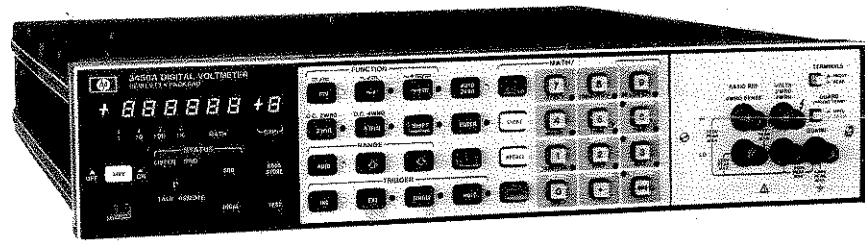# DIGITAL VOLTMETER

3456A

HEWLETT
PACKARD

HEWLETT PACKARD

OPERATING MANUAL

MODEL 3456A
DIGITAL VOLTMETER

SERIAL NUMBERS

This manual applies directly to instruments with a serial number prefix of 2201.

Instruments with a prefix of 2015, and serial numbers 2015A04595 and below, refer to Section VII (Manual Changes) of this manual. For information on instruments with a prefix other than listed in Section VII and on the title page, refer to the manual change sheet.

NOTICE

This Manual is a duplication of Sections I through III of your Operating and Service Manual

Keep with Instrument

WARNING

To help minimize the possibility of electrical fire or shock hazards, do not expose this instrument to rain or excessive mositure.

Manual Part No. 03456-90006

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CERTIFICATION

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

WARRANTY

This Hewlett-Packard instrument product is warranted against defects in materials and workmanship for a period of one year from date of shipment [,except that in the case of certain components listed in Section I of this manual, the warranty shall be for the specified period]. During the warranty period, Hewlett-Packard Company will, at its option, either repair or replace products which prove to be defective.

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

Duration and conditions of warranty for this instrument may be superceded when the instrument is integrated into (becomes a part of) other -hp- instrument products.

Hewlett-Packard warrants that its software and firmware designated by -hp- for use with an instrument will execute its programming instructions when properly installed on that instrument. Hewlett-Packard does not warrant that the operation of the instrument, or software, or firmware will be uninterrupted or error free.

LIMITATION OF WARRANTY

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

NO OTHER WARRANTY IS EXPRESSED OR IMPLIED. HEWLETT-PACKARD SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

EXCLUSIVE REMEDIES

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

ASSISTANCE

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

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

▉hp▉ MANUAL CHANGES

-hp- MODEL 3456A

DIGITAL VOLTMETER

Manual Part No. 03456-90006

ERRATA

Page 1-1. Paragraph 1-15. Change the 3456A options to the following:

Option 050: for 50Hz Power Source
Option 060: for 60Hz Power Source
Option 907: Front Handle Kit
Option 908: Rack Mount Kit
Option 909: Front Handle and Rack Mounting Kit
Option 910: Additional Set of Manuals

Page 1-1. Paragraph 1-17: Change the fuse rating in the paragraph from "3/8" amp to 1/4 amp.

Page 1-2. Table 1-1. Change the sentence under "Filter On" to the following:

Rejection is >60dB at 50Hz. Add 2μV for 0.1V, 1.0V, and 100V ranges and 200μV for 10V and 1000V ranges.

Page 1-3. Table 1-1. Change the "<75pF" Input Impedance in the "Input Characteristics" table under AC RMS VOLTAGE to "<90pF".

Page 1-7. Table 1-1. Under THERMISTOR (°C) change the information as follows:

THERMISTOR (°C): Converts resistance of thermistor -hp- Part No. 0837-0164 to temperature in °C.

Output range: -80 to 150 °C
   Accuracy: -75 <=T <= +130 °C: ±.06 °C max.
                -80 <=T <= +150 °C: ±.15 °C max.

Page 1-8. Table 1-1. Change the information under "Power" to the following:

Power: 100/120/220/240V +5%, -10% 48Hz to 400Hz 45VA max.

Page 2-1. Table 2-1. Change all fuse and current values in the table from "750mA" and "375mA" to "500mA" and "250mA", respectively.

Page 3-3. Figure 3-1. Change the fuse rating in step 29 in Figure 3-1 from ".75A" and "500mA" to "500mA" and ".375A" to "250mA".

Page 3-27. Add the following note after paragraph 3-194.

NOTE

The "SW0" and "SW1" codes are only used to determine in which position the Front/Rear switch is in. They are NOT used to set the switch to a certain position.

Page A-6. Figure A-8. Change the "REN" line in the table from "T" to "F".

CHANGE NUMBER 1. Applies to all Serial Numbers.

Table 1-1. Add the information in Table C-1 to the end of Table 1-1. Specifications.

Table C-1. Specification Table Additions

SUPPLEMENTAL SPECIFICATIONS

3456A TRANSFER SPECIFICATIONS

Transfer Accuracy Constraints:

The measurments are the average of 100 readings at 10 PLC (Power Line Cycles).
Auto-Zero is on.
Measurements are made on the same range.
The same terminals are used for each measurement.
The 3456A has been warmed up at least 2 hours.
In general, the measurements must be made in accordance with good metrology practices. It is suggested to use pure copper wire, low thermal solder, twisted pair wire, and guarded measurements.

DC VOLTS

Transfer Accuracy: ± Number of Counts

1 Hour: ±0.5 degrees C.

Range	6 1/2 Digits (10 PLC)
0.1V	6 counts
1.0V	2 counts
10.0V	2 counts
100.0V	3 counts

24 Hours: ±1 degree C.

Range	6 1/2 Digits (10 PLC)
0.1V	8 counts
1.0V	4 counts
10.0V	4 counts
100.0V	3 counts

Resistance:

Transfer Accuracy: ± Number of Counts. All measurements are made with 4-wire ohms offset compensation.

1 Hour: ±0.5 degrees C.

Range	6 1/2 Digits (10 PLC)
100 ohms	5 counts
1K ohms	3 counts
10K ohms	3 counts
100K ohms	4 counts

24 Hours: ±1 degree C.

Range	6 1/2 Digits (10 PLC)
100 ohms	7 counts
1K ohms	5 counts
10K ohms	5 counts
100K ohms	6 counts

AC Volts:

Transfer Accuracy: dc component <10% of ac component.
Maximum voltage ≤500Vrms. All measurements made with Filter On. Input voltage >1% of full scale.

1 Hour: ±0.5 degrees C.

Frequency	6 1/2 Digits (10 PLC)
30Hz - 20KHz	190 counts
20KHz - 50KHz	240 counts
50KHz - 100KHz	270 counts

24 Hours: ±1 degree C.

Frequency	6 1/2 Digits (10 PLC)
30Hz - 20KHz	220 counts
20KHz - 50KHz	285 counts
50KHz - 100KHz	310 counts

Table C-1. Specification Table Additions (Cont'd)

SUPPLEMENTAL SPECIFICATIONS

AC Volts:

3456A TRANSFER SPECIFICATIONS

For input voltages 1mV to 10mV:

1 Hour: ±0.5degrees C.

Frequency	6 1/2 Digits (10 PLC)
30Hz - 20KHz	205 counts
20KHz - 50KHz	255 counts
50KHz - 100KHz	285 counts

24 Hours: 1 degree C.

Frequency	6 1/2 Digits (10 PLC)
30Hz - 20KHz	250 counts
20KHz - 50KHz	315 counts
50KHz - 100KHz	340 counts

LOW LEVEL AND LOW FREQUENCY
AC SPECIFICATIONS

Low Frequency Measurements Accuracy: ±(1% of Reading + Number of Counts). 10Hz to 20K Hz, Filter On, Auto-Zero On, >1% of full scale, dc component <10% of ac component. For inputs ≥500Vrms add 0.07% of reading to the specifications.

24 Hours: 23 degrees C ±1 degree C for all ranges.

6 1/2 Digit (≥1 PLC)	.45 + 390
5 1/2 Digit (0.1 PLC)	.46 + 54
4 1/2 Digit (0.01 PLC)	.51 + 6

90 days: 23 degrees C ±5 degrees C.

6 1/2 Digit (≥1 PLC)	.47 + 520
5 1/2 Digit (0.1 PLC)	.48 + 90
4 1/2 Digit (0.01 PLC)	.56 + 10

>90 Days: 23 degrees C ±5 degrees C (5 1/2 Digit)

Add ±(0.004% of Reading + 12 counts)/Month to 90 day accuracy. For 6 1/2 Digits, multiply counts by 10. for 4 1/2 Digits, multiply by 0.1.

24 Hours: 23 degrees C ±1 degree C.

Integration Time in Power Line Cycles (PLC)	Frequency in Hz					
	Filter Off		400 to 20K	20K to 50K	50K to 100K	100K to 250K
	10 to 20	20 to 30	30 to 20K	20K to 50K	50K to 100K	100K to 250K
6 1/2 Digits (> = 1 PLC)	.45 + 490	.33 + 400	.05 + 650	.15 + 1600	.53 + 2800	5.0 + 6400
5 1/2 Digits (0.1 PLC)	.46 + 66	.34 + 45	.06 + 67	.16 + 162	.54 + 282	5.0 + 665
4 1/2 Digits (0.01 PLC)	.51 + 9	.39 + 8	.11 + 10	.21 + 20	.59 + 32	5.1 + 68

90 Days: 23 degrees C ±5 degrees C.

Integration Time in Power Line Cycles (PLC)	Frequency in Hz					
	Filter Off		400 to 20K	20K to 50K	50K to 100K	100K to 250K
	10 to 20	20 to 30	30 to 20K	20K to 50K	50K to 100K	100K to 250K
6 1/2 Digits (> = 1 PLC)	.47 + 1020	.35 + 600	.07 + 1200	.17 + 2200	.55 + 3400	5.0 + 7000
5 1/2 Digits (0.1 PLC)	.48 + 142	.36 + 65	.08 + 125	.18 + 225	.56 + 340	5.0 + 705
4 1/2 Digits (0.01 PLC)	.56 + 15	.41 + 10	.13 + 14	.23 + 24	.61 + 36	5.1 + 72

>23 degrees C ±5 degrees C (5 1/2 Digit)

Add ±(0.004% of Reading + 12 counts)/Month to 90 day accuracy. For 6 1/2 Digits, multiply counts by 10. for 4 1/2 Digits, multiply by 0.1.

Temperature Coefficient: (% of Reading + Number of Counts)/degree C (5 1/2 Digits).
±(.008 + 15)/degrees C for dc component <10% ac component. Otherwise add ±(.008 + 20)/degrees C. For 6 1/2 Digit, multiply counts by 10. For 4 1/2 Digit, multiply counts by 0.1.

CHANGE NO. 2. Applies to Serial Prefix 2512 and Above

Title Page. Add the following note to the title page.

〔CAUTION〕

Your instrument may have either metric or english hardware. DO NOT intermix the different hardware or damage to the instrument may result. Follow the cautions in the manual that pertain to the different hardware. Contact your local HP Office if more information is needed.

Section I, Paragraph 1-15. Change the paragraph to the following:

1-15. The following options are available for use with the HP 3456A.

