OPERATING AND SERVICE MANUAL

MODEL 3465A

MULTIMETER

Serial Numbers: 1546A01501 and greater

IMPORTANT NOTICE

This loose leaf manual does not normally require a change sheet. All major change information has been integrated into the manual by page revision. In cases where only minor changes are required, a change sheet may be supplied.

If the Serial Number of your instrument is lower than the one on this title page, the manual contains revisions that do not apply to your instrument. Backdating information given in the manual adapts it to earlier instruments.

Where practical, backdating information is integrated into the text, parts list and schematic diagrams. Backdating changes are denoted by a delta sign. An open delta (Δ) or lettered delta (Δ_A) on a given page, refers to the corresponding backdating note on that page. Backdating changes not integrated into the manual are denoted by a numbered delta (Δ_1) which refers to the corresponding change in the Backdating section (Section VIII).

⚠ This symbol is an international symbol meaning "refer to the Operating and Service Manual." The symbol flags important operating instructions in Figure 3-1 and Paragraphs 3-13, 3-16, 3-21 and 3-27.

WARNING

To prevent potential fire or shock hazard, do not expose equipment to rain or moisture.

-hp- Part No. 03465-90004
(complete Manual including binder)
-hp- Part No. 03465-90001
(Includes Binder, Cover Inserts – no Pages)
-hp- Part No. 03465-90003
(Loose-Leaf Pages Only)
Microfiche Part No. 03465-90051

P O Box 301, Loveland, Colorado 80537 U.S.A.

Revised: October 1975

Printed: June 1975

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

WARRANTY AND ASSISTANCE

This Hewlett-Packard product is warranted against defects in materials and workmanship for a period of one year from the date of shipment, except that in the case of certain components, if any, listed in Section I of this operating manual, the warranty shall be for the specified period. Hewlett-Packard will, at its option, repair or replace products which prove to be defective during the warranty period provided they are returned to Hewlett-Packard, and provided the proper preventive maintenance procedures as listed in this manual are followed. Repairs necessitated by misuse of the product are not covered by this warranty. NO OTHER WARRANTIES ARE EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. HEWLETT-PACKARD IS NOT LIABLE FOR CONSEQUENTIAL DAMAGES.

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Printed in USA July 2004

MANUAL CHANGES

MODEL 3465A

MULTIMETER

Manual Part No. 03465-90004

▌New or Revised Item

ERRATA

Page 1-1, Paragraph 1-16. Change item 5 to "Model 11173A Handle Kit (Rack)

Page 5-0, Table 5-1. Change value in required characteristics column for resistor part no 0698-5049 (last resistor in the table) to 10 M, ± 1%.

Page 5-9, Paragraph 5-36, Step i. Within parenthesis in formula for (R107* + R108*), replace the number 0.9995 with 0.9966.

Page 6-3, Table 6-3. Add diodes A1CR1 through A1CR6 to the parts list as follows:

A1CR1, CR2, 1901-0040, 13, Diode-Switching, 28480, 1901-0040
A1CR3, CR4, 1901-0518, 4, Diode-Schottky, 28480, 1901-0518
A1CR5, CR6, 1901-0040, Diode-Switching, 28480, 1901-0040

Page 6-4, Table 6-3. Add designations A1L2, A1L3 and A1L4 to the parts list. These components are the same as A1L1, part no. 9170-0894, Core-Shielding Bead.

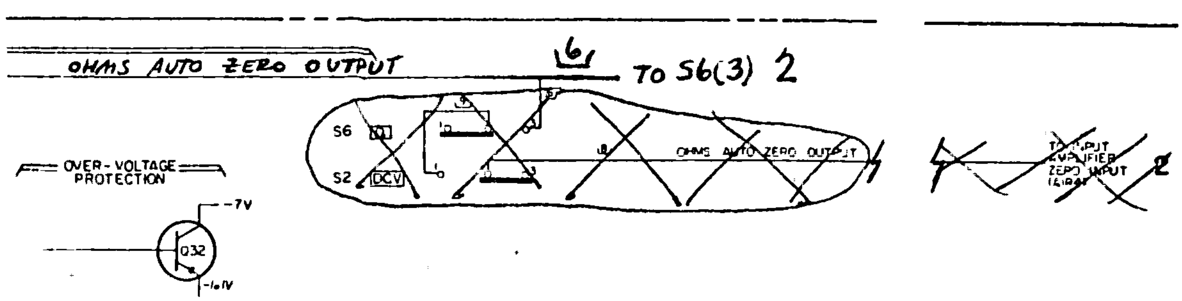
Page 6-5, Table 6-3. Change part no. of the fine line assembly, A1R75 to 1810-0253.

Page 6-7, Table 6-3 Add designation A2L1, part no 9170-0894, Core-Shielding Bead.

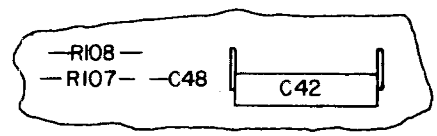
Page 6-8, Table 6-3. Add A10A6C3, part no. 0150-0093, C:fxd .01 µF, 100 V. Change part no. of Transformer, A10A6T1 to 9100-3851. Under A10 Assembly Miscellaneous Parts, add "Battery Clamp" to description of part no. 1460-1426.

Page 6-10, Table 6-3, Mechanical Parts List. Change part no. of MP8a (Rear Panel-Std or Option 001) to 5040-8026. Change part no. of MP18 (Switch Shield) to 03465-60604. This is now a "SWITCH SHIELD ASSEMBLY"

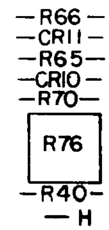
Section VII, Schematic No. 1. Make the following change to the OHMS AUTO ZERO OUTPUT SWITCHING:



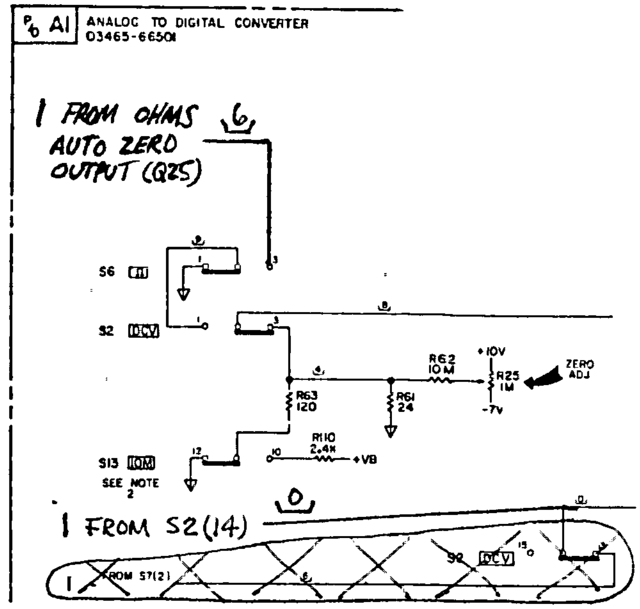
Section VII, Schematics No 1, 2, 3 and 4 Make the following additions and changes to the A1 component locator. Add capacitor C48 between R107 and C42:



Add Jumper J between C15 and C25 and next to R144. Change the location of R40 and Jumper H as follows.



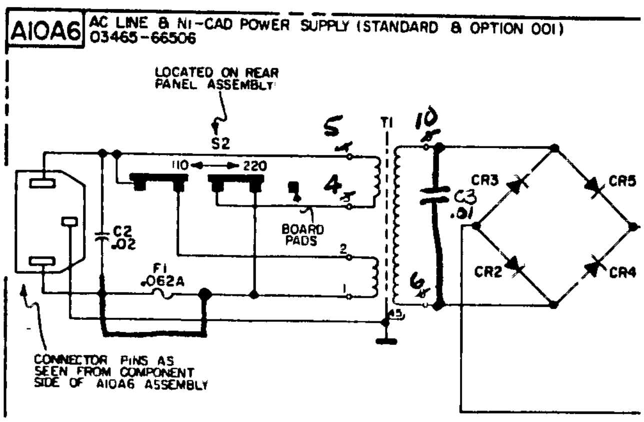
Section VII, Schematic No. 2. Make the following changes to the input amplifier switching:



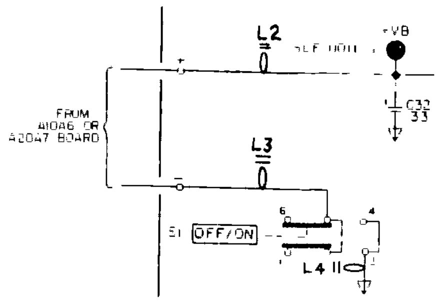
Section VII, Schematic 3. Add shielding bead A2L1 to the emitter of A2Q22 on the Display Interface board

Section VII, Schematic 4 Replace the A10A6 component locator and modify the A10A6 schematic to:

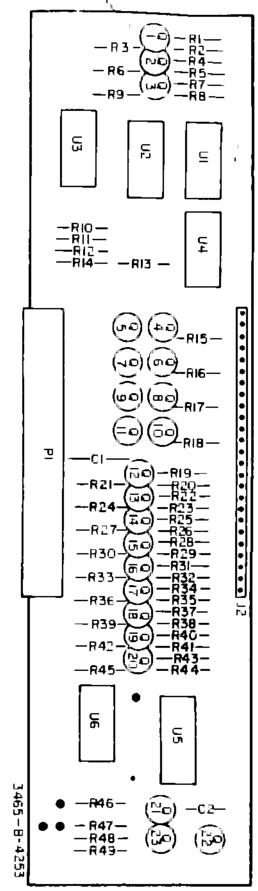
1 Change connection of C2 to other side of Fuse F1.
2. Change pin numbers of transformer T1.
3 Add C3 (see following).



Section VII, Schematic 4. Add shielding beads, A1L2, A1L3 and A1L4 as follows:

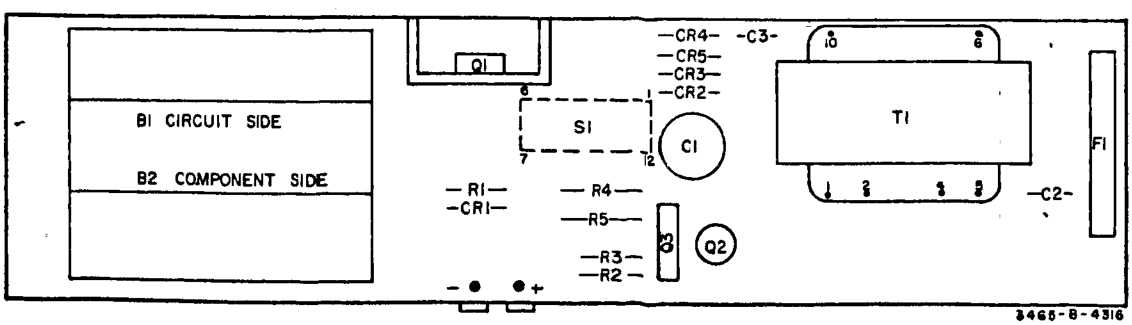


Section VIII, Backdating CHANGE 4 Add the following: "Schematic No. 3, Replace the A2 component locator with the following:



A2

-hp- Part No. 03465-66502, Rev. B



A10A6

-hp- Part No. 03465-66506

ERRATA

Page 3-1, Add to Paragraph 3-10.

NOTE

In protecting batteries and circuitry the low battery voltage detection circuit may shut down the instrument if

1. *the power switch is momentarily turned off then back on, or*
2. *if a live line power cord is attached to the instrument, while it is operating in the battery mode.*

To restore normal operation the instrument must be turned off for a minimum of 10 seconds.

Page 5-9, Paragraph 5-36(i). Change (0.9995 × CONST-1) to (0.9966 × CONST-1).

Page 5-10, Paragraphs 5-39(c) and 5-40(c) Change ± 100 counts to ± 10 counts.

Page 6-8, Table 6-3. Reference Designation A10A6Q3, -hp- Part No 1853-0394, Description Change NPN to PNP.

ERRATA

Page 7-13/7-14, Figure 7-5, Assembly A20A7 Schematic. Add wire connections from pin 4 to 5, and from pin 8 to 9 of S1.

CHANGE NO. 1 applies to S/N 1521A01501 and greater.

Page 7-11/7-12, Figure 7-4, Control Logic Assembly, A1, Schematic. Add capacitor C23, 100 pF from the junction of Y1, R52 and pin 9 of U7 to PC assembly ground.

Page 6-3. Add in sequence Ref. Desig., P/N, Qty and Desc., A1C23 0150-0073, 1, Capacitor - FXD 100 pF 1000 V.

CHANGE NO. 2 applies to S/N 1546A01701 and greater.

Page 7-11/7-12, Figure 7-4, Control Logic Assembly, A1, Schematic. Delete C11, jumper D and Note 3. Renumber Notes 4 and 5 to 3 and 4 respectively

Page 7-11, Figure 7-4, Display Interface, A2, Schematic Delete C2

Page 6-3. Delete A1C11 and all relevant nomenclature

Page 6-7. Delete A2C2 and all relevant nomenclature.

CHANGE NO. 3 applies to S/N 1546A02151 and greater.

Page 6-9 Delete Part No 0363-0108 and all relevant nomenclature Add Part No. and Description 0380-0578, Standoff.

CHANGE NO. 4 applies to S/N 1546A04401 and greater.

Page 6-7. Delete A2Q12, A2R19, A2R20, A2R21 and all relevant nomenclature.

Page 6-8. Delete A5CR1 and all relevant nomenclature.

Page 7-11/7-12, Figure 7-4. Delete R19, R20, R21 and Q12 of the Display Interface, A2, Schematic and CR1 of the Display, A5, Schematic.

CHANGE NO. 5 applies to S/N 1546A01700 and greater.

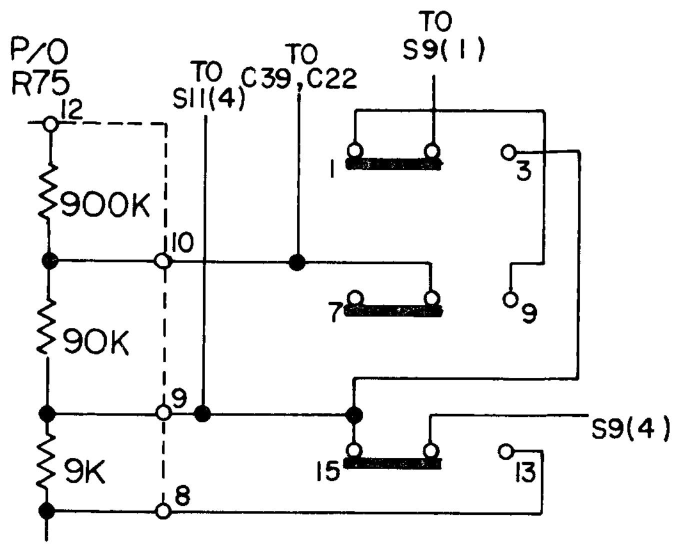
Page 6-5 Change the Part Number and value of A1R103 from 0683-2445, 240 K to 0683-1245, 120 K.

Page 7-7/7-8, Figure 7-2. Change the value of R103 from 240 K to 120 K.

CHANGE NO. 6 applies to S/N 1546A01701 and greater.

Page 6-3. Change the Part Number and value of A1C39 from 0160-2046, 2 pF ± 5 pF to 0160-999P PAD VALUE Star the Reference Designations A1C39 and A1C57

Page 7-7/7-8, Figure 7-2. Change the switch wiring by adding a contact between R75 pin 10 and S12 as shown.



CHANGE NO. 7 applies to all Serial Numbers.

Page 6-8. Change the quantity from 2 to 1 on Part Number 5000-5087
Change the quantity from 1 to 2 on Part Number 5000-5086.

CHANGE NO. 8 applies to Serial Number 1546A02151 and greater.

Page 6-3. Change the Part Number and value of C42 from 0121-0427, 170/780 pf to 0121-0426, 50/380 pf.

Page 6-6. Change the Part Number and value of R135 from 0683-4745 470K .05 to R135* - See padding list under A1 Assy Misc. Parts.

R135*	0683-2445	Resistor 240K 5% .25W FC TC = - 800/+ 900
	0683-4745	Resistor 470K 5% .25W FC TC = - 800/+ 900

CHANGE NO. 9 applies to Serial Number 1546A04201 and greater.

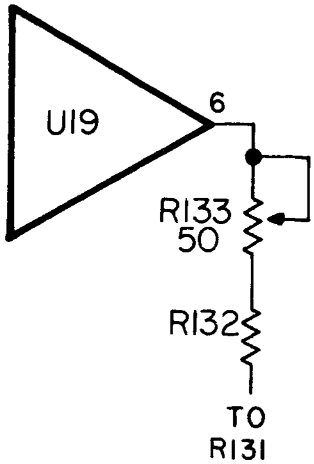
Page 6-3. Change the Part Number of C13, *55, *57 to 0140-0209.

Page 6-8. Change the Part Number of A10A6C3 to 0160-2055.

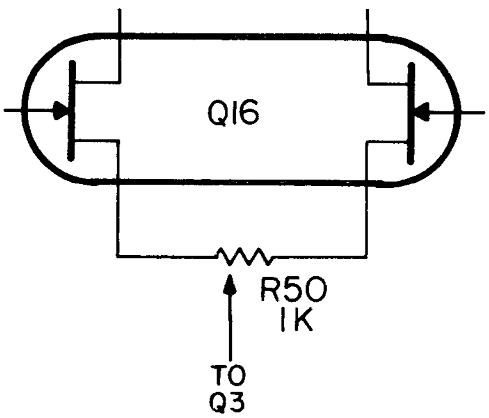
CHANGE NO. 10 applies to Serial Number 1546A02601 and greater.

Page 6-6. Delete * on A1R133*.

Page 7-7/7-8, Figure 7-2. Make the following changes to the output of the Impedance Converter



Page 7-9/7-10, Figure 7-3 Make the following changes to the Input Amplifier.



ERRATA:

Page 6-6. Change the Part Number of A1U8 to **1820-0944.**

Page 5-0, Table 5-1. Revise Resistor Section to read as follows:

1.0 Ω ± 0.02%	Gen. Rad. 1440-9601
10 Ω ± 0.01%	Gen. Rad. 1440-9611
1 kΩ ± 0.01%	Gen. Rad. 1440-9631
10 kΩ ± 0.01%	Gen. Rad. 1440-9641
100 kΩ ± 0 01%	Gen Rad 1440-9651
1 MΩ ± 0.01%	Gen. Rad. 1440-9661
10 MΩ ± 0 1%	-hp- 0698-8194
1 kΩ ± 1%	-hp- 0727-0751
22 kΩ ± 1%	-hp- 0757-1087
10 MΩ ± 1%	-hp- 0698-5049

Page 5-2, Table 5-3. Change tolerance of the 1 Ω value of R_A from 0 1% to 0 02%
Change the tolerance of the remaining values of R_A from 0.1% to 0 01%

Page 5-4, Table 5-6. Delete all mid-range (50 μA, 0.5 mA and 5 mA) tests.

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Calle Lira 81 Oficina 5
Casilla 2118
Santiago 1
Tel 398613
Cable CALMET

COLOMBIA
Instrumentación
Henrik A Langebaek & Kier S A
Carrera 7 No 48 59
Apartado Aéreo 6287
Bogota, 1 D E
Tel 45 78 06 45 55 46
Cable AARIS Bogota
Telex 44400INSTCO

COSTA RICA
Cientifica Costarricense S A
Apartado 10159
San José
Tel 21 86-13
Cable GALGUR San José

GUATEMALA
IPESA
Avenida La Reforma 3 48
Zona 9
Guatemala
Tel 63627 64786
Telex 4192 TELTRO GU

MEXICO
Hewlett Packard Mexicana
S A de C V
Torres Adalid No 21 11 Piso
Col del Valle
Mexico 12 D F
Tel (905) 543 42 32
Telex 017 74 507

Hewlett Packard Mexicana
S A de C V
Ave Constitución No 2184
Monterrey N L
Tel 48 71 32 48 71 84

NICARAGUA
Roberto Terán G
Apartado Postal 689
Edificio Terán
Managua
Tel 3451 3452
Cable ROTERAN Managua

PANAMA
Electrónico Balboa S A
P O Box 4929
Calle Samuel Lewis
Cuidad de Panama
Tel 64 2700
Telex 3431103 Curunda
Canal Zone
Cable ELECTRON Panama

PERU
Compania Electro Medica S A
Ave Enrique Canaval 312
San Isidro
Casilla 1030
Lima
Tel 22 3900
Cable ELMED Lima

PUERTO RICO
San Juan Electronics Inc
P O Box 5167
Ponce de Leon 154
Pda 3 PTA de Tierra
San Juan 00906
Tel (809) 725 3342 722 3342
Cable SATRONICS San Juan
Telex SATRON 3450 332

URUGUAY
Pablo Ferrando S A
Comercial e Industrial
Avenida Italia 2877
Casilla de Correo 370
Montevideo
Tel 40 3102
Cable RADIUM Montevideo

VENEZUELA
Hewlett Packard de Venezuela
C A
Apartado 50933
Edificio Segre
Tercera Transversal
Los Ruices Norte
Caracas 107
Tel 35 00 11
Telex 21146 HEWPACK
Cable HEWPACK Caracas

FOR AREAS NOT LISTED, CONTACT
Hewlett Packard
Inter Americas
3200 Hillview Ave
Palo Alto California 94304
Tel (415) 493 1501
TWX 910 373 1260
Cable HEWPACK Palo Alto
Telex 034 8300 034 8493

EUROPE

AUSTRIA
Hewlett Packard Ges m b H
Handelska 52 3
P O Box 7
A 1205 **Vienna**
Tel (0222) 35 16 21 to 27
Cable HEWPAK Vienna
Telex 75923 hewpak a

BELGIUM
Hewlett Packard Benelux
S A N V
Avenue de Col Vert 1
(Groenkraaglaan)
B 1170 **Brussels**
Tel (02) 672 22 40
Cable PALOBEN Brussels
Telex 23 494 paloben bru

DENMARK
Hewlett Packard A S
Datavej 52
DK 3460 **Birkerod**
Tel (02) 81 66 40
Cable HEWPACK AS
Telex 166 40 hpas

Hewlett Packard A/S
Navervej 1
DK 8600 **Silkeborg**
Tel (06) 82 71 66
Telex 166 40 hp as
Cable HEWPACK AS

