T
Oscilloscope Probes	10:1 Divider Probe Input impedance: 10MΩ	HP 10004D	A, T
	1:1 probe	HP 10007B	A
Test Leads		HP 16048A	P, T

*P = Performance Test, A = Adjustment, T = Troubleshooting

Table 4-1. Recommended Equipment (Sheet 2 of 2)

Equipment	Critical Specifications	Recommended Model/Note	Use*
Capacitance Standards	1pF±0.03% 10pF±0.03% 100pF±0.03% 1000pF±0.03% Useable frequency: Up to 1MHz	HP 16381A HP 16382A HP 16383A HP 16384A	P, A, T
Resistance Standards	0Ω 10Ω 100Ω±0.03% 1kΩ±0.03% 10kΩ±0.03% 100kΩ±0.03% OPEN termination SHORT termination	HP 16074A Standard Resistor Set	P, A, T
Capacitors	1nF±5%	HP P/N 0160-2218	T
Resistors	4.7Ω±5% 1/4W	HP P/N 0683-0475	T
	560Ω±5% 1/4W	HP P/N 0683-5615	T
	1kΩ±5% 1/2W	HP P/N 0757-0159	T
	10kΩ±1% 1/2W	HP P/N 0757-0839	T
	100kΩ±1% 1/8W	HP P/N 0757-0465	T
HP-IB Controller		HP-85/ w 00085-15003/ w 82936A/ w 82937A	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 4277A 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 (16381A, 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 4277A'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 4277A accuracy is tested and verified. As the 4277A 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 4277A 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 4277A, 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.

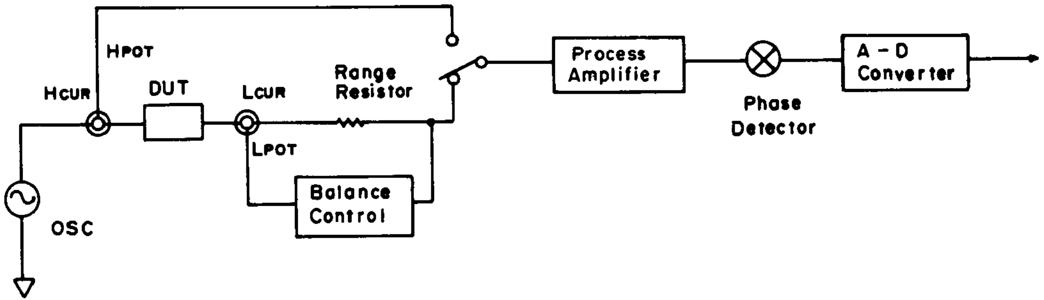
The technician should note that accuracy here is based on arithmetic relationships as are the parameter relationships. Therefore, the accuracy tests can be done by simplified procedures instead of time-consuming tests on the approximately 250000 possible combinations of the fundamental test parameters 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) Bridge Balance Control
4) Phase Detector
5) A-D (Analog to Digital) Converter



4277A Measurement Section

CAPACITANCE ACCURACY TEST verifies Range Resistor accuracy for reactive impedance measurements from the lowest through the highest test frequencies. Balance Control linearity and normal operation of the Phase Detector and A-D Converter are also verified.

RESISTANCE 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.

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.

PHASE ACCURACY TEST verifies phase-flatness characteristics (minimum phase shift) of the overall measurement section and Phase Detector phase accuracy from the lowest through the highest test frequencies.

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). For values up to 10MHz, an extrapolation of the calibrated values at 1kHz is used. This is based on the careful consideration of their inherent residual parameter values and on the actual test measurement to verify the frequency dependency of the values. Capacitance values at frequencies up to 10MHz are read from the graph given on the data sheet of each standard.

Note

A high capacitance standard, useable in high frequency region, is unavailable. This is because a 10μF capacitor, for example, has a low impedance value of 0.16Ω at 100kHz. A capacitance standard would have, in addition, residual impedance which could not be disregarded when compared to the pure impedance of 0.16Ω. Thus, an attempt to conduct tests which would use the standard capacitor at the higher operating frequency ranges is not practicable.

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 and10Ω resistors are used as the (pure resistance) reference device in the Phase Accuracy Test. The 0.1Ω, 1Ω and the quasi-inductors are not used in the 4277A performance tests.

3) Inductance Accuracy Test

The 4277A 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.

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.

4-9. *TEST FREQUENCY ACCURACY TEST*

4-10. This test verifies that test signal frequencies for the 4277A meet the specified frequency accuracy of 0.01%.

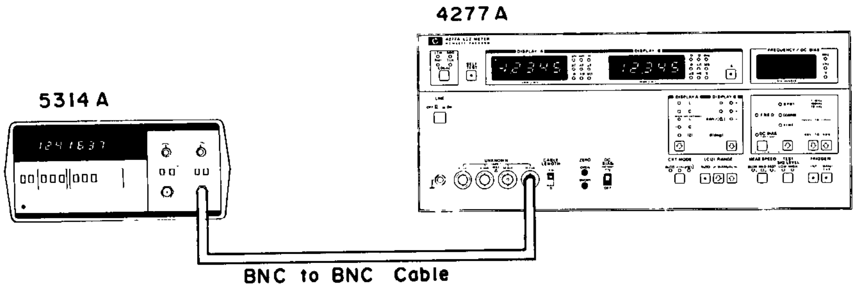


Figure 4-1. Test Frequency Accuracy Test Setup.

EQUIPMENT:

Frequency Counter .... HP 5314A
BNC to BNC cable .... HP 11170A

PROCEDURE:

1. Connect the frequency counter to the 4277A UNKNOWN H_{CUR} terminal as shown in Figure 4-1.

2. Set the 4277A's controls as follows:

   TEST SIG LEVEL .... HIGH
   DC BIAS switch .... OFF
   Test Frequency 10kHz
   Other controls .... Any setting

3. Verify that the frequency reading on the 5314A is 10.000kHz±1Hz.

4. Set the test frequency in the sequence given in Table 4-2. Verify that the frequency readings on the 5314A are within the test limits given in the table.

Table 4-2. Test Frequency Accuracy Test

Frequency Setting	Test Limits
10.0kHz	9.999 to 10.001kHz
100kHz	99.99 to 100.01kHz
202kHz	201.98 to 202.02kHz
500kHz	499.95 to 500.05kHz
1.00MHz	0.9999 to 1.0001MHz

Note

1) Test limits in the table do not account for tolerance dependent on the specified accuracy of the 5314A.

2) If this test fails, the instrument requires troubleshooting.

4-11. *TEST SIGNAL LEVEL ACCURACY TEST*

4-12. This test verifies that test signal level for the 4277A meets the specified level accuracy of 10%.

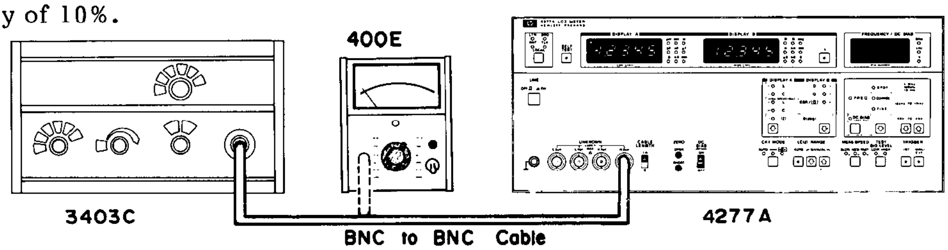


Figure 4-2. Test Signal Level Accuracy Test Setup.

EQUIPMENT:

RF Voltmeter	HP 3403C and HP 400E
BNC to BNC Cable	HP 11170A

Note

Use RF Voltmeter calibrated for frequency response of 10kHz to 1MHz.

PROCEDURE:

1. Connect the 3403C to the 4277A UNKNOWN H_{CUR} terminal as shown in Figure 4-2.
2. Set the RANGE control of the 3403C as appropriate to measure 1Vrms.
3. Set the 4277A's controls as follows:

DC BIAS switch	OFF
Test Frequency	10kHz
TEST SIG LEVEL	HIGH
Other controls	Any setting

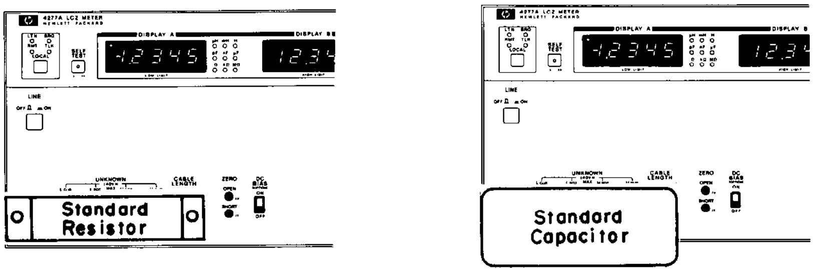
4. The 3403C should read between 0.9V and 1.1Vrms.
5. Successively change the test frequency setting to 100kHz and 1MHz. The voltage readings on the 3403C should be within the test limits given in Table 4-3.
6. Replace the 3403C with the 400E. Set the TEST SIG LEVEL to LOW.
7. Set the test frequency in accordance with Table 4-3. Verify that the voltage readings on the 400E meet the test limits given in the table.

Table 4-3. Test Signal Level Accuracy Test

	Test Limits			Equipment
Level \ Frequency	10kHz	100kHz	1MHz	
High (1Vrms)	0.9 to 1.1Vrms	0.9 to 1.1Vrms	0.9 to 1.1Vrms	HP 3403C
Low (20mVrms)	17 to 23mVrms	17 to 23mVrms	18 to 22mVrms	HP 400E

4-13. *SELF-OPERATING TEST*

4-14. The self-operating test checks operating conditions of the circuits which are critical to maintaining the specified accuracies. To verify that these circuits satisfy the performance requirements for ensuring specified accuracies, the values displayed in the Self Test are compared with test limits. Because basic circuit operating conditions related to accuracy are verified in this test, the instrument should be initially checked with this test.



(a) (b)

Figure 4-3. Self-Operating Test Setup.

EQUIPMENT:

Standard Capacitors .... 10pF: HP 16382A
100pF: HP 16383A
1000pF: HP 16384A

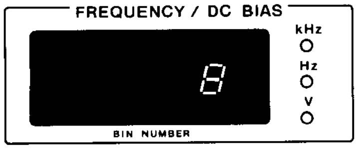
Standard Resistor .... 100Ω: } HP 16074A Standard Resistor Set
Termination .... Open (0S): }

PROCEDURE:

1. Connect Open (0S) termination directly to the 4277A UNKNOWN terminals as shown in Figure 4-3 (a).
2. Set the 4277A's controls as follows:

TEST SIG LEVEL	HIGH
Test Frequency	10kHz
MEAS SPEED	MED
TRIGGER	INT
DC BIAS switch	OFF
CABLE LENGTH switch	0
Other controls	Any setting

3. Press the SELF TEST key and then the FREQUENCY/DC BIAS selector key.
4. Press the FREQUENCY/DC BIAS step control ⇧ (or ⇩) key several times until self test item number "8" appears in the FREQUENCY/DC BIAS display as shown below:



5. The values displayed on DISPLAY A and DISPLAY B should be within the following test limits:

   DISPLAY A: 0.0020 to 0.0048
   DISPLAY B: -0.0020 to -0.0048

6. Set the test frequency to 100kHz and repeat step 5.

7. Set the test frequency to 1MHz and repeat step 5.

8. Press the FREQUENCY/DC BIAS step control ⇧ key to select self test item 9.

9. Press the FREQUENCY/DC BIAS selector key and set the 4277A controls as listed in step 2. Leave the SELF TEST function set to on.

10. The values displayed on DISPLAY A and DISPLAY B should be within the following test limits:

    DISPLAY A: -0.9990 to -1.0010
    DISPLAY B: -0.0010 to 0.0010

11. Set the TEST SIG LEVEL and MEAS SPEED in accordance with Table 4-4, and verify that the displayed values are within the test limits given in the table.

Table 4-4. Self-operating Test (Item 9)

	Test Limits			
Measurement Speed	MED		FAST	
Test Signal Level	Display A	Display B	Display A	Display B
High	-1±0.0010	0±0.0010	-1±0.0050	0±0.0050
Low	-1±0.0020	0±0.0020	-1±0.0100	0±0.0100

12. Set the test frequency to 100kHz and 1MHz, and repeat steps 10 and 11 for each frequency.

13. Press the SELF TEST key to release the self test function, and set the 4277A's controls as follows:

Test frequency	1MHz
TEST SIG LEVEL	HIGH
MEAS SPEED	MED
TRIGGER	INT
DISPLAY A function	C
DISPLAY B function	G
C RANGE	1pF
DC BIAS switch	OFF
CABLE LENGTH	0
Other controls	Any setting

PERFORMANCE TESTS

14. Set the self test item "3" using the procedure described in steps 3 and 4. The value displayed on the DISPLAY A should be within 0 and -200 counts.

15. Disconnect the Open (OS) termination and connect a 10pF standard capacitor directly to the UNKNOWN terminals as shown in Figure 4-3 (b).

16. Set the DISPLAY B function to "D" and press the LC | Z | RANGE selector key once to select the 10pF range.

Note

To verify the selected range, temporarily release the self test function and read the measured value and unit indicator. Thereafter, reset the self test function and select the test item "3."

17. The value displayed on DISPLAY A should be between 0 and -200 counts.

18. Repeat steps 15, 16 and 17 with the 100pF and 1000pF standard capacitors. Set the range (step 16) as listed in Table 4-5.

Table 4-5. Self-Operating Test (Item 3)

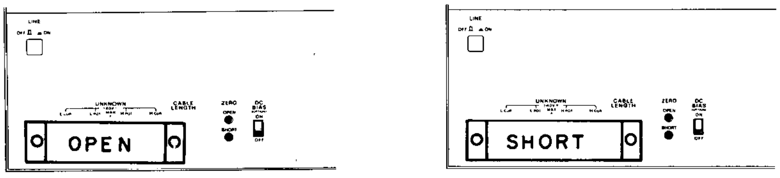
Standard Resistor Capacitor	Function	Range	Test Limits (Display A)
Open (OS)	C-G	1pF	0 to -200 counts
10pF	C-D	10pF	0 to -200 counts
100pF	C-D	100pF	0 to -200 counts
1000pF	C-D	1nF	0 to -200 counts

Note

Only self test items 3, 8 and 9 are used in this test.

4-15. *OPEN/SHORT TEST*

4-16. This test checks that the Zero Offset function is operating correctly.



(a) (b)

Figure 4-4. Open/Short Test Setups.

EQUIPMENT:

Terminations .... Open (0S) } HP 16074A
Short } Standard Resistor Set

PROCEDURE:

1. Connect Open (0S) termination directly to the 4277A UNKNOWN terminals as shown in Figure 4-4 (a).
2. Set the 4277A's controls as follows:

DISPLAY A function	C
DISPLAY B function	ESR/G
Test Frequency	10kHz
C RANGE	1nF
TEST SIG LEVEL	HIGH
CIRCUIT MODE	AUTO
MEAS SPEED	MED
TRIGGER	INT
CABLE LENGTH switch	0
DC BIAS switch	OFF

3. Press the ZERO OPEN button to perform "open" offset adjustment and wait approximately 10 seconds. (Offset values are displayed on both DISPLAY A and B.)
4. The values displayed on the 4277A should be within the following test limits:

   DISPLAY A: 0±0.0008nF
   DISPLAY B: 0±0.07μs

5. Set the TEST SIG LEVEL and test frequency in accordance with Table 4-6 (a). The values displayed on the 4277A should be within the test limits given in the table.

6. Connect Short termination directly to 4277A UNKNOWN terminals as shown in Figure 4-6 (b).

7. Press the ZERO SHORT button and wait a few seconds.

8. Set the 4277A's controls as follows:

    DISPLAY A function L
    DISPLAY B function .... ESR/G
    Test Frequency 10kHz
    L RANGE 1mH
    TEST SIG LEVEL .... HIGH

9. The values displayed on the 4277A should be within the following test limits:

    DISPLAY A: 0±0.0009mH
    DISPLAY B: 0±0.05Ω

10. Successively set the TEST SIG LEVEL, test frequency and LC | Z | RANGE in accordance with Table 4-6 (b). The values displayed on the 4277A should be within the test limits given in the table.

Table 4-6 (a). Open/Short Tests (Open)

Test Frequency	Test Limits			
	TEST SIG LEVEL HIGH		TEST SIG LEVEL LOW	
	DISPLAY A	DISPLAY B	DISPLAY A	DISPLAY B
10kHz	0±0.0008nF	0±0.07μS	0±0.0016nF	0±0.14μS
20kHz	0±0.0013nF	0±0.11μS	0±0.012nF	0±0.22μS
20.2kHz	0±0.0017nF	0±0.0008mS	0±0.012nF	0±0.0016mS
50.5kHz	0±0.0011nF	0±0.0008mS	0±0.011nF	0±0.0016mS
100kHz	0±0.0008nF	0±0.0007mS	0±0.0016nF	0±0.0014mS
200kHz	0±0.0013nF	0±0.0011mS	0±0.012nF	0±0.0022mS
202kHz	0±0.0017nF	0±0.008mS	0±0.012nF	0±0.016mS
505kHz	0±0.0011nF	0±0.008mS	0±0.011nF	0±0.016mS
1MHz	0±0.0005nF	0±0.007mS	0±0.0010nF	0±0.014mS

Table 4-6 (b). Open/Short Tests (Short)

Test Frequency	L RANGE	Test Limits			
		TEST SIG LEVEL HIGH		TEST SIG LEVEL LOW	
		DISPLAY A	DISPLAY B	DISPLAY A	DISPLAY B
10kHz	1mH	0±0.0009mH	0±0.05Ω	0±0.0018mH	0±0.10Ω
20kHz	100μH	0±0.6μH	0±0.08Ω	0±1.2μH	0±0.16Ω
20.2kHz	100μH	0±0.13μH	0±0.08Ω	0±1.2μH	0±0.16Ω
50.5kHz	100μH	0±0.11μH	0±0.08Ω	0±1.1μH	0±0.16Ω
100kHz	100μH	0±0.09μH	0±0.05Ω	0±0.18μH	0±0.10Ω
200kHz	10μH	0±0.06μH	0±0.08Ω	0±0.12μH	0±0.16Ω
202kHz	10μH	0±0.013μH	0±0.08Ω	0±0.12μH	0±0.16Ω
505kHz	10μH	0±0.011μH	0±0.08Ω	0±0.11μH	0±0.16Ω
1MHz	10μH	0±0.009μH	0±0.05Ω	0±0.018μH	0±0.10Ω

4.17. *CAPACITANCE ACCURACY TEST*

4-18. This test checks capacitance measurement accuracy for various combinations of test signal frequency, test signal level and cable length. The capacitance accuracy 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.

Capacitance accuracy check ranges (cable length = 0m)

Freq. Range	10kHz	20kHz	20.2kHz	50.5kHz	100kHz	200kHz	202kHz	500kHz	1MHz
1pF	☒	☒	☒	☒	☒	☒			
10pF	☒	☒							
100pF									
1000pF									

☐ Tested range ☒ Non-applicable range for recommended capacitance standard

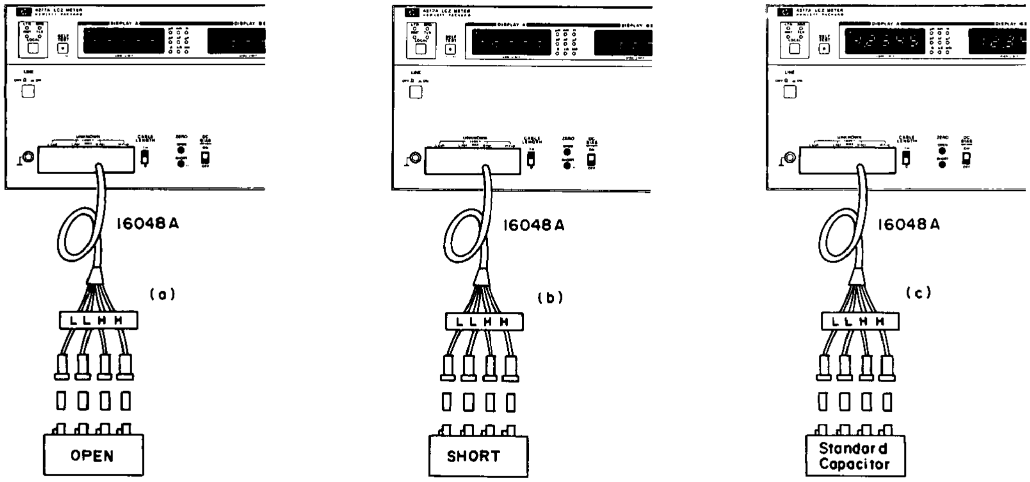


Figure 4-5. Capacitance Accuracy Test Setups (CABLE LENGTH: 1m).

EQUIPMENT:

Standard Capacitors	1pF: HP 16381A 10pF: HP 16382A 100pF: HP 16383A 1000pF: HP 16384A	
Terminations	OPEN (0S) Short	HP 16074A Standard Resistor Set
Test leads with BNC connector	HP 16048A	
BNC (f)-(f) adapter	HP P/N 1250-0080 4 ea.	

Note

1) Use the BNC (f)-(f) adapters furnished with the HP 16380A standard capacitor set.

2) If the 16048A Test Leads are not available, use the 1m Test Leads (HP P/N 16074-61600) furnished with the HP 16074A standard resistor set.

PROCEDURE:

1. Set the 4277A's controls as follows:

DISPLAY A function	C
DISPLAY B function	D
CIRCUIT MODE	AUTO
LC | Z | RANGE	AUTO
MEAS SPEED	MED
TRIGGER	INT
DC BIAS switch	OFF
CABLE LENGTH switch	0
Other controls	Any setting

Note

If Open/Short Test (paragraph 4-15) has not been performed before doing this test, perform zero offset adjustment as described in steps 1, 3, 6 and 7 of paragraph 4-15.

2. Connect a 1pF standard capacitor directly to the UNKNOWN terminals as shown in Figure 4-3 (b).

3. Set the test frequency and TEST SIG LEVEL in accordance with Table 4-7 (a). Capacitance and dissipation factor readings should be within the test limits given in the table.

4. Change the standard capacitor to 10pF, 100pF and 1000pF in that order and verify that the capacitance readings are within the test limits given in Table 4-7 (a).

5. Set the CABLE LENGTH switch to 1m.

6. Disconnect the standard capacitor and connect the 16048A Test Leads to the UNKNOWN terminals. Connect Open termination as shown in Figure 4-5 (a). Use the BNC (f)-(f) adapters to permit connection of the termination. Press ZERO OPEN button to perform "open" offset adjustment.

7. Disconnect Open termination and connect Short termination as shown in Figure 4-5 (b). Press the ZERO SHORT button to perform "short" offset adjustment.

8. Disconnect Short termination and connect a 1pF standard capacitor as shown in Figure 4-5 (c).

9. Set the test frequency to 1MHz and set the TEST SIG LEVEL in accordance with Table 4-7 (b). Capacitance and dissipation factor readings should be within the test limits given in the table.

10. Change the standard capacitor to 10pF, 100pF and 1000pF in that order, and verify that the capacitance and dissipation factor readings are within the test limits given in Table 4-7 (b).

Table 4-7 (a). Capacitance Accuracy Tests (CABLE LENGTH = 0)

Test Frequency	Standard Capacitance 1pF			
	TEST SIG LEVEL HIGH		TEST SIG LEVEL LOW	
	C Test Limits	D Test Limits	C Test Limits	D Test Limits
202kHz	C.V.±0.0052pF	0±0.009	C.V.±0.21pF	0±1.0
505kHz	C.V.±0.0046pF	0±0.0040	C.V.±0.21pF	0±0.11
1MHz	C.V.±0.0043pF	0±0.0040	C.V.±0.027pF	0±0.017

C.V. = Calibrated Value of Standard Capacitor

Table 4-7 (a). Capacitance Accuracy Tests (CABLE LENGTH = 0, continued)

Test Frequency	Standard Capacitance 10pF			
	TEST SIG LEVEL HIGH		TEST SIG LEVEL LOW	
	C Test Limits	D Test Limits	C Test Limits	D Test Limits
20.2kHz	C.V.±0.052pF	0±0.009	C.V.±2.1pF	0±1.0
50.5kHz	C.V.±0.046pF	0±0.0040	C.V.±2.1pF	0±0.11
100kHz	C.V.±0.043pF	0±0.0040	C.V.±0.27pF	0±0.017
200kHz	C.V.±0.048pF	0±0.0040	C.V.±2.1pF	0±0.11
202kHz	C.V.±0.027pF	0±0.008	C.V.±0.14pF	0±0.11
505kHz	C.V.±0.021pF	0±0.0022	C.V.±0.13pF	0±0.013
1MHz	C.V.±0.015pF	0±0.0016	C.V.±0.020pF	0±0.0032

C.V. = Calibrated Value of Standard Capacitor

Table 4-7 (a). Capacitance Accuracy Tests (CABLE LENGTH = 0, continued)

Test Frequency	Standard Capacitance 100pF			
	TEST SIG LEVEL HIGH		TEST SIG LEVEL LOW	
	C Test Limits	D Test Limits	C Test Limits	D Test Limits
10kHz	C.V.±0.43pF	0±0.0040	C.V.±2.7pF	0±0.017
20kHz	C.V.±0.48pF	0±0.0040	C.V.±20pF	0±0.11
20.2kHz	C.V.±0.27pF	0±0.079	C.V.±1.4pF	0±0.10
50.5kHz	C.V.±0.21pF	0±0.0022	C.V.±1.3pF	0±0.013
100kHz	C.V.±0.18pF	0±0.0016	C.V.±0.36pF	0±0.0032
200kHz	C.V.±0.23pF	0±0.0026	C.V.±1.3pF	0±0.014
202kHz	C.V.±0.27pF	0±0.008	C.V.±1.4pF	0±0.11
505kHz	C.V.±0.21pF	0±0.0022	C.V.±1.3pF	0±0.013
1MHz	C.V.±0.15pF	0±0.0016	C.V.±0.20pF	0±0.0032

C.V. = Calibrated Value of Standard Capacitor

Table 4-7 (a). Capacitance Accuracy Tests (CABLE LENGTH = 0, continued)

Test Frequency	Standard Capacitance 1000pF			
	TEST SIG LEVEL HIGH		TEST SIG LEVEL LOW	
	C Test Limits	D Test Limits	C Test Limits	D Test Limits
10kHz	C.V.±0.0018nF	0±0.0016	C.V.±0.0036nF	0±0.0032
20kHz	C.V.±0.0023nF	0±0.0026	C.V.±0.014nF	0±0.014
20.2kHz	C.V.±0.0027nF	0±0.008	C.V.±0.014nF	0±0.11
50.5kHz	C.V.±0.0021nF	0±0.0022	C.V.±0.013nF	0±0.013
100kHz	C.V.±0.0018nF	0±0.0016	C.V.±0.0036nF	0±0.0032
200kHz	C.V.±0.0023nF	0±0.0026	C.V.±0.014nF	0±0.014
202kHz	C.V.±0.0027nF	0±0.008	C.V.±0.014nF	0±0.11
505kHz	C.V± 0.0021nF	0±0.0022	C.V.±0.013nF	0±0.013
1MHz	C.V.±0.0015nF	0±0.0016	C.V.±0.0020nF	0±0.0032

C.V. = Calibrated Value of Standard Capacitor

Table 4-7 (b). Capacitance Accuracy Tests
(CABLE LENGTH = 1m, test frequency = 1MHz)

Standard Capacitor	TEST SIG LEVEL HIGH		TEST SIG LEVEL LOW	
	C Test Limits	D Test Limits	C Test Limits	D Test Limits
1pF	C.V.±0.0083pF	0±0.0050	C.V.±0.035pF	0±0.019
10pF	C.V.±0.020pF	0±0.0019	C.V.±0.030pF	0±0.0038
100pF	C.V.±0.18pF	0±0.0018	C.V.±0.26pF	0±0.0036
1000pF	C.V.±0.0021nF	0±0.0019	C.V.±0.0032nF	0±0.0038

C.V. = Calibrated Value of Standard Capacitor

PERFORMANCE TESTS

4-19. *RESISTANCE ACCURACY TEST*

4-20. This test checks resistance measurement accuracy for various combinations of test signal frequency and test signal level. The resistance accuracy checks are made by connecting a standard resistor to the instrument and comparing the measurement results with the calibrated values of the standard.

EQUIPMENT:

Standard Resistors	100Ω 1kΩ 10kΩ 100kΩ	HP 16074A Standard Resistor Set
Terminations	OPEN (0S) Short	

PROCEDURE:

1. Set the 4277A's controls as follows:

DISPLAY A and B function	|Z| - θ
CIRCUIT MODE	AUTO
LC |Z| RANGE	AUTO
MEAS SPEED	MED
TRIGGER	INT
DC BIAS switch	OFF
CABLE LENGTH switch	0
Other controls	Any setting

2. Perform Open and Short zero offset adjustments as described in steps 1, 3, 6 and 7 of paragraph 4-15.

3. Connect the 100Ω standard resistor directly to the UNKNOWN terminals as shown in Figure 4-3 (a).

4. Set test frequency and TEST SIG LEVEL in accordance with Table 4-8. Absolute values of the impedance readings should be within the test limits given in the table.

5. Change the standard resistor to 1kΩ, 10kΩ and 100kΩ in that order, and verify that the impedance readings are within the test limits given in Table 4-8.

Table 4-8. Resistance Accuracy Tests

Standard Resistor	Test Limits			
	100Ω		1kΩ	
LEVEL / FREQ.	HIGH	LOW	HIGH	LOW
10kHz	C.V.±0.15Ω	C.V.±1.2Ω	C.V.±0.006kΩ	C.V.±0.012kΩ
20kHz	C.V.±0.15Ω	C.V.±1.2Ω	C.V.±0.006kΩ	C.V.±0.012kΩ
50.5kHz	C.V.±0.15Ω	C.V.±1.2Ω	C.V.±0.006kΩ	C.V.±0.012kΩ
100kHz	C.V.±0.15Ω	C.V.±0.30Ω	C.V.±0.006kΩ	C.V.±0.012kΩ
200kHz	C.V.±0.15Ω	C.V.±0.30Ω	C.V.±0.006kΩ	C.V.±0.012kΩ
505kHz	C.V.±0.15Ω	C.V.±0.30Ω	C.V.±0.006kΩ	C.V.±0.012kΩ
1MHz	C.V.±0.15Ω	C.V.±0.30Ω	C.V.±0.006kΩ	C.V.±0.012kΩ

C.V. = Calibrated Value of Standard Resistor

Table 4-8. Resistance Accuracy Tests (continued)

Standard Resistor	Test Limits			
	10kΩ		100kΩ	
LEVEL / FREQ.	HIGH	LOW	HIGH	LOW
10kHz	C.V.±0.06kΩ	C.V.±0.12kΩ	C.V.±0.6kΩ	C.V.±1.2kΩ
20kHz	C.V.±0.06kΩ	C.V.±0.12kΩ	C.V.±0.6kΩ	C.V.±1.2kΩ
50.5kHz	C.V.±0.06kΩ	C.V.±0.12kΩ	C.V.±0.6kΩ	C.V.±1.2kΩ
100kHz	C.V.±0.06kΩ	C.V.±0.12kΩ	C.V.±0.6kΩ	C.V.±1.2kΩ
200kHz	C.V.±0.06kΩ	C.V.±0.12kΩ	———	———
505kHz	C.V.±0.06kΩ	C.V.±0.12kΩ	———	———
1MHz	C.V.±0.06kΩ	C.V.±0.12kΩ	———	———

C.V. = Calibrated Value of Standard Resistor

4-21. ***PHASE ACCURACY TEST***

4-22. This test checks to the accuracy of phase measurements over the full frequency range. The phase accuracy test is made by connecting a resistor with extremely low reactive elements and by reading the displayed phase angle (almost zero) to verify that the impedance vector (phase angle) of the DUT has been accurately detected.

EQUIPMENT:

Standard Resistors	10Ω 0Ω	HP 16074A Standard Resistor Set
Termination	OPEN (0S)	

Note

The resistors used as references in this test have been designed to maintain an extremely low (residual) reactance at frequencies up to 1MHz. The 0Ω termination has been specially designed for use with the 0.1Ω, 1Ω, and 10Ω standard resistors and provides an optimum termination impedance for the "short" offset adjustment to be made before performing tests with these standards.

PROCEDURE:

1. Set the 4277A's controls as follows:

DISPLAY A function	|Z|
CIRCUIT MODE	AUTO
LC|Z| RANGE	AUTO
MEAS SPEED	MED
TRIGGER	INT
CABLE LENGTH switch	0
DC BIAS switch	OFF
Other controls	Any setting

2. Perform OPEN and SHORT zero offset Adjustment as described in steps 1, 3, 6 and 7 of paragraph 4-15.

Note

Be sure to use the OPEN and 0Ω termination of the 16074A for zero offset Adjustment. DO NOT use the Short termination.

3. Disconnect the 0Ω termination and connect the 10Ω standard Resistor directly to the UNKNOWN terminals.

4. Set the test frequency and TEST SIG LEVEL in accordance with Table 4-9. Phase angle readings should be within the test limits given in the table.

Table 4-9. Phase Accuracy Tests

Test Frequency	Phase (DISPLAY B) Test Limits	
	TEST SIG LEVEL HIGH	TEST SIG LEVEL LOW
10kHz	0±0.52 deg.	0±1.4 deg.
20kHz	0±0.52 deg.	0±1.4 deg.
50.5kHz	0±0.52 deg.	0±1.4 deg.
100kHz	0±0.52 deg.	0±1.4 deg.
200kHz	0±0.52 deg.	0±1.4 deg.
505kHz	0±0.52 deg.	0±1.4 deg.
1MHz	0±0.52 deg.	0±1.4 deg.

4-23. *INT DC BIAS VOLTAGE ACCURACY TEST (OPTION 001)*

4-24. This test verifies that Option 001 Internal DC BIAS Supply applies the specified bias voltages to the device under test.

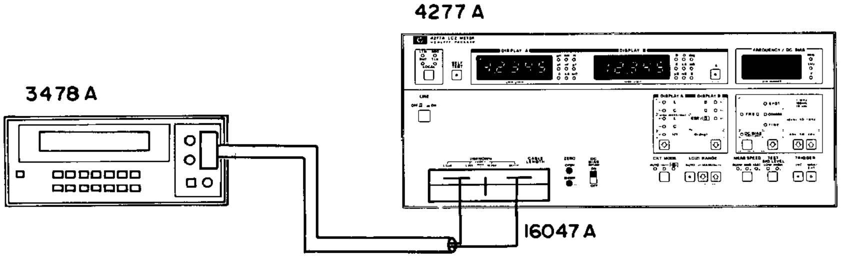


Figure 4-6. Option 001 INT DC Bias Accuracy Test Setup.

EQUIPMENT:

DC Voltmeter	HP 3478A
Test Fixture	HP 16047A

PROCEDUE:

1. Interconnect the 4277A, 16047A, and 3478A as shown in Figure 4-6.

Note

Do not connect a DUT to the 16047A.

CAUTION

BEFORE OPERATING DC BIAS SWITCH, VERIFY THAT DC BIAS VOLTAGE IS SET TO ZERO VOLTS.

PERFORMANCE TESTS

2. Set the 4277A's controls as follows:

DC BIAS selector switch (rear panel) .... INT (OPTION 001)
DC BIAS switch (front panel) .... ON
TEST SIG LEVEL .... LOW
Other controls .... Any setting

3. Set the dc bias voltage in accordance with Table 4-10. The voltage readings on the 3478A should be within the test limits given in the table.

Table 4-10. INT DC Bias Voltage Test Limits

DC Bias Setting	Test Limits
-0.01V	0.1mV to -20.1mV
6.82V	6.7895V to 6.8505V
-9.99V	-9.8801V to -10.0999V
10V	9.915V to 10.085V
-12.7V	-12.538V to -12.862V
40V	39.765V to 40.235V
-40V	-39.565V to -40.435V

4-25. *16064A COMPARATOR/HANDLER INTERFACE TEST (OPTION 002)*

4-26. This test verifies the functions of the 16064A Comparator/Handler Interface.

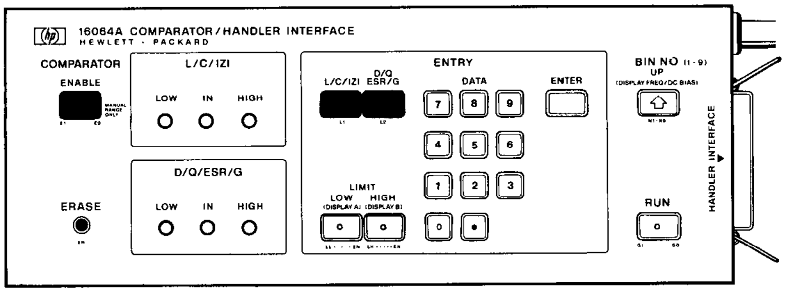


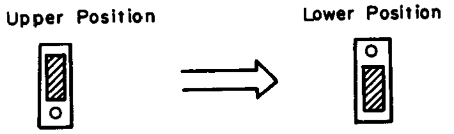
Figure 4-7. 16064A Comparator/Handler Interface.

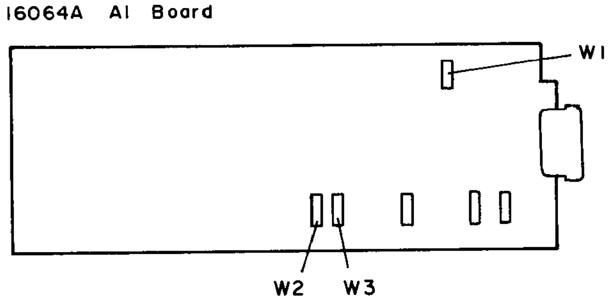
EQUIPMENT:

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 4277A.

3. Turn on the 4277A. "16064" should be displayed on DISPLAY B.

4. Set the 4277A'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 4277A's GUARD terminal.

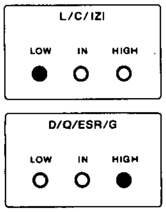
7. Press the 16064A's ERASE key and set the following comparator limits:

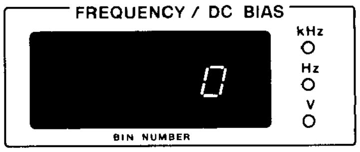
L/C/ | Z | LOW LIMIT (BIN1):	.3
L/C/ | Z | HIGH LIMIT (BIN1):	.9
D/Q/ESR/G LOW LIMIT:	2
D/Q/ESR/G HIGH LIMIT:	8

8. Connect the 100kΩ standard resistor to the 4277A'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 "0" is displayed on the 4277A's FREQUENCY/DC BIAS DISPLAY.

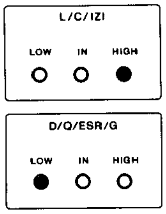


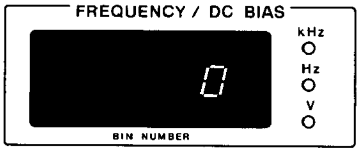


11. Check the states of the comparison data output (TTL) at the HANDLER INTERFACE connector using the 3478A. The pin assignments and the data states are shown in Figure 4-8 and Table 4-11.

12. Disconnect the 100kΩ resistor and connect a 1000pF standard capacitor.

13. Verify that the L/C/ | Z | HIGH and D/Q/ESR/G LOW lamps light, and "0" is displayed on the 4277A's FREQUENCY/DC BIAS DISPLAY.





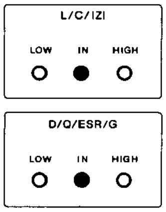
14. Check the comparison data output at the HANDLER INTERFACE connector by comparing it with the Data States shown in Table 4-11.

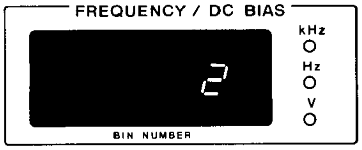
15. Press the ERASE key and set the following comparator limits:

L/C/|Z| HIGH LIMIT	BIN1:	.9
	BIN2:	1.1
	BIN3:	1.9999
D/Q/ESR/G HIGH LIMIT:		.1

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 "2" is displayed on the 4277A'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 4-11.

Table 4-11. 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
10	H	H	H	H	H	H	H	H	H	L	H	H	L	L	H	H
13	H	H	H	H	H	H	H	H	H	L	L	H	H	H	H	L
17	H	L	H	H	H	H	H	H	H	H	H	L	H	H	L	H

H: Approximately 5V
L: Approximately 0V

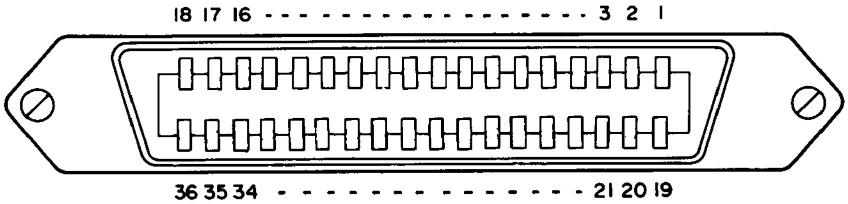


Figure 4-8. Handler Interface Connector Pin Assignments.

4-27. *HP-IB INTERFACE TEST*

4-28. This test verifies the instrument's HP-IB capabilities.

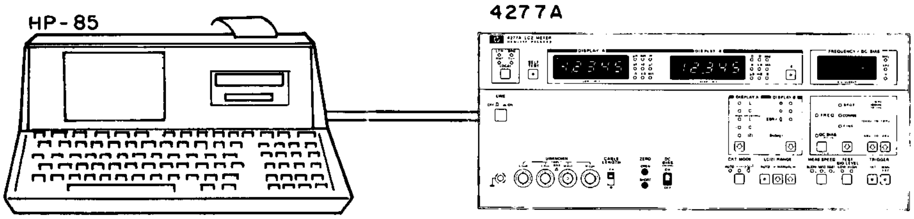


Figure 4-9. HP-IB Interface Test Setup.

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 4277A and the HP-85 off.

2. Connect the 82937A HP-IB Interface between the HP-85 and the 4277A as shown in Figure 4-9, and install the I/O ROM in the ROM Drawer of the HP-85.

3. Set the 4277A'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 4277A and the HP-85.

5. Load one of the three test programs into the personal computer. Test programs are listed on pages 4-26, and 4-28 and 4-30.

6. Execute the program and follow the prompts and instructions that are output by the HP-85. Details on the controller's (personal computer) instructions and the appropriate operator response are given in Tables 4-12 through 4-14.

TEST PROGRAM 1

PURPOSE:

This test verifies that the 4277A has the following HP-IB capabilities:

(1) Remote/Local Capability
(2) Local Lockout
(3) Talk Disable
(4) Listen Disable

PROGRAM LISTING:

```
10 ! 4277A HP-IB TEST No.1
20 ! REMOTE/LOCAL TEST
30 DIM A$[1]
40 N=0 @ M=7 @ M1=717
50 S=SPOLL(M1)
60 CLEAR
70 PRINT "*** 4277A HP-IB TEST No.1 ***"
80 DISP "REMOTE/LOCAL TEST"
90 REMOTE M
100 OUTPUT M1 ;"T1"
110 DISP "LISTEN=1,TALK=0,REMOTE=1"
120 GOSUB 580
130 ABORTIO M
140 DISP "LISTEN=0,TALK=0,REMOTE=1"
150 GOSUB 580
160 LOCAL M
170 DISP "LISTEN=0,TALK=0,REMOTE=0"
180 GOSUB 580
190 REMOTE M1
200 DISP "LISTEN=1,TALK=0,REMOTE=1"
210 GOSUB 580
220 LOCAL LOCKOUT M
230 DISP "PRESS LOCAL KEY"
240 DISP "LISTEN=1,TALK=0,REMOTE=1"
250 GOSUB 580
260 LOCAL M1
270 DISP "LISTEN=1,TALK=0,REMOTE=0"
280 GOSUB 580
290 REMOTE M1
300 OUTPUT M1 ;"T1"
310 DISP "LISTEN=1,TALK=0,REMOTE=1"
320 GOSUB 580
330 IF N=1 THEN 340 ELSE 370
340 PRINT "REMOTE/LOCAL TEST FAIL"
350 DISP "REMOTE/LOCAL TEST FAIL"
360 GOTO 390
370 PRINT "REMOTE/LOCAL TEST PASS"
380 DISP "REMOTE/LOCAL TEST PASS"
390 N=0
400 DISP "LISTEN/TALK  TEST"
410 ENTER M1 ; A
420 DISP "LISTEN=0,TALK=1,REMOTE=1"
430 GOSUB 580
440 OUTPUT M1 ;"T1"
450 DISP "LISTEN=1,TALK=0,REMOTE=1"
460 GOSUB 580
470 IF N=1 THEN 480 ELSE 510
480 PRINT "LISTEN/TALK TEST FAIL"
490 DISP "LISTEN/TALK TEST FAIL"
500 GOTO 530
510 PRINT "LISTEN/TALK TEST PASS"
520 DISP "LISTEN/TALK TEST PASS"
530 PRINT "END"
540 DISP "END"
550 CLEAR M
560 LOCAL M
570 END
580 INPUT A$
590 IF A$="N" THEN N=1
600 RETURN
```

Table 4-12. Controller Instructions and Operator Responses for Test Program 1

Controller Instructions		Operator Response
Displays	Printout	
	*** 4277A 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 4277A 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 4277A 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 4277A 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 4277A has the following HP-IB capabilities:

(1) Talker
(2) Device Trigger

PROGRAM LISTING:

```
10 ! 4277A 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 "*** 4277A 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 4-13. Controller Instructions and Operator Responses for Test Program 2

Controller Instructions		Operator Responses
Displays	Printout	
	*** 4277A 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 desired test frequency value, from 10 to 1000, 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 4277A 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 4277A has the following HP-IB capabilities:

(1) Service Request
(2) Serial Poll

PROGRAM LISTING:

```
10 ! 4277A 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 "*** 4277A 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 4-14. Controller Instructions and Operator Responses for Test Program 3

Controller Instructions		Operator Response
Displays	Printout	
	*** 4277A 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 4277A
LCZ METER

Tested by ______________________

Serial Number ______________________

Date ______________________

Paragraph Number	TEST	Results		
		Minimum	Actual	Maximum
4-9	TEST FREQUENCY ACCURACY TEST			
	Frequency setting			
	10.0kHz	9.999kHz		10.001kHz
	100kHz	99.99kHz		100.01kHz
	202kHz	201.98kHz		202.02kHz
	500kHz	499.95kHz		500.05kHz
	1.00MHz	0.9999MHz		1.0001MHz
4-11	TEST SIGNAL LEVEL ACCURACY TEST			
	Test Signal Level: HIGH			
		Vrms		Vrms
	Frequency 10kHz	0.9		1.1
	100kHz	0.9		1.1
	1MHz	0.9		1.1
	Test Signal Level: LOW			
		mVrms		mVrms
	Frequency 10kHz	17		23
	100kHz	17		23
	1MHz	18		22
4-13	SELF-OPERATING TEST			
	SELF TEST #8			
	Frequency			
	10kHz DISPLAY A	0.0020		0.0048
	DISPLAY B	-0.0048		-0.0020
	100kHz DISPLAY A	0.0020		0.0048
	DISPLAY B	-0.0048		-0.0020
	1MHz DISPLAY A	0.0020		0.0048
	DISPLAY B	-0.0048		-0.0020

PERFORMANCE TEST RECORD

Paragraph Number	TEST	Results		
		Minimum	Actual	Maximum
4-13	SELF-OPERATING TEST (Cont'd)			
	SELF TEST #9			
	Frequency: 10kHz			
	Measurement Speed: MED			
	Test Signal Level:			
	HIGH DISPLAY A	-1.0010		-0.9990
	DISPLAY B	-0.0010		0.0010
	LOW DISPLAY A	-1.0020		-0.9980
	DISPLAY B	-0.0020		0.0020
	Measurement Speed: FAST			
	Test Signal Level:			
	HIGH DISPLAY A	-1.0050		-0.9950
	DISPLAY B	-0.0050		0.0050
	LOW DISPLAY A	-1.0100		-0.9900
	DISPLAY B	-0.0100		0.0100
	Frequency: 100kHz			
	Measurement Speed: MED			
	Test Signal Level:			
	HIGH DISPLAY A	-1.0010		-0.9990
	DISPLAY B	-0.0010		0.0010
	LOW DISPLAY A	-1.0020		-0.9980
	DISPLAY B	-0.0020		0.0020
	Measurement Speed: FAST			
	Test Signal Level:			
	HIGH DISPLAY A	-1.0050		-0.9950
	DISPLAY B	-0.0050		0.0050
	LOW DISPLAY A	-1.0100		-0.9900
	DISPLAY B	-0.0100		0.0100

PERFORMANCE TEST RECORD

Paragraph Number	TEST	Results		
		Minimum	Actual	Maximum
4-13	SELF-OPERATING TEST (Cont'd)			
	Frequency: 1MHz			
	Measurement Speed: MED			
	Test Signal Level:			
	HIGH DISPLAY A	-1.0010		-0.9990
	DISPLAY B	-0.0010		0.0010
	LOW DISPLAY A	-1.0020		-0.9980
	DISPLAY B	-0.0020		0.0020
	Measurement Speed: FAST			
	Test Signal Level:			
	HIGH DISPLAY A	-1.0050		-0.9950
	DISPLAY B	-0.0050		0.0050
	LOW DISPLAY A	-1.0100		-0.9900
	DISPLAY B	-0.0100		0.0100
	SELF TEST #3			
	Standard			
	Open (OS)	-200 counts		0
	10pF	-200 counts		0
	100pF	-200 counts		0
	1000pF	-200 counts		0
4-15	OPEN, SHORT TEST			
	[OPEN]			
	Test Signal Level: HIGH			
	Frequency			
	10kHz C	-0.0008nF		0.0008nF
	G	-0.07μS		0.07μS
	20kHz C	-0.0013nF		0.0013nF
	G	-0.11μS		0.11μS
	20.2kHz C	-0.0017nF		0.0017nF
	G	-0.0008mS		0.0008mS
	50.5kHz C	-0.0011nF		0.0011nF
	G	-0.0008mS		0.0008mS
	100kHz C	-0.0008nF		0.0008nF
	G	-0.0007mS		0.0007mS

PERFORMANCE TEST RECORD

Paragraph Number	TEST		Results		
			Minimum	Actual	Maximum
4-15	OPEN, SHORT TEST (Cont'd)				
	200kHz	C	-.0.0013nF		0.0013nF
		G	-0.0011mS		0.0011mS
	202kHz	C	-0.0017nF		0.0017nF
		G	-0.008mS		0.008mS
	505kHz	C	-0.0011nF		0.0011nF
		G	-0.008mS		0.008mS
	1MHz	C	-0.0005nF		0.0005nF
		G	-0.007mS		0.007mS
	Test Singal Level: LOW				
	Frequency				
	10kHz	C	-0.0016nF		0.0016nF
		G	-0.14μS		0.14μS
	20kHz	C	-0.012nF		0.012nF
		G	-0.22μS		0.22μS
	20.2kHz	C	-0.012nF		0.012nF
		G	-0.0016mS		0.0016mS
	50.5kHz	C	-0.011nF		0.011nF
		G	-0.0016mS		0.0016mS
	100kHz	C	-0.0016nF		0.0016nF
		G	-0.0014mS		0.0014mS
	200kHz	C	-0.012nF		0.012nF
		G	-0.0022mS		0.0022mS
	202kHz	C	-0.012nF		0.012nF
		G	-0.016mS		0.016mS
	505kHz	C	-0.011nF		0.011nF
		G	-0.016mS		0.016mS
	1MHz	C	-0.0010nF		0.0010nF
		G	-0.014mS		0.014mS
	[SHORT]				
	Test Signal Level: HIGH				
	Frequency				
	10kHz	L	-0.0009mH		0.0009mH
		ESR	-0.05Ω		0.05Ω
	20kHz	L	-0.6μH		0.6μH
		ESR	-0.08Ω		0.08Ω

PERFORMANCE TEST RECORD

Paragraph Number	TEST		Results		
			Minimum	Actual	Maximum
4-15	OPEN, SHORT TEST (Cont'd)				
	20.2kHz	L	-0.13μH		0.13μH
		ESR	-0.08Ω		0.08Ω
	50.5kHz	L	-0.11μH		0.11μH
		ESR	-0.08Ω		0.08Ω
	100kHz	L	-0.09μH		0.09μH
		ESR	-0.05Ω		0.05Ω
	200kHz	L	-0.06μH		0.06μH
		ESR	-0.08Ω		0.08Ω
	202kHz	L	-0.013μH		0.013μH
		ESR	-0.08Ω		0.08Ω
	505kHz	L	-0.011μH		0.011μH
		ESR	-0.08Ω		0.08Ω
	1MHz	L	-0.009μH		0.009μH
		ESR	-0.05Ω		0.05Ω
	Test Signal Level: LOW				
	Frequency				
	10kHz	L	-0.0018mH		0.0018mH
		ESR	-0.10Ω		0.10Ω
	20kHz	L	-1.2μH		1.2μH
		ESR	-0.16Ω		0.16Ω
	20.2kHz	L	-1.2μH		1.2μH
		ESR	-0.16Ω		0.16Ω
	50.5kHz	L	-1.1μH		1.1μH
		ESR	-0.16Ω		0.16Ω
	100kHz	L	-0.18μH		0.18μH
		ESR	-0.10Ω		0.10Ω
	200kHz	L	-0.12μH		0.12μH
		ESR	-0.16Ω		0.16Ω
	202kHz	L	-0.12μH		0.12μH
		ESR	-0.16Ω		0.16Ω
	505kHz	L	-0.11μH		0.11μH
		ESR	-0.16Ω		0.16Ω
	1MHz	L	-0.018μH		0.018μH
		ESR	-0.10Ω		0.10Ω

PERFORMANCE TEST RECORD

Paragraph Number	TEST	Results		
		Minimum	Actual	Maximum
4-17	CAPACITANCE ACCURACY TEST			
	1pF Range			
	Test Signal Level: HIGH			
	Frequency			
	202kHz C	C.V.-0.0052pF		C.V.+0.0052pF
	D	-0.009		0.009
	505kHz C	C.V.-0.0046pF		C.V.+0.0046pF
	D	-0.0040		0.0040
	1MHz C	C.V.-0.0043pF		C.V.+0.0043pF
	D	-0.0040		0.0040
	Test Signal Level: LOW			
	Frequency			
	202kHz C	C.V.- 0.21pF		C.V.+ 0.21pF
	D	-1.0		1.0
	505kHz C	C.V.- 0.21pF		C.V.+ 0.21pF
	D	-0.11		0.11
	1MHz C	C.V.- 0.027pF		C.V.+ 0.027pF
	D	-0.017		0.017
	10pF Range			
	Test Signal Level: HIGH			
	Frequency			
	20.2kHz C	C.V.- 0.052pF		C.V.+ 0.052pF
	D	-0.009		0.009
	50.5kHz C	C.V.- 0.046pF		C.V.+ 0.046pF
	D	-0.0040		0.0040
	100kHz C	C.V.- 0.043pF		C.V.+ 0.043pF
	D	-0.0040		0.0040
	200kHz C	C.V.- 0.048pF		C.V.+ 0.048pF
	D	-0.0040		0.0040
	202kHz C	C.V.- 0.027pF		C.V.+ 0.027pF
	D	-0.008		0.008
	505kHz C	C.V.- 0.021pF		C.V.+ 0.021pF
	D	-0.0022		0.0022
	1MHz C	C.V.- 0.015pF		C.V.+ 0.015pF
	D	-0.0016		0.0016

C.V. = Caribrated Value

PERFORMANCE TEST RECORD

Paragraph Number	TEST		Results		
			Minimum	Actual	Maximum
4-17	CAPACITANCE ACCURACY TEST (Cont'd)				
	Test Signal Level: LOW				
	Frequency				
	20.2kHz	C	C.V.- 2.1pF		C.V.+ 2.1pF
		D	-1.0		1.0
	50.5kHz	C	C.V.- 2.1pF		C.V.+ 2.1pF
		D	-0.11		0.11
	100kHz	C	C.V.- 0.27pF		C.V.+ 0.27pF
		D	-0.017		0.017
	200kHz	C	C.V.- 2.1pF		C.V.+ 2.1pF
		D	-0.11		0.11
	202kHz	C	C.V.- 0.14pF		C.V.+ 0.14pF
		D	-0.11		0.11
	505kHz	C	C.V.- 0.13pF		C.V.+ 0.13pF
		D	-0.013		0.013
	1MHz	C	C.V.-0.020pF		C.V.+0.020pF
		D	-0.0032		0.0032
	100pF Range				
	Test Signal Level: HIGH				
	Frequency				
	10kHz	C	C.V.- 0.43pF		C.V.+ 0.43pF
		D	-0.0040		0.0040
	20kHz	C	C.V.- 0.48pF		C.V.+ 0.48pF
		D	-0.0040		0.0040
	20.2kHz	C	C.V.- 0.27pF		C.V.+ 0.27pF
		D	-0.079		0.079
	50.5kHz	C	C.V.- 0.21pF		C.V.+ 0.21pF
		D	-0.0022		0.0022
	100kHz	C	C.V.- 0.18pF		C.V.+ 0.18pF
		D	-0.0016		0.0016
	200kHz	C	C.V.- 0.23pF		C.V.+ 0.23pF
		D	-0.0026		0.0026
	202kHz	C	C.V.- 0.27pF		C.V.+ 0.27pF
		D	0.008		0.008
	505kHz	C	C.V.- 0.21pF		C.V.+ 0.21pF
		D	-0.0022		0.0022

C.V. = Caribrated Value

PERFORMANCE TEST RECORD

Paragraph Number	TEST	Results		
		Minimum	Actual	Maximum
4-17	CAPACITANCE ACCURACY TEST (Cont'd)			
	1MHz C	C.V.- 0.15pF		C.V.+ 0.15pF
	D	-0.0016		0.0016
	Test Signal Level: LOW			
	Frequency			
	10kHz C	C.V.- 2.7pF		C.V.+ 2.7pF
	D	-0.017		0.017
	20kHz C	C.V.- 20pF		C.V.+ 20pF
	D	-0.11		0.11
	20.2kHz C	C.V.- 1.4pF		C.V.+ 1.4pF
	D	-0.10		0.10
	50.5kHz C	C.V.- 1.3pF		C.V.+ 1.3pF
	D	-0.013		0.013
	100kHz C	C.V.- 0.36pF		C.V.+ 0.36pF
	D	-0.0032		0.0032
	200kHz C	C.V.- 1.3pF		C.V.+ 1.3pF
	D	-0.014		0.014
	202kHz C	C.V.- 1.4pF		C.V.+ 1.4pF
	D	-0.11		0.11
	505kHz C	C.V.- 1.3pF		C.V.+ 1.3pF
	D	-0.013		0.013
	1MHz C	C.V.- 0.20pF		C.V.+ 0.20pF
	D	-0.0032		0.0032
	1000pF Range			
	Test Signal Level: HIGH			
	Frequency			
	10kHz C	C.V.-0.0018nF		C.V.+0.0018nF
	D	-0.0016		0.0016
	20kHz C	C.V.-0.0023nF		C.V.+0.0023nF
	D	-0.0026		0.0026
	20.2kHz C	C.V.-0.0027nF		C.V.+0.0027nF
	D	-0.008		0.008
	50.5kHz C	C.V.-0.0021nF		C.V.+0.0021nF
	D	-0.0022		0.0022

C.V. = Caribrated Value

PERFORMANCE TEST RECORD

Paragraph Number	TEST		Results		
			Minimum	Actual	Maximum
4-17	CAPACITANCE ACCURACY TEST (Cont'd)				
	100kHz	C	C.V.-0.0018nF		C.V.+0.0018nF
		D	-0.0016		0.0016
	200kHz	C	C.V.-0.0023nF		C.V.+0.0023nF
		D	-0.0026		0.0026
	202kHz	C	C.V.-0.0027nF		C.V.+0.0027nF
		D	-0.008		0.008
	505kHz	C	C.V.-0.0021nF		C.V.+0.0021nF
		D	-0.0022		0.0022
	1MHz	C	C.V.-0.0015nF		C.V.+0.0015pF
		D	-0.0016		0.0016
	Test Signal Level: LOW				
	Frequency				
	10kHz	C	C.V.-0.0036nF		C.V.+0.0036nF
		D	-0.0032		0.0032
	20kHz	C	C.V.- 0.014nF		C.V.+ 0.014nF
		D	-0.014		0.014
	20.2kHz	C	C.V.- 0.014nF		C.V.+ 0.014nF
		D	-0.11		0.11
	50.5kHz	C	C.V.- 0.013nF		C.V.+ 0.013nF
		D	-0.013		0.013
	100kHz	C	C.V.-0.0036nF		C.V.+0.0036nF
		D	-0.0032		0.0032
	200kHz	C	C.V.- 0.014nF		C.V.+ 0.014nF
		D	-0.014		0.014
	202kHz	C	C.V.- 0.014nF		C.V.+ 0.014nF
		D	-0.11		0.11
	505kHz	C	C.V.- 0.013nF		C.V.+ 0.013nF
		D	-0.013		0.013
	1MHz	C	C.V.-0.0020nF		C.V.+0.0020nF
		D	-0.0032		0.0032

C.V. = Calibrated Value

PERFORMANCE TEST RECORD

Paragraph Number	TEST			Results		
				Minimum	Actual	Maximum
4-17	CAPACITANCE ACCURACY TEST (Cont'd)					
	CABLE LENGTH: 1m					
	1pF Range					
	Test Signal Level:					
		HIGH	C	C.V.-0.0083pF		C.V.+0.0083pF
			D	-0.0050		0.0050
		LOW	C	C.V.- 0.035pF		C.V.+ 0.035pF
			D	-0.019		0.019
	10pF Range					
		HIGH	C	C.V.- 0.020pF		C.V.+ 0.020pF
			D	-0.0019		0.0019
		LOW	C	C.V.- 0.030pF		C.V.+ 0.030pF
			D	-0.0038		0.0038
	100pF Range					
		HIGH	C	C.V.- 0.18pF		C.V.+ 0.18pF
			D	-0.0018		0.0018
		LOW	C	C.V.- 0.26pF		C.V.+ 0.26pF
			D	-0.0036		0.0036
	1000pF Range					
		HIGH	C	C.V.-0.0021nF		C.V.+0.0021nF
			D	-0.0019		0.0019
		LOW	C	C.V.-0.0032nF		C.V.+0.0032nF
			D	-0.0038		0.0038
4-19	RESISTANCE ACCURACY TEST					
	100Ω Range					
		Frequency	Test Signal Level			
		10kHz	HIGH	C.V. - 0.15Ω		C.V. + 0.15Ω
			LOW	C.V. - 1.2Ω		C.V. + 1.2Ω
		20kHz	HIGH	C.V. - 0.15Ω		C.V. + 0.15Ω
			LOW	C.V. - 1.2Ω		C.V. + 1.2Ω
		50.5kHz	HIGH	C.V. - 0.15Ω		C.V. + 0.15Ω
			LOW	C.V. - 1.2Ω		C.V. + 1.2Ω
		100kHz	HIGH	C.V. - 0.15Ω		C.V. + 0.15Ω
			LOW	C.V. - 0.30Ω		C.V. + 0.30Ω

C.V. = Calibrated Value

PERFORMANCE TEST RECORD

Paragraph Number	TEST		Results		
			Minimum	Actual	Maximum
4-19	RESISTANCE ACCURACY TEST (Cont'd)				
	200kHz	HIGH	C.V. - 0.15Ω		C.V. + 0.15Ω
		LOW	C.V. - 0.30Ω		C.V. + 0.30Ω
	505kHz	HIGH	C.V. - 0.15Ω		C.V. + 0.15Ω
		LOW	C.V. - 0.30Ω		C.V. + 0.30Ω
	1MHz	HIGH	C.V. - 0.15Ω		C.V. + 0.15Ω
		LOW	C.V. - 0.30Ω		C.V. + 0.30Ω
	1kΩ Range				
	Frequency	Test Signal Level			
	10kHz	HIGH	C.V.-0.006kΩ		C.V.+0.006kΩ
		LOW	C.V.-0.012kΩ		C.V.+0.012kΩ
	20kHz	HIGH	C.V.-0.006kΩ		C.V.+0.006kΩ
		LOW	C.V.-0.012kΩ		C.V.+0.012kΩ
	50.5kHz	HIGH	C.V.-0.006kΩ		C.V.+0.006kΩ
		LOW	C.V.-0.012kΩ		C.V.+0.012kΩ
	100kHz	HIGH	C.V.-0.006kΩ		C.V.+0.006kΩ
		LOW	C.V.-0.012kΩ		C.V.+0.012kΩ
	200kHz	HIGH	C.V.-0.006kΩ		C.V.+0.006kΩ
		LOW	C.V.-0.012kΩ		C.V.+0.012kΩ
	505kHz	HIGH	C.V.-0.006kΩ		C.V.+0.006kΩ
		LOW	C.V.-0.012kΩ		C.V.+0.012kΩ
	1MHz	HIGH	C.V.-0.006kΩ		C.V.+0.006kΩ
		LOW	C.V.-0.012kΩ		C.V.+0.012kΩ
	10kΩ Range				
	Frequency	Test Signal Level			
	10kHz	HIGH	C.V.- 0.06kΩ		C.V.+ 0.06kΩ
		LOW	C.V.- 0.12kΩ		C.V.+ 0.12kΩ
	20kHz	HIGH	C.V.- 0.06kΩ		C.V.+ 0.06kΩ
		LOW	C.V.- 0.12kΩ		C.V.+ 0.12kΩ
	50.5kHz	HIGH	C.V.- 0.06kΩ		C.V.+ 0.06kΩ
		LOW	C.V.- 0.12kΩ		C.V.+ 0.12kΩ
	100kHz	HIGH	C.V.- 0.06kΩ		C.V.+ 0.06kΩ
		LOW	C.V.- 0.12kΩ		C.V.+ 0.12kΩ
	200kHz	HIGH	C.V.- 0.06kΩ		C.V.+ 0.06kΩ
		LOW	C.V.- 0.12kΩ		C.V.+ 0.12kΩ

C.V. = Calibrated Value

PERFORMANCE TEST RECORD

Paragraph Number	TEST		Results		
			Minimum	Actual	Maximum
4-19	RESISTANCE ACCURACY TEST (Cont'd)				
	50.5kHz	HIGH	C.V.- 0.06kΩ		C.V.+ 0.06kΩ
		LOW	C.V.- 0.12kΩ		C.V.+ 0.12kΩ
	1MHz	HIGH	C.V.- 0.06kΩ		C.V.+ 0.06kΩ
		LOW	C.V.- 0.12kΩ		C.V.+ 0.12kΩ
	100kΩ Range				
	Frequency	Test Signal Level			
	10kHz	HIGH	C.V. - 0.6kΩ		C.V. + 0.6kΩ
		LOW	C.V. - 1.2kΩ		C.V. + 1.2kΩ
	20kHz	HIGH	C.V. - 0.6kΩ		C.V. + 0.6kΩ
		LOW	C.V. - 1.2kΩ		C.V. + 1.2kΩ
	50.5kHz	HIGH	C.V. - 0.6kΩ		C.V. + 0.6kΩ
		LOW	C.V. - 1.2kΩ		C.V. + 1.2kΩ
	100kHz	HIGH	C.V. - 0.6kΩ		C.V. + 0.6kΩ
		LOW	C.V. - 1.2kΩ		C.V. + 1.2kΩ
4-21	PHASE ACCURACY TEST				
	Frequency	Test Signal Level	deg		deg
	10kHz	HIGH	0.52		-0.52
		LOW	1.4		-1.4
	20kHz	HIGH	0.52		-0.52
		LOW	1.4		-1.4
	50.5kHz	HIGH	0.52		-0.52
		LOW	1.4		-1.4
	100kHz	HIGH	0.52		-0.52
		LOW	1.4		-1.4
	200kHz	HIGH	0.52		-0.52
		LOW	1.4		-1.4
	505kHz	HIGH	0.52		-0.52
		LOW	1.4		-1.4
	1MHz	HIGH	0.52		-0.52
		LOW	1.4		1.4

C.V. = Calibrated Value

PERFORMANCE TEST RECORD

Paragraph Number	TEST	Results		
		Minimum	Actual	Maximum
4-23	INT DC BIAS SUPPLY TEST			
	DC Bias Setting			
	-0.01V	-20.1mV	________	0.1mV
	6.82V	6.7895V	________	6.8505V
	-9.99V	-10.0999V	________	-9.8801V
	10V	9.915V	________	10.085V
	-12.7V	-12.862V	________	-12.538V
	40V	39.765V	________	40.235V
	-40V	-40.435V	________	-39.565V

SECTION V
ADJUSTMENT

5-1. INTRODUCTION

5-2. This section describes the adjustments and checks required to return the 4277A 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 4277A is every six months. 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

To ensure proper results and 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 4277A 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-A and B. 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.

Table 5-1. Adjustable Components

Reference Designator	Name of Control	Purpose
A1 R3 (Para. 5-19)		Set the reset voltage level.
A2 C46 C50 (Para. 5-31)	1K/PH 10K/PH	Compensates for stray capacitances in the range resistor circuit and eliminates measurement inaccuracy due to range resistor current phase shift.
A2 C84 (Para. 5-29)	100/PH	Adjusts the phase tracking of the VRD input circuit.
A2 C99 (Para. 5-33)	AM/PH	Eliminates phase errors from the AM Amplifier.
A2 R6 (Para. 5-21)	OSC/LEVEL	Adjusts the test signal level.
A2 R16 R17 (Para. 5-23 27)	OFFSET	Minimizes the offset voltage of the TRD circuit.
A2 R34 R35 (Para. 5-29)	10K/MAG 1K/MAG	Adjusts the range resistor.
A2 R56 (Para. 5-29)	100/MAG	Adjusts the gain of the VRD input circuit for maximum measurement accuracy.
A2 R80 R81 (Para. 5-25)	ZERO/SHIFT ZERO	Adjusts the zero offset value of the integrator.
A4 R16 (Para. 5-17/-19)	V-ADJ	Adjusts the dc power supply output voltage.
A4 R17 (Para. 5-17)	F-ADJ	Adjusts the dc power supply switching frequency.
A22 R6 R7 R8 (Opt. 001) (Para. 5-35)	ZERO ADJ FS ADJ ZERO ADJ	Adjusts the dc bias output voltage.

Table 5-2. Factory Selected Components

Component	Nominal Value Range	Effect on Performance
A2 C47	HP P/N 0160-2236 C: FXD 1.0pF HP P/N 0160-2237 C: FXD 1.2pF *HP P/N 0160-5595 C: FXD 2.0pF HP P/N 0160-5596 C: FXD 3.0pF HP P/N 0160-5597 C: FXD 5.0pF	Changes the range resistor phase compensation adjustment range.
A2 C48	HP P/N 0160-5597 C: FXD 5.0pF *HP P/N 0160-5592 C: FXD 10.0pF HP P/N 0160-4789 C: FXD 15.0pF	
A2 C98	*HP P/N 0160-4794 C: FXD 5.6pF HP P/N 0160-4791 C: FXD 10.0pF HP P/N 0160-4788 C: FXD 18.0pF	Changes the AM Amp phase compensation adjustment range.
A2 C118	HP P/N 0160-4791 C: FXD 10pF *HP P/N 0160-4790 C: FXD 12pF HP P/N 0160-4789 C: FXD 15pF	Changes the frequency-phase compensation characteristic of the Phase Detector Input Amplifier.
A2 C141	*HP P/N 0160-4791 C: FXD 10.0pF HP P/N 0160-4787 C: FXD 22.0pF HP P/N 0160-4786 C: FXD 27.0pF	Changes the VRD input tracking adjustment range from the EDUT circuit.
A2 R97	HP P/N 0757-0398 R: FXD 75.0 *HP P/N 0757-0401 R: FXD 100.0 HP P/N 0757-0403 R: FXD 121.0 HP P/N 0757-0405 R: FXD 162.0	
A2 R24	*HP P/N 0757-0433 R: FXD 3.32k HP P/N 0757-0434 R: FXD 3.65k	Changes the gain of the MOD Amplifier.
A2 R31	HP P/N 0698-4395 R: FXD 78.7 *HP P/N 0757-0399 R: FXD 82.5 HP P/N 0698-4398 R: FXD 86.6	Changes the attenuation value when TEST SIG LEVEL is set to LOW.
A2 L4	HP P/N 8159-0005 JUMPER WIRE (0H) *HP P/N 9100-2251 L: FXD 100nH HP P/N 9100-2251 L: FXD 220nH HP P/N 9100-0368 L: FXD 330nH HP P/N 9100-2255 L: FXD 470nH HP P/N 9140-0141 L: FXD 680nH	Changes the frequency characteristics of the VRD input tracking circuit.
A2 L6	HP P/N 8159-0005 JUMPER WIRE (0H) HP P/N 9100-2247 L: FXD 100nH *HP P/N 9100-2251 L: FXD 220nH HP P/N 9100-0368 L: FXD 330nH HP P/N 9100-2255 L: FXD 470nH HP P/N 9140-0141 L: FXD 680nH	

Note: Component marked (*) in table is usually used.

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 three preliminary procedures. These procedures provide access to the various adjustment points and facilitate a thoroughgoing adjustment.

[BASIC OPERATING CHECK]

Check that the LINE VOLTAGE SELECTOR switches on the rear panel are set for the local line voltage. This check must be performed before the instrument is connected to a power source. When the 4277A is turned on, verify that no error message is displayed on DISPLAY A. 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, refer to the troubleshooting procedures given in Section VIII.

Note

The error message "E68" may be displayed immediately after the 4277A is turned on. If "E68" is displayed, turn the 4277A off and then on. If "E68" is still displayed, refer to the troubleshooting procedures, "E68" denotes a Check Sum Error in the Continuous Memory RAM.

[TOP COVER REMOVAL]

a. Fully loosen the top-cover retaining screw located at the rear of the top cover.

b. Slide the top cover rearward and lift it off.

WARNING

AS A SAFETY PRECAUTION AGAINST POSSIBLE ELECTRICAL AHOCK HAZARDS AND RESULTANT INJURY, USE INSULATED TOOLS FOR ALL ADJUSTMENTS.

Table 5-3. Adjustment Requirements

Assembly repaired or replaced	Required adjustment(s)
A1 04277-66501 (Main Logic)	Para. 5-17
A2 04277-66502 (Analog Circuits)	Para. 5-19, 5-21, 5-23 5-25, 5-27, 5-29 5-31
A4 04277-66502 (Power supply)	Para. 5-15
A5 04277-66505 A6 04277-66506 A21 04276-66521	None
A22 04276-66522 (Opt. 001 DC Bias)	Para. 5-33

5-17. *DC POWER SUPPLY ADJUSTMENT*

5-18. This adjustment accurately sets the dc output voltages and frequency of the switching power supply (A4 board).

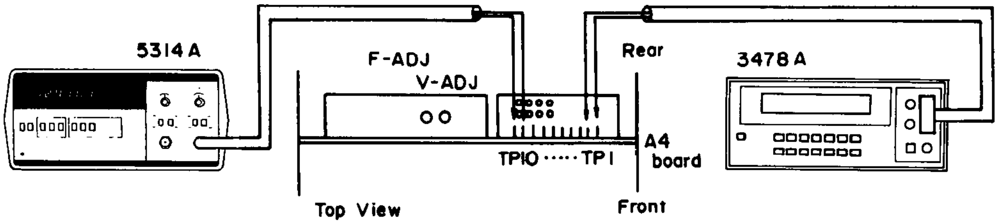


Figure 5-1. DC Power Supply Adjustment Setup.

EQUIPMENT:

Digital Voltmeter	HP 3478A
Frequency Counter	HP 5314A
Dual Banana Plug to Alligator Clip Cable	HP 11002A
1 : 1 Probe	HP 10007B

PROCEDURE:

1. Connect the HI lead of the 3478A to A4TP1 (+5 DIG) and the LO lead to A4TP2 (DIG GND) as shown in Figure 5-1
2. Set the 3478A's controls as follows:

FUNCTION	⎓V
RANGE	AUTO

3. Adjust A4R16 (V-ADJ) until the reading on the 3478A is 5.10V±0.01V.
4. Connect the LO lead of the 3478A to A4TP10 (GND).
5. Verify that the voltages at A4TP3, TP4, TP5, TP6 and TP7 are within the test limits given in Table 5-4. Any voltage outside the limits must be reset by adjusting A4R16.
6. Disconnect the 3478A and connect the 5314A to A4TP9 (DIG PWM) and TP10 (GND) using a 1 : 1 probe as shown in Figure 5-1.
7. Set the 5314A to measure a 20 KHz signal with 10Hz resolution.
8. Adjust A4R17 (F-ADJ) until the reading on the 5314A is 19kHz±100Hz.

Note

It may be necessary to adjust the trigger level of the 5314A for accurate frequency measurement.

Table 5-4. DC Power Supply Voltage Test Limits.

Test point	Test limits
A4TP1	5.09V to 5.11V
A4TP3	11.0 V to 13.0 V
A4TP4	-11.0 V to -13.0 V
A4TP5	15.0 V to 17.0 V
A4TP6	-15.0 V to -17.0 V
A4TP7	8.0 V to 10.0 V

5-19. *RESET CIRCUIT ADJUSTMENT*

5-20. This adjustment accurately sets the reset voltage level of the microprocessor.