   Option 350: for 50 Hz Power Source
   Option 360: for 60 Hz Power Source
   Option 907: Front Handle Kit
      (For Serial Prefix 2201 and below, use HP P/N 5061-0088.
      For Serial Prefix 2512 and above, use HP P/N 5061-9688)
   Option 908: Rack Mounting Kit
      (For Serial Prefix 2201 and below, use HP P/N 5061-0074.
      For Serial Prefix 2512 and above, use HP P/N 5061-9674)
   Option 909: Front Handle and Rack Mounting Kit
      (For Serial Prefix 2201 and below, use HP P/N 5061-0075.
      For Serial Prefix 2512 and above, use HP P/N 5061-9675)

〔CAUTION〕

Your instrument may have either metric or english cabinet hardware. DO NOT intermix the different hardware or damage to the instrument's frame and cabinet may result. For instruments with serial prefix 2512 and above use metric handle/rack mounting hardware, as listed above. For older instruments with serial prefix 2201 and below, use english handle/rack mounting hardware also as listed above. Contact your local HP Office if more information is needed.

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Appendix B

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LIST OF ILLUSTRATIONS

HEWLETT PACKARD

Herstellerbescheinigung

Hiermit wird bescheinigt, daβ das Gerät/System _____ HP 3456A _____
in Übereinstimmung mit den Bestimmungen von Postverfügung 1046/84 funkentstört ist.

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

Zusatzinformation fur Meβ- und Testgeräte

Werden Meβ- und Testgeräte mit ungeschirmten Kabeln und/oder in offenen Meβaufbauten
verwendet, so ist vom Betreiber sicherzustellen, daβ die Funk-Entstörbestimmungen unter
Betriebsbedingungen an seiner Grundstücksgrenze eingehalten werden.

Manufacturer's declaration

This is to certify that the equipment _____ HP 3456A _____
is in accordance with the Radio Interference Requirements of Directive FTZ 1046/84. The German Bundespost was notified that this equipment was put into circulation, the right to check
the series for compliance with the requirements was granted.

Additional Information for Test- and Measurement Equipment

If Test- and Measurement Equipment is operated with unscreened cables and/or used for
measurements on open set-ups, the user has to assure that under operating conditions the Radio
Interference Limits are still met at the border of his premises.

HEWLETT PACKARD

SAFETY SUMMARY

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture, and intended use of the instrument. Hewlett-Packard Company assumes no liability for the customer's failure to comply with these requirements. This is a Safety Class 1 instrument.

GROUND THE INSTRUMENT

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

DO NOT OPERATE IN AN EXPLOSIVE ATMOSPHERE

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

KEEP AWAY FROM LIVE CIRCUITS

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

DO NOT SERVICE OR ADJUST ALONE

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

DO NOT SUBSTITUTE PARTS OR MODIFY INSTRUMENT

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

DANGEROUS PROCEDURE WARNINGS

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

> ### WARNING
>
> Dangerous voltages, capable of causing death, are present in this instrument. Use extreme caution when handling, testing, and adjusting.

A

v

SAFETY SYMBOLS

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

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

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

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

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

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

∿   Alternating current (power line).

⎓   Direct current (power line).

≂   Alternating or direct current (power line).

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

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

NOTE: The NOTE sign denotes important information. It calls attention to procedure, practice, condition or the like, which is essential to highlight.

SECTION I
GENERAL INFORMATION

1-1. INTRODUCTION.

1-2. The information contained in this Manual is for the Installation, Operation, HP-IB Programming and Service of the Hewlett-Packard Model 3456A Digital Voltmeter.

NOTE

HP-IB is Hewlett-Packard's implementation of IEEE Std. 488-1975, "Standard Digital Interface for Programmable Instrumentation."

1-3. The Installation, Operating, and HP-IB Programming information in this Manual is also contained in the Operating Manual.

1-4. This section in the Manual contains general information concerning the 3456A Digital Voltmeter. Included are instrument description, specifications, supplemental characteristics, instrument and manual identification, options, accessories, and other information on the instrument.

1-5. DESCRIPTION.

1-6. The Hewlett-Packard Model 3456A is a versatile Digital Voltmeter with ac, dc, ohms, and various math functions. This voltmeter is an excellent bench meter and since it is remotely programmable it is an exceptional system measurement device. Other features for which you may have some good uses are the selection of power line cycles integrated, the selection of certain number of readings/trigger, settling delay, ratio, and other unique and useful functions.

1-7. The 3456A also employs a feature called AUTO ZERO. This feature of the instrument is very useful for good stability. The internal reference device and reference resistors are also selected for good accuracy and stability. Another good feature is the TEST function of the 3456A. With this function the instrument's operation can be partially verified for correct operation by the operator.

1-8. SPECIFICATIONS.

1-9. Specifications of the 3456A are the performance characteristics of the instrument which are warranted. These specifications are listed in Table 1-1, and are the performance standards or limits against which the instrument can be tested. Included in Table 1-1 are also some supplemental characteristics of the 3456A and should be considered as additional and general information for you, the user. Because of the many operational capablities of the 3456A, exercise care when determining the instrument's specifications.

1-10. Any changes in the specifications due to manufacturing changes, design, or traceability to the National Bureau of Standards will be covered in a manual change supplement or revised manual pages. The specifications listed here supercede any previously published.

1-11. INSTRUMENT AND MANUAL IDENTIFICATION.

1-12. Instrument identification is by a serial number located on the rear panel of the instrument. Hewlett-Packard uses a two-part serial number. The first part (prefix) identifies a series of instruments and the last part (suffix) identifies a particular instrument within a series. A letter between the prefix and suffix identifies the country in which the 3456A is manufactured.

1-13. This Manual applies to instruments with serial number indicated on the title page. Updating of the manual is accomplished either by a change sheet or revised pages.

1-14. OPTIONS.

1-15. The following options are available for use with the 3456A:

Option 350: for 50 Hz Power Source
Option 360: for 60 Hz Power Source
Option 907: Front Handle Kit
Option 908: Rack Mounting Kit
Option 909: Front Handle and Rack Mounting Kit
Option 910: Additional Set of Manuals

1-16. ACCESSORIES SUPPLIED.

1-17. The 3456A is supplied with a 3/8 amp, 250V fuse for the 220V and 240V power line voltages.

1-18. ACCESSORIES AVAILABLE.

1-19. The following is a list of available accessories for the 3456A:

Accessory No.	Description
10631A	HP-IB Cable 1 Meter (39.37 in.)
10631B	HP-IB Cable 2 Meter (78.74 in.)
10631C	HP-IB Cable 4 Meter (157.48 in.)
10631D	HP-IB Cable 0.5 Meter (19.69 in.)
11000A	Test Leads, Dual Banana Both Ends
11002A	Test Leads, Dual Banana to Probe and Alligator
34111A	High Voltage Probe (40 kV dc)
44414A	4 Thermistors

1-20. SAFETY CONSIDERATION.

1-21. The 3456A is a safety class 1 instrument (provided with a protective earth connection). The instrument and manual should be reviewed for safety symbols and instructions before using.

1-22. RECOMMENDED TEST EQUIPMENT.

1-23. Required equipment to maintain the Model 3456A is listed in Table 1-2. Other equipment may be substituted if it meets the requirements listed in the table. The table is also repeated in Section IV of the Operating and Service Manual.

Table 1-1. Specifications.

DC VOLTAGE

Input Characteristics

Range	Maximum Reading (5 digit)	6 Digit	Resolution 5 Digit	4 Digit	Input Resistance	Maximum Input Voltage
0.1V	.119999V	100 nV	1 μV	10 μV	> $10^{10}\Omega$	±1000V peak
1.0V	1.19999V	1 μV	10 μV	100 μV	> $10^{10}\Omega$	
10.0V	11.9999V	10 μV	100 μV	1mV	> $10^{10}\Omega$	
100.0V	119.999V	100 μV	1mV	10mV	10MΩ±.5%	
1000.0V	1000.00V	1mV	10mV	100mV	10MΩ±.5%	

Guard to Chassis: ±500V peak
Guard to Low: ±200V peak

Measurement Accuracy: ± (% of Reading + Number of Counts).
Auto-zero on and filter off.

24 hours: 23°C ± 1°C

Range	6 Digit (≥ 10 PLC*)	6 Digit (1 PLC)	5 Digit (.1 PLC)	4 Digit (.01 PLC)
0.1V	.0022 + 24	0.0024 + 32	0.007 + 14	0.06 + 3
1.0V	0.0009 + 4	0.0012 + 5	0.007 + 3	0.06 + 2
10.0V	0.0008 + 2	0.0011 + 3	0.007 + 2	0.06 + 2
100.0V	0.0011 + 3	0.0014 + 4	0.007 + 2	0.06 + 2
1000.0V[1]	0.0011 + 2	0.0013 + 3	0.007 + 2	0.06 + 2

90 Day: 23°C ± 5°C

Range	6 Digit (≥ 10 PLC)	6 Digit (1 PLC)	5 Digit (.1 PLC)	4 Digit (.01 PLC)
0.1V	0.0034 + 24	0.0035 + 32	0.008 + 14	0.06 + 3
1.0V	0.0024 + 4	0.0025 + 5	0.007 + 3	0.06 + 2
10.0V	0.0023 + 2	0.0024 + 3	0.007 + 2	0.06 + 2
100.0V	0.0026 + 3	0.0027 + 4	0.007 + 2	0.06 + 2
1000.0V[1]	0.0024 + 2	0.0025 + 3	0.007 + 2	0.06 + 2

[1]Add .012 $\left(\dfrac{\text{Input Voltage}}{1000}\right)^2$% to % reading.

> 90 days: 23°C ± 5°C
Add ± .0006% of Reading/month to 90 day accuracy.

Table 1·1. Specifications (Cont'd).

Temperature Coefficient: (5 digit)^2 ± (% of Reading + Number of Count)/°C

Range	0.1V	1.0V	10.0V	100.0V	1000.0V
Temp. Coef.	0.0002 + 0.2	0.0002 + 0.02	.0002 + .002	0.0002 + 0.02	0.0002 + 0.02

Auto-Zero OFF: (5 digit)^2
For a stable environment ± 1°C, add 10 counts for .1V range, 1 count for 1V and 100 ranges, and .1 count for 10V and 1000V ranges.

Filter ON: Rejection is > 60 dB at 50 Hz. Add 2μV for .1V, 1.0V and 10V range and 200 μV for 10V and 1000V range.

^{2}For 6 digits, multiply counts by 10
For 4 digits, multiply counts by .1

Response Time:
Filter OFF - For default delay (0.0 seconds), error is < .0005 % of input voltage step.

Filter ON: For default delay (.65 seconds), error is < .01% of input voltage step.

Integration Time in Power Line Cycles (PLC)	Noise Rejection (dB)		
	AC$^{3, 4}$ NMR	AC$^{3, 4}$ ECMR^4	DC ECMR^4
.01 PLC or .1 PLC	0	90	140
> 1 PLC	60	150	140
> 1 PLC with Filter	120	160	140

*Integration in POWER LINE CYCLES
^{3}For 50, 60 Hz (depending on option) ± .09%.
^{4}1 KΩ unbalance in Lo

AC RMS VOLTAGE

Input Characteristics

Range	Maximum Reading (5 Digit)	6 Digit	Resolution 5 Digit	4 Digit	Input Impedance	Maximum Input Voltage
1.0V	1.19999V	1 μV	10 μV	100 μV	1MΩ ±.5%	±1000V
10.0V	11.9999V	10 μV	100 μV	1mV	shunted by	peak
100.0V	119.999V	100 μV	1mV	10mV	< 75pF	(700V rms)
1000.0V	700.00V	1mV	10mV	100mV		10^{8}VHZ

Guard to Chassis: ±500V peak
Guard to Low: ±200V peak

Measurement Accuracy: ± (% of Reading + Number of Counts)
Auto-zero on, > 1% of full scale, and DC component < 10% of AC Component.
For inputs > 500V rms add .07% of reading.