FINLAND
Hewlett Packard Oy
Nahkahousuntie 5
P O Box 6
SF 00211 **Helsinki** 21
Tel 6923031
Cable HEWPACKOY Helsinki
Telex 12 15363

FRANCE
Hewlett Packard France
Quartier de Courtaboeuf
Boite Postale No 6
F 91401 **Orsay**
Tel (1) 907 78 25
Cable HEWPACK Orsay
Telex 60048

Hewlett Packard France
Agence Regional
Chemin des Mouilles
Boite Postale No 12
F 69130 **Ecully**
Tel (78) 33 81 25
Cable HEWPACK Ecully
Telex 31 617

Hewlett Packard France
Agence Regionale
Zone Aéronautique
Avenue Clément Ader
F 31770 **Colomiers**
Tel (61) 78 11 55
Telex 51957

Hewlett Packard France
Agence Regionale
Centre d aviation generale
F 13721 **Aeroport de Marignane**
Tel (91) 89 12 36
TWX 41770 F

Hewlett Packard France
Agence Regionale
63 Avenue de Rochester
F 35000 **Rennes**
Tel 74912 F
Telex 74 912 F

Hewlett Packard France
Agence Régionale
74 Allee de la Robertsau
F 67000 **Strasbourg**
Tel (88) 35 23 20/21
Telex 89141
Cable HEWPACK STRBG

Medical/Calculator Only
Hewlett Packard France
Agence Régionale
Centre Vauban
201 rue Colbert
Entree A2
F 59000 **Lille**
Tel (20) 51 44 14

GERMAN FEDERAL REPUBLIC
Hewlett Packard GmbH
Vertriebszentrale Frankfurt
Bernerstrasse 117
Postfach 560 140
D 6000 **Frankfurt** 56
Tel (0611) 50 04 1
Cable HEWPACKSA Frankfurt
Telex 41 32 49 fra

Hewlett Packard GmbH
Technisches Buero Boblingen
Herrenbergerstrasse 130
D 7030 **Böblingen** Wurttemberg
Tel (07031) 667 1
Cable HEPAK Böblingen
Telex 07265739 bbn

Hewlett Packard GmbH
Technisches Buero Dusseldorf
Vogelsanger Weg 38
D 4000 **Dusseldorf**
Tel (0211) 63 80 31/5
Telex 85/86 533 hpdd d

Hewlett Packard GmbH
Technisches Buero Hamburg
Wendenstrasse 23
D 2000 **Hamburg** 1
Tel (040) 24 13 93
Cable HEWPACKSA Hamburg
Telex 21 63 032 hphh d

Hewlett Packard GmbH
Technisches Buero Hannover
Mellendorfer Strasse 3
D 3000 **Hannover Kleefeld**
Tel (0511) 55 60 46
Telex 092 3259

Hewlett Packard GmbH
Technisches Buero Nuremberg
Neumeyer Str 90
D 8500 **Nuremberg**
Tel (0911) 56 30 83/85
Telex 0623 860

Hewlett Packard GmbH
Technisches Buero Muchen
Unterhachinger Strasse 28
ISAR Center
D 8012 **Ottobrunn**
Tel (089) 601 30 61/7
Telex 52 49 85
Cable HEWPACKSA Munchen

(West Berlin)
Hewlett Packard GmbH
Technisches Buero Berlin
Keith Strasse 2 4
D 1000 **Berlin** 30
Tel (030) 24 90 86
Telex 18 34 05 hpbln d

GREECE
Kostas Karayannis
18 Ermou Street
GR **Athens** 126
Tel 3230 303 Sales/SVC
3230 305 Adm Order Proc
Cable RAKAR Athens
Telex 21 59 62 rkar gr

Hewlett Packard S A
Mediterranean & Middle East Operations
35 Kolokotroni Street
Platia Kefallariou
GR Kifissia **Athens**
Tel 8080337 8080359
8080429 8018693
Telex 21 6588
Cable HEWPACKSA Athens

Analytical Only
INTECO G Papathanassiou & Co
Marni 17
GR **Athens** 103
Tel 521 915
Cable INTEKNIKA
Telex 21 5329 INTE GR

Medical Only
Technomed Hellas Ltd
52 Skoufa Street
GR **Athens** 135
Tel 626 972
Cable ETALAK Athens
Telex 21 4693 ETAL GR

IRELAND
Hewlett Packard Ltd
King Street Lane
Winnersh Wokingham
GB **Berkshire** RG11 5AR
Tel Wokingham 784774
Telex 847178 848179

Hewlett Packard Ltd
The Graftons
Stamford New Road
GB **Altrincham** Cheshire
Tel (061) 928 9021
Telex 668068

ITALY
Hewlett Packard Italiana S p A
Via Amerigo Vespucci 2
I 20124 **Milan**
Tel (2) 6251 (10 lines)
Cable HEWPACKIT Milan
Telex 32046

Hewlett Packard Italiana S p A
Via Pietro Maroncelli 40
(ang Via Visentini)
I 35100 **Padova**
Tel 66 48 88
Telex 32046 via Milan

Medical Only
Hewlett Packard Italiana S p A
Via Medaglie d Oro 2
I 56100 **Pisa**
Tel (050) 2 32 04
Telex 32046 via Milan

Hewlett Packard S p A
Via G Armellini 10
I 00143 **Rome**-Eur
Tel (6) 5912544/5
Telex 61514
Cable HEWPACKIT Rome

Hewlett Packard Italiana S p A
Via San Quintino 46
I 10121 **Turin**
Tel 53 82 64/54 84 68
Telex 32046 via Milan

Medical/Calculators Only
Hewlett Packard Italiana S p A
Via Principe Nicola 43 G/C
I 95126 **Catania**
Tel (095) 370505

LUXEMBURG
Hewlett Packard Benelux
S A /N V
Avenue de Col Vert 1
(Groenkraaglaan)
B 1170 **Brussels**
Tel (02) 672 22 40
Cable PALOBEN Brussels
Telex 23 494

NETHERLANDS
Hewlett Packard Benelux N V
Van Heuven Goedhartlaan 121
P O Box 667
NL 1134 **Amstelveen**
Tel (020) 47 20 21
Cable PALOBEN Amsterdam
Telex 13 216 hepa nl

NORWAY
Hewlett Packard Norge A S
Nesveien 13
Box 149
N 1344 **Haslum**
Tel 25 38 760
Telex 16621 hpnas n

POLAND
Analytical/Medical Only
Hewlett Packard
Warsaw Technical Office
UL Spitalne 1
00 120 **Warsaw**
Tel 268031 ext 30
Telex 812453

PORTUGAL
Telectra Empresa Tecnica de
Equipamentos Electricos S a r l
Rua Rodrigo da Fonseca 103
P O Box 2531
P **Lisbon** 1
Tel (19) 68 60 72
Cable TELECTRA Lisbon
Telex 12598

Mundinter
Intercambio Mundial de Comércio
Sarl Avenida Antonio Augusto
de Aguiar 138
P O Box 2761
P **Lisbon**
Tel (19) 53 21 31 7
Cable INTERCAMBIO Lisbon

SPAIN
Hewlett Packard Espanola S A
Jerez No 3
E **Madrid** 16
Tel (1) 458 26 00 (10 lines)
Telex 23515 hpe

Hewlett Packard Espanola S A
Milanesado 21 23
E **Barcelona** 17
Tel (3) 203 6200 (5 lines)
Telex 52603 hpbe e

Hewlett Packard Espanola S A
Av Ramon y Cajal 1
Edificio Sevilla I planta 9º
E **Seville**
Tel 64 44 54/58

Hewlett Packard Espanola S A
Edificio Albia II 7 B
E **Bilbao**
Tel 23 83 06/23 82 06

Calculators Only
Hewlett Packard Espanola S A
Alvaro Bazan 12
(Edificio Luz)
E **Valencia** 10
Tel 60 42 00

SWEDEN
Hewlett Packard Sverige AB
Enighetsvagen 1 3
Fack
S 161 20 **Bromma** 20
Tel (08) 730 05 50
Cable MEASUREMENTS Stockholm
Telex 10721

Hewlett Packard Sverige AB
Hagakersgatan 9C
S 431 41 **Molndal**
Tel (031) 27 68 00/01
Telex Via Bromma

SWITZERLAND
Hewlett Packard (Schweiz) AG
Zurcherstrasse 20
P O Box 64
CH 8952 Schlieren **Zurich**
Tel (01) 98 18 21
Cable HPAG CH
Telex 53933 hpag

Hewlett Packard (Schweiz) AG
9 chemin Louis Pictet
CH 1214 Vernier **Geneva**
Tel (022) 41 49 50
Cable HEWPACKSA Geneva
Telex 27 333 hpsa ch

TURKEY
Telekom Engineering Bureau
Saglik Sok No 15/1
Ayaspasa Beyoglu
P O Box 437 Beyoglu
TR **Istanbul**
Tel 49 40 40
Cable TELEMATION Istanbul

UNITED KINGDOM
Hewlett Packard Ltd
King Street Lane
Winnersh Wokingham
GB **Berkshire** RG11 5AR
Tel Wokingham 784774
Telex 847178/848179

Hewlett Packard Ltd
The Graftons
Stamford New Road
GB **Altrincham** Cheshire
Tel (061) 928 9021
Telex 668068

Hewlett Packard Ltd
c/o Makro
South Service Wholesale Centre
Amber Way
Halesowen Industrial Estate
GB **Halesowen** Worcs
Tel Birmingham 7860

Hewlett Packard Ltd
4th Floor
Wedge House
799 London Road
GB **Thornton Heath** CR4 6XL
Surrey
Tel (01) 684 0105
Telex 946825

Hewlett Packard Ltd
c/o Makro
South Service Wholesale Centre
Wear Industrial Estate
Washington
GB **New Town** County Durham
Tel Washington 464001 ext 57 58

Hewlett Packard Ltd s registered
address for V A T purposes
only
70 Finsbury Pavement
London EC2A 1SX
Registered No 690597

USSR
Hewlett Packard USSR
c/o Commercial Office
American Embassy (Box M)
A 1091 **Vienna** Austria
Tel 221 79 71
Telex 7825 hewpak Su

YUGOSLAVIA
Iskra Standard/Hewlett Packard
Office
Miklosiceva 38/VII
61000 **Ljubljana**
Tel 315 879/321 674
Telex 31265

SOCIALIST COUNTRIES PLEASE CONTACT
Hewlett Packard S A
7 rue du Bois du Lan
P O Box 349
CH 1217 Meyrin 1 **Geneva**
Switzerland
Tel (022) 41 54 00
Cable HEWPACKSA Geneva
Telex 2 24 86

AFRICA, ASIA, AUSTRALIA

ANGOLA
Telectra
Empresa Tecnica de
Equipamentos
Electricos S A R L
R Barbosa Rodrigues 42 1ºDT º
Caixa Postal 6487 **Luanda**
Tel 35515/6
Cable TELECTRA Luanda

AUSTRALIA
Hewlett Packard Australia
Pty Ltd
31-41 Joseph Street
Blackburn Victoria 3130
Tel 89-6351 89-6306
Telex 31-024
Cable HEWPARD Melbourne

Hewlett Packard Australia
Pty Ltd
31 Bridge Street
Pymble
New South Wales 2073
Tel 449-6566
Telex 21561
Cable HEWPARD Sydney

Hewlett Packard Australia
Pty Ltd
97 Churchill Road
Prospect 5082
South Australia
Tel 44 8151
Cable HEWPARD Adelaide

Hewlett Packard Australia
Pty Ltd
141 Stirling Highway
Claremont W A 6010
Tel 86 5455
Telex 93859
Cable HEWPARD

Hewlett Packard Australia
Pty Ltd
121 Wollongong Street
Fyshwick A C T 2609
Tel 95 3733

Hewlett Packard Australia
Pty Ltd
5th Floor
Teachers Union Building
495 499 Boundary Street
Spring Hill 4000 Queensland
Tel 29 1544
Telex 44 4 131

CEYLON
United Electricals Ltd
P O Box 681
60 Park St
Colombo 2
Tel 26696
Cable HOTPOINT Colombo

CYPRUS
Kypronics
19 Gregorios & Xenopoulos Rd
P O Box 1152
CY **Nicosia**
Tel 45628 29
Cable KYPRONICS PANDEHIS

HONG KONG
Schmidt & Co (Hong Kong) Ltd
P O Box 297
Connaught Centre
39th Floor
Connaught Road Central
Hong Kong
Tel 255291
Telex 74766SCHMCHX
Cable SCHMIDTCO Hong Kong

INDIA
Blue Star Ltd
Kasturi Buildings
Jamshedji Tata Rd
Bombay 400 020
Tel 29 50 21
Telex 3751
Cable BLUEFROST

Blue Star Ltd
Sahas
414/2 Vir Savarkar Marg
Prabhadevi
Bombay 400 025
Tel 45 78 87
Telex 4093
Cable FROSTBLUE

Blue Star Ltd
Band Box House
Prabhadevi
Bombay 400 025
Tel 45 73 01
Telex 3751
Cable BLUESTAR

Blue Star Ltd
14/40 Civil Lines
Kanpur 208 001
Tel 6 88 82
Cable BLUESTAR

Blue Star Ltd
7 Hare Street
P O Box 506
Calcutta 700 001
Tel 23 0131
Telex 655
Cable BLUESTAR

Blue Star Ltd
Blue Star House
34 Ring Road
Lajpat Nagar
New Delhi 110 024
Tel 62 32 76
Telex 2463
Cable BLUESTAR

Blue Star Ltd
Blue Star House
11 11A Magarath Road
Bangalore 560 025
Tel 55668
Telex 430
Cable BLUESTAR

Blue Star Ltd
Meeakshi Mandiran
xxx 1678 Mahatma Gandhi Rd
Cochin 682 016 Kerala

Blue Star Ltd
1 1 117/1
Sarojini Devi Road
Secunderabad 500 003
Tel 7 63 91 7 73 93
Cable BLUEFROST
Telex 459

Blue Star Ltd
23/24 Second Line Beach
Madras 600 001
Tel 23954
Telex 379
Cable BLUESTAR

Blue Star Ltd
Nathraj Mansions
2nd Floor Bistupur
Jamshedpur 831 001
Tel 38 04
Cable BLUESTAR
Telex 240

INDONESIA
BERCA Indonesia P T
P O Box 496
1st Floor JL Cikini Raya 61
Jakarta
Tel 56038 40369 49886
Telex 2895 Jakarta

IRAN
Multi Corp International Ltd
Avenue Soraya 130
P O Box 1212
IR **Teheran**
Tel 83 10 35 39
Cable MULTICORP Tehran
Telex 2893 mci tn

ISRAEL
Electronics & Engineering
Div of Motorola Israel Ltd
17 Aminadav Street
Tel-Aviv
Tel 36941 (3 lines)
Cable BASTEL Tel Aviv
Telex 33569

JAPAN
Yokogawa Hewlett Packard Ltd
Ohashi Building
1 59 1 Yoyogi
Shibuya ku **Tokyo**
Tel 03 370 2281/92
Telex 232 2024YHP
Cable YHPMARKET TOK 23 724

Yokogawa Hewlett Packard Ltd
Nisei Ibaragi Bldg
2 2 8 Kasuga
Ibaragi Shi
Osaka
Tel (0726) 23 1641
Telex 5332 385 YHP OSAKA

Yokogawa Hewlett Packard Ltd
Nakamo Building
No 24 Kamisasazima cho
Nakamura ku **Nagoya** City
Tel (052) 571 5171

Yokogawa Hewlett Packard Ltd
Tanigawa Building
2 24 1 Tsuruya cho
Kanagawa ku
Yokohama 221
Tel 045 312 1252
Telex 382 3204 YHP YOK

Yokogawa Hewlett Packard Ltd
Mito Mitsui Building
1 4 73 San no maru
Mito 310
Tel 0292 25 7470

Yokogawa Hewlett Packard Ltd
Inoue Building
1348 3 Asahi cho 1 chome
Atsugi 243
Tel 0462 24 0452

KENYA
Technical Engineering Services
P O Box 18311
Nairobi Kenya
Tel 57726
Cable PROTON

KOREA
American Trading Company
Korea
I P O Box 1103
Dae Kyung Bldg 8th Floor
107 Sejong Ro
Chongro Ku **Seoul**
Tel (4 lines) 73 8924 7
Cable AMTRACO Seoul

KUWAIT
Al Khaldiya Trading &
Contracting Co
Al Snor Street
Michaan Bldg No 4
Kuwait
Tel 42 99 10
Cable VISCOUNT

LEBANON
Constantin E Macridis
Clemenceau Street 34
P O Box 7213
RL **Beirut**
Tel 36 63 97 8
Telex 21114 Leb
Cable ELECTRONUCLEAR Beirut

MALAYSIA
MECOMB Malaysia Ltd
2 Lorong 13 6A
Section 13
Petaling Jaya **Selangor**
Cable MECOMB Kuala Lumpur

MOZAMBIQUE
A N Goncalves Lta
162 1 Apt 14 Av D Luis
Caixa Postal 107
Lourenco Marques
Tel 27091 27114
Telex 6 203 Negon Mo
Cable NEGON

NEW ZEALAND
Hewlett Packard (N Z) Ltd
4 12 Cruickshank Street
Kilbirnie Wellington 3
Mailing Address
Hewlett Packard (N Z) Ltd
P O Box 9443
Courtney Place
Wellington
Tel 877 199
Telex NZ 3898

Hewlett Packard (N Z) Ltd
Pakuranga Professional Centre
267 Pakuranga Highway
Box 51092
Pakuranga
Tel 569 651
Cable HEWPACK Auckland

Analytical/Medical Only
Dental & Medical Supply Co Ltd
Scientific Division
79 Carlton Gore Road
Newmarket
P O Box 1234
Auckland
Tel 75 289
Cable DENTAL Auckland

NIGERIA
The Electronics
Instrumentations Ltd
N6B 770 Oyo Road
Oluseun House
P M B 5402
Ibadan
Tel 61577
Cable THETEIL Ibadan

The Electronics Instrumentations Ltd (TEIL)
16th Floor Cocoa House
P M B 5402
Ibadan
Tel 22325
Cable THETEIL Ibadan

PAKISTAN
Mushko & Company Ltd
Oosman Chambers
Abdullah Haroon Road
Karachi 3
Tel 511027 512927
Cable COOPERATOR Karachi

Mushko & Company Ltd
38B Satellite Town
Rawalpindi
Tel 41924
Cable FEMUS Rawalpindi

PHILIPPINES
Electromex Inc
6th Floor Amalgamated
Development Corp Bldg
Ayala Avenue Makati Rizal
C C P O Box 1028
Makati Rizal
Tel 86 18 87 87 76 77
Cable ELEMEX Manila

REUNION ISLANDS
ZOOM
B P 938 97400 Saint Denis
85 Rue Jean Chatel
Ile de la Reunion
Tel 21 13 75
Cable ZOOM

SINGAPORE
Mechanical & Combustion
Engineering Company Pte
Ltd
10/12 Jalan Kilang
Red Hill Industrial Estate
Singapore 3
Tel 647151 (7 lines)
Cable MECOMB Singapore

Hewlett Packard Singapore
(Pte) Ltd
Blk 2 6th FLOOR Jalan
Bukit Merah
Redhill Industrial Estate
Alexandria P O Box 87
Singapore 3
Tel 633022
Telex HPSG RS 21486
Cable HEWPACK Singapore

SOUTH AFRICA
Hewlett Packard South Africa
(Pty) Ltd
Hewlett Packard House
Daphne Street Wendywood
Sandton Transvaal 2001
Tel 802 1040
Telex SA43 4782JH
Cable HEWPACK

Hewlett Packard South Africa
(Pty) Ltd
Breecastle House
Bree Street
Cape Town
Tel 2 6941 2 3
Cable HEWPACK Cape Town
Telex 0006 CT

Hewlett Packard South Africa
(Pty) Ltd
641 Ridge Road Durban
P O Box 37099
Overport Durban 4067
Tel 88 6102
Telex 6 7954

TAHITI
Metagraph
BP 1741
Papeete
Tel 20 320 29 979

TAIWAN
Hewlett Packard Taiwan
39 Chung Shiao West Road
Sec 1 Overseas Insurance
Corp Bldg 7th Floor
Taipei
Tel 389160 1 2
Telex TP824 HEWPACK
Cable HEWPACK Taipei

Hewlett Packard Taiwan
38 Po Ai Lane San Min Chu
Kaohsiung
Tel 297319

THAILAND
UNIMESA Co Ltd
Elsom Research Building
Bangjak Sukumvit Ave
Bangkok
Tel 932387 930338
Cable UNIMESA Bangkok

VIETNAM
Peninsular Trading Inc
P O Box H 3
216 Hien Vuong
Saigon
Tel 20 805 93398
Cable PENTRA SAIGON 242

ZAMBIA
R J Tilbury (Zambia) Ltd
P O Box 2792
Lusaka
Zambia Central Africa
Tel 73793
Cable ARJAYTEE Lusaka

MEDITERRANEAN AND MIDDLE EAST COUNTRIES NOT SHOWN PLEASE CONTACT
Hewlett Packard S A
Mediterranean and Middle
East Operations
35 Kolokotroni Street
Platia Kefallariou
GR Kifissia **Athens**
Telex 21 6588
Cable HEWPACKSA Athens

OTHER AREAS NOT LISTED CONTACT
Hewlett Packard
Export Trade Company
3200 Hillview Ave
Palo Alto California 94304
Tel (415) 493 1501
TWX 910 373 1267
Cable HEWPACK Palo Alto
Telex 034 8300 034 8493

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SECTION I
GENERAL INFORMATION

1-1. INTRODUCTION.

1-2. This section contains general information concerning the -hp- Model 3465A Multimeter. Included is an instrument description, specifications, information about instrument and manual identification, option and accessory information and safety considerations.

1-3. DESCRIPTION.

1-4. The -hp- Model 3465A Multimeter is a 4-1/2 digit, five function digital multimeter. The five functions are dc volts, ac volts, dc current, ac current and ohms. Measurements can be made to four significant digits with a sample rate of 2-1/2 readings per second. Throughout this manual, the 3465A Multimeter will be referred to as Multimeter.

1-5. SPECIFICATIONS.

1-6. Instrument specifications are listed in Table 1-1 These specifications are the performance standards or limits against which the instrument is tested. Any change in the specifications due to manufacturing, design or traceability to the U.S. National Bureau of Standards will be covered by revised pages to this manual. Additional information describing the operating characteristics are not specifications but are supplemental information for the user.