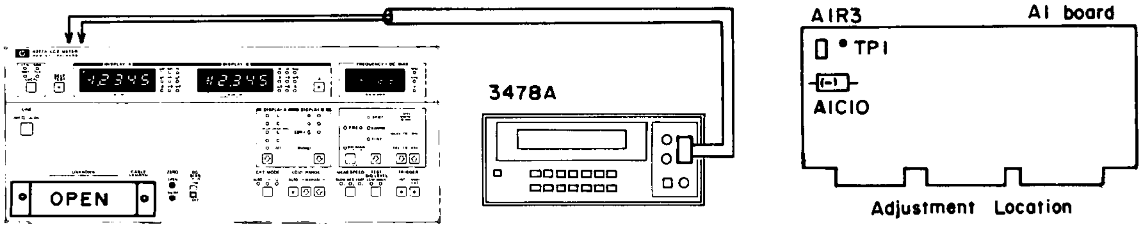


Figure 5-2. Reset Circuit Adjustment Setup.

EQUIPMENT:

Digital Voltmeter	HP 3478A
Dual Banana Plug to Alligator Clip Cable	HP 11002A
Resistance Standard (OPEN Termination)	HP 16074A Standard Resistor Set

Note

If you use Option 001, 002 or HP-IB function, optional components *[1]001, *[2]002 or *[3]HP-IB must be installed before making this adjustment. This adjustment must be performed immediately after Option 001 or 002 has been installed.

*[1] HP P/N 04276-66522
*[2] HP 16064A
*[3] HP P/N 04276-66521

PROCEDURE:

1. Connect the HI lead of the 3478A to A1TP1 and the LO lead to the negative lead of A1C10. Connect the OPEN termination directly to the UNKNOWN terminals.

2. Set the 3478A's controls as follows:

   FUNCTION ………… ⎓V
   RANGE ……………… AUTO

3. Press the SELF TEST key and then the FREQUENCY/DC BIAS select key. Select SELF TEST item number "7" by pressing the FREQUENCY/DC BIAS step control key (⇩ or ⇧) several times until SELF TEST item number "7" is displayed on the FREQUENCY/DC BIAS display.

4. Turn A1R3 all the way to the left, and adjust A4R16 (V-ADJ) until the reading on the 3478A is 4.80V±0.02V.

5. Gradually adjust A1R3 until the 4277A's displays are blank.

Note

The 4277A display may go on and off at this time, this is an acceptable condition.

6. Adjust A4R16 (V-ADJ) until the reading on the 3478A is 5.00V±0.05V, and verify that the 4277A displays any of the alphanumeric figures.

7. Turn A4R16 (V-ADJ) slowly, all the way to the left, until the 4277A displays are blank, and verify that the reading on the 3478A is 4.80V±0.03V.

8. Adjust A4R16 (V-ADJ) until the reading on the 3478A is 5.10V±0.02V.

5-21. TEST SIGNAL LEVEL ADJUSTMENT

5-22. This is the fine adjustment for the test signal level in the HIGH and LOW positions.

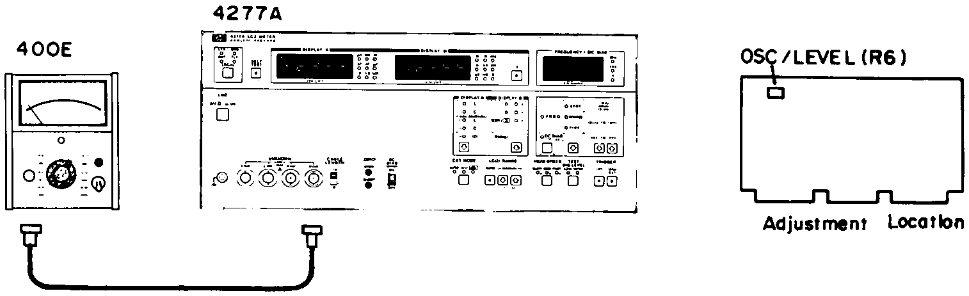


Figure 5-3. Test Signal Level Adjustment Setup.

ADJUSTMENTS

EQUIPMENT:

RF Voltmeter	HP 400E
BNC (m) to BNC (m) Cable	HP 11170B

PROCEDURE:

1. Connect the 400E to the UNKNOWN H_{CUR} terminal of the 4277A using a BNC (m) to BNC (m) cable as shown in Figure 5-3.
2. Set the 4277A's controls as follows:

Test Frequency	1MHz
TEST SIG LEVEL	HIGH
DC BIAS	OFF
Other Controls	Any setting

3. Set RANGE of the 400E to 1Vrms.
4. Adjust A2R6 (LEVEL) until the reading on the 400E is 1.00V±0.01V.
5. Set the Test Frequency and the Test Signal Level in accordance with Table 5-5. Verify that the reading on the 400E is within the test limits given in the table. Change the 400E's range as appropriate for the test signal level.

Table 5-5. Test Signal Level Test Limits

Test Frequency	Test Limits	
	TEST SIG LEVEL "HIGH"	TEST SIG LEVEL "LOW"
1MHz	0.99V to 1.01V	*(18.8mV to 21.2mV)
100KHz	0.94V to 1.06V	18.2mV to 21.8mV
10KHz	0.94V to 1.06V	

Note

For test limits marked with and asterisk *, if a reading on the 400E is greater than 21.2mV, change the value of A2R31 (82.5Ω) to 78.7Ω. If it is less than 18.8mV, change the value of A2R31 to 86.6Ω. Refer to Table 5-2 for the part number of the appropriate resistor.

5-23. *BRIDGE OFFSET ADJUSTMENT*

5-24. This is a preliminary adjustment before making an optimum TRD offset adjustment (in paragraph 5-27).

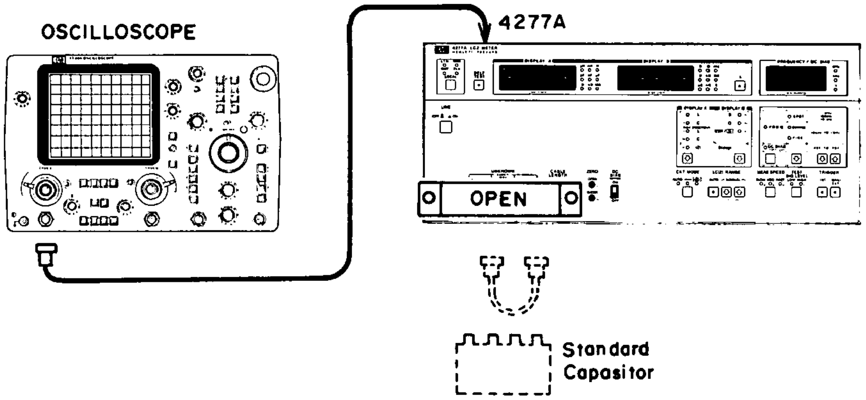
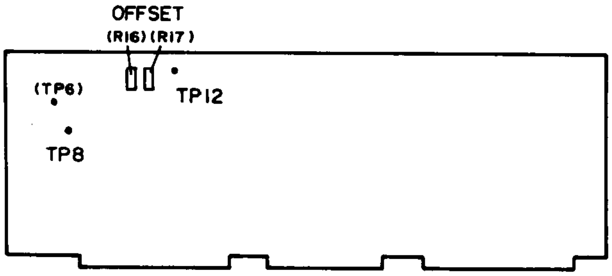


Figure 5-4. Bridge Offset Adjustment Setup.



Adjustment Location

EQUIPMENT:

Oscilloscope	HP 1740A
10:1 Divider Probe	HP 10004D
Resistance Standard (OPEN Termination)	HP 16074A Standard Resistor Set
BNC (m)-to-BNC (m) Cable	10cm long, 1ea.
Standard Capacitor	100pF: HP 16383A

PROCEDURE:

1. Connect the OPEN termination of the 16074A directly to the UNKNOWN terminals as shown in Figure 5-4.

2. Set the 4277A's controls as follows:

DISPLAY A function	C
DISPLAY B function	ESR/G
Test Frequency	100KHz
CIRCUIT MODE	∥
C RANGE	1nF
TEST SIG LEVEL	HIGH
DC BIAS	OFF
SELF TEST	OFF
Other Controls	Any setting

ADJUSTMENTS

3. Set the 1740A's controls as follows:

VOLT/DIV	5mV or 10mV
TIME/DIV	2µs
TRIGGER	INT

4. Connect the 1740A input to A2TP8 as shown in Figure 5-4.

5. Adjust A2R16 and R17 (OFFSET) until the amplitude of the waveform displayed on the oscilloscope is minimized as shown in Figure 5-5.

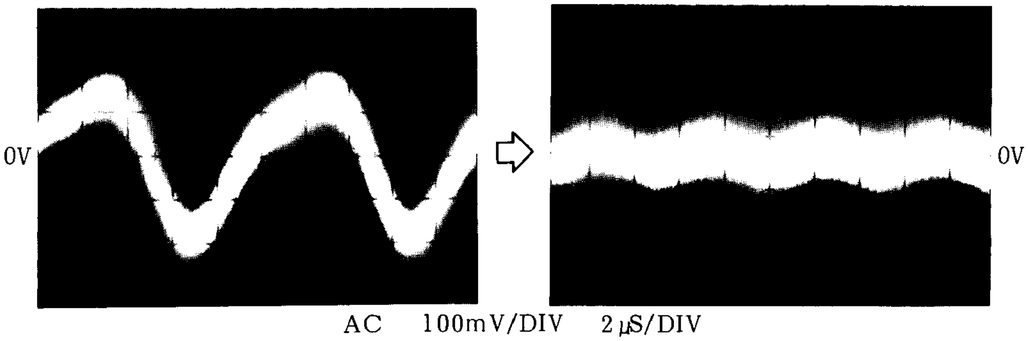


Figure 5-5. Amplitude Adjustment.

Note

A2R16 and R17 are interactive.

6. Disconnect the OPEN termination from the UNKNOWN terminals and connect a BNC (m)-to-BNC (m) cable between the LPOT and the HCUR terminals as shown in Figure 5-4.

7. Set SELF TEST item 16.

Note

To set SELF TEST item 16:

i. Press the SELF TEST key and then the FREQUENCY/DC BIAS select key.

ii. Press the FREQUENCY/DC BIAS step control key (⇩ or ⇧) several times until the SELF TEST item number "16" is displayed on the FREQUENCY/DC BIAS display.

8. Change the vertical sensitivity of the oscilloscope to 0.2V/DIV, and connect the input probe to A2TP12.

9. The amplitude of the waveform on the oscilloscope should be at least 8.5Vp-p. If it is too low, change the value of A2R24. Changing the resistance value (normally 3.32kΩ) to *3.65kΩ increases the amplitude by 10%.
   * HP P/N 0757-0434

10. Disconnect the BNC-to-BNC cable from the LPOT and HCUR terminals and connect the 100pF standard capacitor directly to the UNKNOWN terminals.

11. Set the 4277A's controls as follows:

DISPLAY A Function	C
Test Frequency	1MHz
C RANGE	100pF
TRIGGER	INT
CABLE LENGTH	0
DC BIAS	OFF
SELF TEST	ON (item number 16)
Other controls	Any setting

12. Verify that reading on DISPLAY A is between 0.2000 and 0.8000. If it is not, change the value of A2C118 (Normally 12pF) to 10pF or 15pF. Decreasing the capacitance value increases the reading on DISPLAY A. Refer to Table 5-2 for the part number of the appropriate capacitor.

Note

Do not use a capacitor larger than 15pF.

5-25. *INTEGRATOR ADJUSTMENT*

5-26. This adjustment sets the detection timing of the Zero Detector to minimize the offset count error, which is caused by the A-D converter output offset.

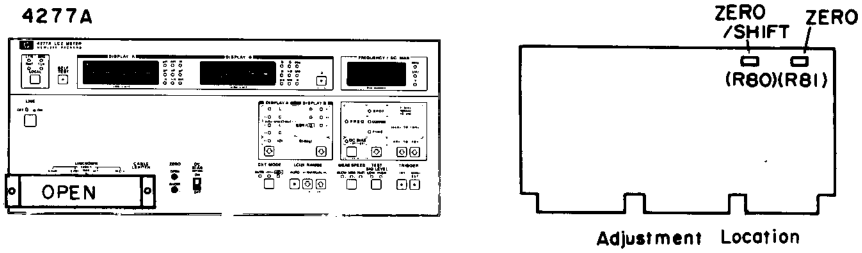


Figure 5-6. Integrator Adjustment Setup.

EQUIPMENT:

Resistance Standard (OPEN termination)	HP 16074A Standard Resistor Set

PROCEDURE:

1. Connect the OPEN termination of the 16074A directly to the UNKNOWN terminals as shown in Figure 5-6.

2. Set the 4277A's controls as follows:

Test Frequency	100kHz
MEAS SPEED	MED
TEST SIG LEVEL	HIGH
SELF TEST	ON (item number 8)
Other Controls	Any setting

3. Adjust A2R81 (ZERO) until the reading on DISPLAY A satisfies the following equation.

   reading on DISPLAY A = -(reading on DISPLAY B) ±0.0002

4. Adjust A2R80 (ZERO/SHIFT) until the readings on DISPLAY A and DISPLAY B are within the following limits.

   reading on DISPLAY A = 0.0034±0.0002
   -(reading on DISPLAY B) = 0.0034±0.0002

5-27. *TRD OFFSET ADJUSTMENT*

5-28. This adjustment eliminates the dc offset voltages from the bridge circuit.

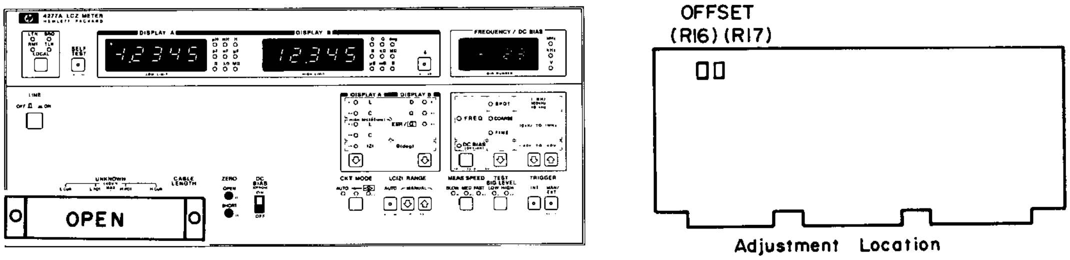


Figure 5-7. TRD Offset Adjustment Setup.

EQUIPMENT:

Resistance Standard (OPEN termination)	HP 16074A Standard Resistor Set

PROCEDURE:

1. Connect the OPEN termination of the 16074A directly to the UNKNOWN terminals as shown in Figure 5-7.

2. Set the 4277A's controls as follows:

DISPLAY A Function	C
DISPLAY B Function	ESR/G
Test Frequency	1MHz
CIRCUIT MODE	
C RANGE	1nF
MEAS SPEED	MED
TEST SIG LEVEL	HIGH
SELF TEST	ON (item number 12)
Other Controls	Any setting

3. Adjust A2R16 and R17 (OFFSET) until the readings on DISPLAY A and DISPLAY B are 0±3 counts.

4. Release the SELF TEST function by pressing the SELF TEST key. Set the test frequency to 20.2kHz.

5. Verify that the reading on DISPLAY A is 0±5 counts. If the reading is outside the limits, readjust A2R17 until the reading on DISPLAY A is +4 or -4 counts.

6. Set the test frequency and the Test Signal Level in accordance with Table 5-6 and verify that the readings on DISPLAY A do not exceed the test limits given in the table.

Table 5-6. TRD Offset Test Limits

Test Frequency	Test Limits			
	TEST SIG LEVEL "HIGH"		TEST SIG LEVEL "LOW"	
	DISPLAY A	DISPLAY B	DISPLAY A	DISPLAY B
1MHz	0±2 counts	0±2 counts	0±3 counts	0±3 counts
202KHz	0±5 counts	0±3 counts	0±2 counts	0±3 counts
100KHz	0±3 counts	0±2 counts	0±4 counts	0±3 counts
20.2KHz	0±5 counts	0±3 counts	0±2 counts	0±3 counts
10KHz	0±4 counts	0±3 counts	0±5 counts	0±4 counts

5-29. ***RANGE RESISTOR AND PHASE TRACKING ADJUSTMENT***

5-30. This adjustment consists of four adjustments and a verification check;

1) 100/MAG Adjustment	adjusts the gain of the VRD input circuit.
2) 10K/MAG Adjustment	adjusts the value of the range resistor.
3) 1K/MAG Adjustment	adjusts the value of the range resistor.
4) 100/PH Adjustment	adjusts VRD input phase tracking.
5) Verification Check	verifies the phase tracking accuracy after the 100/pH adjustment.

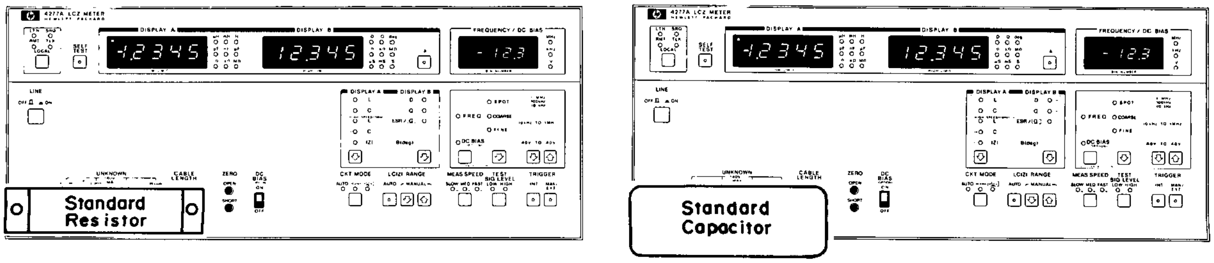


Figure 5-8. Range Resistor and Phase Tracking Adjustment Setup

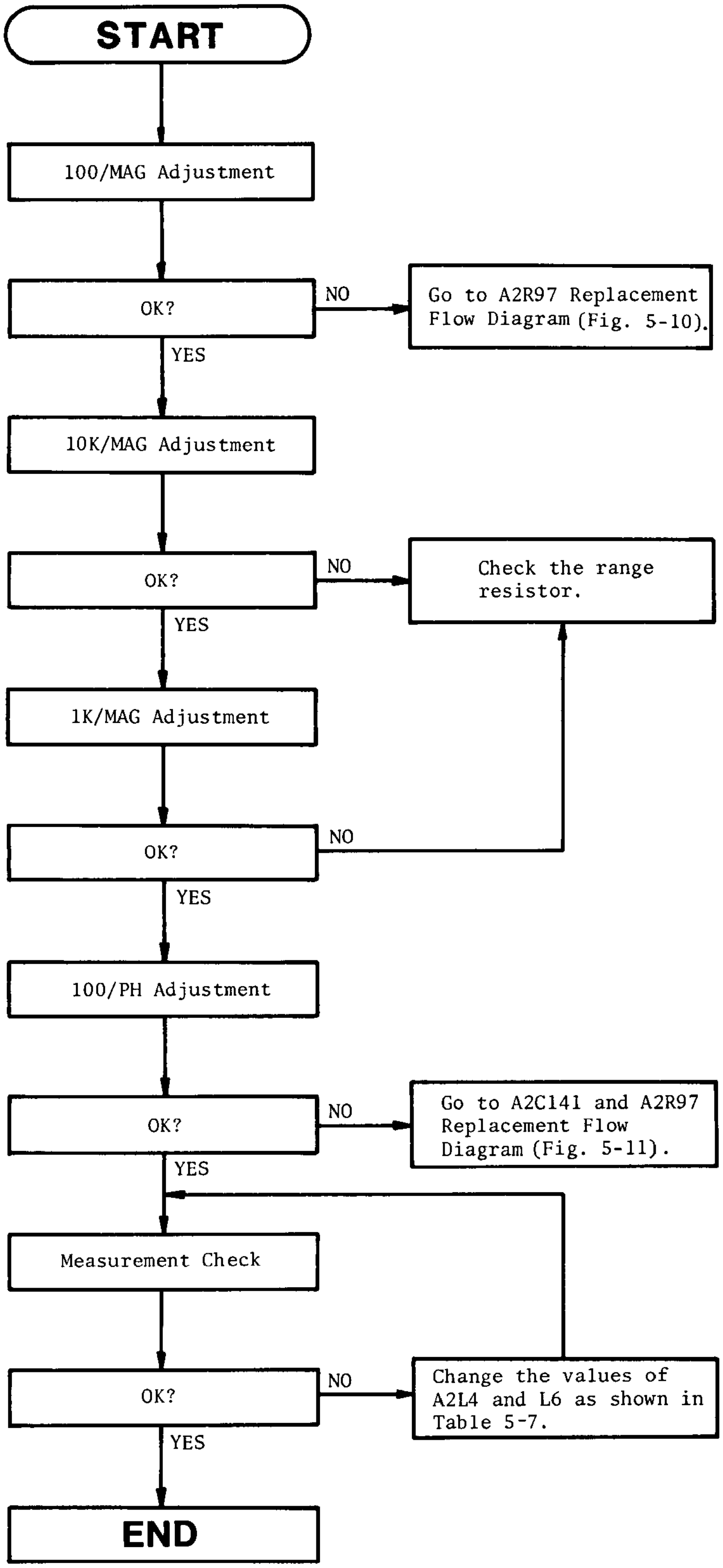
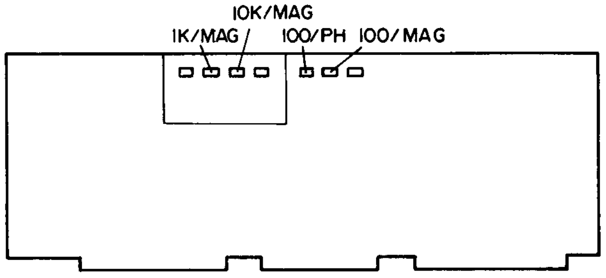


Figure 5-9. Phase Tracking Adjustment Flow Diagram.

ADJUSTMENTS



Adjustment Location

EQUIPMENT:

Standard Resistors (100Ω, 1kΩ and 10kΩ)	HP 16074A Standard Resistor Set
Standard Capacitor	1000pF: HP 16384A

PROCEDURE:

1) 100/MAG Adjustment

1. Set the 4277A's controls as follows:

DISPLAY A Function	C
DISPLAY B Function	ESR/G
Test Frequency	100kHz
CIRCUIT MODE	∥
C RANGE	10nF
TEST SIG LEVEL	HIGH
TRIGGER	INT
DC BIAS	OFF
CABLE LENGTH	0
SELF TEST	OFF

2. Perform Open and Short zero offset adjustments.

3. Connect the 100Ω standard resistor directly to the UNKNOWN terminals.

4. Adjust A2R56 (100/MAG) until the reading on DISPLAY B is 1/C.V.±0.001
   C.V. = calibrated (resistance) value of the standard resistor.

Note

If the 100/MAG adjustment cannot be performed successfully, change the value of A2R97 using the procedure (flow diagram) in Figure 5-10.

2) 10K/MAG Adjustment

1. Select the 100pF Capacitance range by pressing the LC | Z | RANGE key (⇩ or ⇧) and Connect the 10kΩ standard resistor in place of the 100Ω.

2. Adjust A2R34 (10K/MAG) until the reading on DISPLAY B is 1/C.V.±0.01 µS. C.V. is the calibrated (resistance) value of the standard resistor.

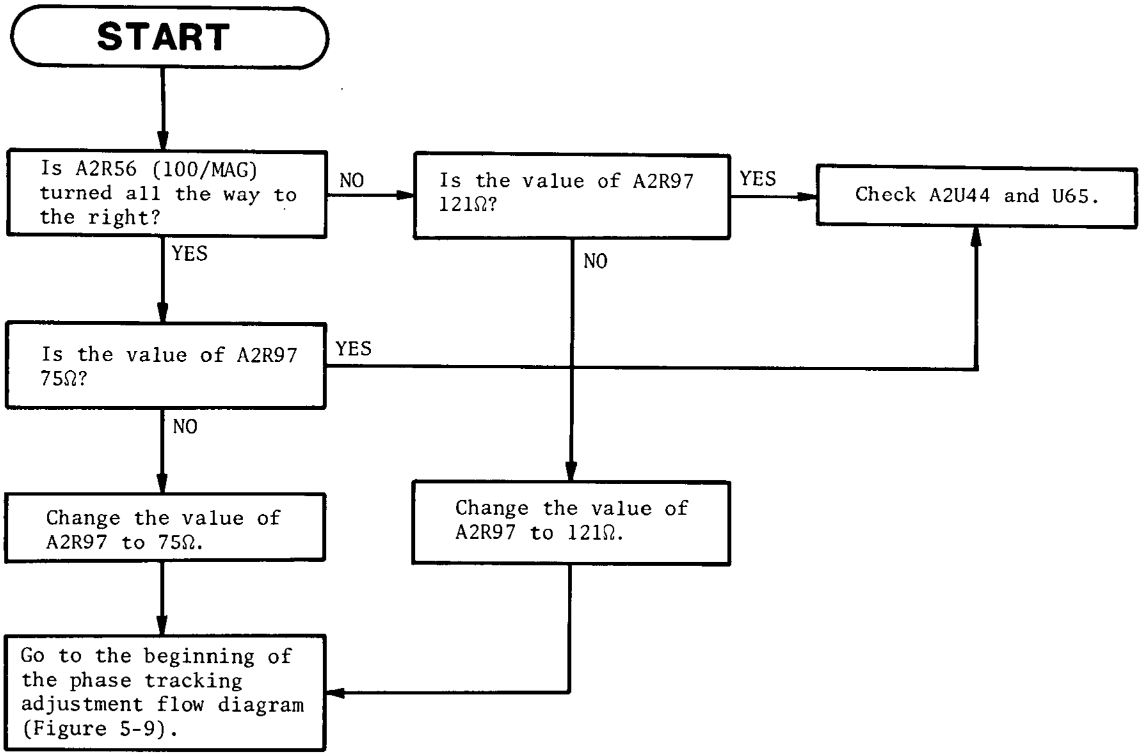


Figure 5-10. A2R97 Replacement Flow Diagram.

3) 1K/MAG Adjustment

1. Set the C range to 1nF and connect the 1kΩ standard resistor to the UNKNOWN terminals.

2. Adjust A2R35 (1K/MAG) until the reading on DISPLAY B is 1/C.V.±0.0001 mS. C.V. is the calibrated (resistance) value of the standard resistor.

4) 100/PH Adjustment

1. Set the 4277A's controls as follows:

DISPLAY B Function	D
Test Frequency	1MHz
C RANGE	1nF

2. Connect the 1000pF standard capacitor directly to the UNKNOWN terminals.

3. Adjust A2C84 (100/PH) until the reading on DISPLAY B is 0±2 counts.

ADJUSTMENTS

Note

If the 100/PH adjustment cannot be performed successfully, change the value of A2C141 or A2R97 using the A2C141/A2R97 replacement flow diagram in Figure 5-11.

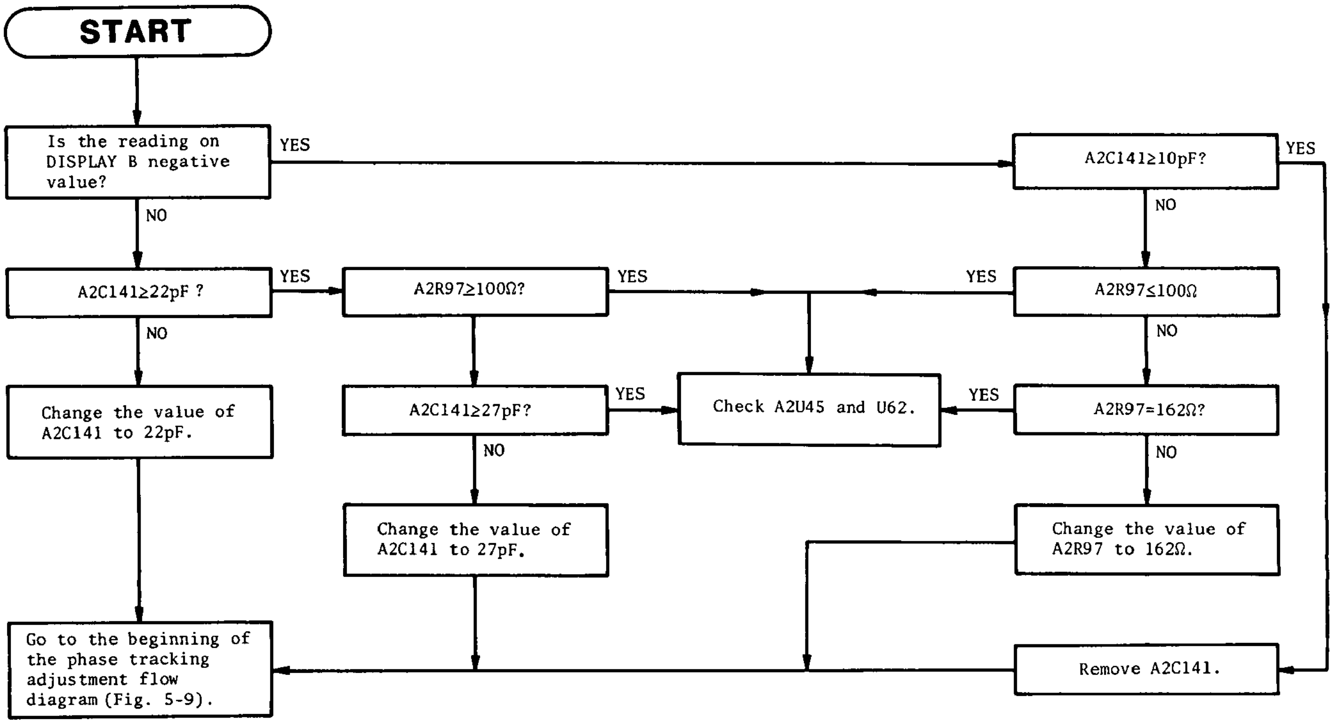


Figure 5-11. A2C141/A2R97 Replacement Flow Disglam.

5) Verification check

1. Connect the 1000pF standard capacitor directly to the UNKNOWN terminals.

2. Set the 4277A's controls as follows:

DISPLAY A Function	C
DISPLAY B Function	D
Test Frequency	1MHz
CIRCUIT MODE	AUTO
LC | Z | RANGE	AUTO
TEST SIG LEVEL	HIGH
TRIGGER	INT
DC BIAS	OFF
CABLE LENGTH	0

3. Verify that the reading on DISPLAY A is C.V.+0.0001nF to C.V.+0.0005nF. C.V. is the calibrated value of the standard capacitor.

Note

If the displayed value exceeds the limits, change the value of A2L4 or L6 to an appropriate value in accordance with Table 5-7.

Table 5-7. A2L4 and A2L6 Nominal Values

Capacitance Reading on DISPLAY A	Reference Designation	Appropriate Value
C.V.+ 0.001nF ~ C.V.+0.0008nF	A2L6	680nH
C.V.+0.0007nF ~ C.V.+0.0006nF	A2L6	470nH
C.V. ~ C.V.±0.0001nF	A2L6	100nH
C.V.-0.0002nF ~ C.V.-0.0004nF	A2L4	470nH
C.V.-0.0005nF ~ C.V.-0.0007nF	A2L4	680nH

C.V.=calibrated value of the standard capacitor.

5-31. *RANGE RESISTOR PHASE ADJUSTMENT*

5-32. This adjustment minimizes phase error in the range resistor circuit.

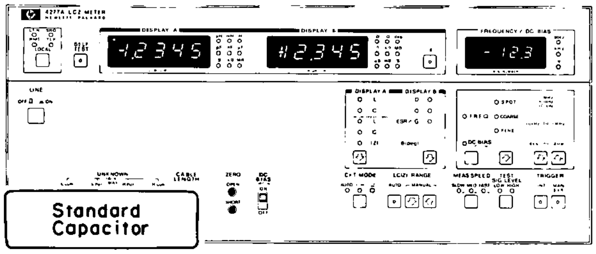
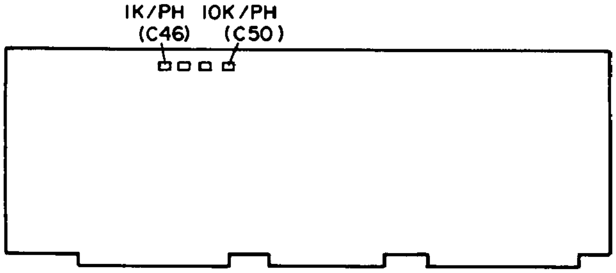


Figure 5-12. Range Resistor Phase Adjustment Setup.



Adjustment Location

EQUIPMENT:

Standard Capacitors .... 10pF: HP 16382A
100pF: HP 16383A

ADJUSTMENTS

PROCEDURE:

1. Connect the 10pF standard capacitor directly to the UNKNOWN terminals.

2. Set the 4277A's controls as follows:

DISPLAY A Function	C
DISPLAY B Function	D
Test Frequency	1MHz
CIRCUIT MODE	
LC | Z | RANGE	AUTO
MEAS SPEED	MED
TEST SIG LEVEL	HIGH
DC BIAS	OFF
CABLE LENGTH	0
SELF TEST	OFF

3. Adjust A2C50 (10K/PH) until the reading on DISPLAY B is between -1 count and 2 counts.

Note

If the 10K/PH adjustment cannot be performed successfully, change the value of A2C47 (normally 2pF) to *1pF or *5pF.

4. Connect the 100pF standard capacitor in place of the 10pF standard capacitor.

5. Adjust A2C46 (1K/PH) until the reading on DISPLAY B is -1 count to 2 counts.

Note

If the 1K/PH adjustment cannot be performed successfully, change the value of A2C48 (normally 10PF) to *5pF or *15pF.

* Refer to Table 5-2 for the part number of the appropriate capacitor.

5-33. *AM AMPLIFIER ADJUSTMENT*

5-34. This adjustment compensates for phase error in the AM Amplifier.

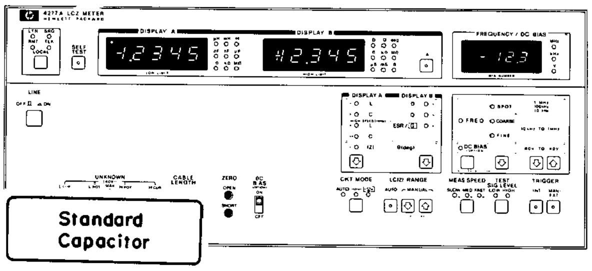
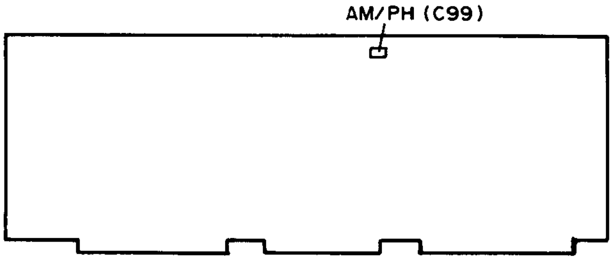


Figure 5-13. AM Amplifier Adjustment Setup.

ADJUSTMENTS



Adjustment Location

EQUIPMENT:

Standard Capacitor 1pF: HP16381A

PROCEDURE:

1. Connect the 1pF standard capacitor directly to the UNKNOWN terminals.
2. Set the 4277A's controls as follows:

DISPLAY A Function	C
DISPLAY B Function	D
Test Frequency	1MHz
CIRCUIT MODE	○—▭—○
LC | Z | RANGE	AUTO
MEAS SPEED	MED
TEST SIG LEVEL	HIGH
SELF TEST	OFF

3. Adjust A2C99 (AM/PH) until the reading on DISPLAY B is between -1 count and 3 counts.
4. Verify that the reading on DISPLAY A is C.V.±0.0015pF. C.V. is the calibrated value of the standard capacitor.

Note

If the reading on DISPLAY B is greater than 4 counts, change the value of A2C98 (normally 5.6pF) to 18pF (HP P/N: 0160-4788). If it is less than -2 counts, remove A2C98.

5-35. ***INT DC BIAS SUPPLY ADJUSTMENT***

5-36. This adjustment sets the gain of the DAC and Amplifier circuit in order to apply accurate dc bias voltage to the DUT.

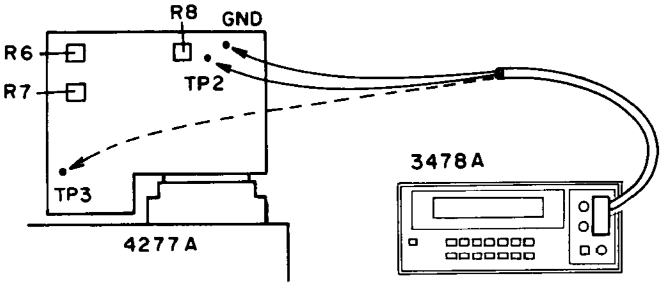


Figure 5-14. INT DC Bias Supply Adjustment Setup.

EQUIPMENT:

Digital Voltmeter	HP 3478A
Dual Banana Plug to Alligator Clip Cable	HP 11002A
BNC to Dual Banana Plug Cable	HP 11001A
Extender Board	HP P/N 04276-66562

PROCEDURE:

1. Extend the A22 board as shown in Figure 5-14.
2. Set the DC Bias voltage to 0.00V.
3. Set the DC BIAS select switch on the rear panel to INT and the DC BIAS switch on the front panel to ON.
4. Connect the HI lead of the 3478A to A22TP2 and the LO lead to the GND pin on the A22 board.
5. Set the 3478A's control as follows:

FUNCTION	⎓V
RANGE	AUTO

6. Adjust A22R8 until the reading on the 3478A is 0V±0.05mV.
7. Connect the HI lead of the 3478A to A22TP3, and adjust A22R6 until the reading on the 3478A is 0V ±0.2mV.
8. Disconnect the dual banana-to-alligator clip cable from the 3478A and connect a BNC-to-dual banana plug cable between the 3478A input and the EXT INPUT/INT MONITOR connector.
9. Set the DC Bias voltage to 9.99V.
10. Adjust A22R7 until the reading on the 3478A is 9.990V±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
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
74970	JOHNSON E F CO	WASECA	MN	56093
75042	TRW INC PHILADELPHIA DIV	PHILADELPHIA	PA	19108
75915	LITTELFUSE INC	DES PLAINES	IL	60016

A1 B'd Replaceable Parts List

MKTG
'93 1.13
大橋

A1	04277-66511	3	1	PCB AY-CTL-LOGIC		04277-66511
A1 C1	0180-1085	5	1	CAP-FXD 4.7uF +-20% 25 V TA		242M2502 475M2
A1 C2	0180-1085	5	1	CAP-FXD 4.7uF +-20% 25 V TA		242M2502 475M2
A1 C3	0180-1085	5	1	CAP-FXD 4.7uF +-20% 25 V TA		242M2502 475M2
A1 C4	0180-1085	5	1	CAP-FXD 4.7uF +-20% 25 V TA		242M2502 475M2
A1 C5	0180-1085	5	1	CAP-FXD 4.7uF +-20% 25 V TA		242M2502 475M2
A1 C6	0180-1085	5	1	CAP-FXD 4.7uF +-20% 25 V TA		242M2502 475M2
A1 C7	0180-1085	5	1	CAP-FXD 4.7uF +-20% 25 V TA		242M2502 475M2
A1 C8	0180-0197	8	1	CAP-FXD 2.2uF +-10% 20 V TA	K7253	TAAA2R2K20RX
A1 C9	0160-4832	4	1	CAP-FXD 0.01uF +-10% 100 V CER X7R		RPA10X7R103K100V
A1 C10	0180-1075	3	1	CAP-FXD 2200uF +-20% 16 V AL-ELCTLT		0180-1075
A1 C11	0160-4801	7	1	CAP-FXD 100pF +-5% 100 V CER C0G		RPA10C0G101J100V
A1 C12	0180-1085	5	1	CAP-FXD 4.7uF +-20% 25 V TA		242M2502 475M2
A1 C13	0180-1085	5	1	CAP-FXD 4.7uF +-20% 25 V TA		242M2502 475M2
A1 C14	0180-1085	5	1	CAP-FXD 4.7uF +-20% 25 V TA		242M2502 475M2
A1 C15	0180-4156	7	1	CAP-FXD 33uF +-20% 16 V AL-ELCTLT		0180-4156
A1 C16	0180-1085	5	1	CAP-FXD 4.7uF +-20% 25 V TA		242M2502 475M2
A1 C17	0180-1085	5	1	CAP-FXD 4.7uF +-20% 25 V TA		242M2502 475M2
A1 C18	0180-1085	5	1	CAP-FXD 4.7uF +-20% 25 V TA		242M2502 475M2
A1 C19	0160-4832	4	1	CAP-FXD 0.01uF +-10% 100 V CER X7R		RPA10X7R103K100V
A1 C20	0180-3590	1	1	CAP-FXD 470uF +-20% 10 V AL-ELCTLT		0180-3590
A1 C21	0180-3590	1	1	CAP-FXD 470uF +-20% 10 V AL-ELCTLT		0180-3590
A1 CR1	1901-0539	3	1	DIODE-SCHOTTKY SM SIG		A2X355
A1 CR2	1901-0539	3	1	DIODE-SCHOTTKY SM SIG		A2X355
A1 I1	0340-0092	2	1	TERMINAL-STUD SPCL-FDTHRU PRESS-MTG	05276	011-6808-00-0-209
A1 I2	0340-0092	2	1	TERMINAL-STUD SPCL-FDTHRU PRESS-MTG	05276	011-6808-00-0-209
A1 J1	1200-0607	0	1	SOCKET-IC-DIP 16-CONT DIP DIP-SLDR		DILB16P-308T
A1 J2	1200-0607	0	1	SOCKET-IC-DIP 16-CONT DIP DIP-SLDR		DILB16P-308T
A1 J4	1200-0567	1	1	SOCKET-IC-DIP 28-CONT DIP DIP-SLDR		DILB28P-308T
A1 J12	1200-0541	1	1	SOCKET-IC-DIP 24-CONT DIP DIP-SLDR		DILB24P-308T
A1 J13	1200-0541	1	1	SOCKET-IC-DIP 24-CONT DIP DIP-SLDR		DILB24P-308T
A1 J15	1200-1326	2	1	SOCKET-IC-DIP 32-CONT DIP DIP-SLDR	06776	ICT-326-S-TT
A1 Q1	1854-0810	2	1	TRANSISTOR NPN SI TO-92 PD=625MW		1854-0810
A1 Q2	1854-0810	2	1	TRANSISTOR NPN SI TO-92 PD=625MW		1854-0810
A1 Q3	1853-0281	9	1	TRANSISTOR PNP 2N2907A SI TO-18 PD=400MW		1853-0281
A1 Q4	1854-0810	2	1	TRANSISTOR NPN SI TO-92 PD=625MW		1854-0810
A1 Q5	1853-0015	7	1	TRANSISTOR PNP SI PD=200MW FT=500MHZ		1853-0015
A1 R1	1810-0488	8	1	NETWORK-RES 8-SIP 4.7K OHM X 4	C1433	750-83-R4.7K
A1 R2	0757-0199	3	1	RESISTOR 21.5K +-1% .125W TF TC=0+-100	91637	CMF-55-1
A1 R3	2100-3103	6	1	RESISTOR-TRMR 10K 10% TKF SIDE-ADJ	73138	89PR10K
A1 R4	0757-0440	7	1	RESISTOR 7.5K +-1% .125W TF TC=0+-100	91637	CMF-55-1
A1 R5	0698-3441	8	1	RESISTOR 215 +-1% .125W TF TC=0+-100	91637	CMF-55-1
A1 R6	0757-0280	3	1	RESISTOR 1K +-1% .125W TF TC=0+-100	91637	CMF-55-1

A1 R7	1810-0607	3	1	NETWORK-RES 8-SIP 47.0K OHM X 4		RAS-G-4734C
A1 R8	0757-0465	6	1	RESISTOR 100K +-1% .125W TF TC=0+-100	91637	CMF-55-1
A1 R9	0698-3454	3	1	RESISTOR 215K +-1% .125W TF TC=0+-100	91637	CMF-55-1
A1 R10	0757-0346	2	1	RESISTOR 10 +-1% .125W TF TC=0+-100	91637	CMF-55-1
A1 R11	0757-0280	3	1	RESISTOR 1K +-1% .125W TF TC=0+-100	91637	CMF-55-1
A1 R12	0757-0395	1	1	RESISTOR 56.2 +-1% .125W TF TC=0+-100	91637	CMF-55-1
A1 R13	0683-0565	0	1	RESISTOR 5.6 +-5% .25W CF TC=0-400		(CR-25) 1-4-5P-5E6
A1 R14	0757-0280	3	1	RESISTOR 1K +-1% .125W TF TC=0+-100	91637	CMF-55-1
A1 R15	1810-0305	8	1	NETWORK-RES 9-SIP 4.7K OHM X 8	11236	750-91-R4.7
A1 R16	1810-0305	8	1	NETWORK-RES 9-SIP 4.7K OHM X 8	11236	750-91-R4.7
A1 R17	1810-0269	3	1	NETWORK-RES 9-SIP 10.0K OHM X 8	56289	216CJ104
A1 R18	1810-0305	8	1	NETWORK-RES 9-SIP 4.7K OHM X 8	11236	750-91-R4.7
A1 R19	1810-0305	8	1	NETWORK-RES 9-SIP 4.7K OHM X 8	11236	750-91-R4.7
A1 R20	1810-0305	8	1	NETWORK-RES 9-SIP 4.7K OHM X 8	11236	750-91-R4.7
A1 R21	0698-3155	1	1	RESISTOR 4.64K +-1% .125W TF TC=0+-100	91637	CMF-55-1
A1 R22	0698-3155	1	1	RESISTOR 4.64K +-1% .125W TF TC=0+-100	91637	CMF-55-1
A1 R23	0698-3155	1	1	RESISTOR 4.64K +-1% .125W TF TC=0+-100	91637	CMF-55-1
A1 R24	0757-0279	0	1	RESISTOR 3.16K +-1% .125W TF TC=0+-100	91637	CMF-55-1
A1 R25	0757-0439	4	1	RESISTOR 6.81K +-1% .125W TF TC=0+-100	91637	CMF-55-1
A1 R26	0698-3155	1	1	RESISTOR 4.64K +-1% .125W TF TC=0+-100	91637	CMF-55-1
A1 R27	0698-3155	1	1	RESISTOR 4.64K +-1% .125W TF TC=0+-100	91637	CMF-55-1
A1 R28	0698-3155	1	1	RESISTOR 4.64K +-1% .125W TF TC=0+-100	91637	CMF-55-1
A1 R30	8159-0005	0	1	RESISTOR 0 CWM	55210	L-2007-1
A1 S1	3101-2885	2	1	SWITCH-DIP SL 7-1A 0.1A 50VDC	K5260	DSS 707
A1 TP1	0360-1653	5	1	CONNECTOR-SGL CONT PIN .045-IN-BSC-SZ SQ	04574	W151-045-375Q
A1 TP2	0360-1653	5	1	CONNECTOR-SGL CONT PIN .045-IN-BSC-SZ SQ	04574	W151-045-375Q
A1 TP3	0360-1653	5	1	CONNECTOR-SGL CONT PIN .045-IN-BSC-SZ SQ	04574	W151-045-375Q
A1 TP4	0360-1653	5	1	CONNECTOR-SGL CONT PIN .045-IN-BSC-SZ SQ	04574	W151-045-375Q
A1 TP5	0360-1653	5	1	CONNECTOR-SGL CONT PIN .045-IN-BSC-SZ SQ	04574	W151-045-375Q
A1 TP6	0360-1653	5	1	CONNECTOR-SGL CONT PIN .045-IN-BSC-SZ SQ	04574	W151-045-375Q
A1 TP7	0360-1653	5	1	CONNECTOR-SGL CONT PIN .045-IN-BSC-SZ SQ	04574	W151-045-375Q
A1 TP8	0360-1653	5	1	CONNECTOR-SGL CONT PIN .045-IN-BSC-SZ SQ	04574	W151-045-375Q
A1 TP9	0360-1653	5	1	CONNECTOR-SGL CONT PIN .045-IN-BSC-SZ SQ	04574	W151-045-375Q
A1 TP10	0360-1653	5	1	CONNECTOR-SGL CONT PIN .045-IN-BSC-SZ SQ	04574	W151-045-375Q
A1 TP11	0360-1653	5	1	CONNECTOR-SGL CONT PIN .045-IN-BSC-SZ SQ	04574	W151-045-375Q
A1 TP12	0360-1653	5	1	CONNECTOR-SGL CONT PIN .045-IN-BSC-SZ SQ	04574	W151-045-375Q
A1 TP14	0360-1653	5	1	CONNECTOR-SGL CONT PIN .045-IN-BSC-SZ SQ	04574	W151-045-375Q
A1 TP15	0360-1653	5	1	CONNECTOR-SGL CONT PIN .045-IN-BSC-SZ SQ	04574	W151-045-375Q
A1 TP16	0360-1653	5	1	CONNECTOR-SGL CONT PIN .045-IN-BSC-SZ SQ	04574	W151-045-375Q
A1 U1	1813-0291	7	1	IC X-TAL 11.52M		1813-0291
A1 U2	1826-0978	4	1	IC MISC 8 PIN DIP-P		1826-0978
A1 U3	1826-0180	0	1	IC TIMER GP 8 PIN DIP-P		1826-0180
A1 U4	1820-2649	8	1	IC-MPU; CLK FREQ=6 MHZ; RAM REFRESH	50088	Z8400BB1N
A1 U5	04277-85102	8	1	PROM 77-66511		04277-85102
A1 U12	1818-3183	2	1	IC 64K SRAM 150-NS CMOS		1818-3183
A1 U13	1820-2024	3	1	IC DRVR TTL/LS BUS OCTL		1820-2024

A1 U14	1820-2024	3	1	IC DRVR TTL/LS BUS OCTL		1820-2024
A1 U15	1820-1730	6	1	IC FF TTL/LS D-TYPE POS-EDGE-TRIG COM		1820-1730
A1 U16	1820-1217	4	1	IC MUXR/DATA-SEL TTL/LS 8-TO-1-LINE	S0167	MB74LS151M
A1 U17	1820-1197	9	1	IC GATE TTL/LS NAND QUAD 2-INP	S4013	HD74LS00P
A1 U18	1820-1112	8	1	IC FF TTL/LS D-TYPE POS-EDGE-TRIG	S4013	HD74LS74AP
A1 U19	1820-1197	9	1	IC GATE TTL/LS NAND QUAD 2-INP	S4013	HD74LS00P
A1 U20	1820-0682	5	1	IC GATE TTL/S NAND QUAD 2-INP		1820-0682
A1 U21	1820-1197	9	1	IC GATE TTL/LS NAND QUAD 2-INP	S4013	HD74LS00P
A1 U23	1820-1199	1	1	IC INV TTL/LS HEX 1-INP	S4013	HD74LS04P
A1 U24	1820-0681	4	1	IC GATE TTL/S NAND QUAD 2-INP	27014	DM74S00N
A1 U25	1820-2150	6	1	IC-PROGRAMMABLE KEYBOARD/DISPLAY	34649	D8279-5
A1 U26	1820-1216	3	1	IC DCDR TTL/LS BIN 3-TO-8-LINE 3-INP	S4013	HD74LS138P
A1 U27	1820-1112	8	1	IC FF TTL/LS D-TYPE POS-EDGE-TRIG	S4013	HD74LS74AP
A1 U28	1820-1112	8	1	IC FF TTL/LS D-TYPE POS-EDGE-TRIG	S4013	HD74LS74AP
A1 U29	1820-1420	1	1	IC CNTR TTL/LS DIV-X-12 ASYNCHRO		1820-1420
A1 U30	1820-1432	5	1	IC CNTR TTL/LS BIN SYNCHRO POS-EDGE-TRIG		1820-1432
A1 U31	1820-1432	5	1	IC CNTR TTL/LS BIN SYNCHRO POS-EDGE-TRIG		1820-1432
A1 U32	1820-1112	8	1	IC FF TTL/LS D-TYPE POS-EDGE-TRIG	S4013	HD74LS74AP
A1 U33	1820-1199	1	1	IC INV TTL/LS HEX 1-INP	S4013	HD74LS04P
A1 U34	1820-2075	4	1	IC TRANSCEIVER TTL/LS BUS OCTL		1820-2075
A1 U35	1820-1216	3	1	IC DCDR TTL/LS BIN 3-TO-8-LINE 3-INP	S4013	HD74LS138P
A1 U36	1820-1624	7	1	IC BFR TTL/S OCTL 1-INP		1820-1624
A1 U37	1820-1199	1	1	IC INV TTL/LS HEX 1-INP	S4013	HD74LS04P
A1 U38	1820-1197	9	1	IC GATE TTL/LS NAND QUAD 2-INP	S4013	HD74LS00P
A1 U39	1820-4356	8	1	IC-PROGRAMMABLE INTERVAL TIMER		MSM82C53-2RS
A1 U41	1820-1216	3	1	IC DCDR TTL/LS BIN 3-TO-8-LINE 3-INP	S4013	HD74LS138P
A1 U42	1820-1112	8	1	IC FF TTL/LS D-TYPE POS-EDGE-TRIG	S4013	HD74LS74AP
A1 U43	1820-1425	6	1	IC SCHMITT-TRIG TTL/LS NAND QUAD 2-INP		1820-1425
A1 U44	1826-0122	0	1	IC V RGLTR-FXD-POS 4.8/5.2V TO-220 PKG		1826-0122
A1 W1	1251-4822	6	1	CONN-POST TYPE .100-PIN-SPCG 3-CONT	18873	68024-403
A1 W2	1251-4822	6	1	CONN-POST TYPE .100-PIN-SPCG 3-CONT	18873	68024-403
A1 W3	1251-4822	6	1	CONN-POST TYPE .100-PIN-SPCG 3-CONT	18873	68024-403

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A1						
A1	04277-66501	1	1	LOGIC BOARD ASSEMBLY	28480	04277-66501
A1C1	0180-1085	5	13	CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C2	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C3	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C4	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C5	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C6	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C7	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C8	0180-0197	8	1	CAPACITOR-FXD 2.2UF+-10% 20VDC TA	56289	150D225X9020A2
A1C9	0160-4832	4	2	CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
A1C10	0180-3219	1	1	CAPACITOR-FXD 2200UF +-20% 6.3VDC AL	28480	0180-3219
A1C11	0160-4801	7	1	CAPACITOR-FXD 100PF +-5% 100VDC CER	28480	0160-4801
A1C12	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C13	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C14	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C15	0180-2951	6	1	CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A1C16	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C17	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C18	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C19	0160-4832	4		CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
A1C20	0180-3217	9	2	CAPACITOR-FXD 470UF	28480	0180-3217
A1C21	0180-3217	9		CAPACITOR-FXD 470UF	28480	0180-3217
A1CR1	1901-0539	3	2	DIODE-SM SIG SCHOTTKY	28480	1901-0539
A1CR2	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
A1J2	1200-0607	0		SOCKET-IC 16-CONT DIP DIP-SLDR	28480	1200-0607
A1J3	1200-0654	7	2	SOCKET-IC 40-CONT DIP DIP-SLDR	28480	1200-0654
A1J10	1200-0541	1		SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
A1J11	1200-0541	1		SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
A1J12	1200-0541	1		SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
A1J13	1200-0541	1		SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
A1J14	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
A1Q2	1854-0810	2		TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
A1Q3	1853-0281	9	1	TRANSISTOR PNP 2N2907A SI TO-18 PD=400MW	04713	2N2907A
A1Q4	1854-0810	2		TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
A1Q5	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
A1R2	0757-0199	3	1	RESISTOR 21.5K 1% .125W F TC=0+-100	24546	C4-1/8-T0-2152-F
A1R3	2100-3103	6	1	RESISTOR-TRMR 10K 10% C SIDE-ADJ 17-TRN	02111	43P103
A1R4	0757-0440	7	1	RESISTOR 7.5K 1% .125W F TC=0+-100	24546	C4-1/8-T0-7501-F
A1R5	0683-2215	1	1	RESISTOR 220 5% .25W FC TC=-400/+600	01121	CB2215
A1R6	0683-4715	0	1	RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
A1R7	1810-0607	3	1	RESISTIVE NETWORK- SIP	28480	1810-0607
A1R8	0683-1045	3	1	RESISTOR 100K 5% .25W FC TC=-400/+800	01121	CB1045
A1R9	0683-2245	7	1	RESISTOR 220K 5% .25W FC TC=-800/+900	01121	CB2245
A1R10	0683-1005	5	1	RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
A1R11	0683-1025	9	2	RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
A1R12	0683-5605	9	1	RESISTOR 56 5% .25W FC TC=-400/+500	01121	CB5605
A1R13	0683-0565	9	1	RESISTOR 5.6 5% .25W FC TC=-400/+500	01121	CB0565
A1R14	0683-1025	9		RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
A1R15	1810-0305	8	5	NETWORK-RES 9-SIP 4.7K OHM X8	28480	1810-0305
A1R16	1810-0305	8		NETWORK-RES 9-SIP 4.7K OHM X8	28480	1810-0305
	1810-0269	3	1	NETWORK-RES 9-SIP10.0K OHM X 8	28480	1810-0269
A1R18	1810-0305	8		NETWORK-RES 9-SIP 4.7K OHM X 8	28480	1810-0305
A1R19	1810-0305	8		NETWORK-RES 9-SIP 4.7K OHM X 8	28480	1810-0305
A1R20	1810-0305	8		NETWORK-RES 9-SIP 4.7K OHM X 8	28480	1810-0305
A1R21	0683-4725	2	5	RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A1R22	0683-4725	2		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A1R23	0683-4725	2		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A1R24	0683-3325	6	1	RESISTOR 3.3K 5% .25W FC TC=-400/+700	01121	CB3325
A1R25	0683-6825	7	1	RESISTOR 6.8K 5% .25W FC TC=-400/+700	01121	CB6825
A1R26	0683-4725	2		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A1R27	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
A1U2	1826-0978	4	1	IC (MISC)	28480	1826-0978
A1U3	1826-0180	0	1	IC TIMER TTL MONO/ASTBL	01295	NE555P
A1U4	1820-2649	8	1	IC- Z80B-CPU	28480	1820-2649
A1U5	04276-85011	5	1	PROM-PROGRAMMED	28480	04276-85011
A1U6	04277-85012	6	1	PROM-PROGRAMMED	28480	04277-85012
A1U7	04277-85003	7	1	PROM-PROGRAMMED	28480	04277-85003
A1U8	04276-85004	8	1	PROM-PROGRAMMED	28480	04276-85004
A1U9	04276-85005	9	1	PROM-PROGRAMMED	28480	04276-85005
A1U10	04276-85016	0	1	PROM-PROGRAMMED	28480	04276-85016
A1U12	1818-1974	5	1	IC-MSM5128-15	28480	1818-1974
A1U13	1820-2024	3	2	IC DRVR TTL LS LINE DRVR OCTL	01295	SN74LS244N
A1U14	1820-2024	3		IC DRVR TTL LS LINE DRVR OCTL	01295	SN74LS244N
A1U15	1820-1730	6	1	IC FF TTL LS D-TYPE POS-EDGE-TRIG COM	01295	SN74LS273N
A1U16	1820-1217	4	1	IC MUXR/DATA-SEL TTL LS 8-TO-1-LINE	01295	SN74LS151N
A1U17	1820-1197	9	4	IC GATE TTL LS NAND QUAD 2-INP	01295	SN74LS00N
A1U18	1820-1112	8	5	IC FF TTL LS D-TYPE POS-EDGE-TRIG	01295	SN74LS74AN
A1U19	1820-1197	9		IC GATE TTL LS NAND QUAD 2-INP	01295	SN74LS00N
A1U20	1820-0682	5	1	IC GATE TTL S NAND QUAD 2-INP	01295	SN74S03N
A1U21	1820-1197	9		IC GATE TTL LS NAND QUAD 2-INP	01295	SN74LS00N
A1U22	1820-1216	3	4	IC DCDR TTL LS 3-TO-8-LINE 3-INP	01295	SN74LS138N
A1U23	1820-1199	1	3	IC INV TTL LS HEX 1-INP	01295	SN74LS04N
A1U24	1820-0681	4	1	IC GATE TTL S NAND QUAD 2-INP	01295	SN74S00N
A1U25	1820-2150	6	1	IC MICPROC-ACCESS NMOS	34649	D8279-5
A1U26	1820-1216	3		IC DCDR TTL LS 3-TO-8-LINE 3-INP	01295	SN74LS138N
A1U27	1820-1112	8		IC FF TTL LS D-TYPE POS-EDGE-TRIG	01295	SN74LS74AN
A1U28	1820-1112	8		IC FF TTL LS D-TYPE POS-EDGE-TRIG	01295	SN74LS74AN
A1U29	1820-1420	1	1	IC CNTR TTL LS DIV-X-12 ASYNCHRO	01295	SN74LS92N
A1U30	1820-1432	5	2	IC CNTR TTL LS BIN SYNCHRO POS-EDGE-TRIG	01295	SN74LS163AN
A1U31	1820-1432	5		IC CNTR TTL LS BIN SYNCHRO POS-EDGE-TRIG	01295	SN74LS163AN
A1U32	1820-1112	8		IC FF TTL LS D-TYPE POS-EDGE-TRIG	01295	SN74LS74AN
A1U33	1820-1199	1		IC INV TTL LS HEX 1-INP	01295	SN74LS04N
A1U34	1820-2075	4	1	IC MISC TTL LS	01295	SN74LS245N
A1U35	1820-1216	3		IC DCDR TTL LS 3-TO-8-LINE 3-INP	01295	SN74LS138N
A1U36	1820-1624	7	1	IC BFR TTL S OCTL 1-INP	01295	SN74S241N
A1U37	1820-1199	1		IC INV TTL LS HEX 1-INP	01295	SN74LS04N
A1U38	1820-1197	9		IC GATE TTL LS NAND QUAD 2-INP	01295	SN74LS00N
A1U39	1820-2873	0	1	IC-UPD8253-5	28480	1820-2873
A1U41	1820-1216	3		IC DCDR TTL LS 3-TO-8-LINE 3-INP	01295	SN74LS138N
A1U42	1820-1112	8		IC FF TTL LS D-TYPE POS-EDGE-TRIG	01295	SN74LS74AN
A1U43	1820-1425	6	1	IC SCHMITT-TRIG TTL LS NAND QUAD 2-INP	01295	SN74LS132N
A1U44	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
A1W2	1251-4822	6		CONNECTOR 3-PIN M POST TYPE	28480	1251-4822
A1W3	1251-4822	6		CONNECTOR 3-PIN M POST TYPE	28480	1251-4822
A1W4	1251-4787	2	1	SHUNT-DIP 8-POSITION	28480	1251-4787
A1W5	8159-0005	0	1	RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
				MISCELLANEOUS PARTS		
	1258-0141	8	3	JUMPER-REM	28480	1258-0141
	04276-26501		1	PC BOARD, BLANK	28480	04276-26501
	04276-01203		1	ANGLE (BOARD)	28480	04276-01203

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						
A2	04277-66502	2	1	ANALOG BOARD ASSEMBLY	28480	04277-66502
A2C1	0160-4814	2	13	CAPACITOR-FXD 150PF +-5% 100VDC CER	28480	0160-4814
A2C2	0180-2951	6	59	CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C3	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C4	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C5	0160-4814	2		CAPACITOR-FXD 150PF +-5% 100VDC CER	28480	0160-4814
A2C6	0160-4812	0	4	CAPACITOR-FXD 220PF +-5% 100VDC CER	28480	0160-4812
A2C7	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C8	0160-4814	2		CAPACITOR-FXD 150PF +-5% 100VDC CER	28480	0160-4814
A2C9	0160-4812	0		CAPACITOR-FXD 220PF +-5% 100VDC CER	28480	0160-4812
A2C10	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C11	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C12	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C13	0180-3233	9	6	CAPACITOR-FXD 22 UF 25VDCW	28480	0180-3233
A2C14	0160-4832	4	13	CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
A2C15	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C16	0160-4835	7	10	CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C17	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C18	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C19	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C20	0160-5499	1	4	CAPACITOR- 0.22UF 100VDC F	28480	0160-5499
A2C21	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C22	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C23	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C24	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C25	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C26	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C27	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C28	0160-4814	2		CAPACITOR-FXD 150PF +-5% 100VDC CER	28480	0160-4814
A2C29	0160-4832	4		CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
A2C30	0160-4832	4		CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
A2C31	0180-1086	6	4	CAPACITOR- 33 UF 16VDCW	28480	0180-1086
A2C32	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C33	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C34	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C35	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C36	0160-4814	2		CAPACITOR-FXD 150PF +-5% 100VDC CER	28480	0160-4814
A2C37	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C38	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C39	0180-1086	6		CAPACITOR- 33 UF 16VDCW	28480	0180-1086
A2C40	0160-5502	7	2	CAPACITOR- 1 UF 63 VDC F	28480	0160-5502
A2C41	0160-5502	7		CAPACITOR- 1 UF 63 VDC F	28480	0160-5502
A2C42	0160-4832	4		CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
A2C43	0180-3233	9		CAPACITOR-FXD 22 UF 25VDCW	28480	0180-3233
A2C44	0180-3233	9		CAPACITOR-FXD 22 UF 25VDCW	28480	0180-3233
A2C45	0180-3233	9		CAPACITOR-FXD 22 UF 25VDCW	28480	0180-3233
A2C46	0121-0059	7	1	CAPACITOR-V TRMR-CER 2-8PF 350V PC-MTG	52763	304324 2/8PF NPO
A2C47*	0160-5595	8	2	CAPACITOR- 2 PF +/- .5 PF	28480	0160-5595
A2C48	0160-5592	5		CAPACITOR- 10PF +/- .5 PF	28480	0160-5592
A2C49*				OPEN		
A2C50	0121-0453	5	1	CAPACITOR-V TRMR-AIR 1.3-5.4PF 175V	74970	187-0303-125
A2C51	0160-5599	3	2	CAPACITOR-0.1 UF 5% F	28480	0160-5599
A2C52	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C53	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C54	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C55	0180-1086	6		CAPACITOR- 33 UF 16VDCW	28480	0180-1086
A2C56	0160-4832	4		CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
A2C57	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C58	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C59	0160-4832	4		CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
A2C60	0160-4791	4		CAPACITOR-FXD 10PF +-5% 100VDC CER 0+-30	28480	0160-4791
A2C61	0160-5499	1		CAPACITOR- 0.22UF 100VDC F	28480	0160-5499
A2C62	0160-4814	2		CAPACITOR-FXD 150PF +-5% 100VDC CER	28480	0160-4814
A2C63	0160-4812	0		CAPACITOR-FXD 220PF +-5% 100VDC CER	28480	0160-4812
A2C64	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C65	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C66	0160-4832	4		CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
A2C67	0160-4814	2		CAPACITOR-FXD 150PF +-5% 100VDC CER	28480	0160-4814
A2C68	0160-5499	1		CAPACITOR- 0.22UF 100VDC F	28480	0160-5499
A2C69	0160-4795	8	3	CAPACITOR-FXD 4.7PF +-.5PF 100VDC CER	28480	0160-4795
A2C70	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951

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	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C72	0160-4801	7	2	CAPACITOR-FXD 100PF +-5% 100VDC CER	28480	0160-4801
A2C73	0160-4814	2		CAPACITOR-FXD 150PF +-5% 100VDC CER	28480	0160-4814
A2C74	0180-1086	6		CAPACITOR- 33 UF 16VDCW	28480	0180-1086
A2C75	0160-0263	7	1	CAPACITOR-FXD .22UF +-20% 50VDC CER	28480	0160-0263
A2C76	0160-4846	0	1	CAPACITOR-FXD 1500PF +-5% 100VDC CER	28480	0160-4846
A2C77	0160-4814	2		CAPACITOR-FXD 150PF +-5% 100VDC CER	28480	0160-4814
A2C78	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C79	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C80	0160-4795	8		CAPACITOR-FXD 4.7PF +-.5PF 100VDC CER	28480	0160-4795
A2C81	0160-4809	5	1	CAPACITOR-FXD 390PF +-5% 100VDC CER	28480	0160-4809
A2C82	0160-4806	2	1	CAPACITOR-FXD 39PF +-5% 100VDC CER 0+-30	28480	0160-4806
A2C83	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C84	0121-0036	0	2	CAPACITOR-V TRMR-CER 5.5-18PF 350V	52763	304324 5.5/18PF NPO
A2C85	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C86	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C87	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C88	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C89	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C90	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C91	0160-4832	4		CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
A2C92	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C93	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C94	0160-4832	4		CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
A2C95	0160-4832	4		CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
A2C96	0160-4832	4		CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
A2C97	0160-4832	4		CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
A2C98*	0160-4794	7	1	CAPACITOR-FXD 5.6PF +-.5PF 100VDC CER	28480	0160-4794
A2C99	0121-0036	0		CAPACITOR-V TRMR-CER 5.5-18PF 350V	52763	304324 5.5/18PF NPO
A2C100	0160-5143	2	1	CAPACITOR-FXD .1UF +-20% 50VDC CER	28480	0160-5143
A2C101	0160-2234	6	1	CAPACITOR-FXD .51PF +-.25PF 500VDC CER	28480	0160-2234
A2C102	0160-4814	2		CAPACITOR-FXD 150PF +-5% 100VDC CER	28480	0160-4814
A2C103	0160-5499	1		CAPACITOR- 0.22UF 100VDC F	28480	0160-5499
A2C104	0160-4801	7		CAPACITOR-FXD 100PF +-5% 100VDC CER	28480	0160-4801
A2C105	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C106	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C107	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C108	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C109	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C110	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C111	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C112	0160-4795	8		CAPACITOR-FXD 4.7PF +-.5PF 100VDC CER	28480	0160-4795
A2C113	0160-4814	2		CAPACITOR-FXD 150PF +-5% 100VDC CER	28480	0160-4814
A2C114	0160-0575	4	1	CAPACITOR-FXD .047UF +-20% 50VDC CER	28480	0160-0575
A2C115	0160-4805	1	1	CAPACITOR-FXD 47PF +-5% 100VDC CER 0+-30	28480	0160-4805
A2C116	0160-4822	2	1	CAPACITOR-FXD 1000PF +-5% 100VDC CER	28480	0160-4822
A2C117	0160-4832	4		CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
A2C118*	0160-4790	3	1	CAPACITOR-FXD 12PF +-5% 100VDC CER 0+-30	28480	0160-4790
A2C119	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C120	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C121	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C122	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C123	0160-4814	2		CAPACITOR-FXD 150PF +-5% 100VDC CER	28480	0160-4814
A2C124	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C125	0160-4814	2		CAPACITOR-FXD 150PF +-5% 100VDC CER	28480	0160-4814
A2C126	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C127	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C128	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C129	0160-5494	6	2	CAPACITOR-FXD 2.2 UF 5% 100VDC	28480	0160-5494
A2C130	0160-0160	3	1	CAPACITOR-FXD 8200PF +-10% 200VDC POLYE	28480	0160-0160
A2C131	0160-5498	0	1	CAPACITOR- 0.01UF 50VDC F	28480	0160-5498
A2C132	0160-5497	9	1	CAAPACITOR- 33 NF 100VDC F	28480	0160-5497
A2C133	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C134	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C135	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C136	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C137	0180-3233	9		CAPACITOR-FXD 22 UF 25VDCW	28480	0180-3233
A2C138	0180-3233	9		CAPACITOR-FXD 22 UF 25VDCW	28480	0180-3233
A2C139	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C140	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C141*	0160-4791	4	2	CAPACITOR-FXD 10PF +-5% 100VDC CER 0+-30	28480	0160-4791
A2C142	0160-5599	3		CAPACITOR-0.1 UF 5% F	28480	0160-5599
A2C143	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C144	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C145	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951

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
A2C146	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C147	0160-4830	2	1	CAPACITOR-FXD 2200PF +-10% 100VDC CER	28480	0160-4830
A2C149	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C150	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C151	0160-5501	6	1	CAPACITOR- 0.1 UF 100VDC F	28480	0160-5501
A2C152*	0160-5595	8		CAPACITOR- 2 PF +/- .5 PF	28480	0160-5595
A2C153*	0160-5596	9	1	CAPACITOR- 3 PF +/- .5 PF	28480	0160-5596
A2C154*	0160-5592	5	2	CAPACITOR- 10PF +/- .5 PF	28480	0160-5592
A2C155	0160-5494	6		CAPACITOR-FXD 2.2 UF 5% 100VDC	28480	0160-5494
A2C156	0160-0127	2	1	CAPACITOR-FXD 1UF +-20% 25VDC CER	28480	0160-0127
A2C157	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C158	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C159	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C160	0160-4812	0		CAPACITOR-FXD 220PF +-5% 100VDC CER	28480	0160-4812
A2C161	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C162	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2CR1	1902-0041	4	2	DIODE-ZNR 5.11V 5% DO-35 PD=.4W	28480	1902-0041
A2CR2	1902-0041	4		DIODE-ZNR 5.11V 5% DO-35 PD=.4W	28480	1902-0041
A2CR3	1902-3059	0	4	DIODE-ZNR 3.83V 5% DO-35 PD=.4W	28480	1902-3059
A2CR4	1902-3059	0		DIODE-ZNR 3.83V 5% DO-35 PD=.4W	28480	1902-3059
A2CR5	1902-3059	0		DIODE-ZNR 3.83V 5% DO-35 PD=.4W	28480	1902-3059
A2CR6	1902-3059	0		DIODE-ZNR 3.83V 5% DO-35 PD=.4W	28480	1902-3059
A2CR7	1901-0033	2	8	DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
A2CR8	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
A2CR9	1902-3082	9	4	DIODE-ZNR 4.64V 5% DO-35 PD=.4W	28480	1902-3082
A2CR10	1902-3082	9		DIODE-ZNR 4.64V 5% DO-35 PD=.4W	28480	1902-3082
A2CR11	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
A2CR12	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
A2CR13	1901-0040	1	11	DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR14	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR15	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR16	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR17	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
A2CR18	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
A2CR19	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR20	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR21	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR22	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR23	0122-0153	4	1	DIODE-VVC 500PF +-10% PD=100MW	28480	0122-0153
A2CR24	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR25	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR26	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR27	1902-3082	9		DIODE-ZNR 4.64V 5% DO-35 PD=.4W	28480	1902-3082
A2CR28	1902-3082	9		DIODE-ZNR 4.64V 5% DO-35 PD=.4W	28480	1902-3082
A2CR29	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
A2CR30	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
A2K1	0490-1269	4	2	RELAY 1C 12VDC-COIL .66A 30VDC	28480	0490-1269
A2K2	0490-1269	4		RELAY 1C 12VDC-COIL .66A 30VDC	28480	0490-1269
A2L1	9100-1629	4	1	INDUCTOR RF-CH-MLD 47UH 5% .166DX.385LG	28480	9100-1629
A2L2	9100-1625	0	1	INDUCTOR RF-CH-MLD 33UH 5% .166DX.385LG	28480	9100-1625
A2L3	9140-0697	8	1	TRANSFORMER- 100 MH	28480	9140-0697
A2L4*	9100-2247	4	1	INDUCTOR RF-CH-MLD 100NH 10% .105DX.26LG	28480	9100-2247
A2L5	9100-0824	9	1	COIL-CHOKE 100 UH	28480	9100-0824
A2L6*	9100-2251	0	1	INDUCTOR RF-CH-MLD 220NH 10% .105DX.26LG	28480	9100-2251
A2Q1	1854-0810	2	5	TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
A2Q2	1854-0810	2		TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
A2Q3	1854-0810	2		TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
A2Q4	1854-0810	2		TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
A2Q5	1854-0810	2		TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
A2Q6	1854-0129	6	2	TRANSISTOR-NPN 2SC1636	28480	1854-0129
A2Q7	1855-0111	8	3	TRANSISTOR-FET 2SK438D	28480	1855-0111
A2Q8	1855-0111	8		TRANSISTOR-FET 2SK438D	28480	1855-0111
A2Q9	1855-0111	8		TRANSISTOR-FET 2SK438D	28480	1855-0111
A2Q10	1854-0129	6		TRANSISTOR-NPN 2SC1636	28480	1854-0129
A2R1	0683-4715	0	1	RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
A2R2	0757-0416	7	2	RESISTOR 511 1% .125W F TC=0+-100	24546	C4-1/8-T0-511R-F
A2R3	0757-0280	3	1	RESISTOR 1K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1001-F
A2R4	1810-0347	8	6	NETWORK-RES 8-SIP2.2K OHM X 4	01121	208B222
A2R5	1810-0347	8		NETWORK-RES 8-SIP2.2K OHM X 4	01121	208B222
A2R6	2100-2574	3	1	RESISTOR-TRMR 500 10% C SIDE-ADJ 1-TRN	30983	ET50X501
A2R7	0683-5615	1	2	RESISTOR 560 5% .25W FC TC=-400/+600	01121	CB5615
A2R8	1810-0347	8		NETWORK-RES 8-SIP2.2K OHM X 4	01121	208B222
A2R9	1810-0347	8		NETWORK-RES 8-SIP2.2K OHM X 4	01121	208B222
A2R10	0683-5615	1		RESISTOR 560 5% .25W FC TC=-400/+600	01121	CB5615