24 hours: 23°C ± 1°C

Integration Time in Power Line Cycles (PLC)	Frequency in Hz				
	Filter Off→ 20 to 30	400-20k 30-20k	20k to 50k 20k to 50k	50k to 100k 50k to 100k	^{1}100k to 250k ^{1}100k to 250k
6 Digit (≥ 1 PLC)	.33 + 300	.05 + 550	.15 + 1500	.53 + 2700	5.0 + 6300
5 Digit (.1 PLC)	.34 + 33	.06 + 55	.16 + 150	.54 + 270	5.0 + 630
4 Digit (.01 PLC)	.39 + 5	.11 + 7	.21 + 17	.59 + 29	5.1 + 65

1-3

Table 1-1. Specifications (Cont'd).

90 day: 23°C ± 5°C

Integration Time in Power Line Cycles (PLC)	Frequency in Hz				
	Filter Off→ 20 to 30	400-20k 30-20k	20k to 50k 20k to 50k	50 k to 100k 50k to 100k	[1]100k to 250k [1]100k to 250k
6 Digit (≥ 1 PLC)	.35 + 500	.07 + 700	.17 + 1700	.55 + 2900	5.0 + 6500
5 Digit (.1 PLC)	.36 + 53	.08 + 73	.18 + 173	.56 to 293	5.0 + 653
4 Digit (.01 PLC)	.41 + 7	.13 + 9	.23 + 19	.61 + 31	5.1 + 67

[1]Frequencies > 100 kHz are specified for 1.0V and 10V ranges only.

> 90 day: 23°C ± 5°C (5 digit)[2]
Add ± (.004% of Reading + 12 counts)/month to 90 day accuracy.

Temperature Coefficient: (5 digit)[2]
± (% of Reading + Number of Counts)/°C
± (.008 +6)/°C for DC component < 10% AC component
± (.008 + 12)/°C otherwise

[2]For 6 digit, multiply counts by 10.
For 4 digit, multiply counts by .1.

DC Component > 10% of AC Component: (5 digit)[2]
Add ± (.05% of Reading + 50 counts) to accuracy.

Crest Factor: > 7 at full scale.

Common Mode Rejection (1kΩ unbalance in Lo): > 90 dB DC to 60 Hz

Auto-Zero Off: For stable environment ± 1°C no accuracy change.

Default Delays:
Filter Off - .06 seconds
Filter On - .80 seconds

Response Time: For default delay, error is < .1% of input voltage step.

RESISTANCE

Input Characteristics

Range	Maximum Reading (5 Digit)	6 Digit	Resolution 5 Digit	4 Digit	Current Through Unknown	Maximum Valid Reading Voltage	Maximum Open Circuit Voltage
100Ω	119.999Ω	100μΩ	1mΩ	10mΩ	1mA	1.2V	5.5V
1kΩ	1199.99Ω	1mΩ	10mΩ	100mΩ	1mA	1.2V	5.5V
10kΩ	11.9999kΩ	10mΩ	100mΩ	1Ω	100μA	1.2V	5.5V
100kΩ	119.999kΩ	100mΩ	1Ω	10Ω	50μA	6V	9.5V
1MΩ	1199.99kΩ	1Ω	10Ω	100Ω	5μA	6V	9.5V
10MΩ	11.9999MΩ	10Ω	100Ω	1kΩ	500nA	6V	9.5V
100MΩ	119.999MΩ	100Ω	1kΩ	10kΩ	≤ 500nA[1]	5V	5.5V
1GΩ	1000.00MΩ	1kΩ	10kΩ	100kΩ	≤ 500nA[1]	5V	5.5V

[1]Ohms source is a 500nA current source in parallel with a 10MΩ resistance.

Non-destructive overload: 350V peak.

Table 1-1. Specifications (Cont'd).

Measurement Accuracy: ± (% of Reading + Number of Counts)
Auto-Zero on, filter off, and 4-wire ohms.

24 hours: 23°C ± 1°C

Range	6 Digit (≥ 10 PLC)	6 Digit (1 PLC)	5 Digit (.1 PLC)	4 Digit (.01 PLC)
100Ω	0.003 + 24	0.003 + 32	0.009 + 14	0.07 + 3
1kΩ	0.002 + 4	0.003 + 5	0.008 + 3	0.07 + 2
10kΩ	0.002 + 4	0.003 + 5	0.008 + 3	0.07 + 2
100kΩ	0.002 + 2	0.003 + 3	0.008 + 2	0.07 + 2
1MΩ	0.006 + 2	0.006 + 3	0.012 + 2	0.07 + 2
10MΩ	0.041 + 2	0.041 + 3	0.07 + 2	0.12 + 2
100MΩ	1.3 + 1	1.3 + 1	1.5 + 1	1.5 + 1
1GΩ	11 + 1	11 + 1	13 + 1	13 + 1

90 days: 23°C ± 5°C

Range	6 Digit (≥ 10 PLC)	6 Digit (1 PLC)	5 Digit (.1 PLC)	4 Digit (.01 PLC)
100Ω	0.004 + 24	0.004 + 32	0.01 + 14	0.07 + 3
1kΩ	0.003 + 4	0.004 + 5	0.009 + 3	0.07 + 2
10kΩ	0.003 + 4	0.004 + 5	0.009 + 3	0.07 + 2
100kΩ	0.003 + 2	0.004 + 3	0.009 + 2	0.07 + 2
1MΩ	0.007 + 2	0.007 + 3	0.013 + 2	0.07 + 2
10MΩ	0.042 + 2	0.042 + 3	0.07 + 2	0.12 + 2
100MΩ	1.8 + 1	1.8 + 1	2.0 + 1	2.0 + 1
1GΩ	16 + 1	16 + 1	18 + 1	18 + 1

> 90 days: 23°C ± 5°C
Add ± .0004% of Reading/month to 90 day accuracy.

2-Wire Ohms Accuracy: Same as 4-wire ohms except add < .2
ohm offset.

Auto-Zero Off Accuracy: (5 digit)[2]
For a stable environment ± 1°C, add 10 counts for 100Ω range,
1 count for 1kΩ range and 10kΩ ranges, and .2 counts for ≥
100kΩ ranges.. Changes in lead resistance are not corrected for a
4-wire ohms.

[2]For 4 digit, multiply counts by .1.
  For 6 digit, multiply counts by 10.

Range	Maximum Lead Resistance for 4-Wire Ohms	Maximum Offset Voltage for Offset Compensated Ohms	Default Delay in Seconds
100Ω	10Ω	.01V	0
1kΩ	100Ω	.1V	0
10kΩ	1000Ω	.1V	0
100kΩ	1000Ω	.5V	.001
1MΩ	1000Ω		.008
10MΩ	1000Ω		.08
100MΩ	1000Ω		.08
1GΩ	1000Ω		.08

Offset Compensated Ohms Accuracy: Same as 2-wire and 4-wire ex-
cept maximum reading may be reduced by 9% for large offset
voltages. 100Ω - 100kΩ range are used.

Response Time: With default delay and < 200pF of capacitance,
first reading is in specification.

Filter is not operational in ohms.

Table 1-1. Specifications (Cont'd).

Temperature Coefficient: (5 digit)^2 ± (% of Reading + Number of Counts)/°C

Range	100Ω	1kΩ 10kΩ 100kΩ	1MΩ	10MΩ	100MΩ	1GΩ
T.C.	.0004 +.2	.0004 +.02	.0004 +.004	.0010 +.004	.16 +0	1.6 +0

RATIO

Type: DC/DC, AC/DC, or (AC+DC)/DC

Method: 4-Wire with Volts Lo input common.

$$\text{Ratio} = \frac{\text{Signal Voltage}}{\text{Ref. Hi Voltage} - \text{Ref. Lo Voltage}}$$

Signal Measurement: Same as DC Volts, or AC+DC Volts.

Reference Measurement: Automatically selects .1V, 1V, or 10V DC Volts range and a 0.0 msec. settling time. Filter is off.

Maximum Reference Voltage:

Ref. Hi:	± 12V
Ref. Lo:	± 9% of Ref. Hi.
Ref. Hi-Ref. Lo:	± 11.9999V
Protection:	± 350V peak

Accuracy: Total % signal error + total % reference error (same as .1V, 1V, or 10V DC volts)

READING RATE

Reading rates are with autorange, math, display and filter off. Output is to internal memory using internal trigger and packed Mode. Packed output in place of internal memory adds .35 msec; ASCII output adds 2.3 msec.

Rates vs. Integration Time and Auto-Zero: DC Volts and 100Ω thru 10kΩ ranges with default (-0.0 sec.) delay. Also, AC or AC+DC Volts and 100kΩ thru 10MΩ ranges with 0.0 sec. delay.

Integration Time in Power Line Cycles (PLC)	Rates			
	Auto-Zero Off		Auto-Zero On	
	60 Hz	50 Hz	60 Hz	50 Hz
0.01	330	290	210	180
.10	210	180	120	100
1.00	48	40	25	20.8
10.00	5.8	4.8	2.9	2.4
100.00	.57	0.47	.29	0.24

Rates with 1 Power Line Cycle Integration and Default Delays.

	Rates	
	60 Hz	50 Hz
— DC Volts and 100Ω thru 10kΩ, Auto-zero Off	48.0	40.00
— DC Volts, Filter ON	1.48	1.47
— AC or AC+DC Volts, Auto-zero OFF	12.0	11.00
— AC or AC+DC Volts, Filter ON	1.2	0.95
— 100kΩ range, Auto-zero OFF	46.0	35.0
— 1MΩ range, Auto-zero OFF	34.0	28.0
— 10MΩ range, Auto-zero OFF	9.9	9.0
— 100MΩ and 1GΩ range, Auto-zero OFF	6.6	6.10
— DC/DC ratio	5.2	4.40
— Offset Compensated Ohms	10.0	9.00

Table 1-1. Specifications (Cont'd).

MATH FUNCTION SPECIFICATIONS

General: Math function specifications do not include error in X (instrument reading) or in entered values (R,L,U,Y,Z). Range of values input or output is $\pm$ (0.000000 x 10^{-9} to 1999999 x 10^9). Out of range values send "LL" to display and + 1999999. x 10^9 to HP-IB.

PASS/FAIL: Displays: "HI" for values > upper limit (U), "LO" for values < lower limie (L), and X for values between the limits, with no introduced error.

SRQ mask can be programmed to respond to HI or LO conditions.

Maximum execution time: 20ms

STATISTICS:

$$\text{Mean (M)} = X_1 + \frac{1}{C} \sum_{i=1}^{C} (X_i - X_1)$$

$$\text{Variance (V)} = \frac{\sum_{i=1}^{C} (X_i - X)^2 - \frac{1}{C} \left[\sum_{i=1}^{C} (X_i - X_1) \right]^2}{C-1}$$

Maximum (U) and Minimum (L) are the most positive and negative instrument readings, respecitvely. X is displayed during calculation of statistics.