1-7. INSTRUMENT AND MANUAL IDENTIFICATION.

1-8. Hewlett-Packard uses a two-section serial number The first section (prefix) identifies a series of instruments The last section (suffix) identifies a particular instrument within the series. If a letter is included with the serial number, it identifies the country where the instrument was manufactured. This manual is kept up–to–date with the instrument at all times by revision. If the serial prefix of your instrument differs from the one on the title page of this manual, refer to Section VIII for backdating information that will adapt this manual to your instrument. All correspondence with Hewlett-Packard should include the complete serial number

1-9. OPTIONS.

1-10. Multimeter options are available to provide alternate methods of powering the instrument. The standard instrument is powered by rechargeable NiCad batteries or can be powered from an ac source of 86 to 127 V or 172 to 254V, 48 to 66 Hz.

1-11. Option 001.

1-12. Option 001 allows ac line operation only. Power is derived from an ac source of 86 to 127 V or 172 to 254 V, 48 to 66 Hz. Two NiCad Battery Packs can be installed at any time to allow portable operation of the Multimeter.

1-13. Option 002.

1-14 Option 002 is powered by four "D" type dry cell batteries (U2 in Europe). Alternate power can be derived from most Hewlett-Packard hand-held calculator battery chargers such as the Model 82002A Battery Charger/AC Adapter through a special rear panel input connector.

1-15. ACCESSORIES.

1-16. The following accessories are available to extend the usefullness of your Multimeter:

1. Model 11096A RF Probe, 100 kHz to 500 MHz (down 3 dB at 10 kHz and 700 MHz), for use on the 10 V and 100 V ranges in the DCV function only
2. Model 11002A Test leads, dual banana to dual alligator.
3. Model 11003A test leads, dual banana to probe and alligator.
4. Submodule front handle, -hp- Part No 5061-2001
5. Handle Kit (Rack), -hp- Part No. 5061-0088.
6. Rack adapter kit (includes 1/2 module filler), -hp- Part No. 5061-0054.
7. Nickel Cadmium Battery Pack (2 required) -hp- Part No 00035-60024.
8. Model 82002A Battery Charger/AC Adapter, alternate power (battery elimination) for the Option 002 Multimeter.
9. 11129A Binding Post Kit.

1-17. SAFETY CONSIDERATIONS.

1-18. This operating and service manual contains cautions and warnings alerting the user to hazardous operating and maintenance conditions This information is flagged by a caution or warning heading and/or the symbol ⚠ . The ⚠ symbol appears on the front panel and is an international symbol meaning "refer to the Operating and Service Manual". This symbol flags important operating instructions located in Section III. To ensure the safety of the operating and maintenance personnel and retain the operating condition of the instrument, these instructions must be adhered to.

Table 1-1. Specifications.

DC VOLTMETER

Ranges: 10 mV, 100 mV, 1 V, 10 V, 100 V, 1000 V

Overrange: 100% on all ranges except 1000 V max. on the 1000 V range.

Accuracy: (90 days, + 23°C ± 5°C)

RANGE	SPECIFICATION ± (% Reading + % Range)
10 mV	± (0.03 % + 0.02%)
100 mV through 100 V	± (0.02 % + 0.01%)
1000 V	± (0.025% + 0.01%)

Temperature Coefficient (0°C to 50°C): ± 0.003% of Reading/°C

Effective Common-Mode Rejection (with 1 kΩ imbalance in either lead):

AC: > 120 dB at 50/60 Hz ± 0.1%

AC Normal-Mode Rejection:

> 60 dB at 50/60 Hz ± 0.1%

Input Resistance:

10 mV through 1 V ranges. (80% R.H.) ≥ 10^{10} Ω

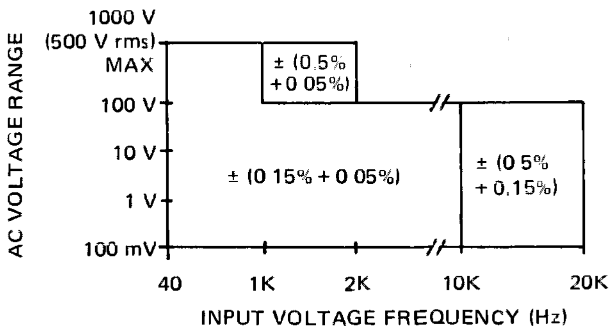
10 V through 1000 V ranges: 10 MΩ ± 1%

AC VOLTMETER

Ranges: 100 mV, 1 V, 10 V, 100 V, 1000 V (500 V Max)

Overrange: 100% on all ranges to 10 kHz decreasing linearly to 0% at 20 kHz. Maximum input voltage on the 1000 V range is 500 V rms.

Accuracy: (90 days, + 23°C ± 5°C) ± (% Reading + % Range)



Temperature Coefficient (0°C to 50°C): ± (0.005% of Reading + 0.002% of Range)/°C

Input Impedance: 1 M ± 1% shunted by < 100 pF

DC AMMETER

Ranges: 100 µA, 1 mA, 10 mA, 100 mA, 1000 mA

Overrange: 100% on all ranges

Accuracy: (90 days, + 23°C ± 5°C)

RANGE	SPECIFICATION ± (% of Reading + % of Range)
100 µA, 1 mA	± (0.07% + 0.01%)
10 mA	± (0.11% + 0.01%)
100 mA, 1000 mA	± (0.6 % + 0.01%)

Temperature Coefficient (0°C to 50°C).

RANGE	SPECIFICATION ± (% of Reading)/°C
100 µA	± 0.006%
1 mA, 10 mA	± 0.004%
100 mA, 1000 mA	± 0.01 %

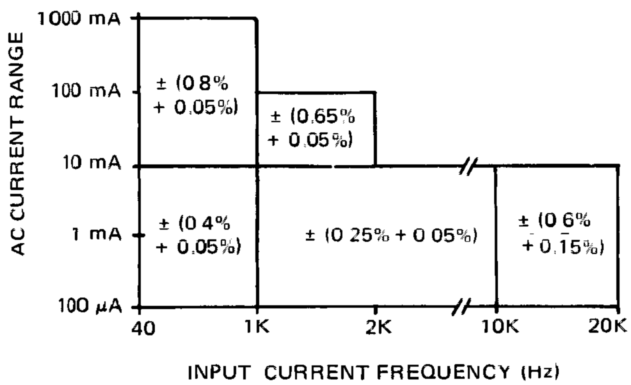
AC AMMETER

Ranges: 100 µA, 1 mA, 10 mA, 100 mA, 1000 mA

Overrange: 100% on all ranges to 10 kHz decreasing linearly to 0% at 20 kHz

Accuracy: (90 days, + 23°C ± 5°C)

± (% of Reading + % of Range)



Temperature Coefficient (0°C to 50°C): ± 0.01% of Reading/°C

OHMMETER

Ranges: 100 Ω, 1 kΩ, 10 kΩ, 100 kΩ, 1000 kΩ, 10 MΩ

Overrange: 100% on all ranges

Accuracy: (90 days, + 23°C ± 5°C)

RANGE	SPECIFICATION ± (% of Reading + % of Range)
100 Ω	± (0.02% + 0.02%)
1 kΩ through 1 MΩ	± (0.02% + 0.01%)
10 MΩ	± (1% + .01%)

Temperature Coefficient (0°C to 50°C):

RANGE	SPECIFICATION ± (% of Reading)/°C
100 Ω through 1 MΩ	± 0.0015%
10 MΩ	± 0.004 %

Table 1-2. General Information.

Maximum Input Voltages:

Between Input HIGH (V, Ω) and COM:

FUNCTION	MAX VOLTAGE
DC Volts	1000 V (dc + peak ac)
AC Volts	600 V dc; 500 V ac rms; 800 V peak ac
Ohms	350 V (dc + peak ac)

Between AMPS (A), HIGH (V, Ω) and COM terminals and ground:

± 500 V (dc + peak ac)

ACA and DCA Voltage Burden (nominal at full-scale):
1000 m range: < 250 mV
All other ranges: < 125 mV

Reading Rate: 2.5 samples per second

Overload Indication: Display Blanks except for overrange "1" and decimal point (also polarity sign on DCV or DCA FUNCTIONS)

Ohms Terminal Characteristics:

Configuration: 2 wire

Open-circuit voltage: < 5 V max.

Overload protection: 350 V (dc + peak ac)

Nominal current through unknown resistance:

RANGE	CURRENT
100 Ω	1 mA
1 KΩ	1 mA
10 KΩ	10 μA
100 KΩ	10 μA
1000 KΩ	1 μA
10 MΩ	0.1 μA

Power Requirements:

Standard	ac source:	86 to 127 V; 48 to 66 Hz 172 to 254 V, 48 to 66 Hz
	batteries:	2 rechargeable NiCad battery packs
Option 001	ac source:	86 to 127 V, 48 to 66 Hz 172 to 254 V; 48 to 66 Hz
Option 002	batteries:	4 "D" type dry cells (U-2 cells in Europe)
	battery elimination:	Most Hewlett-Packard hand-held calculator chargers such as the Model 82002A Battery Charger/AC Adapter

Environmental Considerations:

Operating temperature: 0°C to 55°C (32°F to 131°F)

Humidity range: 95% at 40°C

Storage temperature: -40°C to +75°C (-40°F to 167°F)

SECTION II
INSTALLATION

2-1. INTRODUCTION.

2-2. This section contains information and instructions for the installation and shipping of the Multimeter. Included are initial inspection procedures, power and grounding requirements, environmental information and instructions for repackaging for shipment.

2-3. INITIAL INSPECTION.

2-4. This instrument was carefully inspected both mechanically and electrically before shipment. It should be free of mars or scratches and in perfect electrical order upon receipt. To confirm this, the instrument should be inspected for physical damage in transit, and the electrical performance should be tested using the performance tests outlined in Section V. If there is damage or deficiency, see the warranty inside the front of this manual.

2-5. POWER REQUIREMENTS.

2-6. The Standard and Option 002 Multimeters have an internal battery source. In addition, either Standard or Option 002 instruments can be operated from any ac source of 86 V to 127 V or 172 V to 254 V at 48 Hz to 66 Hz. The Option 002 instrument requires the use of a Hewlett-Packard hand-held calculator Battery Charger/AC Adapter Model 82002A for instrument operation from the ac source.

CAUTION

Verify that the 110 V/220 V Line Voltage Selection switch, located on the rear panel of the Standard, Option 001 Multimeter or the Model 82002A Battery Charger/AC Adapter, is set to the ac source voltage to be used before inserting the power cord and turning the instrument on.

2-7. GROUNDING REQUIREMENTS.

2-8. To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends that the instrument panel and cabinet be grounded. The Standard and Option 001 Multimeters are 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.

2-9. To preserve the protection feature when operating from a two-contact outlet, use a three-prong to two-prong adapter and connect the green pigtail on the adapter to power line ground.

2-10. ENVIRONMENTAL REQUIREMENTS.

2-11. The Multimeter should not be operated where the ambient temperature exceeds 0°C to 55°C (32°F to 131°F) or stored where the ambient temperature exceeds - 40°C to + 75°C (- 40°F to 167°F).

WARNING

To prevent potential electrical or fire hazard, do not expose equipment to rain or moisture.

2-12. REPACKAGING FOR SHIPMENT.

2-13. The following paragraphs contain a general guide for repackaging the instrument for shipment. Refer to Paragraph 2-14 if the original container is to be used; 2-15 if it is not. If you have any questions, contact your nearest -hp- Sales and Service Office (see back of Manual for office locations).

NOTE

If the instrument is to be shipped to Hewlett-Packard for service or repair, attach a tag to the instrument identifying the owner and indicating the service or repair to be accomplished. Include the model number and full serial number of the instrument. In any correspondence, identify the instrument by model number and full serial number.

2-14. Place instrument in original container with appropriate packing material and seal well with strong tape or metal bands. If original container is not available, one can be purchased from your nearest -hp- Sales and Service Office.

2-15. If original container is not to be used, proceed as follows:

a. Wrap instrument in heavy paper or plastic before placing in an inner container.

b. Place packing material around all sides of instrument and protect panel face with cardboard strips.

c. Place instrument and inner container in a heavy carton or wooden box and seal with strong tape or metal bands.

2-16. POWER CORDS AND RECEPTACLES.

2-17. Figure 2-1 illustrates the standard power receptacle (wall outlet) configurations that are used throughout the United States and in other countries. The -hp- part number shown directly above each receptacle drawing is the part number for a Standard or Option 001 Multimeter power cord equipped with the appropriate mating plug for that receptacle. If the appropriate power cord is not included with the instrument, notify the nearest -hp- Sales and Service Office and a replacement cord will be provided. The Multimeter power cord, power input receptacle and mating connectors meet the safety standards set forth by the International Electrotechnical Commission (IEC).

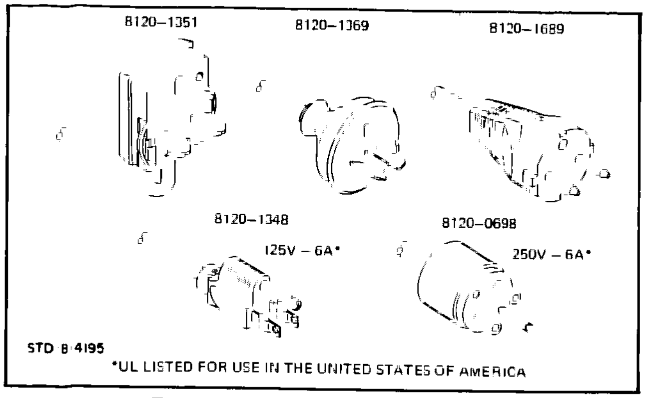


Figure 2-1. Power Receptacles.

SECTION III
OPERATING INSTRUCTIONS

3-1. INTRODUCTION.

3-2. This section contains instructions for using the Multimeter for making dc voltage, ac voltage, dc current, ac current and ohms measurements. The section also contains a description of the front and rear panel features.

WARNING

To prevent potential electrical or fire hazard, do not expose the Multimeter or its accessories to rain or moisture.

3-3. Front and Rear Panel Features.

3-4 An illustration and description of the front and rear panels is provided in Figure 3-1. All controls and connectors are identified and briefly described. Some rear panel features are available with certain options only and are identified in the description.

3-5. Turn-on and Warm-up.

3-6. For specified measurement accuracy, allow the instrument to warm-up for at least 10 minutes

CAUTION

Before operating from an ac source, verify that the 110/220 V line voltage selection switch, located on the rear panel of the Standard and Option 001 Multimeter or the Model 82002A Battery Charger/AC Adapter, is set to the ac source voltage to be used.

3-7. Internal Battery Voltage Measurement and Recharging.

3-8. The Multimeter contains a feature allowing the user to check battery strength to determine the need for battery replacement or recharging The procedure is to place the Multimeter in the DCV function and depress the 10 megohms range switch Batteries with full charge will produce a front panel display of approximately .370. If the front panel display is .300 or less, replace Option 002 dry-cell batteries or recharge the Standard Multimeter NiCad batteries. Recharging of the NiCad batteries is performed by operating the Multimeter on an ac source (verify line voltage selection switch is in correct position for source voltage used). Measurements can be made with the Multimeter operated from the ac source during the recharging period

NOTE

After 14 hours, a completely discharged battery will be fully charged Shorter charge periods will allow reduced battery operating time. There is no danger of overcharge. For convenience, overnight charging is recommended.

3-9. Low Battery Voltage Detection.

3-10. The Standard and Option 002 Multimeters contain an internal battery source (Standard contains rechargeable NiCads, Option 002 contains "D" cell or "U2" batteries). A battery source safety feature of the Multimeter is a low battery voltage detection circuit which turns the instrument off when battery voltage reaches a low level. This protects against cell reversal of the NiCad batteries If during operation the display disappears or immediately after turn-on the display appears and disappears after several seconds, low battery voltage is indicated To verify low battery voltage, the procedure described in the preceding paragraph can be used or verify by placing the OFF/ON switch to OFF and to ON again. The display will appear and again disappear. Operation from an ac line source and recharging of the NiCad batteries is required in a Standard instrument. Replacement of "D" cell or "U2" batteries is required in an Option 002 instrument.

3-11 Overload Indication.

3-12. The Multimeter is capable of displaying up to 100% of range (19999) for all functions and ranges except the 1000 V range in ac or dc volts (see ac and dc voltage measurement paragraphs). In an overload condition where the input exceeds 19999, the last four digits blank and the overrange "1" and decimal point will be displayed The polarity sign is also displayed in the dc volts and dc current functions in the overload condition

3-13. AC VOLTAGE MEASUREMENTS.

⚠ **CAUTION**

Maximum input voltage in the ACV FUNCTION is 500 V rms, 800 V peak and 600 V dc. Do not exceed these voltages or damage to the instrument will occur.

3-14. AC VOLTAGE Ranges.

3-15. The ACV FUNCTION has five ranges from 100 mV to 1000 V. Each range (except the 1000 V range) has a 100% overrange capability up to 10 kHz decreasing linearly to 0% at 20 kHz. Maximum input voltage on the 1000 V range is indicated in the AC VOLTAGE MEASUREMENTS caution in Paragraph 3-13

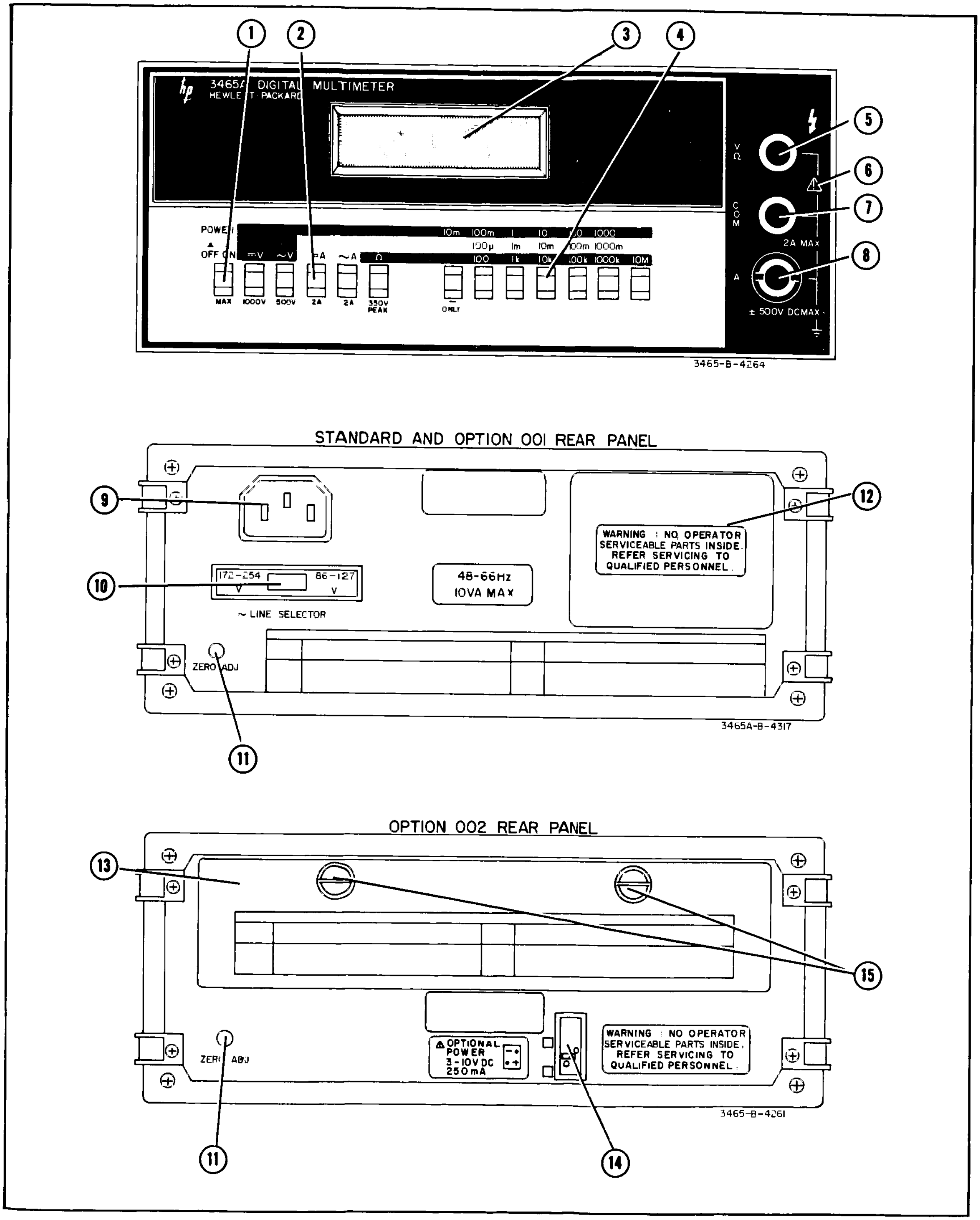


Figure 3-1. Front and Rear Panel Features.

⚠ **CAUTION**

Do not apply a voltage greater than ± 500 V dc or 500 V peak between any terminal and chassis ground or damage to the instrument will occur.

(1) **OFF/ON Switch.** Pushbutton push on/push off switch.

(2) **FUNCTION Switch.** Function markings are located above each pushbutton switch.

⎓V = DC Volts
~V = AC Volts
⎓A = DC Amps
~A = AC Amps
Ω = Ohms

(3) **Display.** Indicates the measured value and polarity of dc volts or amps.

(4) **RANGE Switch.** Range markings are located above each pushbutton switch. Color bands identify the range switches associated with each function switch.

(5) **DCV/ACV/OHMS** High input terminal.

(6) ⚠ **Symbol.** This symbol is an international symbol meaning "refer to the Operating and Service Manual". This symbol will appear in this section of the manual flagging operating instruction information.

(7) **COM** input terminal. This terminal is connected to circuit ground for all measurements except ohms. In the ohms function, the COM terminal is disconnected from circuit ground.

(8) **DCA/ACA** High input terminal. 2 Amp fuse located behind removable "A" terminal cap.

(9) **AC** power input connector.

(10) **Line** voltage selection switch.

(11) **ZERO ADJ.** Internal adjustment used to zero the display in the DCV FUNCTION, 10 mV RANGE

(12) Battery access door (Standard and Option 001).

(13) Battery access door (Option 002 only).

(14) Calculator battery charger (Model 82002A) power input connector (Option 002 only).

(15) Battery access door lock (Option 002 only).

Figure 3-1. Front and Rear Panel Features (cont'd).

3-16. DC VOLTAGE MEASUREMENTS.