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
A2R11	0683-1035	1	9	RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A2R12	0683-2265	1	1	RESISTOR 22M 5% .25W FC TC=-900/+1200	01121	CB2265
A2R13	0683-3325	6	3	RESISTOR 3.3K 5% .25W FC TC=-400/+700	01121	CB3325
A2R14	1810-0478	6	1	NETWORK-RES 8-SIP22.0K OHM X 4	28480	1810-0478
A2R15	0683-3305	2	1	RESISTOR 33 5% .25W FC TC=-400/+500	01121	CB3305
A2R16	2100-3161	6	2	RESISTOR-TRMR 20K 10% C SIDE-ADJ 17-TRN	02111	43P203
A2R17	2100-3161	6		RESISTOR-TRMR 20K 10% C SIDE-ADJ 17-TRN	02111	43P203
A2R18	0757-0402	1	2	RESISTOR 110 1% .125W F TC=0+-100	24546	C4-1/8-T0-111-F
A2R19	1810-0347	8		NETWORK-RES 8-SIP2.2K OHM X 4	01121	208B222
A2R20	0683-1055	5	4	RESISTOR 1M 5% .25W FC TC=-800/+900	01121	CB1055
A2R21	0683-1055	5		RESISTOR 1M 5% .25W FC TC=-800/+900	01121	CB1055
A2R22	0757-0438	3	1	RESISTOR 5.11K 1% .125W F TC=0+-100	24546	C4-1/8-T0-5111-F
A2R23	0757-0416	7		RESISTOR 511 1% .125W F TC=0+-100	24546	C4-1/8-T0-511R-F
A2R24	0757-0433	8	1	RESISTOR 3.32K 1% .125W F TC=0+-100	24546	C4-1/8-T0-3321-F
A2R25	0698-4420	5	1	RESISTOR 226 1% .125W F TC=0+-100	24546	C4-1/8-T0-226R-F
A2R26	0698-4428	3	1	RESISTOR 1.69K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1691-F
A2R27	0699-1021	8	1	RESISTOR- 100 OHM 5% 1/4W	28480	0699-1021
A2R28	0699-1020	7	1	RESISTOR- 470 OHM 1W	28480	0699-1020
A2R29	0683-1035	1		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A2R30	1810-0488	8	4	NETWORK-RES 8-SIP4.7K OHM X 4	28480	1810-0488
A2R31*	0757-0399	5	1	RESISTOR 82.5 1% .125W F TC=0+-100	24546	C4-1/8-T0-82R5-F
A2R32	0683-5635	5	1	RESISTOR 56K 5% .25W FC TC=-400/+800	01121	CB5635
A2R33	1810-0305	8	3	NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
A2R34	2100-2583	4	1	RESISTOR-TRMR 10 20% C SIDE-ADJ 1-TRN	30983	ET50X100
A2R35	2100-2632	4	2	RESISTOR-TRMR 100 10% C SIDE-ADJ 1-TRN	30983	ET50X101
A2R36	1810-0626	6	1	RESISTIVE NETWORK- SIP	28480	1810-0626
A2R37	0698-4125	7	1	RESISTOR 953 1% .125W F TC=0+-100	24546	C4-1/8-T0-953R-F
A2R38	1810-0488	8		NETWORK-RES 8-SIP4.7K OHM X 4	28480	1810-0488
A2R39	1810-0406	0	1	NETWORK-RES 8-SIP10.0K OHM X 4	01121	208B103
A2R40	0683-2215	1	6	RESISTOR 220 5% .25W FC TC=-400/+600	01121	CB2215
A2R41	0683-2215	1		RESISTOR 220 5% .25W FC TC=-400/+600	01121	CB2215
A2R42	0683-1035	1		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A2R43	0683-1045	3	2	RESISTOR 100K 5% .25W FC TC=-400/+800	01121	CB1045
A2R44	0683-3325	6		RESISTOR 3.3K 5% .25W FC TC=-400/+700	01121	CB3325
A2R45	0683-2215	1		RESISTOR 220 5% .25W FC TC=-400/+600	01121	CB2215
A2R46	0683-6805	3	2	RESISTOR 68 5% .25W FC TC=-400/+500	01121	CB6805
A2R47	0757-0402	1		RESISTOR 110 1% .125W F TC=0+-100	24546	C4-1/8-T0-111-F
A2R48	0683-6825	7	2	RESISTOR 6.8K 5% .25W FC TC=-400/+700	01121	CB6825
A2R49	1810-0405	9	1	NETWORK-RES 8-SIP470.0 OHM X 4	01121	208B471
A2R50	1810-0488	8		NETWORK-RES 8-SIP4.7K OHM X 4	28480	1810-0488
A2R51	0683-1015	7	1	RESISTOR 100 5% .25W FC TC=-400/+500	01121	CB1015
A2R52	0683-1025	9	4	RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
A2R53	0683-1035	1		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A2R54	0757-0277	8	1	RESISTOR 49.9 1% .125W F TC=0+-100	24546	C4-1/8-T0-4992-F
A2R54	0757-0401	0		RESISTOR 100 1% .125W F TC=0+-100	24546	C4-1/8-T0-101-F
A2R56	2100-2632	4		RESISTOR-TRMR 100 10% C SIDE-ADJ 1-TRN	30983	ET50X101
A2R57	0683-1005	5	6	RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
A2R58	0683-1005	5		RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
A2R59	0683-1005	5		RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
A2R60	0683-1005	5		RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
A2R61	1810-0620	0	1	RESISTIVE NETWORK- SIP	28480	1810-0620
A2R62	0683-2215	1		RESISTOR 220 5% .25W FC TC=-400/+600	01121	CB2215
A2R64	0683-1055	5		RESISTOR 1M 5% .25W FC TC=-800/+900	01121	CB1055
A2R65	0683-1055	5		RESISTOR 1M 5% .25W FC TC=-800/+900	01121	CB1055
A2R66	1810-0488	8		NETWORK-RES 8-SIP4.7K OHM X 4	28480	1810-0488
A2R67	0698-3444	1	1	RESISTOR 316 1% .125W F TC=0+-100	24546	C4-1/8-T0-316R-F
A2R68	0698-4421	6	1	RESISTOR 249 1% .125W F TC=0+-100	24546	C4-1/8-T0-249R-F
A2R69	0698-4383	9	1	RESISTOR 53.6 1% .125W F TC=0+-100	24546	C4-1/8-T0-53R6-F
A2R70	1810-0347	8		NETWORK-RES 8-SIP2.2K OHM X 4	01121	208B222
A2R71	1810-0224	0	1	NETWORK-RES 8-SIP33.0K OHM X 4	01121	208B333
A2R72	0683-2225	3	2	RESISTOR 2.2K 5% .25W FC TC=-400/+700	01121	CB2225
A2R73	0683-1035	1		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A2R74	1810-0606	2	1	RESISTIVE NETWORK- SIP	28480	1810-0606
A2R75	0683-2225	3		RESISTOR 2.2K 5% .25W FC TC=-400/+700	01121	CB2225
A2R76	0683-1025	9		RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
A2R77	0683-3325	6		RESISTOR 3.3K 5% .25W FC TC=-400/+700	01121	CB3325
A2R78	0683-6805	3		RESISTOR 68 5% .25W FC TC=-400/+500	01121	CB6805
A2R79	0683-1035	1		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A2R80	2100-2489	9	1	RESISTOR-TRMR 5K 10% C SIDE-ADJ 1-TRN	30983	ET50X502
A2R81	2100-2522	1	1	RESISTOR-TRMR 10K 10% C SIDE-ADJ 1-TRN	30983	ET50X103
A2R82	0683-1025	9		RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
A2R83	0683-1515	2	1	RESISTOR 150 5% .25W FC TC=-400/+600	01121	CB1515
A2R84	0683-6825	7		RESISTOR 6.8K 5% .25W FC TC=-400/+700	01121	CB6825
A2R85	0683-1045	3		RESISTOR 100K 5% .25W FC TC=-400/+800	01121	CB1045
A2R85	0683-4745	6	1	RESISTOR 470K 5% .25W FC TC=-800/+900	01121	CB4745

See introduction to this section for ordering information
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Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A2R86	0683-3335	8	1	RESISTOR 33K 5% .25W FC TC=-400/+800	01121	CB3335
A2R87	0683-1525	4	1	RESISTOR 1.5K 5% .25W FC TC=-400/+700	01121	CB1525
A2R88	0683-1035	1		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A2R89	0683-1035	1		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A2R90	0683-1035	1		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A2R91	0698-3160	8	1	RESISTOR 31.6K 1% .125W F TC=0+-100	24546	C4-1/8-T0-3162-F
A2R92	0683-2215	1		RESISTOR 220 5% .25W FC TC=-400/+600	01121	CB2215
A2R93	0683-2215	1		RESISTOR 220 5% .25W FC TC=-400/+600	01121	CB2215
A2R94	0683-1005	5		RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
A2R95	0683-1005	5		RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
A2R96	1810-0305	8		NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
A2R97*	0757-0401	0	2	RESISTOR 100 1% .125W F TC=0+-100	24546	C4-1/8-T0-101-F
A2R98	0757-0459	8	1	RESISTOR 56.2K 1% .125W F TC=0+-100	24546	C4-1/8-T0-5622-F
A2R99	1810-0305	8		NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
A2R100	0683-3315	4	2	RESISTOR 330 5% .25W FC TC=-400/+600	01121	CB3315
A2R101	0698-3157	3	1	RESISTOR 19.6K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1962-F
A2R102	0699-1019	4	2	RESISTOR- 7.071K 0.1W	28480	0699-1019
A2R103	0698-4157	5	2	RESISTOR 10K .1% .125W F TC=0+-50	28480	0698-4157
A2R104	0699-1019	4		RESISTOR- 7.071K 0.1W	28480	0699-1019
A2R105	0698-4157	5		RESISTOR 10K .1% .125W F TC=0+-50	28480	0698-4157
A2R106	0683-1025	9		RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
A2R107	0683-3315	4		RESISTOR 330 5% .25W FC TC=-400/+600	01121	CB3315
A2T1	9140-0698	9	3	TRANSFORMER	28480	9140-0698
A2T2	9140-0698	9		TRANSFORMER	28480	9140-0698
A2T3	9100-0823	8	3	TRANSFORMER- PULSE 113B1	28480	9100-0823
A2T4	9140-0698	9		TRANSFORMER	28480	9140-0698
A2T5	9100-0823	8		TRANSFORMER- PULSE 113B1	28480	9100-0823
A2T6	9100-0823	8		TRANSFORMER- PULSE 113B1	28480	9100-0823
A2U1	1813-0295	1	4	IC (MISC)	28480	1813-0295
A2U2	1813-0295	1		IC (MISC)	28480	1813-0295
A2U3	1813-0295	1		IC (MISC)	28480	1813-0295
A2U4	1813-0295	1		IC (MISC)	28480	1813-0295
A2U5	1813-0300	9	13	IC (MISC)	28480	1813-0300
A2U6	1813-0300	9		IC (MISC)	28480	1813-0300
A2U7	1826-0122	0	6	IC 7805 V RGLTR TO-220	07263	7805UC
A2U8	5080-3837	2	1	IC V RGLTR TO-220(SEL)	04713	MC7905.2CT
A2U9	1826-0122	0		IC 7805 V RGLTR TO-220	07263	7805UC
A2U10	1820-0693	8	1	IC FF TTL S D-TYPE POS-EDGE-TRIG	01295	SN74S74N
A2U11	1813-0297	3	1	IC (MISC)	28480	1813-0297
A2U12	1826-0519	9	2	IC OP AMP LOW-BIAS-H-IMPD 8-DIP-P PKG	01295	TL071CP
A2U13	1820-0630	3	1	IC MISC TTL	04713	MC4044P
A2U14	1820-1430	3	1	IC CNTR TTL LS BIN SYNCHRO POS-EDGE-TRIG	01295	SN74LS161AN
A2U15	1820-1244	7	1	IC MUXR/DATA-SEL TTL LS 4-TO-1-LINE DUAL	01295	SN74LS153N
A2U16	1820-2885	4	1	IC- HD74LS390	28480	1820-2885
A2U17	1820-0683	6	1	IC INV TTL S HEX 1-INP	01295	SN74S04N
A2U18	1826-0122	0		IC 7805 V RGLTR TO-220	07263	7805UC
A2U19	1813-0301	0	2	IC (MISC)	28480	1813-0301
A2U20	1813-0301	0		IC (MISC)	28480	1813-0301
A2U21	1820-1313	1	6	IC MULTIPLXR 2-CHAN-ANLG TRIPLE 16-DIP-P	3L585	CD4053BE
A2U22	1813-0298	4	2	IC (MISC)	28480	1813-0298
A2U23	1813-0300	9		IC (MISC)	28480	1813-0300
A2U24	1813-0300	9		IC (MISC)	28480	1813-0300
A2U25	1813-0298	4		IC (MISC)	28480	1813-0298
A2U26	1820-1730	6	3	IC FF TTL LS D-TYPE POS-EDGE-TRIG COM	01295	SN74LS273N
A2U27	5080-3838	0	5	IC V RGLTR TO-220(SEL)	04713	MC7912CT
A2U28	1826-0147	9	3	IC 7812 V RGLTR TO-220	04713	MC7812CP
A2U29	1826-0971	7	4	IC- UPC7908H	28480	1826-0971
A2U30	1826-0971	7		IC- UPC7908H	28480	1826-0971
A2U31	1826-0146	8	4	IC 7808 V RGLTR TO-220	04713	MC7808CP
A2U32	1826-0146	8		IC 7808 V RGLTR TO-220	04713	MC7808CP
A2U33	5080-3838	0		IC V RGLTR TO-220(SEL)	04713	MC7912CT
A2U34	1826-0147	9		IC 7812 V RGLTR TO-220	04713	MC7812CP
A2U35	1820-2111	9	1	IC DRVR TTL INV	01295	SN75468N
A2U36	1820-1314	2	2	IC MULTIPLXR 4-CHAN-ANLG DUAL 16-DIP-P	3L585	CD4052BE
A2U37	1813-0299	5	5	IC (MISC)	28480	1813-0299
A2U38	1813-0300	9		IC (MISC)	28480	1813-0300
A2U39	1813-0300	9		IC (MISC)	28480	1813-0300
A2U40	1813-0300	9		IC (MISC)	28480	1813-0300
A2U41	1813-0300	9		IC (MISC)	28480	1813-0300
A2U42	1820-1313	1		IC MULTIPLXR 2-CHAN-ANLG TRIPLE 16-DIP-P	3L585	CD4053BE
A2U43	1820-1313	1		IC MULTIPLXR 2-CHAN-ANLG TRIPLE 16-DIP-P	3L585	CD4053BE
A2U44	1813-0299	5		IC (MISC)	28480	1813-0299
A2U45	1820-1313	1		IC MULTIPLXR 2-CHAN-ANLG TRIPLE 16-DIP-P	3L585	CD4053BE

See introduction to this section for ordering information
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Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A2U46	1820-1314	2		IC MULTIPLXR 4-CHAN-ANLG DUAL 16-DIP-P	3L585	CD4052BE
A2U47	1826-0122	0		IC 7805 V RGLTR TO-220	07263	7805UC
A2U48	1813-0299	5		IC (MISC)	28480	1813-0299
A2U49	1826-0146	8		IC 7808 V RGLTR TO-220	04713	MC7808CP
A2U50	1826-0971	7		IC- UPC7908H	28480	1826-0971
A2U51	1813-0300	9		IC (MISC)	28480	1813-0300
A2U52	1820-1313	1		IC MULTIPLXR 2-CHAN-ANLG TRIPLE 16-DIP-P	3L585	CD4053BE
A2U53	1813-0299	5		IC (MISC)	28480	1813-0299
A2U54	1813-0300	9		IC (MISC)	28480	1813-0300
A2U55	1813-0300	9		IC (MISC)	28480	1813-0300
A2U56	1813-0300	9		IC (MISC)	28480	1813-0300
A2U57	1813-0300	9		IC (MISC)	28480	1813-0300
A2U58	1820-0475	4	2	IC COMPARATOR HS TO-99 PKG	27014	LM306H
A2U59	1826-0547	3	1	IC OP AMP LOW-BIAS-H-IMPD DUAL 8-DIP-P	01295	TL072ACP
A2U60	1826-0146	8		IC 7808 V RGLTR TO-220	04713	MC7808CP
A2U61	1826-0971	7		IC- UPC7908H	28480	1826-0971
A2U62	1820-1313	1		IC MULTIPLXR 2-CHAN-ANLG TRIPLE 16-DIP-P	3L585	CD4053BE
A2U63	1820-1730	6		IC FF TTL LS D-TYPE POS-EDGE-TRIG COM	01295	SN74LS273N
A2U64	1820-1730	6		IC FF TTL LS D-TYPE POS-EDGE-TRIG COM	01295	SN74LS273N
A2U65	1813-0299	5		IC (MISC)	28480	1813-0299
A2U66	1820-1112	8	2	IC FF TTL LS D-TYPE POS-EDGE-TRIG	01295	SN74LS74AN
A2U67	1826-0122	0		IC 7805 V RGLTR TO-220	07263	7805UC
A2U68	1826-0122	0		IC 7805 V RGLTR TO-220	07263	7805UC
A2U69	1826-0519	9		IC OP AMP LOW-BIAS-H-IMPD 8-DIP-P PKG	01295	TL071CP
A2U70	1813-0296	2	3	IC (MISC)	28480	1813-0296
A2U71	1813-0296	2		IC (MISC)	28480	1813-0296
A2U72	1813-0296	2		IC (MISC)	28480	1813-0296
A2U73	1820-1469	8	1	IC FF TTL LS J-K NEG-EDGE-TRIG CLEAR	01295	SN74LS107AN
A2U74	1820-1112	8		IC FF TTL LS D-TYPE POS-EDGE-TRIG	01295	SN74LS74AN
A2U75	1820-1975	1	3	IC SHF-RGTR TTL LS NEG-EDGE-TRIG PRL-IN	01295	SN74LS165N
A2U76	1820-1975	1		IC SHF-RGTR TTL LS NEG-EDGE-TRIG PRL-IN	01295	SN74LS165N
A2U77	1820-1975	1		IC SHF-RGTR TTL LS NEG-EDGE-TRIG PRL-IN	01295	SN74LS165N
A2U78	5080-3838	0		IC V RGLTR TO-220 (SEL)	04713	MC7912CT
A2U79	1813-0302	1	1	IC (MISC)	28480	1813-0302
A2U80	5080-3838	0		IC V RGLTR TO-220 (SEL)	04713	MC7912CT
A2U81	1826-0147	9		IC 7812 V RGLTR TO-220	04713	MC7812CP
A2U82	5080-3838	0		IC V RGLTR TO-220 (SEL)	04713	MC7912CT
A2U83	1820-0475	4		IC COMPARATOR HS TO-99 PKG	27014	LM306H
A2W1	04277-61651	2	2	CABLE ASSEMBLY	28480	04277-61651
A2W1	04277-61651	2		CABLE ASSEMBLY	28480	04277-61651
A2W2	8159-0005	0	9	RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
A2W3	8159-0005	0		RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
A2W4	8159-0005	0		RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
A2W5	8159-0005	0		RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
A2W6	8159-0005	0		RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
A2W7	8159-0005	0		RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
A2W8	8159-0005	0		RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
A2W9	8150-0456	7	1	WIRE-24 AWG	28480	8150-0456
A2W10	8159-0005	0		RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
A2W11	8159-0005	0		RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
				MISCELLANEOUS PARTS		
	04277-00611	6	1	PLATE (SHIELD)	28480	04277-00611
	04277-00612	7	1	PLATE (SHIELD)	28480	04277-00612
	04277-00613		3	SHIELD COVER	28480	04277-00613
	04277-00614		3	SHIELD COVER	28480	04277-00614
	04276-01203		1	ANGLE (BOARD)	28480	04276-01203
	04277-26502		1	PC BOARD, BLANK	28480	04277-26502

See introduction to this section for ordering information
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Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A4						
A4	04277-66504	4	1	POWER SUPPLY BOARD ASSEMBLY	28480	04277-66504
A4C1	0180-1075	3	5	CAPACITOR-FXD 2200 UF 16VDC AL	28480	0180-1075
A4C2	0180-1075	3		CAPACITOR-FXD 2200 UF 16VDC AL	28480	0180-1075
A4C3	0180-1075	3		CAPACITOR-FXD 2200 UF 16VDC AL	28480	0180-1075
A4C4	0180-2980	1	2	CAPACITOR-FXD 1000UF+-20% 35VDC AL	28480	0180-2980
A4C5	0180-2980	1		CAPACITOR-FXD 1000UF+-20% 35VDC AL	28480	0180-2980
A4C6	0180-1075	3		CAPACITOR-FXD 2200 UF 16VDC AL	28480	0180-1075
A4C7	0180-3221	5	6	CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
A4C8	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
A4C9	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
A4C10	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
A4C11	0180-1050	4	5	CAPACITOR-FXD 100UF 25VDC	28480	0180-1050
A4C12	0180-1050	4		CAPACITOR-FXD 100UF 25VDC	28480	0180-1050
A4C13	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
A4C14	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
A4C15	0180-1050	4		CAPACITOR-FXD 100UF 25VDC	28480	0180-1050
A4C16	0180-1050	4		CAPACITOR-FXD 100UF 25VDC	28480	0180-1050
A4C17	0180-1050	4		CAPACITOR-FXD 100UF 25VDC	28480	0180-1050
A4C18	0160-4297	5	1	CAPACITOR-FXD .022UF +80-20% 100VDC CER	56289	C023F101H223ZS22-CDH
A4C19	0180-1075	3		CAPACITOR-FXD 2200 UF 16VDC AL	28480	0180-1075
A4C20	0160-3456	6	1	CAPACITOR-FXD 1000PF +-10% 1KVDC CER	28480	0160-3456
A4C21	0180-0197	8	1	CAPACITOR-FXD 2.2UF+-10% 20VDC TA	56289	150D225X9020A2
A4C22	0160-4822	2	1	CAPACITOR-FXD 1000PF +-5% 100VDC CER	28480	0160-4822
A4C23	0180-0291	3	1	CAPACITOR-FXD 1UF+-10% 35VDC TA	56289	150D105X9035A2
A4C24	0160-3094	8	1	CAPACITOR-FXD .1UF +-10% 100VDC CER	28480	0160-3094
A4C25	0180-1704	5	1	CAPACITOR-FXD 47UF+-10% 6VDC TA	56289	150D476X9006B2
A4C26	0180-0228	6	2	CAPACITOR-FXD 22UF+-10% 15VDC TA	56289	150D226X9015B2
A4C27	0160-0127	2	3	CAPACITOR-FXD 1UF +-20% 25VDC CER	28480	0160-0127
A4C28	0160-0127	2		CAPACITOR-FXD 1UF +-20% 25VDC CER	28480	0160-0127
A4C29	0160-4593	4	2	CAPACITOR-FXD 1.5UF +-20% 400VDC	28480	0160-4593
A4C30	0160-0127	2		CAPACITOR-FXD 1UF +-20% 25VDC CER	28480	0160-0127
A4C31	0180-1746	5	1	CAPACITOR-FXD 15UF+-10% 20VDC TA	56289	150D156X9020B2
A4C32	0160-4593	4		CAPACITOR-FXD 1.5UF +-20% 400VDC	28480	0160-4593
A4C33	0180-3231	7	4	CAPACITOR-FXD 4.7 UF 450VDC	28480	0180-3231
A4C34	0180-3231	7		CAPACITOR-FXD 4.7 UF 450VDC	28480	0180-3231
A4C35	0180-3231	7		CAPACITOR-FXD 4.7 UF 450VDC	28480	0180-3231
A4C36	0180-3231	7		CAPACITOR-FXD 4.7 UF 450VDC	28480	0180-3231
A4C37	0180-3253	7	2	CAPACITOR- FXD 470 UF 200VDC	28480	0180-3253
A4C38	0180-3253	7		CAPACITOR- FXD 470 UF 200VDC	28480	0180-3253
A4C39	0160-3969	6	2	CAPACITOR-FXD .015UF +-20PF 250VAC(RMS)	28480	0160-3969
A4C40	0160-3969	6		CAPACITOR-FXD .015UF +-20PF 250VAC(RMS)	28480	0160-3969
A4C41	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
A4CR2	1902-3208	1	2	DIODE-ZNR 15.4V 5% DO-35 PD=.4W TC=+.06%	28480	1902-3208
A4CR3	1902-3208	1		DIODE-ZNR 15.4V 5% DO-35 PD=.4W TC=+.06%	28480	1902-3208
A4CR4	1902-3234	3	2	DIODE-ZNR 19.6V 5% DO-35 PD=.4W	28480	1902-3234
A4CR5	1902-3234	3		DIODE-ZNR 19.6V 5% DO-35 PD=.4W	28480	1902-3234
A4CR6	1901-0025	2	11	DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR7	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR8	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR9	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR10	1901-0691	8	10	DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR11	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR12	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR13	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR14	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR15	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR16	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR17	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR18	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR19	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR20	1901-0969	3	2	DIODE-POWER RECT.	28480	1901-0969
A4CR21	1901-0969	3		DIODE-POWER RECT.	28480	1901-0969
A4CR22	1902-3182	0	1	DIODE-ZNR 12.1V 5% DO-35 PD=.4W	28480	1902-3182
A4CR23	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR24	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR25	1902-3203	6	1	DIODE-ZNR 14.7V 5% DO-35 PD=.4W	28480	1902-3203
A4CR26	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR27	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR28	1902-0555	5	1	DIODE-ZNR 13V 5% PD=1W IR=5UA	28480	1902-0555
A4CR29	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR30	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025

See introduction to this section for ordering information
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Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A4CR31	1901-1065	2	3	DIODE-PWR RECT 1N4936 400V 1A 200NS	14936	1N4936
A4CR32	1901-1065	2		DIODE-PWR RECT 1N4936 400V 1A 200NS	14936	1N4936
A4CR33	1901-1065	2		DIODE-PWR RECT 1N4936 400V 1A 200NS	14936	1N4936
A4CR34	1902-3191	1	1	DIODE-ZNR 13V 2% DO-35 PD=.4W TC=+.06%	28480	1902-3191
A4CR35	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR36	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
A4F2	2110-0305	5	1	FUSE 1.25A 250V TD 1.25X.25 UL	75915	3131.25
A4F3	2110-0007	4	1	FUSE 1A 250V TD 1.25X.25 UL	75915	313001
A4J1	1251-4938	5	1	CONNECTOR 3-PIN M METRIC POST TYPE	28480	1251-4938
A4J2	1251-3837	1	1	CONNECTOR 4-PIN M UTILITY	28480	1251-3837
A4L1	9100-3139	5	1	INDUCTOR 75UH 15% .50X.875LG	28480	9100-3139
A4L2	9140-0171	3	6	INDUCTOR RF-CH-MLD 40UH 10% .296DX.968LG	28480	9140-0171
A4L3	9140-0171	3		INDUCTOR RF-CH-MLD 40UH 10% .296DX.968LG	28480	9140-0171
A4L4	9140-0758	3	2	INDUCTOR- 787 UH	28480	9140-0758
A4L5	9140-0758	3		INDUCTOR- 787 UH	28480	9140-0758
A4L6	9140-0171	3		INDUCTOR RF-CH-MLD 40UH 10% .296DX.968LG	28480	9140-0171
A4L7	9140-0171	3		INDUCTOR RF-CH-MLD 40UH 10% .296DX.968LG	28480	9140-0171
A4L8	9140-0462	5	1	INDUCTOR 355UH	28480	9140-0462
A4L9	9140-0757	0	1	INDUCTOR- 980 UH	28480	9140-0757
A4L10	9140-0171	3		INDUCTOR RF-CH-MLD 40UH 10% .296DX.968LG	28480	9140-0171
A4L11	9140-0463	6	1	INDUCTOR 10MH 6%	28480	9140-0463
A4L12	9140-0171	3		INDUCTOR RF-CH-MLD 40UH 10% .296DX.968LG	28480	9140-0171
A4L13	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
A4Q2	1854-0477	7	5	TRANSISTOR NPN 2N2222A SI TO-18 PD=500MW	04713	2N2222A
A4Q3	1854-0477	7		TRANSISTOR NPN 2N2222A SI TO-18 PD=500MW	04713	2N2222A
A4Q4	1854-0477	7		TRANSISTOR NPN 2N2222A SI TO-18 PD=500MW	04713	2N2222A
A4Q5	1853-0281	9		TRANSISTOR PNP 2N2907A SI TO-18 PD=400MW	04713	2N2907A
A4Q6	1854-0477	7		TRANSISTOR NPN 2N2222A SI TO-18 PD=500MW	04713	2N2222A
A4Q7	1853-0281	9		TRANSISTOR PNP 2N2907A SI TO-18 PD=400MW	04713	2N2907A
A4Q8	1854-0624	6	2	TRANSISTOR NPN 2N6308 SI TO-3 PD=125W	04713	2N6308
A4Q9	1854-0624	6		TRANSISTOR NPN 2N6308 SI TO-3 PD=125W	04713	2N6308
A4Q10	1854-0935	2	1	TRANSISTOR-NPN	28480	1854-0935
A4Q11	1854-0936	3	1	TRANSISTOR-NPN	28480	1854-0936
A4Q12	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
A4R2	0683-4705	8	3	RESISTOR 47 5% .25W FC TC=-400/+500	01121	CB4705
A4R3	0683-1005	5	3	RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
A4R4	0683-1515	2	1	RESISTOR 150 5% .25W FC TC=-400/+600	01121	CB1515
A4R5	0683-1025	9	3	RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
A4R6	0683-1025	9		RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
A4R7	0683-4715	0	3	RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
A4R8	0683-4715	0		RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
A4R9	0683-4735	4	2	RESISTOR 47K 5% .25W FC TC=-400/+800	01121	CB4735
A4R10	0683-4735	4		RESISTOR 47K 5% .25W FC TC=-400/+800	01121	CB4735
A4R11	0683-4715	0		RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
A4R12	0683-1525	4	2	RESISTOR 1.5K 5% .25W FC TC=-400/+700	01121	CB1525
A4R13	0683-1525	4		RESISTOR 1.5K 5% .25W FC TC=-400/+700	01121	CB1525
A4R14	0683-4705	8		RESISTOR 47 5% .25W FC TC=-400/+500	01121	CB4705
A4R15	0683-4705	8		RESISTOR 47 5% .25W FC TC=-400/+500	01121	CB4705
A4R16	2100-3352	7	1	RESISTOR-TRMR 1K 10% C SIDE-ADJ 1-TRN	28480	2100-3352
A4R17	2100-3274	2	1	RESISTOR-TRMR 10K 10% C SIDE-ADJ 1-TRN	28480	2100-3274
A4R18	0683-1025	9		RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
A4R19	0764-0015	7	1	RESISTOR 560 5% 2W MO TC=0+-200	28480	0764-0015
A4R20	0683-0335	2	2	RESISTOR 3.3 5% .25W FC TC=-400/+500	01121	CB33G5
A4R21	0683-1005	5		RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
A4R22	0683-0335	2		RESISTOR 3.3 5% .25W FC TC=-400/+500	01121	CB33G5
A4R23	0683-1005	5		RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
A4R24	0683-5615	1	1	RESISTOR 560 5% .25W FC TC=-400/+600	01121	CB5615
A4R25	0683-1035	1	1	RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A4R26	0683-0275	9	4	RESISTOR 2.7 5% .25W FC TC=-400/+500	01121	CB27G5
A4R27	0683-0275	9		RESISTOR 2.7 5% .25W FC TC=-400/+500	01121	CB27G5
A4R28	0683-0275	9		RESISTOR 2.7 5% .25W FC TC=-400/+500	01121	CB27G5
A4R29	0683-0275	9		RESISTOR 2.7 5% .25W FC TC=-400/+500	01121	CB27G5
A4R30	0766-0033	3	1	RESISTOR 2K 2% 3W MO TC=0+-250	27167	FP3-3-250-2001-G
A4R31	0761-0004	8	1	RESISTOR 20K 5% 1W MO TC=0+-200	28480	0761-0004
A4R32	0699-1057	4	1	RESISTOR- 15 OHM 10% 3W	28480	0699-1057
A4R33	0686-3945	2	1	RESISTOR 390K 5% .5W CC TC=0+882	01121	EB3945
A4R34	0683-5635	5	1	RESISTOR 56K 5% .25W FC TC=-400/+800	01121	CB5635
A4R35	0686-1055	1	1	RESISTOR 1M 5% .5W CC TC=0+1000	01121	EB1055
A4R36	0698-3657	8	2	RESISTOR 68K 5% 2W MO TC=0+-200	27167	FP42-2-T00-6802-J
A4R37	0698-3657	8		RESISTOR 68K 5% 2W MO TC=0+-200	27167	FP42-2-T00-6802-J
A4R38	0811-1670	3	1	RESISTOR 2.2 5% 2W PW TC=0+-400	75042	BWH2-2R2-J

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
A4RT1	0839-0006	5	1	THERMISTOR DISC	28480	0839-0006
A4T1	9100-4287	1	1	TRANSFORMER-POWER	28480	9100-4287
A4T2	9100-0857	8	1	TRANSFORMER-PULSE 114H1	28480	9100-0857
A4T3	9100-4293	2	1	TRANSFORMER-PULSE	28480	9100-4293
A4U1	1813-0255	3	1	IC-REGULATOR, HYBRID	28480	1813-0255
A4RV1	0837-0237	0	1	VARISTOR	28480	0837-0237
A4RV2	0837-0106	2	1	VARISTOR	28480	0837-0106
A4W1	8159-0005	0	1	RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
				MISCELLANEOUS PARTS		
	2110-0269	0	6	FUSEHOLDER-CLIP TYPE.25D-FUSE	28480	2110-0269
	04276-01204	4	1	ANGLE (HEATSINK)	28480	04276-01204
	04276-00613		1	SHIELD COVER	28480	04276-00613
	04276-00614		1	SHIELD COVER	28480	04276-00614
	04276-00615		1	SHIELD COVER	28480	04276-00615
	04276-00616		1	SHIELD COVER	28480	04276-00616
	04276-01206		1	ANGLE (BOARD)	28480	04276-01206
	04276-26504		1	PC BOARD, BLANK	28480	04276-26504

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						
A5	04277-66505	5	1	DISPLAY BOARD ASSEMBLY	28480	04277-66505
A5C1	0180-1085	5	4	CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A5C2	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A5C3	0180-3218	0	1	CAPACIOTOR-FXD 1 UF 63VDC AL	28480	0180-3218
A5C4	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A5C5	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
A5DS2	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
A5DS3	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
A5DS4	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
A5DS5	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
A5DS6	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
A5DS7	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
A5DS8	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
A5DS9	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
A5DS10	1990-0540	3		DISPLAY-NUM-SEG 1-CHAR .43-H	28480	5082-7650
A5DS11	1990-0531	2	4	DISPLAY-NUM-SEG 1-CHAR .3-H	28480	5082-7610
A5DS12	1990-0531	2		DISPLAY-NUM-SEG 1-CHAR .3-H	28480	5082-7610
A5DS13	1990-0531	2		DISPLAY-NUM-SEG 1-CHAR .3-H	28480	5082-7610
A5DS14	1990-0531	2		DISPLAY-NUM-SEG 1-CHAR .3-H	28480	5082-7610
A5DS15	1990-0486	6	42	LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS16	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS17	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS18	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS19	1990-0665	3	5	LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	1990-0665
A5DS20	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS21	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS22	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS23	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS25	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS26	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS27	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS29	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS30	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS31	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS33	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS34	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS35	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS36	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS37	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS38	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS40	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS41	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS42	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS43	1990-0665	3		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	1990-0665
A5DS44	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS45	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS46	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS47	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS48	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS49	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS50	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS51	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS52	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS53	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS54	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS55	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS56	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS57	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS58	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS59	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS60	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS61	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS62	1990-0486	6		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	5082-4684
A5DS63	1990-0665	3		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	1990-0665
A5DS69	1990-0665	3		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	1990-0665
A5DS70	1990-0665	3		LED-LAMP LUM-INT=1MCD IF=20MA-MAX BVR=5V	28480	1990-0665
A5R1	1810-0301	4	2	NETWORK-RES 16-DIP51.0 OHM X 8	01121	316B510
A5R2	1810-0627	7	3	RESISTIVE NETWORK	28480	1810-0627
A5R3	1810-0301	4		NETWORK-RES 16-DIP51.0 OHM X 8	01121	316B510
A5R4	1810-0627	7		RESISTIVE NETWORK	28480	1810-0627
A5R5	1810-0627	7		RESISTIVE NETWORK	28480	1810-0627

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
A5R6	0683-4725	2	2	RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A5R7	0683-4725	2		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A5S1	5060-9436	7	17	PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S2	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S3	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S4	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S5	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S6	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S7	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S8	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S9	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S10	3101-2046	7	2	SWITCH-SLIDE DPDT-NS	28480	3101-2046
A5S11	3101-1074	9	2	SWITCH-PUSHBUTTON SPST NO	28480	3101-1074
A5S12	3101-1074	9		SWITCH-PUSHBUTTON SPST NO	28480	3101-1074
A5S13	3101-2046	7		SWITCH-SLIDE DPDT-NS	28480	3101-2046
A5S14	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S15	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S16	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S17	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S18	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S19	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S20	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S21	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5U1	1858-0038	4	4	TRANSISTOR ARRAY	28480	1858-0038
A5U2	1820-0495	8	1	IC DCDR TTL 4-TO-16-LINE 4-INP	01295	SN74154N
A5U3	1820-1624	7	2	IC BFR TTL S OCTL 1-INP	01295	SN74S241N
A5U4	1820-1624	7		IC BFR TTL S OCTL 1-INP	01295	SN74S241N
A5U5	1858-0038	4		TRANSISTOR ARRAY	28480	1858-0038
A5U6	1858-0038	4		TRANSISTOR ARRAY	28480	1858-0038
A5U7	1858-0038	4		TRANSISTOR ARRAY	28480	1858-0038
A5U8	1820-1216	3	1	IC DCDR TTL LS 3-TO-8-LINE 3-INP	01295	SN74LS138N
A5U9	1816-1533	8	1	IC-MB7051	28480	1816-1533
				MISCELLANEOUS PARTS		
	0360-1901	6	2	CABLE TRANSISTION	28480	0360-1901
	1200-0638	7	14	SOCKET-IC 14-CONT DIP DIP-SLDR	28480	1200-0638
	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 GRAY)	28480	5041-0384
	5041-0922	8	8	KEY CAP-QUARTER (EBY-PEARL)	28480	5041-0922
	04191-40002	0	1	INSULATOR	28480	04191-40002
	5040-3327	5	6	INSULATOR	28480	5040-3327
	04274-40003	1	3	INSULATOR	28480	04274-40003
	04276-61641	9	1	CABLE ASSEMBLY-FLAT	28480	04276-61641
	04276-26505		1	PC BOARD, BLANK	28480	04276-26505

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						
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
A6J2	1251-5382	5	1	CONNECTOR 4-PIN M METRIC POST TYPE	28480	1251-5382
A6J4	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
A6XA1R	1251-2582	1		CONNECTOR-PC EDGE 24-CONT/ROW 2-ROWS	28480	1251-2582
A6XA2C	1251-2026	8	2	CONNECTOR-PC EDGE 18-CONT/ROW 2-ROWS	28480	1251-2026
A6XA2L	1251-2582	1		CONNECTOR-PC EDGE 24-CONT/ROW 2-ROWS	28480	1251-2582
A6XA2R	1251-2582	1		CONNECTOR-PC EDGE 24-CONT/ROW 2-ROWS	28480	1251-2582
A6XA4C	1251-2026	8		CONNECTOR-PC EDGE 18-CONT/ROW 2-ROWS	28480	1251-2026
A6XA4R	1251-2582	1		CONNECTOR-PC EDGE 24-CONT/ROW 2-ROWS	28480	1251-2582
A6XA21	1251-4978	3	3	CONNECTOR-PC EDGE 18-CONT/ROW 2-ROWS	05574	000231-3944
A6XA22	1251-4978	3		CONNECTOR-PC EDGE 18-CONT/ROW 2-ROWS	05574	000231-3944
A6XA23	1251-4978	3		CONNECTOR-PC EDGE 18-CONT/ROW 2-ROWS	05574	000231-3944
				MISCELLANEOUS PARTS		
	0360-1244	0	4	TERMINAL-STUD SPCL-FDTHRU PRESS-MTG	28480	0360-1244
	04276-26506		1	PC BOARD, BLANK	28480	04276-26506
A21						
A21	04276-66521	4	1	HP-IB BOARD ASSEMBLY	28480	04276-66521
A21C1	0180-2981	2	1	CAPACITOR-FXD 220UF+-20% 10VDC AL	28480	0180-2981
A21C2	0180-1085	5	1	CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A21J1	1200-0485	2	1	SOCKET-IC 14-CONT DIP DIP-SLDR	28480	1200-0485
A21J2	1200-0654	7	1	SOCKET-IC 40-CONT DIP DIP-SLDR	28480	1200-0654
A21R1	1810-0305	8	1	NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
A21R2	0683-4725	2	3	RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A21R3	0683-4725	2		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A21R4	0683-4725	2		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A21S1	3101-1973	7	1	SWITCH-SL 7-1A DIP-SLIDE-ASSY .1A 50VDC	28480	3101-1973
A21U1	1820-2024	3	1	IC DRVR TTL LS LINE DRVR OCTL	01295	SN74LS244N
A21U2	1820-2058	3	4	IC MISC TTL S QUAD	07263	MC3448AL
A21U3	1820-2058	3		IC MISC TTL S QUAD	07263	MC3448AL
A21U4	1820-2549	7	1	IC-8291A P HPIB	28480	1820-2549
A21U5	1820-1199	1	1	IC INV TTL LS HEX 1-INP	01295	SN74LS04N
A21U6	1820-2058	3		IC MISC TTL S QUAD	07263	MC3448AL
A21U7	1820-2058	3		IC MISC TTL S QUAD	07263	MC3448AL
A21U8	1820-2075	4	1	IC MISC TTL LS	01295	SN74LS245N
A21W1	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
	04276-26521		1	PC BOARD, BLANK	28480	04276-26521

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
A22						
				OPTION 001		
A22	04276-66522	5	1	INTERNAL DC BIAS BOARD ASSEMBLY	28480	04276-66522
A22C1	0180-2951	6	4	CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A22C2	0160-5498		3	CAPACITOR-FXD .01UF +-10% 50VDC F	28480	0160-5498
A22C3	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A22C4	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A22C5	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A22C6	0180-3220	4	2	CAPACITOR-FXD 10 UF 63VDC AL	28480	0180-3220
A22C7	0180-3220	4		CAPACITOR-FXD 10 UF 63VDC AL	28480	0180-3220
A22C8	0160-5599	3	1	CAPACITOR-FXD .1UF +-5% 100VDC F	28480	0160-5599
A22C9	0160-5498			CAPACITOR-FXD .01UF +-10% 50VDC F	28480	0160-5498
A22C10	0160-1631		1	CAPACITOR-FXD 1000PF +-10% 100VDC F	28480	0160-1631
A22C11	0160-5498			CAPACITOR-FXD .01UF +-10% 50VDC F	28480	0160-5498
A22CR1	1902-0692	1	1	DIODE-ZNR 6.3V 1% DO-7 PD=.4W TC=+.001%	28480	1902-0692
A22CR2	1901-0040	1	2	DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A22CR3	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A22Q1	1854-0358	3	2	TRANSISTOR NPN SI PD=310MW FT=60MHZ	28480	1854-0358
A22Q2	1853-0080	6	2	TRANSISTOR PNP SI PD=300MW FT=30MHZ	28480	1853-0080
A22Q3	1853-0080	6		TRANSISTOR PNP SI PD=300MW FT=30MHZ	28480	1853-0080
A22Q4	1854-0358	3		TRANSISTOR NPN SI PD=310MW FT=60MHZ	28480	1854-0358
A22Q5	1854-0523	4	1	TRANSISTOR NPN SI TO-39 PD=1W FT=150MHZ	28480	1854-0523
A22Q6	1853-0037	3	1	TRANSISTOR PNP SI TO-39 PD=1W FT=100MHZ	28480	1853-0037
A22R1	1810-0629	9	1	RESISTIVE NETWORK- DIP	28480	1810-0629
A22R2	1810-0625	5	1	RESISTIVE NETWORK- DIP	28480	1810-0625
A22R3	1810-0302	5	1	NETWORK-RES 8-SIP47.0 OHM X 4	01121	208B470
A22R4	0699-1020	7	1	RESISTOR- 470 OHM 1W	28480	0699-1020
A22R5	0683-2255	9	1	RESISTOR 2.2M 5% .25W FC TC=-900/+1100	01121	CB2255
A22R6	2100-3214	0	2	RESISTOR-TRMR 100K 10% C TOP-ADJ 1-TRN	28480	2100-3214
A22R7	2100-0567	0	1	RESISTOR-TRMR 2K 10% C TOP-ADJ 1-TRN	28480	2100-0567
A22R8	2100-3214	0		RESISTOR-TRMR 100K 10% C TOP-ADJ 1-TRN	28480	2100-3214
A22R9	0683-3355	2	1	RESISTOR 3.3M 5% .25W FC TC=-900/+1100	01121	CB3355
A22R10	0683-1035	1	1	RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A22U1	1820-1730	6	2	IC FF TTL LS D-TYPE POS-EDGE-TRIG COM	01295	SN74LS273N
A22U2	1820-1730	6		IC FF TTL LS D-TYPE POS-EDGE-TRIG COM	01295	SN74LS273N
A22U3	1826-0485	8	1	IC CONV 10-B-D/A 16-DIP-P PKG	24355	AD7530LN
A22U4	1826-0416	5	1	IC SWITCH ANLG QUAD 16-DIP-C PKG	27014	LF13331D
A22U5	1826-0522	4	1	IC OP AMP LOW-BIAS-H-IMPD QUAD 14-DIP-P	01295	TL074CN
A22U7	1826-0282	3	1	IC V RGLTR TO-92	04713	MC79L12ACP
A22U12	1826-0275	4	1	IC 78L12A V RGLTR TO-92	04713	MC78L12ACP
				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
	04276-26522		1	PC BOARD, BLANK	28480	04276-26522

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 ASSEMBLY		
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 04276-61605		
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	04277-00204		1	REAR PANEL		
34	2110-0569		2	FUSEHOLDER NUT		
35	3101-1877		1	SLIDE 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	04277-00201		1	FRONT PANEL (HP)		
	04277-00202		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	1901-1065		4	DIODE		
64	0140-0200		2	CAPACITOR 390pF		
65	0160-2230		1	CAPACITOR 3300pF		
66	1902-0657		4	DIODE		
67	0764-0016		1	RESISTOR 1kΩ		
68	0683-2245		1	RESISTOR 220kΩ		
69	0698-3634		1	RESISTOR 470Ω		

See introduction to this section for ordering information
*Indicates factory selected value

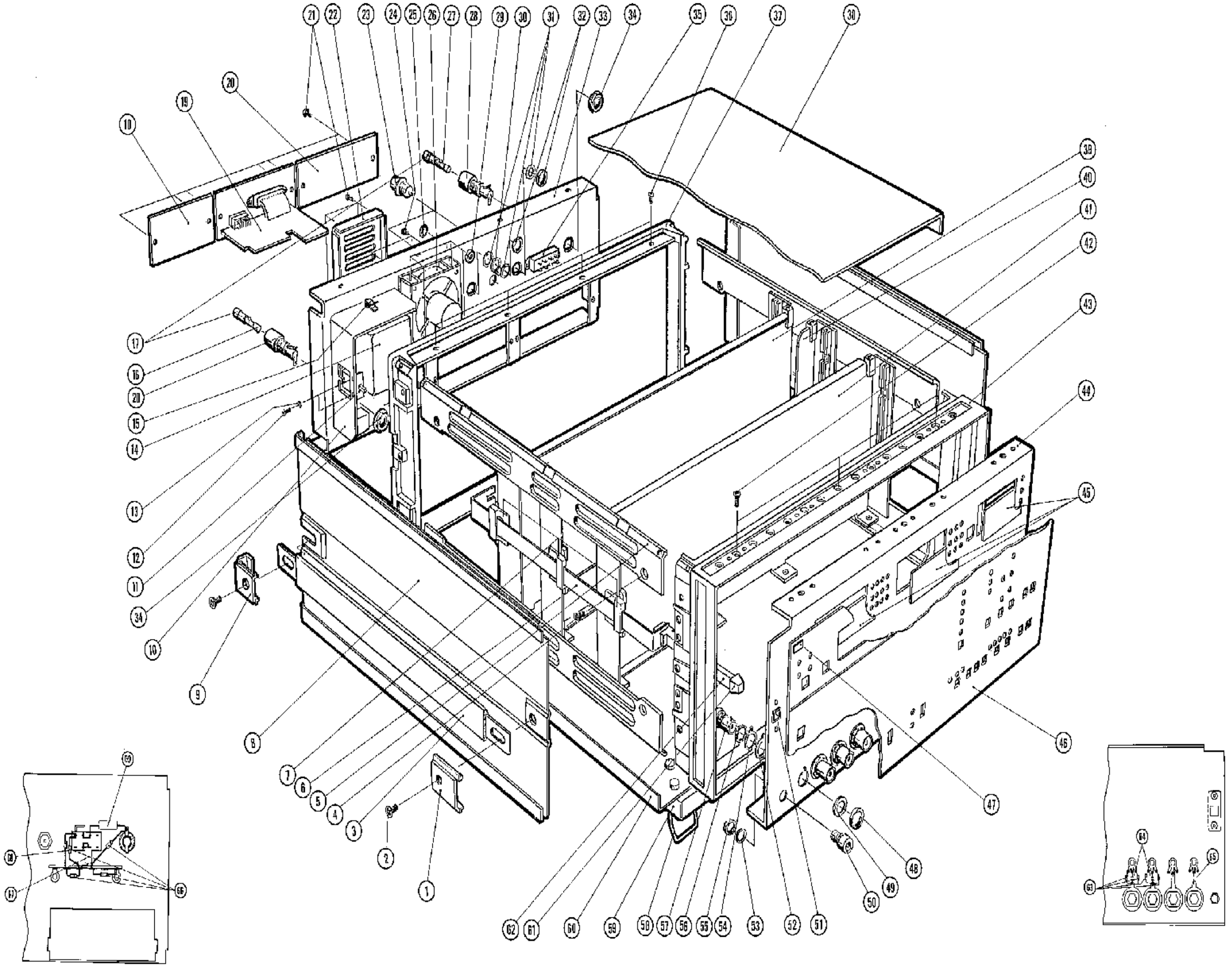


Figure 6-1. Major Mechanical Parts - Exploded View.

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
2228J00155 and below	1, 2, 3
2228J00165 and below	2, 3
2228J00190 and below	3

Table 7-2. Summary of Changes by Assembly

CHANGE	Assembly						
	A1	A2	A4	A5	A6	A21	A22
1	U5, U10						
2	U6						
3	W5						

CHANGE 1

Page 6-4, Table 6-3, Replaceable Parts:
Change the part numbers for A1U5 and U10 to read:

A1U5: 04276-85001
A1U10: 04276-85006

Page 8-61, Figure 8-41, A1 Troubleshooting Flow Diagram (Sheet 4 of 7):
Change Signature Sets 5-4, 5-6, 5-7, and 5-11 as follows:

Signature Set 5-4

A1J1 pin 9	1PHU
pin 10	286P
pin 11	5369
pin 12	F02A
pin 13	6U4P
pin 14	5669
pin 15	191P
pin 16	622U

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

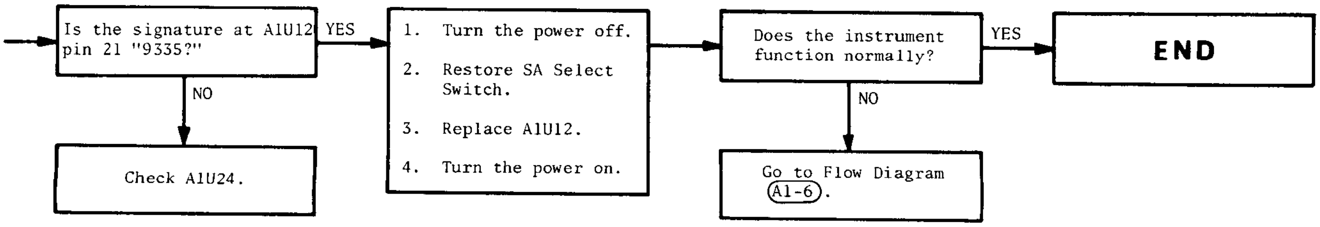
Signature Set 5-7

A1U6 pin 9	8F8C
pin 10	4P38
pin 11	P3UP
pin 13	64F7
pin 14	A3HP
pin 15	5U57
pin 16	9801
pin 17	001C

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

Partially change the flow diagram as follows:



CHANGE 2

Page 6-4, Table 6-3, Replaceable Parts:
Change the part number for A1U6 to read:

A1U6: 04277-85002

Page 8-61, Figure 8-41, A1 Troubleshooting Flow Diagram (Sheet 4 of 7):
Change Signature Sets 5-4 and 5-7 as follows:

Signature Set 5-4

A1J1 pin 9	U95F
pin 10	2P34
pin 11	52A9
pin 12	293F
pin 13	8FH2
pin 14	56AA
pin 15	AH32
pin 16	CAA1

Signature Set 5-7

A1U6 pin 9	8F8C
pin 10	4P38
pin 11	P3UP
pin 13	64F7
pin 14	A3HP
pin 15	5U57
pin 16	9801
pin 17	001C

CHANGE 3

Page 6-4, Table 6-3, Replaceable Parts:
Delete the part number and description for A1W5.

Page 8-108, Figure 8-47, A1 Component Locations:
Partially change the diagram as follows:

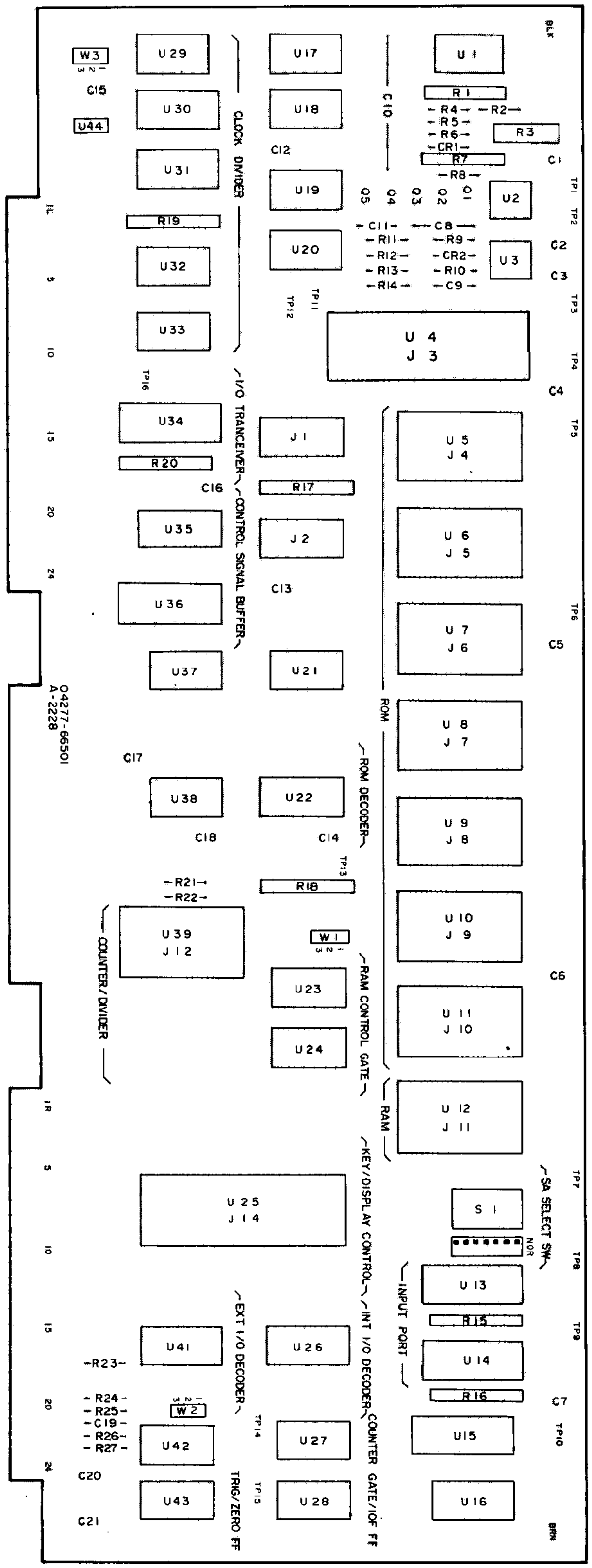


Figure 8-47. A1 Component Locations.

Page 8-109, Figure 8-48, A1 Schematic Diagram:
Partially change the diagram as follows:

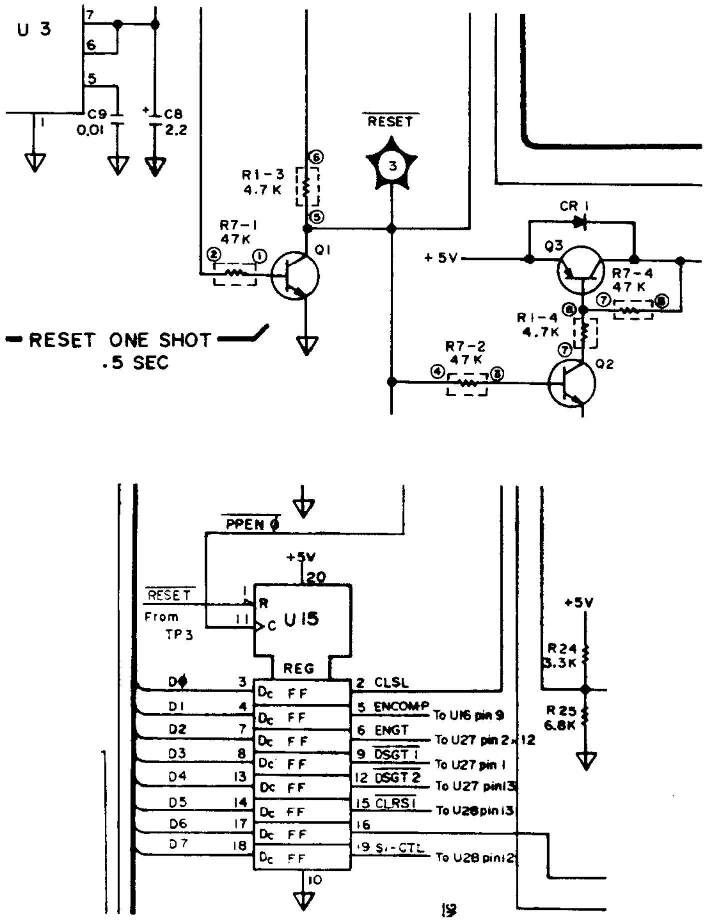


Figure 8-48. A1 Schematic Diagram.

SECTION VIII
SERVICE

8-1. INTRODUCTION

8-2. This section provides the information and instructions required to service the Model 4277A 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 4277A 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 8-36.

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 4277A adapted for accurately measuring the DUT and for achieving automated measurements. The block diagram discussion describes the overall circuit operating theory of the 4277A 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 4277A Digital Section, the troubleshooting guide for the logic circuits uses signature analysis. An outline of signature analysis is provided in Figure 8-39.

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. Correct disassembly and the exchange procedures for such special parts are outlined in paragraphs 8-119. 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 descriptions starting with this paragraph explain the measurement principles of the 4277A LCZ Meter. The block diagram of the 4277A measurement circuit is shown in Figure 8-1. The solid lines in the block diagram show the main test signal flow and the dashed lines show the measurement control signal.

8-15. AUTO-BALANCE BRIDGE MEASUREMENT CIRCUIT

8-16. The measurement function of the 4277A is based on the vector-voltage-current ratio measurement method. In this method, the impedance of the DUT is determined by measuring the vector ratio between the applied test signal voltage and the current flowing through the DUT. In low frequency applications of the vector-voltage-current method, a voltage-to-current (I-V) converter amplifier which has a range resistor feedback circuit is employed to detect the DUT vector current. See Figure 8-2. The I-V converter causes a current to flow through the range resistor equal to the current through the DUT. Thus, the output voltage of the I-V converter is equal to the product of the DUT current and the range resistor value. Accordingly, the DUT impedance is determined from the test signal voltage applied to the DUT, the output voltage of the I-V converter, and the range resistor value. The potential at the LOW terminal is approximately zero (virtual ground at the feedback node); therefore, the range resistor value has no effect on the current through the DUT. Additionally, the actual test signal level applied to the DUT is constant, regardless of the range resistor value. The frequency bandwidth of the I-V converter amplifier, where the flat gain-phase characteristic is achieved, determines the frequency limitations of this method. Because of the difficulty involved in achieving a broad bandwidth for an amplifier with a high open-loop gain, this method does not lend itself well to high frequency impedance measurements.

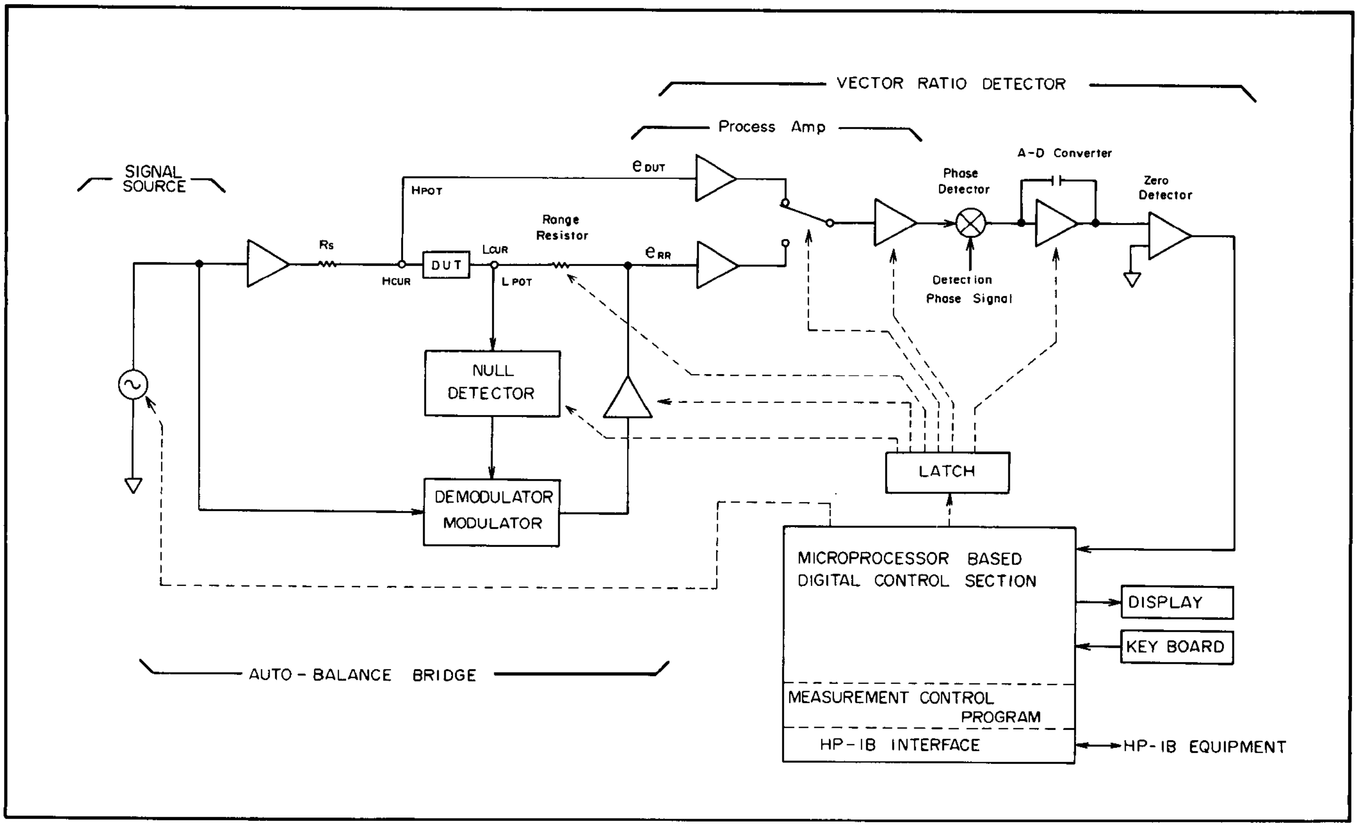
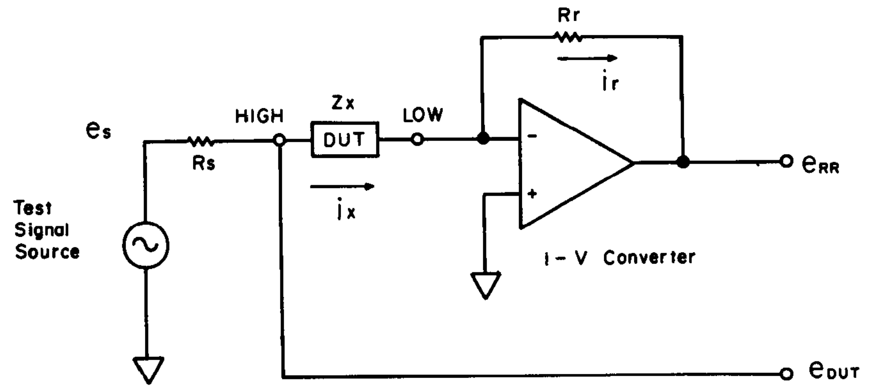


Figure 8-1. 4277A Block Diagram.



$$i_x = \frac{e_{DUT}}{Z_x} = \frac{e_{RR}}{R_r} \qquad \therefore Z_x = R_r \frac{e_{DUT}}{e_{RR}}$$

Figure 8-2. Vector-Voltage-Current-Ratio Measurement Method Using the Range Resistor Amplifier.

8-17. The auto-balance bridge circuit employed in the 4277A permits the vector voltage across the range resistor to be accurately proportional to DUT current. Figure 8-3 shows the basic configuration of the auto-balance bridge circuit. The test signal source applies a test signal, e_s, to the DUT through the source resistor, Rs, and causes a current, i_x, to flow through the DUT. This yields the current, i_r, which flows through the range resistor, Rr. When the bridge circuit is unbalanced (that is, $i_x \neq i_r$), the Null Detector detects the unbalance current, i_d, ($= i_x - i_r$), through the UNKNOWN "L" (L_{POT}) terminal. The null detector output vector indicates how the bridge is unbalanced for the real and imaginary vector components of the range resistor current. In response to the null detector output, the Modulator varies the amplitude and phase of the e_s input signal to develop a vector signal, e_d, so as to suppress an increase in the unbalance current. This feedback control of the unbalance current automatically balances the bridge. When the bridge is balanced (that is, $i_d = 0$), the potential at the LOW terminal is approximately zero volts (virtual ground). The current flowing through the DUT is then equal to that flowing through the range resistor. Therefore, the impedance, Zx, of the DUT is calculated from the vector voltages, e_{DUT} and e_{RR}, as follows:

$$i_x = \frac{e_{DUT}}{Z_x}, \quad i_r = \frac{e_{RR}}{R_r}, \quad i_x = i_r$$

where, e_{DUT} : The voltage applied to the DUT

Zx: DUT impedance value

e_{RR} : The voltage across the range resistor

Rr: Range resistor value

Thus,

$$\frac{e_{DUT}}{Z_x} = \frac{e_{RR}}{R_r} \qquad \therefore Z_x = R_r \frac{e_{DUT}}{e_{RR}}$$

Accordingly, the impedance of the DUT is known by measuring the ratio between the vector voltages, e_{DUT} and e_{RR}. Note that the e_{DUT} signal is voltage-divided by the source resistor and the DUT impedance as the following equation:

$$e_{DUT} = \left| \frac{Z_x}{R_s + Z_x} \right| \cdot e_s$$

In comparison with the range resistor amplifier method, the combination of the Null Detector and the Modulator may be considered an ideal feedback amplifier with a broad-bandwidth.

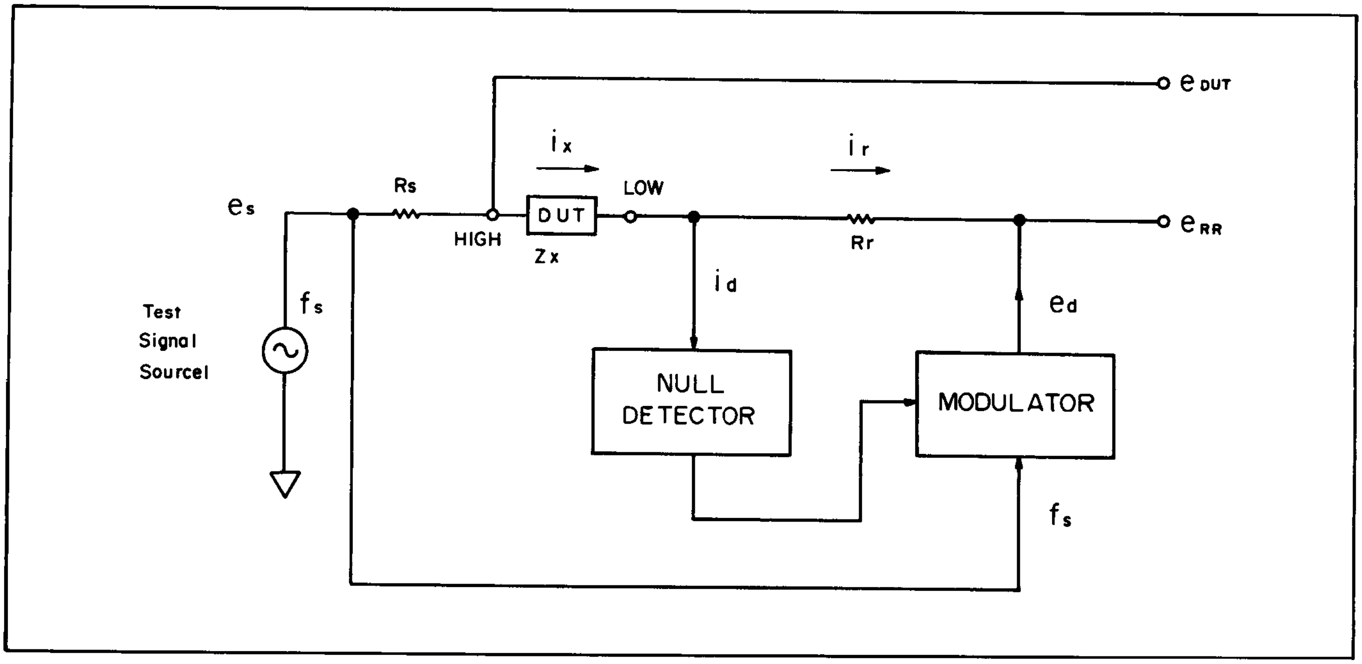


Figure 8-3. Auto-Balance Bridge Circuit.

8-18. VECTOR VOLTAGE RATIO DETECTOR

8-19. The Vector Voltage Ratio Detector (VRD) detects the individual real and imaginary vector components of the two input vector signals--the test signal applied to the DUT and the voltage across the range resistor—and provides the A-D conversion outputs which represent the ratio of the vector components necessary for calculating the various parameters. The basic theory of the vector voltage ratio measurement is described as follows.

8-20. When the bridge is balanced, the impedance, Zx, (or admittance, Yx) of the DUT, the test signal applied to the DUT, e_{DUT}, and the voltage across the range resistor, e_{RR}, are related to each other by the equation:

$$Z_x = R_r \frac{e_{DUT}}{e_{RR}}$$

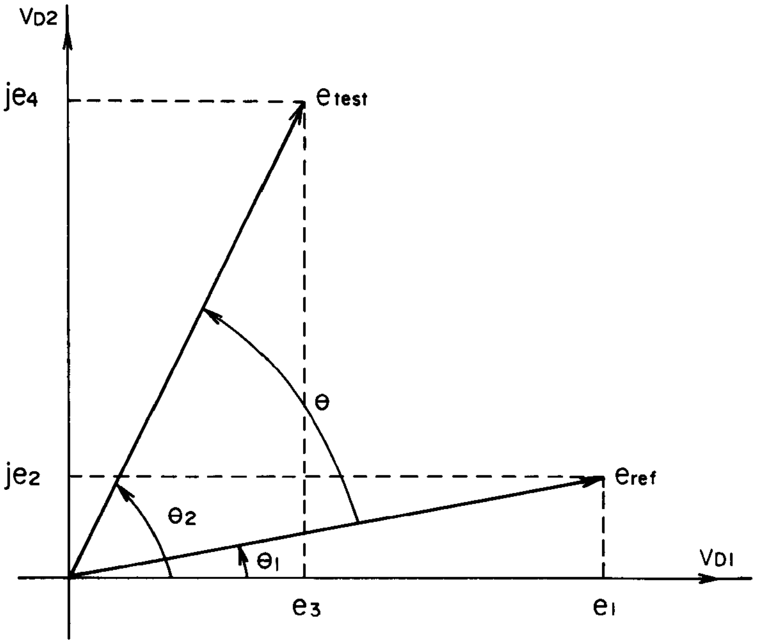
or

$$Y_x = \frac{1}{R_r} \cdot \frac{e_{RR}}{e_{DUT}}$$

For accurate measurement of the vector voltages, the Process Amplifier detects the e_{DUT} and e_{RR} signals with differential inputs. The Process Amplifier alternately selects and sequentially feeds the e_{DUT} and e_{RR} signals to the Phase Detector. To derive the vector ratio of the e_{DUT} and e_{RR} signals, the Phase Detector separates them into their orthogonal phase components using a set of detection phase signals which are exactly 90 degrees out of phase with each other. Figure 8-4 is a graphic representation of the relationship between the measurement signals (e_{ref} and e_{test}) and the detection phase signals (V_{D1} and V_{D2}). With these detection phases, the e_{ref} and e_{test} signals are divided into the phase components e_1, e_2, e_3, and e_4. The e_{DUT} and e_{RR} signals are selected as the e_{ref} or e_{test} signal in accordance with the bridge measurement circuit mode. The relationship of this is shown in Table 8-1. The 4277A employs a bridge measurement circuit mode, as shown in Figure 8-5.

Table 8-1. Phase Detection Vector Selection in Accordance with the Bridge Measurement Circuit Mode.

Phase Detector Vector / Bridge Circuit Mode	e_{ref}	e_{test}
Z mode	e_{RR}	e_{DUT}
Y mode	e_{DUT}	e_{RR}



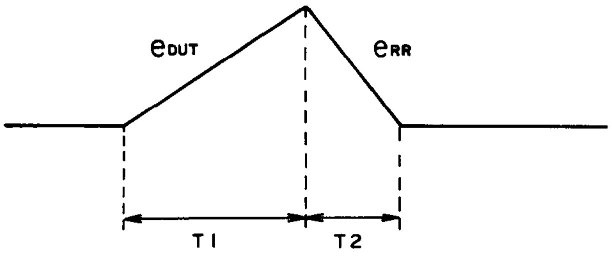
e_{ref} : The reference vector for the vector ratio measurement

e_{test}: The test vector for the vector ratio measurement

Figure 8-4. Phase Detection Vector Diagram.

8-21. The voltage ratio measurement is made using a dual slope integration technique as follows:

For example, the e_{DUT} voltage charges the integrator for time T_1. The e_{RR} voltage then fully discharges the integrator in time T_2. The resultant integrator output is shown in the figure below.



T_1 : Constant charge period by e_{DUT} signal
T_2 : Discharge period by e_{RR} signal

Because the amount of the charge and discharge quantities is zero, relation between the integrator input voltages and time periods is:

$$k_1 e_{DUT} T_1 + k_2 e_{RR} T_2 = 0$$

$$\frac{e_{DUT}}{e_{RR}} = k\frac{T_2}{T_1} \quad (k = \text{constant})$$

As the charge time T_1 is fixed ($T_1 = 5.2$ms), the e_{DUT}/e_{RR} value can be obtained by measuring time T_2.

The vector ratio measurement employed in the 4277A consists of three measurement periods as shown in Figure 8-6. The description of each integration period is as follows:

C-D Measurement

C Range	Test Frequency (Hz)		
	10.0k to 20.0k	20.2k to 200k	202k to 1.00M
10µF	Z mode	▨	▨
1µF	Z mode	Z mode	▨
100nF	Y mode	Z mode	Z mode
10nF	Y mode	Y mode	Z mode
1nF	Y mode	Y mode	Y mode
100pF	Y mode	Y mode	Y mode
10pF	▨	Y mode	Y mode
1pF	▨	▨	Y mode

C-ESR/G Measurement

ESR/G Range	Test Frequency (Hz)
	10.0k to 1.00M
1MΩ/10µS	Y mode
100kΩ/100µS	
10kΩ/1mS	
1kΩ/10mS	
100Ω/100mS	Z mode
10Ω/1S	

L-D Measurement

L Range	Test Frequency (Hz)		
	10.0k	10.1k to 100k	101k to 1.00M
1H	Y mode	▨	▨
100mH	Y mode	Y mode	▨
10mH	Y mode	Y mode	Y mode
1mH	Z mode	Y mode	Y mode
100µH	Z mode	Z mode	Y mode
10µH	▨	Z mode	Z mode
1µH	▨	▨	Z mode

L-ESR/G Measurement

ESR/G Range	Test Frequency (Hz)
	10.0k to 1.00M
100kΩ/100µS	Y mode
10kΩ/1mS	
1kΩ/10mS	
100Ω/100mS	Z mode
10Ω/1S	

|Z|-θ Measurement

|Z| Range	Test Frequency (Hz)
	10.0k to 1.00M
1MΩ	Y mode
100kΩ	
10kΩ	
1kΩ	
100Ω	Z mode
10Ω	

Figure 8-5. Bridge Measurement Circuit Mode in Accordance with Measurement Ranges.

Period 1:

The 90° phase component of the e_{ref} signal is detected by the 90° detection phase. The e_2 component charges the integrator for a constant time T_c. Next, the 0° phase component of the e_{ref} signal is detected by the 0° detection phase. The e_1 component discharges the integrator. Thus, the value of e_2/e_1 is calculated as the tangent of the phase angle θ_1.

Period 2:

The 90° phase component of the e_{test} signal (e_4) and the 0° phase component of the e_{ref} signal (e_1) are detected to obtaian the value of e_4/e_1 in the same manner as Period 1.

Period 3:

The 0° phase components of the e_{test} and e_{ref} signals (e_3 and e_1) are detected to obtain the value of e_3/e_1 in the ESR/G measurement. In the D measurement, the 0° phase component and the 90° phase component of the e_{test} signal (e_3 and e_4) are detected to obtain the value of e_3/e_4 calculated as the tangent of the phase angle θ_2.