X_1 is the first reading taken after enabling statistics and is stored in the Z register. The number of readings taken (C) is stored in the count register.

$$\text{Accuracy of Mean:} \quad < \pm \frac{C(U\text{-}L)}{10^{11}} + 1 \text{ LSD}$$

$$\text{Accuracy of Variance:} \quad < \pm \frac{C(U\text{-}L)^2}{10^8} + 1 \text{ LSD}$$

Maximum execution time: 50ms

NULL: $X - X_1$ (X_1 is the first valid reading taken after enabling null and is stored in the Z register).

Maximum execution time: 15ms

dBm(R): $10 \log \frac{x^2/R}{1mW}$ R is the user-entered impedance.

Output range: -280 to +340 dBm

Accuracy: $\pm$ .001 dBm

Maximum execution time: 150ms

THERMISTOR (°F): Converts resistance of thermistor HP0837-0164 to temperature in °F.

Output range: -112 to 302°F

Accuracy: $-103 \leq T \leq + 266$ °F: ± 11°F max. $-116 \leq T \leq + 320$°F: ± 27°F max.

Maximum execution time: 150ms

THERMISTOR (°C): Converts resistance of thermistor HP0837-1064 to temperature in °C.

Output range: -80 to 150°C

Accuracy: $-75 \leq T \leq + 130$°C ± 06°C max. $-80 \leq T \leq + 150$°C ± 15°C max.

Maximum execution time: 100ms

SCALE: (X-Y)/Y

Accuracy: $\pm$ 1 LSD

Maximum execution time: 60ms

% ERROR: 100% x (X-Y)/Y

Accuracy: $\pm$ 1 LSD

Maximum execution time: 60ms

dB: $20 \log \frac{x}{y}$

Output Range: -620 to +620 dB

Accuracy: .001 dB

Maximum execution time: 100ms

MEMORY

Reading Store:

● Can store up to 350 most recent readings.

● Can be recalled from the HP-IB interface or the front panel.

Program Memory:

● Can execute an internal program which controls instrument configuration and measurement sequence.

● Program is input from the HP-IB interface with up to 1400 ASCII characters.

Memory Size:

● Total size = 1400 bytes

● Memory used = 1 byte per ASCII character + 4 bytes per reading stored.

GENERAL

Voltmeter Control Functions: Description: The voltmeter control function in the math section of the front panel is designed to control the measurement parameters of the 3456A. Included in this front panel section is the:

    1) Number of digits displayed.
    2) Number of readings per trigger.
    3) Delay time between readings.
    4) Integration time in number of power line cycles (PLC).

Number of Digits Displayed allows selection of 3 to 6 digits displayed plus sign and exponent. The range of the display is $\pm$ 1,999,999 $\pm$ 9.

Number of Readings per Trigger allows selection of specific number of readings to be taken with just one trigger. The time between readings is controlled by the delay time selected.

Delay Time allows selection of the time between measurement cycles. It is provided to allow the selection of settling time. The range is from 0 to 999.999 sec. in 0.001/sec. increments. Accuracy is 1% of time selected.

Integration Time in Power Line Cycles allows the selection of the time for measurement integration. The units of integration time in power line cycles (PLC) apply for both 50 and 60 Hz power line frequencies. The range of integration time selection is from 0.01 to 100 power line cycles (PLC) per measurement.

Front-Rear Terminal Switch - On the front panel. Operated manually. Its status can be read via software.

Table 1-1. Specifications (Cont'd).

The actual measurement time is a function of the integration time, the delay time, auto zero, filter, etc., voltmeter complete, external trigger, and function selected.

Operating Temperature: 0 C to 50 C

Warmup Time: One hour to meet all specifications

Humidity Range: 95% R.H., 0 C to 40 C

Storage Temperature: -40 C to +75 C

Power: 100/120/240V + 5%, -10% 48 Hz to line operation 80VA; 220V ± 10% 48 Hz to line operation 80VA.

Size: 88.9mm high x 425.5mm wide x 527.1mm deep (3½" high x 16¾" wide x 20¾" deep)

Weight: Net 10.49 kg (23.13lbs.)

Table 1-2. Recommended Test Equipment

Instrument	Critical Specification	Recommended Model	Use
DC Voltage Standard	Voltage: 10mV to 1000V Accuracy: ±.005%	Systron Donner Model M107	PAT
DC Transfer Standard	Output Voltages:1V, 10V, 1.018V, 1.019V Accuracy: ±5ppm Stability: ±.001% (30 Days)	Fluke Model 731B	PA
AC Calibrator	Frequency: 20 Hz to 250 kHz Output Level: 100mV to 1000V Accuracy: ±.1% Voltage Stability (6 mos.) ±.02%	Fluke Model 5200A and Model 5215A	PAT
Reference Divider	Division Ratio Accuracy: ±.001% Output Voltage Range: 1V to 1kV	Fluke Model 750A	PA
Resistance Standard	Resistance: 100Ω Accuracy: ±.0005%	Guildline Model 9330/100 or 9330A/100	P
	Resistance: 1kΩ Accuracy: ±.0005%	9330/1K or 9330A/1K	PA
	Resistance: 10kΩ Accuracy: ±.001%	9330/10K or 9330A/10K	PA
	Resistance: 100kΩ Accuracy: ±.001%	9330/100K or 9330A/100K	PA
	Resistance: 1MΩ Accuracy: ±.002%	9330/1M	PA
	Resistance: 10MΩ Accuracy: ±.01%	9330/10M	PA
	Resistance*: 1GΩ Accuracy: ±2%	-hp- Part No. 03456-67902	P
DC Null Voltmeter	Voltage Range: 1μV to 10V	-hp- Model 419A	PA
Bus System Analyzer**	HP-IB Control Capability	-hp- Model 59401A	T
Desktop Computer	HP-IB Control Capability serves as printer for output data	-hp- Model 9825A, 9825B, 9835A, 9845B, or 85A	OT
Oscilloscope**	Bandwidth: DC to 100 MHz Sweep Time: 50ns to 20ms/div	-hp- Model 1740A	T
Digital Voltmeter**	Voltage Range: 100μV to 1000V Resolution: 1 μV	-hp- Model 3456A (or 3455A)	T
Resistors	Resistances: 1 kΩ ± 10%	-hp- Part No. 0684-1021	
Signature Analyzer**		-hp- Model 5004A	T
Test Program Cartridges*		-hp- Part Number 03456-10001 (9825A/B) 03456-10002 (9835A, (9845A/B) 03456-10003 (85A)	T

Table 1-2. Recommended Test Equipment (Cont'd).

Instrument	Critical Specification	Recommended Model	Use
Isolation Logic Test Jumper*		-hp- Part No. 03456-61602	T
HP-IB Signature Analysis Modules*,**		-hp- Part Number 5061-1153 5061-1154 5061-1155	T

*These items included in 3456A Digital Voltmeter Service Kit for Component Level Repair (-hp- Part Number 03456-69800)

**These items are not required if a board level repair strategy is to be used. This strategy does require a 3456A Digital Voltmeter Service Kit for Board Level Repair (-hp- Part Number 03456-69801).

P = Performance Test   T = Troubleshooting
A = Adjustment   O = Operators Check

SECTION II

INSTALLATION

2-1. INTRODUCTION.

2-2. This section of the manual contains the necessary information and instructions to install and interface the Model 3456A Digital Voltmeter. Included are initial inspection procedures, power and grounding requirements, enviromental information, and instructions for repacking the instrument 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. The instrument should be inspected for any damage that may have occurred in transit. If the shipping container or cushioning material is damaged, it should be kept until the contents of the shipment have been checked for completeness and the instrument has been mechanically and electrically checked. Procedures for checking the electrical performance of the 3456A are given in Section IV. If there is mechanical damage, or the contents are incomplete, or the instrument does not pass the performance tests, notify the nearest Hewlett-Packard Office (a list of the -hp- Sales and Service Offices is located at the back of the manual). If the shipping container is damaged, or the cushioning material shows signs of stress, notify the carrier as well as the Hewlett-Packard Office. Save the shipping materials for the carrier's inspection.

2-5. PREPARATION FOR USE.

2-6. Power Requirements.

2-7. The Model 3456A requires a power source of 100, 120, 220, or 240 V ac (− 10%, + 5%), 48 Hz to 66 Hz single phase. Maximum power consumption is 80 VA.

2-8. Line Voltage Selection.

2-9. Figure 2-1 provides information for line voltage and fuse selection. Make sure the rear panel line selector switches are in the correct position and the correct fuse is installed in the 3456A, before applying ac power to the instrument.

2-10. Power Cords and Receptacles.

2-11. Figure 2-2 illustrates the different power plug configurations that are available to provide ac power to the 3456A. The -hp- part number shown directly below the individual power plug drawing is the part number

for the power cord set 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.

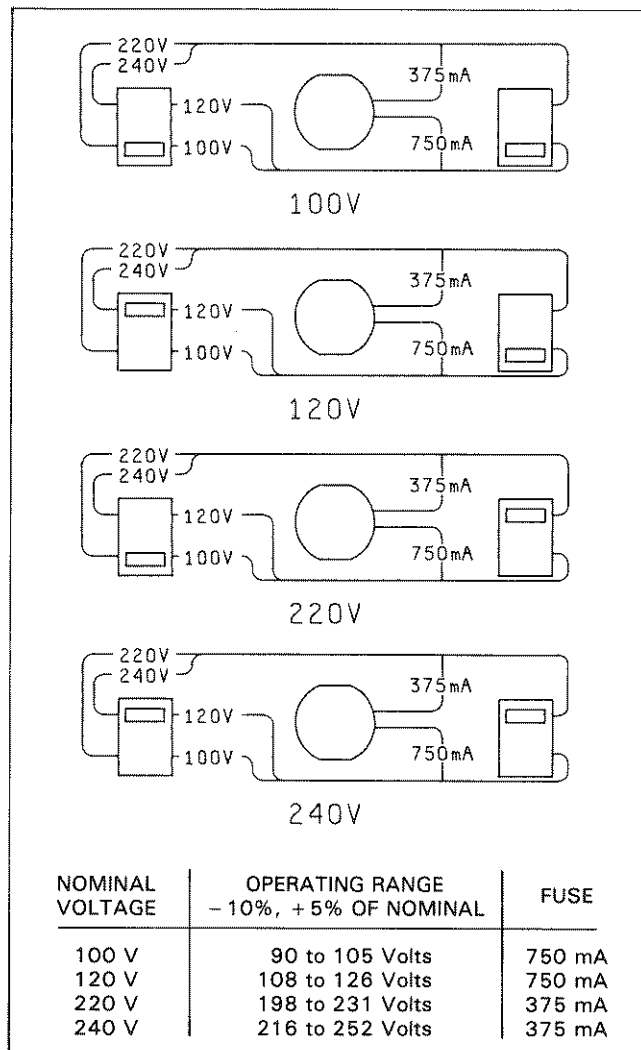| NOMINAL VOLTAGE	OPERATING RANGE − 10%, + 5% OF NOMINAL	FUSE
100 V	90 to 105 Volts	750 mA
120 V	108 to 126 Volts	750 mA
220 V	198 to 231 Volts	375 mA
240 V	216 to 252 Volts	375 mA

Figure 2-1. Line Voltage Selection.

2-12. Grounding Requirements.