⚠ **CAUTION**

Do not exceed a maximum input voltage of 1000 V dc and peak ac on the 1000 V range or damage to the instrument will occur. There is no overrange capability on the 1000 V range.

3-17. 10 mV Range Zero Adjust.

3-18. When using the Multimeter on the 10 mV range in DC volts, short the input terminals and zero the Multimeter display with the rear panel ZERO ADJ control (see Figure 3-1). The display should indicate 0.000 before proceeding with measurements.

3-19. DC Voltage Ranges.

3-20. DC Voltage measurements can be made from 10 mV to 1000 V full-range. Each range has 100% overrange capability except the 1000 V range which has a maximum input of 1000 V dc and peak ac (see DC Voltage measurements caution in Paragraph 3-16).

3-21. CURRENT MEASUREMENTS.

⚠ **CAUTION**

Do not exceed a maximum dc or ac rms input current of 2 A or the amps fuse, located directly behind the "A" terminal, will open. See the following paragraph for replacement instructions.

3-22. The Multimeter is protected from the application of excessive current by a 2 A fuse located directly behind the front panel "A" terminal. If it is necessary to replace this fuse, use the side slots on the "A" terminal to rotate the terminal. The terminal and fuse will protrude from the front panel. Remove the terminal and fuse, replace fuse with a 2 A rated fuse as listed in Table 6-3 Miscellaneous Parts General, and designated F1

3-23. AC Current Ranges.

3-24. AC current measurements can be made over a frequency of 40 Hz to 20 kHz. There are five current ranges from 100 μA to 1000 mA with 100% overrange up to 10 kHz decreasing linearly to 0% at 20 kHz (See current measurements Caution in Paragraph 3-21.)

3-25. DC Current Ranges.

3-26. DC Current measurements can be made on five current ranges from 100 μA to 1000 mA. Each range has a 100% overrange capability (see current measurements caution in Paragraph 3-21).

3-27. OHMS MEASUREMENTS.

⚠ CAUTION

Do not apply voltage greater than ± 350 V dc + Peak AC between the ohms and common input terminals in the ohms function or damage to the instrument will occur.

3-28. Ohmmeter Ranges.

3-29. Resistance measurements can be made on six ranges from 100 ohms to 10 megohms each with a 100% over-range capability. Both input terminals (Ω and COM) are floating with respect to circuit ground.

3-30. Ohmmeter Reference Current.

3-31. The ohmmeter reference current through the unknown resistance for each range is shown in Table 3-1.

Table 3-1. Ohmmeter Current Through Unknown.

Range	Current Through Unknown
100 Ω	1 mA
1 KΩ	1 mA
10 KΩ	10 μA
100 KΩ	10 μA
1000 KΩ	1 μA
10 MΩ	0.1 μA

Maximum open-circuit voltage at the ohms input terminals is less than 5 V.

SECTION IV
THEORY OF OPERATION

4-1. INTRODUCTION.

4-2. This section contains the theory of operation for the Multimeter. The information is divided into two parts:

1. Simplified Theory
2. Detailed Theory

The simplified theory provides an overview of the operation of each section in the Multimeter while the detailed theory describes the circuit operation of each section.

4-3. Description.

4-4. The Multimeter is a five-function, 4-1/2 digit multimeter with 100% overrange capability on all ranges except the 1000 V range. The five functions measured are dc volts, ac volts, dc current, ac current and ohms The dual-slope integration technique is used for measurements. This technique charges an integrator for a fixed length of time, to a voltage proportional to the input signal, then discharges the integrator at a fixed rate determined by a known reference voltage. The measurement display is determined by the discharge time of the integrator, which is proportional to the input signal.

4-5. Figure 4-1, Basic Block Diagram and Measurement Sequence, illustrates the major functional blocks of the Multimeter The illustration of the measurement sequence shows the integrator output for each interval of a measurement cycle This diagram is to supplement the functional block diagram for the simplified theory discussion.

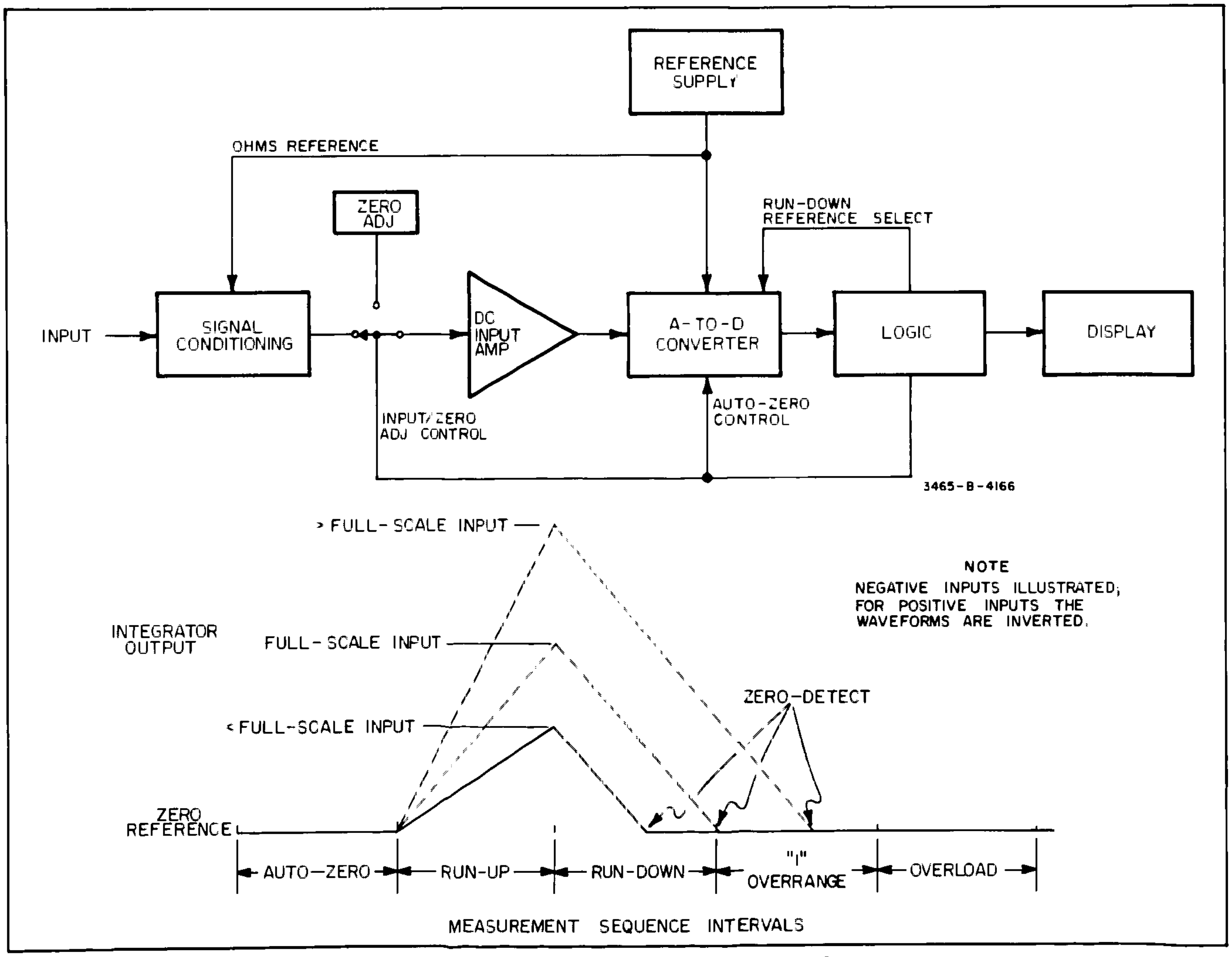


Figure 4-1. Basic Block Diagram and Measurement Sequence.

4-6. SIMPLIFIED THEORY.

4-7. A simplified theory of operation of the Multimeter is presented in the following paragraphs. The simplified theory describes each section of the functional block diagram, Figure 7-1 These sections are the signal conditioning section, analog–to–digital section, logic section and the display section. Also presented is a simplified description of the power supply. Refer to Figure 7-1, Functional Block Diagram, and Figure 4-1, Basic Block Diagram and Measurement Sequence, for this discussion.

4-8. Signal Conditioning.

4-9. Signal conditioning consists of attenuating and/or converting the input signal to a dc voltage within the working limits of the input amplifier. For full-scale inputs, this voltage can vary from 10 mV dc to 1 V dc depending on the function and range.

4-10. The signal conditioning section consists of current shunts, an input attenuator, ohms converter and an ac–to–dc converter. The output from the signal conditioning section is applied to the input amplifier during the run–up interval of the measurement sequence. The Input Amplifier Gain Table located on Figure 7-3 indicates the full-scale input level applied to the input amplifier for each function and range. This signal is the output of the signal conditioning section.

4-11. **Ohms Converter.** The ohms converter is a high gain integrating amplifier. A simplified diagram of the ohms converter is presented in Figure 4-2. The blocks of the ohms converter are the integrating amplifier, protection diodes, over-voltage protection circuit and the overload loop. An integrating amplifier is used because this type of amplifier is less susceptible to oscillations. The protection diodes clamp the HI terminal to a voltage of about + 1.2 V in the positive direction or - .7 V in the negative direction. With the HI terminal clamped, protection against excessive voltages applied to the ohms terminals is provided by an over-voltage protection circuit located between the ohms amplifier and the LOW terminal. For excessive voltages, this circuit isolates the LOW terminal from the ohms amplifier.

4-12. Figure 4-2 shows two outputs of the ohms converter being applied to the input amplifier. The ohms output is the ohms converter measurement signal and the auto-zero output is the ohms amplifier dc offset signal which is called the auto-zero (AZ) signal This AZ signal is applied to the input amplifier during the auto-zero interval of the measurement sequence and establishes the reference for the analog–to–digital converter An AZ signal greater than ± 1 mV causes the instrument readings to be invalid. This condition (AZ signal > ± 1 mV) is present when the unknown resistance, R_x, is removed and an open loop is present on the ohms amplifier. To maintain the AZ signal at < ± 1 mV when an open loop is present, an overload feedback circuit is used.

4-13. The ohms output, (LO terminal of the ohms converter) is applied to the input amplifier. This output is a dc voltage, the level of which is dependent on the ratio of the unknown resistance, R_x, to the variable resistance, 10^n, and the ohms reference supply The variable resistance, 10^n, is a resistor string located in the precision resistor pack R75. The value of 10^n is selected by the range switches shorting those resistors in the string that are not required. The value of 10^n can range from 10 kΩ to 10 MΩ. A discussion of the precision resistor pack R75 can be found in the detailed theory.

4-14. The formula for the ohms converter output voltage is:

$$\text{Ohms Output} = -\left[\frac{R_x}{10^n}\right] \text{Reference Supply Voltage} + V_{offset}$$

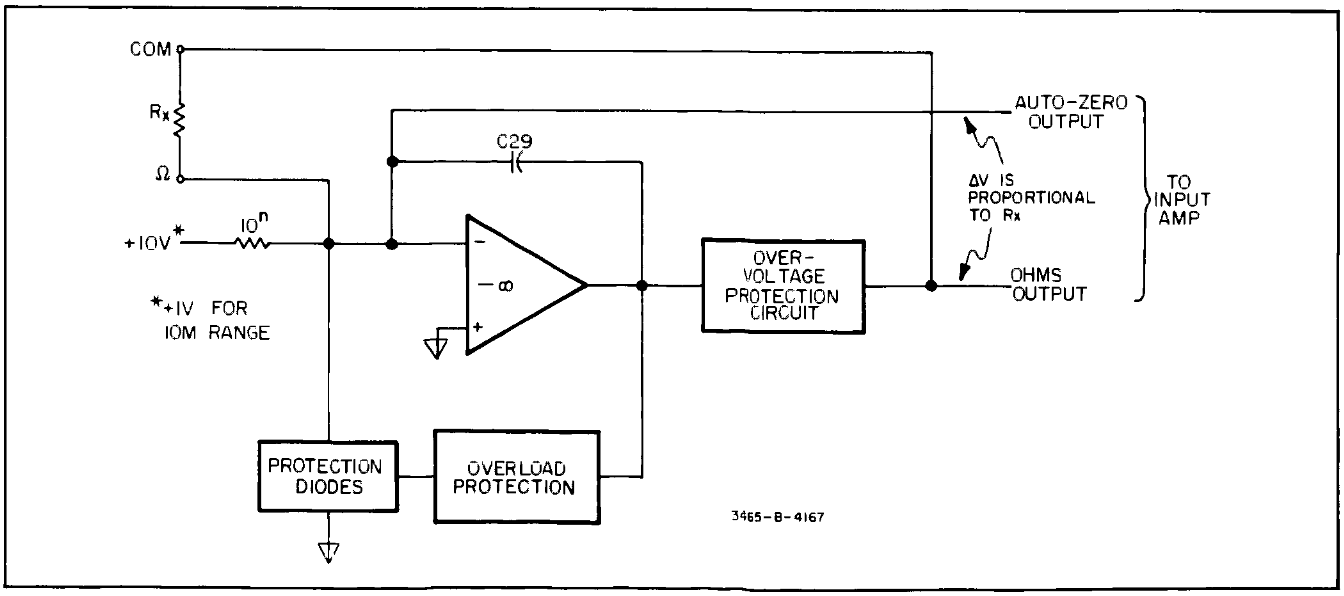


Figure 4-2. Simplified Diagram, Ohms Converter.

The reference supply is + 10 V for all ranges except the 10 M range. For this range the reference supply is + 1 V. The full-scale output of the ohms converter is 1 V dc. On the 10 M range with a R_x of 10 MΩ (full-scale), an output of 1 V dc is needed. From the formula for the ohms output, it can be seen that 10^n would have to equal 100 MΩ Since the range of 10^n is 10 kΩ to 10 MΩ, a 10^n of 10 MΩ combined with a reference supply of 1 V provides the desired 1 V dc full-scale ohms converter output.

4-15. AC–DC Converter. The ac–dc converter is an average responding ac converter. It measures the average value of a sine wave and multiplies this by a fixed scale factor to convert it to an rms value. The output of the converter is a dc voltage equal to the rms value of the sine wave.

4-16. Figure 4-3 is a block diagram of the ac-dc converter. The blocks consist of an impedance converter, an ac converter and a filter. The impedance converter has a high input impedance to prevent loading of the input signal. It also provides the gain necessary to drive the ac converter. An impedance converter gain of unity, 9.964 or 10 is selected by the function and range switching. The gain of 9.964 is used with the ACI function and the gain of 10 is used with the 100 mV, .1 mA, 100 Ω and 10 V, 10 mA, 10 kΩ ranges.

4-17. The ac converter amplifies the signal from the impedance converter by the scale factor. This converts the average value of the sine wave to the rms value. Half-wave rectification of the sine wave is also performed by the ac converter. This rectified signal is filtered to provide the proportional dc output which is applied to the analog–to–digital converter.

4-18. Analog–to–Digital (A–D) Converter.

4-19. The A–D converter block is comprised of an input amplifier, reference supply, integrator, slope amplifier, comparator and auto-zero circuit. It makes an analog–to–digital conversion using the dual-slope integrating technique. Four control state signals from the logic section (IO, IZ, I1 and I2) regulate the measurement sequence IO and IZ regulate the input amplifier and auto-zero switching respectively while I1 and I2 select the reference supply required during the run-down interval.

4-20. Input Amplifier. The first stage of the A–D converter is the input amplifier. During the run-up interval of the measurement sequence, control state signal IO switches the output of the signal conditioning block to the input amplifier. The output of the signal conditioning block is a dc voltage which varies between 10 mV and 1 V for full-scale inputs, depending on the function and range selected. The gain of the input amplifier is adjusted by the function and range switching to provide an output of 1 V dc for any full-scale input signal. See Input Amplifier Gain Table on Figure 7-3.

4-21. Reference Supply. The A–D converter uses a monopolar reference supply of + 10 V. A reference voltage is applied to the integrator during the run-down interval to discharge the integrating capacitor. Since the discharge rate is constant, the time required for the integrator to reach a zero reference is proportional to the input signal This time period is the run-down interval and is processed to determine the display. A positive and negative reference voltage is required since the input signal can be either polarity A detailed discussion of the operation of the monopolar reference supplv can be found in the detailed theory.

4-22. Integrator. The integrator output is a result of a current summation at the integrator summing junction (inverting input). A positive current summation (current flowing into the integrator input) will cause the integrator to ramp negative. A negative current summation (current flowing out of the integrator input) will cause the integrator to ramp positive. The integrator sums currents from the input amplifier. reference supply, - 7 V supply and the auto-zero loop.

4-23. Slope Amplifier. Following the integrator is a X4000 amplifier. This amplifier is divided into two stages; the first with a gain of 40 and the second with a gain of 100. The slope amplifier amplifies the integrator output to provide a more vertical crossing of this output with the reference level. This provides greater accuracy of the voltage–to–time conversion during the run-down interval.

4-24. Comparator. The comparator provides two logic outputs; a high output of 0 V or a low output of - 7 V. The comparator output is high when the integrator output is greater than the reference level. The comparator is low when the integrator output is less than the reference level.

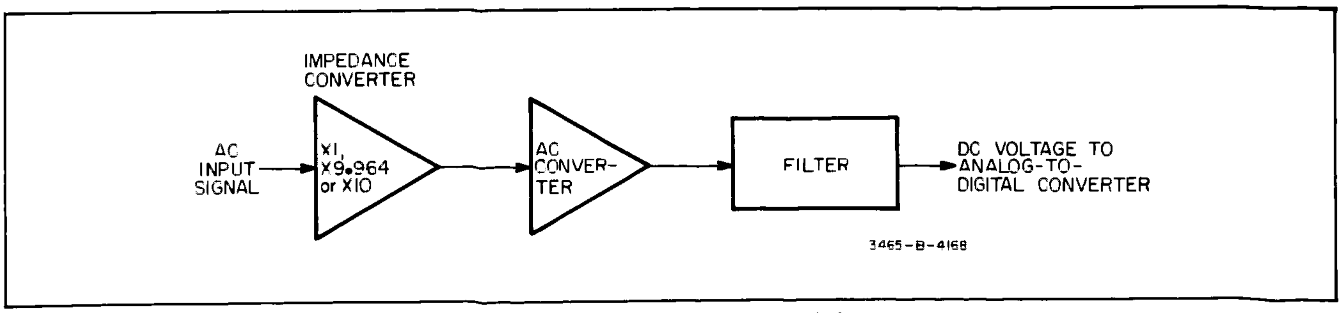


Figure 4-3. Block Diagram, AC–to–DC Converter.

This logic level is sensed by the logic section to determine polarity and zero-detect.

4-25. Auto-Zero Circuit. During the measurement sequence, the auto-zero loop is closed except for the run-up and run-down intervals. This loop includes the slope amplifier and the integrator but does not physically include the input amplifier although the loop does compensate for the input amplifier offset. When the auto-zero loop is closed, the input of the input amplifier is grounded. If the summation of currents at the integrator summing junction is not zero, the integrator begins to ramp up for a negative summation or ramp down for a positive summation. The integrator output is applied through the X4000 slope amplifier to the auto-zero capacitor, C4. The voltage on the auto-zero capacitor causes a current to flow at the summing junction that returns the summation to zero. This auto-zero configuration compensates for the analog offset of the input amplifier and integrator by providing a current at the summing junction that cancels the currents resulting from the offset.

4-26. Logic Section.

4-27. The Logic Section is comprised of combinational and state logic. This section processes the comparator output to determine the polarity of the input signal and to make a voltage–to–time conversion of the input signal. Time accumulated during the conversion is proportional to the input signal and is stored. The display is derived from this accumulated time. A voltage–to–time conversion with the accumulated time being stored occurs once each measurement sequence.

4-28. Seven blocks make up the logic section. These blocks are:

1. Clock
2. State Clock
3. Polarity and Zero Detect
4. Data Transfer and Reset
5. Control State Counter
6. Control State Decode
7. Data Accumulator

The HIGH and LOW logic levels used in the logic section are 0 V and -7 V respectively. The following discussion describes the basic operation of the logic section.

4-29. Clock and State Clock. The timing of the logic section is derived from the clock circuit. The clock operates at 100 kHz and is crystal-controlled. A state clock, driven by the clock output and the count extend line from the data accumulator, drives the control state counter to initiate each measurement interval.

4-30. Polarity and Zero Detect. The polarity and zero-detect circuit monitors the comparator output. The state of this output at the beginning of the run-down interval determines the polarity of the input signal. Zero-detect is determined at the point the comparator output changes states during the run-down, overrange or overflow intervals. If the integrator ramps positive (negative input signal) during run-up, the comparator output goes HIGH and returns to LOW at the zero-detect point. If the integrator ramps negative (positive input signal) during run-up, the comparator output goes low and returns to high at the zero-detect point. These comparator output logic states are stored in a D flip–flop. At the beginning of the run-down interval, this state identifies the polarity of the input signal. The outputs of the D flip–flop provide the signals needed to select the correct polarity display and the correct reference supply signal (I1, I2) during the run-down interval. An EXCLUSIVE OR and latch processes the comparator output to provide the zero-detect signal.

4-31. Data Transfer and Reset. The data transfer and reset circuits provide logic signals to the data accumulator required to load the storage latches and reset the decade counters. A detailed description of the data accumulator is provided in the detailed theory section. While the $\overline{TXFR}$ input of the data accumulator is low, data in the decade counters is transferred to the static storage latches. The RESET input resets the decade counters to zero when low. This must occur after the transfer to the storage latches has taken place. To ensure that reset occurs after termination of transfer, an RC delay circuit precedes the reset gates.

4-32. Control State Counter. The control state counter provides the timing for the measurement sequence intervals. The output from the counter establishes the timing of the analog control signals (IZ, IO, I1 and I2) which are applied to the A–D converter. The state clock and reset inputs to the control state counter determine the outputs of the counter.

4-33. Control State Decode. The control state decode converts the polarity, zero-detect and control state counter inputs to the correct analog control signals. These signals, applied to the A–D converter, perform the measurement sequence switching. This switching consists of the input amplifier switch, the auto-zero switch and the reference supply switches.

4-34. Data Accumulator. The data accumulator consists of a counter, data latches, a multiplexer, digit select decoder and output buffers. At the beginning of the Run-Down interval of the measurement sequence, the data accumulator begins to count clock pulses until zero-detect occurs. This count is proportional to the input signal and is the time conversion used to generate the display. The digit select decoder scans the display digits from the most significant digit to the least significant digit while the multiplexer provides the corresponding BCD outputs for each digit. A detailed discussion of the data accumulator is presented in the detailed theory.