To simplify the calculations for derivation of each parameter of the DUT, the values obtained in Periods 1, 2 and 3 are replaced with a, b and c respectively. That is,

$$\frac{e_{ref}\ (90^\circ)}{e_{ref}\ (0^\circ)} = \frac{e_2}{e_1} = a$$

$$\frac{e_{test}\ (90^\circ)}{e_{ref}\ (0^\circ)} = \frac{e_4}{e_1} = b$$

$$\frac{e_{test}\ (0^\circ)}{e_{ref}\ (0^\circ)} = \frac{e_3}{e_1} = c$$

(in ESR/G measurements)

or

$$\frac{e_{test}\ (0^\circ)}{e_{test}(90^\circ)} = \frac{e_3}{e_4} = c \text{ (in D measurements)}$$

The DUT's impedance component values (R and X), admittance values (G and B) or the dissipation factor can be calculated from the following equations. The phase angle of the DUT impedance is:

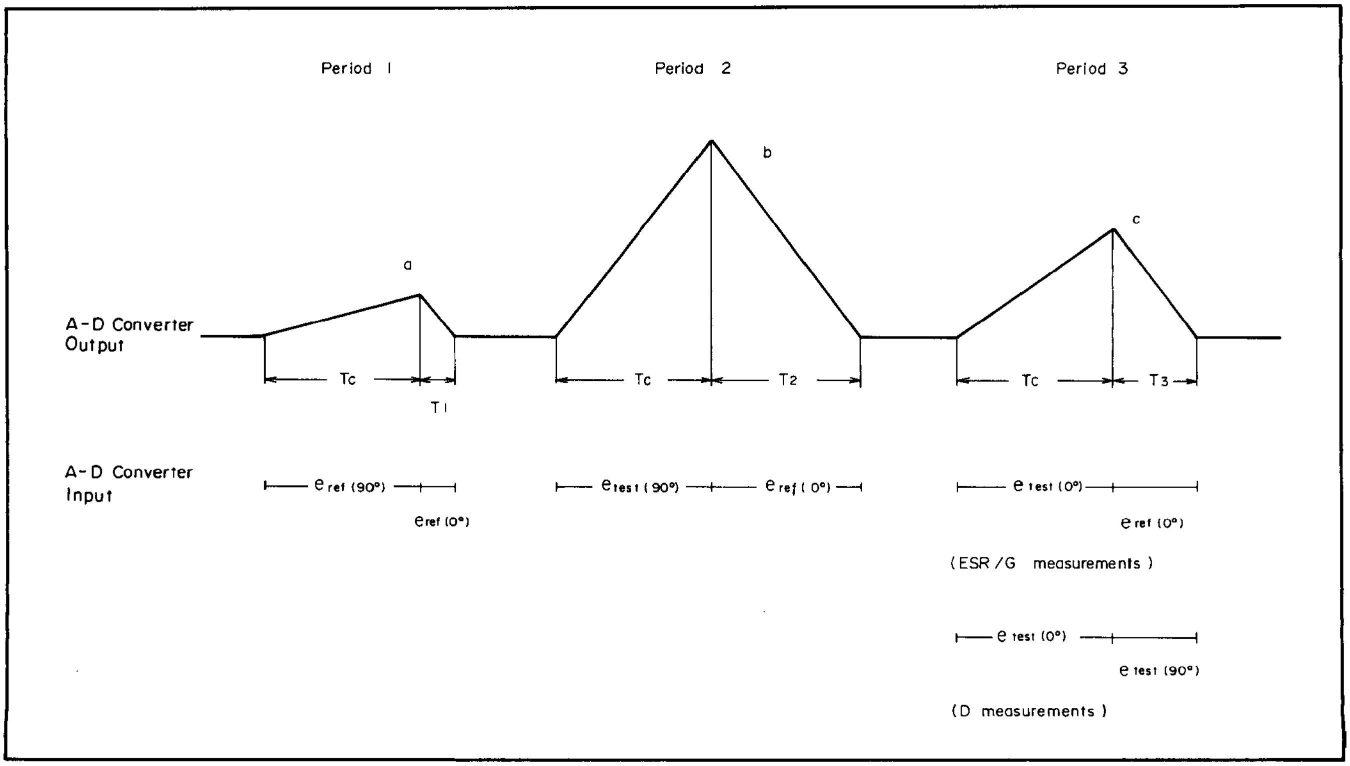


Figure 8-6. Vector Voltage Ratio Detection Timing.

$$\theta = \theta_2 - \theta_1 = \tan^{-1} A$$

$$= \cos^{-1} \frac{1}{\sqrt{1 + A^2}} = \sin^{-1} \frac{A}{\sqrt{1 + A^2}}$$

(1) ESR/G measurements

$$A = \frac{b - ac}{c + ab} \left(= \frac{T_2 - T_1T_3}{T_3 + T_1T_2} \right)$$

$$ESR/G = \left| \frac{e_{test}}{e_{ref}} \right| \cos\theta$$

$$= \frac{c + ab}{1 + a^2} \left(= \frac{T_3 + T_1T_2}{1 + T_1{}^2} \right)$$

$$X/B = \left| \frac{e_{test}}{e_{ref}} \right| \sin\theta$$

$$= \frac{b - ac}{1 + a^2} \left(= \frac{T_2 - T_1T_3}{1 + T_1{}^2} \right)$$

(2) D measurements

$$A = \frac{1 - ac}{a + c} \left(= \frac{1 - T_1T_3}{T_1 + T_3} \right)$$

$$B/X = \left| \frac{e_{test}}{e_{ref}} \right| \sin\theta$$

$$= \frac{b\ (1 - ac)}{1 + a^2}$$

$$\left(= \frac{T_2\ (1 - T_1T_3}{1 + T_1{}^2} \right)$$

$$D = \frac{1}{A} = \frac{a + c}{1 - ac} \left(= \frac{T_1 + T_3}{1 - T_1T_3} \right)$$

8-22. The basic measurement parameter of the 4277A differs depending on the impedance of the DUT. When the DUT's impedance value is measured on a range below 100Ω, the 4277A basically calculates the vector impedance component values R and X (or D and X). For DUTs which have higher impedance values, the 4277A calculates the vector admittance component values G and B (or D and B). Other measurement parameter values are subsequently calculated from the measured R (or D) and X (G (or D) and B) values using the stored parameter conversion formulas. Refer to Table 8-2.

8-23. When a high impedance DUT is measured, the test signal applied to the DUT is constant regardless the DUT's value (Y mode). Therefore, the e_{DUT} voltage is constant and the voltage across the range resistor (e_{RR}) is inversely proportional to the DUT's impedance (that is, e_{RR} is directly proportional to the admittance). On the other hand, when a low impedance DUT is measured, a 100Ω source resistor (test signal source output resistance) causes a constant test signal current to flow through the DUT. In this case, the range resistor voltage, e_{RR}, is constant and the voltage across the DUT (e_{DUT} is proportional to the DUT's impedance (Z mode). The relation between the test signal voltage/current and the DUT's impedance is given in Figure 8-7.

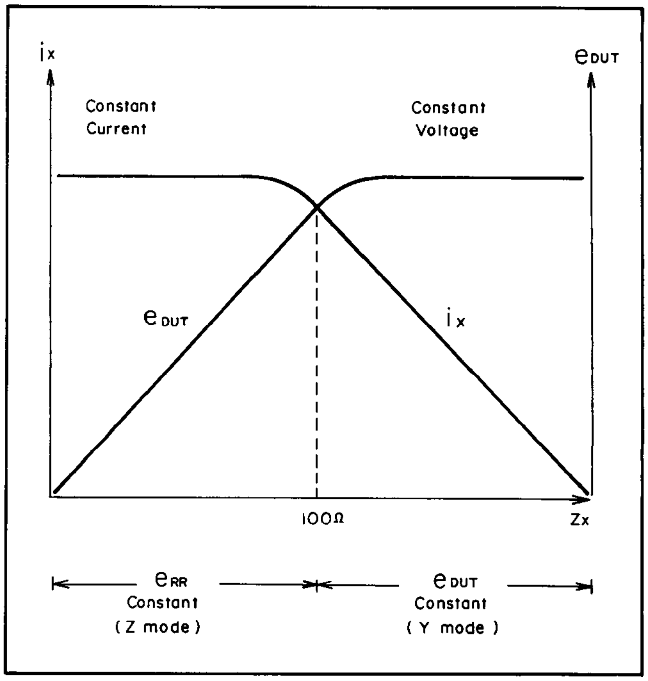


Figure 8-7. Test Signal Voltage and Current Relationship to DUT's Impedance.

8-24. When the instrument is set to HIGH SPEED L or HIGH SPEED C mode, the DISPLAY B measurement functions (D, Q, ESR or G) are not performed and the e_{ref} signal approaches the 0° phase detection signal (V_{D1}) (that is, the real axis) due to the auto phase adjustment circuit. Therefore, in these modes, the vector ratio measurement is performed for one period only, without the periods 1 and 3. This integration value is B or X. Also, when MEASUREMENT SPEED is set to FAST, the charging time is one fourth that of medium speed measurements (that is, T_C = 1.3ms).

Table 8-2. Parameter Conversion Formulas

C-D (or C-Q) Measurement

Bridge Circuit Mode	Input Data	C		D (or Q)	
					
Z	X, D	$-\frac{1}{2\pi f}\cdot\frac{1}{X}$	$-\frac{1}{2\pi f}\cdot\frac{1}{(1+D^2)X}$	D (or $\frac{1}{D}$)	
Y	B, D	$\frac{1}{2\pi f}\cdot(1+D^2)B$	$\frac{1}{2\pi f}\cdot B$		

C-ESR/G Measurement

Bridge Circuit Mode	Input Data	C		ESR/G	
					
Z	X, R	$-\frac{1}{2\pi f}\cdot\frac{1}{X}$	$-\frac{1}{2\pi f}\cdot\frac{X}{R^2+X^2}$	R	$\frac{X}{R^2+X^2}$
Y	B, G	$\frac{1}{2\pi f}\cdot\frac{G^2+B^2}{B}$	$\frac{1}{2\pi f}\cdot B$	$\frac{G}{G^2+B^2}$	G

L-D (or L-Q) Measurement

Bridge Circuit Mode	Input Data	L		D (or Q)	
					
Z	X, D	$\frac{1}{2\pi f}\cdot X$	$\frac{1}{2\pi f}\cdot(1+D^2)X$	D (or $\frac{1}{D}$)	
Y	B, D	$-\frac{1}{2\pi f}\cdot\frac{1}{(1+D^2)B}$	$-\frac{1}{2\pi f}\cdot\frac{1}{B}$		

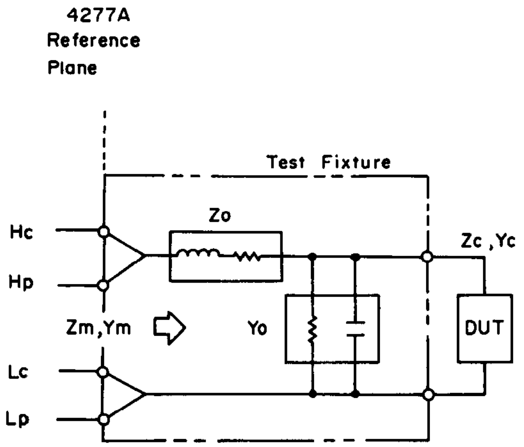
L-ESR/G Measurement

Bridge Circuit Mode	Input Data	L		ESR/G	
					
Z	X, R	$\frac{1}{2\pi f}\cdot X$	$\frac{1}{2\pi f}\cdot\frac{X^2+R^2}{X}$	R	$\frac{R}{R^2+X^2}$
Y	B, G	$-\frac{1}{2\pi f}\cdot\frac{B}{G^2+B^2}$	$-\frac{1}{2\pi f}\cdot\frac{1}{B}$	$\frac{G}{G^2+B^2}$	G

Z-θ Measurement

Bridge Circuit Mode	Input Data	Z		θ	
					
Z	X, R	$\sqrt{R^2+X^2}$		$\tan^{-1}\frac{X}{R}$	
Y	B, G	$1/\sqrt{G^2+B^2}$		$\tan^{-1}(-\frac{B}{G})$	

8-25. The Zero Offset Adjustment (Open and Short) function measures the residual impedance of the test fixture under short-circuit conditions and the stray admittance under open-circuit conditions. Correction calculations in the subsequent DUT measurements are made using the following equations and equivalent circuit mode for the residuals.

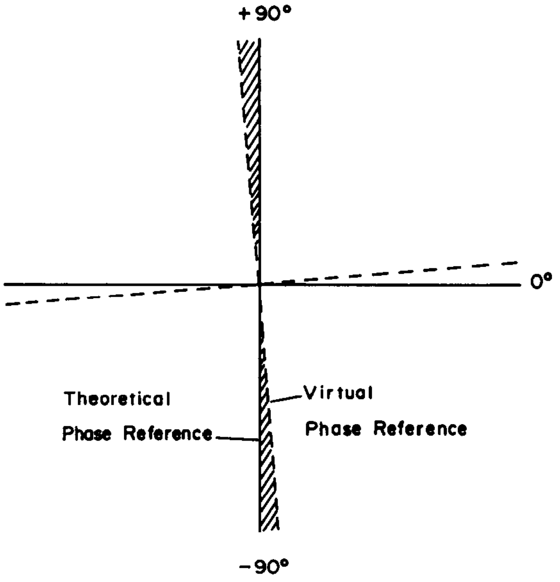


$$Zc = \frac{Z_M - Z_0}{1 - Z_M Y_0}$$

$$Yc = \frac{Y_M - Y_0}{1 - Y_M Z_0}$$

where, Z_C: Corrected impedance value
Y_C: Corrected admittance value
Z_0: Residual impedance value
Y_0: Stray admittance value
Z_M: Measured DUT impedance value
Y_M: Measured DUT admittance value

8-26. Dissipation factor, D, and quality factor, Q, of reactive components are, of course, always positive values. However, when measuring very low-loss devices (almost purely capacitive or inductive components), the displayed D and Q values may be negative. This is because the axis of coordinates rotate in the impedance plane due to the slight measurement error in the measurement circuits. If the DUT's loss is close to zero (impedance vector of the DUT goes into the shaded area in the figure), the instrument will judge that DUT has a negative loss (D/Q).



8-27. DIGITAL CONTROL

8-28. The microprocessor based digital control circuit controls the analog measurement circuit in accordance with the programs stored in the ROM. The 4277A contains a Z80B (6MHz version) microprocessor. The HP-IB interface circuit, which is part of the digital control circuit, provides the means to connect the instrument to other HP-IB compatible equipment.

8-29. BLOCK DIAGRAM DISCUSSION

8-30. ANALOG MEASUREMENT SECTION (A2 Board)

8-31. The 4277A's measurement section consists of three main subsections: (1) Signal Source, (2) Auto-Balance Bridge, and (3) Vector Ratio Detector (VRD). A detailed description of each section is given in the following paragraphs. The block diagram of the 4277A analog measurement section is shown in Figure 8-26.

8-32. SIGNAL SOURCE

The signal source consists of a phase-locked loop, divider, four-stage low-pass filter, and the H/CUR amplifier. Figure 8-8 shows the block diagram of the signal source.

8-33. PHASE-LOCKED LOOP AND DIVIDER

8-34. The 4277A employs a conventional phase-locked loop (PLL) frequency synthesis technique. The test signal is a 10kHz to 1MHz sine wave, synthesized from the output of an 11.5200MHz crystal oscillator on the A1 board and a tunable 8MHz-to-20MHz voltage-controlled oscillator (VCO) on the A2 board.

The phase detector in the PLL compares the programmable divider's output signal, NFVCO, with an accurate 8kHz reference signal, REF8K, and outputs an error signal which represents the frequency difference between the two input signals. The error signal is filtered by the loop filter, and the dc voltage output from the filter is the control voltage for the VCO. The 8kHz reference signal is generated by dividing down the 11.5200MHz signal from the crystal oscillator on the A1 board. When the NFVCO signal is in-phase with and has the same frequency as the 8kHz reference signal, the VCO will be locked at the frequency given by the following equation:

$$f_{VCO} = 10 \cdot N_1 \cdot f_{ref} = 10 \cdot N_1 \cdot 8kHz$$

$$(8.00MHz \leq f_{VCO} \leq 20.0MHz)$$

The divisor, N_1, of the programmable divider is set by the microprocessor to an integer between 100 and 250.

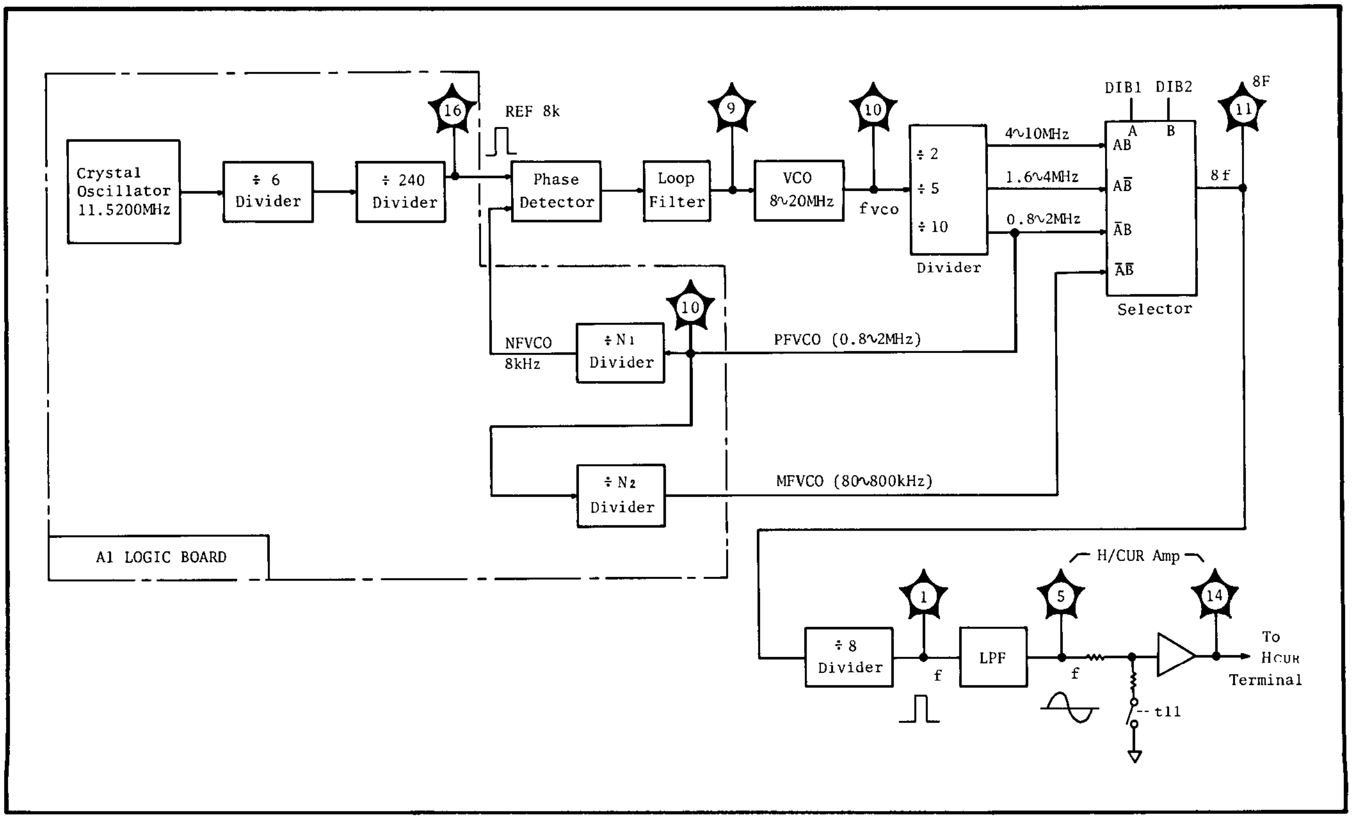


Figure 8-8. Signal Source Block Diagram.

8-35. The VCO's output signal is divided into four frequency bands--80kHz to 800kHz, 800kHz to 2MHz, 1.6MHz to 4MHz, and 4MHz to 10MHz--by the ÷2/÷5/÷10 divider, $\div N_2$ divider, and the four-channel selector. The 80kHz to 800kHz range is used for test frequencies from 10kHz to 100kHz; the other three ranges are used for test frequencies from 101kHz to 1MHz.

To obtain test frequencies from 10kHz to 100kHz, the ÷10 divider counts down the VCO's output signal to an 800kHz to 2MHz signal (PFVCO) which is fed back to the $\div N_1$ divider for PLL control and to the $\div N_2$ divider. The N_2 divisor is set by the microprocessor so that the $\div N_2$ divider's output signal, MFVCO, is eight times the selected test frequency. Finally, the four-channel selector, which is also controlled by the microprocessor, outputs the MFVCO to the ÷8 divider for count-down to the requisite frequency.

For higher test frequencies--from 101kHz to 1MHz--the VCO's output is divided down by the ÷2, ÷5, and ÷10 dividers to obtain, respectively, a 4MHz-to-10MHz signal, a 1.6MHz-to-4MHz signal, and an 800kHz-to-2MHz signal. One of these signals will have a frequency that is eight times the selected test frequency and will be output by the four-channel selector to the ÷8 divider.

The relationship between the test frequency and each of the PLL control parameters--N_1 and N_2 divisors, VCO frequency, etc.--is given in Table 8-3.

8-36. As mentioned earlier, there are four test frequency ranges. The microprocessor automatically selects the appropriate range by setting the DIB1 and DIB2 control lines of the four-channel selector in accordance with the test frequency set on the front panel. Refer to Table 8-4.

Table 8-4. Test Frequency Range Control

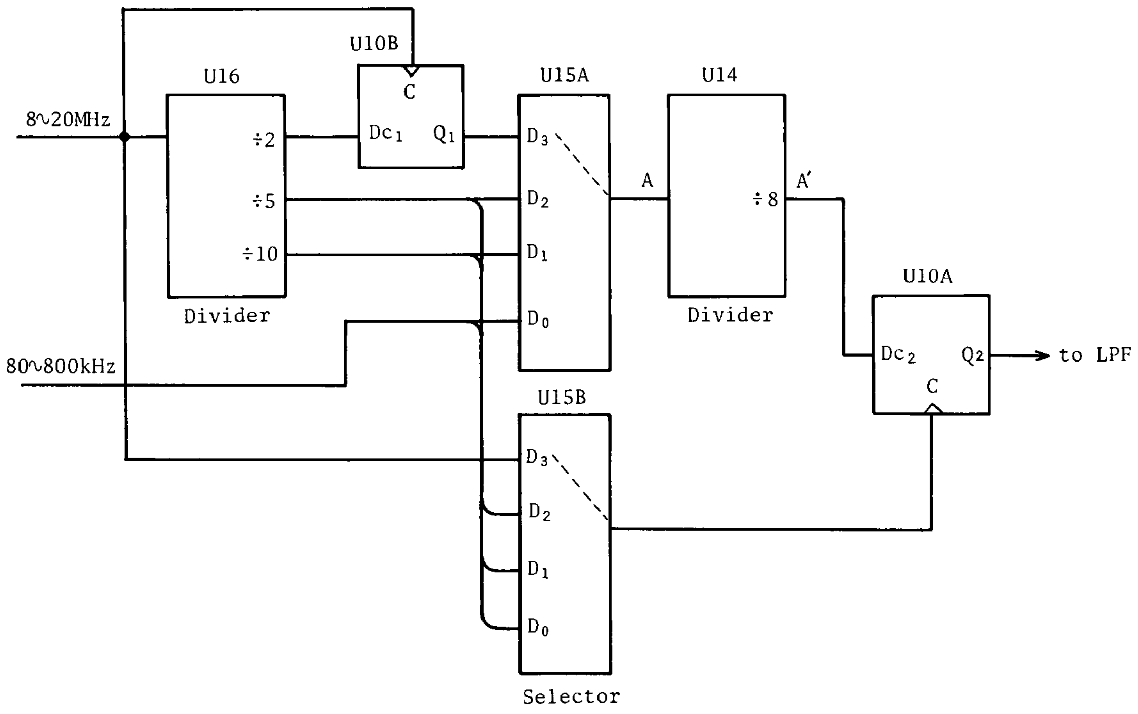
Test Frequency (Hz)	Control Signals	
	DIB1	DIB2
10.0k to 100k	LOW	LOW
101k to 200k	LOW	HIGH
202k to 500k	HIGH	LOW
505k to 1.00M	HIGH	HIGH

The 8F signal output from the four-channel selector is divided down to the selected frequency by the ÷8 divider. The signal at the output of the ÷8 divider is a fairly clean square wave.

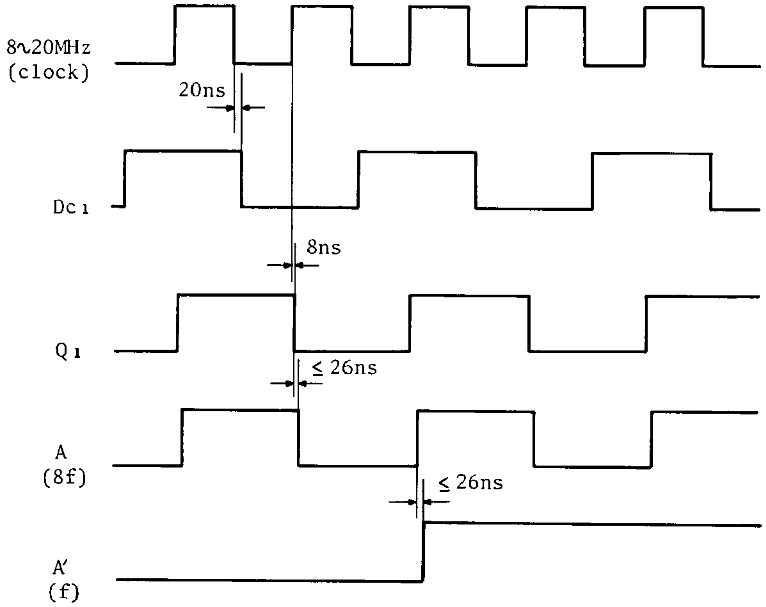
8-37. The ÷2/÷5/÷10 divider used in the signal source is a dual decade counter on a single integrated circuit, A2U16. One counter, U16A, performs the ÷2 and ÷10 operations. The other counter, U16B, performs the ÷5 operation. A special reclock circuit, U10B, shown in Figure 8-9, is used to eliminate ÷5 signal and ÷10 signal noise (especially 200kHz and 500kHz) superimposed on the ÷2 signal as a result of capacitive coupling within the ÷2/÷5/÷10 counter. A second reclock circuit, U10A, reduces noise caused by switching within the dividers. Both reclock circuits consist of a single D-type flip-flop.

Table 8-3. PLL Control Parameters

Parameter	Test Frequency (Hz)					
	10.0k to 20.0k	20.2k to 50.0k	50.5k to 100k	101k to 200k	202k to 500k	505k to 1.00M
VCO (at TP10)	8.00M to 16.0M	8.08M to 20.0M	8.08M to 16.0M	8.08M to 16.0M	8.08M to 20.0M	8.08M to 16.0M
Divider	÷10	÷10	÷10	÷10	÷5	÷2
PFVCO	800k to 1.60M	808k to 2.00M	808k to 1.60M	808k to 1.60M	808k to 2.00M	808k to 1.60M
N_1	100 to 200	101 to 250	101 to 200	101 to 200	101 to 250	101 to 200
N_2	10	5	2	-	-	-
MFVCO	80.0k to 160k	161.6k to 400k	404k to 800k	-	-	-
8F (at TP11)	80.0k to 160k	161.6k to 400k	404k to 800k	808k to 1.60M	1.616M to 4.00M	4.04M to 8.00M



Reclock Circuit



Timing Diagram

Figure 8-9. Reclock Circuit.

8-38. LOW-PASS FILTER

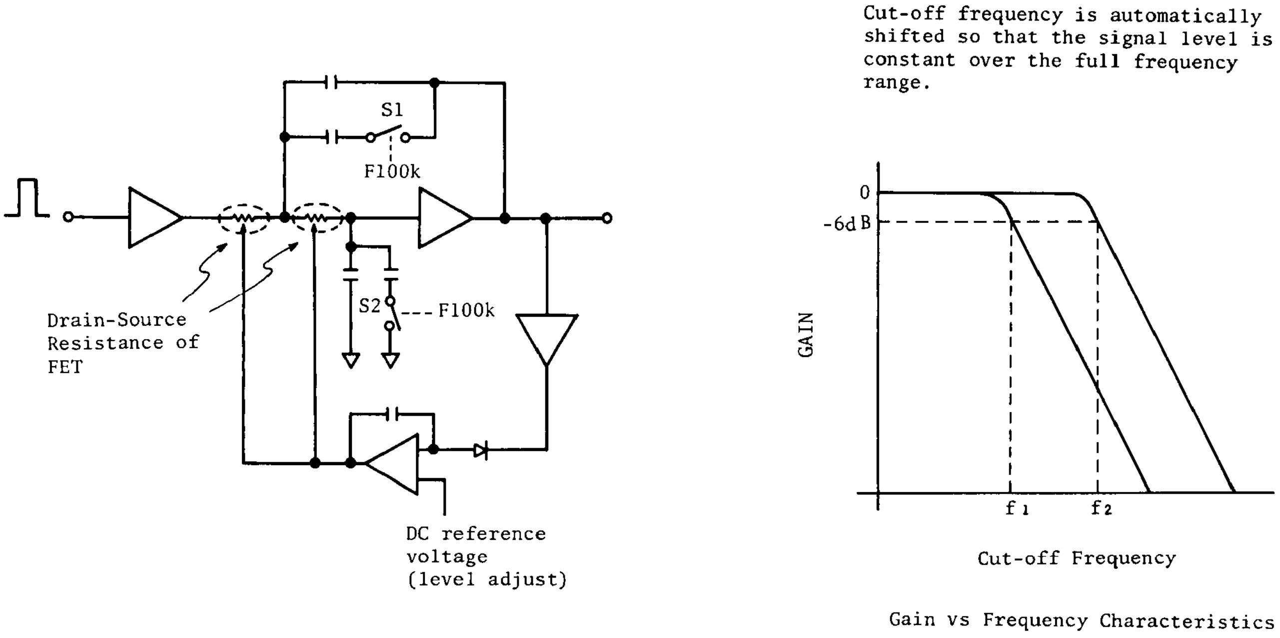
8-39. The four-stage low-pass filter passes the fundamental of the square wave signal output from the ÷8 divider, while attenuating the harmonics to a level that is -50dB or more below the fundamental. The filter's -6dB cut-off frequency automatically follows the frequency of the input signal so that the level of the filtered output (sine wave) is constant at 300mVrms (approximate) over the 4277A's full frequency range. A simplified circuit schematic of one stage of the low-pass filter, along with its gain versus frequency characteristics, is shown in Figure 8-10.

The third and fourth stages of the low-pass filter also provide the 90° and 0° phase reference signals for the phase tracking circuits. This will be explained in more detail in paragraph 8-49.

8-40. H/CUR AMPLIFIER

8-41. The H/CUR amplifier controls the level of the test signal applied to the device under test (DUT) as directed by the TEST SIG LEVEL setting on the instrument's front panel. When TEST SIG LEVEL is set to HIGH, the tll signal connected to the base of Q5 is LOW, turning off Q5. The 300mVrms signal from the low-pass filter is attenuated by R30-3 and R32, which construct a simple voltage divider. When TEST SIG LEVEL is set to LOW, the tll signal goes HIGH, turning on Q5 and thereby connecting R31 in parallel with R32 of the voltage divider. The amplitude of the signal applied to the amplifier, U24 and U25, is thus reduced. The amplifier's gain is approximately x3.8.

Test Frequency	S1, S2
10k to 100kHz	ON (Closed)
101k to 1MHz	OFF (Open)



Cut-off frequency is automatically shifted so that the signal level is constant over the full frequency range.

Drain-Source Resistance of FET

DC reference voltage (level adjust)

Cut-off Frequency

Gain vs Frequency Characteristics

Figure 8-10. Low Pass Filter.

8-42. AUTO-BALANCE BRIDGE

8-43. The auto-balance bridge consists of the unknown sample, a range resistor, the Null Detector and the Modulator. Figure 8-11 shows the block diagram of the auto-balance bridge.

8-44. NULL DETECTOR

8-45. The unbalance current which results when the bridge is not completely balanced is detected by an I-V converter (in the null detector) through the LPOT terminal and is converted into a vector voltage signal. To improve gain at high frequencies, the I-V converter employs a staggered circuit configuration. Because the I-V converter's feedback magnitude varies depending on the DUT impedance, the feedback circuit elements are automatically changed in response to selection of measurement range (test frequency and range resistor). Refer to Figure 8-12.

8-46. The Gain Normalizer Amplifier and the x100 Amplifier amplify the unbalance vector voltage signal in order to maintain the sensitivity of the balance control loop (the Null Detector and the Modulator circuits) almost constant against changes in the test signal level and DUT impedance. In input stage of the Modulator Amplifier, the signal is attenuated to compensate for the gain of the Gain Normalizer Amplifier stage. The microprocessor does this by setting the SPAM and TLPAM control signals to suit the test signal and measurement conditions. Figure 8-13 shows the SPAM and TLPAM control settings.

8-47. MODULATOR

8-48. Figure 8-11 shows the basic circuit configuration of the Modulator. The unbalance vector signal which is detected by the Null Detector is phase detected and separated into its orthogonal vector components. The phase detectors output dc voltages proportional to the magnitudes of the respective vector components. Reverse-phase components yield reverse-polarity voltage outputs (negative dc levels) from the phase detectors. The vector modulators vary the amplitudes of the four orthogonal phase vector signals (0 °, 90 °, 180 °, -90 °), which are generated by the low-pass filter in the signal source and the phase tracking

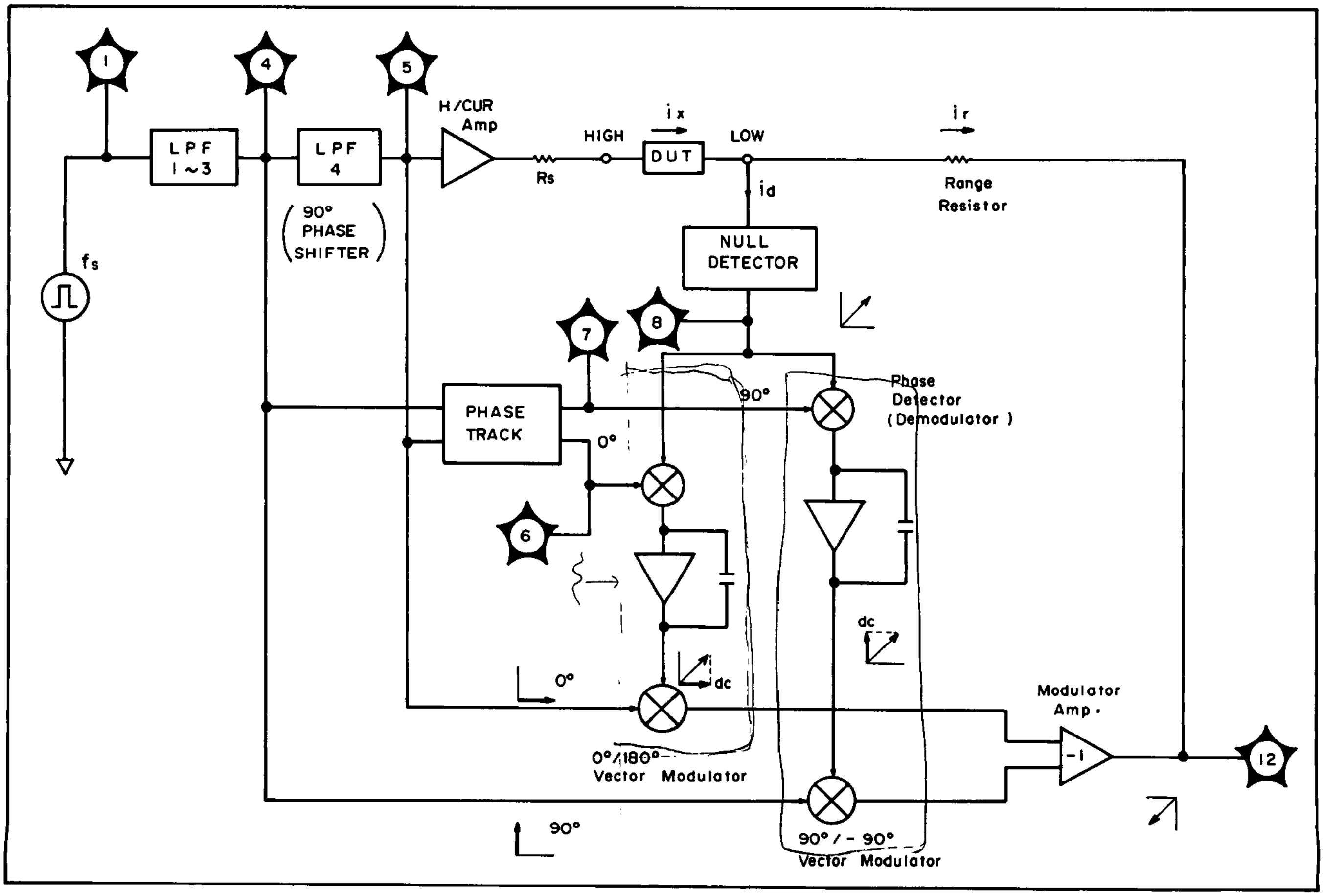
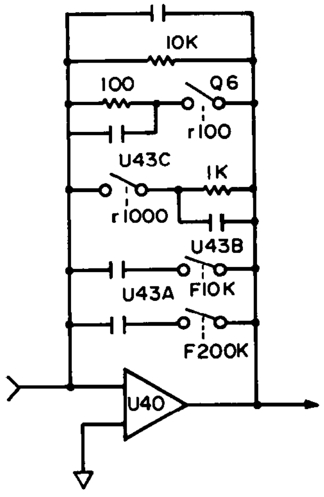


Figure 8-11. Auto-Balance Bridge Block Diagram.

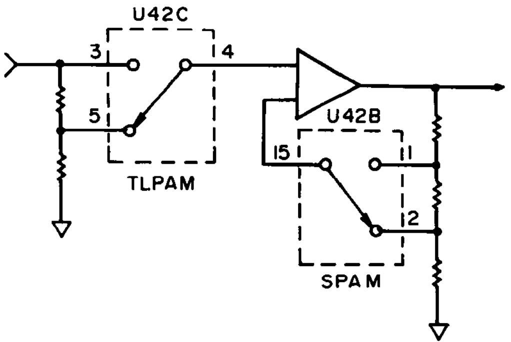


I-V Converter

Feedback Resistance	Q6	U43C
100Ω	ON	OFF
1kΩ	OFF	ON

Test Frequency	U43B	U43A
10k to 20kHz	ON	ON
20.2k to 200kHz	OFF	ON
202k to 1MHz	OFF	OFF

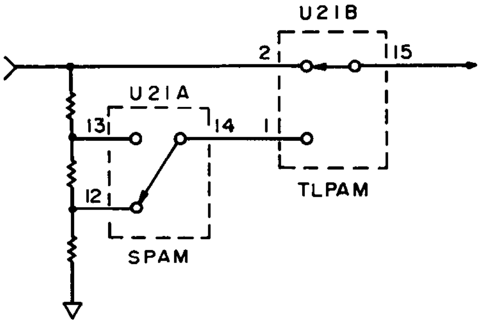
Figure 8-12. Feedback Circuit Element Selection in I-V Converter.



Gain Normalizer Amplifier

SPAM Control Setting

Measurement Condition	U42B	U21A
TLH·(Y mode)· (1MΩ range)· (C or Z)	15 → 1	14 → 13
Others	15 → 2	14 → 12



Input Stage of the Modulator Amplifier

TLPAM Control Setting

TEST SIG LEVEL	Measurement Condition	U42C	U21B
HIGH	(Y mode)· (1MΩ range)· (C or Z)	4 → 3	15 → 1
	Others	4 → 5	15 → 2
LOW	All	4 → 3	15 → 1

Figure 8-13. SPAM and TLPAM Control Signals.

circuits, in response to the null detector output vector components. The 0°/180° vector modulator provides an amplitude-controlled output which is in-phase with the test signal when the 0° phase detector output is a positive voltage. Conversely, it provides a reverse phase output for a negative voltage output from the phase detector. Thus, the 0°/180° vector modulator's output signal is represented by a vector on the real axis of the coordinates shown in Figure 8-14. The 90°/-90° vector modulator operates similarly to the 0°/180° vector modulator with respect to the 90° phase shifted input signal. The 90°/-90° vector modulator output signal is represented by a vector on the imaginary axis (see Figure 8-14). As a result of this vector modulation, the magnitudes of the real and imaginary vector components of the null detector output are transferred to the orthogonal vectors of the vector modulator outputs. The modulator amplifier sums the signals output from the 0°/180° and 90°/-90° vector modulators and, simultaneously, reverses the phase of the resultant vector signal (the modulator amplifier provides 180° phase shift). Consequentially, the modulator amplifier output, e_d, has a vector direction opposite that of the unbalance current. The e_d signal changes in response to the unbalance current so as to suppress increases in the unbalance current. Thus, the unbalance current approaches zero. Because the e_d signal is controlled with respect to the individual magnitudes of the real and imaginary components of the unbalance current, the bridge can reach accurate balance even if the balance control loop has a phase error related to test signal.

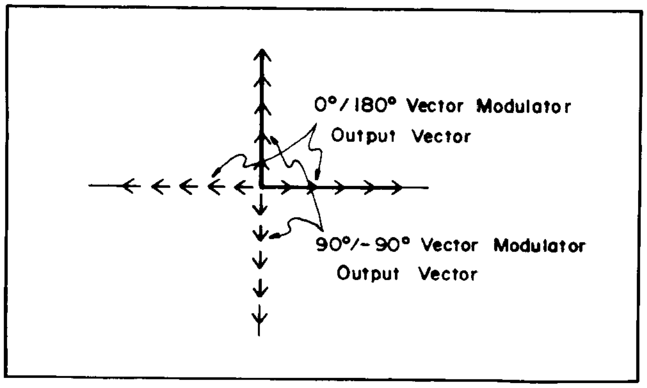


Figure 8-14. Vector Representation of the Vector Modulator Outputs.

8-49. PHASE TRACKING CIRCUITS OF THE BRIDGE CONTROL LOOP

8-50. If the phase shift in the balance control loop is so large that the bridge cannot be automatically balanced, the phase characteristics of the balance control loop can be compensated by properly adjusting the phase of the 0° and 90° reference phase signals used by the phase detectors in reference to the test signal.

The output from the third stage of the low-pass filter in the signal source is used as the 90° reference phase signal. The output from the fourth stage of the low-pass filter is used as the 0° reference phase signal. The fourth stage of the low-pass filter functions as a 90° phase shifter. Depending on the frequency of the test signal, the input vs. output phase lag is between -105° and -85°. Thus, the 0° and 90° reference phase signals do not always maintain a precise 90° phase relationship. This does not, however, affect the detection of the unbalance current.

The phase tracking circuits shift the phase relationship of the reference phase signals as appropriate for the selected test frequency without changing the signal amplitude and thereby ensure the bridge being automatically balanced over the entire test frequency range.

8-51. RANGE RESISTOR

8-52. The values of the range resistors used in the auto-balance bridge are 100Ω, 1kΩ and 10kΩ. To ensure accurate range resistor values and minimum residual reactance (mainly stray capacitance), an potentiometer and a phase compensation trimmer capacitor are provided for each range resistor. Range resistor selection and CMR Amplifier switching is controlled by the RRa and RRb control signals. Refer to Table 8-5.

Table 8-5. Range Resistor Selection

Range Resistor	Control Signals	
	RRa	RRb
100Ω	LOW	LOW
1kΩ	HIGH	LOW
10kΩ	LOW	HIGH

8-53. The CMR (Common Mode Rejection) amplifier provides compensation for any decrease in the range resistor signal caused by the inherent impedance of the internal cabling from the LCUR terminal to the range resistor.

8-54. VECTOR RATIO DETECTOR

8-55. The block diagram of the vector ratio detector (VRD) is shown in Figure 8-15. This section consists of the Process Amplifier, Phase Detector, Phase Generator, and A-D Converter.

8-56. PROCESS AMPLIFIER

8-57. The Process Amplifier contains the VRD's Input Tracking circuits, AM Amplifier, and Test Level Low Amplifier.

8-58. VRD INPUT TRACKING

8-59. The input tracking circuit of the voltage ratio detector consists of two carefully matched buffer amplifiers which detect and pass the e_{RR} and e_{DUT} signals without altering the phase relationship between the two inputs. The e_{RR} signal, the complex voltage across the range resistor, is input to one of the buffer amplifiers from the range resistor circuit; the e_{DUT} signal, the complex voltage across the device under test, is input to the other buffer amplifier from the H_{POT} UNKNOWN terminal. An analog switch alternately selects the output from each buffer amplifier for processing by the voltage ratio detector. In normal operation, switching

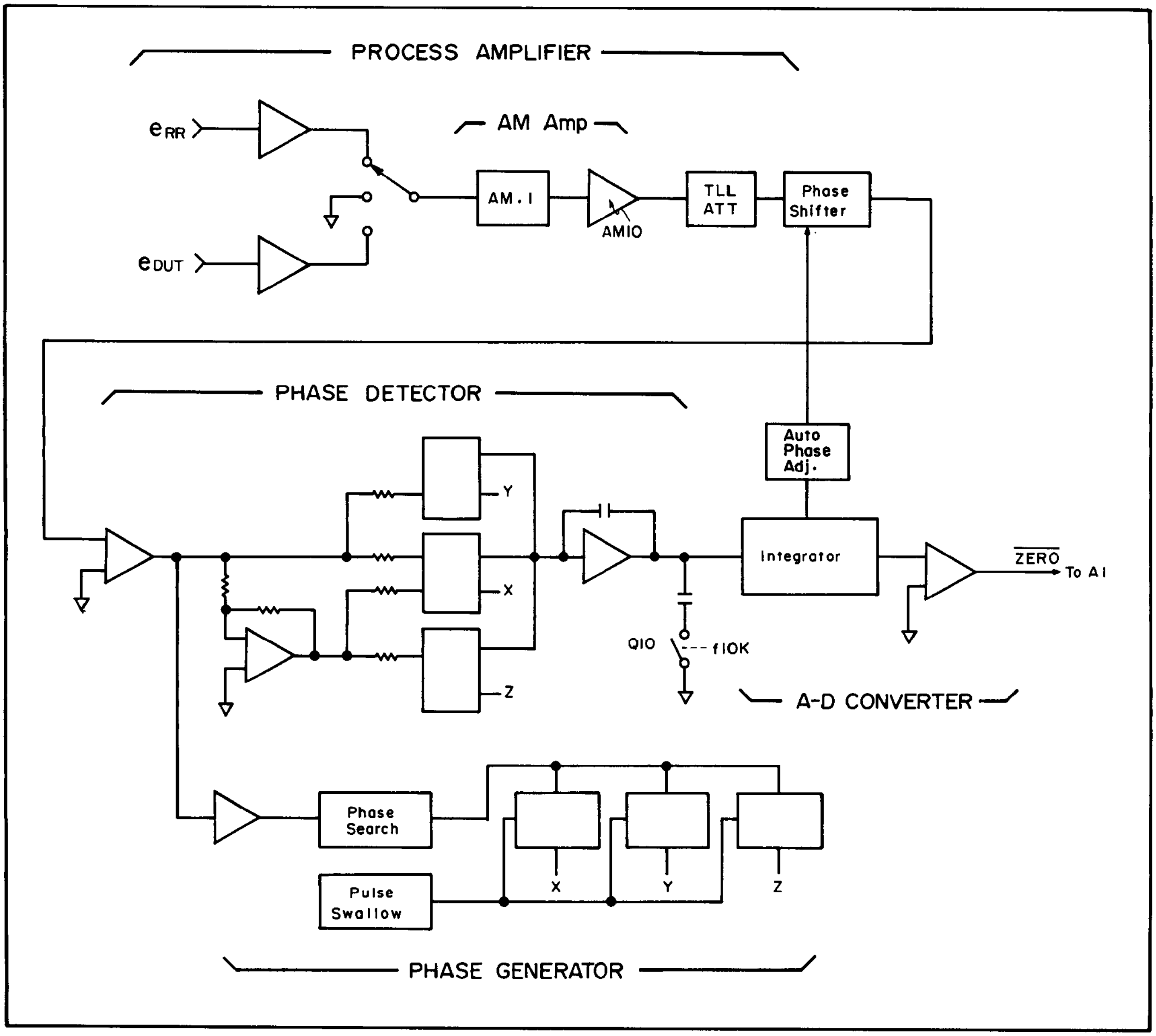


Figure 8-15. Vector Ratio Detector Block Diagram.

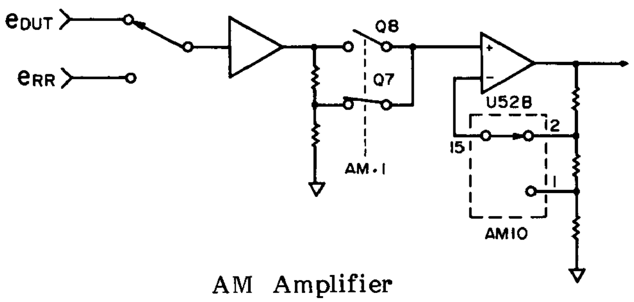
(signal selection) is controlled by the EDUT and EOFF signals sent from the microprocessor. See Table 8-6.

Table 8-6. ERR and EDUT Switching Control

Control Signal		Selected Signal
EDUT	EOFF	
LOW	LOW	e_{RR}
HIGH	LOW	e_{DUT}
LOW	HIGH	off
HIGH	HIGH	N.C.

8-60. AM AMPLIFIER

8-61. The AM Amplifier expands the 4277A's measurement range by attenuating or amplifying the incoming e_{ref} or e_{test} signal by a factor of 10. (The signals input to the input tracking circuit are called e_{RR} and e_{DUT}. The signal at the output of the input tracking circuit is more properly called e_{ref} or e_{test}.) By selectively attenuating or amplifying the e_{ref} and e_{test} signals, the AM Amplifier increases the ratio between the signals by 10. Figure 8-16 shows the AM.1 and AM10 control settings. Table 8-7 shows the relationship between the signal-to-signal ratio and the control settings. Range information is given in Figure 8-18.



AM Amplifier

AM.1 and AM10 Control Settings

Control Signal		Q7	Q8	U52B
AM.1	HIGH (am.1)	ON	OFF	—
	LOW ($\overline{\text{am.1}}$)	OFF	ON	—
AM10	HIGH	—	—	15 → 1
	LOW	—	—	15 → 2

Figure 8-16. AM.1 and AM10 Control Signals.

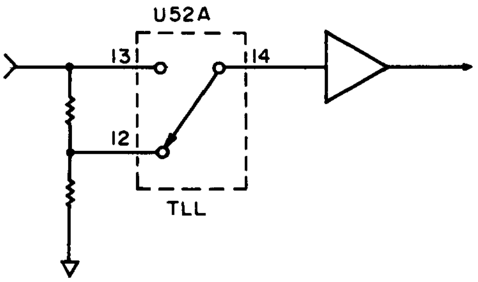
Table 8-7. AM Amplifier Control

Code*	Ratio	e_{test}		e_{ref}	
		AM.1	AM10	AM.1	AM10
A1	1 — 1	LOW	LOW	LOW	LOW
A2	10 — 1	LOW	HIGH	HIGH	HIGH
A3	10 —10	LOW	HIGH	LOW	HIGH

* Refer to the tables listed in Figure 8-18.

8-62. TEST LEVEL LOW (TLL) AMPLIFIER

8-63. The attenuator at the input of the TLL Amplifier is controlled in accordance with the selected test signal level. When the TEST SIG LEVEL is set to LOW, the measurement signal passes through the attenuator without attenuation and is then amplified so that the test signal level is sufficient for accurate phase detection. When the TEST SIG LEVEL is set to HIGH, the measurement signal is attenuated so that the amplitude of the signal input to the TLL Amplifier is approximately the same as that of the low level signal. This keeps the level of the signal applied to the A-D converter constant and improves the accuracy of vector ratio detection for low level test signal measurements. The TLL Amplifier's control settings are shown in Figure 8-17.



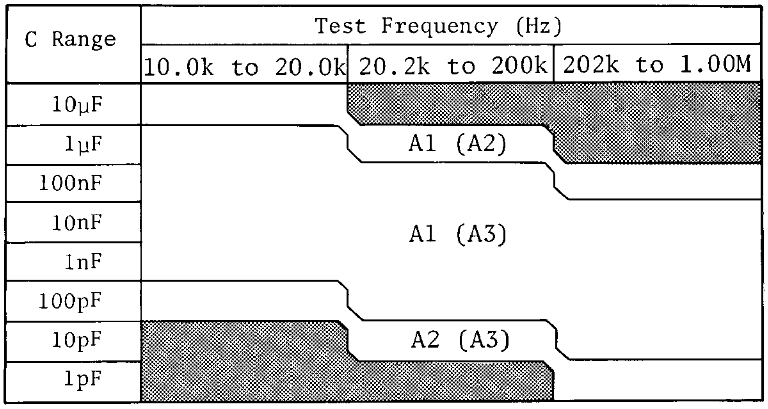
TLL Amplifier

TLL Control Setting

TEST SIG LEVEL	U52A
HIGH	14 → 12
LOW	14 → 13

Figure 8-17. TLL Control Signal.

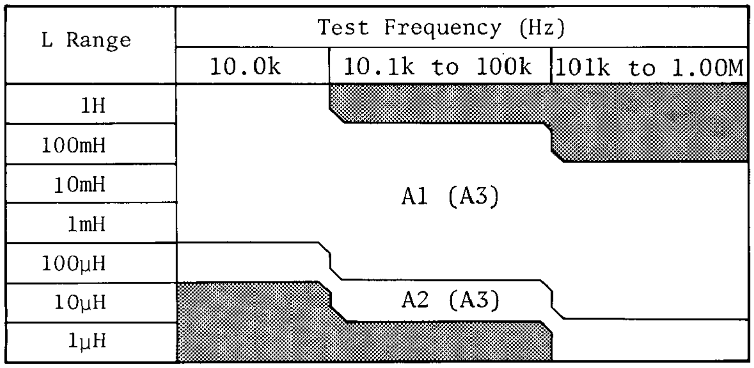
C-D Measurement



C-ESR/G Measurement

ESR/G Range	Test Frequency (Hz)
	10.0k to 1.00M
1MΩ/10µS	A2 (A3)
100kΩ/100µS	A1 (A3)
10kΩ/1mS	
1kΩ/10mS	
100Ω/100mS	
10Ω/1S	A1 (A2)

L-D Measurement



L-ESR/G Measurement

ESR/G Range	Test Frequency (Hz)
	10.0k to 1.00M
100kΩ/100µS	A1 (A3)
10kΩ/1mS	
1kΩ/10mS	
100Ω/100mS	
10Ω/1S	A2 (A3)

|Z|-θ Measurement

|Z| Range	Test Frequency (Hz)
	10.0k to 1.00M
1MΩ	A3 (A3)
100kΩ	
10kΩ	
1kΩ	
100Ω	
10Ω	

Note: The meanings for codes A1, A2, and A3 are given in Table 8-7. Codes enclosed in parentheses apply when TEST SIG LEVEL is set to LOW.

Figure 8-18. AM Amplifier Control Conditions in Accordance with Measurement Ranges.

8-64. PHASE DETECTOR

8-65. The phase detector separates the incoming e_{ref} and e_{test} signals into their individual 0 ° (real) and 90 ° (imaginary) components for measurement by the integrator and zero detector. The phase detector circuit consists of three parallel-connected phase detectors. Each is controlled by its own phase reference signal. The phase relationships among the phase reference signals is constant. The phase relationship between the e_{ref} signal and the phase reference signals, however, is either 0 ° or 90 ° depending on which vector component (real or imaginary) of the incoming e_{ref} or e_{test} signal is to be detected. Figure 8-20 shows the timing diagram when the 0 ° (real) component of the e_{test} signal is being detected. The phase detector circuit's output waveform will be the sum of the three individual waveforms shown in the figure. When the 90 ° (imaginary) component is to be detected, the X, Y, and Z phase reference signals are all phase shifted 90 ° in reference to the e_{ref} signal. Keep in mind that both incoming signals, e_{ref} and e_{test} , are phase detected to compensate for any phase error caused by the phase detector's input circuitry. The inverting amplifier increases detection efficiency. Transistor Q10 at the output of the phase detector is turned on to reduce ripple in the phase detector's output when the test frequency is in the 10kHz to 20kHz range.

Most methods of phase detection use only one phase detector and one phase reference signal which is either a sine wave or a square wave. Square wave phase detectors are, by far, more popular than sine wave phase detectors, but they output signals that include low amplitude harmonics corresponding to the vector products of the input signal's harmonic content and the harmonics of the square wave phase reference signal. (This comes from the fact that a phase detector is basically a mixer.) These harmonics cause a measurement error. Sine wave phase detectors have less harmonic content in their outputs, but they cannot offer the accuracy obtainable with square wave phase detectors.

The 4277A's phase detector uses three phase reference signals which, if summed, produce a digital sine wave. See Figure 8-19. Using such phase reference signals significantly reduces the amplitude of the third and fifth harmonics in the output, as shown in the figure. The phase reference signals are generated by the Phase Generator.

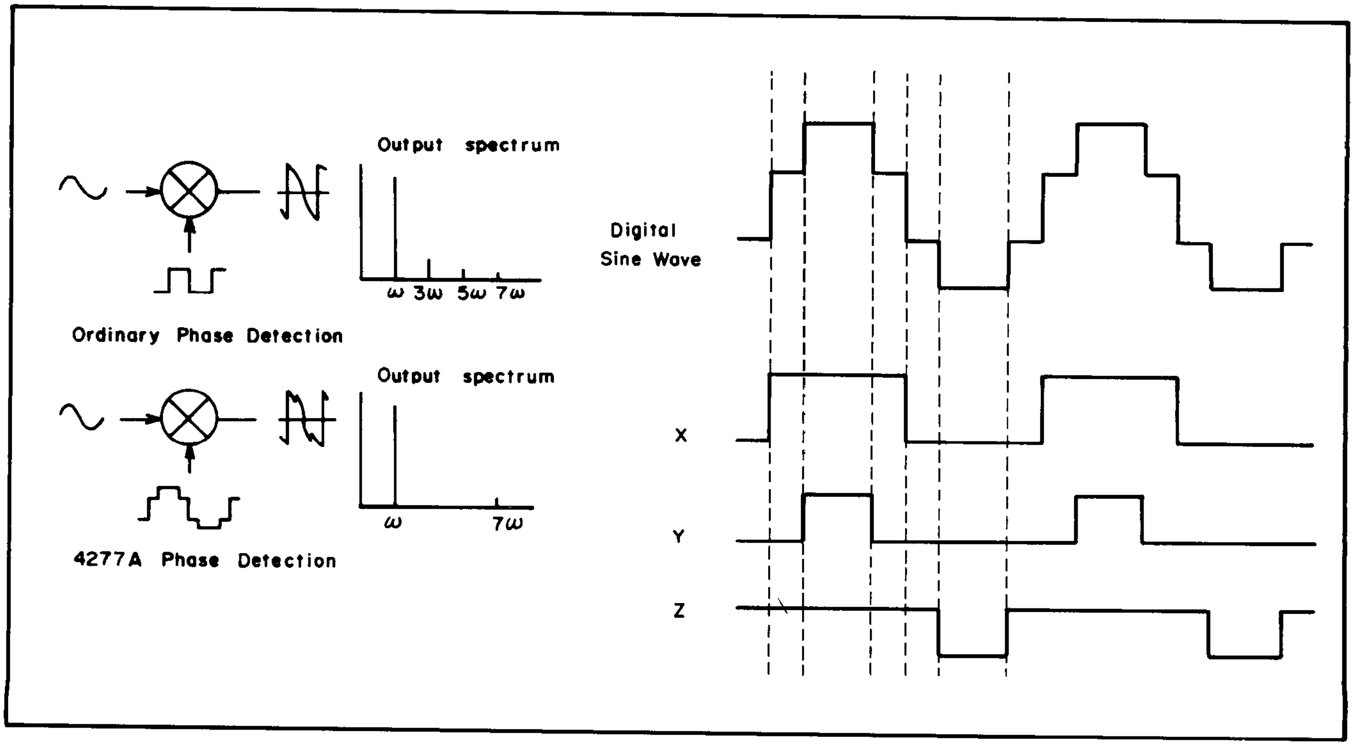


Figure 8-19. Phase Detection Principle.

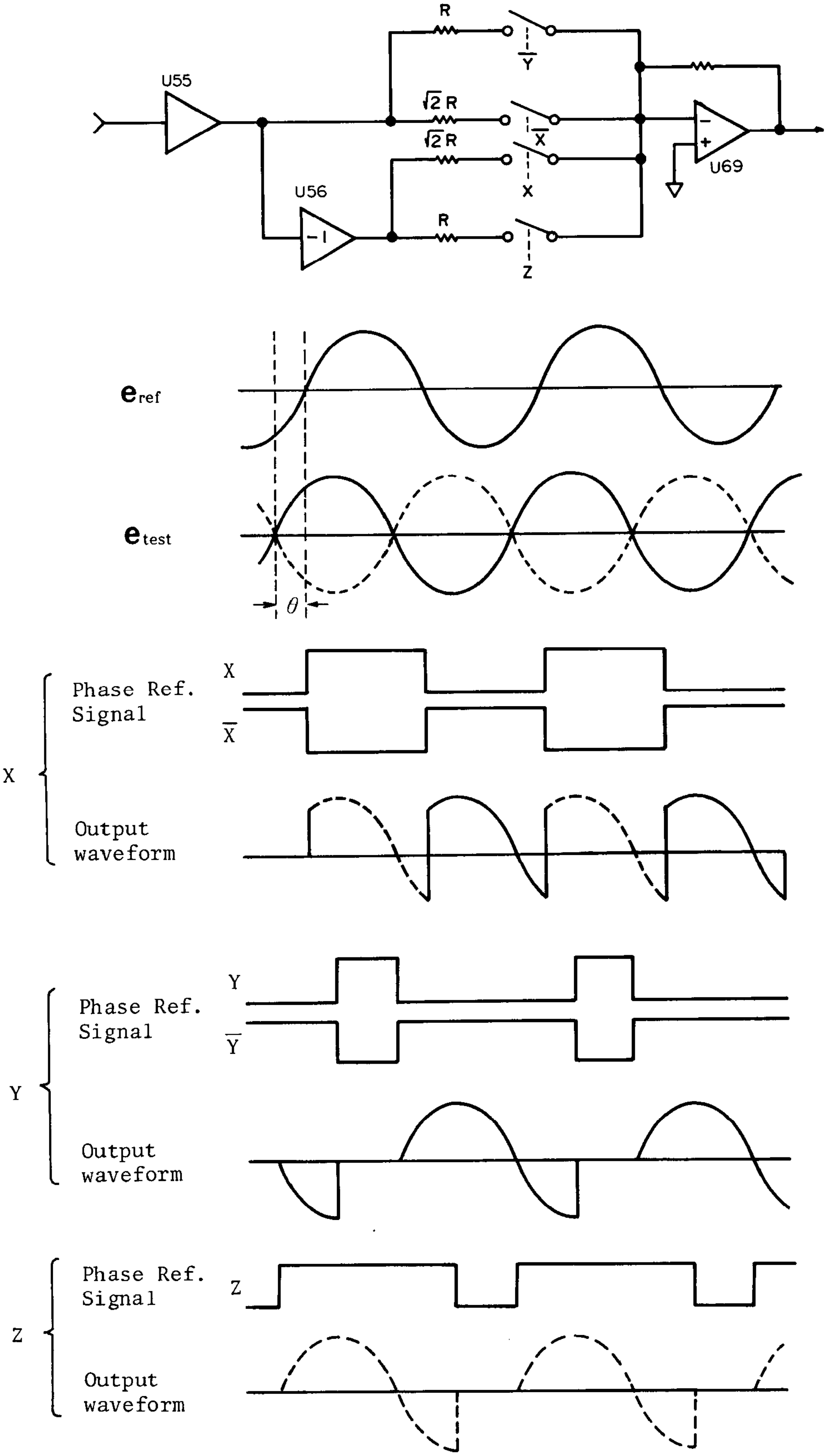


Figure 8-20. Phase Detector Signals.

8-66. PHASE GENERATOR

8-67. The Phase Generator, consisting of a Reference Detector, a Pulse Swallow circuit, and three parallel-to-serial shift registers, produces the synchronized phase reference signals (X, Y, and Z in Figure 8-20) required for phase detection.

8-68. REFERENCE DETECTOR

8-69. The Reference Detector establishes the phase relationship between the e_{ref} signal and the synchronized phase reference signals used for phase detection. Refer to the simplified schematic and the timing diagram shown in Figure 8-21. It shows how the X phase reference signal is produced. The e_{ref} signal is first squared and then input to a flip-flop. When the PSCH signal goes HIGH, the flip-flop's Q output goes HIGH at the leading edge of the next REF (squared e_{ref}) pulse. The Q output of the first flip-flop is connected to the D input of a second flip-flop. With the D input HIGH, the second flip-flop's Q output will go HIGH at the leading edge of the next 8f pulse, generating the REF DET signal, which enables the parallel-to-serial shift register. The shift register outputs one pulse for every eight 8f pulses. The on and off periods of the shift register's output are determined by the parallel inputs. Because an 8f signal (frequency is eight times that of the e_{ref} signal) is used, the X phase reference signal cannot be more than ±45 ° out of phase with the e_{ref} signal.

8-70. PULSE SWALLOW

8-71. The Pulse Swallow circuit shifts the phase of the three phase reference signals 45 ° by disabling the three parallel-to-serial shift registers for one 8f period. Refer to the circuit schematic and timing diagram shown in Figure 8-22. The number of pulse swallows, or more precisely the amount of phase shift, depends on the type of measurement being made. Refer to Table 8-8 and Figure 8-27.

Table 8-8. Phase Detection Signal Control

1) Y Measurement Mode

Measurement Signal	Integration							
	Period 1		Period 2		Period 3 (ESR/G)		Period 3 (D)	
	Charge	Discharge	Charge	Discharge	Charge	Discharge	Charge	Discharge
e_{ref} (e_{DUT})	-90°	0° or 180°	--	0° or 180°	--	0° or 180°	--	--
e_{test} (e_{RR})	--	--	90°	--	0°	--	0°	90° or -90°

2) Z Measurement Mode

Measurement Signal	Integration							
	Period 1		Period 2		Period 3 (ESR/G)		Period 3 (D)	
	Charge	Discharge	Charge	Discharge	Charge	Discharge	Charge	Discharge
e_{ref} (e_{RR})	-45°	45° or 225°	--	45° or 225°	--	45° or 225°	--	--
e_{test} (e_{DUT})	--	--	135°	--	45°	--	45°	135° or -45°

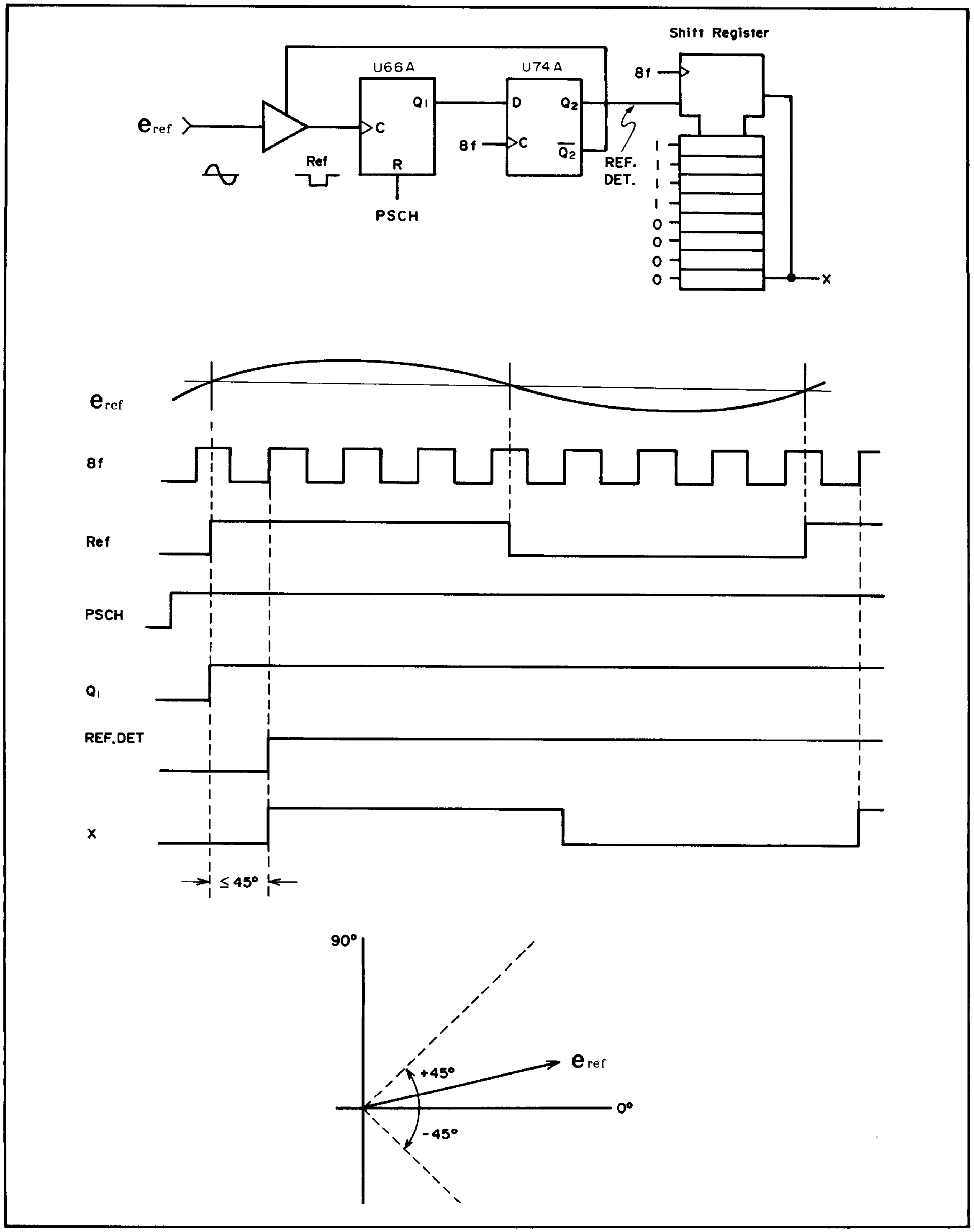
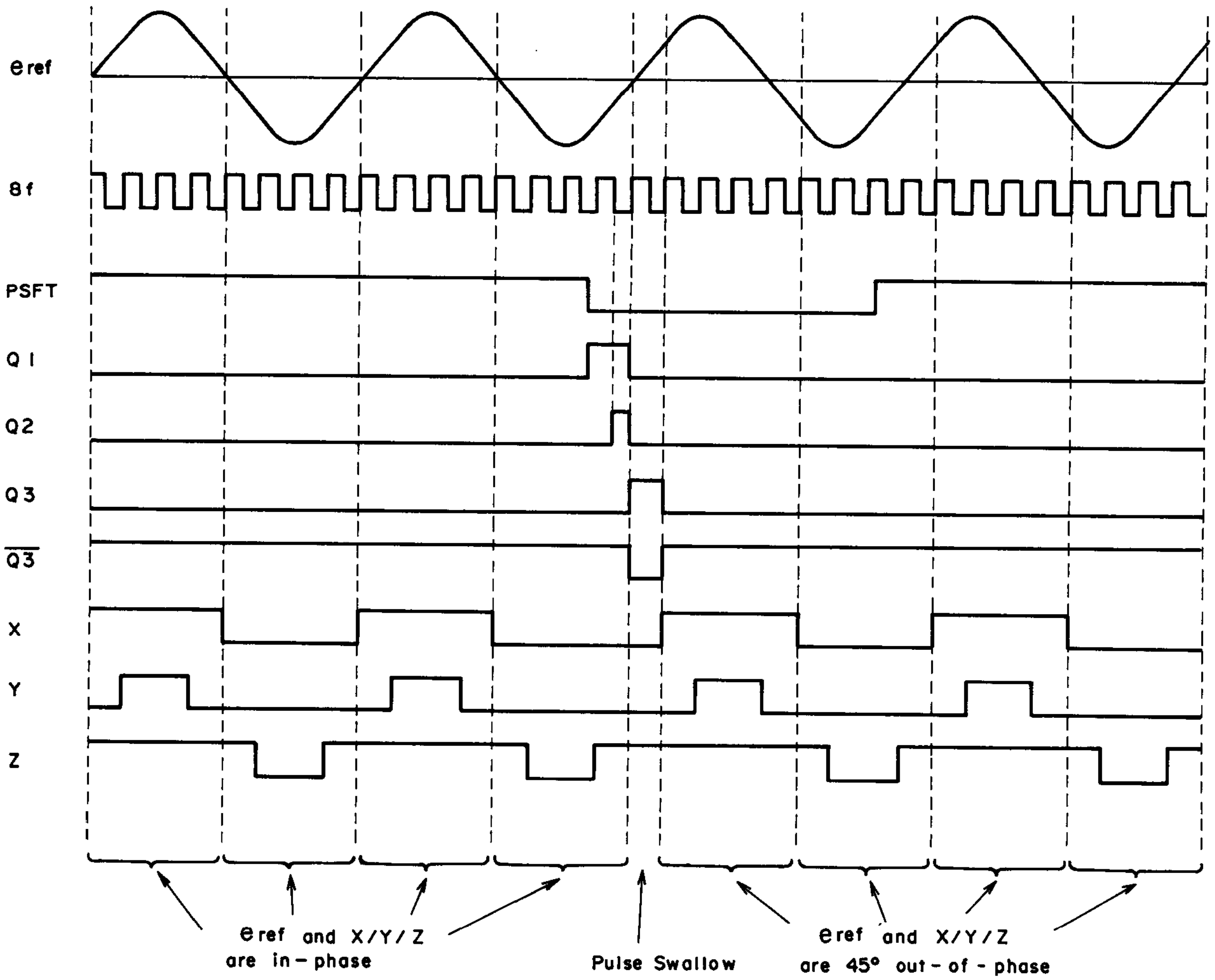
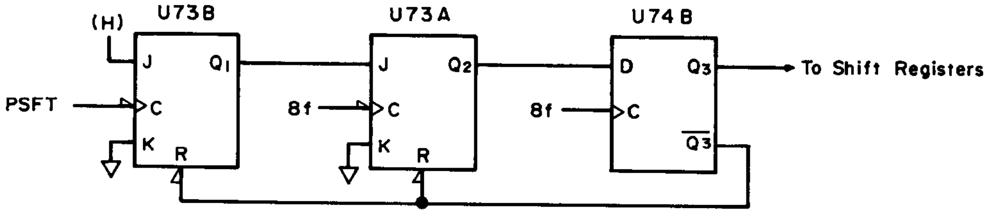


Figure 8-21. Reference Detector Operating Principle.



Timing Diagram



Circuit Schematic

Figure 8-22. Pulse Swallow Operating Principle.

8-72. A-D CONVERTER

8-73. The analog section of the A-D Converter includes an Auto-Zero circuit, Integrator, Auto-Phase Adjust circuit, and Zero Detector. The Auto-Zero circuit and Integrator are on a single hybrid IC. The digital section of the A-D Converter is on the A1 board. Only the analog section will be described. Figure 8-23 shows a block diagram of the A-D Converter and related circuits. Figure 8-27 shows the timing diagram for one measurement.

8-74. AUTO-ZERO CIRCUIT

8-75. Auto-zero is performed before each measurement to cancel the offset voltages inherent in the phase detector and integrator. At the start of the auto-zero period, the input of the AM Amplifier is grounded and the AZT signal is brought HIGH, closing S1 and S3. Offset voltages from the phase detector and integrator (S5 is closed, and S4 and S7 are open) charge storage capacitor C155. When a measurement is made, AZT is brought LOW (S2 is closed, and S1 and S3 are open) and voltages output from the integrator are compensated with the voltage held in C155.

8-76. INTEGRATOR

8-77. The integrator charges with the phase detector output signal (vector component of the e_{ref} or e_{test} signal) when input switch S4 is closed (IOFF control signal is LOW). The integrator charge time is automatically controlled by the microprocessor in accordance with test frequency, measurement range, test signal level, and measurement speed, as shown in Figure 8-24 and Table 8-9. A short hold time is provided before each charge and discharge period to eliminate any transient response signals incident to switching of the measurement vector signal. The integrator discharges with the phase detector output signal (vector component of the e_{ref} or e_{test} signal) until its output reaches the voltage determined by the Zero Shift circuit. The feedback loop switch (S5) closes (IRST control signal is HIGH) to keep the integrator discharged when dual-slope integration is not being performed.