2-13. To protect operating personnel, the National Electrical Manufacturer's Association (NEMA) recommendation is to ground the instrument panel and cabinet. The -hp-Model 3456A is equipped with a three conductor power cable which, when plugged into an appropriate receptacle, grounds the instrument.
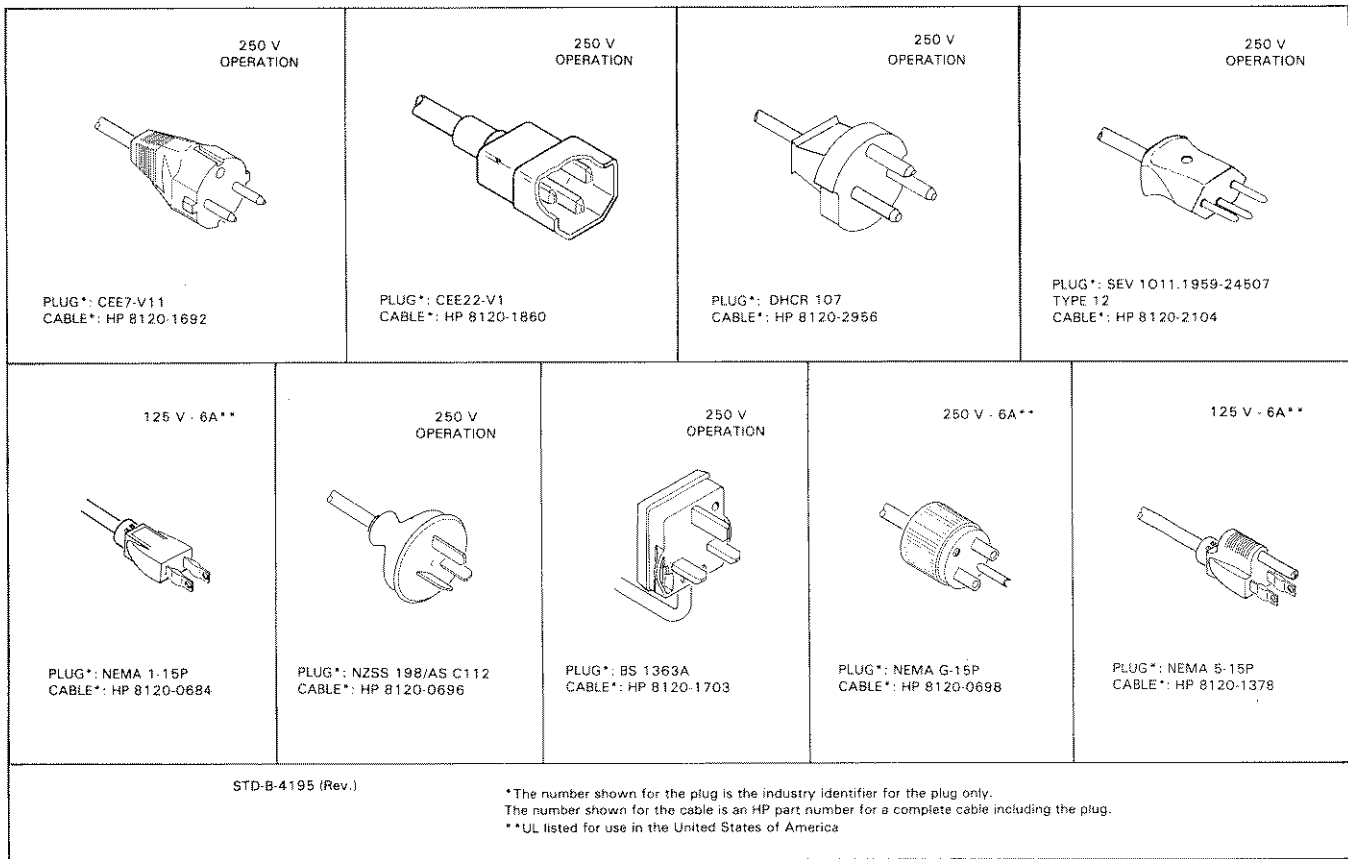
2-1

Figure 2-2. Power Cables.

2-14. Bench Use.

2-15. The Model 3456A is shipped with feet and tilt stands installed and is ready for use as a bench instrument. The feet are shaped to permit "stacking" with other full-module Hewlett-Packard instruments.

2-16. Rack Mounting.

2-17. The -hp- Model 3456A can be rack mounted by adding rack mounting kit Option 908 or Option 909. The basic hardware and instructions for rack mounting are contained in Option 908 and addition of front handles to the basic rack mount kit are contained in Option 909. The rack mount kits are designed to permit mounting of the 3456A in a standard 19 inch rack, provided that sufficient rear support is available. Also make sure the air intake at the rear of the instrument is unobstructed.

2-18. Interface Connections.

2-19. The -hp- Model 3456A is compatible with the Hewlett-Packard Interface Bus (HP-IB).

NOTE

HP-IB is Hewlett-Packard's implementation of IEEE Std. 488-1975, "Standard Digital Interface for Programmable Instrumentation."

The 3456A's HP-IB connection is made by an HP-IB Interface cable to the 24 pin HP-IB connector located at the rear panel. A typical interconnection of HP-IB is shown in Figure 2-3 in which system interconnection is made by three HP-IB Interface Cables. The ends of the cables have both a male and female connector to enable connections to other instruments and cables. As many as 15 instruments can be connected by the same interface bus. However, the maximum length of cable that can effectively be used to connect a group of instruments should not exceed 2 meters (6.5 feet) times the number of instruments to be connected, or 20 meters (65.6 feet), whichever is less. For a pictorial view of the HP-IB connector and its pin designation, refer to Figure 2-4.

2-20. Address Selection.

2-21. The HP-IB "talk" and "listen" address of the Model 3456A is set by the instrument's address switch, located at the rear panel. The talk and listen address is a 5-bit code which is selected to provide a unique address for each HP-IB instrument. The 3456A normally leaves the factory with the address switch set to decimal code "22." The corresponding ASCII code is a listen address code of "6" and a talk code of "V." Refer to Figure 2-5 for the factory address switch setting.
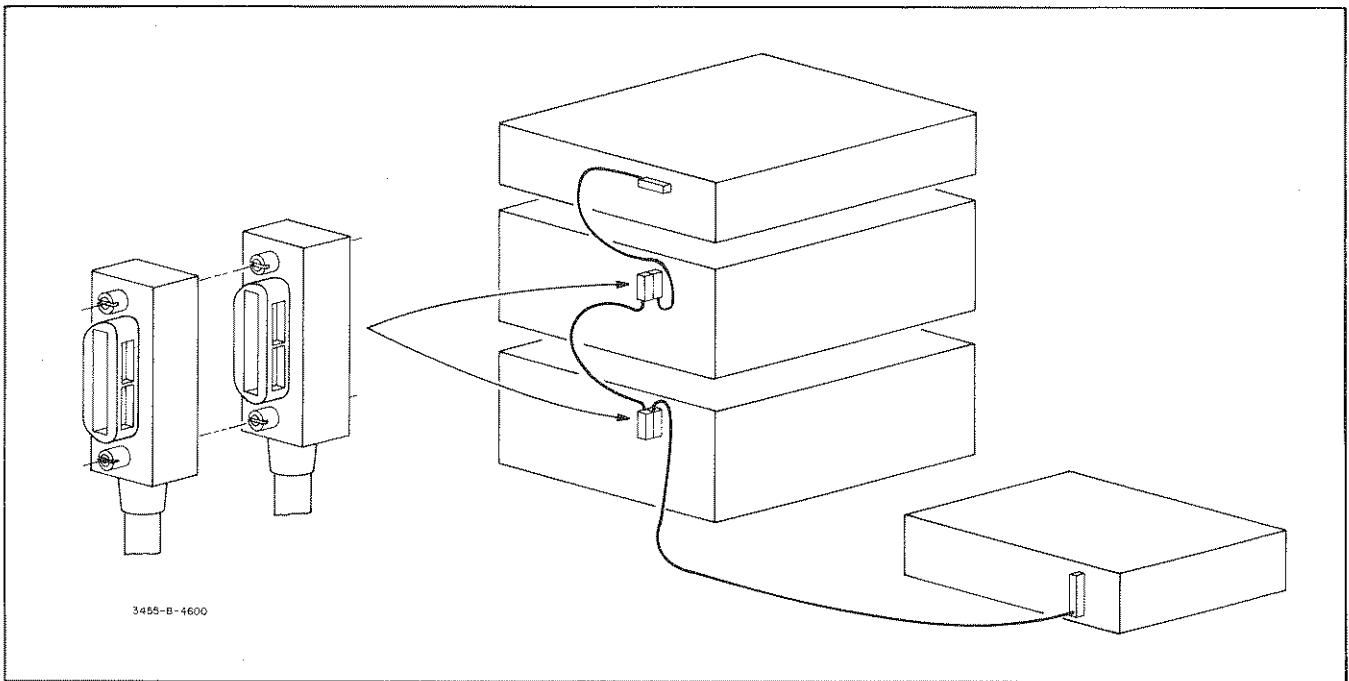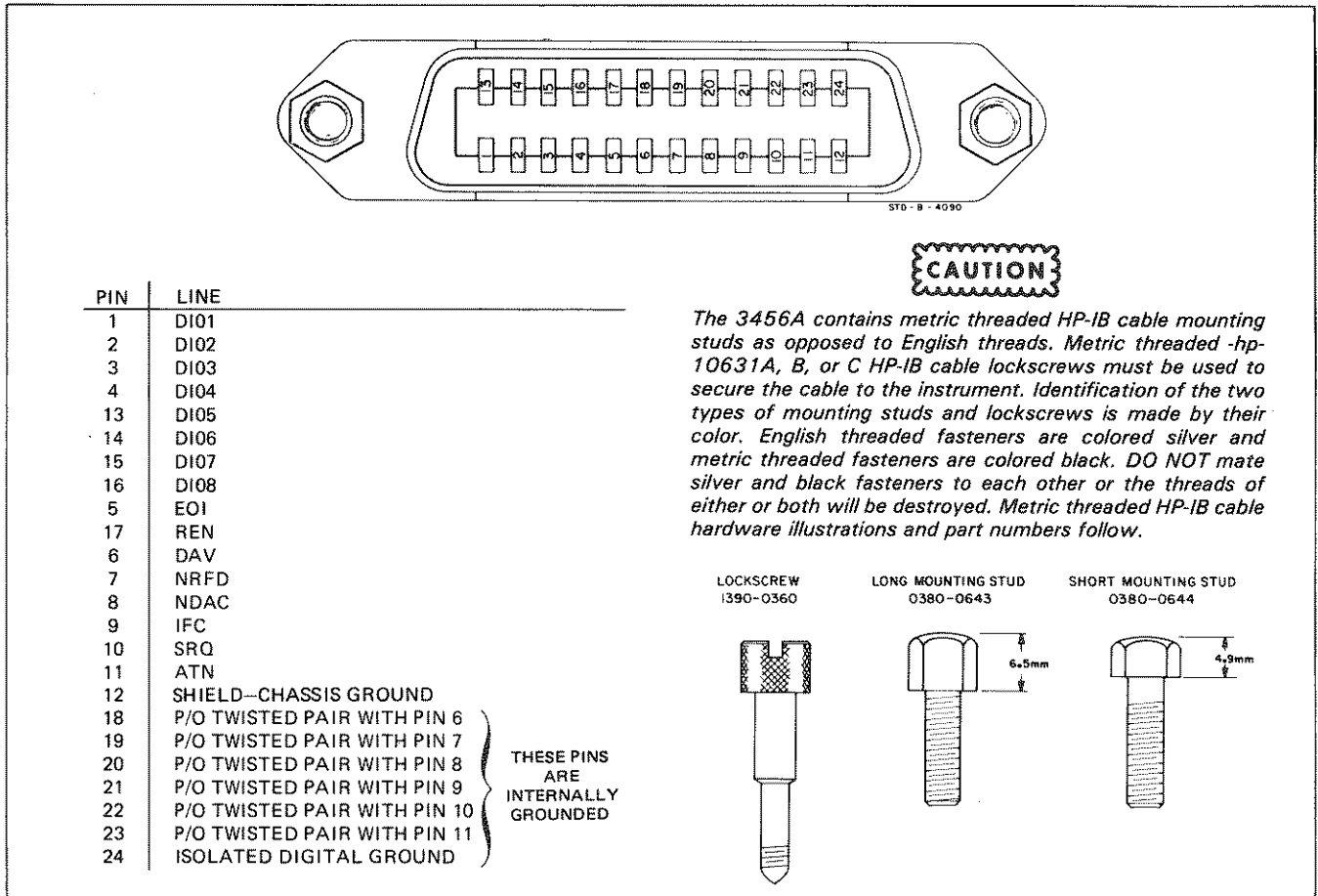
Figure 2-3. Typical HP-IB System Interconnections.