4-35. Display.

4-36 The multimeter display contains four full digits with an overrange "1", polarity sign and sample rate indicators. All segments and indicators are light-emitting diodes. A BCD–to–seven–segment decoder receives BCD information from the data accumulator and applies the seven-segment code to the display drivers. The display drivers apply the seven-segment code to all digits simultaneously. Digit strobe lines activate the digit corresponding to the seven-segment code at that point in time Scanning of the digits is from the most significant to the least significant digit. To complete the display, the proper decimal point is enabled by range switching.

4-37. Power Supply.

4-38. Figure 4-4 is a block diagram of the power supply. The power supply develops four output voltages from a single dc input voltage (+VB). This dc input voltage is applied to a dc—to—dc converter which develops output voltages of +11 V dc and -7 V dc. A series regulated +10 V output is developed from the +11 V converter output This +10 V is used as the reference voltage in the A—D converter and to develop the reference current in the ohms converter and as the reference voltage for the converter regulator. The converter regulator controls the converter and regulates the -7 V and +11 V outputs of the converter. The fourth voltage (-12 V) is derived from the -7 V converter output with a voltage doubler circuit driven by the 100 kHz clock. A discussion of the operation and regulation process of the dc-to-dc converter is presented in the detailed theory

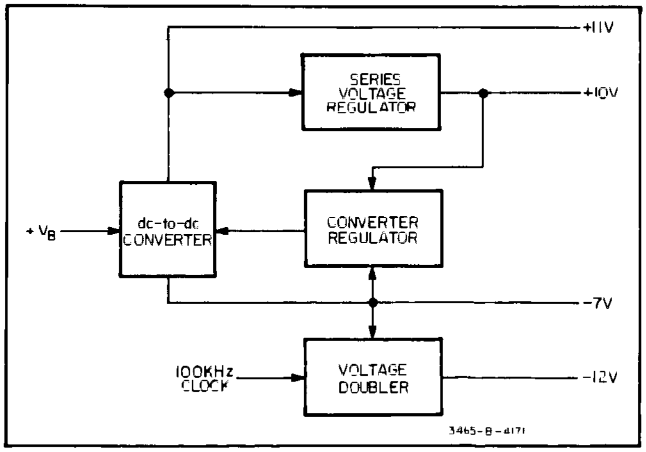


Figure 4-4. Block Diagram, Power Supply.

4-39. DETAILED THEORY.

4-40. This portion of the theory of operation provides a detailed discussion of the circuits in the Multimeter. The circuits described here are the ohms converter, ac—dc converter, monopolar reference supply, data accumulator of the logic section, display and the power supply A discussion of the precision resistor pack (R75) is also provided. The detailed discussion makes use of the schematics in Section VII.

4-41. Precision Resistor Pack (R75).

4-42. The precision resistor pack, R75, is a laser trimmed substrate providing high precision resistances. A diagram of R75 is shown on Figure 7-2. The input attenuator, power supply, ohms reference supply, A—D reference supply and the input amplifier require highly accurate resistances to maintain the accuracy of the Multimeter. These resistances are part of the resistor pack. The advantage to the resistor pack is high precision resistors and good temperature tracking. As resistance values of the resistor pack change due to temperature changes, the ratio of the resistors remains the same.

4-43. Ohms Converter.

4-44. Refer to Figure 7-2 for this discussion Both ends of the ohms converter are floating with respect to the instrument ground. The unknown resistor, R_x, becomes the feedback loop of the ohms amplifier. The ratio of R_x to 10^n determines the gain of the ohms amplifier, Q25 and U15. 10^n is a variable resistance between 10 kΩ and 10 MΩ selected by the range switching. The ohms converter input is the reference voltage provided by the ohms reference supply. This reference voltage times the amplifier gain is the ohms converter output supplied to the input amplifier during the run-up interval. Full-scale ohms converter gain and output values are provided in the ohms converter table located on Figure 7-2.

4-45. The HI terminal of the ohms converter is connected to the reference supply through 10^n of the resistor pack R75. The HI terminal is clamped by protection diodes CR15 and CR25 to prevent the destruction of FET Q25 and R75 by the application of large voltages. These diodes clamp the HI terminal to about +1.2 V positive or -0.7 V negative.

4-46. With the HI terminal clamped, over-voltage protection must be provided to protect the ohms amplifier from excess voltage. The over-voltage protection circuit is located between the ohms amplifier and the LO terminal and is shown in Figure 4-5 During normal operation <2 mA of current flows through Q30, R94 and Q32 If a large voltage is applied to the ohms terminals, the current through this circuit will try to exceed 2 mA. This current will cause a large enough voltage drop across R94 to turn on Q31. When Q31 is on, it removes the base drive from Q30, which turns off, disconnecting the LO terminal from the ohms converter. Since Q30 is a high voltage transistor, large voltages are not applied to the ohms converter.

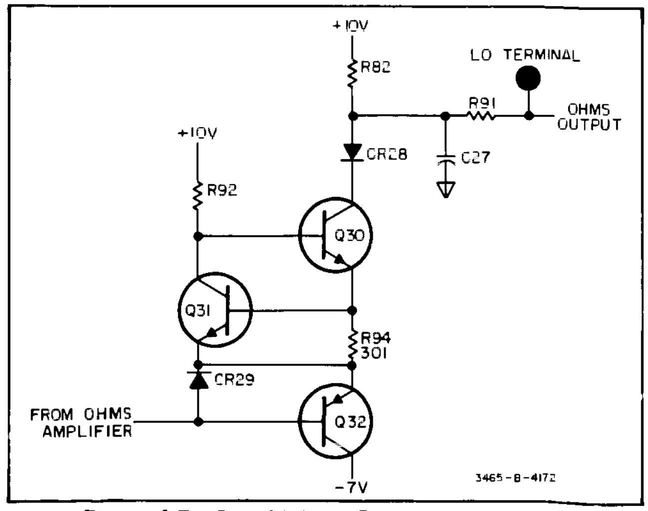


Figure 4-5. Over-Voltage Protection Circuit.

4-47. In the event of open loop ($R_x = \infty$), the ohms amplifier output begins to drive negative. The input (negative port), which is the auto-zero output, could exceed ± 1 mV under an open loop condition due to the lack of negative feedback through an R_x. This auto-zero output must be maintained at ≤ ± 1 mV for accurate operation of the A–D converter. To satisfy this requirement, an overload protection circuit consisting of CR23, CR24 and R86 is used. When the ohms amplifier output goes below approximately + 1.5 V, the zener diode (CR23) turns off. The overload loop, CR24 and R86, is introduced by the turn-on of CR24 when CR23 is off. This loop provides the negative feedback required to maintain an auto-zero output < ± 1 mV. When an R_x is introduced, CR23 turns-on, CR24 turns-off, and the overload loop is inoperative.

4-48. A maximum output by the ohms converter of ≤ 5 V is guaranteed by a voltage divider composed of R93 and R95. Additional protection components of the ohms converter are, A) CR29 which prevents Q32 junction breakdown due to fast transients, B) CR28 which blocks negative transients that could come in via the LO terminal and C) R91 and C27 which prevent high voltage and high frequency transients.

4-49. Degradation of accuracy in the ohms function due to changes in the ohms reference with respect to the A–D reference is minimized since both reference voltages are derived from the same + 10 V reference supply. If the reference supply voltage changes, both the ohms reference and the A–D reference are affected alike and any change is effectively cancelled.

4-50. AC–to–DC Converter.

4-51. The AC–to–DC converter is an average responding ac converter. It has a bandwidth of 40 Hz to 20 kHz. The converter is composed of two stages (see Figure 7-2). The first stage, U19, is an impedance converter. The purpose of this amplifier is to provide a high impedance to the input so loading of the input signal does not occur. It also provides high drive capability for the ac converter stage, U18. The input of the impedance converter is protected against large voltage swings by diodes CR35 and CR37. Voltages in excess of + 10 V or - 7 V peak ac will turn these diodes, returning excess current to the power supply.

4-52. The impedance converter, U19, has a selection of three gains; the 100 mV, .1 mA, 100 Ω and 10 V, 10 mA, 10 kΩ ranges select a gain of 10. The ACI function selects a gain of 9.964, while the remainder of the ranges and functions select a gain of unity (see U19 Gain Table, Figure 7-2).

4-53. The second stage of the AC–to–DC converter is the ac converter, U18. A basic diagram of this stage is shown in Figure 4-6. The amplifier has three feedback loops. These loops are the ac negative feedback loop, the dc negative feedback loop, and the positive feedback loop. The ac negative feedback loop is divided into two branches, one branch for the positive cycle and the second branch for the negative cycle. Diodes CR33 and CR34 switch between the positive and negative half-cycles to introduce the correct loop for its respective half-cycle.

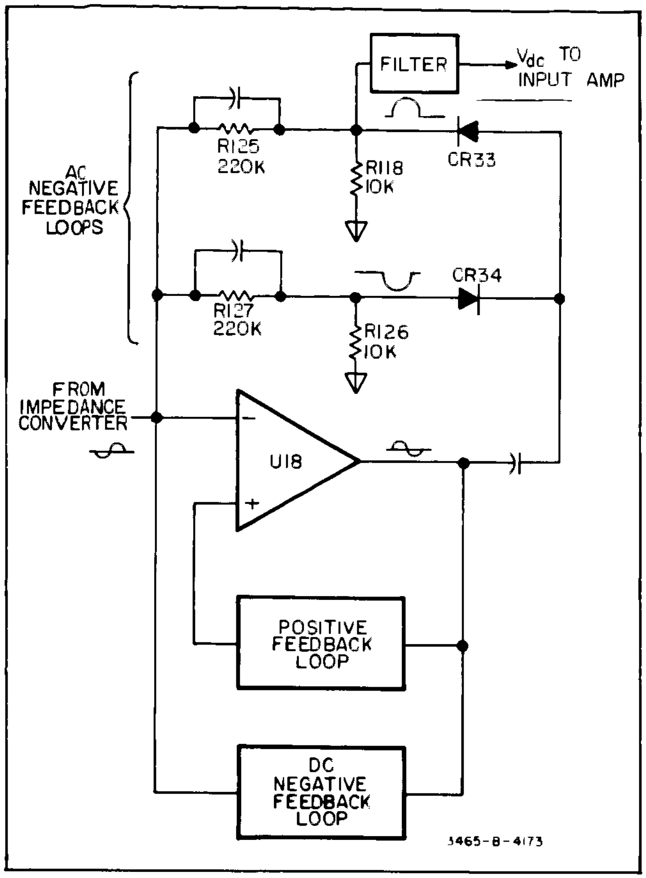


Figure 4-6. Basic Diagram, AC Converter Amplifier.

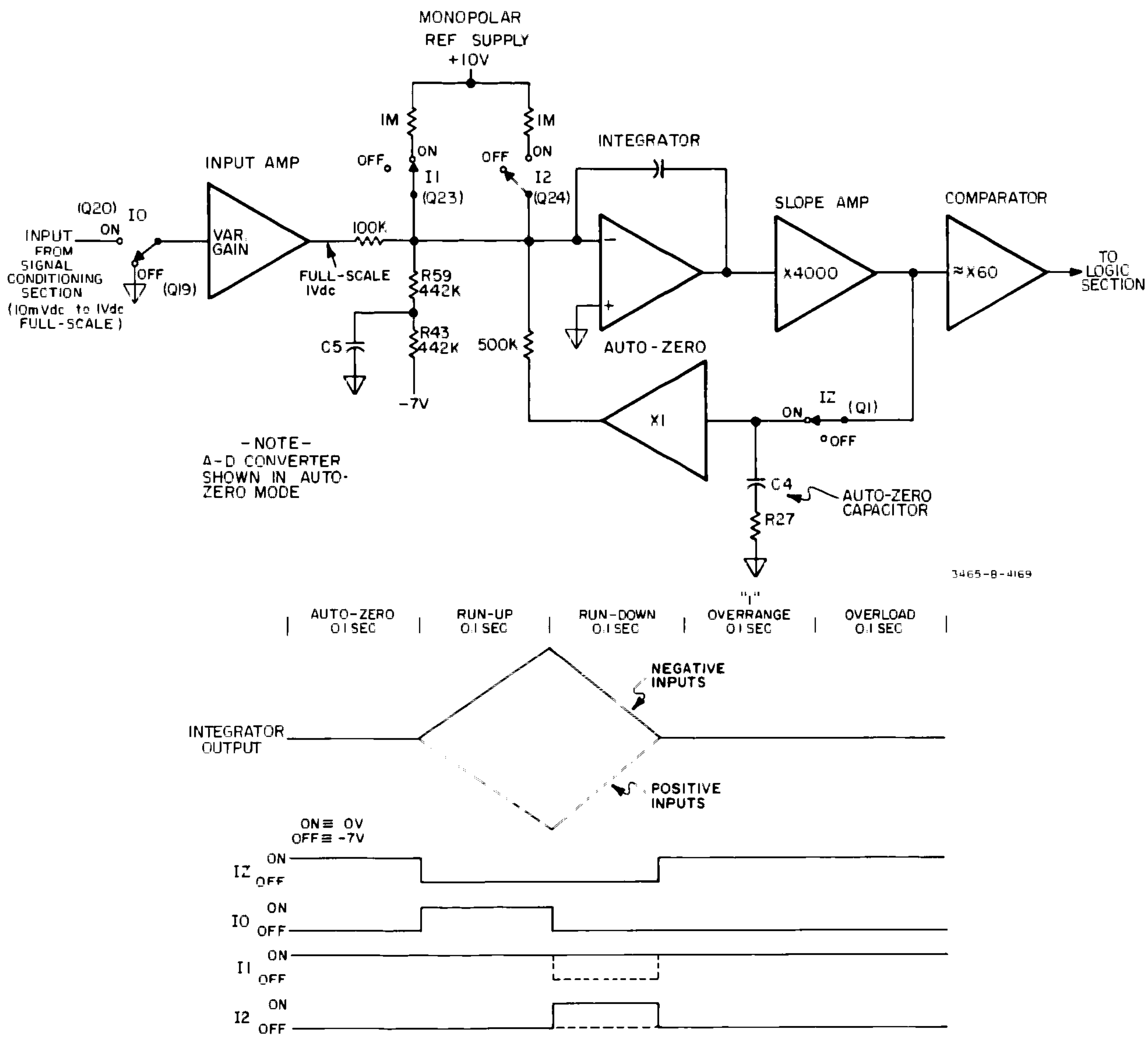
4-54. During switching of the diodes, little negative feedback is present. During the switching transition, the positive feedback loop (C45, R120 and R123) boosts the amplifier gain. This boost in gain speeds the switching transition of the diodes which gives a good frequency response at low signal levels. Once the switching transition has occurred, negative feedback is again present. The negative feedback overrides the effects of the positive feedback loop at all times other than the diode switching transition period.

4-55. The output of the AC–to–DC converter is derived from the positive half-cycle, negative feedback loop. The positive half-cycle developed across the load resistor R118 is the half-wave rectified signal of the ac converter amplifier output. This rectified signal is filtered to provide the dc output that is applied to the input amplifier during the run-up interval of the measurement sequence. For full-scale inputs, the AC–to–DC converter output is 0.8 V dc. This output is kept relatively free of the dc offset present on the negative port of U18 (pin 2) by the voltage divider R125 and R118. The portion of the offset appearing across the load resistor R118 is attenuated by a factor of 23.

4-56. A–D Conversion Using a Monopolar Reference.

4-57. Before preceeding with this discussion, review the

A–D converter description of the integrator, slope amplifier and auto-zero circuit in the simplified theory. Figure 4-7, Functional Diagram, A–D Converter, illustrates these circuits in relation to the monopolar reference supply, the input amplifier and the comparator. It also illustrates the integrator output and the four control state signals, IZ, IO, I1 and I2, with respect to the measurement sequence intervals.



MEASUREMENT INTERVAL	INPUT SIGNAL POLARITY	STATE OF CURRENT SWITCH	
		I1	I2
AUTO-ZERO	+	CLOSED	OPEN
	-	CLOSED	OPEN
RUN-UP	+	CLOSED	OPEN
	-	CLOSED	OPEN
RUN-DOWN	+	OPEN	OPEN
	-	CLOSED	CLOSED

Figure 4-7. Functional Diagram, A–D Converter.

4-58. The A–D converter of Figure 4-7 is shown in the auto-zero mode. The input amplifier is grounded at the input, control state switch I1 is closed, I2 is open and the auto-zero loop is closed. Note that the auto-zero loop does not include the input amplifier but is connected to the integrator summing junction (integrator inverting input). Also connected to the summing junction are the input amplifier output, two current paths from the monopolar reference supply and the - 7 V supply through R59 and R43.

4-59. The auto-zero loop uses a current balancing technique at the integrator summing junction to establish the reference. The basic principle is that the algebraic sum of currents at the integrator summing junction must be equal to zero. When the sum is zero, the output of the integrator will not change. If the sum is not zero, the integrator will ramp up for a negative current or ramp down for a positive current because of the inverting input.

4-60 When the auto-zero loop is closed, the currents summed at the integrator summing junction come from four sources; 1) the output of the input amplifier with its input grounded, 2) one current path of the monopolar reference supply (switch I1 closed), 3) the - 7 V supply through R43 and R59 and 4) the auto-zero loop. The input amplifier output is the analog offset of this amplifier. The current due to the - 7 V supply is roughly the negative of the current from the monopolar reference supply. The auto-zero loop then stores a voltage on the auto-zero capacitor that produces a current through R28 and R42 of the correct magnitude to force the summation of currents at the integrator summing junction to zero. Forcing the summation of currents to zero compensates for the analog offset of the input amplifier and integrator

4-61. During the run-up interval, the auto-zero loop is opened by control state switch IZ. The voltage stored on the auto-zero capacitor is still applied to the integrator summing junction and the summation of currents remains zero. At the time the auto-zero loop is opened, the output of the signal conditioning section is switched to the input amplifier by control state signal IO. The output of the input amplifier causes the algebraic summation of currents at the integrator summing junction to deviate from zero This causes the integrator to run-up

4-62. At the end of the run-up interval, the input amplifier is switched back to ground by control state signal IO. The summation of currents at the integrator summing junction is again zero and if no other action were taken, the integrator output would not change. The integrator output is positive at the end of run-up for negative inputs and negative for positive inputs. At the end of the run-up interval, the polarity of the integrator output is determined by the logic section. This also identifies the polarity of the input signal

4-63. At the beginning of the run-down interval, the logic section selects the appropriate reference to return the integrator output to zero. Run-down uses the summation of currents principle at the summing junction of the integrator. The two current paths (I1 and I2) of the monopolar reference supply provide the means of changing the summation of the currents. The summation of currents at the summing junction can be made negative by opening switch I1 and removing this current flow to the junction. The summation can be made positive by closing switch I2 in addition to I1, and providing twice the current from the monopolar reference supply Opening switch I1 with I2 open, runs the integrator up which is required for positive inputs (see Figure 4-7). Closing I1 and I2 runs the integrator down which is required for negative inputs. The time required for the integrator to reach zero-detect during the run-down interval is proportional to the input voltage which caused run-up and determines the display.

4-64. Data Accumulator.

4-65. Refer to Figure 4-8, Data Accumulator Diagram, for this discussion. The data accumulator processes the logic signals from the logic section and provides the BCD output and the scan signals that determine the dsiplay. The data accumulator consists of a counter, data latches, a multiplexer, digit select decoder and output buffers. At the beginning of the measurement, the reset signal ($\overline{\text{RESET}}$) goes to a logic 0 to initialize the counter and digit select decoder. At the beginning of the run-down interval of the measurement sequence, the counter begins to accumulate a count proportional to the run-down time.

4-66. The counter consists of four divide by 10 circuits. The output of each circuit is a BCD number representing one digit of the input signal. At the end of the run-down interval, the transfer signal ($\overline{\text{TXFR}}$) is set to a logic 0. This stores the counter outputs in the data latches.

4-67 The scan signal will gate each BCD signal from the latches, beginning with the most significant digit first, through the multiplexer to the output. At the same time that the scan gates the digits through the multiplexer, the gating signal is output to the display as a digit activation pulse.

4-68. The BCD output of the multiplexer is applied to the display section (see Figure 7-4). The $\overline{\text{BCD}}$ is applied to quad NAND gates in the display section where the $\overline{\text{BCD}}$ logic is converted to BCD logic. The BCD is applied to the seven segment decoder where it is transformed to a seven bit binary number and applied to each numeral in the display. As the digit activation pulse from the data accumulator sequentially activates each numeral from most significant to least significant, the seven bit binary data will be displayed.

4-69. Display.