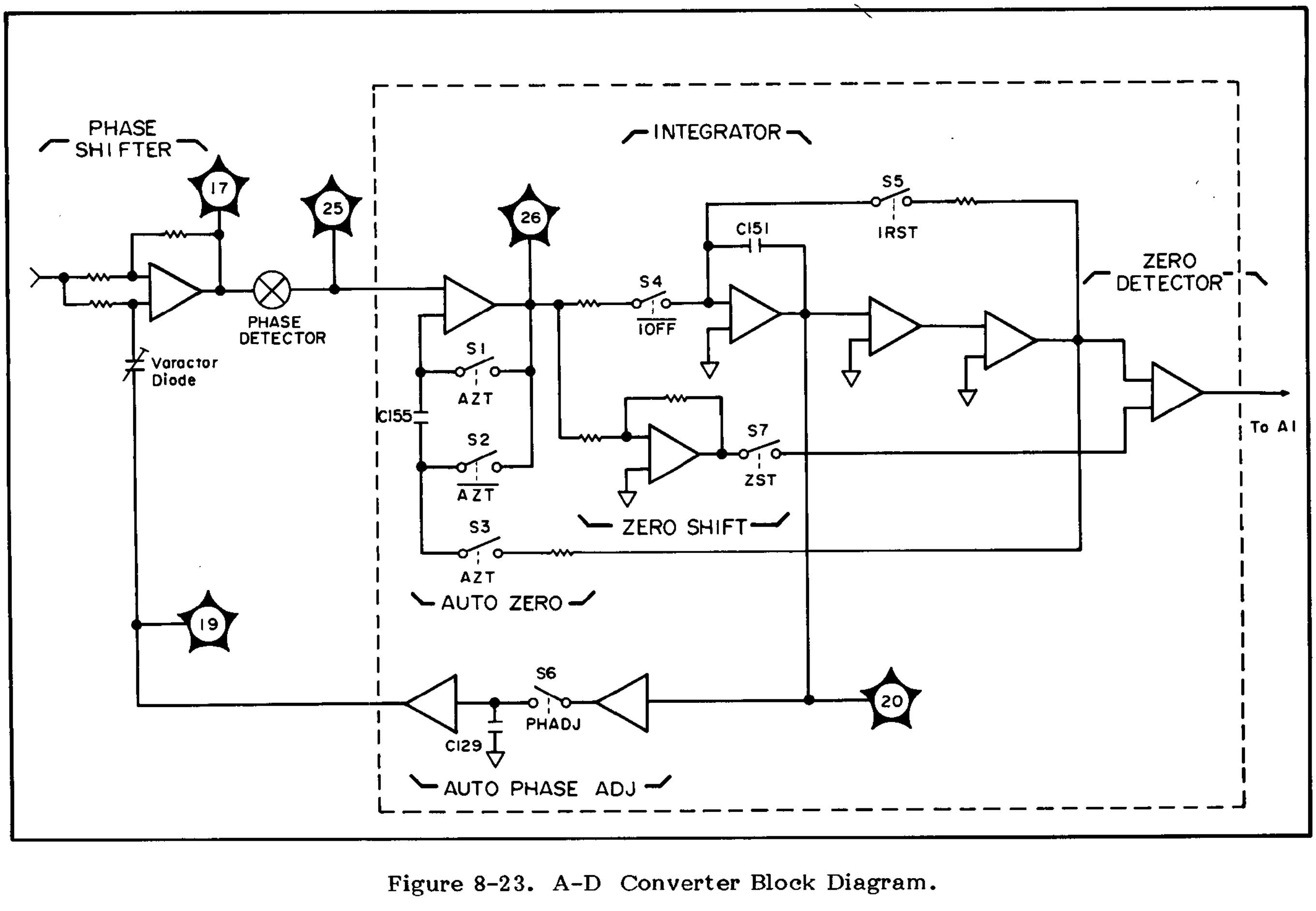


Figure 8-23. A-D Converter Block Diagram.

C-D Measurement

C Range	Test Frequency (Hz)		
	10.0k to 20.0k	20.2k to 200k	202k to 1.00M
10µF	T7 (T3)	▨	▨
1µF	T3 (T3)	T7 (T3)	▨
100nF	T1 (T1)	T3 (T3)	T7 (T3)
10nF	T1 (T1)	T1 (T1)	T3 (T3)
1nF	T1 (T1)	T1 (T1)	T1 (T1)
100pF	T1 (T1)	T1 (T1)	T1 (T1)
10pF	▨	T1 (T1)	T1 (T1)
1pF	▨	▨	T1 (T1)

C-ESR/G Measurement

ESR/G Range	Test Frequency (Hz)
	10.0k to 1.00M
1MΩ/10µS	T0 (T0)
100kΩ/100µS	
10kΩ/1mS	
1kΩ/10mS	
100Ω/100mS	T3 (T3)
10Ω/1S	T7 (T3)

L-D Measurement

L Range	Test Frequency (Hz)		
	10.0k	10.1k to 100k	101k to 1.00M
1H	T5 (T5)	▨	▨
100mH	T5 (T5)	T5 (T5)	▨
10mH	T4 (T4)	T5 (T5)	T5 (T5)
1mH	T2 (T2)	T4 (T4)	T5 (T5)
100µH	T2 (T2)	T2 (T2)	T4 (T4)
10µH	▨	T2 (T2)	T2 (T2)
1µH	▨	▨	T2 (T2)

L-ESR/G Measurement

ESR/G Range	Test Frequency (Hz)
	10.0k to 1.00M
100kΩ/100µS	T0 (T0)
10kΩ/1mS	
1kΩ/10mS	T4 (T4)
100Ω/100mS	T0 (T0)
10Ω/1S	

|Z|-θ Measurement

|Z| Range	Test Frequency (Hz)
	10.0k to 1.00M
1MΩ	T6 (T6)
100kΩ	
10kΩ	
1kΩ	
100Ω	T0 (T0)
10Ω	

Note: The meanings for codes T0 through T7 are given in Table 8-9. Codes enclosed in parentheses apply when TEST SIG LEVEL is set to LOW.

Figure 8-24. Integrator Charge Time vs Measurement Range.

Table 8-9. Integrator Charge Time vs Frequency

<table>
<tr><th rowspan="2">Charge Time</th><th colspan="5">Test Frequency (Hz)</th></tr>
<tr><th>10.0k</th><th>10.1k to 20.0k</th><th>20.2k to 100k</th><th>101k to 200k</th><th>202k to 1.00M</th></tr>
<tr><td>T0</td><td colspan="5">a</td></tr>
<tr><td>T1</td><td colspan="2">$\frac{10a}{fk}$</td><td colspan="2">$\frac{100a}{fk}$</td><td>$\frac{1000a}{fk}$</td></tr>
<tr><td>T2</td><td>$\frac{10a}{fk}$</td><td colspan="2">$\frac{100a}{fk}$</td><td colspan="2">$\frac{1000a}{fk}$</td></tr>
<tr><td>T3</td><td colspan="2">$\frac{fk \cdot a}{10}$</td><td colspan="2">$\frac{fk \cdot a}{100}$</td><td>$\frac{fk \cdot a}{1000}$</td></tr>
<tr><td>T4</td><td>$\frac{fk \cdot a}{10}$</td><td colspan="2">$\frac{fk \cdot a}{100}$</td><td colspan="2">$\frac{fk \cdot a}{1000}$</td></tr>
<tr><td>T5</td><td>$fk \cdot a$</td><td colspan="2">$\frac{fk \cdot a}{10}$</td><td colspan="2">$\frac{fk \cdot a}{100}$</td></tr>
<tr><td>T6</td><td colspan="5">2a</td></tr>
<tr><td>T7</td><td colspan="2">$\frac{fk \cdot a}{2}$</td><td colspan="2">$\frac{fk \cdot a}{20}$</td><td>$\frac{fk \cdot a}{200}$</td></tr>
</table>

fk: in kHz

Measurement Speed	SLOW/MED	FAST
a	5.20ms	1.30ms

8-78. AUTO-PHASE ADJUST CIRCUIT

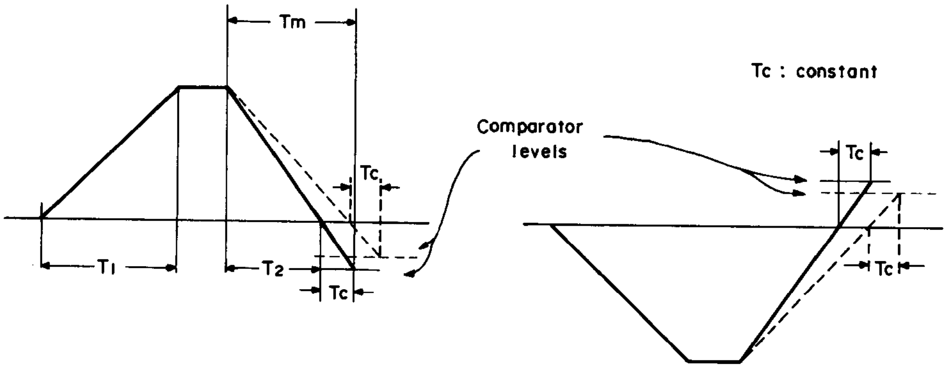
8-79. The Auto-Phase Adjust circuit controls the Phase Shifter in the VRD so that precise phase relationships exist between the e_{ref} signal and the three phase reference signals used for phase detection. Auto-phase adjustment is performed when the test frequency is in the 505kHz to 1MHz region. Refer to the timing diagram given in Figure 8-27 (sheet 2 of 2). The settings for the switches in the A-D converter (see Figure 8-23) during auto-phase adjustment are given below.

S1: OPEN
S2: CLOSED
S3: OPEN
S4: CLOSED
S5: OPEN
S6: CLOSED
S7: OPEN

The e_{ref} signal is input to the phase detector and is phase detected using the 90° phase reference signals. If e_{ref} is exactly 90° out-of-phase with the phase reference signals, the average level of the phase detector's output will be zero. If a phase error exists between the e_{ref} signal and the 90° phase reference signals, the phase detector outputs a signal whose dc content is proportional to the magnitude and direction of the phase error. The auto-phase adjust circuit feeds this dc signal back to the Phase Shifter, where it controls the capacitance of two varactor diodes so that the phase error is minimized. Storage capacitor C129 holds the dc voltage to continuously control the capacitance of the varactor diode while the measurement is performed.

8-80. ZERO DETECTOR

8-81. The Zero Detector reverses its output logic (HIGH to LOW or LOW to HIGH) the instant the integrator's output crosses the zero level. This signals the microprocessor that an integration period has been completed. During discharge, 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. The 4277A employs a Zero Shift circuit to intercept any transient signals incident to switching of integrator control. This does not cause measurement error caused by spike noise even if a zero input signal is integrated. The comparison level for zero cross depends on the slope of the discharge signal. The zero shift time, Tc in Figure 8-25, is constant. The microprocessor compensates for the count error caused by Tc.



Integration in the positive domain

Integration in the negative domain

T_2 = Tm-Tc
T_2 : Actual Discharge Time
Tm : Measured Discharge Time
Tc : Zero Shift Time

Figure 8-25. Zero Shift.

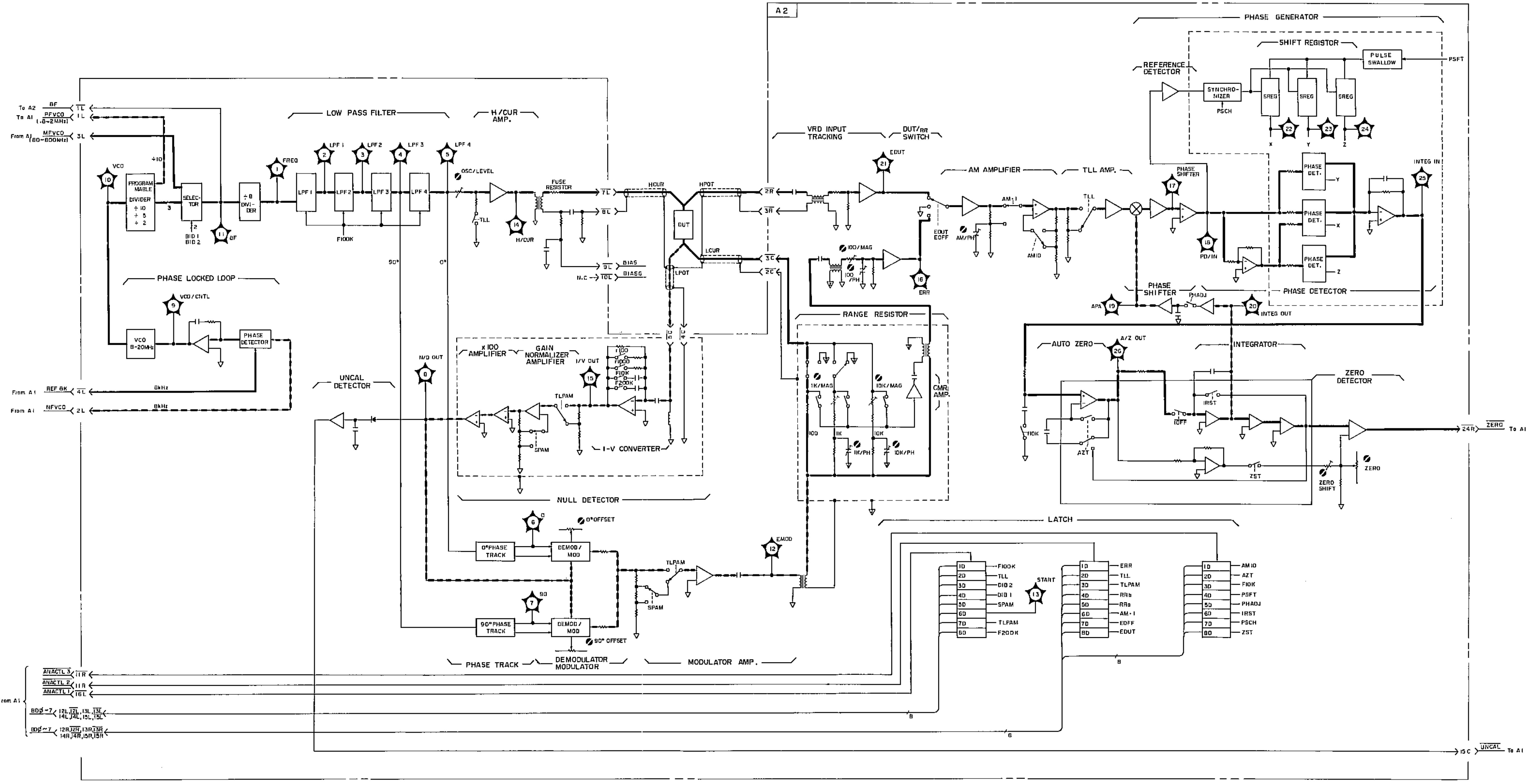
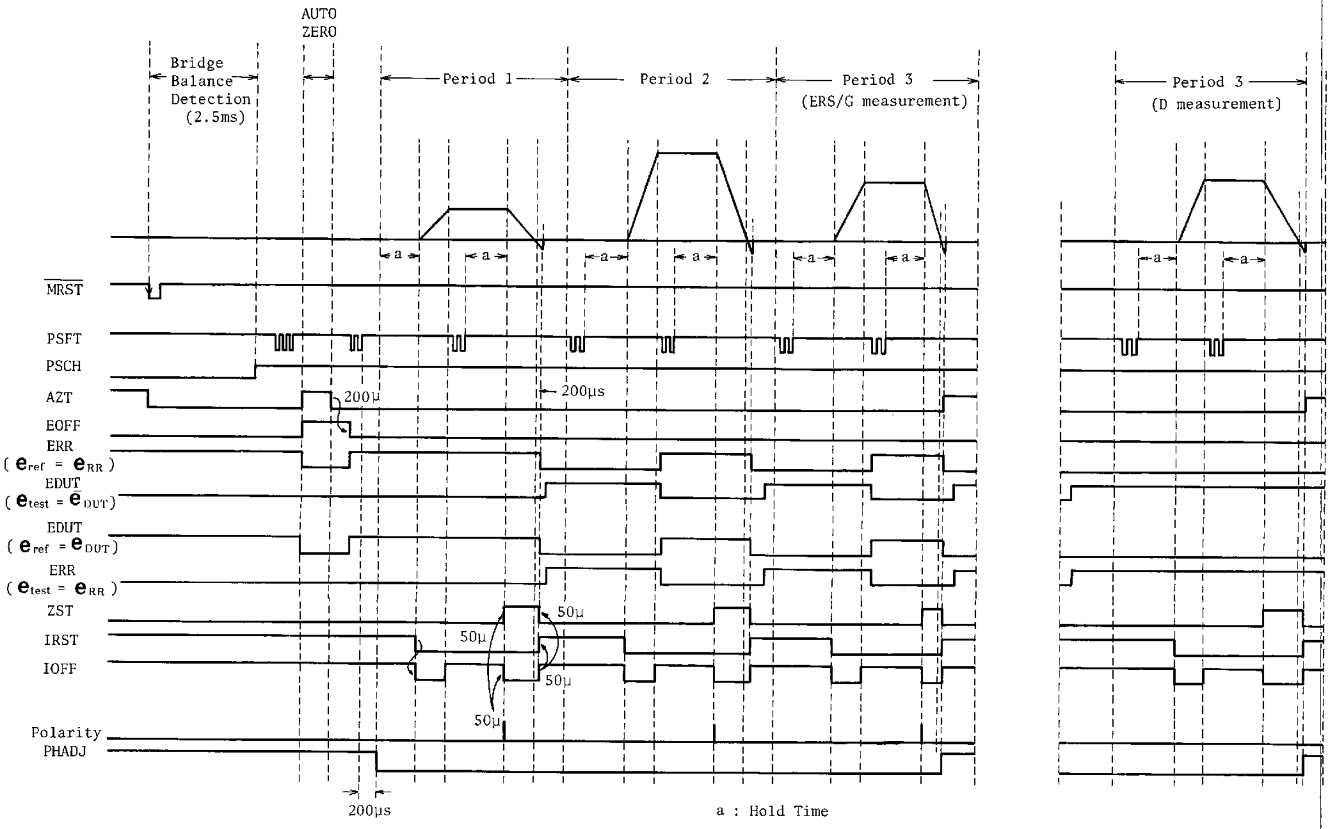


Figure 8-26. Analog Measurement Section Block Diagram.

ANALOG BLOCK DIAGRAM

SEE INSIDE

Mode 1 (Frequency : 10k to 500kHz)



Test Frequency	Pulse Width of PSFT
10.0k to 99.5kHz	200µs
100k to 1.00MHz	20µs

Test Signal Level	Hold Time		Auto Zero Time	
	Test Frequency (Hz)		Test Frequency (Hz)	
	10.0k to 19.9k	20.0k to 1.00M	10.0k to 20.0k	20.0k to 1.00M
1V	7ms	2ms	8ms	5ms
20mV	8ms	3ms	8ms	5ms

Figure 8-27. Timing Diagram (Sheet 1 of 2).

Mode 2 (Frequency : 505k to 1MHz)

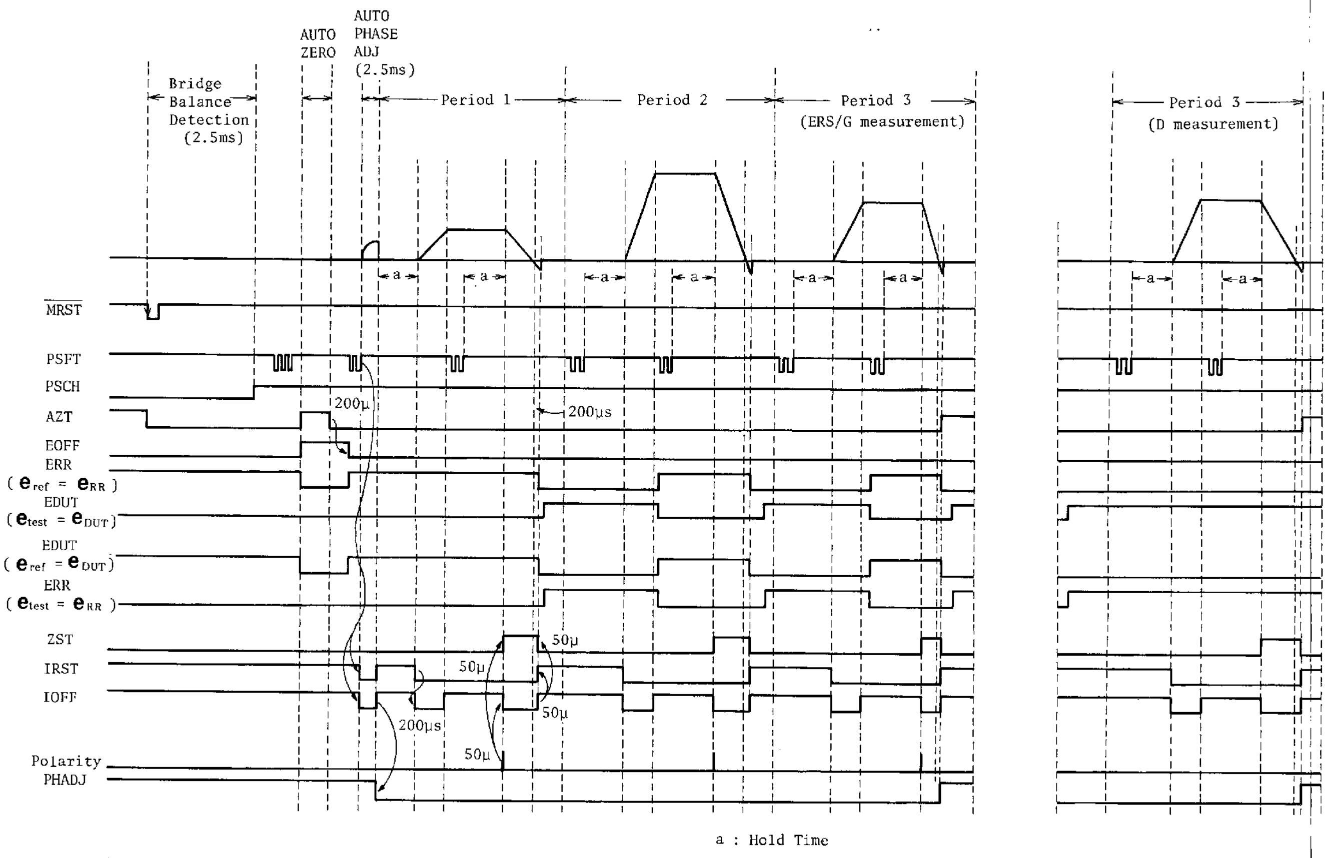


Figure 8-27. Timing Diagram (Sheet 2 of 2).

8-82. DIGITAL CONTROL SECTION

8-83. Figure 8-33 shows the block diagram of the 4277A digital control section. The digital control section consists of the A1 Logic board, the A5 Display and Keyboard Control board, and the A21 HP-IB board.

8-84. A1 MAIN LOGIC

8-85. The A1 board contains the instrument's microprocessor, memory (ROM and RAM), crystal oscillator and divider, VRD control circuits, input port, and front panel control circuits. Overall instrument control--timing for the digital circuits, measurement program selection and execution, response to input commands, etc.--is done by a high speed Z80 microprocessor (A1U4) driven by a 5.76MHz clock. An outline of the digital control operating theory follows.

8-86. 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 (collector of A1Q1) goes LOW. $\overline{\text{RESET}}$ goes LOW whenever the +5V supplied to the A1 board falls below +4.8V (because the instrument has been turned off or has experienced a power loss). Refer to Figure 8-28. A1U2 (voltage detector) detects the low voltage condition and triggers A1U3 (one-shot multivibrator), which turns on A1Q1, generating $\overline{\text{RESET}}$. $\overline{\text{RESET}}$ remains active (LOW) for approximately 500ms after the +5V supply rises above +4.8V. A1Q2 and Q3 provide power to the static RAM (A1U12) and charge the 2.4V Ni-Cd battery on the A6 board during normal operation. When $\overline{\text{RESET}}$ goes LOW, Q2 and Q3 are off and the RAM is powered by the battery.

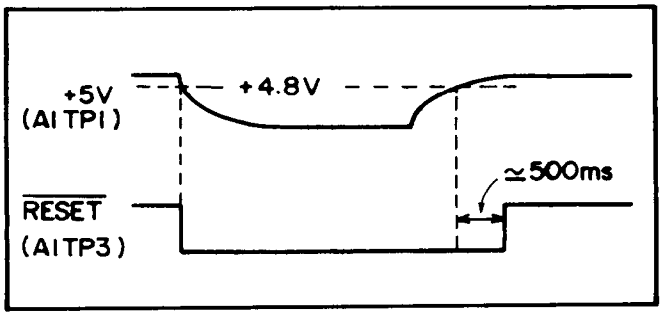


Figure 8-28. Reset Signal.

8-87. MEMORY

8-88. The Program Control ROM has a 24K byte capacity and contains the analog section control programs and digital data processing routines (counting, calculation, data transfer, and storage). To accept the measurement control instructions from the Program ROM, the microprocessor sequentially addresses the ROM through the Address Bus Lines. 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 used on special option (H03 and H04) instruments. The correspondence between address lines A12 through A15 and ROMs U5 through U10 is given in Table 8-10. 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 microprocessor operates in accordance with the instructions and data stored in the ROMs.

Table 8-10. ROM Addresses

Address Lines				Addressed ROM
A15	A14	A13	A12	
LOW	LOW	LOW	LOW	A1U5
LOW	LOW	LOW	HIGH	A1U6
LOW	LOW	HIGH	LOW	A1U7
LOW	LOW	HIGH	HIGH	A1U8
LOW	HIGH	LOW	LOW	A1U9
LOW	HIGH	LOW	HIGH	A1U10

8-89. The microprocessor addresses a 2K byte static RAM (A1U12) and various data bus control devices--A1U26 (Internal I/O Decoder), A1U41 (External I/O Decoder), and A1U35 (Control Signal Buffer)--to sequentially execute the programs stored in the ROMs. The microprocessor uses the static RAM to store front panel control settings when the instrument is turned off and to temporarily store measurement results and data yielded from calculations. A 2.4V Ni-Cd battery on the A6 board powers the RAM when the instrument is turned off or ac power is removed.

Write enable and output enable for the RAM are controlled by the $\overline{\text{WR}}$ and $\overline{\text{ROE}}$ signals, respectively. The chip select signal, generated from address line A15 and the $\overline{\text{MREQ}}$ signal, is output from U24A. $\overline{\text{ROE}}$ enables the ROMs (U5 through U11) also. The $\overline{\text{IORQ}}$ signal enables I/O Decoders and Control Signal Buffer (A1U26, U41, and U35). A1U26, U41, and U35 are selected by address lines A6 and A7. The correspondence between address lines A6 and A7 and the selected control device—A1U26, U41, and U35—is given in Table 8-11.

Table 8-11. Line Control Device Addresses

Address Lines		Addressed Line Control Device
A7	A6	
HIGH	LOW	A1U41
LOW	HIGH	A1U26
HIGH	HIGH	A1U35

8-90. A1U35 provides five signal lines—$\overline{\text{ANACTL1}}$ through $\overline{\text{ANACTL5}}$—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 8-12 for the correspondence between address lines A3 through A5 and I/O lines $\overline{\text{IOEN0}}$ through $\overline{\text{IOEN5}}$.

Table 8-12. I/O Enable Signals

Address Lines			I/O Enable Signal
A5	A4	A3	
LOW	LOW	LOW	$\overline{\text{IOEN0}}$
LOW	LOW	HIGH	$\overline{\text{IOEN1}}$
LOW	HIGH	LOW	$\overline{\text{IOEN2}}$
LOW	HIGH	HIGH	$\overline{\text{IOEN3}}$
HIGH	LOW	LOW	$\overline{\text{IOEN4}}$
HIGH	LOW	HIGH	$\overline{\text{IOEN5}}$

8-91. READ/WRITE CONTROL

8-92. The Read/Write ($\overline{\text{RD}}$, $\overline{\text{WR}}$) timing control signal is sent to the various storage devices, registers, decoders and the HP-IB interface adapter to control the transfer of data as follows:

Read: Causes a selected register or storage device to output stored data, or sets bus driver or HP-IB Interface Adapter to the drive mode. Microprocessor accesses (Reads) the data sent from the addressed device.

Write: Enables a selected register or RAM to store data, or sets decoder or HP-IB Interface Adapter to the receiver mode. Microprocessor sends (writes) data to the enabled device.

Read/Write control is performed in conjunction with the appropriate address signals to enable the correct device for the data transfer.

8-93. 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 the HP-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.

8-94. A1U1 is an 11.5200MHz crystal oscillator. Its output is counted down by U29, U30, U31 and U32 to provide the 5.76MHz clock signal for the microprocessor, the 3.84MHz clock signal for the voltage-ratio detector, the 1.92MHz clock signal for key and display control, and the 8kHz reference signal for the phase-locked loop on the A2 board.

8-95. VRD CONTROL

8-96. The 4277A performs voltage-ratio detection by measuring the time required to charge and discharge the integrator on the A2 board. This is done by A1U39 and related control ICs—U16, U27, and U28. At the start of integration, the ENGT signal goes HIGH, enabling A1U39. Simultaneously, the IOFF signal goes LOW to enable input to the integrator. The integrator starts charging with the voltage from the phase detector, and A1U39 starts counting the pulses of the 3.84MHz clock signal (TCLK) output from A1U16. At the end of the charge period, whose duration is controlled by the microprocessor and varies depending on test frequency and measurement range (refer to Table 8-9), the OUT2 signal goes LOW, forcing the IOFF signal HIGH.

At the start of the integrator discharge period, A1U39 is cleared and enabled, and then begins counting the pulses of the 3.84MHz clock signal. When the integrator is completely discharged (output reaches the voltage determined by the Zero Shift circuit), the Zero Detector on the A2 board sends the $\overline{\text{ZERO}}$ signal, which stops the clock. The time required for the integrator to discharge is indicated by the number in A1U39. See Figure 8-30.

8-97. INPUT PORT

8-98. The Input Port, A1U13 and U14, monitors the status of the CABLE LENGTH Switch and DC BIAS Switch on the front-panel, DC BIAS board installation (Option 001), Trigger, FREQUENCY/DC BIAS Step Control Keys, Bridge Balance condition, Zero Cross, and the SA SELECT Switch (A1S1). The microprocessor accesses the input port via the data bus to read the selected functions after the instrument is turned on and each time a measurement starts.

8-99. FRONT PANEL CONTROL

8-100. A1U25 handles data transfer to and from the A5 board. When a key on the front panel (or on the 16064A, Option 002) is pressed, the KEYINT signal goes HIGH, instructing the microprocessor to read the key status data stored in U25's internal data RAM. The DA and DB output bus lines (DA0 through DA3 and DB0 through DB3) of U25 transfer display data to the cathode drivers on the A5 board.

8-101. A5 DISPLAY

8-102. The A5 board is functionally divided into two sections: the display section and the key control section. The display section consists of a decoder (U2), four anode drivers (U1, U5, U6, U7), an LED cathode driver (U3), a seven-segment display cathode driver (U4, U9), and various LEDs and seven-segment displays.

8-103. A5U2, anode scan decoder, decodes four address signals, SL0 to SL3, sent from the A1 board into sixteen anode drive signals, AD0 to AD15. Each anode drive signal controls one group of display elements. AD7, for example, drives the anodes of DS8, DS52, DS53, and DS54. Accordingly, the display elements of each group are lit for a period equal to 1/16 of the display cycle time. See Figure 8-29. The cathodes of all LEDs are driven by U3. Each LED lights when its cathode drive signal is LOW and its anode drive signal is HIGH.

The numeric displays, DS1 through DS14, are driven by U4 and U9 in response to the BCD data sent from the A1 board via data lines DB0 through DB3. The DB signals address the display segment data stored in U9 (256-bit ROM). Display segment signals, $\overline{\text{SEGA}}$ through $\overline{\text{SEGG}}$, drive the cathodes of the displays.

8-104. A1U8 decodes SL0, SL1, and SL2 into eight key scan signals (KY0 through KY7), which sequentially enable individual key groups. See Figure 8-31. A key group is enabled when its key

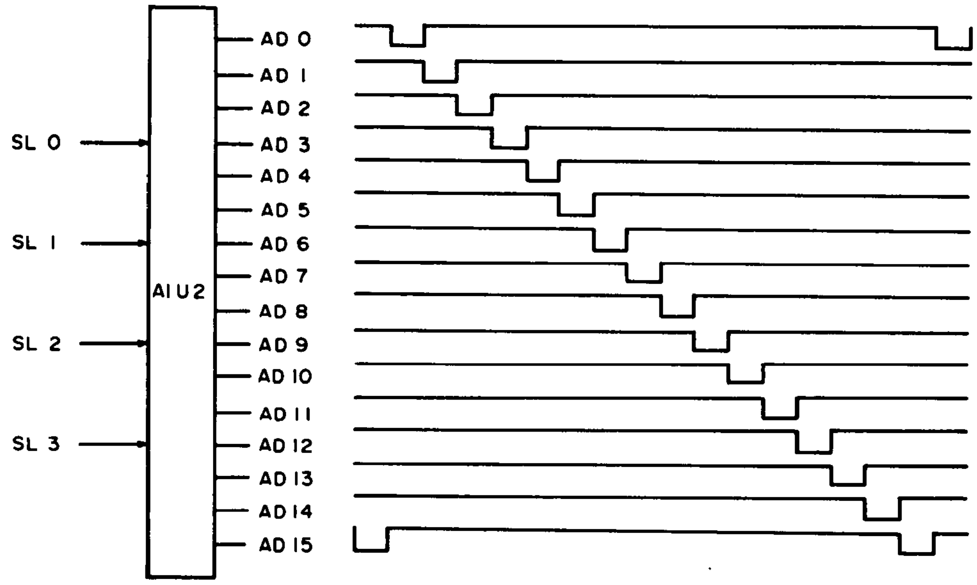
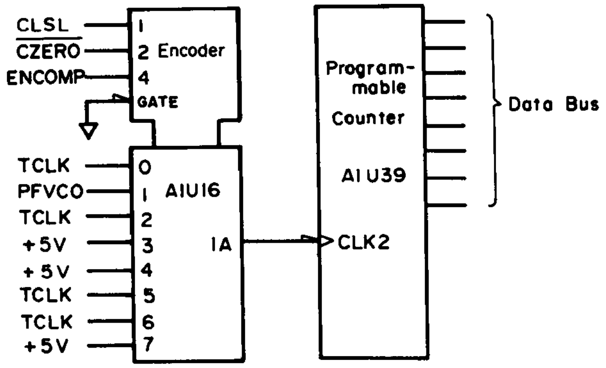
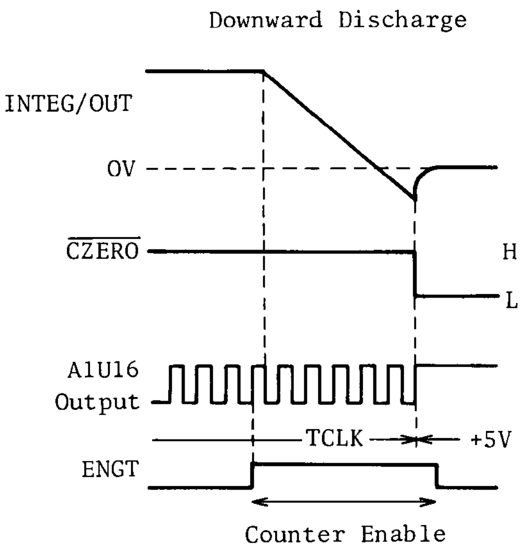


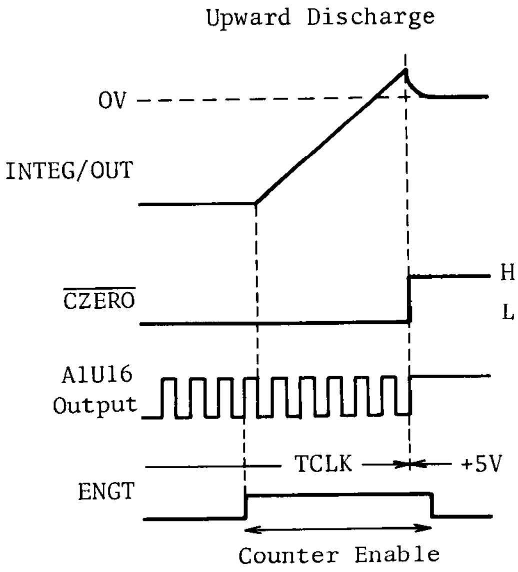
Figure 8-29. A1U2 Anode Scan Decoder Output.



Select Input			A1U16 Output (1A)
4	2	1	
LOW	LOW	LOW	TCLK
LOW	LOW	HIGH	PFVCO
LOW	HIGH	LOW	TCLK
LOW	HIGH	HIGH	+5V
HIGH	LOW	LOW	+5V
HIGH	LOW	HIGH	TCLK
HIGH	HIGH	LOW	TCLK
HIGH	HIGH	HIGH	+5V



Control Signal			A1U16 Output
ENCOMP	$\overline{\text{CZERO}}$	CLSL	
HIGH	HIGH	LOW	TCLK
HIGH	LOW	LOW	+5V



Control Signal			A1U16 Output
ENCOMP	$\overline{\text{CZERO}}$	CLSL	
HIGH	LOW	HIGH	TCLK
HIGH	HIGH	HIGH	+5V

Figure 8-30. VRD Control.

scan signal is LOW. When a key is pressed (for example, the CKT MODE key), the corresponding output line--RL0, RL1, RL2, RL6, and RL7--goes LOW (RL1 for the CKT MODE key) the instant the related key scan signal from U8 goes LOW. In addition to RL0, RL1, RL2, RL6, and RL7 there are three similar signals--CRL3, CRL4, CRL5--from the keyboard of the 16064A (Option 002). These eight signal are encoded by A1U25. The encoded 3-bit data is stored in a register in A1U25, where it can be read by the microprocessor via the data bus.

8-105. A21 HP-IB

8-106. All HP-IB interface functions are handled by A21U4 HP-IB interface chip. The interface chip controls the "handshake" between the microprocessor and external HP-IB equipment. The architecture of the interface chip's internal register is shown in Figure 8-32. The eight pairs of registers in the interface chip store data transferred to and from peripherals as directed by asynchronous operation of the control bus signals. Each register pair corresponds to one line of the 8-bit data bus. The address lines (BA0 to BA2) select the internal register of the interface chip which is to store or write out the data.

When the instrument is turned on, the $\overline{\text{IOEN5}}$ control line is set to LOW. The microprocessor reads the HP-IB address stored in A21U1 and then displays the address, in decimal, on the front panel. When an interrupt control request from the external HP-IB controller pulls down the $\overline{\text{IBINT}}$ output line of the interface chip, the microprocessor responds to the interrupt input.

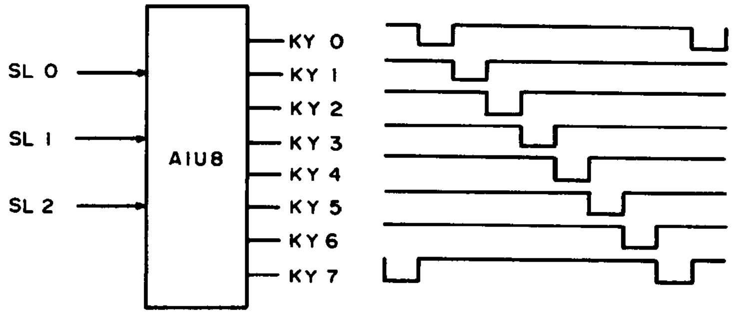


Figure 8-31. A1U8 Key Scan Decoder Output.

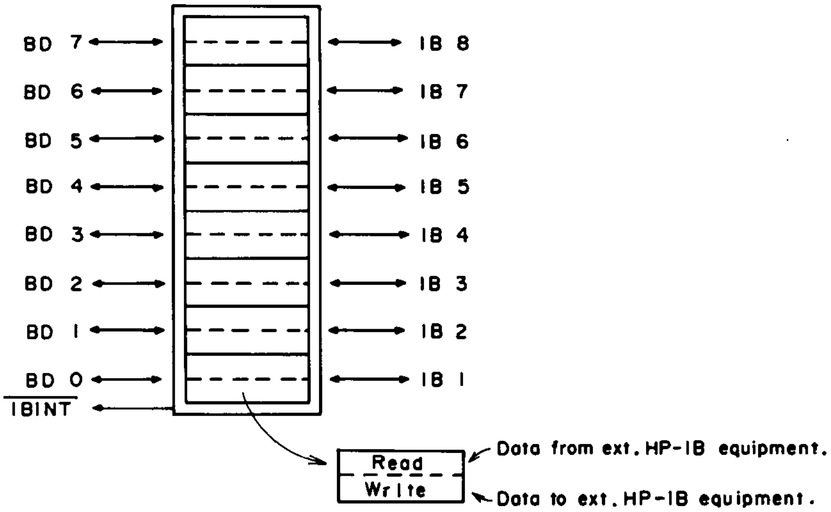


Figure 8-32. HP-IB Interface Adapter Internal Register Configuration.

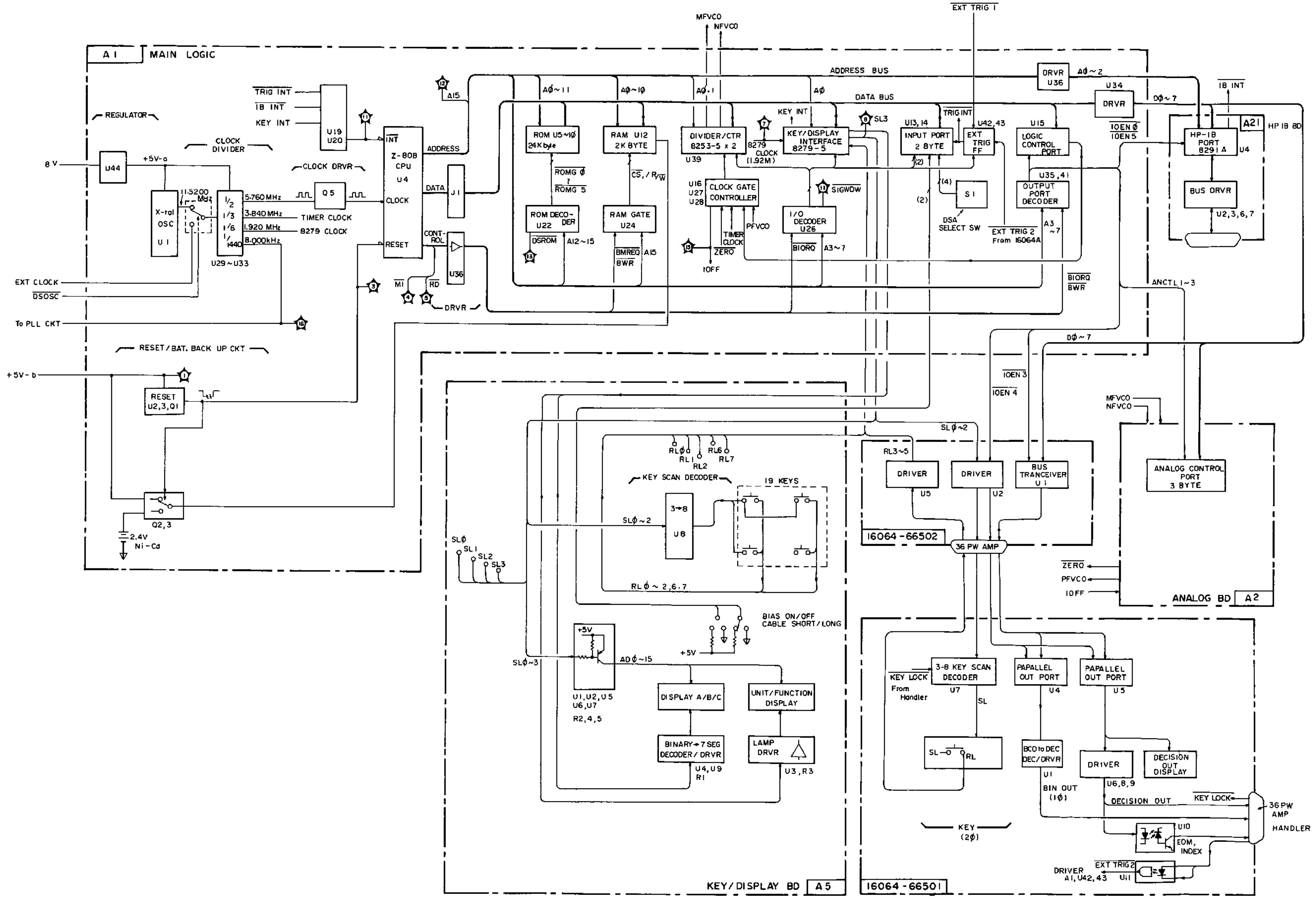


Figure 8-33. Digital Control Section Block Diagram.

DIGITAL BLOCK DIAGRAM
SEE INSIDE

8-107. OPTIONS

8-108. The theory of operation for the 4277A's optional circuits is outlined in the following paragraphs.

8-109. OPTION 001 INTERNAL DC BIAS (A22)

8-110. The A22 board primarily contains a DAC (A22U3) and an output amplifier, as shown in Figure 8-34. The DAC outputs a dc voltage whose polarity and magnitude are determined by the reference voltage, V_{ref}, and the digital data sent from the microprocessor and stored in latches U1 and U2. Output voltage is calculated as follows:

$$Vout = -V_{ref} \cdot \sum_{n=1}^{10} Bn \cdot 2^{-n}$$

(Bn: 0 or 1)

where V_{ref} is determined as follows:

Internal DC Bias Voltage Range	V_{ref}
.00V to 40.0V	-6.3V
-.01V to -40.0V	+6.3V

The output from the 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 $\overline{\text{IOEN1}}$ and $\overline{\text{IOEN2}}$ 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.

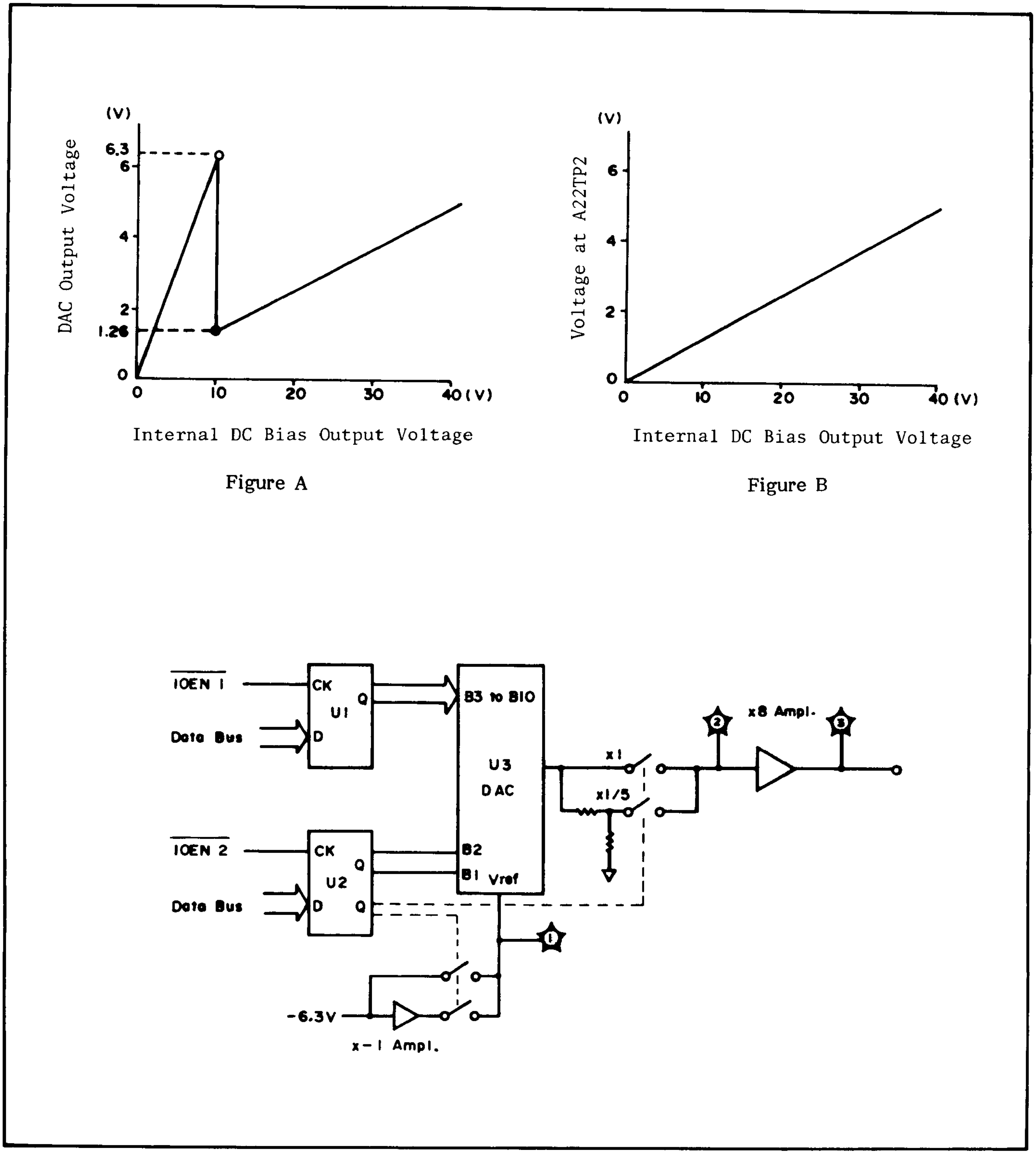


Figure A

Figure B

Figure 8-34. A22 Board Block Diagram.

8-111. TIMING DIAGRAM DISCUSSION

8-112. Figure 8-27 shows the timing diagram for the various signals necessary for VRD operation. A brief explanation of the signals shown in the diagram is given below. When the instrument is triggered (internally or externally), bridge balance detection is performed for at least 2.5ms. The $\overline{\text{UNCAL}}$ signal can be either HIGH or LOW during the bridge balance detection period. If the bridge is not balanced at the end of this period, $\overline{\text{UNCAL}}$ will be LOW, instructing the microprocessor to wait an additional 20ms (max.). If, after the additional 20ms period, the bridge is still not balanced, the microprocessor will display OF or UF on DISPLAY A. If the bridge becomes balanced at any time during the additional 20ms period, the measurement will begin. At the end of the bridge balance detection, the PSCH signal goes HIGH. Auto Zero is performed when the AZT signal goes HIGH. The time required for Auto Zero depends on test frequency. Refer to the table given in Figure 8-27, sheet 1 of 2.

If the test frequency is 505kHz or higher, Auto Phase Adjust will be performed after Auto Zero. IRST and IOFF are both LOW during the 2.5ms required for Auto Phase Adjust. After Auto Zero and Auto Phase Adjust, the A-D converter is operated three times to measure the vector-voltage ratios in accordance with the programmed measurement sequence. Charge and discharge voltages are determined by the ERR and EDUT signals. Integration is performed while the IOFF signal is LOW. Before the integrator is discharged, a polarity check is performed to determine the discharge direction. During discharge, the ZST signal goes HIGH and Zero Shift is performed. The PSFT (phase shift) signal goes LOW briefly before Auto Zero, Auto Phase Adjust, integrator charge, and integrator discharge. The number of PSFT pulses is controlled so that the phase reference signals used for phase detection have the correct phase angle. Refer to Table 8-8. The pulse width of the PSFT signal depends on the test frequency. Refer to the table given in Figure 8-27, sheet 1 of 2.

8-113. TROUBLESHOOTING

8-114. Board level isolation of most instrument failures can be quickly accomplished by using the troubleshooting flow diagram given in Figure 8-40. When the faulty board has been isolated, proceed to the component level troubleshooting flow diagram for that board. Table 3-3 lists error codes for the ROM/RAM Self Test, which is performed when the instrument is turned on.

8-115. WARNINGS and CAUTIONS

8-116. Warnings and cautions are given throughout the troubleshooting and repair procedures to ensure the safety of service personnel and to protect the instrument against possible damage.

CAUTION

THE OPENING OF COVERS OR REMOVAL OF PARTS, EXCEPT THOSE TO WHICH ACCESS CAN BE GAINED BY HAND, IS LIKELY TO EXPOSE ELECTRICALLY LIVE PARTS AND TERMINALS.

THE INSTRUMENT SHOULD BE DISCONNECTED FROM ALL VOLTAGE SOURCES BEFORE ANY ADJUSTMENT, PARTS REPLACEMENT, OR MAINTENANCE/REPAIR, FOR WHICH THE INSTRUMENT MUST BE OPENED, IS PERFORMED.

IF ADJUSTMENT, MAINTENANCE, OR REPAIR MUST BE PERFORMED WITH VOLTAGE APPLIED, IT SHOULD BE PERFORMED BY QUALIFIED SERVICE PERSONNEL AWARE OF THE HAZARDS INVOLVED.

WARNING

WHENEVER IT IS LIKELY THAT THE PROTECTION PROVIDED BY THE FUSES HAS BEEN IMPAIRED, THE INSTRUMENT MUST BE MADE INOPERATIVE AND MUST BE SECURED AGAINST ANY UNINTENDED OPERATION.

CAUTION

CAPACITORS INSIDE THE INSTRUMENT MAY MAINTAIN A CHARGE EVEN IF THE INSTRUMENT HAS BEEN DISCONNECTED FROM ALL VOLTAGE SOURCES FOR AN EXTENDED PERIOD. BE SURE THAT ONLY FUSES OF THE REQUIRED RATES CURRENT AND OF THE SPECIFIED TYPE ARE USED FOR REPLACEMENT. THE USE OF MENDED FUSES OR SHORT-CIRCUITING OF FUSE HOLDERS MUST BE AVOIDED.

8-117. REPAIR

WARNING

DISCONNECT THE INSTRUMENT FROM THE AC SOURCE BEFORE PROCEEDING WITH REPAIR.

8-118. Board assembly locations are shown in Figure 8-36. Graphic symbols used in the schematic diagrams are explained in Figure 8-37.

8-119. A5 DISPLAY BOARD DISASSEMBLY

8-120. To troubleshoot or replace a component on the A5 Display board or on the front panel assembly, perform the following procedure.

(1) Remove the top cover.

(2) Carefully remove the top trim strip from the front frame (use a screwdriver to lift out the trim).

(3) Remove the three screws from the top of the front frame.

(4) Stand the instrument on its side.

(5) Remove the three screws from the bottom of the front frame.

(6) Firmly press the front panel assembly forward from inside the instrument until it is clear of the frame. Do not allow the cables connected between the front panel and the mother board to become taut. See Figure 8-35.

(7) Remove the eleven screws securing the A5 board to the front panel assembly.

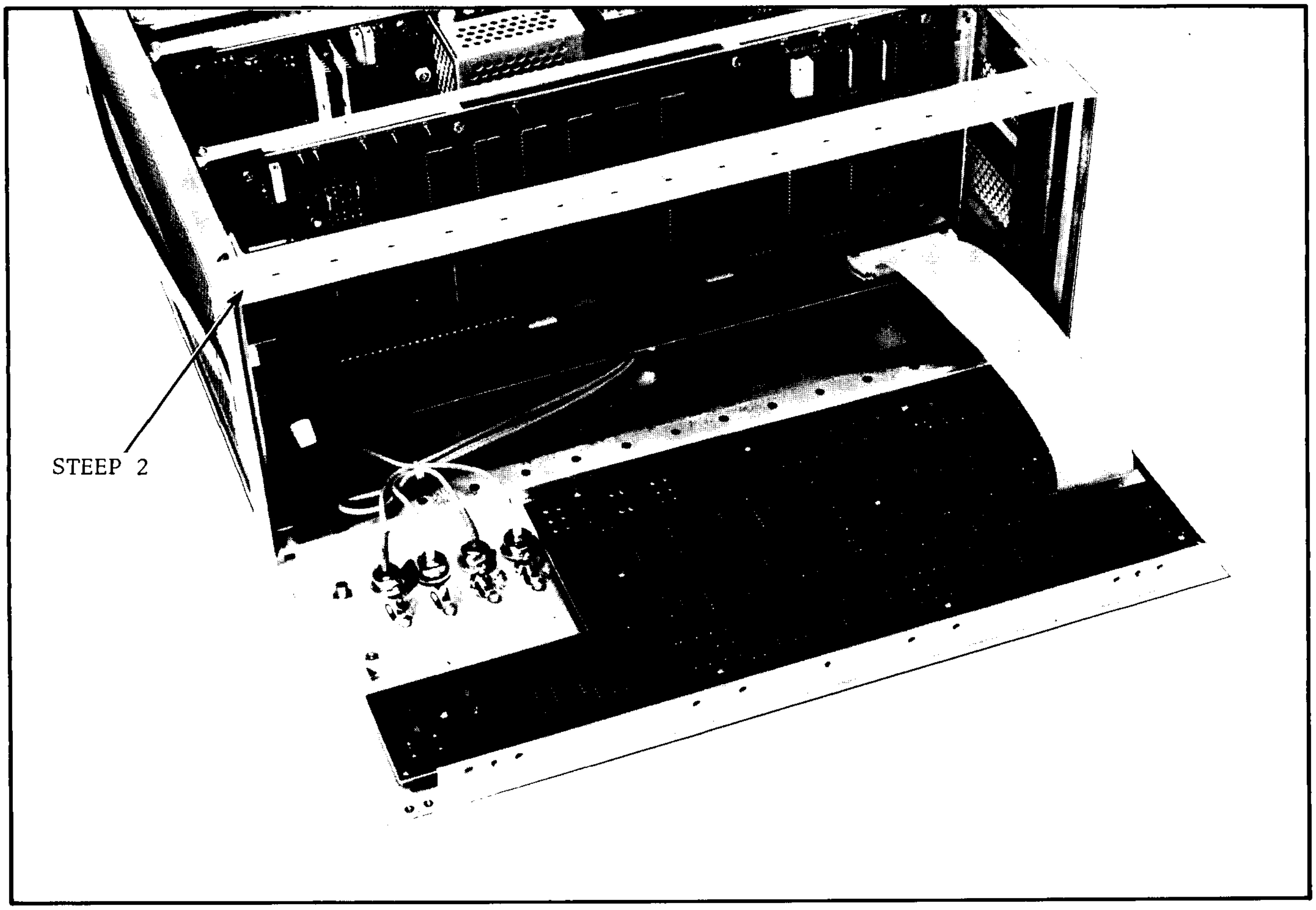
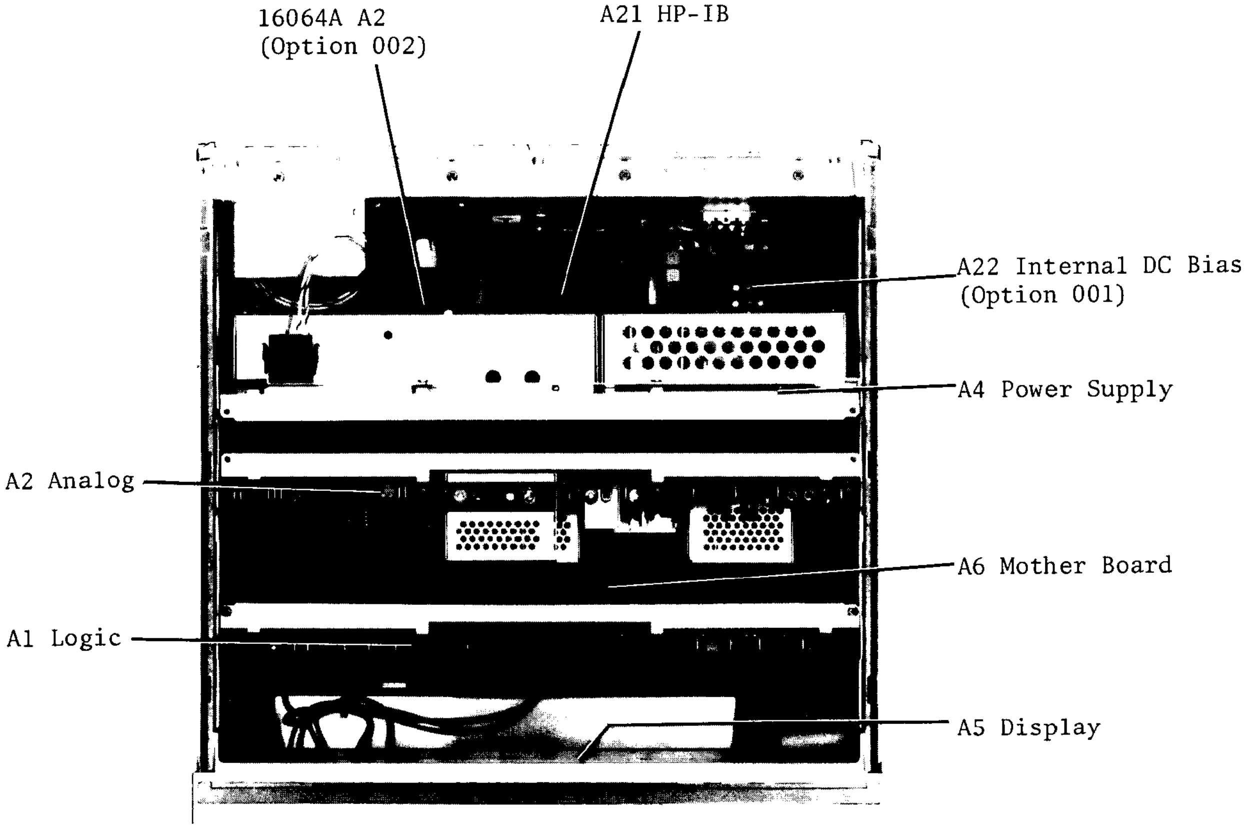


Figure 8-35. A5 Display Board Disassembly.



A1 Logic Board: P/N 04277-66501
A2 Analog Board: P/N 04277-66502
A4 Power Supply Board: P/N 04277-66504
A5 Display Board: P/N 04277-66505
A6 Mother Board: P/N 04276-66506
A21 HP-IB Board: P/N 04276-66521
A22 Internal DC Bias Board: P/N 04276-66522
16064A A2 Board: P/N 16064-66502

P/N: Part Number

Figure 8-36. Assembly Locations (Top View).

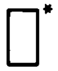
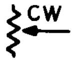
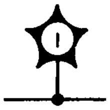
P/O	Part of.
○	Knob control.
⊘	Screwdriver adjustment.
——— - - ———	Circuit assembly boarderline.
*	Asterisk denotes a factory selected value. Value shown is typical, part may be omitted.
	Bead inductance.
	Circuit board pattern inductance.
———	Heavy line indicates main signal path.
▬ ▬ ▬	Heavy dashed 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.
-(947)-	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 8-37. Schematic Diagram Notes.

8-121. PRODUCT SAFETY CHECKS

WARNING

WHENEVER IT APPEARS LIKELY THAT SAFETY PROTECTIVE PROVISIONS HAVE BEEN IMPAIRED, THE INSTRUMENT MUST BE MADE INOPERATIVE AND MUST BE SECURED AGAINST ANY UNINTENDED OPERATION. SAFETY PROTECTION MAY BE COMPROMISED IF, FOR EXAMPLE:

- THE INSTRUMENT SHOWS VISIBLE DAMAGE.
- THE INSTRUMENT FAILS TO PERFORM THE INTENDED MEASUREMENT.
- THE INSTRUMENT HAS UNDERGONE PROLONGED STORAGE UNDER UNFAVORABLE CONDITIONS.
- THE INSTRUMENT HAS SUFFERED SEVERE STRESS DURING SHIPMENT.

8-122. The following five checks are recommended to verify the product safety of the 4277A instrument (these checks may also be done to check for product safety after troubleshooting and repair). When such checks are needed, perform the following:

(1) Visually inspect the interior of instrument for any signs of abnormal internally generated heat, such as discolored printed circuit boards or components, damaged insulation, or evidence of arcing. Determine and remedy cause of any such condition.

(2) Using a suitable ohmmeter, measure the resistance from the instrument's chassis to the ground pin on the power cord plug. The reading must be less than 0.5 ohms. Flex the power cord while making this measurement to determine whether intermittent discontinuities exist.

(3) Check the GUARD terminal on the front panel using procedure (2).

(4) Disconnect the instrument from the power source. Turn power switch to on. Measure the resistance from the instrument's chassis to line and neutral (tied together). The minimum acceptable resistance is two megohms. Replace any component which fails or causes a failure.

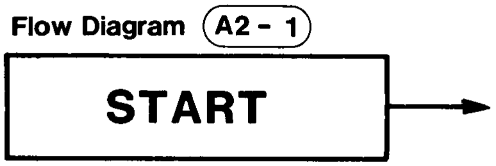
(5) Verify that the line fuse is installed and that it is of the correct rating.

FLOW DIAGRAM NOTES

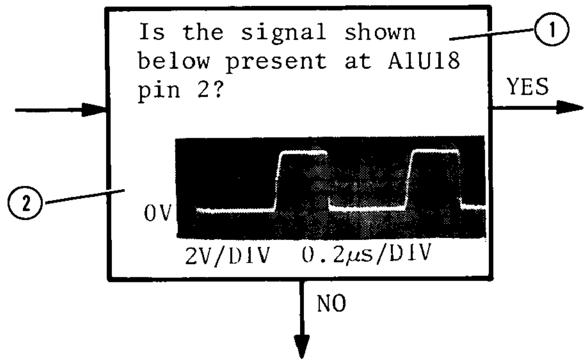
Digital Section Troubleshooting Notes

There are ten digital section troubleshooting flow diagrams--nine for the A1 Logic Board and one for the A5 Display board. These flow diagrams provide the instructions, signature analyzer control settings, and signature analyzer probe and connection points necessary for component level troubleshooting. Signature Analysis is used to troubleshoot the Digital Section of the 4277A. If you are not familiar with signature analysis, refer to Figure 8-39. It gives a brief description of the technique.

Troubleshooting Flow Diagram Notes



Indicates the lead-in, or initial, troubleshooting flow diagram for a faulty board isolated by the Board Isolation Flow Diagram.



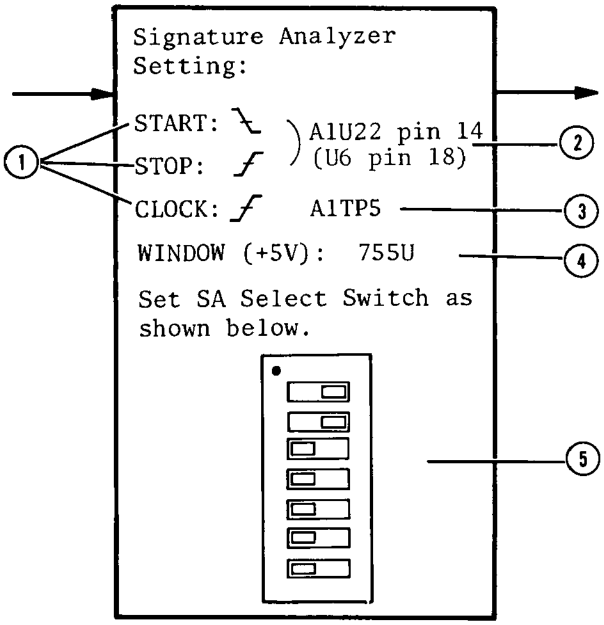
① Compare the actual (observed) signal with the one given in the figure ②.

② Connect the 1740A (recommended oscilloscope) to A1U18 pin 2. Set the 1740A's controls as follows when using a 10:1 divider probe:

VOLT/DIV ·········· 0.2
TIME/DIV ··········· 0.2μs

Figure 8-38. Flow Diagram Notes (Sheet 1 of 2).

FLOW DIAGRAM NOTES



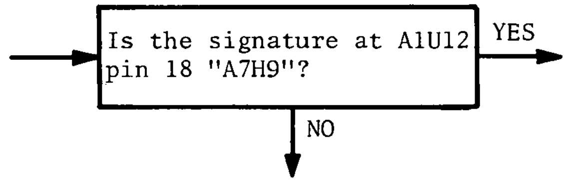
① Set the Signature Analyzer's START, STOP and CLOCK controls as indicated (╱: ■ OUT) (╲: ▄ IN).

② Connect both the START and STOP leads of the Signature Analyzer's active pod to the indicated points. In the example given, START and STOP should be connected to A1U22 pin 14 (or U6 pin 18).

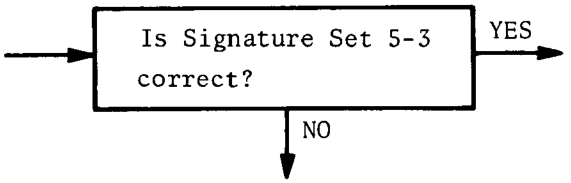
③ Connect the CLOCK lead of the Signature Analyzer's active pod to the indicated point. In the example given, CLOCK should be connected to A1TP5.

④ This is the signature for the window test (+5V). It should be displayed on the signature analyzer. If the correct signature is not displayed, press the RESET button on the probe. If the window is still incorrect, check the component from which the window signal or clock signal is taken. In the example given, this would be A1U22 and the component directly connected to A1TP5.

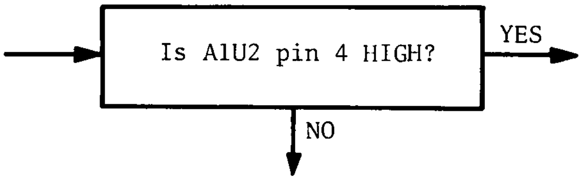
⑤ Set the bit-switches of the indicated switch as shown. In the example given, A1S1 should be set to 0011111. After troubleshooting, set A1S1 to its initial setting (1111111).



Check that the signature at A1U12 pin 18 is A7H9.



Check the signatures listed in the table titled Signature Set 5-3. The table is included in the flow diagram.



Check that the logic level at A1U2 pin 4 is HIGH.

Figure 8-38. Flow Diagram Notes (Sheet 2 of 2).

Signature Analysis

Signature Analysis is a unique technique for component-level troubleshooting. The signature analyzer detects and displays the unique digital signature of the data at a given node in the circuit under test. By comparing the actual signature to the correct one, the service technician can quickly back-trace to the faulty node, and, ultimately, to the faulty component. To represent the signature, a nonstandard character set (0123456789 ACFHPU) was chosen for readability and compatibility with 7-segment displays.

Stated simply, the signature analyzer displays a compressed four-digit "fingerprint" of the data stream present at a node. This "fingerprint" is unique for a good node. Any fault associated with a device on that node will force a change in the data stream and, consequently, result in an incorrect signature. If, for example, the signature at the input of a device is correct but the signature at the output is not, the device is regarded as faulty and should be replaced.

This technique is especially useful in troubleshooting microprocessor based instruments like the 4277A, where data streams are long and complex and where there are no conventional means to efficiently troubleshoot to the component level.

The signature analyzer's active logic probe and active pod detect and develop the signature for display on the signature analyzer. The logic probe is applied to the desired node in the circuit under test and transfers the data to the signature analyzer. The four leads on the active pod are connected to appropriate points on the 4277A, and provide the necessary START, STOP, and CLOCK signals and GND reference. The START signal opens the measurement "window" and instructs the signature analyzer to prepare to receive data from the logic probe; the STOP signal closes the "window." The CLOCK signal provides the appropriate measurement timing pulses. Probe points; connection locations for START, STOP, and CLOCK; and control settings for the signature analyzer are given in the troubleshooting flow diagrams.

MEASUREMENT GATING EXAMPLE, POSITIVE EDGE START, STOP, AND CLOCK

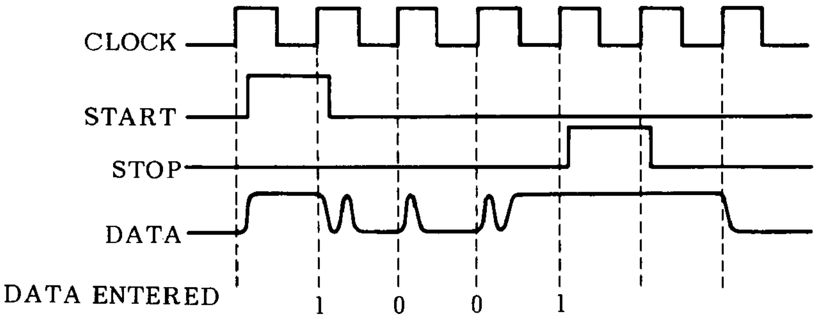
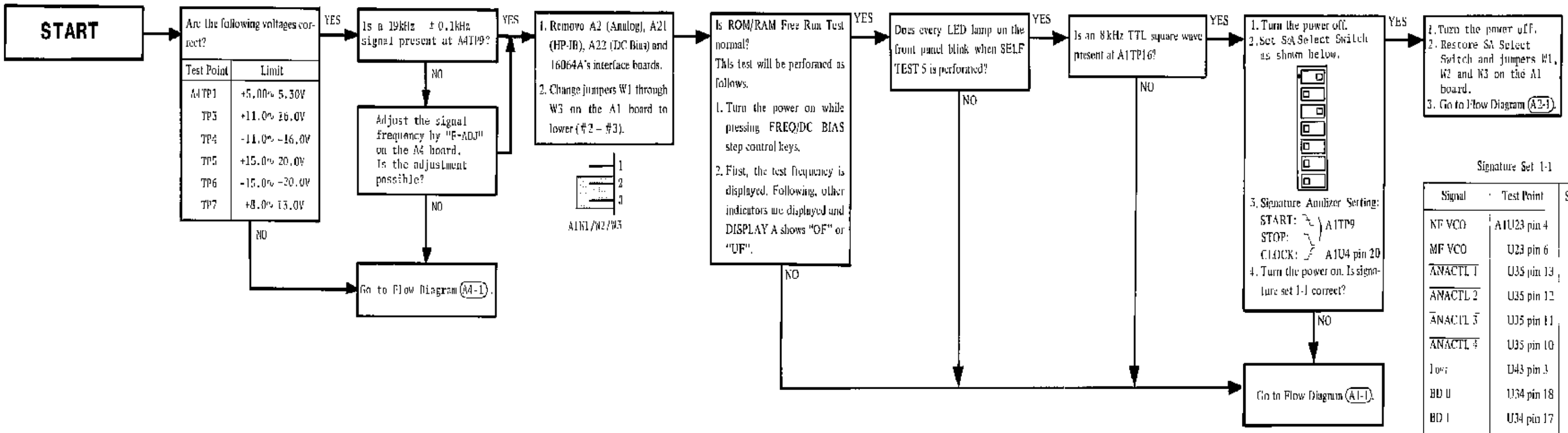


Figure 8-39. Signature Analysis.

Board Isolation Flow Diagram



Signature Set 1-1

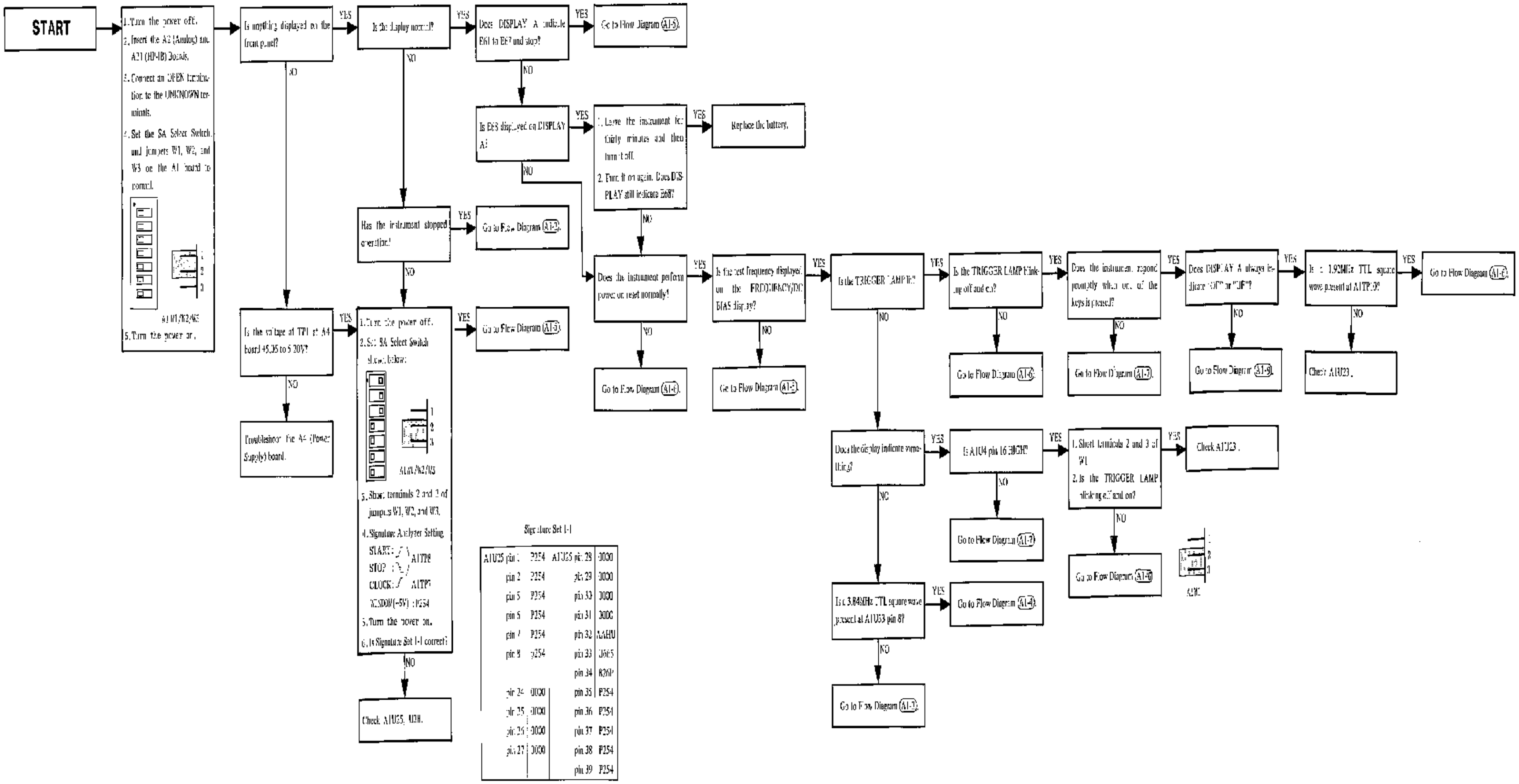
Signal	Test Point	Signature
NF VCO	A1U23 pin 4	CF47
MF VCO	U23 pin 6	F3C8
$\overline{\text{ANACTL 1}}$	U35 pin 13	K4U4
$\overline{\text{ANACTL 2}}$	U35 pin 12	P4P5
$\overline{\text{ANACTL 3}}$	U35 pin 11	7FP4
$\overline{\text{ANACTL 4}}$	U35 pin 10	44A6
Low	U43 pin 3	4625
BD 0	U34 pin 18	6UAC
BD 1	U34 pin 17	2P3P
BD 2	U34 pin 16	708A
BD 3	U34 pin 15	U5PF
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

Figure 8-40. Board Isolation Troubleshooting Flow Diagram.