PIN	LINE
1	DIO1
2	DIO2
3	DIO3
4	DIO4
13	DIO5
14	DIO6
15	DIO7
16	DIO8
5	EOI
17	REN
6	DAV
7	NRFD
8	NDAC
9	IFC
10	SRQ
11	ATN
12	SHIELD—CHASSIS GROUND
18	P/O TWISTED PAIR WITH PIN 6
19	P/O TWISTED PAIR WITH PIN 7
20	P/O TWISTED PAIR WITH PIN 8
21	P/O TWISTED PAIR WITH PIN 9
22	P/O TWISTED PAIR WITH PIN 10
23	P/O TWISTED PAIR WITH PIN 11
24	ISOLATED DIGITAL GROUND

THESE PINS ARE INTERNALLY GROUNDED

CAUTION

The 3456A contains metric threaded HP-IB cable mounting studs as opposed to English threads. Metric threaded -hp-10631A, B, or C HP-IB cable lockscrews must be used to secure the cable to the instrument. Identification of the two types of mounting studs and lockscrews is made by their color. English threaded fasteners are colored silver and metric threaded fasteners are colored black. DO NOT mate silver and black fasteners to each other or the threads of either or both will be destroyed. Metric threaded HP-IB cable hardware illustrations and part numbers follow.

LOCKSCREW 1390-0360   LONG MOUNTING STUD 0380-0643   SHORT MOUNTING STUD 0380-0644
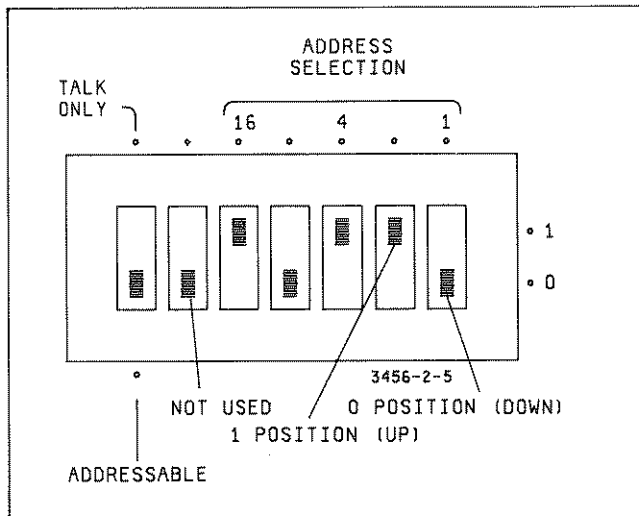
Figure 2-4. HP-IB Connector.

Figure 2-5. 3456A Address Switch.

NOTE

The 5-bit decimal code, consisting of bits A1 through A5, is often used by controllers which use this convention as a System Device Number for instruments.

2-22. "Talk-Only" mode. The instrument has a "Talk-Only" mode which can also be set by the address switch. The Remote Operation chapter in Section III of this manual gives a detailed description of the 3456A's "Talk-Only" mode, including the address codes.

2-23. External Trigger.

2-24. An External Trigger input to the 3456A is provided by a BNC connector located at the rear panel of the instrument. The trigger input should be driven by negative going TTL level signals. For more information refer to Section III in this manual.

2-25. Voltmeter Complete Connector.

2-26. A Voltmeter Complete output is also provided by the 3456A through a BNC connector located at the rear panel. This connector provides an output which is composed of a TTL level signal and is generated during a measurement cycle.

2-27. ENVIRONMENTAL REQUIREMENTS.

WARNING

To prevent electrical fire or shock hazards, do not expose the instrument to rain or excess moisture.

2-28. Operating and Storage Temperature.

2-29. In order to meet and maintain the specifications listed in Table 1-1, the 3456A should be operated within an ambient temperature range of 23°C +/- 5°C (73°F +/- 9°F). The instrument may be operated within an ambient temperature range of 0°C to 55°C (+ 32°F to 131°F) with less accuracy.

2-30. The 3456A may be stored or shipped within an ambient temperature range of - 40C to + 75C (- 40F to + 167F).

2-31. Humidity.

2-32. The instrument may be operated in environments with relative humidity of up to 95%. The instrument must, however, be protected from temperature extremes which may cause condensation within the instrument.

2-33. Altitude.

2-34. The instrument may be operated at altitudes up to 4572 meters (15,000 feet).

2-35. REPACKAGING FOR SHIPMENT.

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 made. Include the model number and full serial number of the instrument. In any correspondence, identify the instrument by model number and full serial number. If you have any questions, contact your nearest -hp- Sales and Service Office.

2-36. Place instrument in original container with appropriate packaging material and secure with strong tape or metal bands. If the original container is not available, a replacement container can be purchased from your nearest -hp- Sales and Service Office.

2-37. If the original container is not to be used, do the following:

1. Wrap the instrument in heavy plastic before placing in an inner container.

2. Place packing material around all sides of the instrument and protect the front panel with cardboard strips.

3. Place the instrument in the inner container in a heavy carton and seal with strong tape or metal bands.

4. Mark shipping container "DELICATE INSTRUMENT," "FRAGILE," etc.

SECTION III
OPERATION

3-1. INTRODUCTION.

3-2. This is the information and instructions for the operation of the -hp- Model 3456A Voltmeter showing front panel and remote operations. In addition, you will find functional checks you can perform. For more advanced users a Quick Reference Guide is shipped with the instrument. The information in the guide is most of the 3456A's operating characteristics, including remote programming codes.

3-3. Before reading the operating information in this section, familiarize yourself with the front and rear panel features as indicated in Figure 3-1. Use the figure as a reference by folding the page out while reading this section.

3-4. Read the front panel operations of the 3456A before the remote operations since most front panel operations also apply to the remote operations.

3-5. PRE-OPERATING INSTRUCTIONS.

3-6. The 3456A's operation can be separated into five main areas. A good understanding of these areas is fundamental to learning the operation of the instrument. The five areas are:

  a. Reset and Test Operation.

  b. Function, Range and Trigger.

  c. Voltmeter Control Functions, (Delay, Number of Readings/Trigger, Number of Digits Displayed).

  d. Math.

  e. Remote Operation.

3-7. Refer to Figure 3-1. Note that the 3456A's front panel can be separated into three areas: Display, Voltmeter Configuration, and Numbered Keyboard. Keep these areas in mind when you use the 3456A.

3-8. To learn the operation of the instrument, a logical approach is to ask yourself the following questions:

  a. "What type of measurement do I want to make?" - FUNCTION

  b. "Do I want autoranging?" - RANGE

  c. "Do I want the input filter in?" - FILTER

  d. "Is a math operation desired?" - MATH FUNC-TION

  e. "Do I want remote control of the 3456A?" -REMOTE OPERATION

Once you have decided what you want the 3456A to do, the next step is to learn how to do it.

3-9. GENERAL OPERATING CHARACTERISTICS.

3-10. These paragraphs describe some of the 3456A's General Operating Characteristics. Refer to Figure 3-2, the Display Area, for the following discussion.
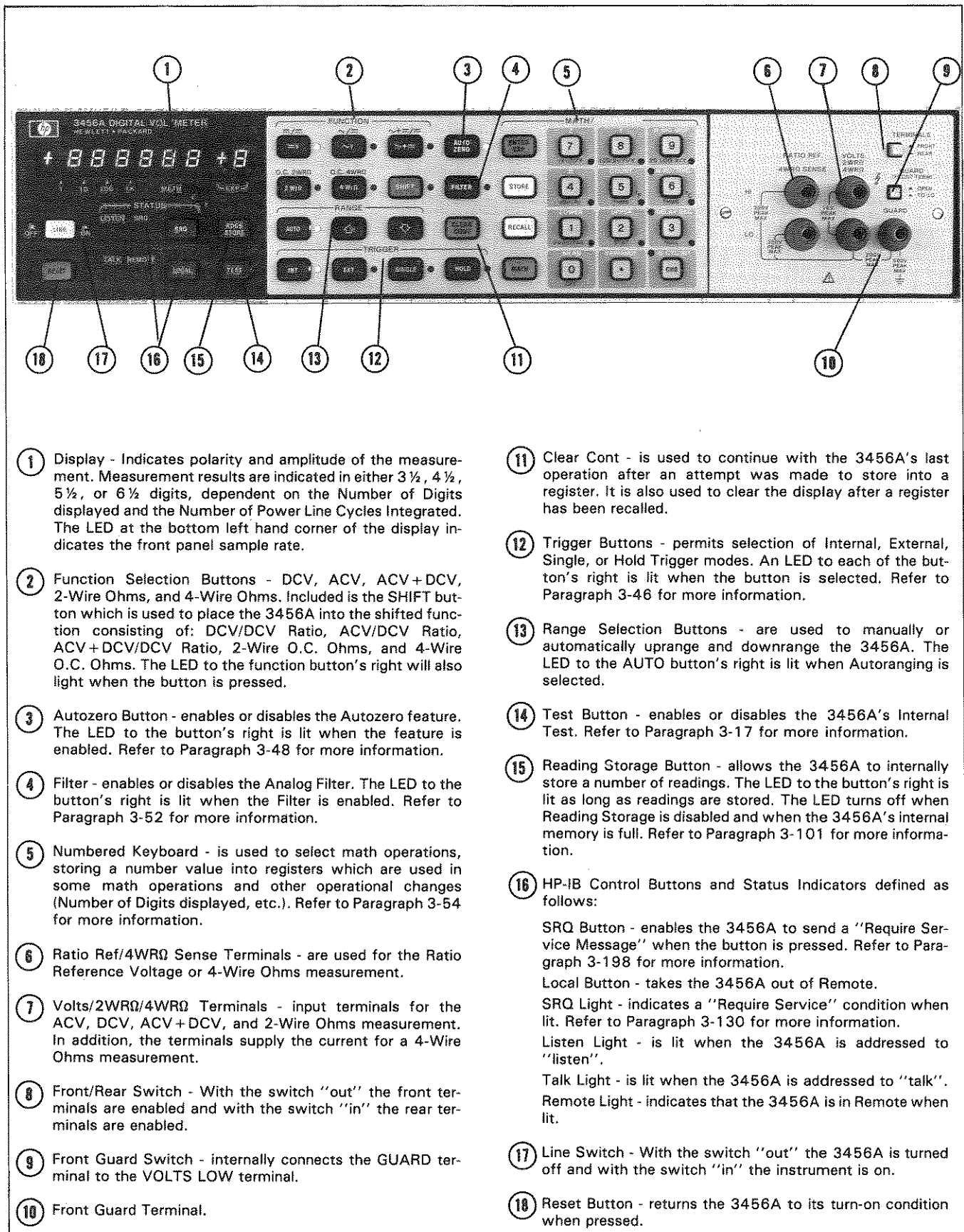
3-11. Turn-On and Warm-Up.