4-70. Refer to Figure 7-4 for this discussion. The display segments are powered by a + 3 V supply. This voltage is

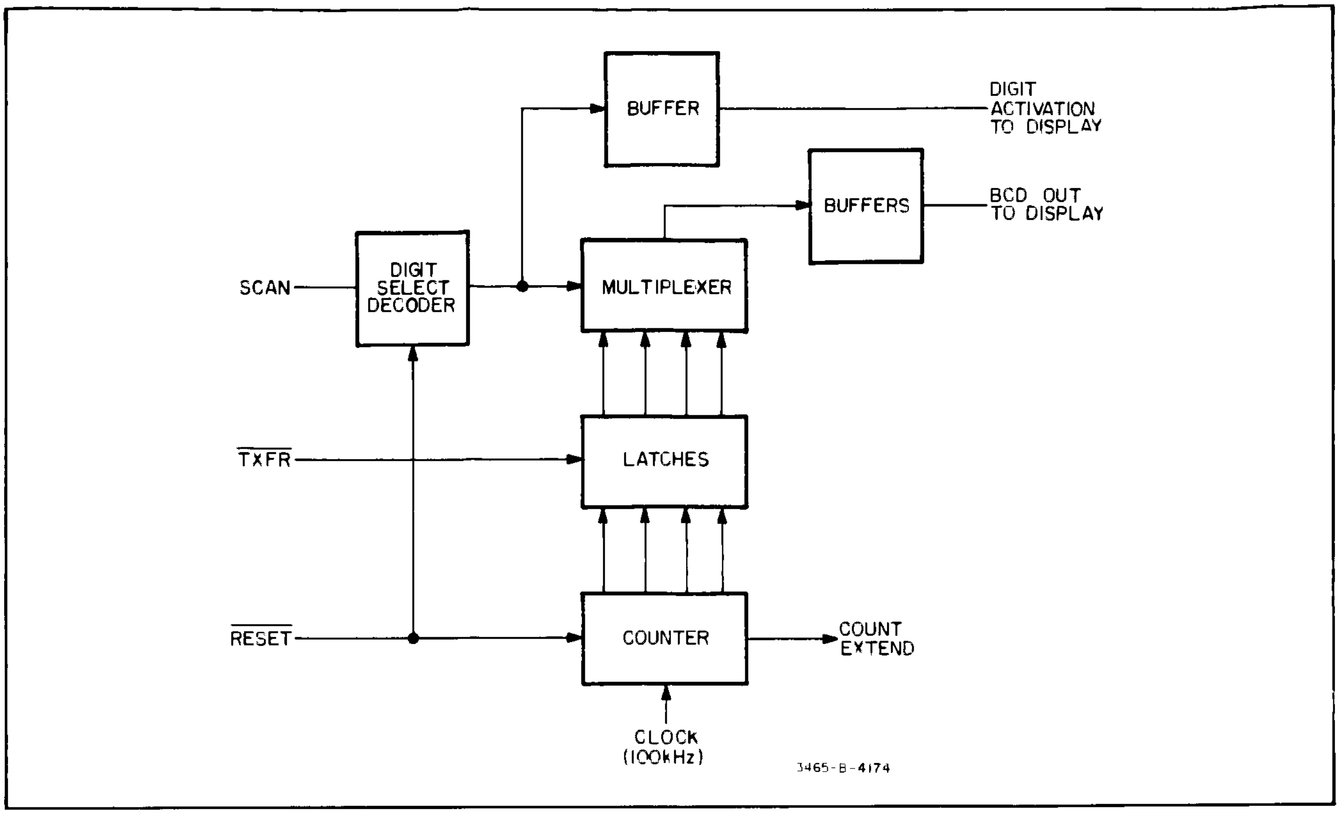


Figure 4-8. Data Accumulator.

derived from VB and the +11 V output of the power supply. A series voltage regulator, Q21, Q22 and Q23 maintains the +3 V output constant. This provides constant display intensity for changes in the magnitude of VB due to battery life and results in low power consumption for a high VB (new or recharged batteries).

4-71. Twenty-five connections interface the display and the main assembly. Table 4-1 indicates each terminal and the source of the signal from the main assembly

Table 4-1. Display Interface Connections.

CONNECTION DESIGNATION	SOURCE OF SIGNAL	
DIGIT STROBES: MSD, 2MSD, 3MSD, LSD BCD: 1, 2, 4, 8	DATA ACCUMULATOR (A1U11)	
DECIMAL POINT: A, B, C, D	RANGE SWITCHES	
$\overline{\text{POLARITY ENABLE}}$: $\overline{\text{PE}}$	FUNCTION SWITCHES	
POLARITY: PL SAMPLE RATE: SR	A1U4	LOGIC SECTION
OVERRANGE: OR OVERLOAD: OL	A1U5	LOGIC SECTION
$\overline{\text{TRANSFER}}$: $\overline{\text{TR}}$	A1U6	LOGIC SECTION
+VB, +11 V, GND, -7 V, -7 V_F and -12 V.	POWER SUPPLY	
PIN 25	NO CONNECTION	

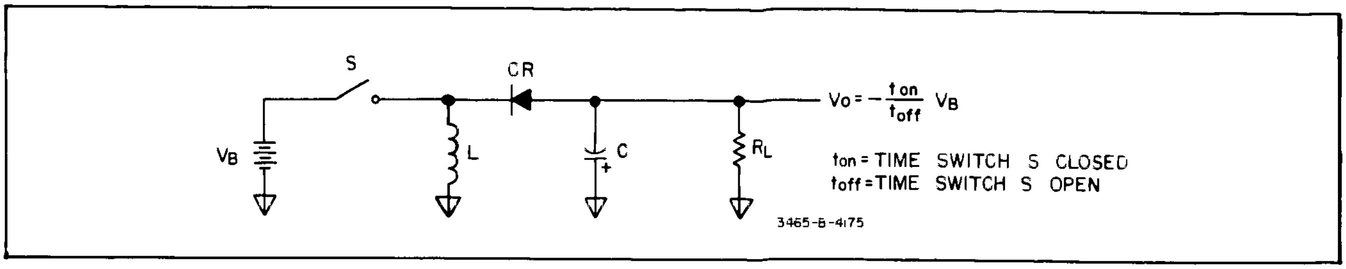


Figure 4-9. Basic Diagram, DC–to–DC Converter.

4-72. Power Supply.

4-73 This paragraph is a description of a simple dc-to-dc converter. Figure 4-9 is a diagram of this converter. When switch S is closed (t_{on}), battery voltage VB is applied to the inductor L. Since the battery voltage is constant, the inductor current increases linearly with time. The inductor current establishes a magnetic field which stores energy transferred from the battery. During t_{on}, C supplies current to the load, R_L. When switch S is opened (t_{off}), the voltage across the inductor inverts and forward biases diode CR. For a constant V_o, the inductor current decreases linearly with time and transfers energy to the capacitor and load resistor, C and R_L. The energy transferred from the battery to the load is controlled by switch S. By controlling switch S the output voltage can be made greater than, equal to or less than the battery voltage VB and can be regulated for changes in the battery voltage (VB) and in the load (R_L). For a steady state condition, the duty-cycle of switch S is

$$\frac{t_{on}}{T} = \frac{|V_o|}{|V_o| + VB}$$

t_{on} = time switch S closed.
T = period of one cycle.

The duty-cycle depends only on the output voltage (V_o) and the battery voltage (VB).

4-74. A simplified diagram of the dc-to-dc converter is shown in Figure 4-10. Refer to this diagram and the converter of Figure 7-5 for this discussion. A negative output is derived from a portion of the energy stored in the primary winding inductance or magnetizing inductance of T1 while the switch, Q33 is on. This output is obtained by the same process described previously for the simple switch-type dc–to–dc converter. A positive output is developed by transformer-coupling a portion of the energy stored in the primary winding inductance through the secondary winding of T1. This output is equal to the turns-ratio times the voltage developed by the primary of T1 across C34 when switch Q33 is off.

4-75. The following paragraphs describe the circuit operation of the dc–to–dc converter. When the battery voltage VB is applied to the circuit, Q33 saturates. A constant voltage is applied across the primary of T1. The collector current determined by the constant battery voltage (VB) and the primary winding inductance, increases linearly with time until Q33 comes out of saturation ($h_{FE}I$) As this occurs, the collector of Q33 begins a negative transition. This transition at pin 1 of transformer T1 causes pin 3 of T1 to begin a positive transition. The positive transition is applied to the base of Q33 by the feedback circuit R81 and C25 and turns Q33 off. As Q33 turns off, the voltage across

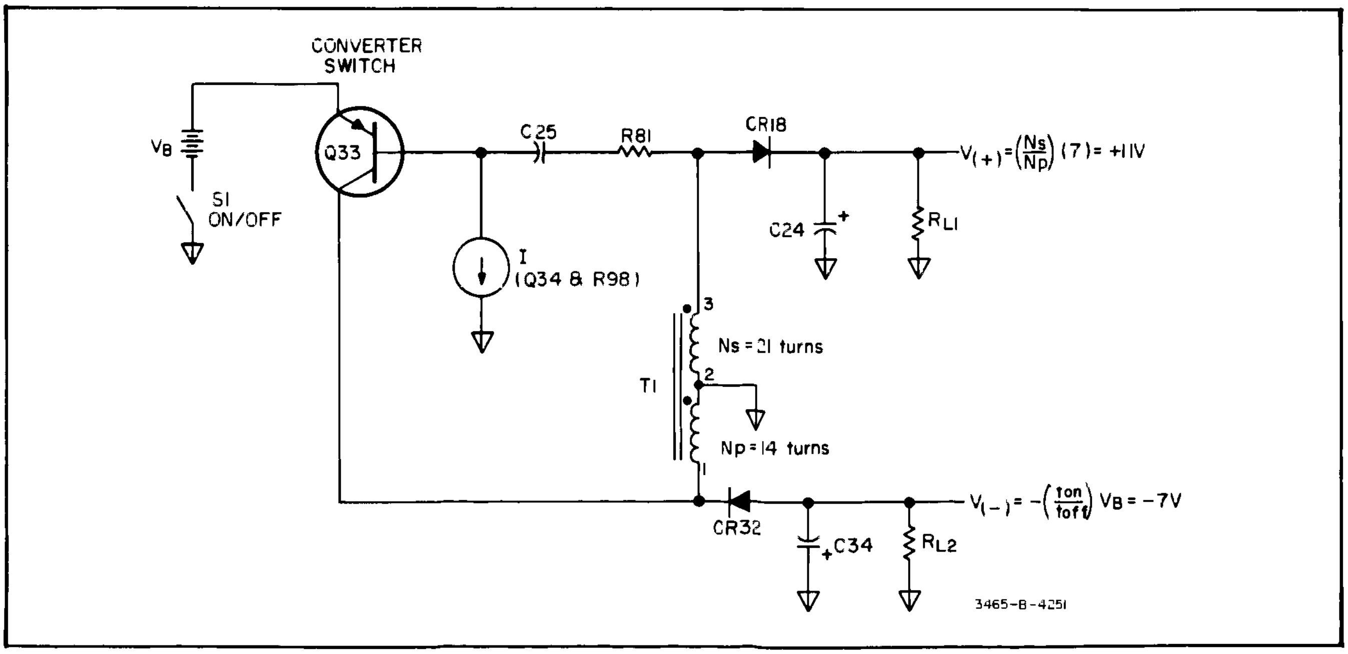


Figure 4-10. Simplified Diagram, DC–to–DC Converter.

the primary and secondary windings of T1 inverts and forward biases CR18 and CR32. The energy stored in the primary winding inductance of T1 is transferred to the output capacitors, C24 and C34, and their loads.

4-76. The cycle ends as Q33 turns on. This results when either the voltage at the base of Q33 decreases to the point that Q33 begins to turn on or the energy stored in transformer T1 goes to zero. Both events cause the collector of Q33 to begin a positive transition. Pin 3 of transformer T1 begins a negative transition at the same time and is applied to the base of Q33 through the feedback circuit of R81 and C25. This action causes Q33 to saturate and the cycle begins again.

4-77. Converter Regulation. Regulation of the dc–to–dc converter is accomplished by controlling the energy transfer to the load. The energy transfer to the load is controlled by the switch. Q33 and the current source I. The magnitude of I is determined by Q34, R98 and the voltage at the base of Q34. The base of Q34 is driven by U17. The inverting input of U17 is connected to ground through R116. A 10–to–7 voltage divider (R117 and R114) is connected to the non-inverting input of U17. One end of the divider (R117) senses the constant voltage of the + 10 V series voltage regulator. The other end of the divider (R114) senses the - 7 V output of the dc–to–dc converter. A change in voltage at the - 7 V output results in an error voltage at the non-inverting input of U17 and is amplified by U17. The output voltage of U17 drives the base of Q34 and regulation of the - 7 V output is achieved. Since the + 11 V output is the transformer turns-ratio times the - 7 V output, this output is also regulated.

4-78. + 10 V Series Voltage Regulation.

4-79. The temperature compensated zener diode CR17 is the voltage reference from which the + 10 V reference is derived. The zener voltage is applied to the non-inverting input of U16. A resistor divider in the precision resistor pack (R75) senses the voltage at the output. A portion of the voltage is fed to the inverting input of U16. This error voltage is amplified by U16 to drive Q26. The collector current of Q26 then provides base drive for the series pass transistor Q27. To ensure turn-on of the dc–to–dc converter, the collector, as opposed to the emitter of the series pass transistor Q27, is connected to the output. The low collector–to–emitter saturation voltage aids in the turn-on process of the converter. This ensures start-up for battery voltages as low as 2 to 3 volts. One advantage to this configuration is that the + 11 V supply can decrease to within the collector–to–emitter saturation voltage of the + 10 V regulated output and regulation is still maintained.

4-80. - 12 V Supply.

4-81. Refer to Figure 7-5. The - 12 V output is developed from the - 7 V supply by use of a voltage doubler circuit driven by the 100 kHz clock generated in the logic section. Transistors Q21 and Q22 prevent loading of the clock.

4-82. Battery Low-Voltage Detection.

4-83. Refer to the power supply schematic, Figure 7-5. The battery low-voltage detection circuit is comprised of a differential amplifier, Q36 and Q37. The voltage at the base of Q36 is set at about + 2.9 V by the voltage divider R139 and R141. If the battery voltage (+VB) is greater than + 2.9 V, Q36 conducts and Q37 is off. When the battery voltage drops below + 2.9 V, Q37 turns on providing base drive for Q38. When Q38 is on, the base of Q34 is pulled to - 7 V and Q34 turns off. This action turns the ac-to-dc converter of the power supply off removing all power supply outputs. This removes the front panel display indication. To reinstate the display, the OFF/ON switch must be turned OFF and again ON. The display indication will reappear while capacitor C51 charges to + 2.9 V. When the voltage on C51 (which is the base voltage of Q36) exceeds the battery voltage (+ VB), the circuit deactivates the power supply as previously described and the display indication disappears again.

WARNING

These servicing instructions are for use by qualified personnel only. To avoid electrical shock, do not perform any servicing other than that contained in the operating instructions unless you are qualified to do so.

Table 5-1. Test Equipment Required.

INSTRUMENT TYPE	REQUIRED CHARACTERISTICS	RECOMMENDED MODEL
Digital Volt/Ohmmeter	DC Volts: 1 V, 10 V and 100 V range Accuracy: ± 0.04% Input Resistance: 10 MΩ Ohms: 200 kΩ Accuracy: ± 0.07%	-hp- 3470 System; -hp- 34702A Multimeter
Digital Voltmeter	DC Volts: 5 digit resolution to 1 μV on 100 mV dc range Accuracy: ± 0.007% AC Volts: 1 V and 10 V range Frequency: 40 Hz to 20 kHz Accuracy: 0.25%	-hp- 3450B
AC Calibrator/ High Voltage Amplifier	Frequency: 20 Hz to 100 kHz Output: 1 mV to 1000 V Accuracy (mid band): ± 0.1%	-hp- 745A/746A
DC Standard	Output: 1 mV to 1000 V Accuracy: ± 0.02%	-hp- 740B
Meter Calibrator	Output: 1 A Accuracy: ± 0.1%	-hp- 6920B
Electronic Counter	Frequency: 50 and 60 Hz Accuracy: ± 0.01%	-hp- 5300A/5302A
Power Supply	Output: 20 V, 1 A	-hp- 6294A
Resistor Decade Box	10 Ω, 100 Ω, 1 kΩ, 10 kΩ, 100 kΩ and 1 MΩ steps Accuracy: ± 0.005%	General Radio Mdl GR 1433-Z
Capacitor	1 μF ± 10%	0160-3407
Resistors	1 Ω ± 0.1% 10 Ω ± 0.1% 1 kΩ ± 0.1% 2 kΩ ± 0.1% 10 kΩ ± 0.1% 20 kΩ ± 0.1% 100 kΩ ± 0.1% 1 MΩ ± 0.1% 10 MΩ ± 0.1% 30 Ω ± 1% 100 Ω ± 1% 1 kΩ ± 1% 22 kΩ ± 1% 66.5 kΩ ± 1% 1 MΩ ± 1%	0811-0615 0698-5452 0698-3491 0698-6612 0698-4157 0698-6943 0698-4158 0698-6369 0698-8194 0757-0388 0698-7320 0727-0751 0757-1087 0698-4503 0698-5049

SECTION V
MAINTENANCE

5-1. INTRODUCTION.

5-2 This section of the manual contains Performance Tests and Adjustment Procedures The Performance Tests are designed to verify the critical specifications listed in Table 1-1. A Performance Test Card is at the end of this section for recording the results of the performance tests.

5-3. Test Equipment Required.

5-4. Equipment required for the performance tests and adjustment procedures is listed in Table 5-1, Recommended Test Equipment. Equipment that satisfies the critical specifications given in the table may be substituted for a recommended model

NOTE

Throughout the Performance Tests and Adjustment Procedures, the -hp- Model 3465A is referred to as Multimeter.

5-5. PERFORMANCE TESTS.

5-6. DC Voltmeter Accuracy Test.

5-7 A DC Standard is required for this test

a. Set the Multimeter function to DCV (⎓ V) and range to 10 m. Short the VΩ and COM terminals together and adjust the display for 0.000, using the ZERO ADJ on the rear panel.

b. Disconnect the short and connect the DC Standard between the VΩ and COM terminals

c. Check all the dc ranges listed in Table 5-2 for the tolerances indicated.

CAUTION

Do not apply more than 1000 V, otherwise damage to the instrument may result.

Table 5-2. DC Voltmeter Accuracy Test.

DC Range	DC Standard Output	Multimeter Display Limits
10 mV	± 0 00100 V ± 0.00500 V ± 0.01000 V	.998 – 1.002 mV 4.996 – 5.004 mV 9.995 – 10.005 mV
100 mV	± 0.01000 V ± 0.05000 V ± 0.10000 V	9.99 – 10.01 mV 49.98 – 50.02 mV 99.97 – 100.03 mV
1 V	± 0.10000 V ± 0 50000 V ± 1.00000 V	.0999 – .1001 V .4998 – .5002 V .9997 – 1.0003 V
10 V	± 1.00000 V ± 5.00000 V ± 10.0000 V	.999 – 1.001 V 4.998 – 5.002 V 9 997 – 10.003 V
100 V	± 10.0000 V ± 50.0000 V ± 100.000 V	9 99 – 10.01 V 49.98 – 50.02 V 99.97 – 100.03 V
1000 V	± 100.000 V ± 500 000 V ± 1000.00 V	99.8 – 100.2 V 499 7 – 500 3 V 999.6 – 1000.4 V

5-8. DC Ammeter Accuracy Test.

5-9. This test requires the use of a power supply, a DC Differential Voltmeter and a precision resistor listed in Table 5-3 (part numbers are given in Table 5-1) or a resistor decade box.

a Connect the Multimeter and test equipment as shown in Figure 5-1.

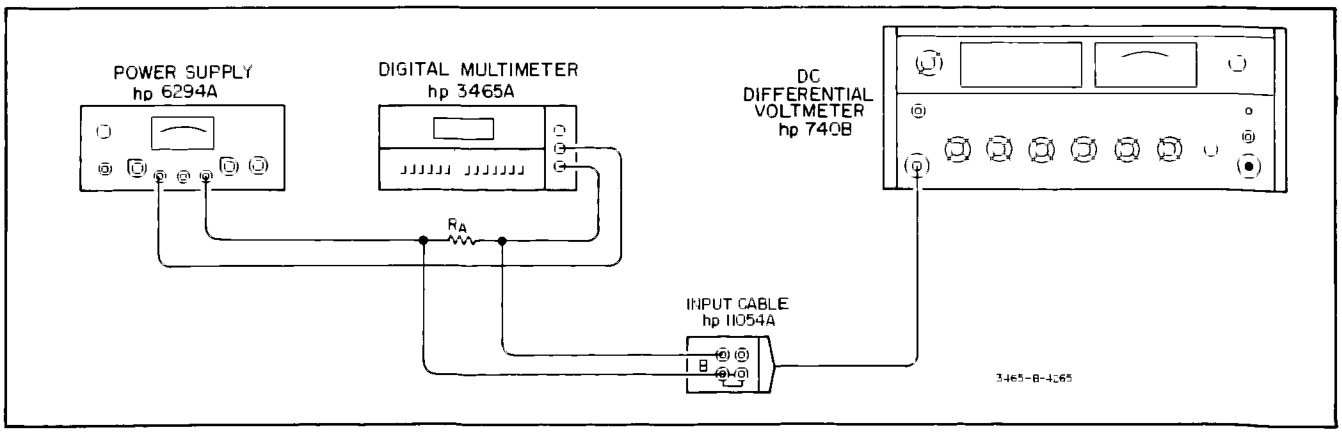


Figure 5-1. DC Ammeter Accuracy Test.

Table 5-3. DC Ammeter Accuracy Test.

Multimeter Range	Current Level	R_A	Differential VM Reading	Multimeter Display Limits
100 μA	10 μA 50 μA 100 μA	100 kΩ ± 0.1%	1.0000 V 5.0000 V 10.000 V	9.98 – 10.02 μA 49.95 – 50.05 μA 99.92 – 100.08 μA
1 mA	.1 mA .5 mA 1 mA	1 kΩ ± 0.1%	.10000 V .50000 V 1.0000 V	.0998 – .1002 mA .4995 – .5005 mA .9992 – 1.0008 mA
10 mA	1 mA 5 mA 10 mA	1 kΩ ± 0.1%	1.0000 V 5.0000 V 10.000 V	.998 – 1.002 mA 4.993 – 5.007 mA 9.988 – 10.012 mA
100 mA	10 mA 50 mA 100 mA	10 Ω 0.1%	.10000 V .5000 V 1.0000 V	9.93 – 10.07 mA 49.69 – 50.31 mA 99.39 – 100.61 mA
1000 mA	100 mA 500 mA 1000 mA	1 Ω 0.1%	.10000 V .50000 V 1.0000 V	99.3 – 100.7 mA 496.9 – 503.1 mA 993.9 – 1006.1 mA

b. Connect the 100 kilohm ± 0.1% resistor in the R_A position as shown.

c. Set the Multimeter function to DCA (⎓ A) and range to 100 μA. Adjust the power supply output for a differential voltmeter reading of 1.000 V. The Multimeter should indicate 99.98 to 100.02 μA.

d. Check all the Multimeter ranges, using the values of R_A and differential voltmeter readings shown in Table 5-3. The Multimeter display should indicate within the limits provided.

5-10. Ohms Accuracy Test.

5-11. A precision resistive decade box will be required for this test. It should be calibrated and have a known accuracy of .005%.

a. Connect the equipment as shown in Figure 5-2.

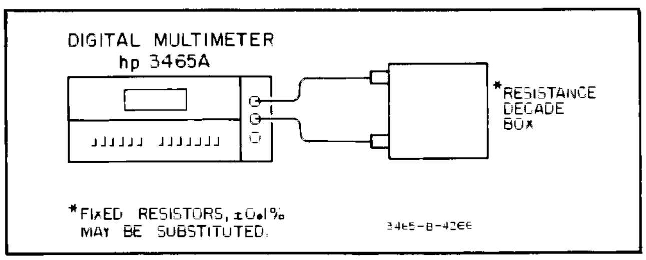


Figure 5-2. Ohms Accuracy Test.

b. Set the Multimeter function to OHMS (Ω) and check all the ranges in Table 5-4 using the decade box to supply the indicated resistances. The Multimeter display should indicate within the limits provided.