Board Isolation Troubleshooting Flow Diagram

SEE INSIDE

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	000C
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

Figure 8-41. A1 LOGIC Board Troubleshooting Flow Diagram (Sheet 1 of 7).

A1 Troubleshooting Flow Diagram (Sheet 1 of 7)

SEE INSIDE

Flow Diagram (A1 - 2)

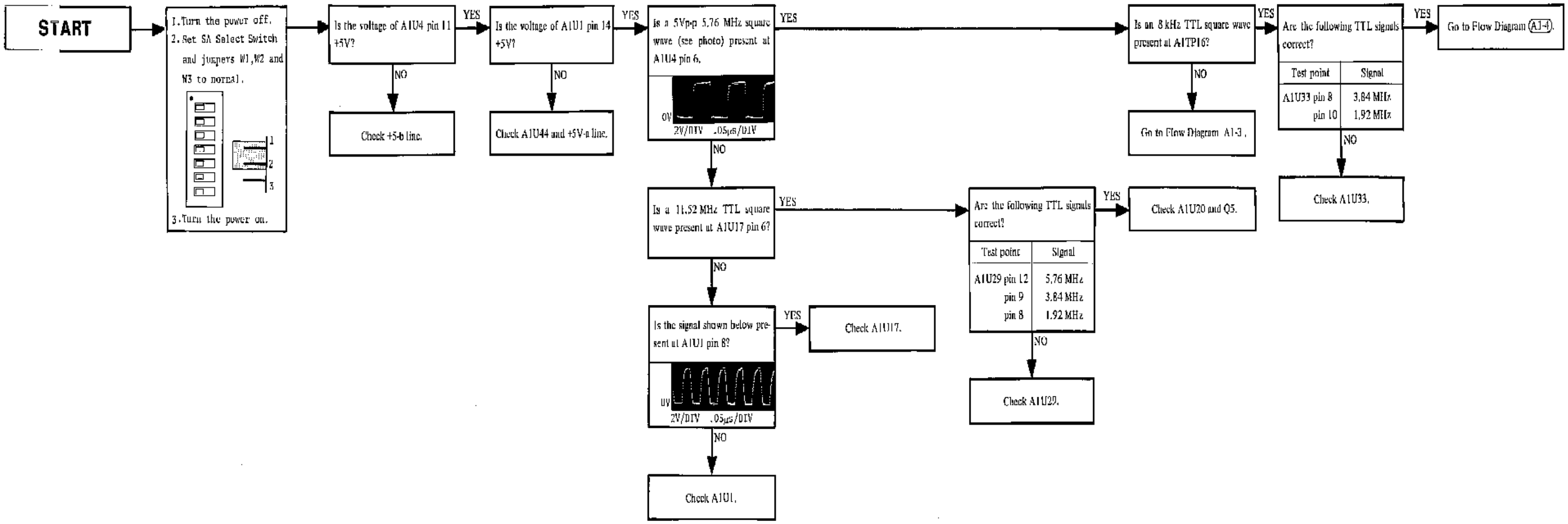


Figure 8-41. A1 LOGIC Board Troubleshooting Flow Diagram (Sheet 2 of 7).

A1 Troubleshooting Flow Diagram (Sheet 2 of 7)

SEE INSIDE

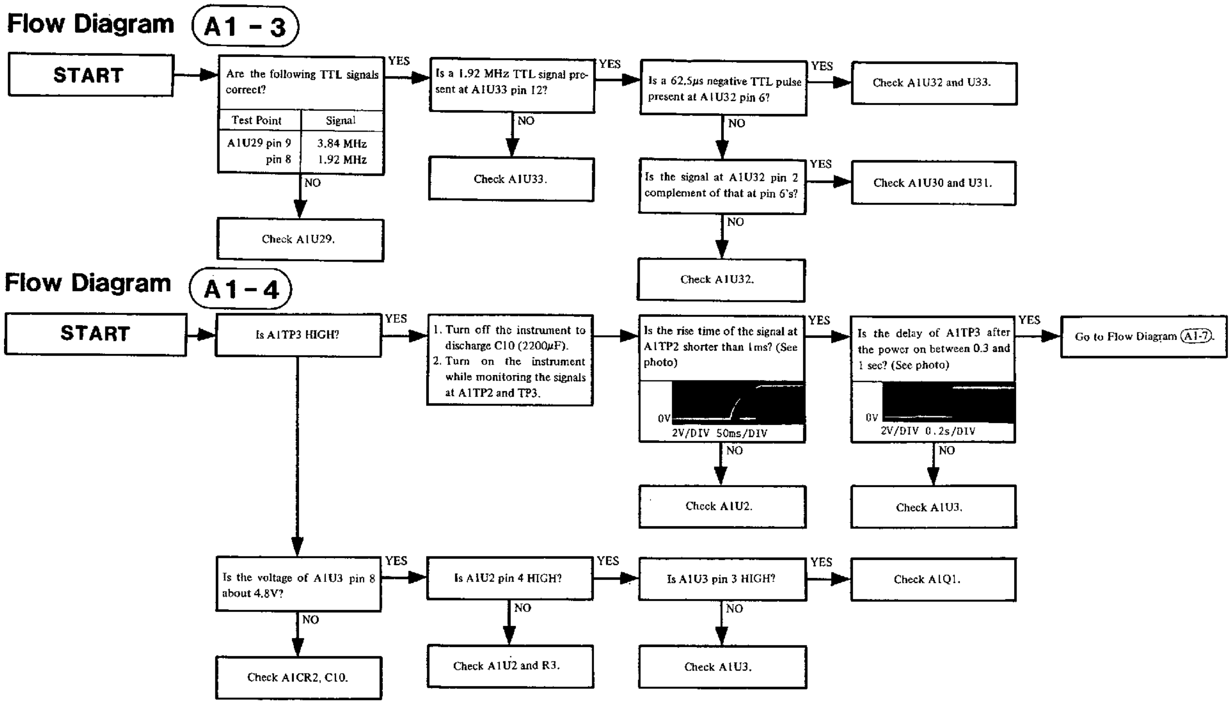
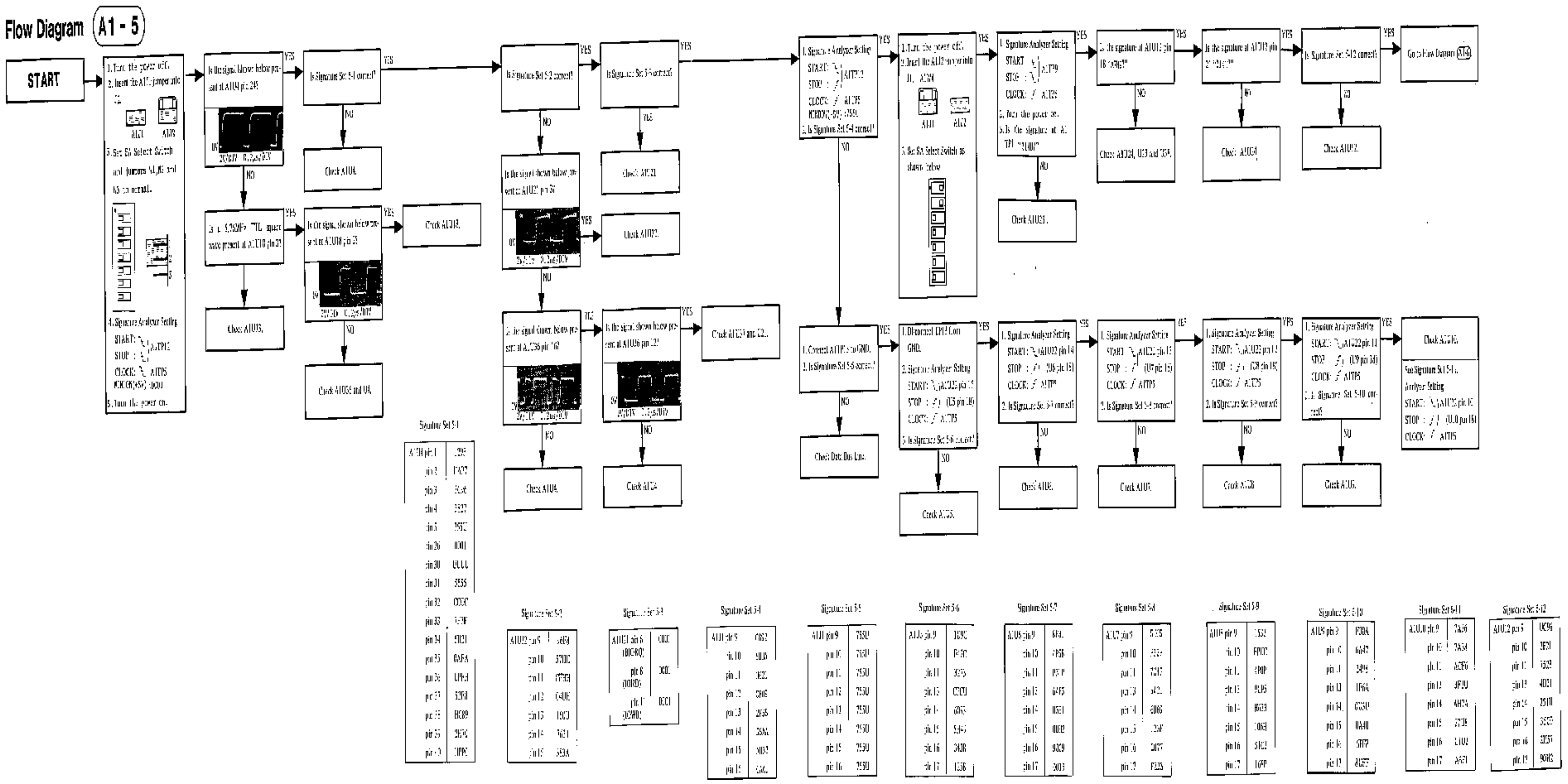


Figure 8-41. A1 LOGIC Board Troubleshooting Flow Diagram (Sheet 3 of 7).

A1 Troubleshooting Flow Diagram (Sheet 3 of 7)

SEE INSIDE



Signature Set 5-1

A1U4 pin 1	[illegible]
pin 2	FA07
pin 3	[illegible]
pin 4	[illegible]
pin 5	[illegible]
pin 26	0001
pin 30	UUUU
pin 31	5555
pin 32	CCCC
pin 33	[illegible]
pin 34	5U21
pin 35	0AFA
pin 36	UP[illegible]
pin 37	52P8
pin 38	HC89
pin 39	2U7C
pin 40	1PPC

Signature Set 5-2

A1U22 pin 9	[illegible]
pin 10	57UC
pin 11	[illegible]
pin 12	C4UE
pin 13	19C0
pin 14	[illegible]
pin 15	553A

Signature Set 5-3

A1U31 pin 6 (IORQ)	0000
pin 8 (IORD)	0001
pin 11 (IOWR)	0001

Signature Set 5-4

A1U1 pin 9	0852
pin 10	9U36
pin 11	[illegible]
pin 12	[illegible]
pin 13	2F55
pin 14	3A8A
pin 15	5U32
pin 16	[illegible]

Signature Set 5-5

A1U1 pin 9	755U
pin 10	755U
pin 11	7550
pin 12	7550
pin 13	7550
pin 14	7550
pin 15	7550
pin 16	7550

Signature Set 5-6

A1U5 pin 9	0890
pin 10	P490
pin 11	3275
pin 13	C7C0
pin 14	6965
pin 15	5945
pin 16	3408
pin 17	1556

Signature Set 5-7

A1U6 pin 9	6F8U
pin 10	4P58
pin 11	P57P
pin 13	64F5
pin 14	0521
pin 15	0082
pin 16	9029
pin 17	3003

Signature Set 5-8

A1U7 pin 9	5335
pin 10	[illegible]
pin 11	7217
pin 13	[illegible]
pin 14	2066
pin 15	125F
pin 16	2077
pin 17	F225

Signature Set 5-9

A1U8 pin 9	1532
pin 10	FP0C
pin 11	4P0P
pin 13	9UP5
pin 14	H033
pin 15	1063
pin 16	5702
pin 17	169P

Signature Set 5-10

A1U9 pin 9	F00A
pin 10	6A47
pin 11	2495
pin 13	1F6A
pin 14	C05P
pin 15	0A40
pin 16	5FFP
pin 17	8U57

Signature Set 5-11

A1U10 pin 9	7A36
pin 10	7A34
pin 11	A2F6
pin 12	4F99
pin 14	4H74
pin 15	2709
pin 16	1102
pin 17	A671

Signature Set 5-12

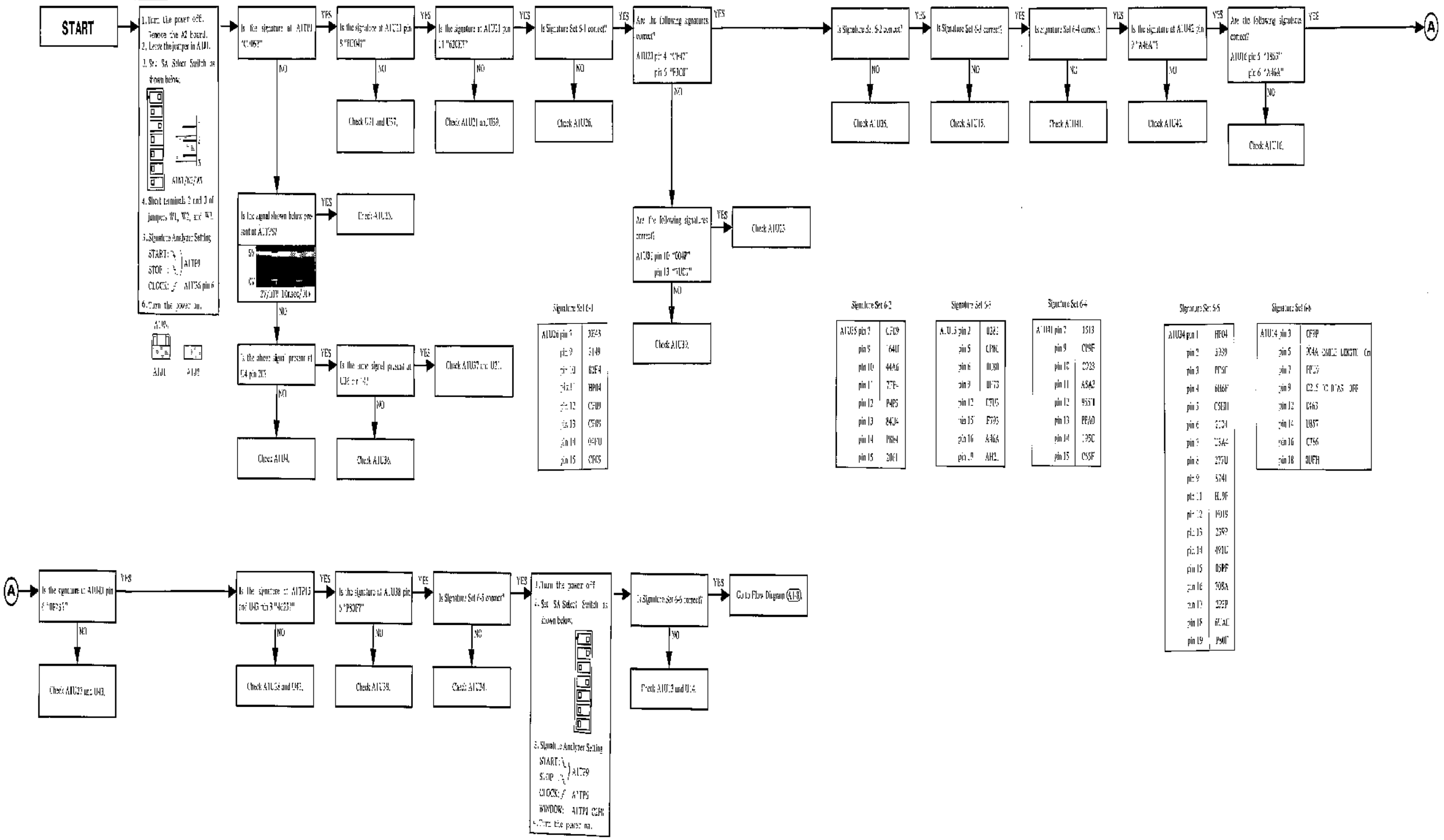
A1U12 pin 5	UC96
pin 10	3F21
pin 11	7529
pin 13	4031
pin 14	2511
pin 15	3555
pin 16	2057
pin 19	90H3

Figure 8-41. A1 LOGIC Board Troubleshooting Flow Diagram (Sheet 4 of 7).

A1 Troubleshooting Flow Diagram (Sheet 4 of 7)

SEE INSIDE

Flow Diagram (A1 - 6)



Signature Set 6-1

A1U26 pin 7	3E43
pin 9	5149
pin 10	82F4
pin 11	HP04
pin 12	CFU9
pin 13	CF89
pin 14	04FU
pin 15	CFC5

Signature Set 6-2

A1U35 pin 2	CFC9
pin 9	164U
pin 10	44A6
pin 11	77F-
pin 12	P4P5
pin 13	84J4
pin 14	P884
pin 15	2061

Signature Set 6-3

A1U15 pin 2	0281
pin 5	CP8C
pin 6	0080
pin 9	UF73
pin 12	C7U5
pin 15	F595
pin 16	A46A
pin 19	AH2L

Signature Set 6-4

A1U41 pin 7	1513
pin 9	C09F
pin 10	C023
pin 11	A5A2
pin 12	9557
pin 13	PEA0
pin 14	195C
pin 15	C55F

Signature Set 6-5

A1U34 pin 1	HE04
pin 2	5389
pin 3	PP5C
pin 4	6H6F
pin 5	C5EH
pin 6	2234
pin 7	23A4
pin 8	277U
pin 9	5741
pin 11	HL9F
pin 12	P015
pin 13	2592
pin 14	491U
pin 15	05PF
pin 16	908A
pin 17	225P
pin 18	6CAC
pin 19	P90F

Signature Set 6-6

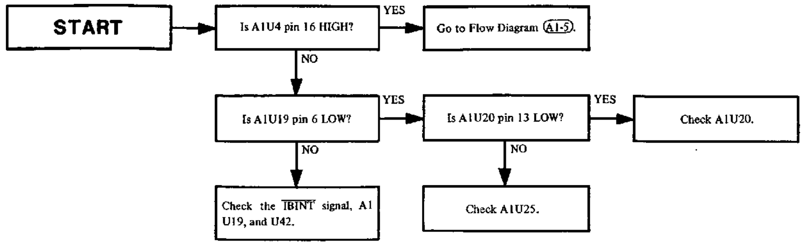
A1U14 pin 3	CF9P
pin 5	9C4A
pin 7	PPC7
pin 9	C315
pin 12	C463
pin 14	1857
pin 16	C756
pin 18	0UFH

Figure 8-41. A1 LOGIC Board Troubleshooting Flow Diagram (Sheet 5 of 7).

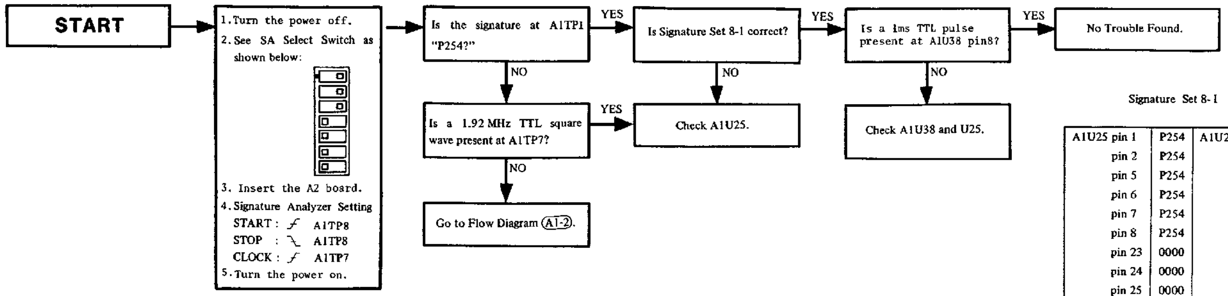
A1 Troubleshooting Flow Diagram (Sheet 5 of 7)

SEE INSIDE

Flow Diagram (A1 - 7)



Flow Diagram (A1 - 8)



Signature Set 8-1

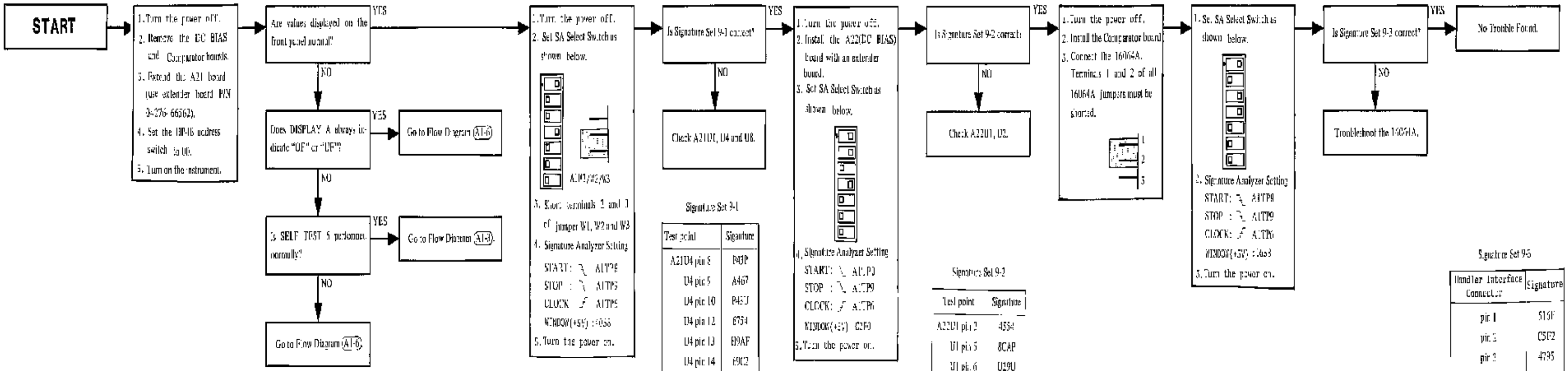
A1U25 pin 1	P254	A1U25 pin 28	0000
pin 2	P254	pin 29	0000
pin 5	P254	pin 30	0000
pin 6	P254	pin 31	0000
pin 7	P254	pin 32	AAHU
pin 8	P254	pin 33	U665
pin 23	0000	pin 34	826P
pin 24	0000	pin 35	P254
pin 25	0000	pin 36	P254
pin 26	0000	pin 37	P254
pin 27	0000	pin 38	P254
		pin 39	P254

Figure 8-41. A1 LOGIC Board Troubleshooting Flow Diagram (Sheet 6 of 7).

A1 Troubleshooting Flow Diagram (Sheet 6 of 7)

SEE INSIDE

Flow Diagram (A1 - 9)



Signature Set 9-1

Test point	Signature
A21U4 pin 8	P43P
U4 pin 9	A467
U4 pin 10	P45U
U4 pin 12	6754
U4 pin 13	H9AF
U4 pin 14	69C2
U4 pin 15	C360
U4 pin 16	2A2A
U4 pin 17	52HA
U4 pin 18	3U34
U4 pin 19	U13H
U4 pin 21	0301
U4 pin 22	0099
U4 pin 23	033A

Signature Set 9-2

Test point	Signature
A22U1 pin 2	4554
U1 pin 5	8CAP
U1 pin 6	U29U
U1 pin 9	74C.
U1 pin 11	47H4
U1 pin 12	3N9U
U1 pin 15	U33H
U1 pin 16	34H2
U1 pin 19	25C7
U2 pin 2	F5F2
U2 pin 5	57UF
U2 pin 11	1PC7
U2 pin 12	66U9
U2 pin 15	49CH
U2 pin 16	870P
U2 pin 19	2489

Signature Set 9-3

Handler Interface Connector	Signature
pin 1	515F
pin 2	C5F2
pin 3	4795
pin 4	CPCP
pin 5	F22C
pin 6	7F61
pin 7	2344
pin 8	8F136
pin 9	HC1U
pin 10	9831
pin 19	2C60
pin 20	F337
pin 21	4881
pin 22	U68F
pin 23	3349
pin 24	2666

Figure 8-41. A1 LOGIC Board Troubleshooting Flow Diagram (Sheet 7 of 7).

A1 Troubleshooting Flow Diagram (Sheet 7 of 7)

SEE INSIDE

7 of 7)

Flow Diagram (A2 - 1) (A2 board block isolation)

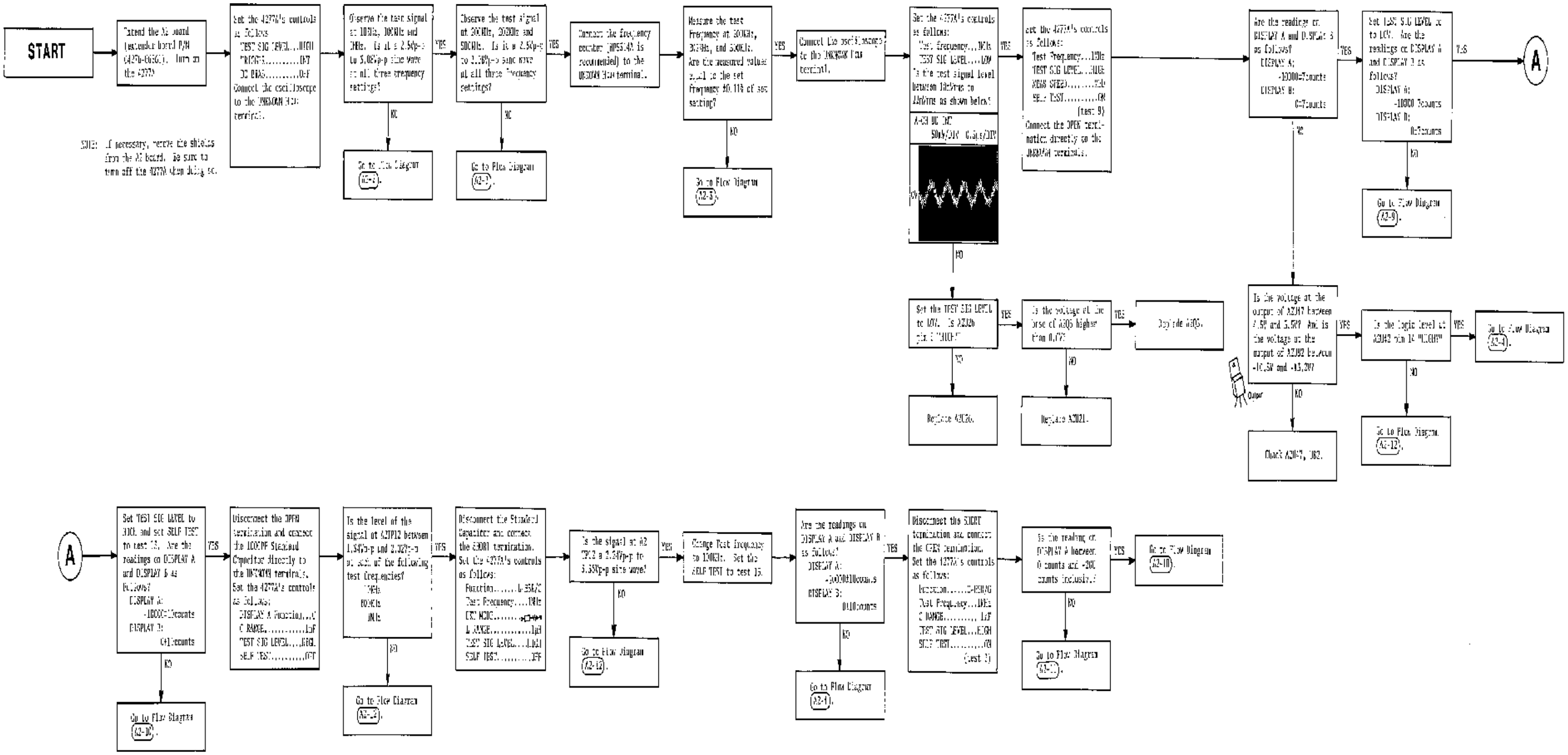


Figure 8-42. A2 ANALOG Board Troubleshooting Flow Diagram (Sheet 1 of 15).

A2 Troubleshooting Flow Diagram (Sheet 1 of 15)

SEE INSIDE

Flow Diagram A2 - 2 (Signal Source)

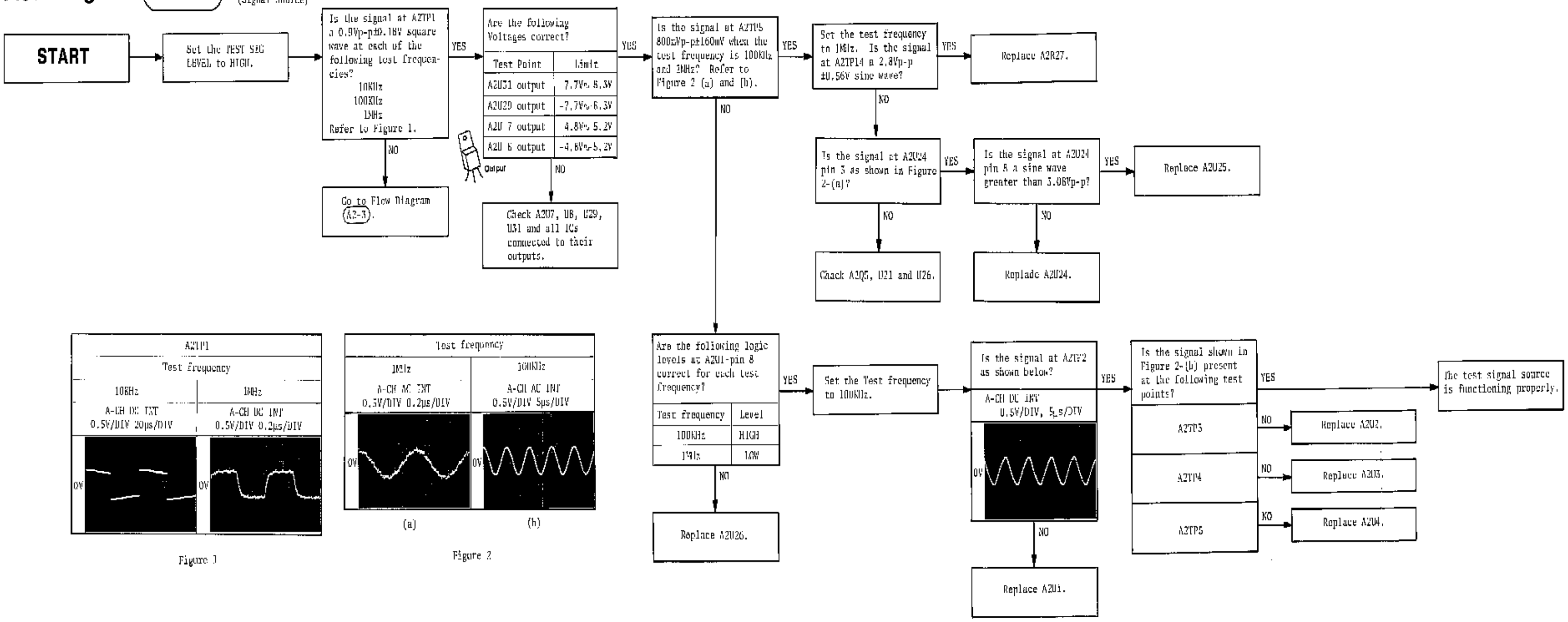


Figure 8-42. A2 ANALOG Board Troubleshooting Flow Diagram (Sheet 2 of 15).

Signal Source

A2 Troubleshooting Flow Diagram (Sheet 2 of 15)

SEE INSIDE

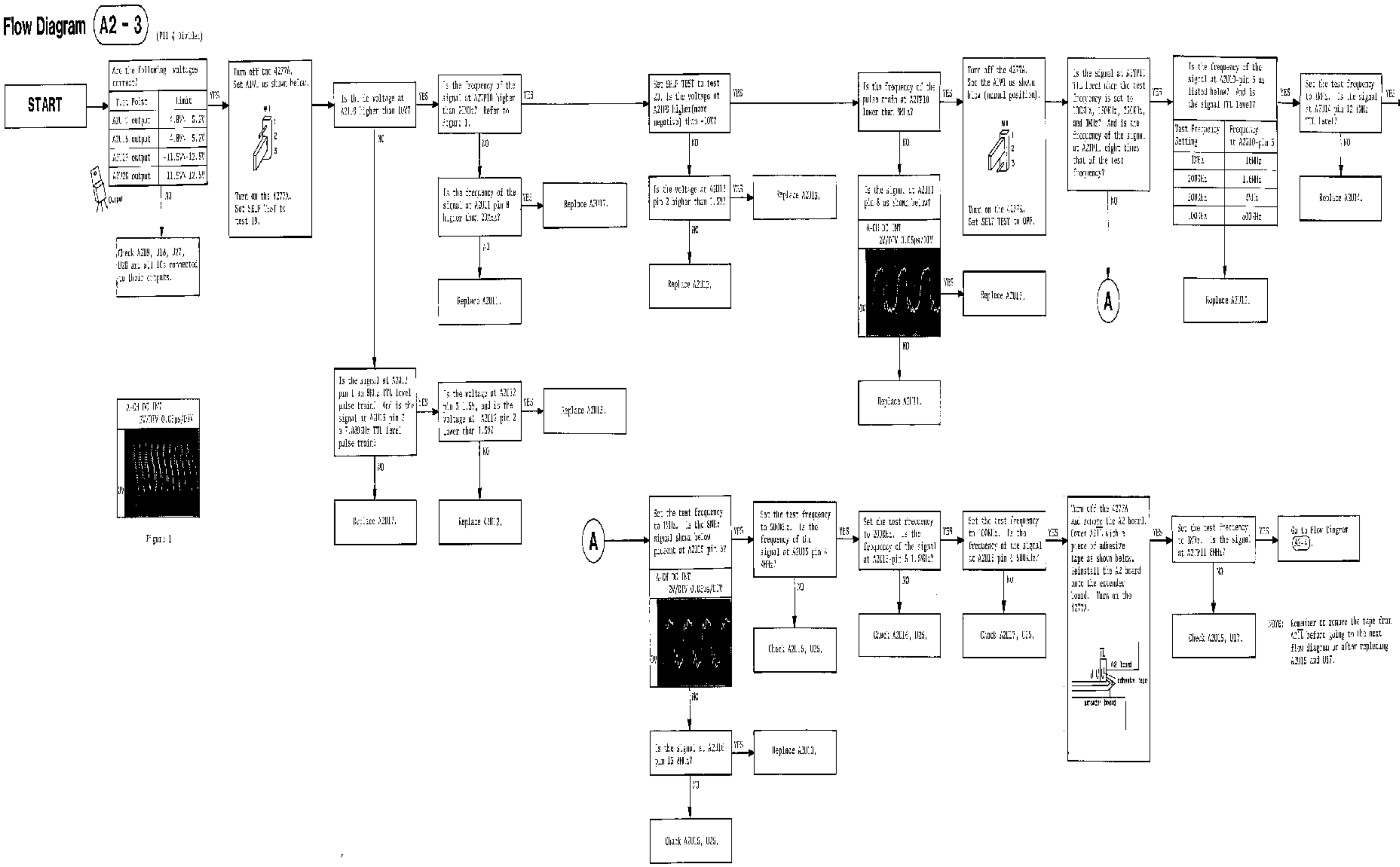


Figure 8-42. A2 ANALOG Board Troubleshooting Flow Diagram (Sheet 3 of 15).

PLC & Driver

A2 Troubleshooting Flow Diagram (Sheet 3 of 15)

SEE INSIDE

Flow Diagram (A2 - 4) (VRD)

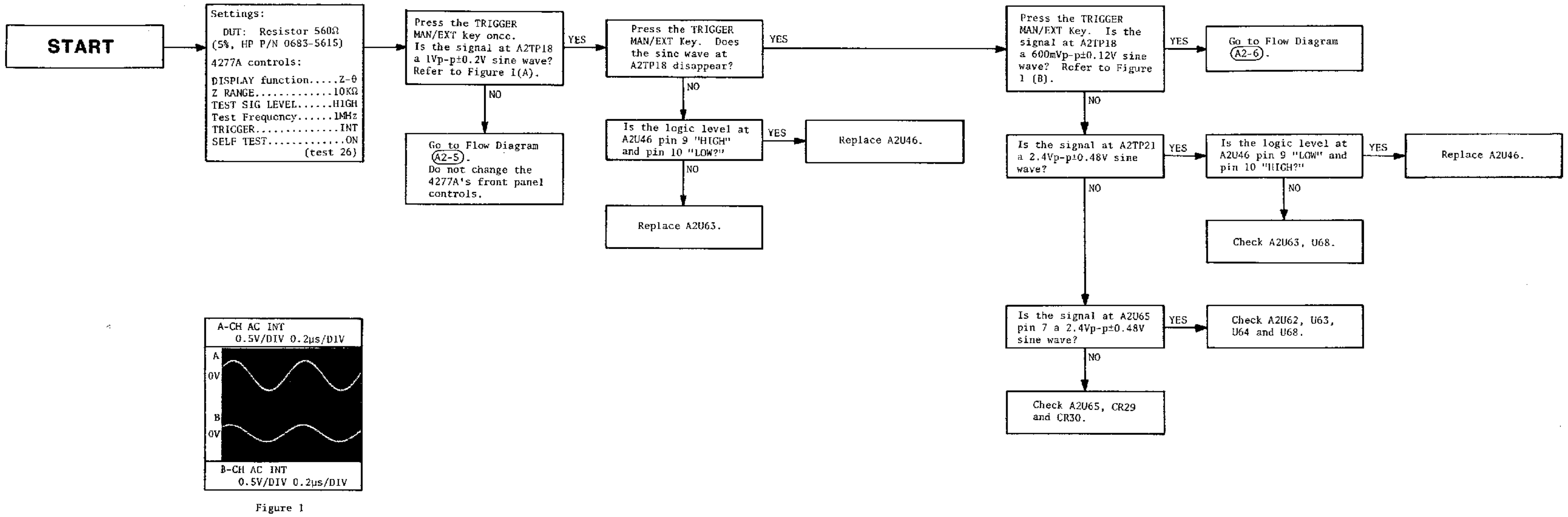


Figure 8-42. A2 ANALOG Board Troubleshooting Flow Diagram (Sheet 4 of 15).

VRD

A2 Troubleshooting Flow Diagram (Sheet 4 of 15

SEE INSIDE

Flow Diagram (A2 - 5)

(Process Amplifier)

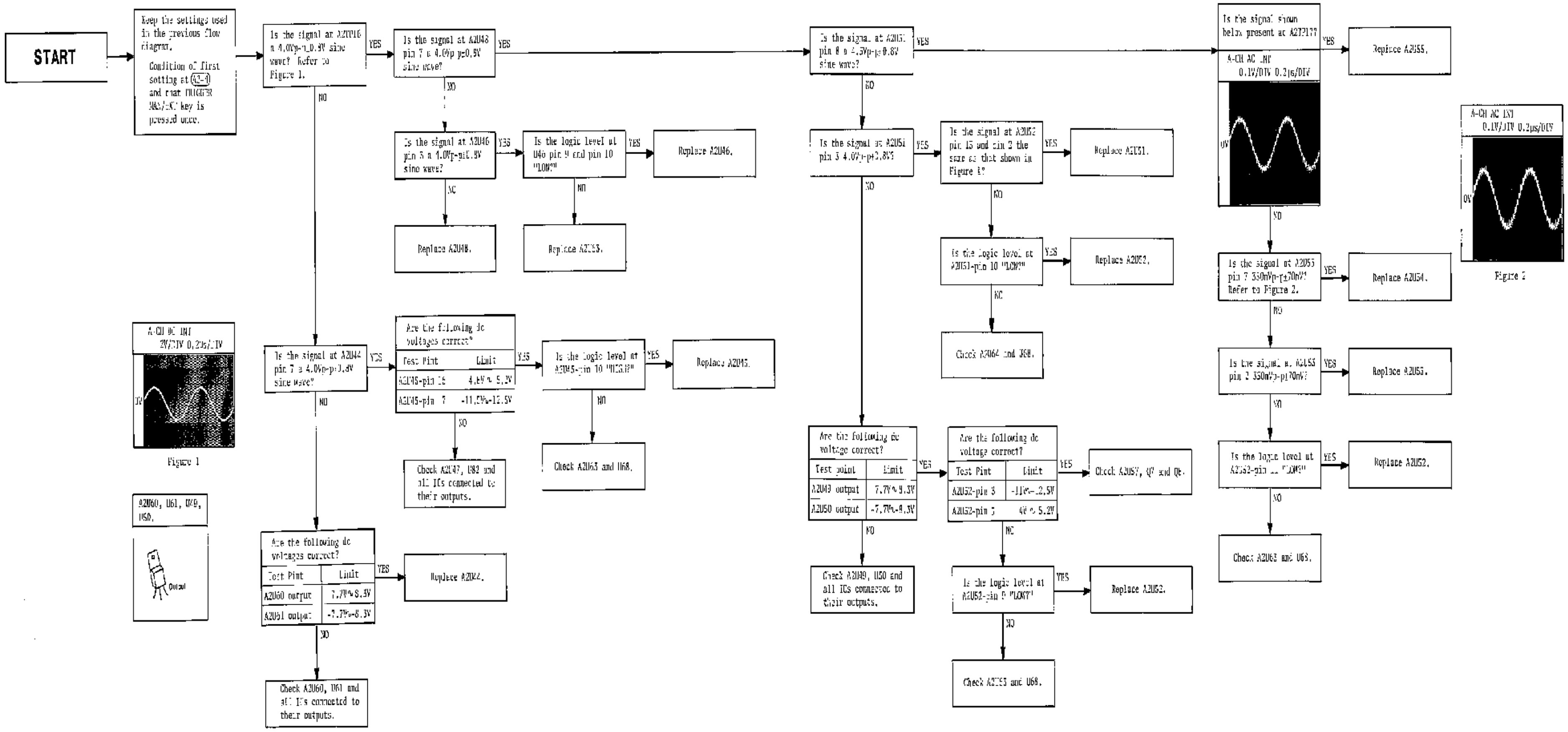


Figure 8-42. A2 ANALOG Board Troubleshooting Flow Diagram (Sheet 5 of 15).

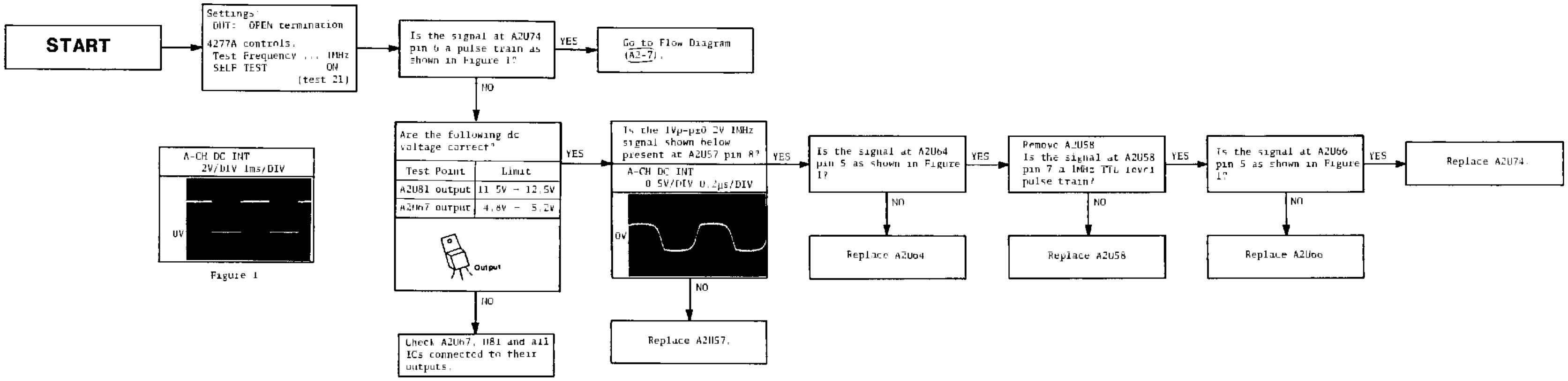
Process Amp

A2 Troubleshooting Flow Diagram (Shee

SEE INSIDE

of 15)

Flow Diagram (A2 - 6) (VRD, A-D Converter)



Test Point	Limit
A2U81 output	11.5V ~ 12.5V
A2U67 output	4.8V ~ 5.2V

Figure 8-42. A2 ANALOG Board Troubleshooting Flow Diagram (Sheet 6 of 15).

URD, A/D

◀ **A2** Troubleshooting Flow Diagram (Sheet 6 of 15)

SEE INSIDE

Flow Diagram (A2 - 7)

(Pulse swallow, Phase detector)

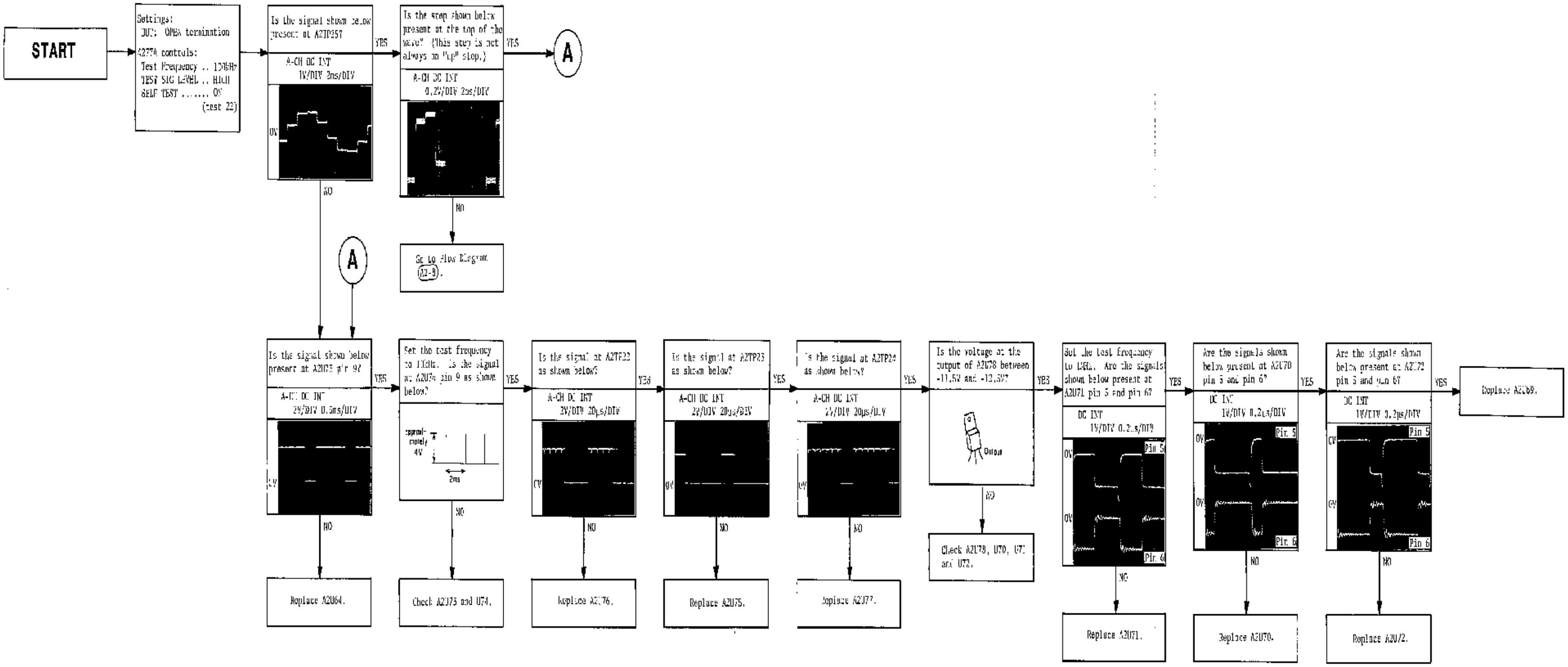


Figure 8-42. A2 ANALOG Board Troubleshooting Flow Diagram (Sheet 7 of 13).

Pulse Swallow, Phase Detector

◀ **A2** Troubleshooting Flow Diagram (Sheet 7 of 1

SEE INSIDE

Flow Diagram A2 - 8 (A-D Converter)

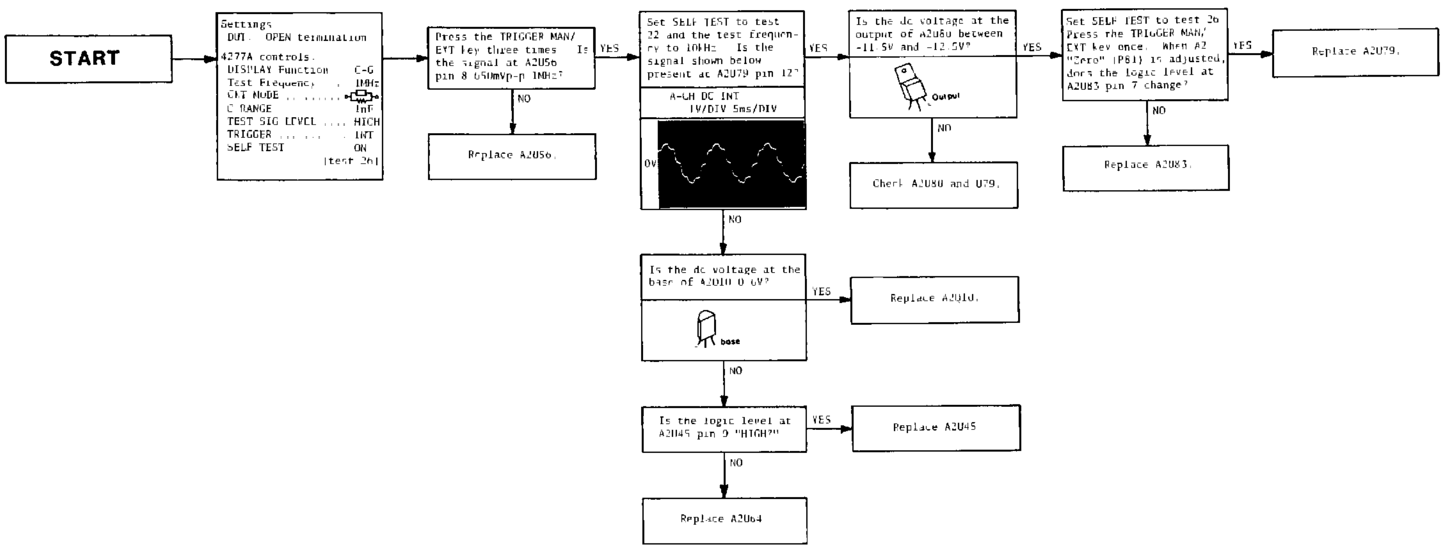


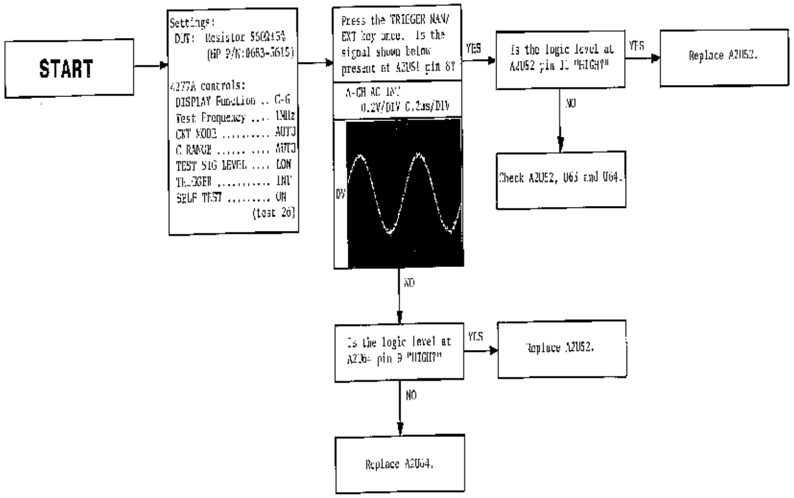
Figure 8-42. A2 ANALOG Board Troubleshooting Flow Diagram (Sheet 8 of 15).

A/D

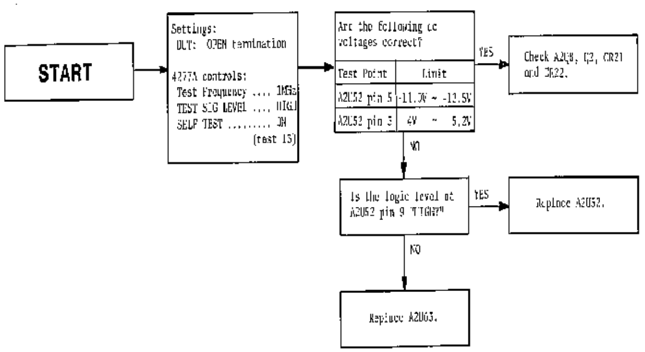
A2 Troubleshooting Flow Diagram (Sheet 8 of 15)

SEE INSIDE

Flow Diagram A2 - 9 (VRC, TTL Amp)



Flow Diagram A2 - 10



Flow Diagram A2 - 11

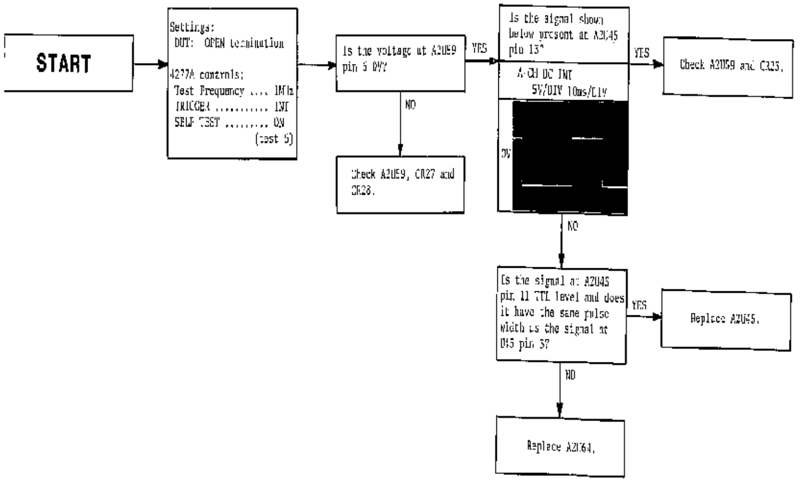


Figure 8-42. A2 ANALOG Board Troubleshooting Flow Diagram (Sheet 9 of 15).

VRD

A2 Troubleshooting Flow Diagram (Sheet 9 of 1

SEE INSIDE

Flow Diagram (A2 - 12)

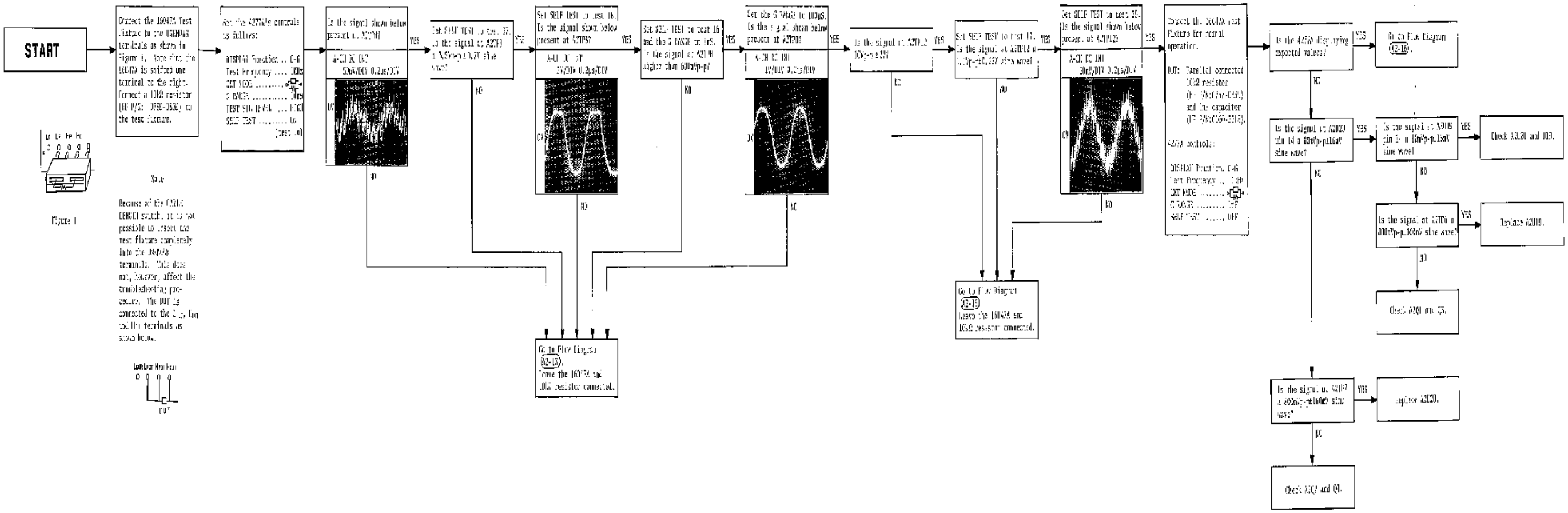


Figure 1

Note

Because of the CABLE LENGTH switch, it is not possible to insert the test fixture completely into the 4277A terminals. This does not, however, affect the troubleshooting procedure. The DUT is connected to the Lcur, Lpot Hpot, Hcur terminals as shown below.

Figure 8-42. A2 ANALOG Board Troubleshooting Flow Diagram (Sheet 10 of 15).

TRB

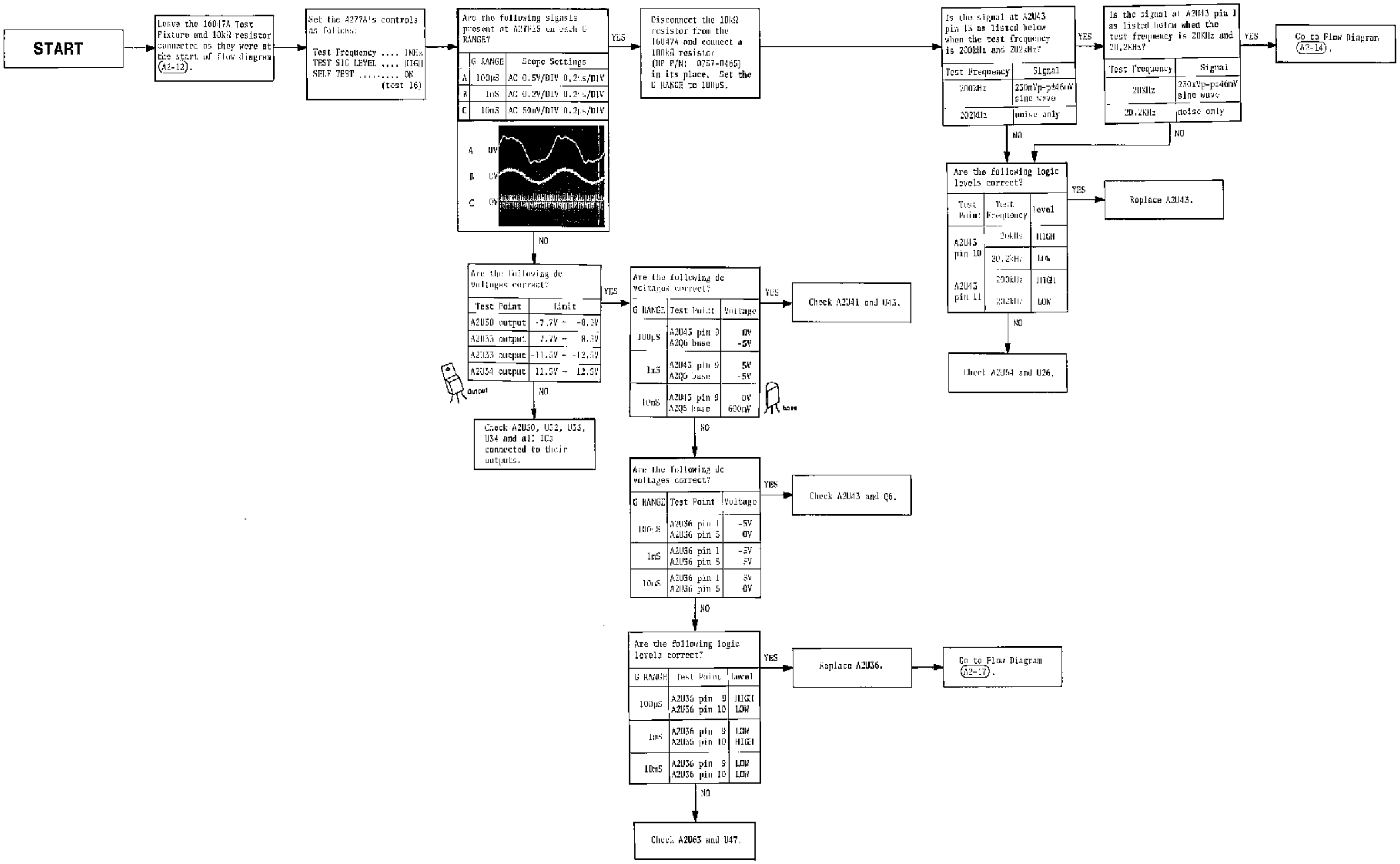
A2

SEE INSIDE

Troubleshooting Flow Diagram (Sheet 10 of 15)

Flow Diagram (A2 - 13)

(null detector)



Leave the 16047A Test Fixture and 10kΩ resistor connected as they were at the start of flow diagram (A2-12).

Set the 4277A's controls as follows:

Test Frequency 1MHz
TEST SIG LEVEL .... HIGH
SELF TEST .... ON
(test 16)

Are the following signals present at A2TP15 on each G RANGE?

	G RANGE	Scope Settings
A	100μS	AC 0.5V/DIV 0.2μs/DIV
B	1mS	AC 0.2V/DIV 0.2μs/DIV
C	10mS	AC 50mV/DIV 0.2μs/DIV

Disconnect the 10kΩ resistor from the 16047A and connect a 100kΩ resistor (HP P/N: 0757-0465) in its place. Set the G RANGE to 100μS.

Is the signal at A2U43 pin 15 as listed below when the test frequency is 200kHz and 202kHz?

Test Frequency	Signal
200kHz	230mVp-p±46mV sine wave
202kHz	noise only

Is the signal at A2U43 pin 1 as listed below when the test frequency is 20KHz and 20.2KHz?

Test Frequency	Signal
20KHz	230mVp-p±46mV sine wave
20.2KHz	noise only

Go to Flow Diagram (A2-14).

Are the following logic levels correct?

Test Point	Test Frequency	level
A2U43 pin 10	20kHz	HIGH
	20.2kHz	LOW
A2U43 pin 11	200kHz	HIGH
	202kHz	LOW

Replace A2U43.

Check A2U54 and U26.

Are the following dc voltages correct?

Test Point	Limit
A2U30 output	-7.7V ~ -8.3V
A2U33 output	7.7V ~ 8.3V
A2U33 output	-11.5V ~ -12.5V
A2U34 output	11.5V ~ 12.5V

Check A2U30, U32, U33, U34 and all ICs connected to their outputs.

Are the following dc voltages correct?

G RANGE	Test Point	Voltage
100μS	A2U43 pin 9 A2Q6 base	0V -5V
1mS	A2U43 pin 9 A2Q6 base	5V -5V
10mS	A2U43 pin 9 A2Q6 base	0V 600mV

Check A2U41 and U43.

Are the following dc voltages correct?

G RANGE	Test Point	Voltage
100μS	A2U36 pin 1 A2U36 pin 5	-5V 0V
1mS	A2U36 pin 1 A2U36 pin 5	-5V 5V
10mS	A2U36 pin 1 A2U36 pin 5	5V 0V

Check A2U43 and Q6.

Are the following logic levels correct?

G RANGE	Test Point	Level
100μS	A2U36 pin 9 A2U36 pin 10	HIGH LOW
1mS	A2U36 pin 9 A2U36 pin 10	LOW HIGH
10mS	A2U36 pin 9 A2U36 pin 10	LOW LOW

Replace A2U36.

Go to Flow Diagram (A2-17).

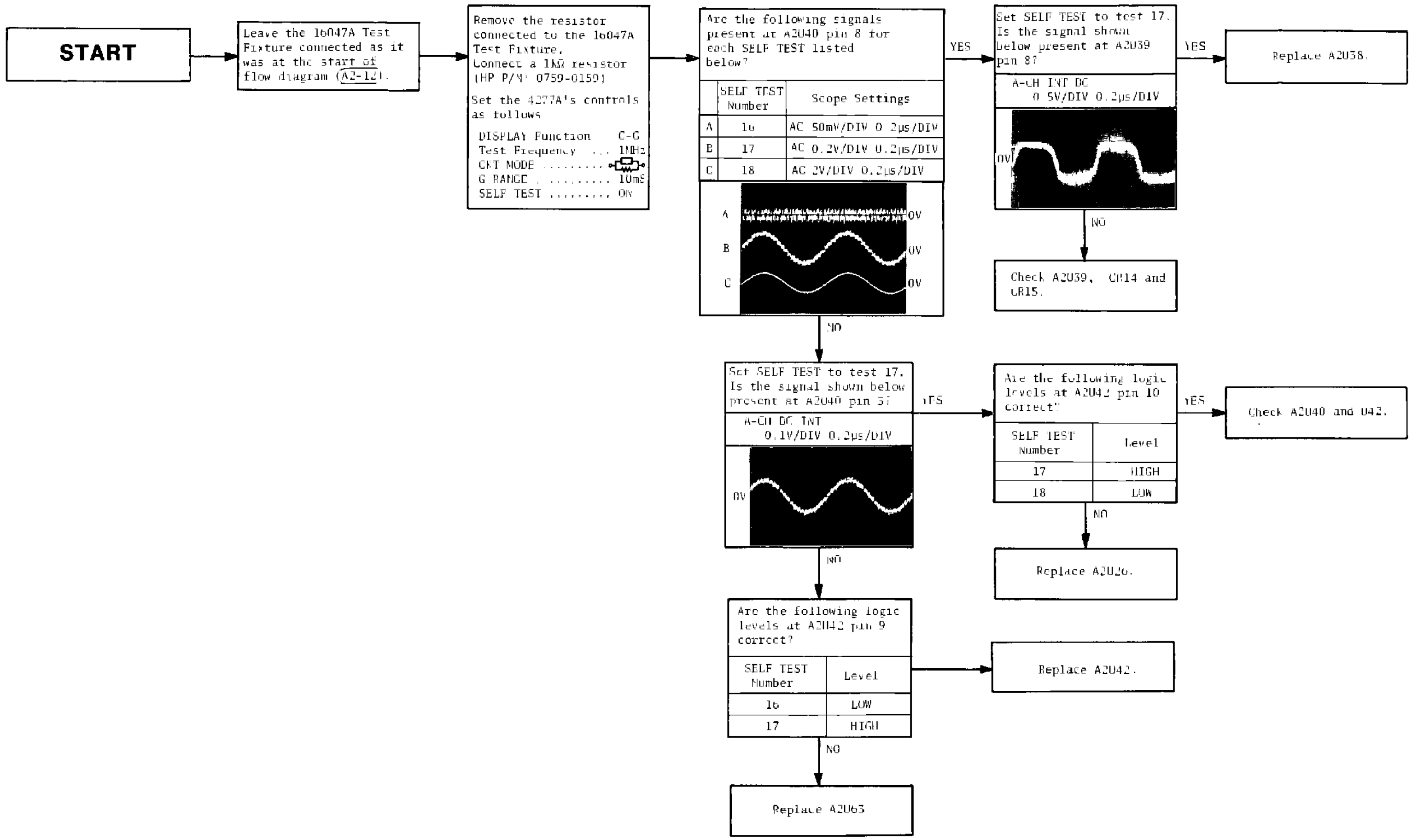
Check A2U63 and U47.

Figure 8-42. A2 ANALOG Board Troubleshooting Flow Diagram (Sheet 11 of 15).

A2 Troubleshooting Flow Diagram (Sheet 11 of 15)

SEE INSIDE

Flow Diagram (A2 - 14) (null amplifier)



Leave the 16047A Test Fixture connected as it was at the start of flow diagram (A2-12).

Remove the resistor connected to the 16047A Test Fixture.
Connect a 1kΩ resistor (HP P/N 0759-0159)

Set the 4277A's controls as follows

DISPLAY Function .... C-G
Test Frequency 1MHz
CKT MODE .... -[parallel]-
G RANGE 10mS
SELF TEST .... ON

Are the following signals present at A2U40 pin 8 for each SELF TEST listed below?

	SELF TEST Number	Scope Settings
A	16	AC 50mV/DIV 0.2µs/DIV
B	17	AC 0.2V/DIV 0.2µs/DIV
C	18	AC 2V/DIV 0.2µs/DIV

Set SELF TEST to test 17. Is the signal shown below present at A2U39 pin 8?

A-CH INT DC
0.5V/DIV 0.2µs/DIV

Replace A2U38.

Check A2U39, CR14 and CR15.

Set SELF TEST to test 17. Is the signal shown below present at A2U40 pin 5?

A-CH DC INT
0.1V/DIV 0.2µs/DIV

Are the following logic levels at A2U42 pin 10 correct?

SELF TEST Number	Level
17	HIGH
18	LOW

Check A2U40 and U42.

Replace A2U26.

Are the following logic levels at A2U42 pin 9 correct?

SELF TEST Number	Level
16	LOW
17	HIGH

Replace A2U42.

Replace A2U63

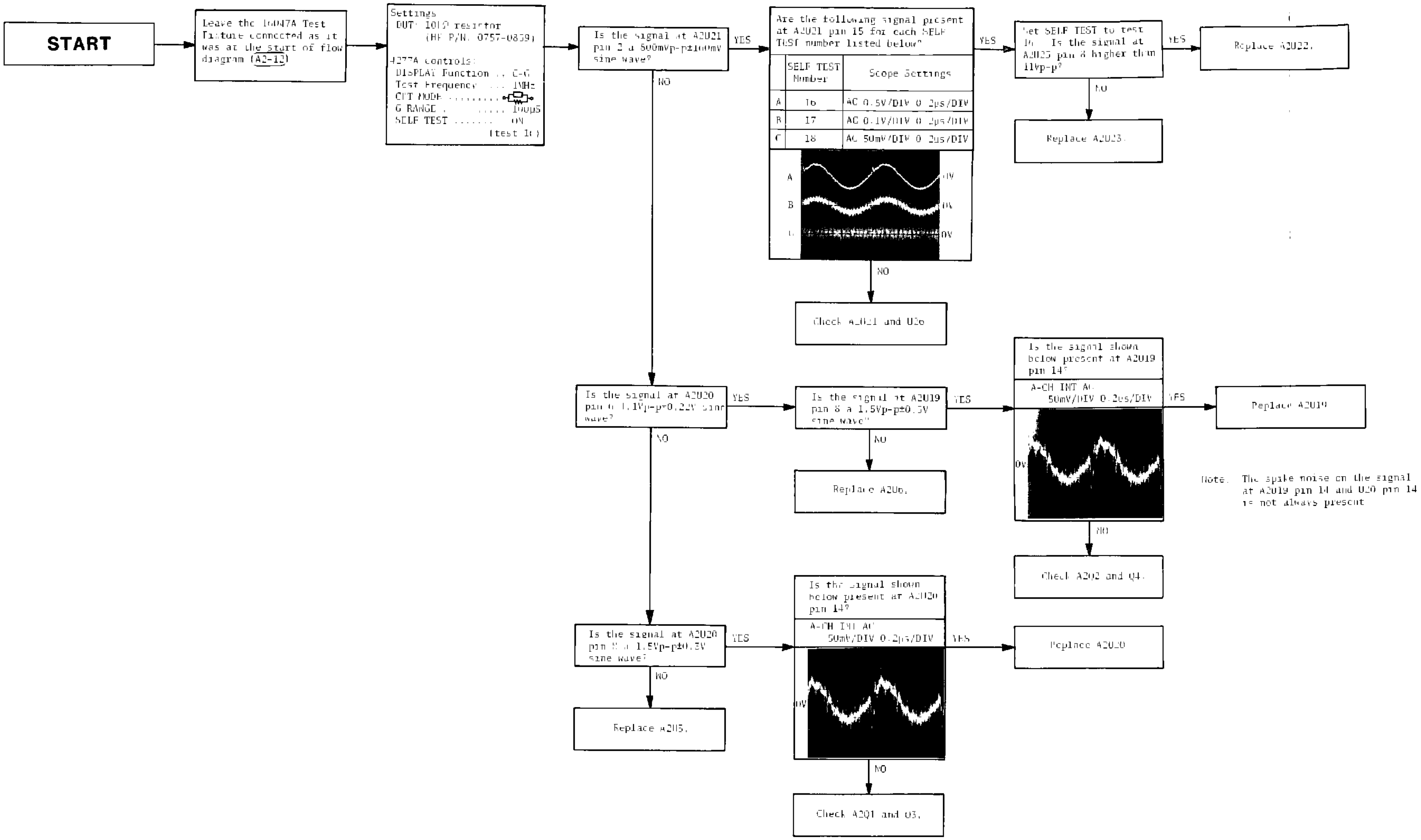
Figure 8-42. A2 ANALOG Board Troubleshooting Flow Diagram (Sheet 12 of 15).

A2

SEE INSIDE

Troubleshooting Flow Diagram (Sheet 12 of 1

Flow Diagram A2 - 15 (MOD/DEMOD amp)



Note. The spike noise on the signal at A2U19 pin 14 and U20 pin 14 is not always present

Figure 8-42. A2 ANALOG Board Troubleshooting Flow Diagram (Sheet 13 of 15).

A2 Troubleshooting Flow Diagram (Sheet 13 of 15)

SEE INSIDE

Flow Diagram (A2 - 16) (Range Resisteor)

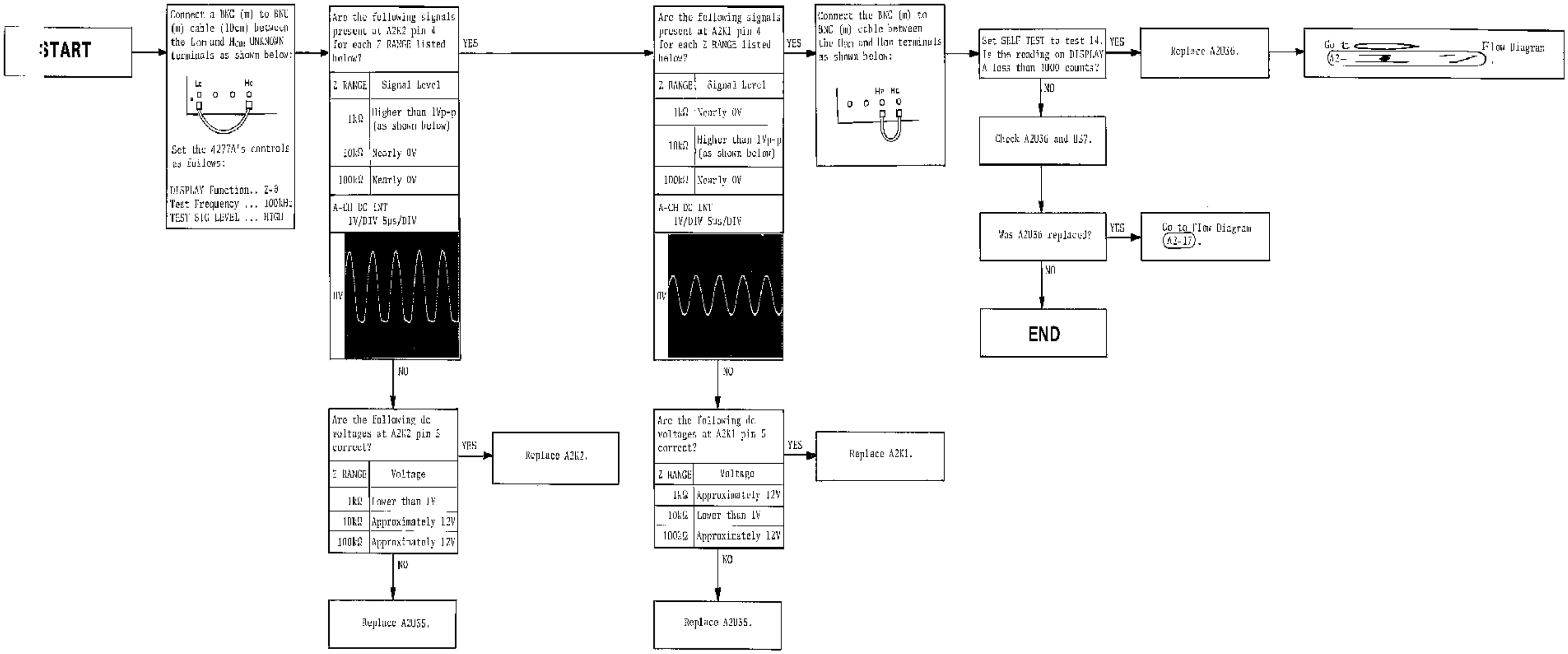


Figure 8-42. A2 ANALOG Board Troubleshooting Flow Diagram (Sheet 14 of 15).