3-12. Before connecting ac power to the 3456A, make sure the rear panel line selector switches are set to correspond to the available power line voltage. Be certain the correct fuse is installed in the instrument. To meet accuracy specifications, the 3456A should be warmed up for at least one hour.

3-13. Reset.

3-14. After power connection and warm-up, to make sure the instrument is in the "turn-on" state, press the RESET button. This places the instrument in the power-up condition without cycling power. This provides you a convenient starting place and avoids thermal and electrical shock to the instrument, therefore maintaining its accuracy and improving reliability. The turn-on state is:
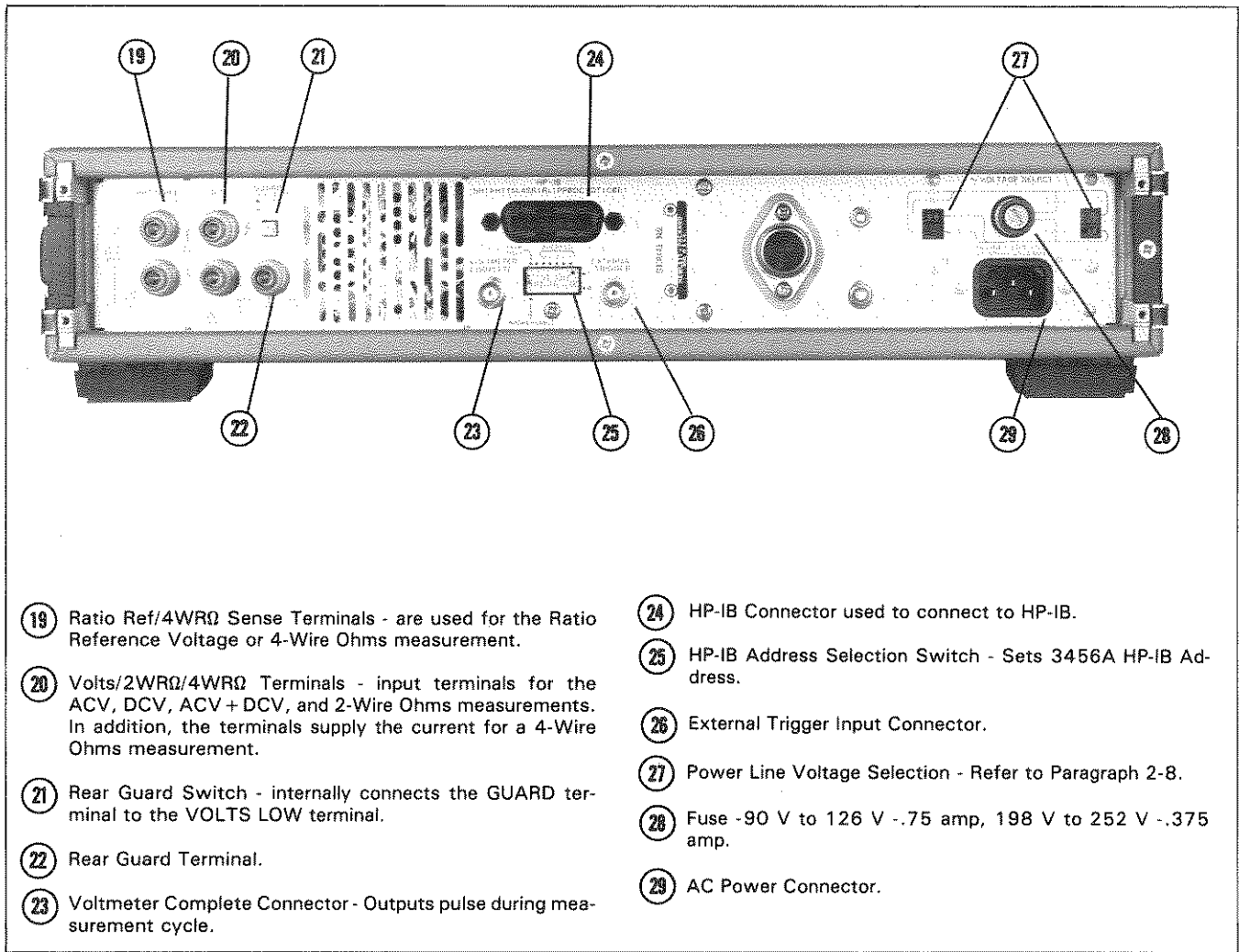
```
FUNCTION...........................DC
RANGE ............................AUTO
TRIGGER .....................INTERNAL
MATH ..............................OFF
DELAY..................DEFAULT (0 SEC.)
NUMBER OF READ-
INGS/TRIGGER ........................1
NUMBER OF POWER
LINE CYCLES INT. ....................10
NUMBER OF DIGITS DISPLAYED.........5
AUTOZERO ...........................ON
OPERATING MODE...............LOCAL
FILTER .............................OFF
READING STORAGE...................OFF
```

Figure 3-1. Front and Rear Panel Features.

(1) Display - Indicates polarity and amplitude of the measurement. Measurement results are indicated in either 3½, 4½, 5½, or 6½ digits, dependent on the Number of Digits displayed and the Number of Power Line Cycles Integrated. The LED at the bottom left hand corner of the display indicates the front panel sample rate.

(2) Function Selection Buttons - DCV, ACV, ACV + DCV, 2-Wire Ohms, and 4-Wire Ohms. Included is the SHIFT button which is used to place the 3456A into the shifted function consisting of: DCV/DCV Ratio, ACV/DCV Ratio, ACV + DCV/DCV Ratio, 2-Wire O.C. Ohms, and 4-Wire O.C. Ohms. The LED to the function button's right will also light when the button is pressed.

(3) Autozero Button - enables or disables the Autozero feature. The LED to the button's right is lit when the feature is enabled. Refer to Paragraph 3-48 for more information.

(4) Filter - enables or disables the Analog Filter. The LED to the button's right is lit when the Filter is enabled. Refer to Paragraph 3-52 for more information.

(5) Numbered Keyboard - is used to select math operations, storing a number value into registers which are used in some math operations and other operational changes (Number of Digits displayed, etc.). Refer to Paragraph 3-54 for more information.

(6) Ratio Ref/4WRΩ Sense Terminals - are used for the Ratio Reference Voltage or 4-Wire Ohms measurement.

(7) Volts/2WRΩ/4WRΩ Terminals - input terminals for the ACV, DCV, ACV + DCV, and 2-Wire Ohms measurement. In addition, the terminals supply the current for a 4-Wire Ohms measurement.

(8) Front/Rear Switch - With the switch "out" the front terminals are enabled and with the switch "in" the rear terminals are enabled.

(9) Front Guard Switch - internally connects the GUARD terminal to the VOLTS LOW terminal.

(10) Front Guard Terminal.

(11) Clear Cont - is used to continue with the 3456A's last operation after an attempt was made to store into a register. It is also used to clear the display after a register has been recalled.

(12) Trigger Buttons - permits selection of Internal, External, Single, or Hold Trigger modes. An LED to each of the button's right is lit when the button is selected. Refer to Paragraph 3-46 for more information.

(13) Range Selection Buttons - are used to manually or automatically uprange and downrange the 3456A. The LED to the AUTO button's right is lit when Autoranging is selected.

(14) Test Button - enables or disables the 3456A's Internal Test. Refer to Paragraph 3-17 for more information.

(15) Reading Storage Button - allows the 3456A to internally store a number of readings. The LED to the button's right is lit as long as readings are stored. The LED turns off when Reading Storage is disabled and when the 3456A's internal memory is full. Refer to Paragraph 3-101 for more information.

(16) HP-IB Control Buttons and Status Indicators defined as follows:

SRQ Button - enables the 3456A to send a "Require Service Message" when the button is pressed. Refer to Paragraph 3-198 for more information.

Local Button - takes the 3456A out of Remote.

SRQ Light - indicates a "Require Service" condition when lit. Refer to Paragraph 3-130 for more information.

Listen Light - is lit when the 3456A is addressed to "listen".

Talk Light - is lit when the 3456A is addressed to "talk".

Remote Light - indicates that the 3456A is in Remote when lit.

(17) Line Switch - With the switch "out" the 3456A is turned off and with the switch "in" the instrument is on.

(18) Reset Button - returns the 3456A to its turn-on condition when pressed.
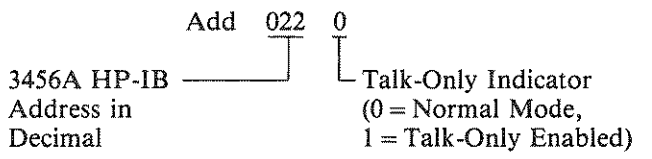
(19) Ratio Ref/4WRΩ Sense Terminals - are used for the Ratio Reference Voltage or 4-Wire Ohms measurement.

(20) Volts/2WRΩ/4WRΩ Terminals - input terminals for the ACV, DCV, ACV + DCV, and 2-Wire Ohms measurements. In addition, the terminals supply the current for a 4-Wire Ohms measurement.

(21) Rear Guard Switch - internally connects the GUARD terminal to the VOLTS LOW terminal.

(22) Rear Guard Terminal.

(23) Voltmeter Complete Connector - Outputs pulse during measurement cycle.

(24) HP-IB Connector used to connect to HP-IB.

(25) HP-IB Address Selection Switch - Sets 3456A HP-IB Address.

(26) External Trigger Input Connector.

(27) Power Line Voltage Selection - Refer to Paragraph 2-8.

(28) Fuse -90 V to 126 V -.75 amp, 198 V to 252 V -.375 amp.

(29) AC Power Connector.

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

3-15. When pressing the RESET button, the display will momentarily display this for about 1 second:

Add   022   0

3456A HP-IB ————┘   └ Talk-Only Indicator
Address in   (0 = Normal Mode,
Decimal   1 = Talk-Only Enabled)

See Paragraph 3-150 for the HP-IB address setting and Paragraph 3-154 for the "Talk-Only" mode.

3-16. When power is cycled, "HP 3456" is momentarily displayed and then the address code is displayed.

3-17. Self Test Operation.