5-12. AC Voltage Accuracy Test.

5-13 An AC Calibrator and High Voltage Amplifier will be required for the following tests.

Table 5-4. Ohms Accuracy Test.

Multimeter Range	Resistive Decade Setting	Multimeter Display Limits
100 Ω	10 Ω 50 Ω 100 Ω	9.98 – 10.02 Ω 49.97 – 50.03 Ω 99.96 – 100.04 Ω
1 kΩ	100 Ω 500 Ω 1 kΩ	.0999 – .1001 kΩ .4998 – .5002 kΩ .9997 – 1.0003 kΩ
10 kΩ	1 kΩ 5 kΩ 10 kΩ	.999 – 1.001 kΩ 4.998 – 5.002 kΩ 9.997 – 10.003 kΩ
100 kΩ	10 kΩ 50 kΩ 100 kΩ	9.99 – 10.01 kΩ 49.98 – 50.02 kΩ 99.97 – 100.03 kΩ
1000 kΩ	100 kΩ 500 kΩ 1000 kΩ	99.9 – 100.1 kΩ 499.8 – 500.2 kΩ 999.7 – 1000.3 kΩ
10 M	1 MΩ 5 MΩ 10 MΩ	.998 – 1.002 MΩ 4.994 – 5.006 MΩ 9.989 – 10.011 MΩ

a. Set the Multimeter function to ACV (~V). Connect the AC Calibrator between the VΩ terminal and COM terminal. Be sure to connect the Calibrator sense leads.

b. Check the voltage ranges listed in Table 5-5 at each frequency listed. The Multimeter should indicate within the limits provided.

5-14. AC Ammeter Accuracy Test.

5-15. An AC Calibrator, a 3450B Digital Voltmeter and discrete resistors (R_A) indicated in Table 5-6 are required for this test.

a. Set the Multimeter function to ACA (~ A) and range to 100 μA. Connect the equipment as shown in Figure 5-3 using a discrete resistor for R_A. (To select R_A, note the

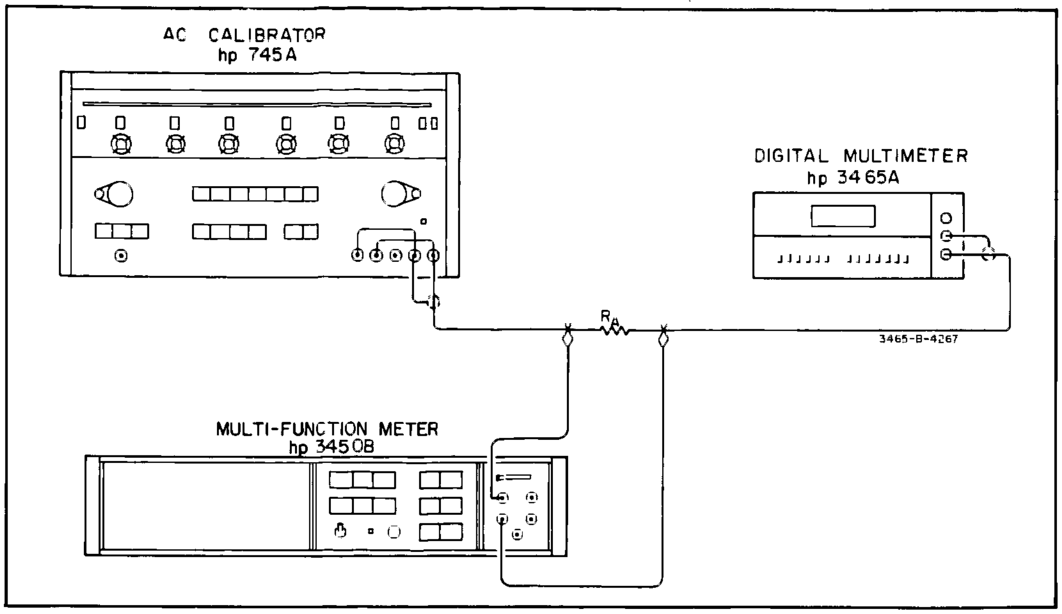


Figure 5-3. AC Ammeter Accuracy Test 100 μA thru 10 mA Range.

Table 5-5. AC Voltage Accuracy Test.

Multimeter Range	AC Standard Output	Test Frequency	Multimeter Display Limits
100 mV	10 mV	40 Hz, 400 Hz, 10 kHz	9.93 – 10.07 mV
	50 mV	40 Hz, 1 kHz, 10 kHz	49.87 – 50.13 mV
	100 mV	40 Hz, 5 kHz, 10 kHz	99 80 – 100 20 mV
	10 mV	11 kHz, 15 kHz, 20 kHz	9.80 – 10.20 mV
	50 mV	11 kHz, 15 kHz, 20 kHz	49.60 – 50.40 mV
	100 mV	11 kHz, 15 kHz, 20 kHz	99.35 – 100.65 mV
1 V	100 mV	40 Hz, 400 Hz, 10 kHz	.0993 – .1007 V
	500 mV	40 Hz, 1 kHz, 10 kHz	.4987 – 5013 V
	1 V	40 Hz, 5 kHz, 10 kHz	.9980 – 1.0020 V
	100 mV	11 kHz, 15 kHz, 20 kHz	.0980 – .1020 V
	500 mV	11 kHz, 15 kHz, 20 kHz	.4960 – .5040 V
	1 V	11 kHz, 15 kHz, 20 kHz	.9960 – 1 0065 V
10 V	1 V	40 Hz, 400 Hz, 10 kHz	993 – 1 007 V
	5 V	40 Hz, 1 kHz, 10 kHz	4.987 – 5.013 V
	10 V	40 Hz, 5 kHz, 10 kHz	9 980 – 10.020 V
	1 V	11 kHz, 15 kHz, 20 kHz	.980 – 1.020 V
	5 V	11 kHz, 15 kHz, 20 kHz	4.960 – 5.040 V
	10 V	11 kHz, 15 kHz, 20 kHz	9.935 – 10.065 V
100 V	10 V	40 Hz, 400 Hz, 10 kHz	9.99 – 10.07 V
	50 V	40 Hz, 1 kHz, 10 kHz	49 87 – 50 13 V
	100 V	40 Hz, 5 kHz, 10 kHz	99.80 – 100.20 V
	10 V	11 kHz, 15 kHz, 20 kHz	9.80 – 10.20 V
	50 V	11 kHz, 15 kHz, 20 kHz	49.60 – 50.40 V
	100 V	11 kHz, 15 kHz, 20 kHz	99.35 – 100.65 V
1000 V	100 V	40 Hz, 400 Hz, 1 kHz	99.3 – 100 7 V
	500 V	40 Hz, 400 Hz, 1 kHz	498.7 – 501.3 V
	100 V	1.5 kHz, 2 kHz	99.0 – 101.0 V
	500 V	1.5 kHz, 2 kHz	497.0 – 503.0 V

value of R_A as directed in Table 5-6 and install the part number indicated in Table 5-1 A resistor decade box *WILL NOT* provide the accuracy required of R_A because of the introduction of wire-wound resistor inductance by the decade box).

b. Set the AC Calibrator frequency to the desired test frequency indicated in Table 5-6.

c. Adjust the AC Calibrator amplitude for a 3450B Digital Voltmeter display as indicated in Table 5-6 for the range and current level being tested.

d *REMOVE* the 3450B Digital Voltmeter from the test setup.

e. Verify the Multimeter Display Limits as indicated in the last column of Table 5-6.

f. Reconnect the 3450B Digital Voltmeter as shown in Figure 5-3.

g Repeat Steps b through f for each frequency of each range and current level listed in Table 5-6 Change R_A as indicated for each current level.

h. To check the 100 mA and 1 A ranges, it is necessary to use an ac current source capable of these current outputs such as the 6920B Meter Calibrator Set the 6920B OUTPUT SWITCH to OFF and replace the AC Calibrator with the 6920B.

i. Set the 6920B FUNCTION switch to AC and RANGE switch to 100 milliamperes. Adjust the digital potentiometer readout control to provide a 10 mA output.

j. Set the OUTPUT SWITCH to ON HOLD. Verify Multimeter Display Limits shown in Table 5-7.

k Return the 6920B OUTPUT SWITCH to OFF before changing ranges Adjust the 6920B for the 100 mA range outputs listed in Table 5-7 and verify the Multimeter Display Limits.

l. Change Multimeter range to 1000 mA and verify Multimeter Display Limit for the 100 mA input.

m With the 6920B OUTPUT switch at OFF, change the 6920B range to 1A Check the Multimeter Display Limits for the 500 mA and 1000 mA inputs indicated in Table 5-7

Table 5-6. AC Ammeter Accuracy Test, 100 μA thru 10 mA Ranges.

Multimeter Range	3450B Digital Voltmeter Display Indication	AC Calibrator Frequency	R_A Value	Current Level	Multimeter Display Limits
100 μA	.99985 to 1.00015	40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	100 kΩ ± .1%	10 μA	9.91 – 10.09 μA 9.92 – 10.08 μA 9.79 – 10.21 μA
		40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	20 kΩ ± .1%	50 μA	49.75 – 50.25 μA 49.82 – 50.18 μA 49.55 – 50.75 μA
		40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	10 kΩ ± 1%	100 μA	99.55 – 100.45 μA 99.70 – 100.30 μA 99.25 – 100.75 μA
1 mA	9.9985 to 10.0015	40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	100 kΩ ± .1%	.1 mA	.0991 – .1009 mA .0992 – .1008 mA .0979 – .1021 mA
		40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	20 kΩ ± .1%	.5 mA	.4975 – .5025 mA .4982 – .5018 mA .4955 – .5045 mA
		40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	10 kΩ ± 1%	1 mA	.9955 – 1.0045 mA .9970 – 1.0030 mA .9925 – 1.0075 mA
10 mA	9.9985 to 10.0015	40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	10 kΩ ± 0.1%	1 mA	.991 – 1.009 mA .992 – 1.008 mA .979 – 1.021 mA
		40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	2 kΩ ± .1%	5 mA	4.975 – 5.025 mA 4.982 – 5.018 mA 4.955 – 5.045 mA
		40 Hz and 400 Hz 1 kHz, 5 kHz, 10 kHz 15 kHz and 20 kHz	1 kΩ ± 1%	10 mA	9.955 – 10.045 mA 9.970 – 10.030 mA 9.925 – 10.075 mA

Table 5-7. AC Ammeter Accuracy Test, 100 mA and 1000 mA Ranges.

Multimeter Range	Output Meter Calibration	Multimeter Display Limits
100 mA	10 mA	9.87 – 10.13 mA
	50 mA	49.55 – 50.45 mA
	100 mA	99.15 – 100.85 mA
1000 mA	100 mA	98.7 – 101.3 mA
	500 mA	495.5 – 504.5 mA
	1000 mA	991.5 – 1008.5 mA

5-16. AC Normal-Mode Rejection Test

5-17. AC normal-mode rejection is the ratio of the peak normal-mode voltage to the resultant error in reading.

$$NMR_{(db)} = 20 \log_{10} \frac{\text{Peak ac superimposed voltage}}{\text{Effect on reading (peak volts)}}$$

An AC Calibrator, an Electronic Counter, a 1 μF capacitor (-hp- Part No. 0160-3407) and a 22 kΩ resistor (-hp- Part No. 0757-1087) are required for this test.

a. Connect the test equipment as shown in Figure 5-4. Do not connect the Multimeter at this time.

b. Using the Electronic Counter as a monitor, adjust the AC Calibrator frequency to 60 Hz ± 0.1%.

c. Set the Multimeter function to DCV (⎓ V) and range to 10 V. Short the Multimeter input and note the indication.

d. Disconnect the short and connect the AC Calibrator to the Multimeter input. Adjust the Calibrator output to 7.07 V rms (10 V peak).

e. The Multimeter indication should not vary more than .007 V from the indication noted in Step C. This verifies a normal-mode rejection of greater than 60 dB.

f. Repeat Steps c, d and e for an AC Calibrator output frequency of 50 Hz ± 0.1% as monitored by the Electronic Counter.

5-18. AC Effective Common-Mode Rejection Test

5-19. An AC Calibrator, an Electronic Counter and a 1 kΩ ± 1% resistor are required for this test.

a. Connect a 1 kΩ resistor between the VΩ and COM terminals.

b. Set the Multimeter function to DCV (⎓ V) and range to 1 V. Note the Multimeter indication.

c. Connect the AC Calibrator to the Multimeter as shown in Figure 5-5.

d. Using the Electronic Counter as a monitor, set the AC Calibrator frequency to 60 Hz ± 0.1% (50 Hz ± 0.1% if operating Multimeter from a 50 Hz source).

e. Adjust the Calibrator output to 7.07 V rms (10 V peak).

f. Note the Multimeter indication. The reading should not vary more than .00001 V from reading noted in Step b verifying an ac common-mode rejection of greater than 120 dB.

5-20. DC Voltmeter Input Resistance Test

5-21. A DC Standard and a 10 MΩ ± 0.1% resistor (-hp- Part No. 0698-8194) are required for this test.

a. Connect the Multimeter, DC Standard and resistor as shown in Figure 5-6.

b. Set the Multimeter function to DCV (⎓ V) and range to 10 V.

c. Connect a jumper across the 10 MΩ resistor and adjust the DC Standard to provide a Multimeter display of +10.000.

d. Remove the jumper from the 10 MΩ resistor. The Multimeter display should indicate 4.950 to 5.027 verifying an input resistance of 10 MΩ ± 1% on the 10 V through 1000 V ranges.

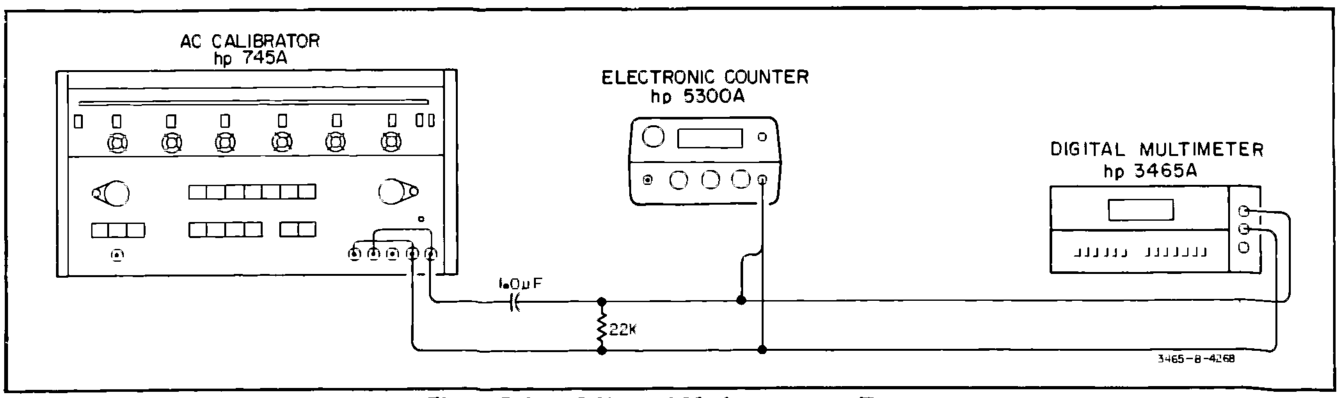


Figure 5-4. AC Normal-Mode Rejection Test

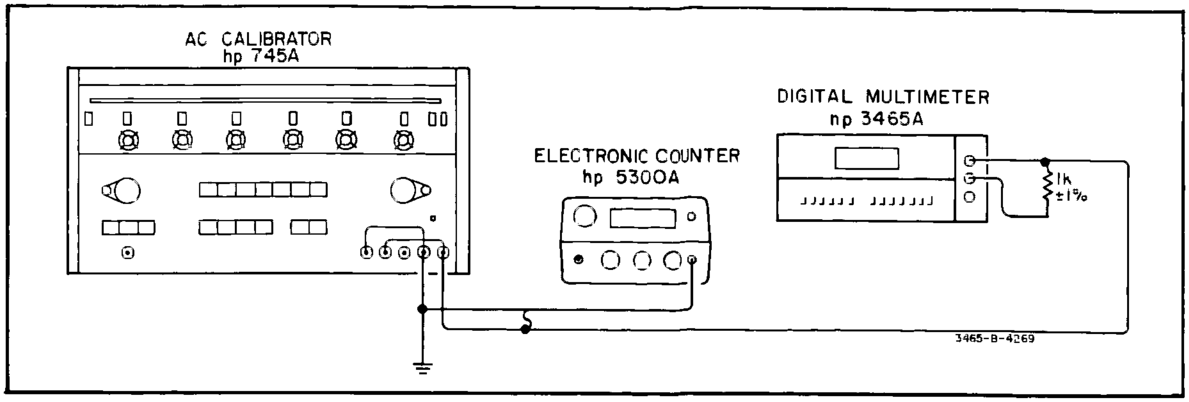


Figure 5-5. AC Effective Common-Mode Rejection Test.

e. Change the DC Standard output to 0 V and change the Multimeter range to 1 V.

f. Connect a jumper across the 10 MΩ resistor and adjust the DC Standard to provide a Multimeter display of + 1.0000.

g. Remove the jumper from the 10 MΩ resistor. The Multimeter display should indicate .9990 or greater verifying an input resistance of ⩾ 10^{10} on the 10 mV through 1 V ranges.

5-22. AC Voltmeter Input Impedance Test

5-23. An AC Calibrator and a 1 MΩ ± 0.1% resistor (-hp- Part No. 0698-6369) are reqired for this test.

a. Connect the AC Calibrator and a 1 MΩ resistor as shown in Figure 5-7. Connect a jumper across the resistor.

b Set the Multimeter function to ACV (~ V) and range to 1 V.

c Set the AC Calibrator frequency to 40 Hz and adjust the output amplitude for a Multimeter display of 1.0000.

d. Remove the jumper from the 1 MΩ resistor. The Multimeter display should indicate .4950 to .5027 verifying an input impedance resistive component of 1 MΩ ± 1%.

e Maintain the AC Calibrator at 40 Hz and adjust the output amplitude for a Multimeter display of 1.0000.

f. Change the AC Calibrator frequency to 3183 Hz. The Multimeter display should indicate .7071 to 1.0000 verifying a shunt capacitance less than 100 pF.

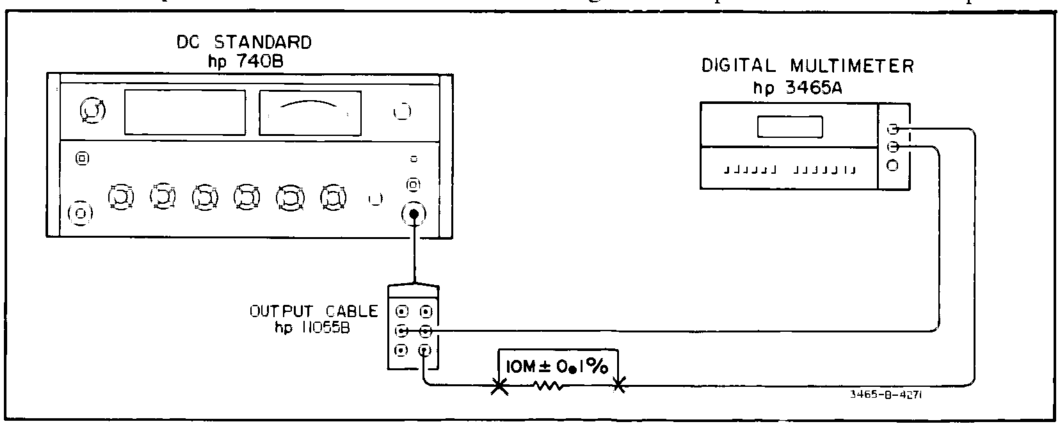


Figure 5-6. DC Voltmeter Input Resistance Test.

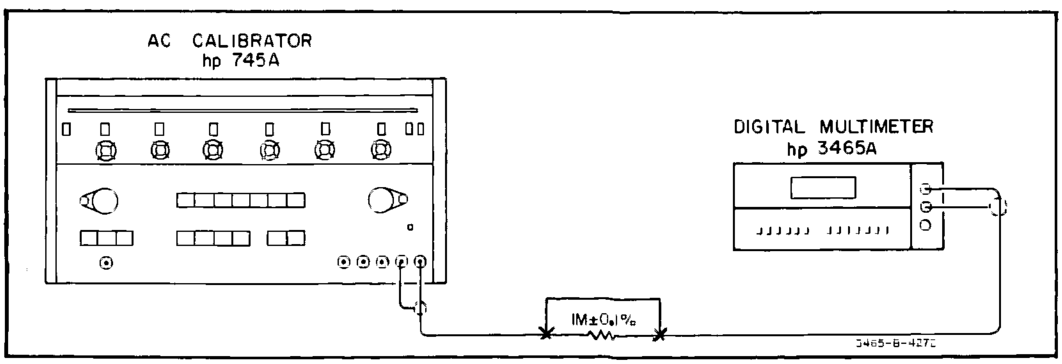


Figure 5-7. AC Voltmeter Input Impedance Test.

ADJUSTMENT PROCEDURES

5-24 ADJUSTMENT PROCEDURES.

WARNING

Adjustment Procedures of Section V are intended for qualified service personnel only. To reduce the possibility of electrical shock, only qualified personnel are to perform maintenance duties.

5-25. The following procedures should be performed only after it has been determined from Performance Tests that the Multimeter does not meet specifications. If any adjustment in these procedures cannot be made, refer to the troubleshooting procedures of Section VII. Location of the Multimeter adjustments is shown in Figure 5-8.

NOTE

After use of a soldering iron, flux remover or freon on the A1 Assembly, allow 10 to 15 minutes for the instrument to thermally stabalize before an adjustment is performed.