A2 Troubleshooting Flow Diagram (Sheet 14 of 15

SEE INSIDE

Flow Diagram (A2 - 17)

(A2U36 cheak)

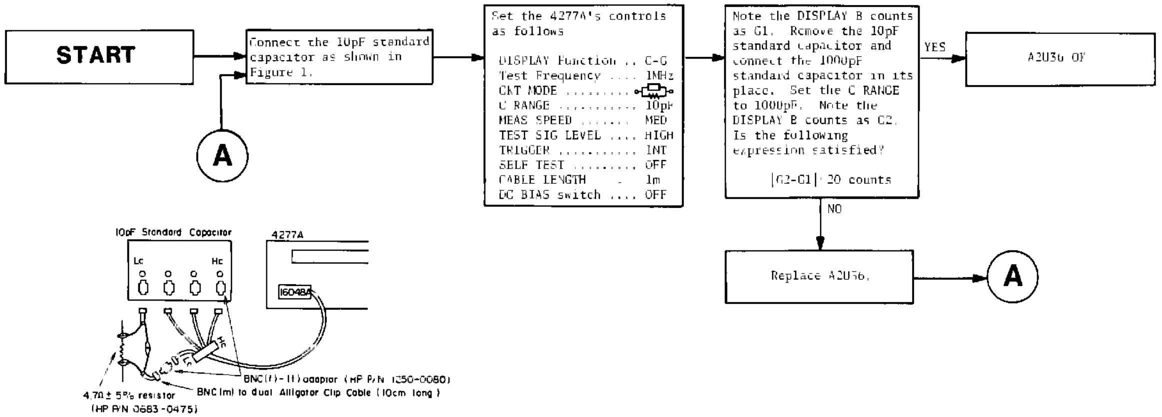


Figure 1

Note: If 10cm BNC (m) to dual alligator clip cables are not available, fabricate your own from a BNC (m) to BNC (m) cable. The HP 11170A can be used for this.

Flow Diagram (A2 - 18)

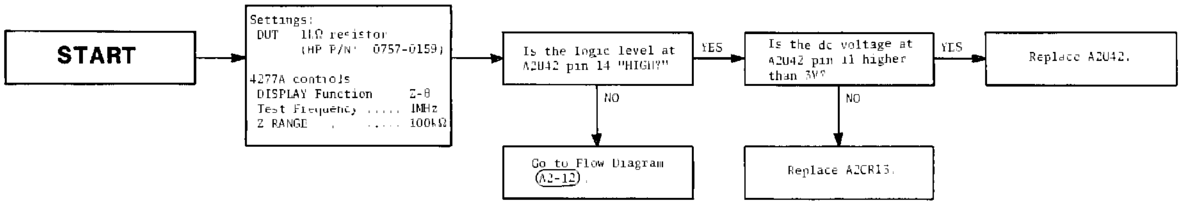


Figure 8-42. A2 ANALOG Board Troubleshooting Flow Diagram (Sheet 15 of 15).

A2
SEE INSIDE

Troubleshooting Flow Diagram (Sheet 15 of 15

Flow Diagram (A4-1)

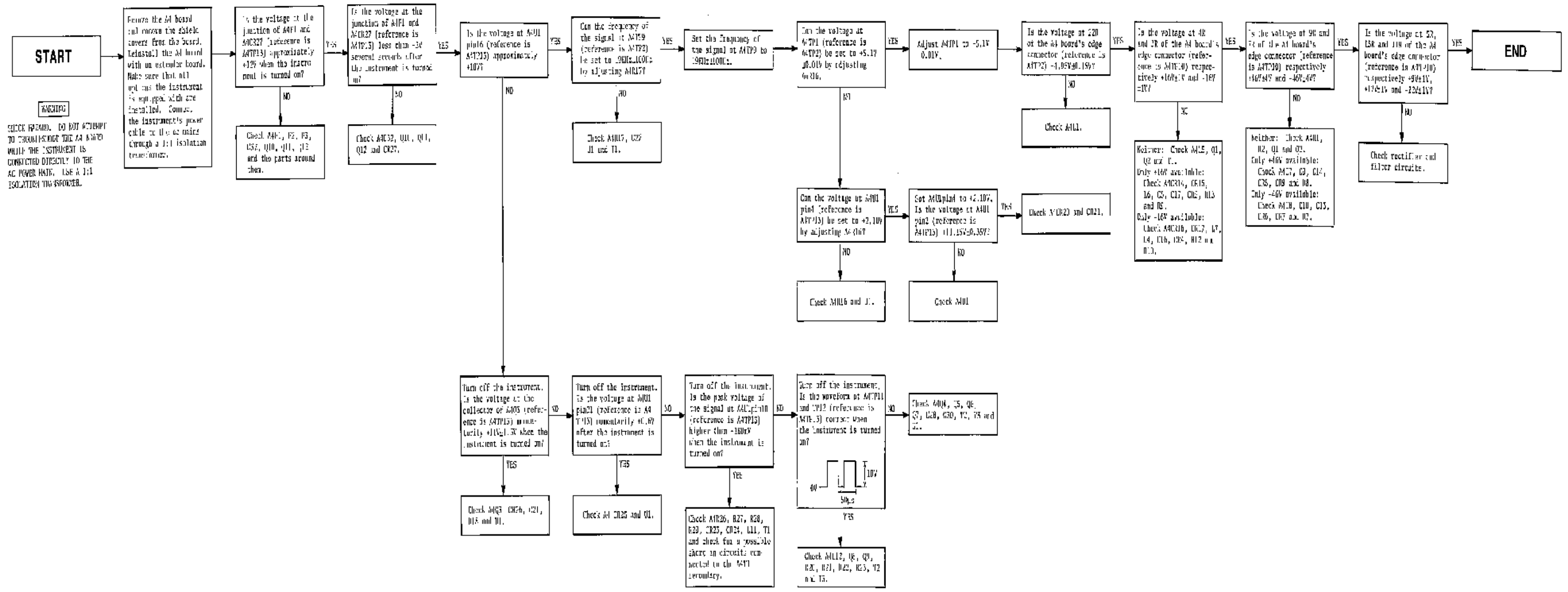
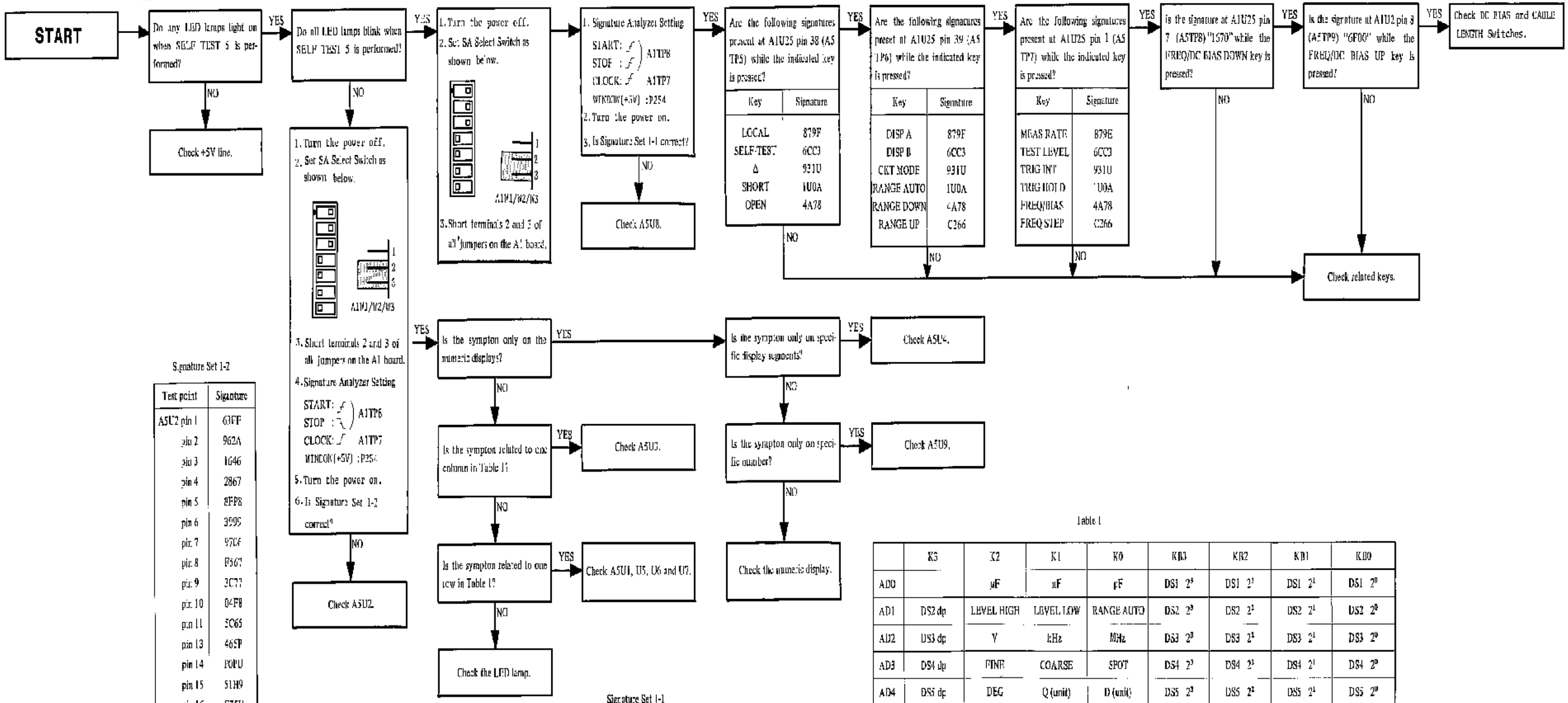


Figure 8-43. A4 POWER SUPPLY Board Troubleshooting Flow Diagram.

A4 Troubleshooting Flow Diagram

SEE INSIDE

Flow Diagram (A5 - 1)



Signature Set 1-2

Test point	Signature
A5U2 pin 1	63FF
pin 2	962A
pin 3	1646
pin 4	2867
pin 5	8FP8
pin 6	3995
pin 7	97C6
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	K0	KB3	KB2	KB1	KB0
AD0		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	kHz	MHz	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)	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		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)	REMOTE	SRQ	TALK	LISTEN

Figure 8-44. A5 DISPLAY Board Troubleshooting Flow Diagram.

A5 Troubleshooting Flow Diagra

SEE INSIDE

DC BIAS Flow Diagram

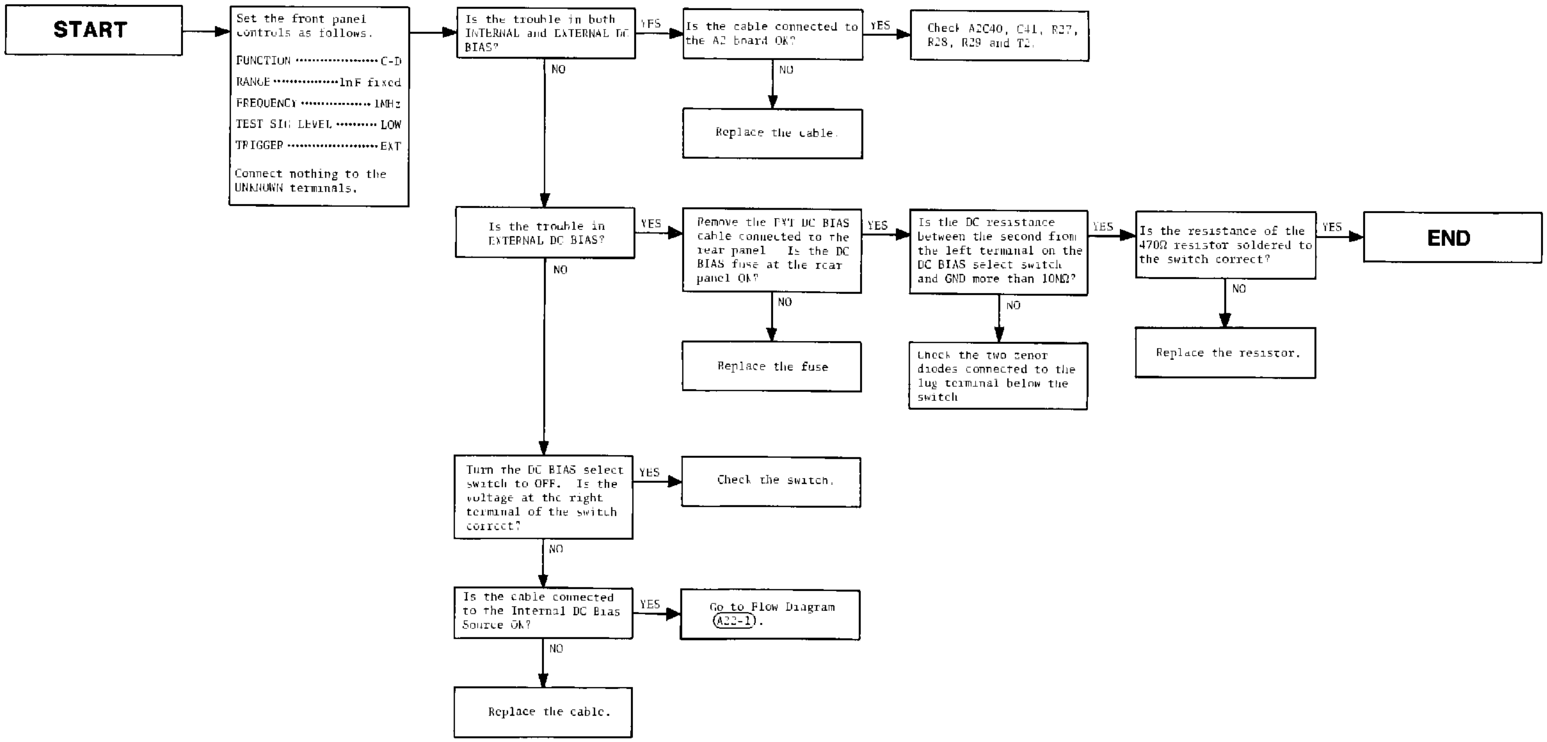


Figure 8-45. DC BIAS Troubleshooting Flow Diagram.

DC BIAS Troubleshooting Flow Diagram

SEE INSIDE

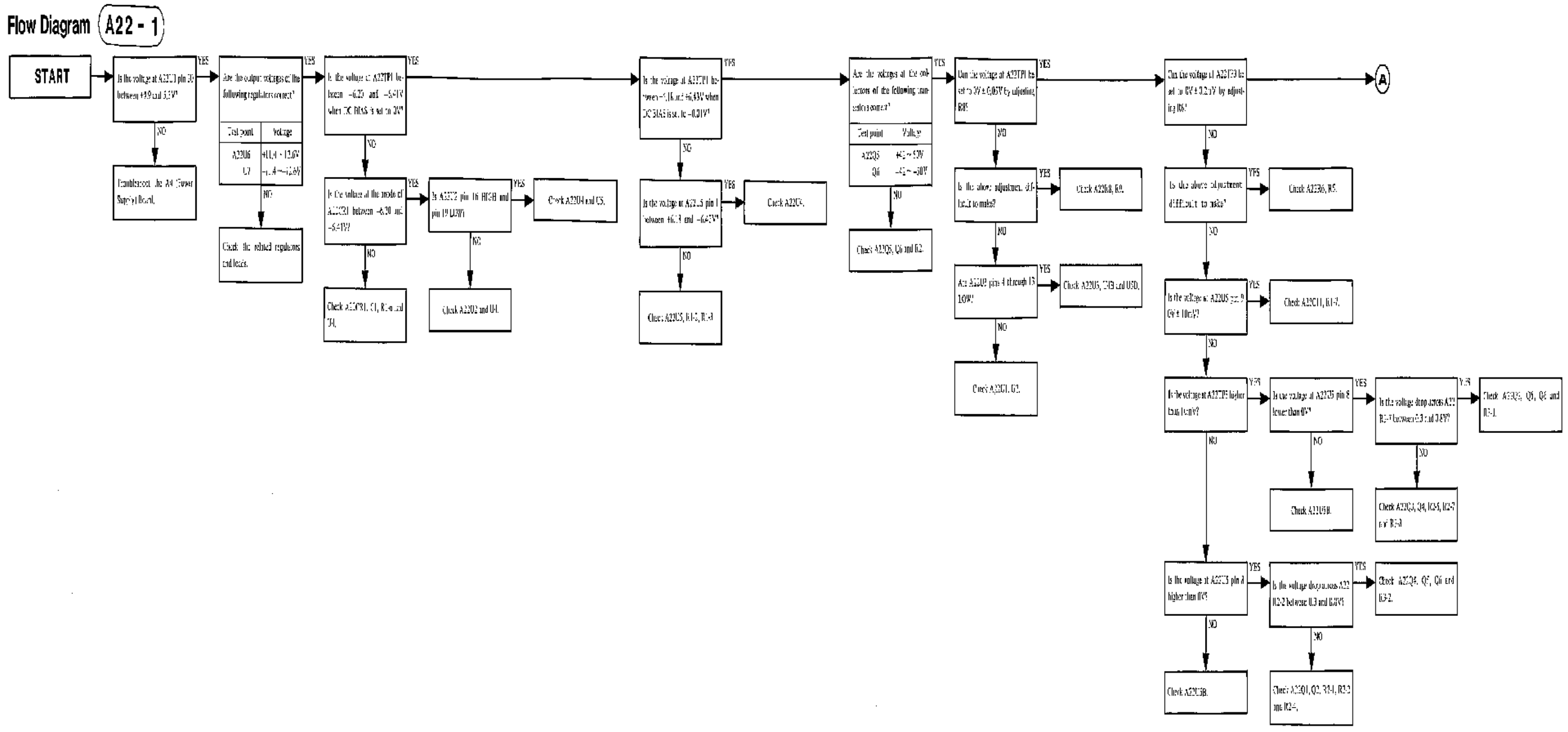


Figure 8-46. A22 OPTION 001 INTERNAL DC BIAS Board Troubleshooting Flow Diagram (Sheet 1 of 2).

A22 Troubleshooting Flow Diagram (Sheet 1 of 2)

SEE INSIDE

Flow Diagram A22 - 1

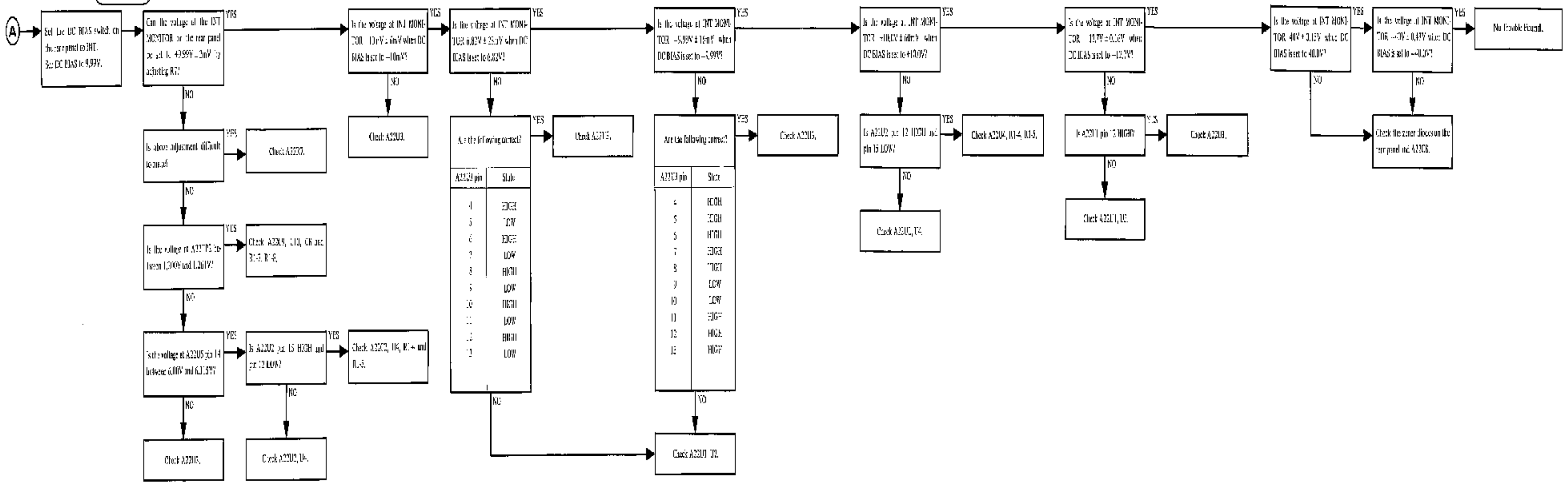


Figure 8-46. A22 OPTION 001 INTERNAL DC BIAS Board Troubleshooting Flow Diagram (Sheet 2 of 2).

A22 Troubleshooting Flow Diagram (Sheet 2 of 2)

SEE INSIDE

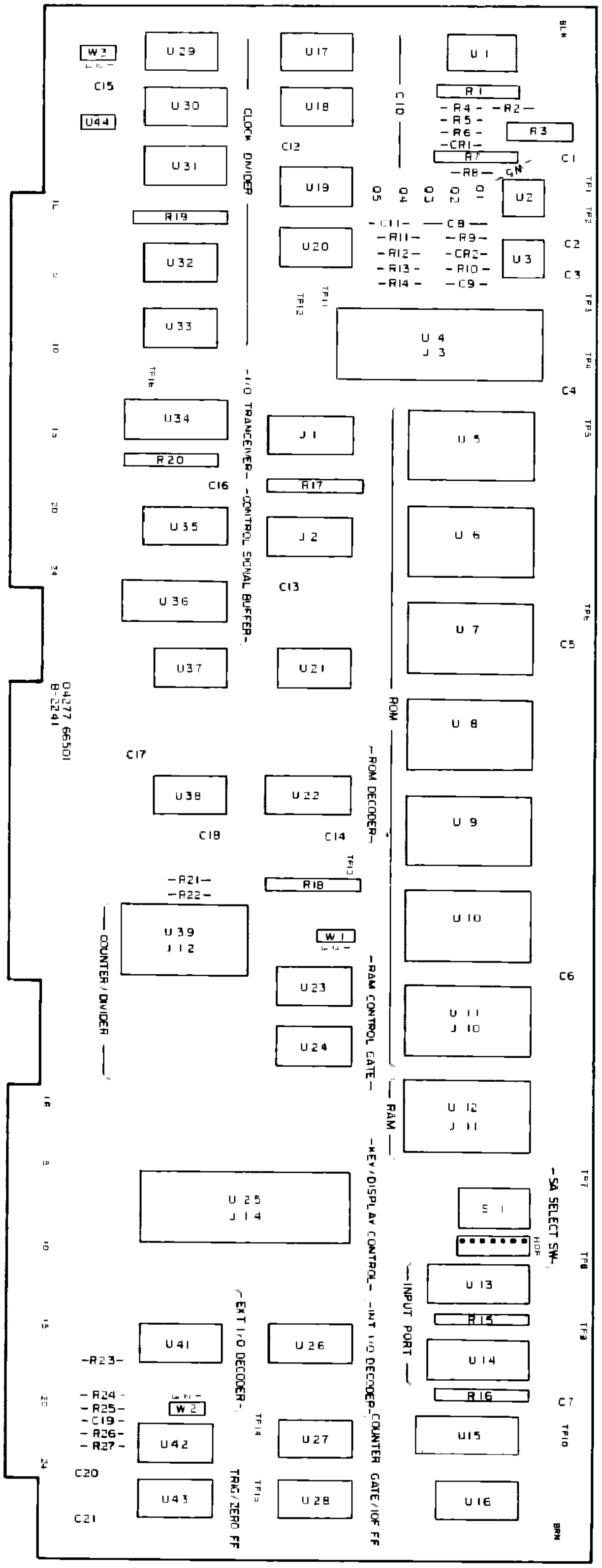


Figure 8-47. A1 LOGIC Board Assembly Component Locations.

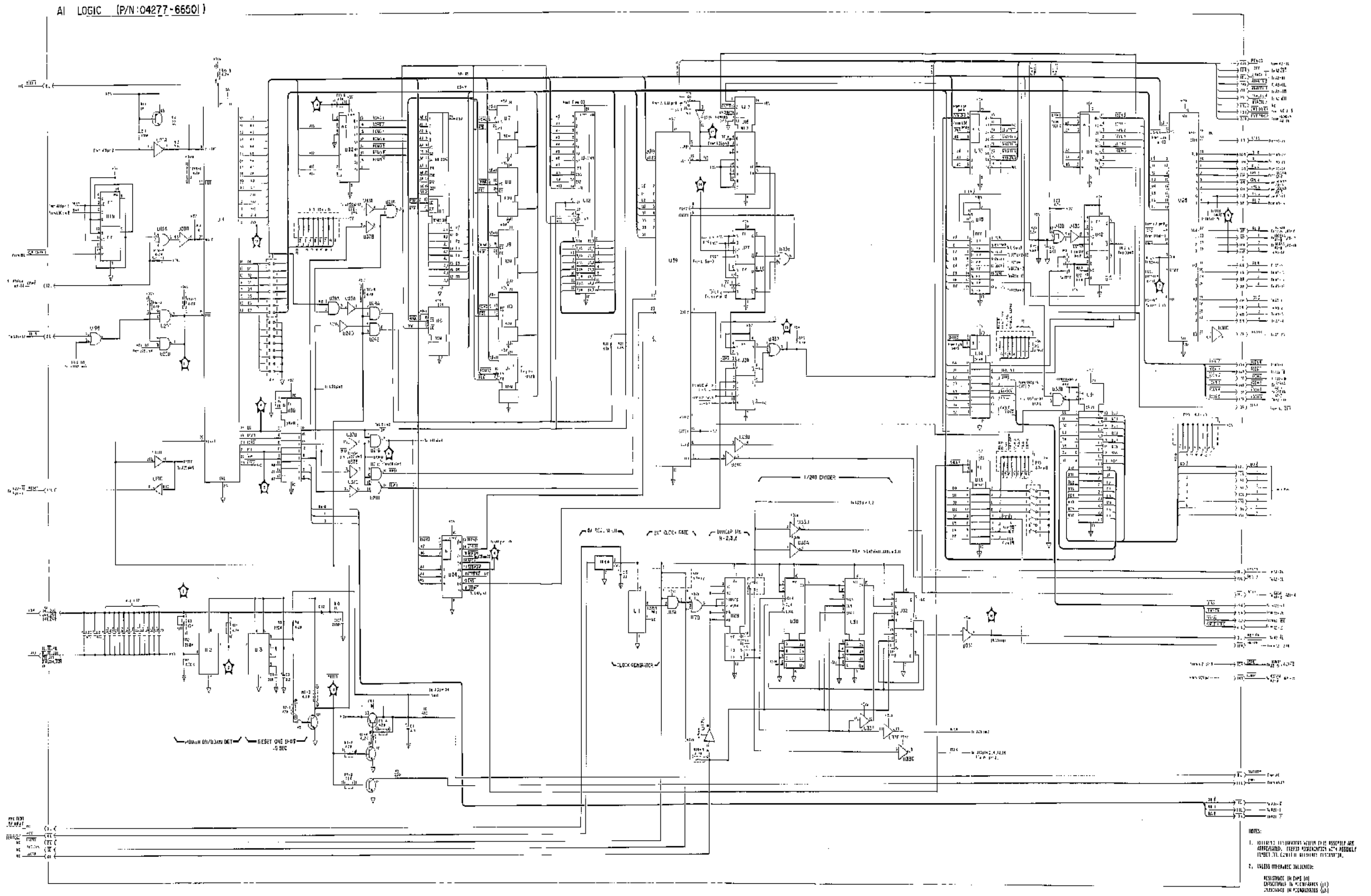


Figure 8-48. A1 LOGIC Board Assembly Schematic Diagram.

A1 BOARD

SEE INSIDE

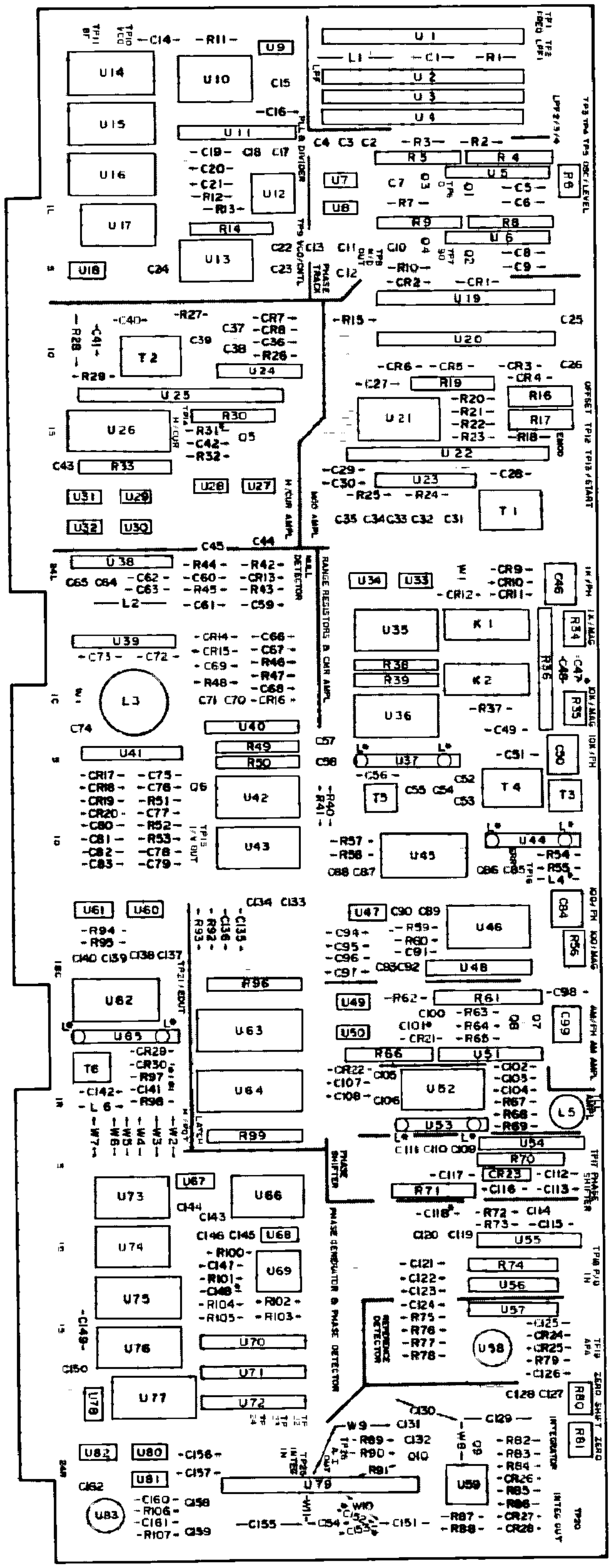


Figure 8-49. A2 ANALOG Board Assembly Component Locations.

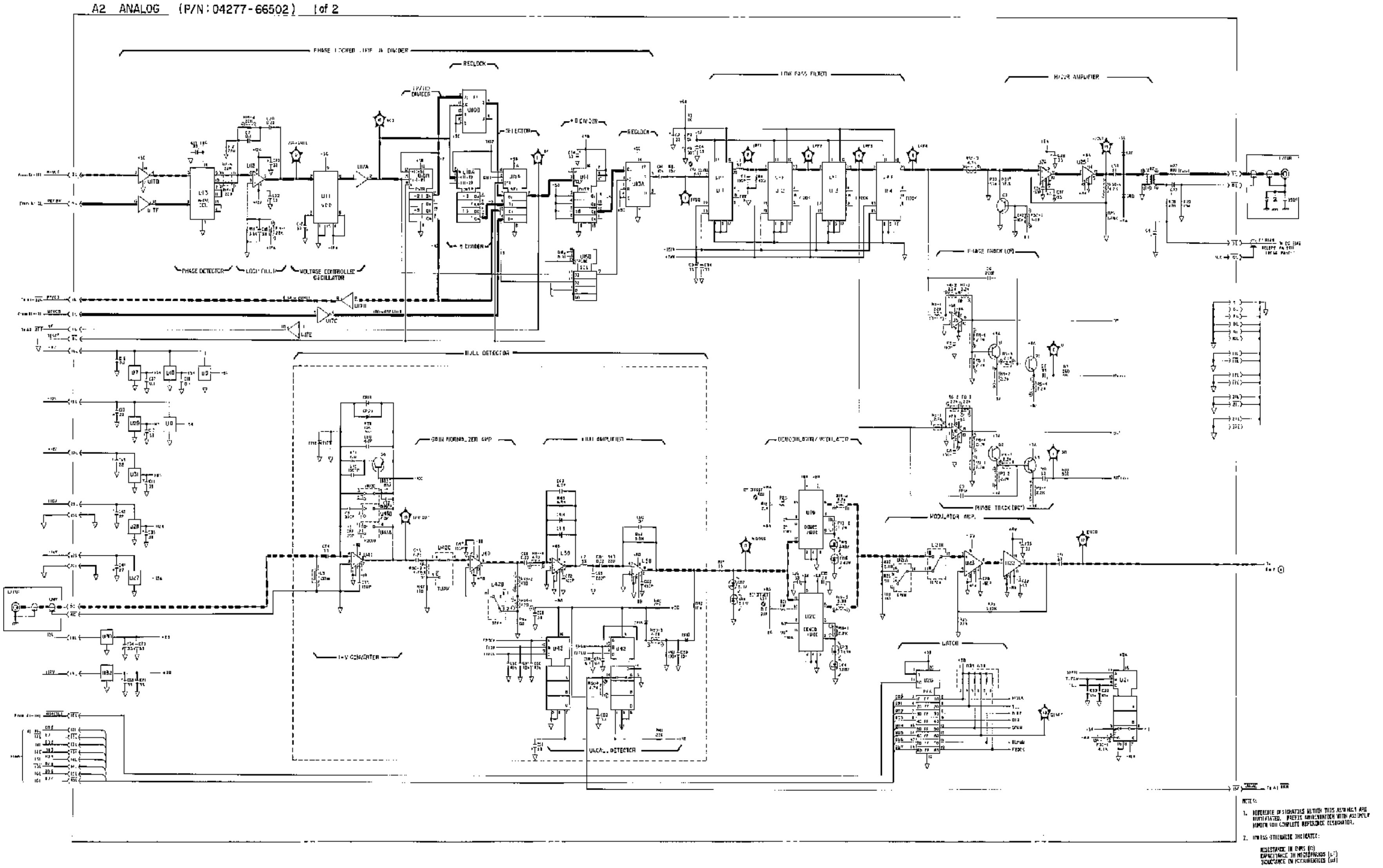


Figure 8-50. A2 ANALOG Board Assembly Schematic Diagram (Sheet 1 of 2).

A2 BOARD (Sheet 1 of 2)

SEE INSIDE

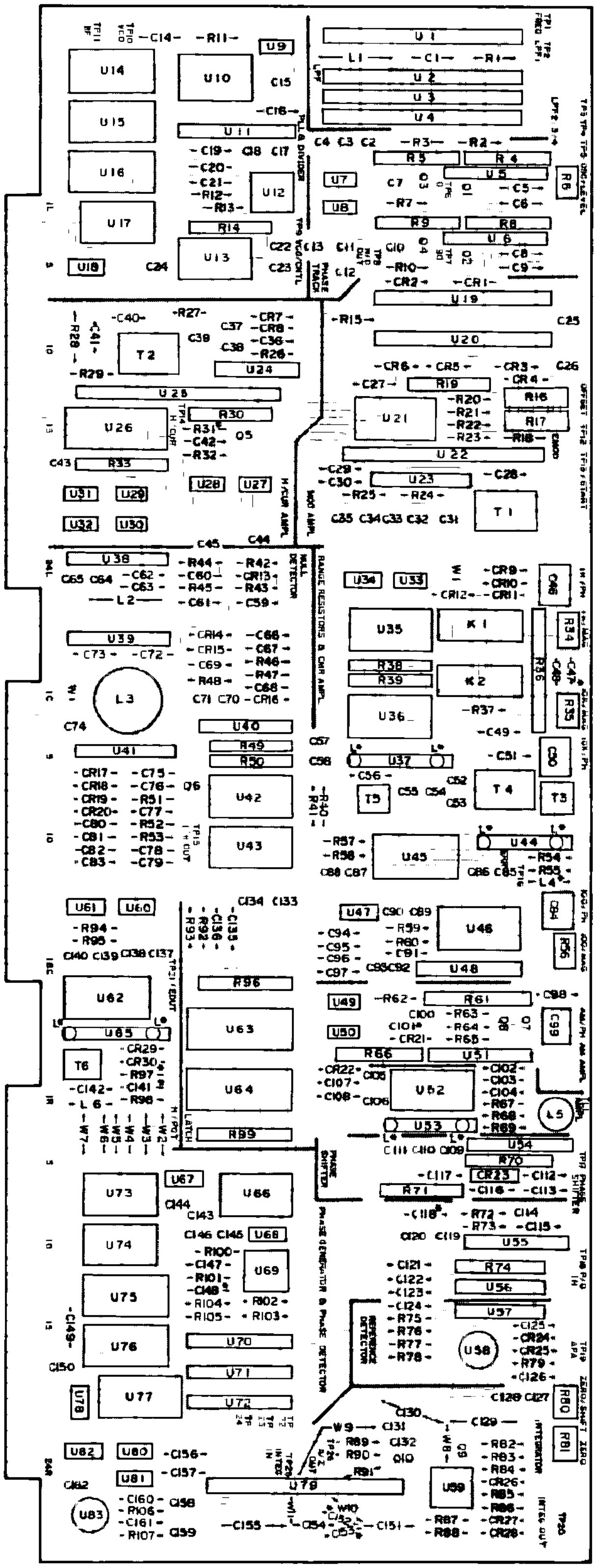


Figure 8-49. A2 ANALOG Board Assembly Component Locations.

A2 ANALOG (P/N:04277-66502) 2 of 2

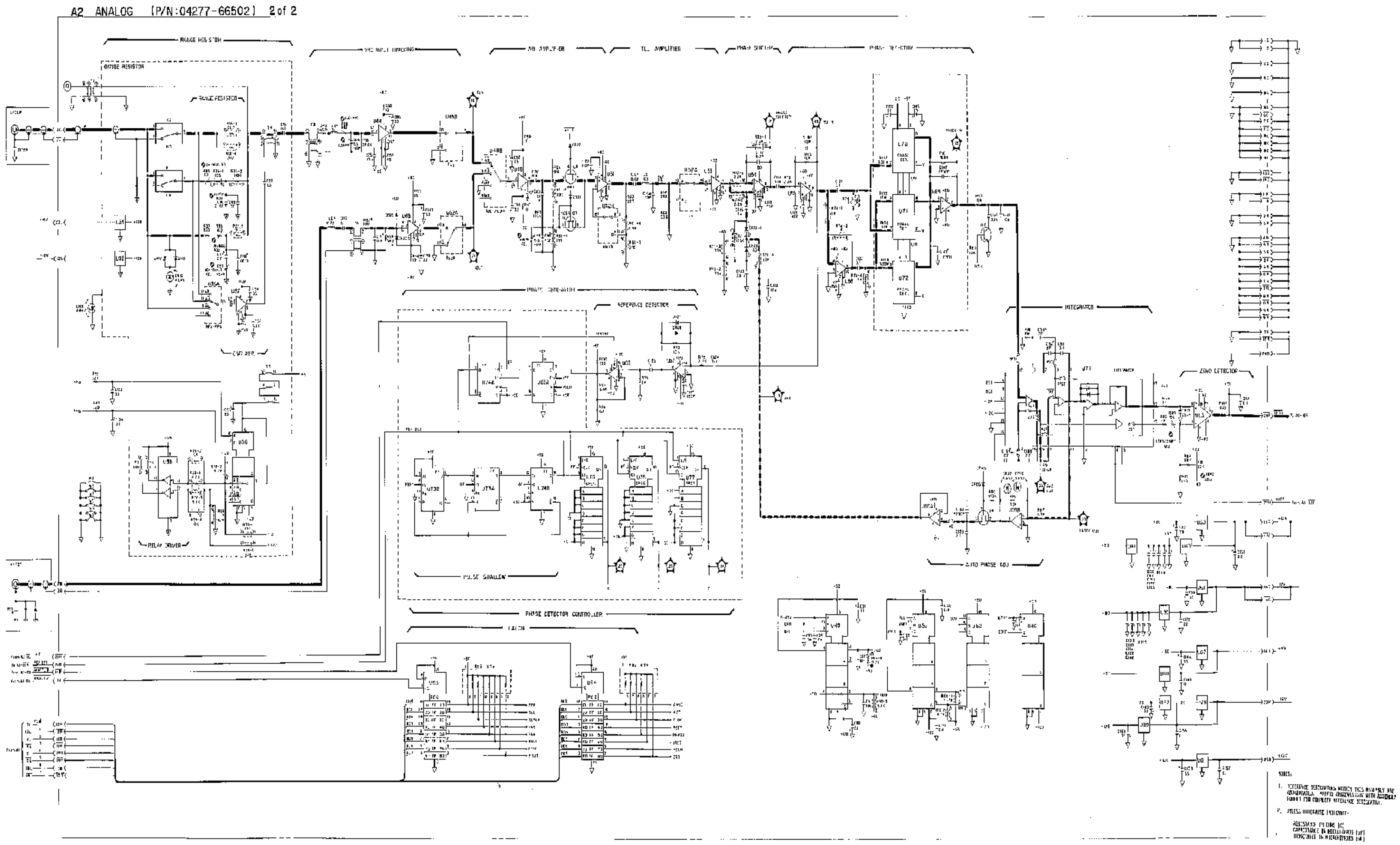


Figure 8-50. A2 ANALOG Board Assembly Schematic Diagram (Sheet 2 of 2).

A2 BOARD (Sheet 2 Of 2)

SEE INSIDE

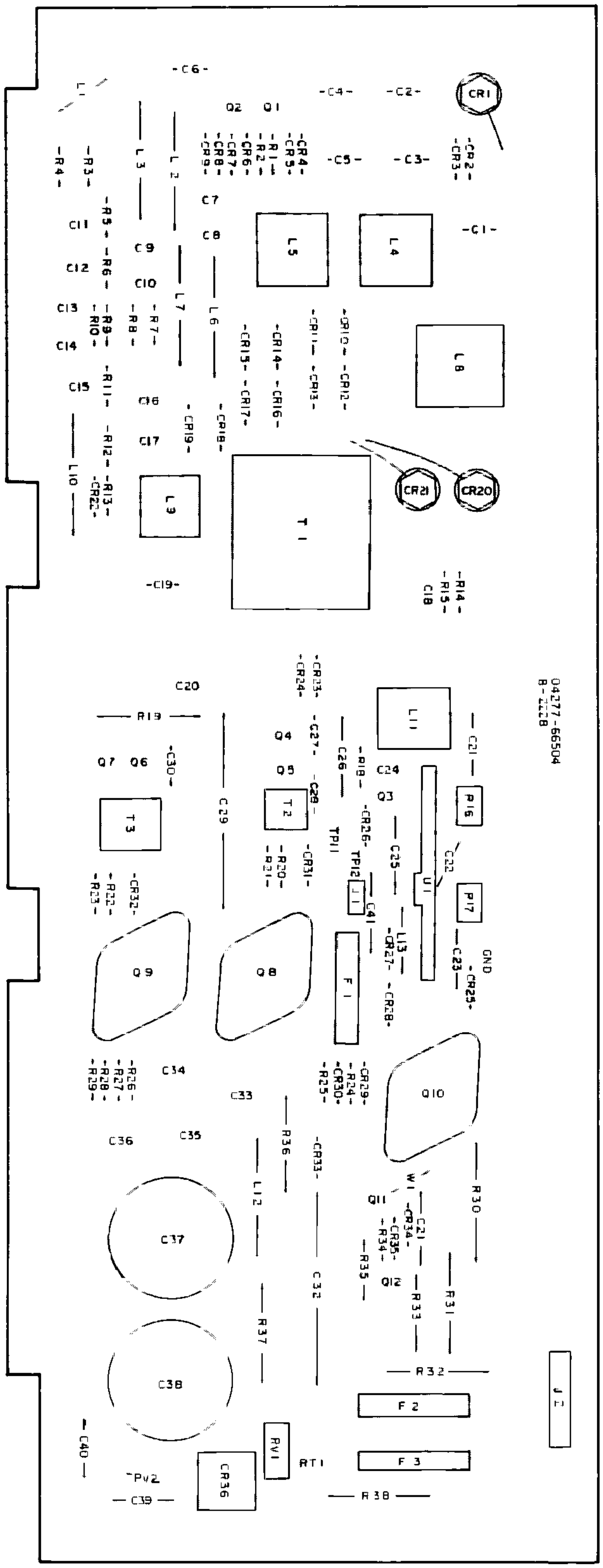
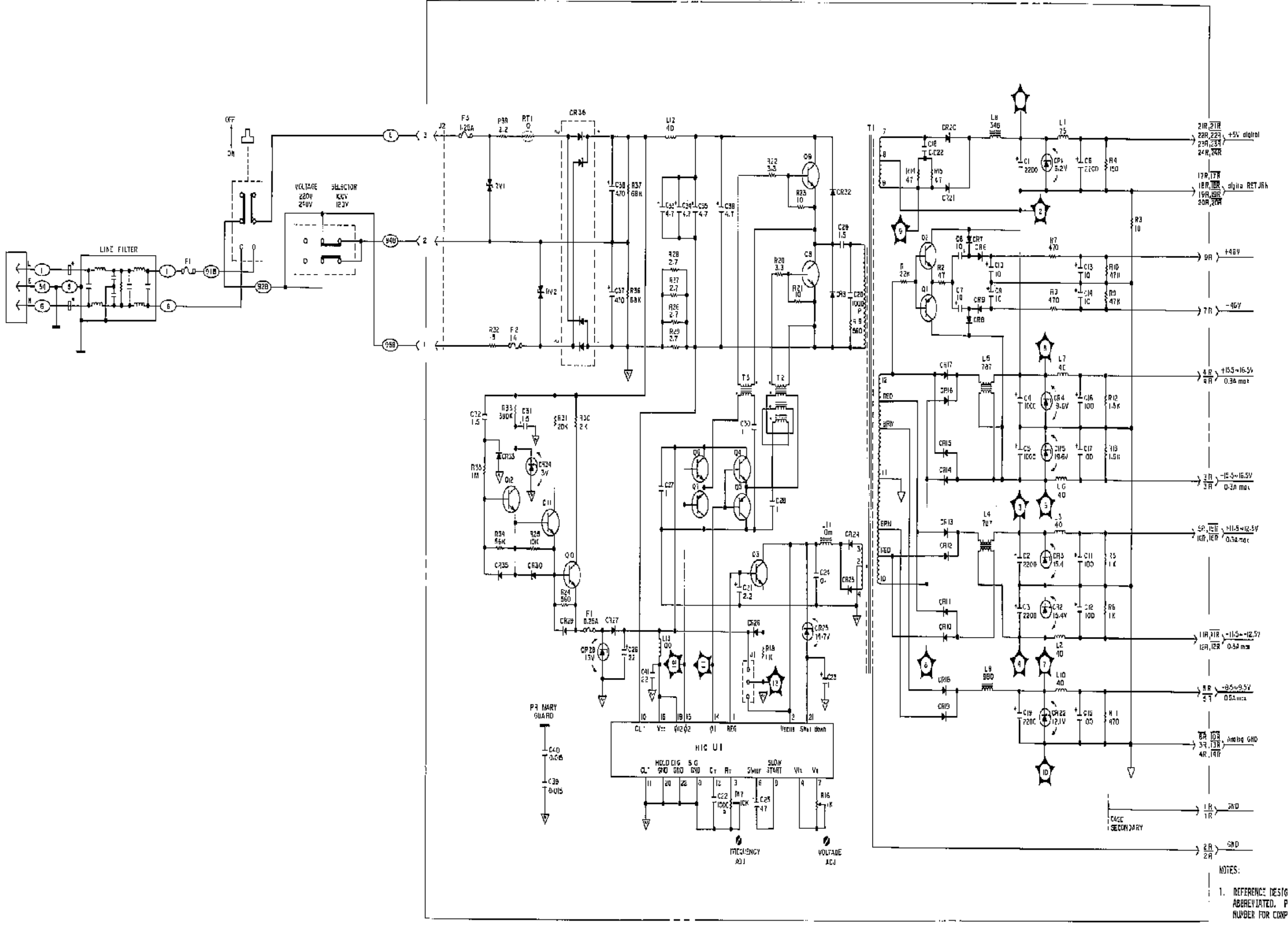


Figure 8-51. A4 POWER SUPPLY Board Assembly Component Locations.

A4 POWER SUPPLY (P/N:04277-66504)



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 8-52. A4 POWER SUPPLY Board Assembly Schematic Diagram.

◀**A4 BOARD**

SEE INSIDE

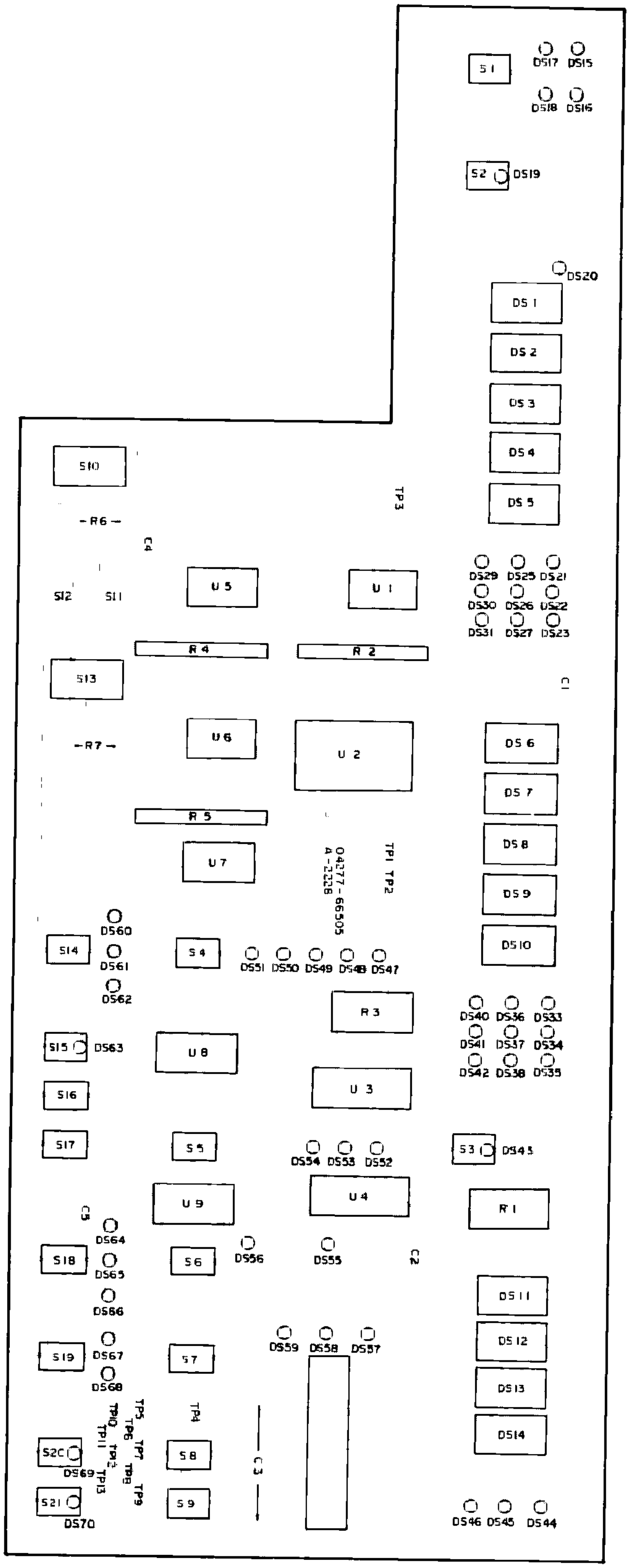
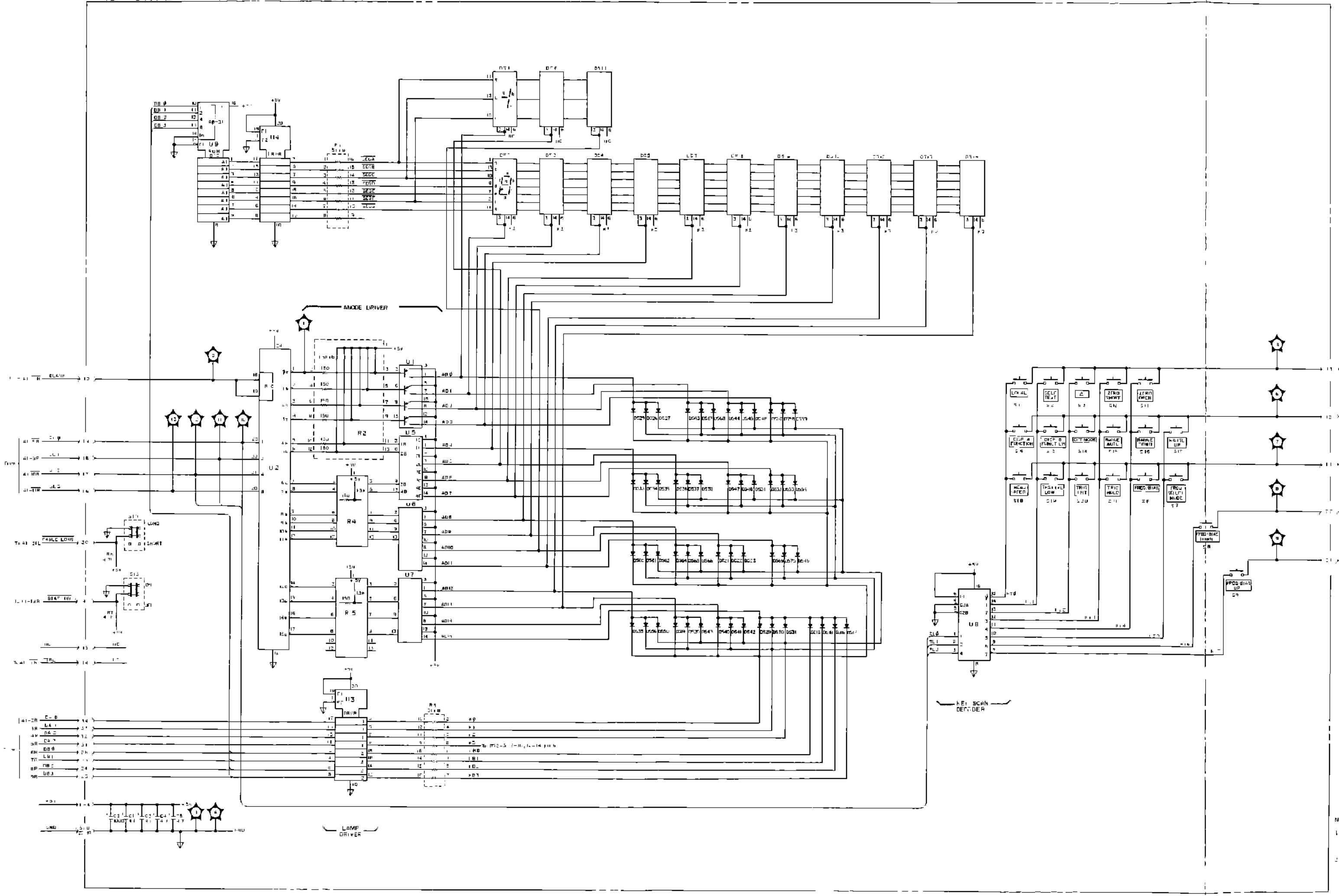


Figure 8-53. A5 DISPLAY Board Assembly Component Locations.

A5 DISPLAY (P/N:04277-66505)



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 8-54. A5 DISPLAY board Assembly Schematic Diagram.

◀ **A5 BOARD**

SEE INSIDE

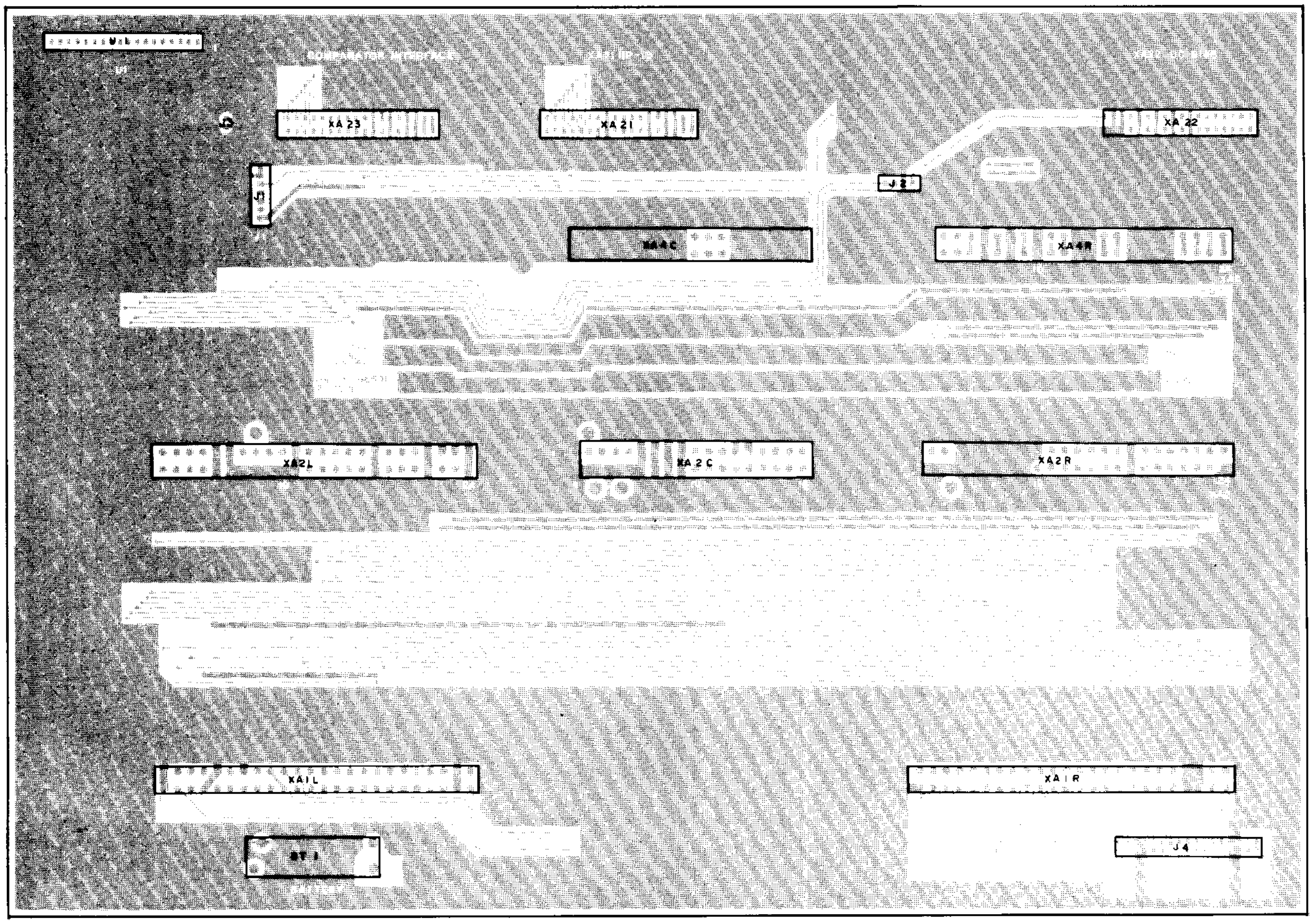


Figure 8-55. A6 MOTHER Board Assembly Component Locations.

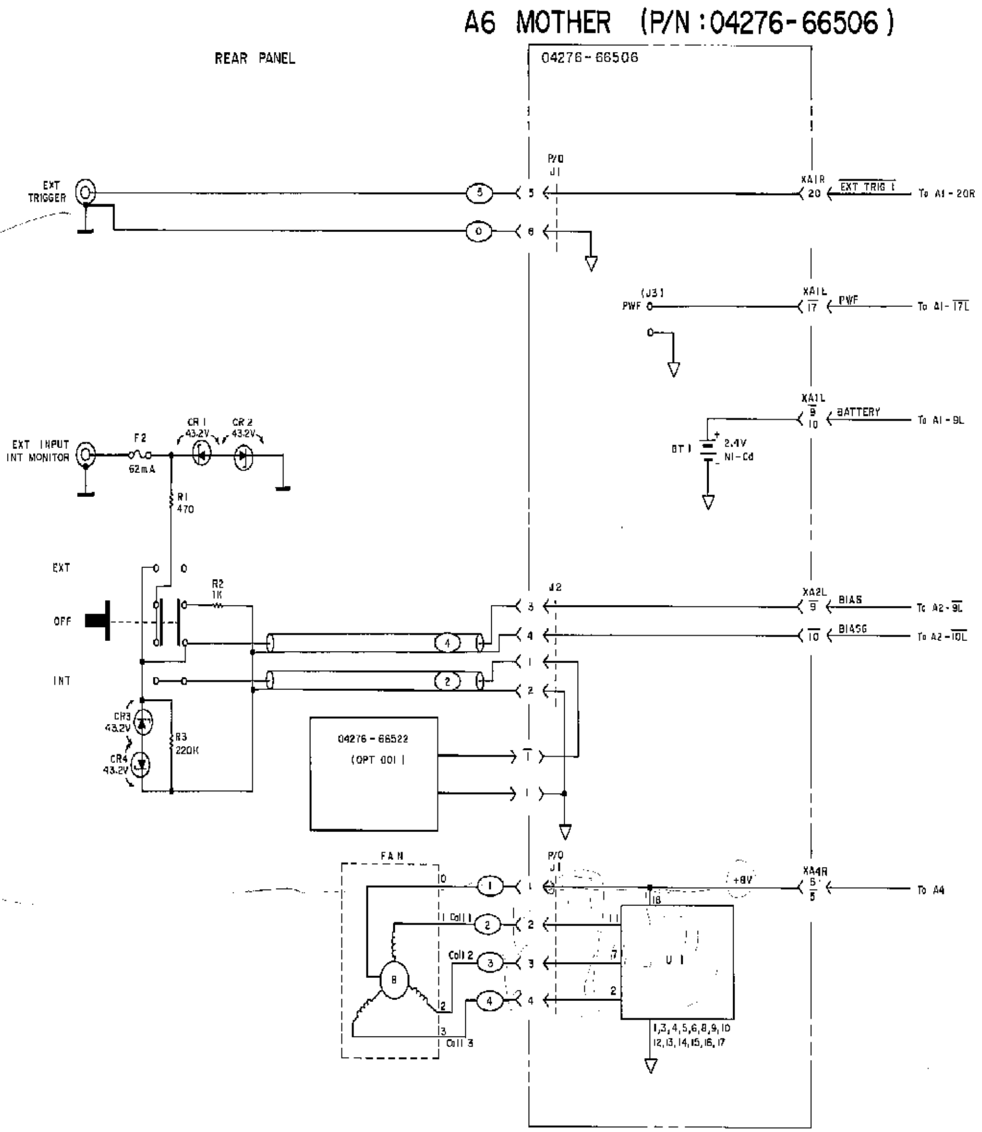


Figure 8-56. A6 MOTHER Board Assembly Schematic Diagram.

◀ **A6 BOARD**

SEE INSIDE

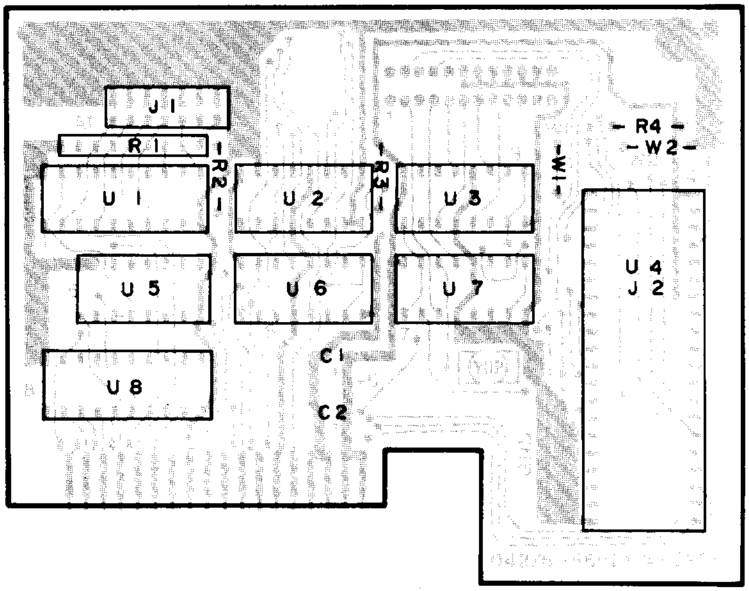
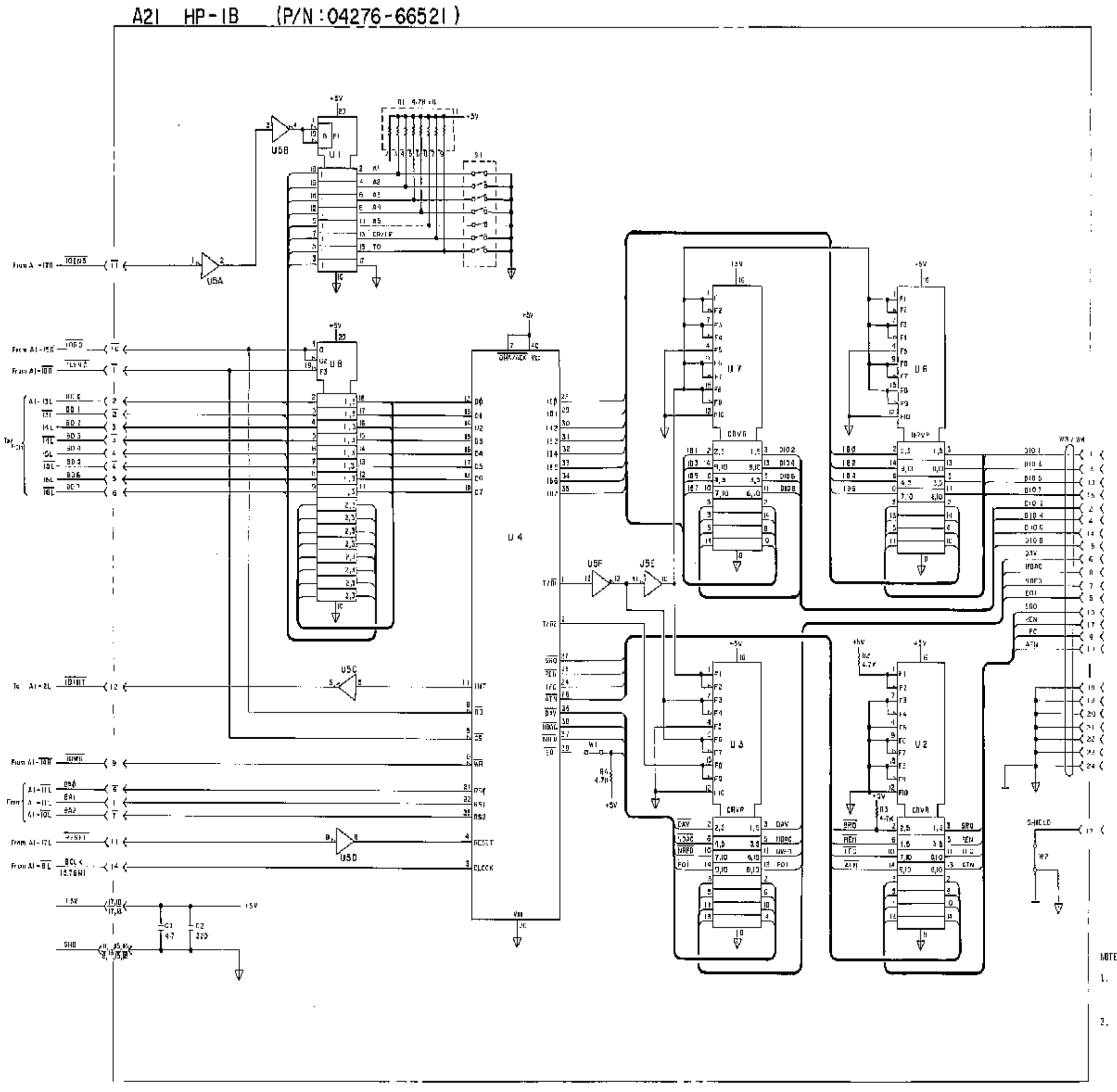


Figure 8-57. A21 HP-IB Board Assembly Component Locations.



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 8-58. A21 HP-IB Board Assembly Schematic Diagram.

◀A21 BOARD

SEE INSIDE

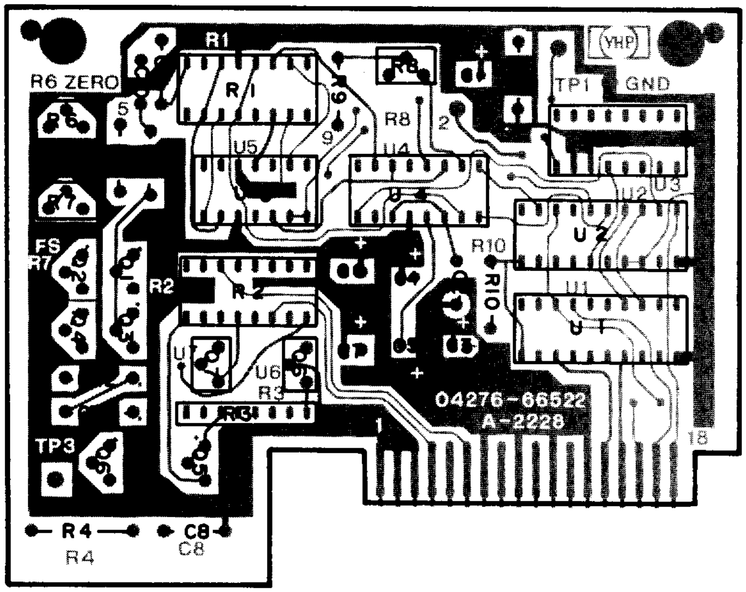
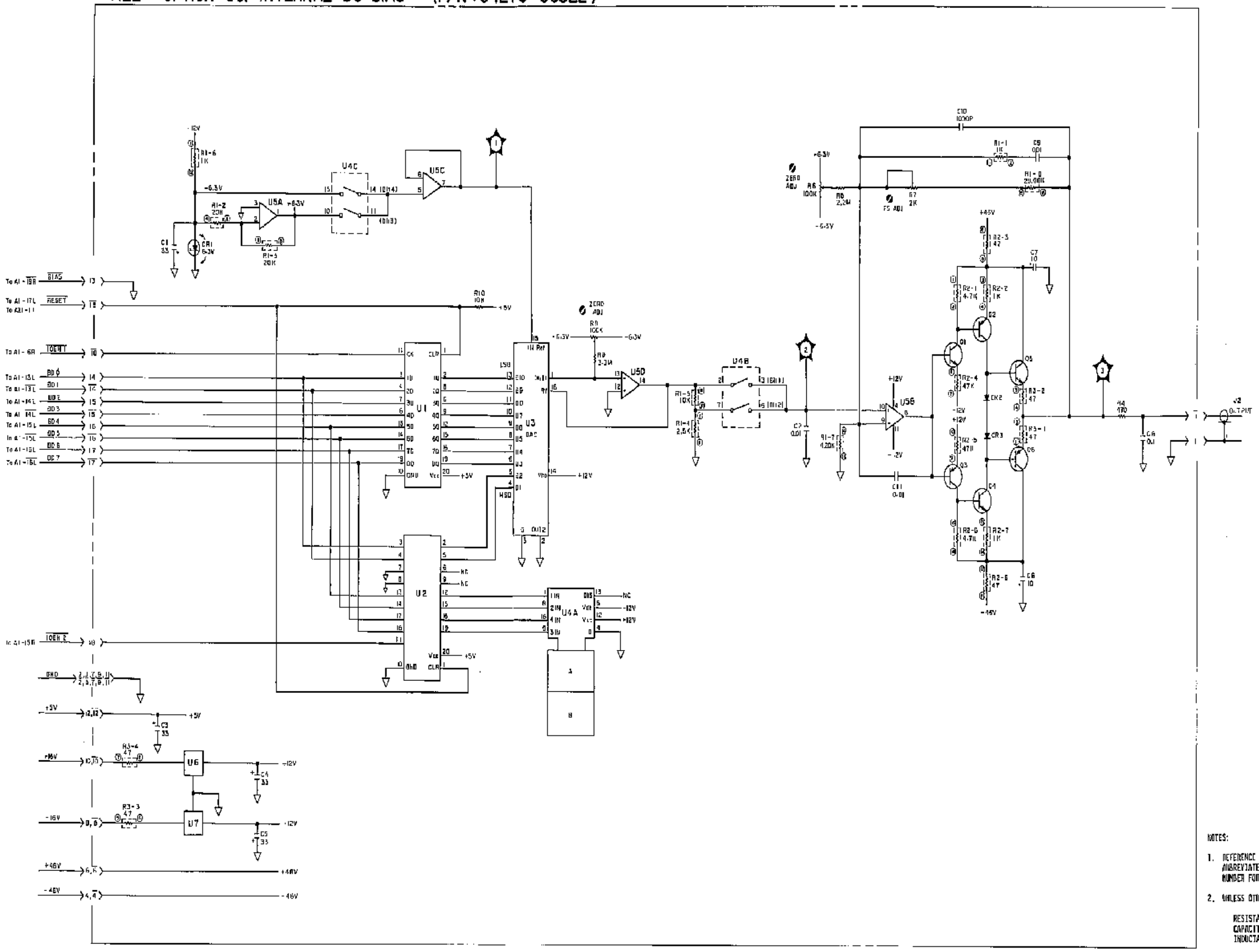


Figure 8-59. A22 OPTION 001 INTERNAL DC BIAS Board Assembly Component Locations.

A22 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)

Figure 8-60. A22 OPTION 001 INTERNAL DC BIAS Board Assembly Schematic Diagram.

◀A22 BOARD

SEE INSIDE

SALES & SUPPORT OFFICES

Arranged alphabetically by country

Product Line Sales/Support Key

Key Product Line
- A Analytical
- CM Components
- C Computer Systems
- E Electronic Instruments & Measurement Systems
- M Medical Products
- P Personal Computation Products
- * Sales only for specific product line
- ** Support only for specific product line

IMPORTANT These symbols designate general product line capability They do not insure sales or support availability for all products within a line at all locations. Contact your local sales office for information regarding locations where HP support is available for specific products.

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August 1988

HEWLETT
PACKARD

OPERATION AND SERVICE MANUAL

MODEL 4277A
LCZ METER
(Including Options 001 and 002)

SERIAL NUMBERS

This manual applies directly to instruments with serial numbers prefixed 2228J.

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

MANUAL PART NO. 04277-90000
Microfiche Part No. 04277-90050

Printed: JAN. 198

YID MKTG INTER-OFFICE MEMO

TO: MKTG #1 長山様

MKTG I '85. 9. 5 長山

MKTG 小原

C/C:

FROM: YID MKTG 田中(豐)
(EXT: 346)

DATE: 85・08・28

FILE NO.: MKTG-MEMO-85-3070

APPROVAL
MKTG '85.8.28 海老原

SUBJECT: 4277Aの パフォーマンステストの マニュアル変更のお願い

マニュアル 4-25 16064A COMPARATOR/HANDLER INTERFACE TEST において誤りの訂正および追記をお願いいたします。

(訂正)
ページ 4-22 PROCEDURE：4

(誤) Test Frequency 1.00 KHz

(正) Test Frequency 10.0 KHz

(変更) ページ 4-23 PROCEDURE：7

Press the 16034A's ERASE key and set the .....

↓

Press the 16034A's ENABLE and ERASE and set the ....

(追記) 4-24 PROCEDURE：19 として

Reset the jumpers A1W1/W2/W3 in the 16064A.

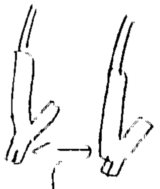
以上

1/2 部 担当者（　　）殿 → 本田 (file)

モデルNo. オプション シリアルNo.	4277A +16048C	客先名 FE/CE/SE [✓ BT]/RSE	相 加藤
Part No.		Tel	
標題			

日時	応対の内容	処理
MKTG '85.11.19 本田信	16048C とつけて Self-Test をすると E-4~~2~~3が出る.	

ごめん まちがい [illegible]



この間隔が10cm以上なら
Error 出ない

Para. 3-11

Self-Test は OPEN termination の状態でないとまずい。マニュアルには単に「テスト・フィクスチャを接続し」と書いてある

MKTG '85.11.19 本田信

Table 4-1. Recommended Equipment (Sheet 1 of 2)

Equipment	Critical Specifications	Recommended Model/Note	Use*
Digital Voltmeter	Voltage range: 10mV to 100Vf.s. Resolution: 0.1mV Accuracy: 0.05% Input impedance: >10MΩ	HP 3478A	P, A, T
RF Voltmeter	Voltage range: 10mV to 3Vrms f.s. Bandwidth: 10kHz to 1MHz Accuracy: 1%	HP 400E and HP 3403C	P, A
Frequency Counter	Maximum frequency: >1MHz Accuracy: 0.001% Trigger level: Adjustable	HP 5314A	P, A, T
DC Power Supply	Maximum output voltage: >50V Resolution: <100mV	HP 6206B	P
Oscilloscope	Bandwidth: 100MHz Sensitivity: 5mV/DIV	HP 1740A	A, T
Oscillator	Frequency: 1kHz Output voltage: 1mV	HP 652A	T
Signature Analyzer		HP 5004A	T
Test Cables	BNC (m)-to-BNC (m), 61cm long, 1 ea.	PN 8120-1839 ~~HP 11170B~~	P, A
	BNC (m)-to-BNC (m), 10cm long, 1 ea.	PN 8120-1838	
	BNC (m)-to-BNC (m), 30cm long, 2 ea.	~~HP 11170A~~	
	BNC (m)-to-Dual Banana Plug, 1 ea.	HP 11001A	
	Dual Banana Plug-to-Alligator Clip, 1 ea.	HP 11002A	P, A, T
	BNC (m)-to-Dual Alligator Clip, 10cm long, 2 ea.	Refer to the troubleshooting diagram A2-17.	T
	Alligator Clip-to-Alligator Clip, 20cm long, 1 ea.		T
Adaptors	BNC (f)-to-BNC (f), 5 ea.	HP P/N 1250-0080	P, T
Oscilloscope Probes	10:1 Divider Probe Input impedance: 10MΩ	HP 10004D	A, T
	1:1 probe	HP 10007B	A
Test Leads		HP 16048A	P, T

*P = Performance Test, A = Adjustment, T = Troubleshooting

Table 4-1. Recommended Equipment (Sheet 2 of 2)

Equipment	Critical Specifications	Recommended Model/Note	Use*
Capacitance Standards	1pF±0.03% 10pF±0.03% 100pF±0.03% 1000pF±0.03% Useable frequency: Up to 1MHz	HP 16381A HP 16382A HP 16383A HP 16384A	P, A, T
Resistance Standards	0Ω 10Ω 100Ω±0.03% 1kΩ±0.03% 10kΩ±0.03% 100kΩ±0.03% OPEN termination SHORT termination	HP 16074A Standard Resistor Set	P, A, T
Capacitors	1nF±5%	HP P/N 0160-2218	T
Resistors	4.7Ω±5% 1/4W	HP P/N 0683-0475	T
	560Ω±5% 1/4W	HP P/N 0683-5615	T
	1kΩ±5% 1/2W	HP P/N 0757-0159	T
	10kΩ±1% 1/2W	HP P/N 0757-0839	T
	100kΩ±1% 1/8W	HP P/N 0757-0465	T
HP-IB Controller		HP-85/ w 00085-15003/ w 82936A/ w 82937A	A

*P = Performance Test, A = Adjustment, T = Troubleshooting

エクステンダ ボード PN 追加

4-9. *TEST FREQUENCY ACCURACY TEST*

4-10. This test verifies that test signal frequencies for the 4277A meet the specified frequency accuracy of 0.01 %.

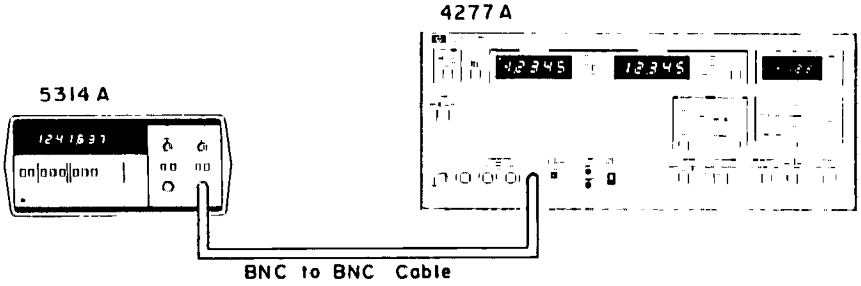


Figure 4-1. Test Frequency Accuracy Test Setup.

EQUIPMENT:

Frequency Counter	HP 5314A
BNC to BNC cable	~~HP 11170A~~ PN 8120-1836

PROCEDURE:

1. Connect the frequency counter to the 4277A UNKNOWN H_{cur} terminal as shown in Figure 4-1.

2. Set the 4277A's controls as follows:

TEST SIG LEVEL	HIGH
DC BIAS switch	OFF
Test Frequency	10kHz
Other controls	Any setting

3. Verify that the frequency reading on the 5314A is 10.000kHz ± 1Hz.

4. Set the test frequency in the sequence given in Table 4-2. Verify that the frequency readings on the 5314A are within the test limits given in the table.

Table 4-2. Test Frequency Accuracy Test

Frequency Setting	Test Limits
10.0kHz	9.999 to 10.001kHz
100kHz	99.99 to 100.01kHz
202kHz	201.98 to 202.02kHz
500kHz	499.95 to 500.05kHz
1.00MHz	0.9999 to 1.0001MHz

Note

1) Test limits in the table do not account for tolerance dependent on the specified accuracy of the 5314A.

2) If this test fails, the instrument requires troubleshooting.

PERFORMANCE TESTS

4-11. *TEST SIGNAL LEVEL ACCURACY TEST*

4-12. This test verifies that test signal level for the 4277A meets the specified level accuracy of 10%.

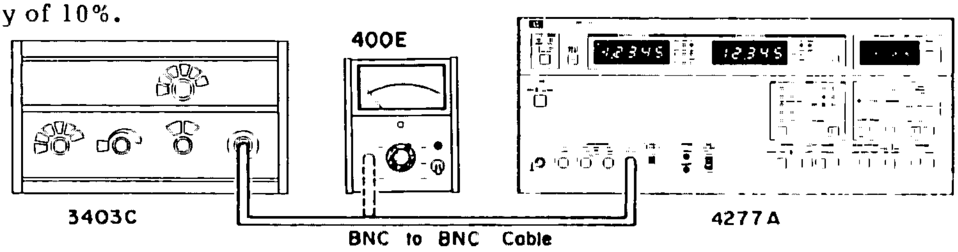


Figure 4-2. Test Signal Level Accuracy Test Setup.

EQUIPMENT:

RF Voltmeter	HP 3403C and HP 400E
BNC to BNC Cable	~~HP 11170A~~ TN 8120-1838

Note

Use RF Voltmeter calibrated for frequency response of 10kHz to 1MHz.

PROCEDURE:

1. Connect the 3403C to the 4277A UNKNOWN $\mathrm{H_{CUR}}$ terminal as shown in Figure 4-2.

2. Set the RANGE control of the 3403C as appropriate to measure 1Vrms.

3. Set the 4277A's controls as follows:

DC BIAS switch	OFF
Test Frequency	10kHz
TEST SIG LEVEL	HIGH
Other controls	Any setting

4. The 3403C should read between 0.9V and 1.1Vrms.

5. Successively change the test frequency setting to 100kHz and 1MHz. The voltage readings on the 3403C should be within the test limits given in Table 4-3.

6. Replace the 3403C with the 400E. Set the TEST SIG LEVEL to LOW.

7. Set the test frequency in accordance with Table 4-3. Verify that the voltage readings on the 400E meet the test limits given in the table.

Table 4-3. Test Signal Level Accuracy Test

	Test Limits			Equipment
Frequency / Level	10kHz	100kHz	1MHz	
High (1Vrms)	0.9 to 1.1Vrms	0.9 to 1.1Vrms	0.9 to 1.1Vrms	HP 3403C
Low (20mVrms)	17 to 23mVrms	17 to 23mVrms	18 to 22mVrms	HP 400E

ADJUSTMENTS

EQUIPMENT:

RF Voltmeter	HP 400E
BNC (m) to BNC (m) Cable	~~HP 11170B~~ PN8120-1839

PROCEDURE:

1. Connect the 400E to the UNKNOWN H_{CUR} terminal of the 4277A using a BNC (m) to BNC (m) cable as shown in Figure 5-3.

2. Set the 4277A's controls as follows:

Test Frequency	1MHz
TEST SIG LEVEL	HIGH
DC BIAS	OFF
Other Controls	Any setting

3. Set RANGE of the 400E to 1Vrms.

4. Adjust A2R6 (LEVEL) until the reading on the 400E is 1.00V±0.01V.

5. Set the Test Frequency and the Test Signal Level in accordance with Table 5-5. Verify that the reading on the 400E is within the test limits given in the table. Change the 400E's range as appropriate for the test signal level.

Table 5-5. Test Signal Level Test Limits

Test Frequency	Test Limits	
	TEST SIG LEVEL "HIGH"	TEST SIG LEVEL "LOW"
1MHz	0.99V to 1.01V	*(18.8mV to 21.2mV)
100KHz	0.94V to 1.06V	18.2mV to 21.8mV
10KHz	0.94V to 1.06V	

Note

For test limits marked with and asterisk *, if a reading on the 400E is greater than 21.2mV, change the value of A2R31 (82.5Ω) to 78.7Ω. If it is less than 18.8mV, change the value of A2R31 to 86.6Ω. Refer to Table 5-2 for the part number of the appropriate resistor.

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
A1U2	1826-0978	4	1	IC (MISC)	28480	1826-0978
A1U3	1826-0180	0	1	IC TIMER TTL MONO/ASTBL	01295	NE555P
A1U4	1820-2649	8	1	IC- Z80B-CPU	28480	1820-2649
A1U5	04276-85011	5	1	PROM-PROGRAMMED	28480	04276-85011
A1U6	04277-85012	6	1	PROM-PROGRAMMED	28480	04277-85012
A1U7	04277-85003	7	1	PROM-PROGRAMMED	28480	04277-85003
A1U8	04276-85004	8	1	PROM-PROGRAMMED	28480	04276-85004
A1U9	04276-85005	9	1	PROM-PROGRAMMED	28480	04276-85005
A1U10	04276-85016	0	1	PROM-PROGRAMMED	28480	04276-85016
A1U12	1818-1974	5	1	IC-MSM5128-15	28480	1818-1974
A1U13	1820-2024	3	2	IC DRVR TTL LS LINE DRVR OCTL	01295	SN74LS244N
A1U14	1820-2024	3		IC DRVR TTL LS LINE DRVR OCTL	01295	SN74LS244N
A1U15	1820-1730	6	1	IC FF TTL LS D-TYPE POS-EDGE-TRIG COM	01295	SN74LS273N
A1U16	1820-1217	4	1	IC MUXR/DATA-SEL TTL LS 8-TO-1-LINE	01295	SN74LS151N
A1U17	1820-1197	9	4	IC GATE TTL LS NAND QUAD 2-INP	01295	SN74LS00N
A1U18	1820-1112	8	5	IC FF TTL LS D-TYPE POS-EDGE-TRIG	01295	SN74LS74AN
A1U19	1820-1197	9		IC GATE TTL LS NAND QUAD 2-INP	01295	SN74LS00N
A1U20	1820-0682	5	1	IC GATE TTL S NAND QUAD 2-INP	01295	SN74S03N
A1U21	1820-1197	9		IC GATE TTL LS NAND QUAD 2-INP	01295	SN74LS00N
A1U22	1820-1216	3	4	IC DCDR TTL LS 3-TO-8-LINE 3-INP	01295	SN74LS138N
A1U23	1820-1199	1	3	IC INV TTL LS HEX 1-INP	01295	SN74LS04N
A1U24	1820-0681	4	1	IC GATE TTL S NAND QUAD 2-INP	01295	SN74S00N
A1U25	1820-2150	6	1	IC MICPROC-ACCESS NMOS	34649	D8279-5
A1U26	1820-1216	3		IC DCDR TTL LS 3-TO-8-LINE 3-INP	01295	SN74LS138N
A1U27	1820-1112	8		IC FF TTL LS D-TYPE POS-EDGE-TRIG	01295	SN74LS74AN
A1U28	1820-1112	8		IC FF TTL LS D-TYPE POS-EDGE-TRIG	01295	SN74LS74AN
A1U29	1820-1420	1	1	IC CNTR TTL LS DIV-X-12 ASYNCHRO	01295	SN74LS92N
A1U30	1820-1432	5	2	IC CNTR TTL LS BIN SYNCHRO POS-EDGE-TRIG	01295	SN74LS163AN
A1U31	1820-1432	5		IC CNTR TTL LS BIN SYNCHRO POS-EDGE-TRIG	01295	SN74LS163AN
A1U32	1820-1112	8		IC FF TTL LS D-TYPE POS-EDGE-TRIG	01295	SN74LS74AN
A1U33	1820-1199	1		IC INV TTL LS HEX 1-INP	01295	SN74LS04N
A1U34	1820-2075	4	1	IC MISC TTL LS	01295	SN74LS245N
A1U35	1820-1216	3		IC DCDR TTL LS 3-TO-8-LINE 3-INP	01295	SN74LS138N
A1U36	1820-1624	7	1	IC BFR TTL S OCTL 1-INP	01295	SN74S241N
A1U37	1820-1199	1		IC INV TTL LS HEX 1-INP	01295	SN74LS04N
A1U38	1820-1197	9		IC GATE TTL LS NAND QUAD 2-INP	01295	SN74LS00N
A1U39	~~1820-2873~~	0	1	IC-UPD8253-5	28480	1820-2873
A1U41	1820-1216	3		IC DCDR TTL LS 3-TO-8-LINE 3-INP	01295	SN74LS138N
A1U42	1820-1112	8		IC FF TTL LS D-TYPE POS-EDGE-TRIG	01295	SN74LS74AN
A1U43	1820-1425	6	1	IC SCHMITT-TRIG TTL LS NAND QUAD 2-INP	01295	SN74LS132N
A1U44	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
A1W2	1251-4822	6		CONNECTOR 3-PIN M POST TYPE	28480	1251-4822
A1W3	1251-4822	6		CONNECTOR 3-PIN M POST TYPE	28480	1251-4822
A1W4	1251-4787	2	1	SHUNT-DIP 8-POSITION	28480	1251-4787
A1W5	8159-0005	0	1	RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
				MISCELLANECUS PARTS		
	1258-0141	8	3	JUMPER-REM	28480	1258-0141
	04276-26501		1	PC BOARD, BLANK	28480	04276-26501
	04276-01203		1	ANGLE (BOARD)	28480	04276-01203

1820-4469

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
A2C146	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C147	0160-4830	2	1	CAPACITOR-FXD 2200PF +-10% 100VDC CER	28480	0160-4830
A2C149	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C150	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C151	0160-5501	6	1	CAPACITOR- 0.1 UF 100VDC F	28480	0160-5501
A2C152*	0160-5595	8		CAPACITOR- 2 PF +/- .5 PF	28480	0160-5595
A2C153*	0160-5596	9	1	CAPACITOR- 3 PF +/- .5 PF	28480	0160-5596
A2C154*	0160-5592	5	2	CAPACITOR- 10PF +/- .5 PF	28480	0160-5592
A2C155	0160-5494	6		CAPACITOR-FXD 2.2 UF 5% 100VDC	28480	0160-5494
A2C156	0160-0127	2	1	CAPACITOR-FXD 1UF +-20% 25VDC CER	28480	0160-0127
A2C157	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C158	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C159	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2C160	0160-4812	0		CAPACITOR-FXD 220PF +-5% 100VDC CER	28480	0160-4812
A2C161	0160-4835	7		CAPACITOR-FXD .1UF +-10% 50VDC CER	28480	0160-4835
A2C162	0180-2951	6		CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A2CR1	1902-0041	4	2	DIODE-ZNR 5.11V 5% DO-35 PD=.4W	28480	1902-0041
A2CR2	1902-0041	4		DIODE-ZNR 5.11V 5% DO-35 PD=.4W	28480	1902-0041
A2CR3	1902-3059	0	4	DIODE-ZNR 3.83V 5% DO-35 PD=.4W	28480	1902-3059
A2CR4	1902-3059	0		DIODE-ZNR 3.83V 5% DO-35 PD=.4W	28480	1902-3059
A2CR5	1902-3059	0		DIODE-ZNR 3.83V 5% DO-35 PD=.4W	28480	1902-3059
A2CR6	1902-3059	0		DIODE-ZNR 3.83V 5% DO-35 PD=.4W	28480	1902-3059
A2CR7	1901-0033	2	8	DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
A2CR8	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
A2CR9	1902-3082	9	4	DIODE-ZNR 4.64V 5% DO-35 PD=.4W	28480	1902-3082
A2CR10	1902-3082	9		DIODE-ZNR 4.64V 5% DO-35 PD=.4W	28480	1902-3082
A2CR11	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
A2CR12	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
A2CR13	1901-0040	1	11	DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR14	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR15	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR16	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR17	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
A2CR18	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
A2CR19	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR20	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR21	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR22	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR23	0122-0153	4	1	DIODE-VVC 500PF +-10% PD=100MW	28480	0122-0153
A2CR24	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR25	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR26	1901-0040	1		DIODE-SWITCHING 30V 50MA 2NS DO-35	28480	1901-0040
A2CR27	1902-3082	9		DIODE-ZNR 4.64V 5% DO-35 PD=.4W	28480	1902-3082
A2CR28	1902-3082	9		DIODE-ZNR 4.64V 5% DO-35 PD=.4W	28480	1902-3082
A2CR29	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
A2CR30	1901-0033	2		DIODE-GEN PRP 180V 200MA DO-7	28480	1901-0033
A2K1	0490-1269	4	2	RELAY 1C 12VDC-COIL .66A 30VDC	28480	0490-1269
A2K2	0490-1269	4		RELAY 1C 12VDC-COIL .66A 30VDC	28480	0490-1269
A2L1	9100-1629	4	1	INDUCTOR RF-CH-MLD 47UH 5% .166DX.385LG	28480	9100-1629
A2L2	9100-1625	0	1	INDUCTOR RF-CH-MLD 33UH 5% .166DX.385LG	28480	9100-1625
A2L3	9140-0697	8	1	TRANSFORMER- 100 MH	28480	9140-0697
A2L4*	9100-2247	4	1	INDUCTOR RF-CH-MLD 100NH 10% .105DX.26LG	28480	9100-2247
A2L5	9100-0824	9	1	COIL CHOKE 100 UH	28480	9100-0824
A2L6*	9100-2251	0	1	INDUCTOR RF-CH-MLD 220NH 10% .105DX.26LG	28480	9100-2251
A2Q1	1854-0810	2	5	TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
A2Q2	1854-0810	2		TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
A2Q3	1854-0810	2		TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
A2Q4	1854-0810	2		TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
A2Q5	1854-0810	2		TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
A2Q6	1041 1854-0129	6	2	TRANSISTOR-NPN ~~2SC1636~~	28480	1854-0129
A2Q7	1855-0111 0571	8	3	TRANSISTOR-FET ~~2SK438D~~	28480	1855-0111
A2Q8	1855-0111	8		TRANSISTOR-FET ~~2SK438D~~	28480	1855-0111 0571 1041
A2Q9	1855-0111	8		TRANSISTOR-FET ~~2SK438D~~	28480	1855-0111
A2Q10	1854-0129 1041	6		TRANSISTOR-NPN ~~2SC1636~~	28480	1854-0129
A2R1	0683-4715	0	1	RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
A2R2	0757-0416	7	2	RESISTOR 511 1% .125W F TC=0+-100	24546	C4-1/8-T0-511R-F
A2R3	0757-0280	3	1	RESISTOR 1K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1001-F
A2R4	1810-0347	8	6	NETWORK-RES 8-SIP2.2K OHM X 4	01121	208B222
A2R5	1810-0347	8		NETWORK-RES 8-SIP2.2K OHM X 4	01121	208B222
A2R6	2100-2574	3	1	RESISTOR-TRMR 500 10% C SIDE-ADJ 1-TRN	30983	ET50X501
A2R7	0683-5615	1	2	RESISTOR 560 5% .25W FC TC=-400/+600	01121	CB5615
A2R8	1810-0347	8		NETWORK-RES 8-SIP2.2K OHM X 4	01121	208B222
A2R9	1810-0347	8		NETWORK-RES 8-SIP2.2K OHM X 4	01121	208B222
A2R10	0683-5615	1		RESISTOR 560 5% .25W FC TC=-400/+600	01121	CB5615

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
A2R86	0683-3335	0	1	RESISTOR 33K 5% .25W FC TC=-400/+800	01121	CB3335
A2R87	0683-1575	4	1	RESISTOR 1.5M 5% .25W FC TC=-400/+700	01121	CB1575
A2R88	0683-1035	1		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A2R89	0683-1035	1		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A2R90	0683-1035	1		RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A2R91	0698-3160	8	1	RESISTOR 31.6K 1% .125W F TC=0+-100	24546	C4-1/8-T0-3162-F
A2R92	0683-2215	1		RESISTOR 220 5% .25W FC TC=-400/+600	01121	CB2215
A2R93	0683-2215	1		RESISTOR 220 5% .25W FC TC=-400/+600	01121	CB2215
A2R94	0683-1005	5		RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
A2R95	0683-1005	5		RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
A2R96	1810-0305	8		NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
A2R97*	0757-0401	0	2	RESISTOR 100 1% .125W F TC=0+-100	24546	C4-1/8-T0-101-F
A2R98	0757-0459	8	1	RESISTOR 56.2K 1% .125W F TC=0+-100	24546	C4-1/8-T0-5622-F
A2R99	1810-0305	8		NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
A2R100	0683-3315	4	2	RESISTOR 330 5% .25W FC TC=-400/+600	01121	CB3315
A2R101	0698-3157	3	1	RESISTOR 19.6K 1% .125W F TC=0+-100	24546	C4-1/8-T0-1962-F
A2R102	0699-1019	4	2	RESISTOR- 7.071K 0.1W	28480	0699-1019
A2R103	0698-4157	5	2	RESISTOR 10K 1% .125W F TC=0+-50	28480	0698-4157
A2R104	0699-1019	4		RESISTOR- 7.071K 0.1W	28480	0699-1019
A2R105	0698-4157	5		RESISTOR 10K .1% .125W F TC=0+-50	28480	0698-4157
A2R106	0683-1025	9		RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
A2R107	0683-3315	4		RESISTOR 330 5% .25W FC TC=-400/+600	01121	CB3315
A2T1	9140-0698	9	3	TRANSFORMER	28480	9140-0698
A2T2	9140-0698	9		TRANSFORMER	28480	9140-0698
A2T3	9100-0823	8	3	TRANSFORMER- PULSE 113B1	28480	9100-0823
A2T4	9140-0698	9		TRANSFORMER	28480	9140-0698
A2T5	9100-0823	8		TRANSFORMER- PULSE 113B1	28480	9100-0823
A2T6	9100-0823	8		TRANSFORMER- PULSE 113B1	28480	9100-0823
A2U1	1813-0295	1	4	IC (MISC)	28480	1813-0295
A2U2	1813-0295	1		IC (MISC)	28480	1813-0295
A2U3	1813-0295	1		IC (MISC)	28480	1813-0295
A2U4	1813-0295	1		IC (MISC)	28480	1813-0295
A2U5	1813-0300	9	13	IC (MISC)	28480	1813-0300
A2U6	1813-0300	9		IC (MISC)	28480	1813-0300
A2U7	1826-0122	0	6	IC 7805 V RGLTR TO-220	07263	7805UC
A2U8	5080-3837	2	1	IC V RGLTR TO-220(SEL)	04713	MC7905.2CT
A2U9	1826-0122	0		IC 7805 V RGLTR TO-220	07263	7805UC
A2U10	1820-0693	8	1	IC FF TTL S D-TYPE POS-EDGE-TRIG	01295	SN74S74N
A2U11	1813-0297	3	1	IC (MISC)	28480	1813-0297
A2U12	1826-0519	9	2	IC OP AMP LOW-~~BIAS-H-IMPD 8-DIP-P PKG~~	01295	TL071CP
A2U13	1820-0630	3	1	IC MISC TTL	04713	MC4044P
A2U14	1820-1430	3	1	IC CNTR TTL LS BIN SYNCHRO POS-EDGE-TRIG	01295	SN74LS161AN
A2U15	1820-1244	7	1	IC MUXR/DATA-SEL TTL LS 4-TO-1-LINE DUAL	01295	SN74LS153N
A2U16	1820-2805	4	1	IC- HD74LS390	28480	1820-2805
A2U17	1820-0683	6	1	IC INV TTL S HEX 1-INP	01295	SN74S04N
A2U18	1826-0122	0		IC 7805 V RGLTR TO-220	07263	7805UC
A2U19	1813-0301	0	2	IC (MISC)	28480	1813-0301
A2U20	1813-0301	0		IC (MISC)	28480	1813-0301
A2U21	1820-1510 ~~1820-1313~~	1	6	IC MULTIPLXR 2-CHAN-ANLG TRIPLE 16-DIP-P	~~31585~~	~~CD4053BE~~ PCO 16213
A2U22	1813-0298	4	2	IC (MISC)	28480	1813-0298
A2U23	1813-0300	9		IC (MISC)	28480	1813-0300
A2U24	1813-0300	9		IC (MISC)	28480	1813-0300
A2U25	1813-0298	4		IC (MISC)	28480	1813-0298
A2U26	1820-1730	6	3	IC FF TTL LS D-TYPE POS-EDGE-TRIG COM	01295	SN74LS273N
A2U27	5080-3838	0	5	IC V RGLTR TO-220(SEL)	04713	MC7912CT
A2U28	1826-0147	9	3	IC 7812 V RGLTR TO-220	04713	MC7812CP
A2U29	1826-0971	7	4	IC- UPC7908H	28480	1826-0971
A2U30	1826-0971	7		IC- UPC7908H	28480	1826-0971
A2U31	1826-0146	8	4	IC 7808 V RGLTR TO-220	04713	MC7808CP
A2U32	1826-0146	8		IC 7808 V RGLTR TO-220	04713	MC7808CP
A2U33	5080-3838	0		IC V RGLTR TO-220(SEL)	04713	MC7912CT
A2U34	1826-0147	9		IC 7812 V RGLTR TO-220	04713	MC7812CP
A2U35	1820-2111	9	1	IC DRVR TTL INV	01295	SN75468N
A2U36	1820-1314	2	2	IC MULTIPLXR 4-CHAN-ANLG DUAL 16-DIP-P	31585	CD4052BE
A2U37	1813-0299	5	5	IC (MISC)	28480	1813-0299
A2U38	1813-0300	9		IC (MISC)	28480	1813-0300
A2U39	1813-0300	9		IC (MISC)	28480	1813-0300
A2U40	1813-0300	9		IC (MISC)	28480	1813-0300
A2U41	1813-0300	9		IC (MISC)	28480	1813-0300
A2U42	1820-1313	1		IC MULTIPLXR 2-CHAN-ANLG TRIPLE 16-DIP-P	~~31585~~	~~CD4053BE~~
A2U43	~~1820-1313~~	1		IC MULTIPLXR 2-CHAN-ANLG TRIPLE 16-DIP-P	~~31585~~	~~CD4053BE~~
A2U44	1813-0299	5		IC (MISC)	28480	1813-0299
A2U45	~~1820-1313~~	1		IC MULTIPLXR 2-CHAN-ANLG TRIPLE 16-DIP-P	~~31585~~	~~CD4053BE~~

1820-1510

See introduction to this section for ordering information
*Indicates factory selected value

PCo 30930

PCo [illegible]

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A4CR31	1901-1065	2	3	DIODE-PWR RECT 1N4936 400V 1A 200NS	14936	1N4936
A4CR32	1901-1065	2		DIODE-PWR RECT 1N4936 400V 1A 200NS	14936	1N4936
A4CR33	1901-1065	2		DIODE-PWR RECT 1N4936 400V 1A 200NS	14936	1N4936
A4CR34	1902-3191	1	1	DIODE-ZNR 13V 2% DO-35 PD=.4W TC=+.06%	28480	1902-3191
A4CR35	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR36	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
A4F2	2110-0305	5	1	FUSE 1.25A 250V TD 1.25X.25 UL	75915	3131.25
A4F3	2110-0007	4	1	FUSE 1A 250V TD 1.25X.25 UL	75915	313001
A4J1	1251-4938	5	1	CONNECTOR 3-PIN M METRIC POST TYPE	28480	1251-4938
A4J2	1251-3837	1	1	CONNECTOR 4-PIN M UTILITY	28480	1251-3837
A4L1	9100-3139	5	1	INDUCTOR 75UH 15% .50X.875LG	28490	9100-3139
A4L2	9140-0171	3	6	INDUCTOR RF-CH-MLD 40UH 10% .296DX.968LG	28480	9140-0171
A4L3	9140-0171	3		INDUCTOR RF-CH-MLD 40UH 10% .296DX.968LG	28480	9140-0171
A4L4	9140-0758	3	2	INDUCTOR- 787 UH	28480	9140-0758
A4L5	9140-0758	3		INDUCTOR- 787 UH	28480	9140-0758
A4L6	9140-0171	3		INDUCTOR RF-CH-MLD 40UH 10% .296DX.968LG	28480	9140-0171
A4L7	9140-0171	3		INDUCTOR RF-CH-MLD 40UH 10% .296DX.968LG	28480	9140-0171
A4L8	9140-0462	5	1	INDUCTOR 355UH	28480	9140-0462
A4L9	9140-0757	0	1	INDUCTOR- 980 UH	28480	9140-0757
A4L10	9140-0171	3		INDUCTOR RF-CH-MLD 40UH 10% .296DX.968LG	28480	9140-0171
A4L11	9140-0463	6	1	INDUCTOR 10MH 6%	28480	9140-0463
A4L12	9140-0171	3		INDUCTOR RF-CH-MLD 40UH 10% .296DX.968LG	28480	9140-0171
A4L13	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
A4Q2	1854-0477	7	5	TRANSISTOR NPN 2N2222A SI TO-18 PD=500MW	04713	2N2222A
A4Q3	1854-0477	7		TRANSISTOR NPN 2N2222A SI TO-18 PD=500MW	04713	2N2222A
A4Q4	1854-0477	7		TRANSISTOR NPN 2N2222A SI TO-18 PD=500MW	04713	2N2222A
A4Q5	1853-0281	9		TRANSISTOR PNP 2N2907A SI TO-18 PD=400MW	04713	2N2907A
A4Q6	1854-0477	7		TRANSISTOR NPN 2N2222A SI TO-18 PD=500MW	04713	2N2222A
A4Q7	1853-0281	9		TRANSISTOR PNP 2N2907A SI TO-18 PD=400MW	04713	2N2907A
A4Q8 1854-0787 ←	~~1854-0624~~	6	2	TRANSISTOR NPN 2N6308 SI TO-3 PD=125W	04713	2N6308
A4Q9	~~1854-0624~~	6		TRANSISTOR NPN 2N6308 SI TO-3 PD=125W	04713	2N6308
A4Q10	1854-0935	2	1	TRANSISTOR-NPN	28480	1854-0935
A4Q11 1854-1167	~~1854-0936~~	3	1	TRANSISTOR-NPN	28480	1854-0936
A4Q12	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
A4R2	0683-4705	8	3	RESISTOR 47 5% .25W FC TC=-400/+500	01121	CB4705
A4R3	0683-1005	5	3	RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
A4R4	0683-1515	2	1	RESISTOR 150 5% .25W FC TC=-400/+600	01121	CB1515
A4R5	0683-1025	9	3	RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
A4R6	0683-1025	9		RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
A4R7	0683-4715	0	3	RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
A4R8	0683-4715	0		RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
A4R9	0683-4735	4	2	RESISTOR 47K 5% .25W FC TC=-400/+800	01121	CB4735
A4R10	0683-4735	4		RESISTOR 47K 5% .25W FC TC=-400/+800	01121	CB4735
A4R11	0683-4715	0		RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
A4R12	0683-1525	4	2	RESISTOR 1.5K 5% .25W FC TC=-400/+700	01121	CB1525
A4R13	0683-1525	4		RESISTOR 1.5K 5% .25W FC TC=-400/+700	01121	CB1525
A4R14	0683-4705	8		RESISTOR 47 5% .25W FC TC=-400/+500	01121	CB4705
A4R15	0683-4705	8		RESISTOR 47 5% .25W FC TC=-400/+500	01121	CB4705
A4R16	2100-3352	7	1	RESISTOR-TRMR 1K 10% C SIDE-ADJ 1-TRN	28480	2100-3352
A4R17	2100-3274	2	1	RESISTOR-TRMR 10K 10% C SIDE-ADJ 1-TRN	28480	2100-3274
A4R18	0683-1025	9		RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
A4R19	0764-0015	7	1	RESISTOR 560 5% 2W MO TC=0+-200	28480	0764-0015
A4R20	0683-0335	2	2	RESISTOR 3.3 5% .25W FC TC=-400/+500	01121	CB33G5
A4R21	0683-1005	5		RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
A4R22	0683-0335	2		RESISTOR 3.3 5% .25W FC TC=-400/+500	01121	CB33G5
A4R23	0683-1005	5		RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
A4R24	0683-5615	1	1	RESISTOR 560 5% .25W FC TC=-400/+600	01121	CB5615
A4R25	0683-1035	1	1	RESISTOR 10K 5% .25W FC TC=-400/+700	01121	CB1035
A4R26	0683-0275	9	4	RESISTOR 2.7 5% .25W FC TC=-400/+500	01121	CB27G5
A4R27	0683-0275	9		RESISTOR 2.7 5% .25W FC TC=-400/+500	01121	CB27G5
A4R28	0683-0275	9		RESISTOR 2.7 5% .25W FC TC=-400/+500	01121	CB27G5
A4R29	0683-0275	9		RESISTOR 2.7 5% .25W FC TC=-400/+500	01121	CB27G5
A4R30	0766-0033	3	1	RESISTOR 2K 2% 3W MO TC=0+-250	27167	FP3-3-250-2001-G
A4R31	0761-0004	8	1	RESISTOR 20K 5% 1W MO TC=0+-200	28480	0761-0004
A4R32	0699-1057	4	1	RESISTOR- 15 OHM 10% 3W	28400	0699-1057
A4R33	0686-3945	2	1	RESISTOR 390K 5% .5W CC TC=0+882	01121	EB3945
A4R34	0683-5635	5	1	RESISTOR 56K 5% .25W FC TC=-400/+800	01121	CB5635
A4R35	0686-1055	1	1	RESISTOR 1M 5% .5W CC TC=0+1000	01121	EB1055
A4R36	0698-3657	8	2	RESISTOR 68K 5% 2W MO TC=0+-200	27167	FP42-2-T00-6802-J
A4R37	0698-3657	8		RESISTOR 68K 5% 2W MO TC=0+-200	27167	FP42-2-T00-6802-J
A4R38	0811-1670	3	1	RESISTOR 2.2 5% 2W PW TC=0+-400	75042	BWH2-2R2-J

See introduction to this section for ordering information
*Indicates factory selected value

PCO 29707

MKTG '91.3.22

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A4RT1	0039-0006	5	1	THERMISTOR DISC	28480	0839-0306
A4T1	9100-4287	1	1	TRANSFORMER-POWER	28480	9100-4287
A4T2	9100-0857	8	1	TRANSFORMER-PULSE 114H1	28480	9100-0857
A4T3	9100-4293	2	1	TRANSFORMER-PULSE	28480	9100-4293
A4U1	1813-0255	3	1	IC-REGULATOR, HYBRID	28480	1813-0255
A4RV1	0837-0237	0	1	VARISTOR	28480	0837-0237
A4RV2	~~0837-0106~~ 1901-1711	~~2~~	~~1~~	~~VARISTOR~~ PCO#31877	28480	0837-0106
A4W1	8159-0005	0	1	RESISTOR-ZERO OHMS 22 AWG LEAD DIA	28480	8159-0005
				MISCELLANEOUS PARTS		
	2110-0726 ~~2110-0269~~	0	6	FUSEHOLDER-CLIP TYPE.25D-FUSE	28480	2110-0269
	04276-01204	4	1	ANGLE (HEATSINK)	28480	04276-01204
	04276-00613		1	SHIELD COVER	28480	04276-00613
	04276-00614		1	SHIELD COVER	28480	04276-00614
	04276-00615		1	SHIELD COVER	28480	04276-00615
	04276-00616		1	SHIELD COVER	28480	04276-00616
	04276-01206		1	ANGLE (BOARD)	28480	04276-01206
	04276-26504		1	PC BOARD, BLANK	28480	04276-26504

MKTG '91.10.23 大橋

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
A5R6	0683-4725	2	2	RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A5R7	0683-4725	2		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A5S1	5060-9436	7	17	PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S2	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S3	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S4	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S5	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S6	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S7	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S8	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S9	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S10	~~3101-2046~~ 3101-2550	7	2	SWITCH-SLIDE DPDT-NS	28480	3101-2046
A5S11	3101-1074	9	2	SWITCH-PUSHBUTTON SPST NO	28480	3101-1074
A5S12	3101-1074	9		SWITCH-PUSHBUTTON SPST NO	28480	3101-1074
A5S13	3101-255 ~~3101-2046~~	7		SWITCH-SLIDE DPDT-NS	28480	3101-2046
A5S14	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S15	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S16	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S17	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S18	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S19	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S20	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5S21	5060-9436	7		PUSHBUTTON SWITCH P.C. MOUNT	28480	5060-9436
A5U1	1858-0038	4	4	TRANSISTOR ARRAY	28480	1858-0038
A5U2	1820-0495	8	1	IC DCDR TTL 4-TO-16-LINE 4-INP	01295	SN74154N
A5U3	1820-1624	7	2	IC BFR TTL S OCTL 1-INP	01295	SN74S241N
A5U4	1820-1624	7		IC BFR TTL S OCTL 1-INP	01295	SN74S241N
A5U5	1858-0038	4		TRANSISTOR ARRAY	28480	1858-0038
A5U6	1858-0038	4		TRANSISTOR ARRAY	28480	1858-0038
A5U7	1858-0038	4		TRANSISTOR ARRAY	28480	1858-0038
A5U8	1820-1216	3	1	IC DCDR TTL LS 3-TO-8-LINE 3-INP	01295	SN74LS138N
A5U9	1816-1533	8	1	IC-MB7051	28480	1816-1533
				MISCELLANEOUS PARTS		
	0360-1901	6	2	CABLE TRANSISTION	28480	0360-1901
	1200-0638	7	14	SOCKET-IC 14-CONT DIP DIP-SLDR	28480	1200-0638
	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 GRAY)	28480	5041-0384
	5041-0922	8	8	KEY CAP-QUARTER (FBY-PEARL)	28480	5041-0922
	04171-40002	0	1	INSULATOR	28480	04171-40002
	5040-3327	5	6	INSULATOR	28480	5040-3327
	04274-40003	1	3	INSULATOR	28480	04274-40003
	04276-61641	9	1	CABLE ASSEMBLY-FLAT	28480	04276-61641
	04276-26505		1	PC BOARD, BLANK	28480	04276-26505

See introduction to this section for ordering information
*Indicates factory selected value

PCO 17003 (メトリックネジ)

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
1 5041-5715	~~5040-7219~~		2	STRAP HANDLE CAP (FRONT)		
2 0515-1132	~~2680-0172~~		4	SCREW		
3 [illegible]	~~5060-9803~~		2	STRAP HANDLE		
4 0515-1331	~~2510-0192~~		16	~~SCREW~~		
5 5021-5832	~~5020-8836~~		4	STRUT		
6	04276-01202		1	ANGLE (POWER SWITCH)		
7 [illegible]	04274-40002		3	GUIDE (ANGLE)		
8 [illegible]	~~5060-9941~~		2	SIDE COVER		
9 [illegible]	~~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 ASSEMBLY		
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	04277-00204		1	REAR PANEL		
34	2110-0569		2	FUSEHOLDER NUT		
35	3101-1877		1	SLIDE SWITCH		
36	2360-0113		8	SCREW		
37 [illegible]	~~5020-8806~~		1	REAR FRAME		
38 [illegible]	~~5060-9834~~		1	TOP COVER		
39	04276-00102		1	CHASSIS (YELLOW)		
40	04276-00103		1	CHASSIS (RED)		
41	04276-00101		1	CHASSIS (BROWN)		
42 0515-1857	~~2360-0333~~		6	SCREW		
43 5021-5[illegible]	~~5020-8805~~		1	FRONT FRAME		
44 [illegible]	~~04276-00203~~		1	SUB PANEL		
45	04276-25001		3	WINDOW		
46	04277-00201		1	FRONT PANEL (HP)		
	04277-00202		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 [illegible]	~~5060-9846~~		1	BOTTOM COVER		
61	5041-0564		1	KEY CAP		
62	04274-40001		1	ROD (POWER SWITCH)		
63	1901-1065		4	DIODE		
64	0140-0200		2	CAPACITOR 390pF		
65	0160-2230		1	CAPACITOR 3300pF		
66	1902-0657		4	DIODE		
67	0764-0016		1	RESISTOR 1kΩ		
68	0683-2245		1	RESISTOR 220kΩ		
69	0698-3634		1	RESISTOR 470Ω		

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 ASSEMBLY		
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	04277-00204		1	REAR PANEL		
34	2110-0569		2	FUSEHOLDER NUT		
35	3101-1877		1	SLIDE 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	04277-00201		1	FRONT PANEL (HP)		
	04277-00202		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-~~0018~~ 0150		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	1901-1065		4	DIODE		
64	0140-0200		2	CAPACITOR 390pF		
65	0160-2230		1	CAPACITOR 3300pF		
66	1902-0657		4	DIODE		
67	0764-0016		1	RESISTOR 1kΩ		
68	0683-2245		1	RESISTOR 220kΩ		
69	0698-3634		1	RESISTOR 470Ω		

See introduction to this section for ordering information
*Indicates factory selected value

8-42. AUTO-BALANCE BRIDGE

8-43. The auto-balance bridge consists of the unknown sample, a range resistor, the Null Detector and the Modulator. Figure 8-11 shows the block diagram of the auto-balance bridge.

8-44. NULL DETECTOR

8-45. The unbalance current which results when the bridge is not completely balanced is detected by an I-V converter (in the null detector) through the LPOT terminal and is converted into a vector voltage signal. To improve gain at high frequencies, the I-V converter employs a staggered circuit configuration. Because the I-V converter's feedback magnitude varies depending on the DUT impedance, the feedback circuit elements are automatically changed in response to selection of measurement range (test frequency and range resistor). Refer to Figure 8-12.

8-46. The Gain Normalizer Amplifier and the x100 Amplifier amplify the unbalance vector voltage signal in order to maintain the sensitivity of the balance control loop (the Null Detector and the Modulator circuits) almost constant against changes in the test signal level and DUT impedance. In the input stage of the Modulator Amplifier, the signal is attenuated to compensate for the gain of the Gain Normalizer Amplifier stage. The microprocessor does this by setting the SPAM and TLPAM control signals to suit the test signal and measurement conditions. Figure 8-13 shows the SPAM and TLPAM control settings.

8-47. MODULATOR

8-48. Figure 8-11 shows the basic circuit configuration of the Modulator. The unbalance vector signal which is detected by the Null Detector is phase detected and separated into its orthogonal vector components. The phase detectors output dc voltages proportional to the magnitudes of the respective vector components. Reverse-phase components yield reverse-polarity voltage outputs (negative dc levels) from the phase detectors. The vector modulators vary the amplitudes of the four orthogonal phase vector signals (0 °, 90 °, 180 °, -90 °), which are generated by the low-pass filter in the signal source and the phase tracking

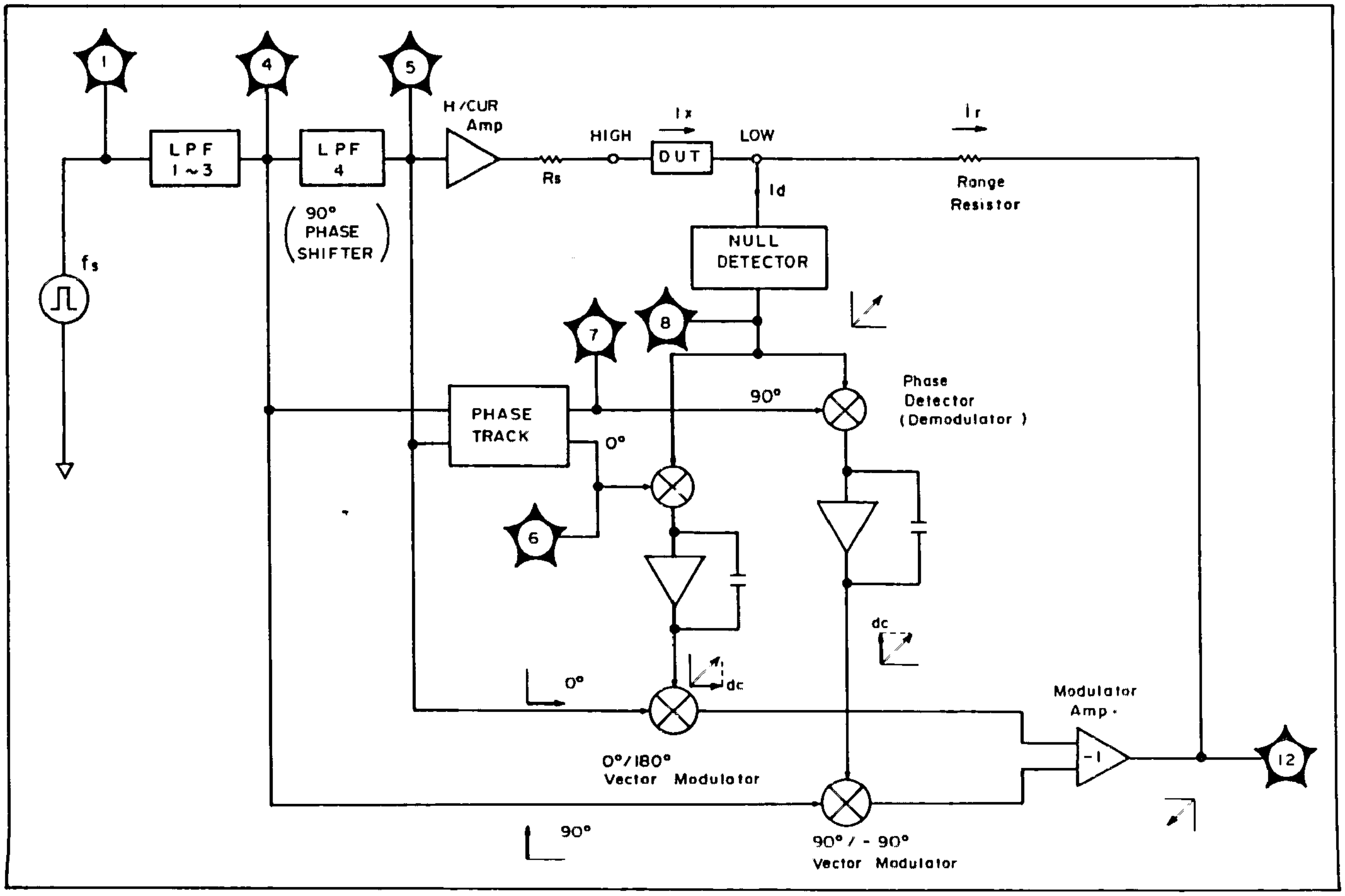


Figure 8-11. Auto-Balance Bridge Block Diagram.

circuits, in response to the null detector output vector components. The 0°/180° vector modulator provides an amplitude-controlled output which is in-phase with the test signal when the 0° phase detector output is a positive voltage. Conversely, it provides a reverse phase output for a negative voltage output from the phase detector. Thus, the 0°/180° vector modulator's output signal is represented by a vector on the real axis of the coordinates shown in Figure 8-14. The 90°/-90° vector modulator operates similarly to the 0°/180° vector modulator with respect to the 90° phase shifted input signal. The 90°/-90° vector modulator output signal is represented by a vector on the imaginary axis (see Figure 8-14). As a result of this vector modulation, the magnitudes of the real and imaginary vector components of the null detector output are transferred to the orthogonal vectors of the vector modulator outputs. The modulator amplifier sums the signals output from the 0°/180° and 90°/-90° vector modulators and, simultaneously, reverses the phase of the resultant vector signal (the modulator amplifier provides 180° phase shift). Consequentially, the modulator amplifier output, e_d, has a vector direction opposite that of the unbalance current. The e_d signal changes in response to the unbalance current so as to suppress increases in the unbalance current. Thus, the unbalance current approaches zero. Because the e_d signal is controlled with respect to the individual magnitudes of the real and imaginary components of the unbalance current, the bridge can reach accurate balance even if the balance control loop has a phase error related to test signal.

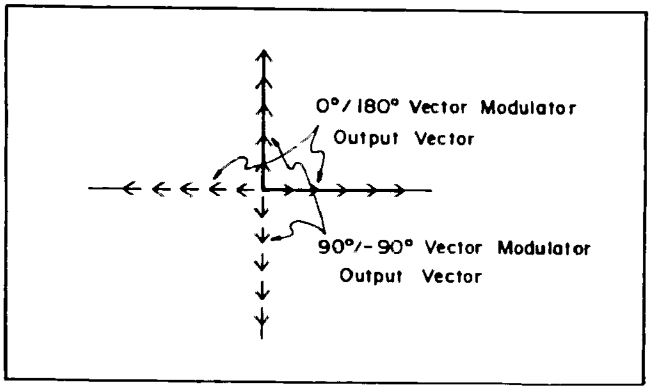


Figure 8-14. Vector Representation of the Vector Modulator Outputs.

8-49. PHASE TRACKING CIRCUITS OF THE BRIDGE CONTROL LOOP

8-50. If the phase shift in the balance control loop is so large that the bridge cannot be automatically balanced, the phase characteristics of the balance control loop can be compensated by properly adjusting the phase of the 0° and 90° reference phase signals used by the phase detectors in reference to the test signal.

The output from the third stage of the low-pass filter in the signal source is used as the 90° reference phase signal. The output from the fourth stage of the low-pass filter is used as the 0° reference phase signal. The fourth stage of the low-pass filter functions as a 90° phase shifter. Depending on the frequency of the test signal, the input vs. output phase lag is between -105° and -85°. Thus, the 0° and 90° reference phase signals do not always maintain a precise 90° phase relationship. This does not, however, affect the detection of the unbalance current.

The phase tracking circuits shift the phase relationship of the reference phase signals as appropriate for the selected test frequency without changing the signal amplitude and thereby ensure the bridge being automatically balanced over the entire test frequency range.

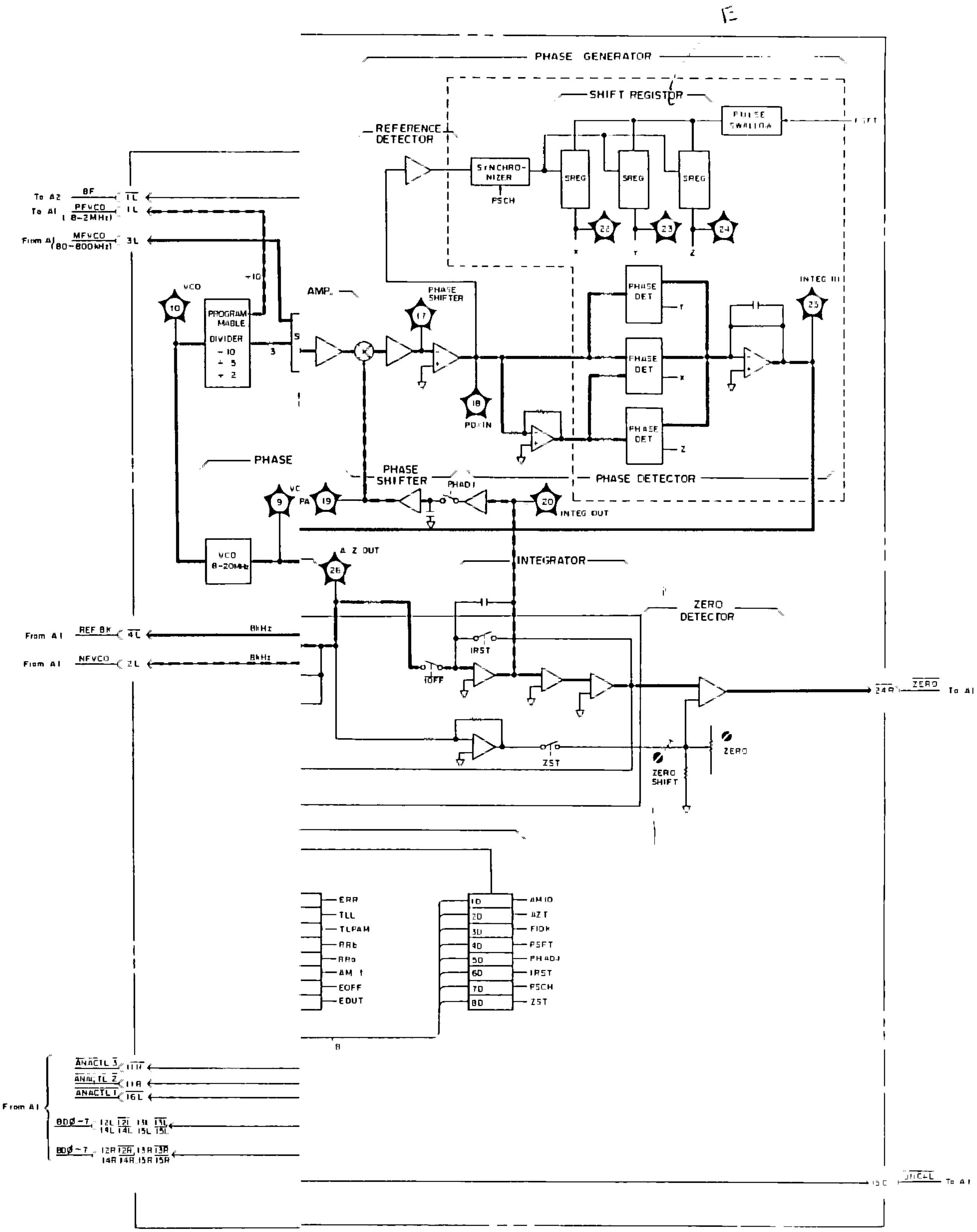
8-51. RANGE RESISTOR

8-52. The values of the range resistors used in the auto-balance bridge are 100Ω, 1kΩ and 10kΩ. To ensure accurate range resistor values and minimum residual reactance (mainly stray capacitance), an potentiometer and a phase compensation trimmer capacitor are provided for each range resistor. Range resistor selection and CMR Amplifier switching is controlled by the RRa and RRb control signals. Refer to Table 8-5.

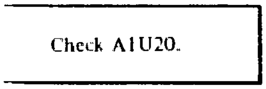
Table 8-5. Range Resistor Selection

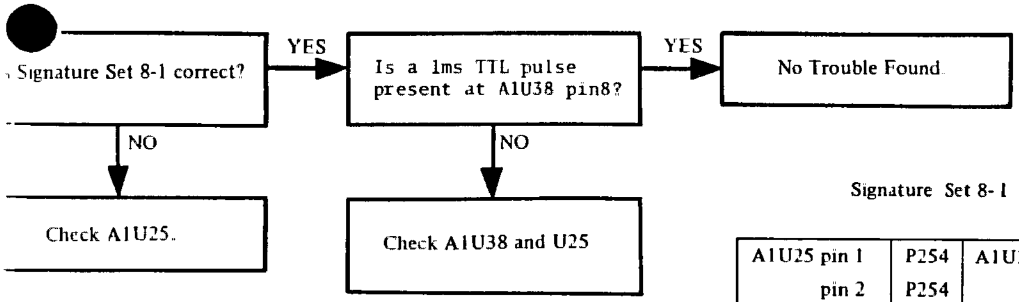
Range Resistor	Control Signals	
	RRa	RRb
100Ω	LOW	LOW
1kΩ	HIGH	LOW
10kΩ	LOW	HIGH

8-53. The CMR (Common Mode Rejection) amplifier provides compensation for any decrease in the range resistor signal caused by the inherent impedance of the internal cabling from the L_{CUR} terminal to the range resistor.



ı Block Diagram.



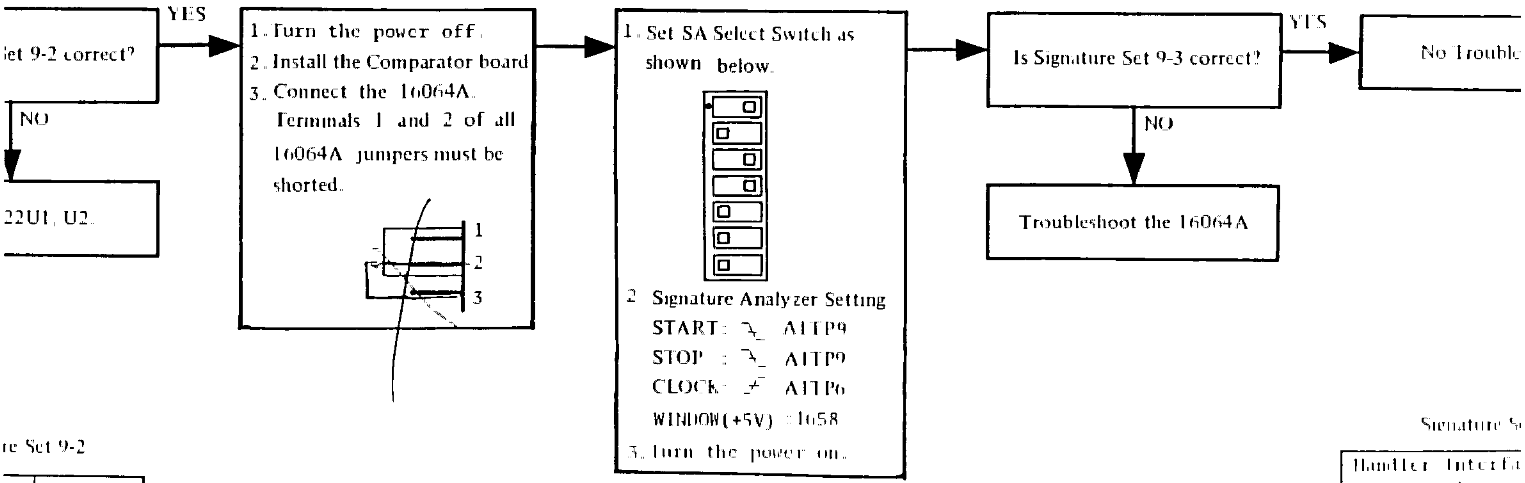


Signature Set 8-1

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 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

1-31

LOGIC Board Troubleshooting Flow Diagram (Sheet 6 of 7).



re Set 9-2

	Signature
	4554
	8CAP
	U29U
	74C1
1	47H4
2	389U
5	H33H
6	34H2
9	25C7
	F5F2
	571F
1	1PC7
2	66P4
5	49C8
6	800P
9	2489

1

Signature S

Handler Interfa Connector
pin 1
pin 2
pin 3
pin 4
pin 5
pin 6
pin 7
pin 8
pin 9
pin 10
pin 19
pin 20
pin 21
pin 22
pin 23
pin 24

l LOGIC Board Troubleshooting Flow Diagram (Sheet 7 of 7).

Table 6-3. Replaceable Parts

Reference Designation	HP Part Number	C D	Qty	Description	Mfr Code	Mfr Part Number
A6						
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
A6J2	1251-5382	5	1	CONNECTOR 4-PIN M METRIC POST TYPE	28480	1251-5382
A6J4	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
A6XA1R	1251-2582	1		CONNECTOR-PC EDGE 24-CONT/ROW 2-ROWS	28480	1251-2582
A6XA2C	1251-2026	8	2	CONNECTOR-PC EDGE 18-CONT/ROW 2-ROWS	28480	1251-2026
A6XA2L	1251-2582	1		CONNECTOR-PC EDGE 24-CONT/ROW 2-ROWS	28480	1251-2582
A6XA2R	1251-2582	1		CONNECTOR-PC EDGE 24-CONT/ROW 2-ROWS	28480	1251-2582
A6XA4C	1251-2026	8		CONNECTOR-PC EDGE 18-CONT/ROW 2-ROWS	28480	1251-2026
A6XA4R	1251-2582	1		CONNECTOR-PC EDGE 24-CONT/ROW 2-ROWS	28480	1251-2582
A6XA21	1251-4978	3	3	CONNECTOR-PC EDGE 18-CONT/ROW 2-ROWS	05574	000231-3944
A6XA22	1251-4978	3		CONNECTOR-PC EDGE 18-CONT/ROW 2-ROWS	05574	000231-3944
A6XA23	1251-4978	3		CONNECTOR-PC EDGE 18-CONT/ROW 2-ROWS	05574	000231-3944
				MISCELLANEOUS PARTS		
	0360-1244	0	4	TERMINAL-STUD SPCL-FDTHRU PRESS-MTG	28480	0360-1244
	04276-26506		1	PC BOARD, BLANK	28480	04276-26506
	1420-0362			Ni-Cd Battery		
	1400-0757			Battery Clamp も注 Svc Note 4277A-09 or FCO- 23485		
A21						
A21	04276-66521	4	1	HP-IB BOARD ASSEMBLY	28480	04276-66521
A21C1	0180-2981	2	1	CAPACITOR-FXD 220UF+-20% 10VDC AL	28480	0180-2981
A21C2	0180-1085	5	1	CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A21J1	1200-0485	2	1	SOCKET-IC 14-CONT DIP DIP-SLDR	28480	1200-0485
A21J2	1200-0654	7	1	SOCKET-IC 40-CONT DIP DIP-SLDR	28480	1200-0654
A21R1	1810-0305	8	1	NETWORK-RES 9-SIP4.7K OHM X 8	28480	1810-0305
A21R2	0683-4725	2	3	RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A21R3	0683-4725	2		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A21R4	0683-4725	2		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A21S1	3101-1973	7	1	SWITCH-SL 7-1A DIP-SLIDE-ASSY .1A 50VDC	28480	3101-1973
A21U1	1820-2024	3	1	IC DRVR TTL LS LINE DRVR OCTL	01295	SN74LS244N
A21U2	1820-2058	3	4	IC MISC TTL S QUAD	07263	MC3448AL
A21U3	1820-2058	3		IC MISC TTL S QUAD	07263	MC3448AL
A21U4	1820-2549	7	1	IC-8291A P HPIB	28480	1820-2549
A21U5	1820-1199	1	1	IC INV TTL LS HEX 1-INP	01295	SN74LS04N
A21U6	1820-2058	3		IC MISC TTL S QUAD	07263	MC3448AL
A21U7	1820-2058	3		IC MISC TTL S QUAD	07263	MC3448AL
A21U8	1820-2075	4	1	IC MISC TTL LS	01295	SN74LS245N
A21W1	0159-0005	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
	04276-26521		1	PC BOARD, BLANK	28480	04276-26521

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
A1						
A1	04277-66501	1	1	LOGIC BOARD ASSEMBLY	28480	04277-66501
A1C1	0180-1085	5	13	CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C2	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C3	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C4	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C5	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C6	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C7	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C8	0180-0197	8	1	CAPACITOR-FXD 2.2UF+-10% 20VDC TA	56289	150D225X9020A2
A1C9	0160-4832	4	2	CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
A1C10	0180-3219	1	1	CAPACITOR-FXD 2200UF +-20% 6 3VDC AL	28480	0180-3219
A1C11	0160-4801	7	1	CAPACITOR-FXD 100PF +-5% 100VDC CER	28480	0160-4801
A1C12	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C13	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C14	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C15	0180-2951	6	1	CAPACITOR-FXD 33UF+-20% 16VDC AL	28480	0180-2951
A1C16	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C17	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C18	0180-1085	5		CAPACITOR-FXD 4.7UF 16VDC TA	28480	0180-1085
A1C19	0160-4832	4		CAPACITOR-FXD .01UF +-10% 100VDC CER	28480	0160-4832
A1C20	0180-3217	9	2	CAPACITOR-FXD 470UF	28480	0180-3217
A1C21	0180-3217	9		CAPACITOR-FXD 470UF	28480	0180-3217
A1CR1	1901-0539	3	2	DIODE-SM SIG SCHOTTKY	28480	1901-0539
A1CR2	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
A1J2	1200-0607	0		SOCKET-IC 16-CONT DIP DIP-SLDR	28480	1200-0607
A1J3	1200-0654	7	2	SOCKET-IC 40-CONT DIP DIP-SLDR	28480	1200-0654
A1J10	1200-0541	1		SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
A1J11	1200-0541	1		SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
A1J12	1200-0541	1		SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
A1J13	1200-0541	1		SOCKET-IC 24-CONT DIP DIP-SLDR	28480	1200-0541
A1J14	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
A1Q2	1854-0810	2		TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
A1Q3	1853-0281	9	1	TRANSISTOR PNP 2N2907A SI TO-18 PD=400MW	04713	2N2907A
A1Q4	1854-0810	2		TRANSISTOR NPN SI PD=625MW FT=200MHZ	28480	1854-0810
A1Q5	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
A1R2	0757-0199	3	1	RESISTOR 21.5K 1% .125W F TC=0+-100	24546	C4-1/8-T0-2152-F
A1R3	2100-3103	6	1	RESISTOR-TRMR 10K 10% C SIDE-ADJ 17-TRN	02111	43P103
A1R4	0757-0440	7	1	RESISTOR 7.5K 1% .125W F TC=0+-100	24546	C4-1/8-T0-7501-F
A1R5	0683-2215	1	1	RESISTOR 220 5% .25W FC TC=-400/+600	01121	CB2215
A1R6 0757-0280	~~0683-4715~~	0	1	RESISTOR 470 5% .25W FC TC=-400/+600	01121	CB4715
A1R7	1810-0607	3	1	RESISTIVE NETWORK- SIP	28480	1810-0607
A1R8 Hr 23155	0683-1045	3	1	RESISTOR 100K 5% .25W FC TC=-400/+800	01121	CB1045
A1R9	0683-2245	7	1	RESISTOR 220K 5% .25W FC TC=-800/+900	01121	CB2245
A1R10 大橋	0683-1005	5	1	RESISTOR 10 5% .25W FC TC=-400/+500	01121	CB1005
A1R11 4277 07	0683-1025	9	2	RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
A1R12	0683-5605	9	1	RESISTOR 56 5% .25W FC TC=-400/+500	01121	CB5605
A1R13	0683-0565	9	1	RESISTOR 5.6 5% .25W FC TC=-400/+500	01121	CB0565
A1R14	0683-1025	9		RESISTOR 1K 5% .25W FC TC=-400/+600	01121	CB1025
A1R15	1810-0305	8	5	NETWORK-RES 9-SIP 4 7K OHM X8	28480	1810-0305
A1R16	1810-0305	8		NETWORK-RES 9-SIP 4.7K OHM X8	28480	1810-0305
	1810-0269	3	1	NETWORK-RES 9-SIP10.0K OHM X 8	28480	1810-0269
A1R18	1810-0305	8		NETWORK-RES 9-SIP 4 7K OHM X 8	28480	1810-0305
A1R19	1810-0305	8		NETWORK-RES 9-SIP 4 7K OHM X 8	28480	1810-0305
A1R20	1810-0305	8		NETWORK-RES 9-SIP 4 7K OHM X 8	28480	1810-0305
A1R21	0683-4725	2	5	RESISTOR 4 7K 5% .25W FC TC=-400/+700	01121	CB4725
A1R22	0683-4725	2		RESISTOR 4 7K 5% .25W FC TC=-400/+700	01121	CB4725
A1R23	0683-4725	2		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A1R24	0683-3325	6	1	RESISTOR 3.3K 5% .25W FC TC=-400/+700	01121	CB3325
A1R25	0683-6825	7	1	RESISTOR 6.8K 5% .25W FC TC=-400/+700	01121	CB6825
A1R26	0683-4725	2		RESISTOR 4.7K 5% .25W FC TC=-400/+700	01121	CB4725
A1R27	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

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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						
A4	04277-66504	4	1	POWER SUPPLY BOARD ASSEMBLY	28480	04277-66504
A4C1	0180-1075	3	5	CAPACITOR-FXD 2200 UF 16VDC AL	28480	0180-1075
A4C2	0180-1075	3		CAPACITOR-FXD 2200 UF 16VDC AL	28480	0180-1075
A4C3	0180-1075	3		CAPACITOR-FXD 2200 UF 16VDC AL	28480	0180-1075
A4C4	0180-2980	1	2	CAPACITOR-FXD 1000UF+-20% 35VDC AL	28480	0180-2980
A4C5	0180-2980	1		CAPACITOR-FXD 1000UF+-20% 35VDC AL	28480	0180-2980
A4C6	0180-1075	3		CAPACITOR-FXD 2200 UF 16VDC AL	28480	0180-1075
A4C7	0180-3221	5	6	CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
A4C8	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
A4C9	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
A4C10	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
A4C11	0180-1050	4	5	CAPACITOR-FXD 100UF 25VDC	28480	0180-1050
A4C12	0180-1050	4		CAPACITOR-FXD 100UF 25VDC	28480	0180-1050
A4C13	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
A4C14	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
A4C15	0180-1050	4		CAPACITOR-FXD 100UF 25VDC	28480	0180-1050
A4C16	0180-1050	4		CAPACITOR-FXD 100UF 25VDC	28480	0180-1050
A4C17	0180-1050	4		CAPACITOR-FXD 100UF 25VDC	28480	0180-1050
A4C18	0160-4297	5	1	CAPACITOR-FXD .022UF +80-20% 100VDC CER	56289	C023F101H223ZS22-CDH
A4C19	0180-1075	3		CAPACITOR-FXD 2200 UF 16VDC AL	28480	0180-1075
A4C20	0160-3456	6	1	CAPACITOR-FXD 1000PF +-10% 1KVDC CER	28480	0160-3456
A4C21	0180-0197	8	1	CAPACITOR-FXD 2.2UF+-10% 20VDC TA	56289	150D225X9020A2
A4C22	0160-4822	2	1	CAPACITOR-FXD 1000PF +-5% 100VDC CER	28480	0160-4822
A4C23	0180-0291	3	1	CAPACITOR-FXD 1UF+-10% 35VDC TA	56289	150D105X9035A2
A4C24	0160-3094	8	1	CAPACITOR-FXD .1UF +-10% 100VDC CER	28480	0160-3094
A4C25	0180-1704	5	1	CAPACITOR-FXD 47UF+-10% 6VDC TA	56289	150D476X9006B2
A4C26	0180-0228	6	2	CAPACITOR-FXD 22UF+-10% 15VDC TA	56289	150D226X9015B2
A4C27	0160-0127	2	3	CAPACITOR-FXD 1UF +-20% 25VDC CER	28480	0160-0127
A4C28	0160-0127	2		CAPACITOR-FXD 1UF +-20% 25VDC CER	28480	0160-0127
A4C29	0160-4593	4	2	CAPACITOR-FXD 1.5UF +-20% 400VDC	28480	0160-4593
A4C30	0160-0127	2		CAPACITOR-FXD 1UF +-20% 25VDC CER	28480	0160-0127
A4C31	0180-1746	5	1	CAPACITOR-FXD 15UF+-10% 20VDC TA	56289	150D156X9020B2
A4C32	0160-4593	4		CAPACITOR-FXD 1.5UF +-20% 400VDC	28480	0160-4593
A4C33	0180-3231	7	4	CAPACITOR-FXD 4.7 UF 450VDC	28480	0180-3231
A4C34	0180-3231	7		CAPACITOR-FXD 4.7 UF 450VDC	28480	0180-3231
A4C35	0180-3231	7		CAPACITOR-FXD 4.7 UF 450VDC	28480	0180-3231
A4C36	0180-3231	7		CAPACITOR-FXD 4.7 UF 450VDC	28480	0180-3231
A4C37	0180-3253	7	2	CAPACITOR- FXD 470 UF 200VDC	28480	0180-3253
A4C38	0180-3253	7		CAPACITOR- FXD 470 UF 200VDC	28480	0180-3253
A4C39	0160-3969	6	2	CAPACITOR-FXD .015UF +-20PF 250VAC(RMS)	28480	0160-3969
A4C40	0160-3969	6		CAPACITOR-FXD .015UF +-20PF 250VAC(RMS)	28480	0160-3969
A4C41	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
A4CR2	1902-3208	1	2	DIODE-ZNR 15.4V 5% DO-35 PD=.4W TC=+.06%	28480	1902-3208
A4CR3	1902-3208	1		DIODE-ZNR 15.4V 5% DO-35 PD=.4W TC=+.06%	28480	1902-3208
A4CR4	1902-3234	3	2	DIODE-ZNR 19.6V 5% DO-35 PD=.4W	28480	1902-3234
A4CR5	1902-3234	3		DIODE-ZNR 19.6V 5% DO-35 PD=.4W	28480	1902-3234
A4CR6	1901-0025	2	11	DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR7	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR8	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR9	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR10	1901-0691	8	10	DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR11	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR12	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR13	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR14	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR15	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR16	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR17	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR18	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR19	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR20	1901-0969	3	2	DIODE-POWER RECT	28480	1901-0969
A4CR21	1901-0969	3		DIODE-POWER RECT	28480	1901-0969
A4CR22	1902-3182	0	1	DIODE-ZNR 12.1V 5% DO-35 PD=.4W	28480	1902-3182
A4CR23	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR24	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR25	1902-3203	6	1	DIODE-ZNR 14.7V 5% DO-35 PD=.4W	28480	1902-3203
A4CR26	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR27	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR28	1902-0555	5	1	DIODE-ZNR 13V 5% PD=1W IR=5UA	28480	1902-0555
A4CR29	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR30	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025

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						
A4	04277-66504	4	1	POWER SUPPLY BOARD ASSEMBLY	28480	04277-66504
A4C1	0100-1075	3	5	CAPACITOR-FXD 2200 UF 16VDC AL	28480	0180-1075
A4C2	0180-1075			16VDC AL	28480	0180-1075
A4C3	0180-1075			0180-2980 PCD 16VDC AL	28480	0180-1075
A4C4	0180-2980			-20% 35VDC AL	20480	0180-2980
A4C5	0180-2900			↓ 32725 -20% 35VDC AL	28480	0180-2980
A4C6	0180-1075			0180-3587 16VDC AL	28480	0100-1075
A4C7	0100 3221	[illegible]	[illegible]	[illegible] 100VDC	20480	0180-3221
A4C8	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
A4C9	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
A4C10	0180-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
A4C11	0180 1050	4	5	CAPACITOR-FXD 100UF 25VDC	28480	0180-1050
A4C12	0180-1050	4		CAPACITOR-FXD 100UF 25VDC	28480	0180 1050
A4C13	0100-3221	5		CAPACITOR-FXD 10 UF 100VDC	28480	0180-3221
A4C14	0100-3221	5		CAPACITOR-FXD 10 UF 100VDC	28400	0180-3221
A4C15	0180-1050	4		CAPACITOR-FXD 100UF 25VDC	28480	0180-1050
A4C16	0180-1050	4		CAPACITOR-FXD 100UF 25VDC	28480	0180-1050
A4C17	0180-1050	4		CAPACITOR FXD 100UF 25VDC	28480	0180-1950
A4C18	0160-4297	5	1	CAPACITOR-FXD .022UF +80-20% 100VDC CER	51289	C023F101H223ZS22-CDH
A4C19	0180-1075	3		CAPACITOR-FXD 2200 UF 16VDC AL	28480	0180-1075
A4C20	0160-3456	6	1	CAPACITOR-FXD 1000PF +-10% 1KVDC CER	28480	0160-3456
A4C21	0180-0197	8	1	CAPACITOR-FXD 2.2UF+-10% 20VDC TA	56289	150D225X9020A2
A4C22	0160-4822	2	1	CAPACITOR-FXD 1000PF +-5% 100VDC CER	28480	0160-4822
A4C23	0180-0291	3	1	CAPACITOR-FXD 1UF+-10% 35VDC TA	56289	150D105X9035A2
A4C24	0160-3094	8	1	CAPACITOR-FXD .1UF +-10% 100VDC CER	28480	0160-3094
A4C25	0180 1704	5	1	CAPACITOR-FXD 47UF+-10% 6VDC TA	56289	150D476X9006B2
A4C26	0180-0228	6	2	CAPACITOR-FXD 22UF+-10% 15VDC TA	56289	150D226X9015B2
A4C27	0160-0127	2	3	CAPACITOR-FXD 1UF +-20% 25VDC CER	28480	0160 0127
A4C28	0160-0127	2		CAPACITOR-FXD 1UF +-20% 25VDC CER	28480	0160-0127
A4C29	0160-4593	4	2	CAPACITOR-FXD 1.5UF +-20% 400VDC	28480	0160-4593
A4C30	0160-0127	2		CAPACITOR-FXD 1UF +-20% 25VDC CER	28480	0160-0127
A4C31	0180 1746	5	1	CAPACITOR FXD 15UF+-10% 20VDC TA	56289	150D156X9020B2
A4C32	0160-4593	4		CAPACITOR-FXD 1.5UF +-20% 400VDC	28480	0160-4593
A4C33	0100-3231	7	4	CAPACITOR-FXD 4.7 UF 450VDC	28480	0180-3231
A4C34	0180-3231	7		CAPACITOR-FXD 4.7 UF 450VDC	28480	0180-3231
A4C35	0180-3231	7		CAPACITOR-FXD 4 7 UF 450VDC	28480	0180-3231
A4C36	0180-3231	7		CAPACITOR-FXD 4.7 UF 450VDC	28480	0180-3231
A4C37	0180-3253	7	2	CAPACITOR- FXD 470 UF 200VDC	28480	0180-3253
A4C38	0180-3253	7		CAPACITOR- FXD 470 UF 200VDC	28480	0180-3253
A4C39	0160-3969	6	2	CAPACITOR-FXD .015UF +-20PF 250VAC(RMS)	28480	0160-3969
A4C40	0160-3969	6		CAPACITOR-FXD .015UF +-20PF 250VAC(RMS)	28480	0160-3969
A4C41	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
A4CR2	1902-3208	1	2	DIODE-ZNR 15.4V 5% DO-35 PD=.4W TC=+.06%	28480	1902-3208
A4CR3	1902-3208	1		DIODE-ZNR 15.4V 5% DO-35 PD=.4W TC=+.06%	20480	1902-3208
A4CR4	1902-3234	3	2	DIODE ZNR 19.6V 5% DO-35 PD=.4W	28480	1902-3234
A4CR5	1902-3234	3		DIODE-ZNR 19.6V 5% DO-35 PD=.4W	28480	1902-3234
A4CR6	1901-0025	2	11	DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR7	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR8	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR9	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR10	1901-0691	8	10	DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR11	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR12	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR13	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR14	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR15	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR16	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR17	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR18	1901-0691	8		DIODE PWR RECT 100V 3A 200NS	03508	A115A
A4CR19	1901-0691	8		DIODE-PWR RECT 100V 3A 200NS	03508	A115A
A4CR20	1901-0969	3	2	DIODE-POWER RECT.	28480	1901-0969
A4CR21	1901-0969	3		DIODE-POWER RECT.	28480	1901-0969
A4CR22	1902-3182	0	1	DIODE-ZNR 12.1V 5% DO-35 PD=.4W	28480	1902-3182
A4CR23	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR24	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR25	1902-3203	6	1	DIODE-ZNR 14.7V 5% DO-35 PD=.4W	28480	1902-3203
A4CR26	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR27	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR28	1902-0555	5	1	DIODE-ZNR 13V 5% PD=1W IR=5UA	28480	1902-0555
A4CR29	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025
A4CR30	1901-0025	2		DIODE-GEN PRP 100V 200MA DO-7	28480	1901-0025

See introduction to this section for ordering information
*Indicates factory selected value