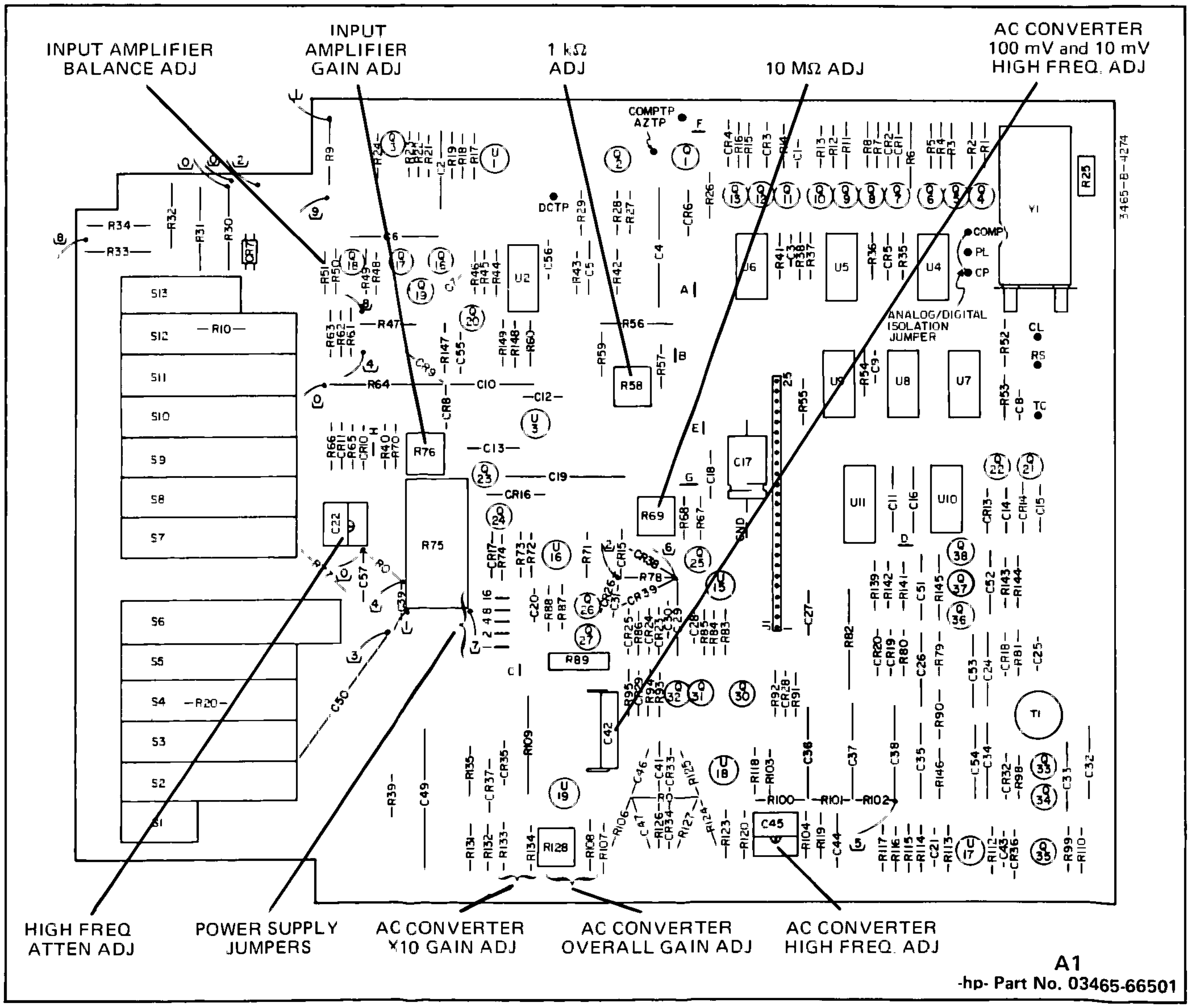


Figure 5-8. Multimeter Adjustment Location.

5-26. Power Supply Adjustment.

5-27. Power Supply + 10 V Reference Voltage Adjustment. Coarse adjustment of the + 10 V reference voltage is made by selecting the proper combination of power supply jumpers designated 1, 2, 4, 8 and 16. Coarse adjustment is necessary whenever the + 10 V reference cannot be adjusted with A1R89 (+ 10 V ADJ - fine adjustment) to obtain a display of 1.0000 for a 1 V dc input. This can occur after replacement of A1CR17, A1R75 or A1U16 or because of the long-term drift of the A1CR17 zener voltage.

5-28. Power supply jumpers 1, 2, 4, 8 and 16 parallel resistors in A1R75 which are used as a regulator feedback network. Removing a jumper decreases the + 10 V reference voltage and results in an increase in the Multimeter display for a given input. Clockwise rotation of the + 10 V ADJ, A1R89 (fine adjustment), also results in an increase in the Multimeter display for a given input.

5-29. A DC Standard is required for this adjustment.

a. Set Multimeter function to DCV (⎓ V) and range to 1 V.

b. Connect A1R75 pin 22 to ground.

c. Apply + 1 V dc from the DC Standard between the VΩ and COM terminals.

d. Note and record the Multimeter display.

e. Refer to Table 5-8, Power Supply Jumpers. Locate the line with LO and HI reading limits that bound the Multimeter display recorded and note the jumper combination. (If reading is out of range of table, check A1CR17 for 6.95 V ± 0.25 V, A1R75 and A1U16).

f. A "0" means to remove jumper; a "1" means leave jumper in place. Introduce the jumper combination noted in Step e.

g. Remove the connection from R75 pin 22 to ground.

h. Adjust A1R89 (+10 V ADJ) for a Multimeter display of + 1.0000 ± 2 counts.

NOTE

If a display of + 1.0000 cannot be attained with A1R89 after installing the proper jumper combination, a new jumper combination must be selected. If the + 1.0000 display is low, install the jumper combination from the line in Table 5-8 preceeding the jumper combination installed. If the + 1.0000 display is high, install the jumper combination from the line in Table 5-8 succeeding the jumper combination installed.

Table 5-8. Power Supply Jumpers.

READING		POWER SUPPLY JUMPER				
LO	HI	16	8	4	2	1
NOTE 1	.8961	0	0	0	0	0
.8962	.8984	0	0	0	0	1
.8985	9008	0	0	0	1	0
.9009	.9032	0	0	0	1	1
.9033	.9057	0	0	1	0	0
.9058	9082	0	0	1	0	1
.9083	.9108	0	0	1	1	0
.9109	.9134	0	0	1	1	1
.9135	.9161	0	1	0	0	0
.9162	.9189	0	1	0	0	1
.9190	9217	0	1	0	1	0
.9218	.9245	0	1	0	1	1
.9246	.9274	0	1	1	0	0
.9275	.9304	0	1	1	0	1
.9305	.9335	0	1	1	1	0
.9336	9366	0	1	1	1	1
.9367	.9397	1	0	0	0	0
.9398	.9430	1	0	0	0	1
.9431	.9463	1	0	0	1	0
.9464	.9497	1	0	0	1	1
.9498	9532	1	0	1	0	0
.9533	.9568	1	0	1	0	1
.9569	.9604	1	0	1	1	0
.9605	9641	1	0	1	1	1
.9642	.9680	1	1	0	0	0
.9681	.9719	1	1	0	0	1
.9720	.9759	1	1	0	1	0
.9760	.9800	1	1	0	1	1
.9801	9843	1	1	1	0	0
.9844	.9886	1	1	1	0	1
.9887	.9930	1	1	1	1	0
.9931	NOTE 2	1	1	1	1	1

"0" = Remove Jumper
"1" = Leave Jumper In Place

NOTE 1. For Readings less than .8922, adjustment cannot be made. Check A1CR17 zener voltage for 6.95 V ± 0.25 V.

NOTE 2. Adjustment cannot be made for readings greater than 1.0000. Check A1CR17 zener voltage for 6.95 V ± 0.25 V.

5-30. Input Amplifier Adjustments.

5-31. Input Amplifier Gain Adjustment (R76). A DC Standard is required for this adjustment.

a. Set the Multimeter function to DCV (⎓ V) and range to 10 m.

b. Connect a short across the input terminals (VΩ and COM) and adjust the Multimeter display for 0.000 with R25 (rear panel ZERO ADJ)

c. Remove the short from the input terminals and apply + 10 mV to the input terminals from the DC Standard.

d. Adjust R76 (INPUT AMP GAIN ADJ) for a Multimeter display of + 10.000 ± 3 counts.

5-32 Input Amplifier Balance Adjustment (R50/R51 potentiometer). The input amplifier balance adjustment must be performed if A1Q16, A1U1 or A1R75 are replaced. A Digital Voltmeter is required for this adjustment.

a. Set Multimeter function to DCV (⎓ V) and range to 1 V.

b. Connect ground to the gate of A1Q16 at the junction of A1C7.

c. Connect the Digital Voltmeter to DCTP.

d. Adjust R50/R51 for a Digital Voltmeter reading at DCTP of less than 1 mV

5-33. Ohms Converter Adjustments (R58 and R69).

5-34. A Digital Voltmeter, a 1 kΩ ± 1% resistor -hp- Part No. 0727-0751 and a 10 MΩ ± 1% resistor, -hp- Part No. 0698-5049 are required for this adjustment.

a. Set Multimeter function to OHMS (Ω) and range to 1K

b. Short the Multimeter input terminals (VΩ and COM).

c. Connect Digital Voltmeter to junction of A1R78 and A1Q25 gate.

d. Adjust A1R69 (10 MΩ ADJ) for a Digital Voltmeter reading of < 0.5 mV.

e. Remove the input short and the Digital Voltmeter.

f. Put a 1 kΩ ± 1% resistor across the input terminals and adjust A1R58 (1 kΩ ADJ) for Multimeter display of 1.0000 ± 2 counts If R58 does not have enough range to achieve this display, cut jumper B to introduce A1R57 and readjust A1R58 for the 1.0000 ± 2 count display.

g. Change Multimeter range to 10 M.

h. Remove the 1 kΩ resistor at the input terminals and apply a 10 MΩ ± 1% resistor across the input terminals. Adjust A1R69 for a display of 10.000 ± 3 counts.

i Remove the 10 MΩ resistor at the input and change range to 1K.

j. Repeat Steps f, g, h and i (1 kΩ ADJ and 10 MΩ ADJ) until both adjustment specifications of Steps f and h are met.

NOTE

If the A1 Assembly switch shield (component side) has been removed, the ac-to-dc converter must be recalibrated by readjusting C45, C42 and C22 with the shield replaced

5-35. AC – DC Converter Adjustments.

5-36. AC Overall Gain Adjustment (R107*, R108* and R128).

NOTE

The selection of a new resistance value of R107 and R108* should be performed* **ONLY if** *the AC Converter amplifier, A1U18, is replaced. If A1U18 has not been replaced, the AC Overall Gain Adjustment can be made by performing Steps a, k, l and m which adjust A1R128 only*

A digital Voltmeter with 5 digit resolution, an Ohmmeter and an AC Standard are required for this adjustment.

a. Set Multimeter function ACV (~ V) and range to 1 V.

b. Remove one end of A1R107 from the pc board and connect A1U2 pin 8 to ground.

c. Apply a 1 V, 200 Hz signal from the AC Standard at the junction of A1R106 and A1R107*

d. Measure and record the dc voltage at DCTP. Designate this reading V_1.

e. Decrease the AC Standard output to 0.1 V, 200 Hz.

f. Measure and record the dc voltage at DCTP. Designate this reading V_2.

g. Calculate the AC Converter constant (CONST):

$$\text{CONST} = \frac{V_1 - V_2}{0.9}$$

h. Disconnect the AC Standard and disconnect one end of R106 from the pc board. Measure and record the actual resistance value of R106.

i. Calculate and record the R107*, R108* resistance total:

$$(\text{R107*} + \text{R108*}) = \text{R106}\,(0.9995 \times \text{CONST} - 1) - 500$$

j. Select a resistance combination for R107* and R108* nearest the (R107* + R108*) calculated value from the R107*, R108*, R133* and R134* Padding List located in the miscellaneous parts list of Section VI. Install the selected resistors.

k. Apply a 1 V, 200 Hz signal from the AC Standard to the Multimeter input terminals.

l Adjust A1R128 (AC GAIN ADJ) for a Multimeter display of 1.0000 ± 12 counts

m. Remove the AC Standard.

5-37. AC–DC Converter X10 Gain Adjustment (R133 and R134).

An AC Standard is required for this adjustment.

a. Set the Multimeter function to ACV (~ V) and range to 100 m.

b. Apply a 100 mV, 200 Hz signal from the AC Standard to the Multimeter input terminals (VΩ and COM).

c. Adjust the R133/R134 potentiometer for a Multimeter display of 100.00 ± 12 counts.

5-38. AC Converter High Frequency Adjustment (C45). An AC Standard is required for this adjustment.

a. Set Multimeter function to ACV (~ V) and range to 1 V.

b. Apply a 0.1 V, 20 kHz signal with the AC Standard to the input terminals.

c. Adjust A1C45 (CONVERTER HIGH FREQ ADJ) for a Multimeter display of .1000 ± 100 counts.

d. Maintain the AC Standard for the following adjustment

5-39. AC Converter 100 mV and 10 V High Frequency Adjustment (C42). An AC Standard is required for this adjustment

a. Set Multimeter function to ACV (~ V) and range to 100 m.

b. Apply a 0.1 V, 20 kHz signal with the AC Standard to the input terminals.

c. Adjust A1C42 (100 mV and 10 V HIGH FREQ ADJ) for a Multimeter display of 100.00 ± 100 counts.

d. Maintain the AC Standard for the following adjustment.

5-40. High Frequency Attenuator Adjustment (C22). An AC Standard is required for this adjustment.

a. Set Multimeter function to ACV (~ V) and range to 10 V

b. Apply a 10 V, 20 kHz signal with the AC Standard to the input terminals.

c. Adjust A1C22 (HIGH FREQ ATTEN ADJ) for a Multimeter display of 10.000 ± 100 counts.

d. Remove AC Standard from input terminals.

PERFORMANCE TEST CARD

Hewlett-Packard Model 3465A
Multimeter
Serial No. ______________

Tests Performed By ______________
Date ____________

PARAGRAPH NUMBER	TEST	TEST LIMIT	TEST RESULT
5-6	DC Voltmeter Accuracy		
	10 mV Range		
	1 mV	998 – 1 002 mV	________
	5 mV	4.996 – 5.004 mV	________
	10 mV	9.995 – 10.005 mV	________
	100 mV Range		
	10 mV	9.99 – 10.01 mV	________
	50 mV	49.98 – 50.02 mV	________
	100 mV	99.97 – 100.03 mV	________
	1 V Range		
	0.1 V	0999 – 1001 V	________
	0.5 V	.4998 – .5002 V	________
	1.0 V	.9997 – 1.0003 V	________
	10 V Range		
	1 V	.999 – 1.001 V	________
	5 V	4.998 – 5.002 V	________
	10 V	9.997 – 10.003 V	________
	100 V Range		
	10 V	9.99 – 10.01 V	________
	50 V	49.98 – 50.02 V	________
	100 V	99.97 – 100.03 V	________
	1000 V Range		
	100 V	99.8 – 100.2 V	________
	500 V	499.7 – 500.3 V	________
	1000 V	999.6 – 1000.4 V	________
5-8	DC Ammeter Accuracy		
	100 µA Range		
	10 µA	9.98 – 10.02 µA	________
	50 µA	49.95 – 50.05 µA	________
	100 µA	99 92 – 100.08 µA	________
	1 mA Range		
	0.1 mA	.0998 – .1002 µA	________
	0.5 mA	.4995 – .5005 µA	________
	1.0 mA	.9992 – 1.0008 µA	________
	10 mA Range		
	1 mA	0.998 – 1.002 mA	________
	5 mA	4.993 – 5.007 mA	________
	10 mA	9.988 – 10.012 mA	________

PERFORMANCE TEST CARD (cont'd)

PARAGRAPH NUMBER	TEST	TEST LIMIT	TEST RESULT
5-8	100 mA Range		
(cont'd)	10 mA	09.93 – 10.07 mA	________
	50 mA	49.69 – 50.31 mA	________
	100 mA	99.39 – 100.61 mA	________
	1000 mA Range		
	100 mA	099.3 – 100.7 mA	________
	500 mA	496.9 – 503.1 mA	________
	1000 mA	993.9 – 1006.1 mA	________
5-10	Ohms Accuracy		
	100 Ω Range		
	10 Ω	09.98 – 010.02 Ω	________
	50 Ω	49.97 – 50.03 Ω	________
	100 Ω	99.96 – 100.04 Ω	________
	1 kΩ Range		
	0.1 kΩ	.0999 – .1001 kΩ	________
	0.5 kΩ	.4998 – .5002 kΩ	________
	1 kΩ	.9997 – 1.0003 kΩ	________
	10 kΩ Range		
	1 kΩ	.999 – 1.001 kΩ	________
	5 kΩ	4.998 – 5.002 kΩ	________
	10 kΩ	9.997 – 10.003 kΩ	________
	100 kΩ Range		
	10 kΩ	9.99 – 10.01 kΩ	________
	50 kΩ	49.98 – 50.02 kΩ	________
	100 kΩ	99.97 – 100.03 kΩ	________
	1000 kΩ Range		
	100 kΩ	99.9 – 100.1 kΩ	________
	500 kΩ	499.8 – 500.2 kΩ	________
	1000 kΩ	999.7 – 1000.3 kΩ	________
	10 MΩ Range		
	1 MΩ	0.998 – 1.002 MΩ	________
	5 MΩ	4.994 – 5.006 MΩ	________
	10 MΩ	9.989 – 10.011 MΩ	________

PERFORMANCE TEST CARD (cont'd)

PARAGRAPH NUMBER	TEST	TEST LIMIT	TEST RESULT
5-12	AC Voltage Accuracy		
	100 mV Range		
	40 Hz to 10 kHz		
	10 mV	9.93 – 10.07 mV	________
	50 mV	49.87 – 50.13 mV	________
	100 mV	99.80 – 100.20 mV	________
	10 kHz – 20 kHz		
	10 mV	9.80 – 10.20 mV	________
	50 mV	49.60 – 50.40 mV	________
	100 mV	99.35 – 100.65 mV	________
	1 V Range		
	40 Hz – 10 kHz		
	0.1 V	.0993 – .1007 V	________
	0.5 V	.4987 – .5013 V	________
	1.0 V	.9980 – 1.0020 V	________
	10 kHz – 20 kHz		
	0.1 V	.0980 – .1020 V	________
	0.5 V	.4960 – .5040 V	________
	1.0 V	.9935 – 1.0065 V	________
	10 V Range		
	40 Hz – 10 kHz		
	1 V	.993 – 1.007 V	________
	5 V	4.987 – 5.013 V	________
	10 V	9.980 – 10.020 V	________
	10 kHz – 20 kHz		
	1 V	.980 – 1.020 V	________
	5 V	4.960 – 5.040 V	________
	10 V	9.935 – 10.065 V	________
	100 V Range		
	40 Hz – 10 kHz		
	10 V	9.93 – 10.07 V	________
	50 V	49.87 – 50.13 V	________
	100 V	99.80 – 100.20 V	________
	10 kHz – 20 kHz		
	10 V	9.80 – 10.20 V	________
	50 V	49.60 – 50.40 V	________
	100 V	99.35 – 100.65 V	________
	1000 V Range		
	40 Hz – 1 kHz		
	100 V	99.3 – 100.7 V	________
	500 V	498.7 – 501.3 V	________
	1 kHz – 2 kHz		
	100 V	99.0 – 101.0 V	________
	500 V	497.0 – 503.0 V	________

PERFORMANCE TEST CARD (cont'd)

PARAGRAPH NUMBER	TEST	TEST LIMIT	TEST RESULT
5-14	AC Ammeter Accuracy		
	100 μA Range		
	10 μA		
	40 Hz – 1 kHz	9.91 – 10.09 μA	________
	1 kHz – 10 kHz	9.92 – 10.08 μA	________
	10 kHz – 20 kHz	9.79 – 10.21 μA	________
	50 μA		
	40 Hz – 1 kHz	49.75 – 50.25 μA	________
	1 kHz – 10 kHz	49.82 – 50.18 μA	________
	10 kHz – 20 kHz	49.55 – 50.45 μA	________
	100 μA		
	40 Hz – 1 kHz	99.55 – 100.45 μA	________
	1 kHz – 10 kHz	99.70 – 100.30 μA	________
	10 kHz – 20 kHz	99.25 – 100.75 μA	________
	1 mA Range		
	0.1 mA		
	40 Hz – 1 kHz	.0991 – .1009 mA	________
	1 kHz – 10 kHz	.0992 – .1008 mA	________
	10 kHz – 20 kHz	.0979 – .1021 mA	________
	0.5 mA		
	40 Hz – 1 kHz	4975 – .5025 mA	________
	1 kHz – 10 kHz	4982 – 5018 mA	________
	10 kHz – 20 kHz	4955 – 5045 mA	________
	1.0 mA		
	40 Hz – 1 kHz	.9955 – 1.0045 mA	________
	1 kHz – 10 kHz	.9970 – 1.0030 mA	________
	10 kHz – 20 kHz	9925 – 1.0075 mA	________
	10 mA Range		
	1 mA		
	40 Hz – 1 kHz	991 – 1.009 mA	________
	1 kHz – 10 kHz	.992 – 1.008 mA	________
	10 kHz – 20 kHz	.979 – 1.021 mA	________
	5 mA		
	40 Hz – 1 kHz	4.975 – 5.025 mA	________
	1 kHz – 10 kHz	4.982 – 5.018 mA	________
	10 kHz – 20 kHz	4.955 – 5.045 mA	________
	10 mA		
	40 Hz – 1 kHz	9.955 – 10.045 mA	________
	1 kHz – 10 kHz	9.970 – 10.030 mA	________
	10 kHz – 20 kHz	9.925 – 10.075 mA	________
	100 mA Range		
	10 mA	9.87 – 10.13 mA	________

PERFORMANCE TEST CARD (cont'd)

PARAGRAPH NUMBER	TEST	TEST LIMIT	TEST RESULT
5-14 (cont'd)	50 mA	49 55 – 50 45 mA	________
	100 mA	99.15 – 100.85 mA	________
	1000 mA Range		
	100 mA	98 7 – 101 3 mA	________
	500 mA	495.5 – 504.5 mA	________
	1000 mA	991 5 – 1008 5 mA	________
5-15	Normal Mode Rejection	< .007 V (60 dB)	________
5-17	Common Mode Rejection	< 00001 V (120 dB)	________
5-20	DC Input Resistance		
	10 V – 1000 V Range	4 950 – 5 027 (10 M)	________
	10 mV – 1 V Range	≥ 9990 (10^{10} ohms)	________
5-22	Input Impedance		
	Resistive component	.4950 – .5027	________
	Shunt capacitance	.7071 – 1.0000	________