3-18. The 3456A's Test Operation consists of certain analog gain, offset, and digital checks when the TEST button is pressed. Make sure the 3456A's input terminals are completely floating and the GUARD switch is in the "IN" position, when selecting the test operation. The test may not pass if external connections are

made to the input terminals, because certain input circuitry measurements are made. When the TEST button is pressed, the instruments displays

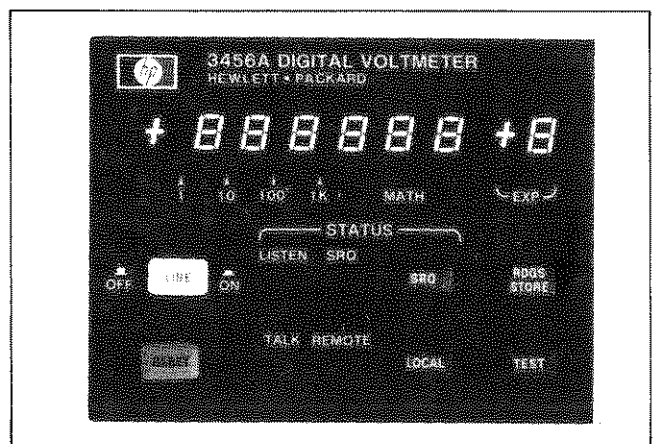"+ 1.8.8.8.8.8.8. + 8."

Figure 3-2. Front Panel Display Area.

and light all the front panel LEDs. This remains until the test is completed. Once the test is completed, the display and the LEDs go blank for a time and the test operation starts again. If any of the internal checks do not pass, a negative integer corresponding to the check which did not pass is displayed. The displayed number is also output over the HP-IB with the 3456A in remote. A '100'' is output when the test passes. To disable the test operation press the TEST button a second time.

NOTE

Make sure no connection is made at the 3456A's Input Terminals and the GUARD switch is in the "IN" position during the Test mode.

NOTE

Refer the 3456A to a Service Trained Person, if the Internal Test does not pass.

3-19. Display.

3-20. Refer to Figure 3-3 to see how readings are displayed. Note that the 1 V through 1000 V ranges are displayed as they are measured with the decimal point in the correct place like this:

1.00000 — 1 V Range
10.0000 — 10 V Range
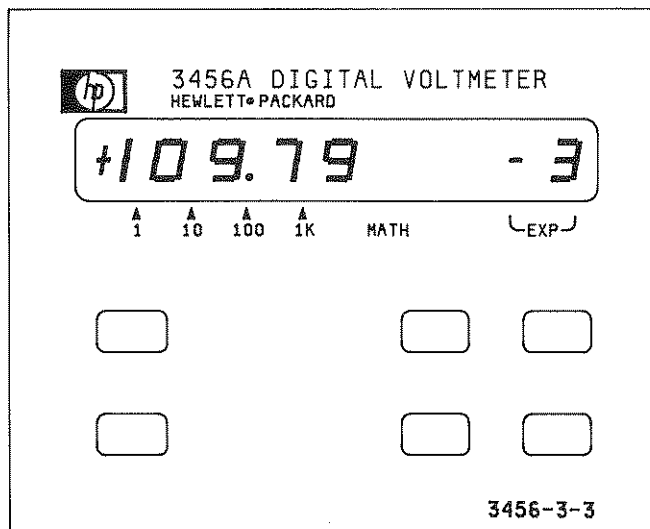100.000 — 100 V Range
1000.00 — 1000 V Range

Figure 3-3. 3456A Display.

Additionally, a 1, 10, 100, and 1 K are marked on the front panel and are located below the decimal point of the respective ranges with the other ranges indicated in engineering notation. The position of the decimal point on the display marks the decade multiplier.The range is easily determined by multiplying the displayed exponent by the decade multiplier. For example:

$$\begin{array}{cccccc} & 1 & 0 & 9 & . & 7 & 9 & -3 \\ \text{decade multiplier} \rightarrow & 1 & 10 & 100 & 1K & \text{EXP} \end{array}$$

shows a reading of .10979 V or 109.79 mV. The decade multiplier is not used in the 3456A's Ratio and Math functions.

3-21. Error Messages.

3-22. Error Messages are displayed for invalid operating conditions. They are displayed like this:

E D

where ''D'' is the number indicating which error is generated. The instrument keeps displaying the Error Message until the condition producing the error is changed to a valid state. A listing of the various error messages is given in Table 3-1.

Table 3-1. Error Messages.

Error No.	Description
1	Autozero disabled in any Shifted Functions. Displayed in Remote only.
2	Analog Filter enabled in any Ohms Functions. Displayed in Remote only.
3	Any invalid Range and Function combination (Example: 10 M ohm Range selected for the DCV Function). Displayed in Remote only.
4	Attempt was made to store invalid number into a register (Example: a ''9'' is stored into the Number of Digits Displayed register).
5	Attempt was made to store any number into register C, M, or V.
6	Attempt was made to recall non-existent stored readings from memory.

3-23. OPERATING CHARACTERISTICS.

3-24. Refer to Figure 3-4, the front panel's Voltmeter Configuration area, for the following paragraphs.
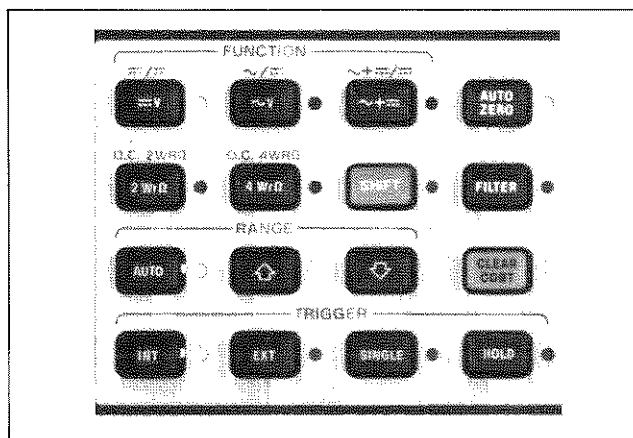

Figure 3-4. Front Panel Voltmeter Configuration Area.

3-25. DC Voltage Measurement.

3-26. The -hp- Model 3456A is capable of measuring dc voltages from 100 nanovolts through 1000 volts in five

ranges: 100 mV, 1 V, 10 V, 100 V, and 1000 V. All ranges are overload protected from input voltages up to 1000 V peak. The DCV input impedance is greater than 10^{10} ohms in the 100 mV to 10 V ranges and 10 M ohms in the 100 V and 1000 V ranges.

3-27. The measurement data can be displayed either as a 6½, 5½, 4½, or a 3½ digit reading, depending on the Number of Power Line Cycles Integrated (see Paragraph 3-61) and the Number of Digits selected (see Paragraph 3-63). Refer to Table 1-1 for accuracy specifications.

3-28. AC Voltage Measurement.

3-29. The -hp- Model 3456A uses a True RMS convertor and is able to measure voltages from 1 μV to 700 V RMS in four ranges: 1 V, 10 V, 100 V and 1000 V. All ranges are protected from input voltages up to 1000 V peak or 700 V RMS, whichever is less. Measurement data can be displayed either as a 6½, 5½, 4½, or a 3½ digit reading, depending on the selected Number of Power Line Cycles Integrated (see Paragraph 3-61) and the Number of Digits selected (see Paragraph 3-63). The frequency response of the convertor is from 20 Hz to 250 kHz with a maximum input voltage of 1000 V peak (700 V RMS, 10^8 VHz). The input impedance of the convertor is 1 M ohms shunted by < 75 pF. Refer to Table 1-1 for accuracy specifications.

3-30. AC+DC Measurement.

3-31. The AC+DC mode of the 3456A measures the combined ac and dc components of the input signal and displays its RMS value. Other operating characteristics are the same as the ACV function. Refer to Table 1-1 for accuracy specifications.

3-32. One use of the AC+DC function is to determine the necessary power rating of an amplifier. Since many amplifiers have ac signals with dc components, the true RMS value of those complex waveforms may need to be known. The AC+DC feature of the 3456A can simplify these measurements since it can measure the RMS value of the sum of the ac plus the dc voltage on the waveform.

3-33. Resistance Measurement.

3-34. The Model 3456A is capable of measuring resistance from 100 micro-ohm to 1 giga-ohm in eight ranges. The ranges extend from the 100 ohm full scale to the 1000 Meg-ohm full scale range. Resistance Measurement can be made using either the 2-wire or the 4-wire configuration. Refer to Figure 3-5 for the correct ohms connection.

3-35. Resistance Measurements can be displayed as either a 6½, 5½, 4½, or a 3½ digit reading, depending on the Number of Power Line Cycles Integrated (see Paragraph 3-61) and the Number of Digits selected (see Paragraph 3-63). The 4-WIRE ohm sense terminals are protected to a maximum level of 350 V peak. Refer to Table 1-1 for accuracy specifications.

3-36. The 3456A displays negative (minus) resistance under two conditions:

    a. The inputs to the 4 WIRE SENSE (RATIO REF) or the 2WRΩ/4WRΩ (VOLTS) terminals are reversed from each other in 4-wire ohms function.

    b. Small negative voltages on measuring circuitry.

NOTE

With the measuring leads shorting or when measuring small resistances, negative readings may be displayed due to offsets in the ohms circuitry.
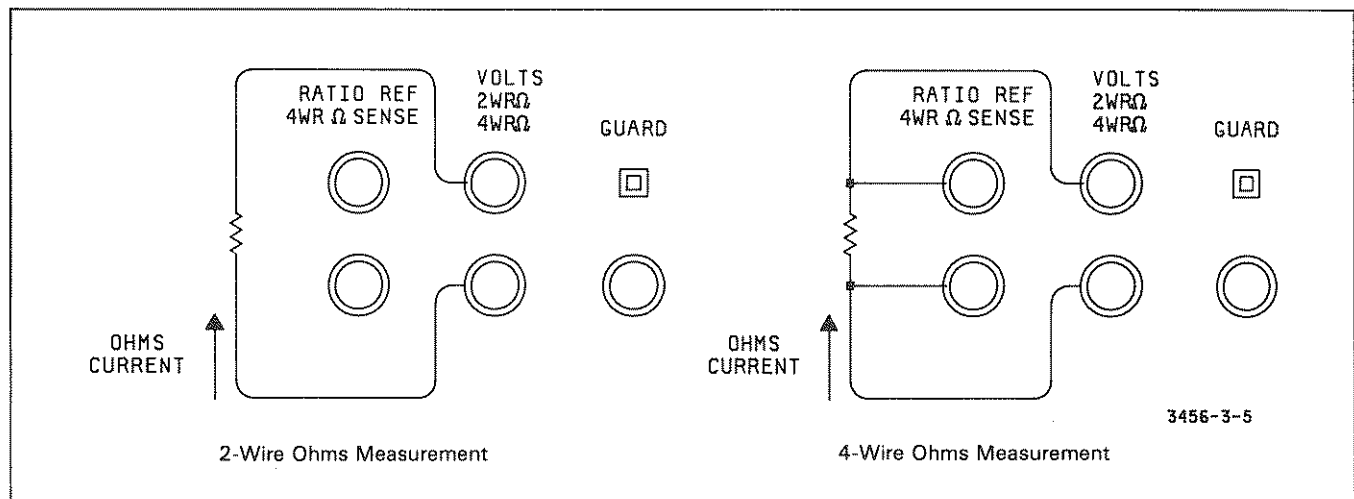

Figure 3-5. Ohms Connection.

NOTE

The 3456A's Analog Filter (see Paragraph 3-52) should not be used with any ohms functions. The filter is disabled when the ohms functions are selected from the front panel.

3-37. Shift Operation.

3-38. The purpose of the SHIFT button is to place the 3456A in the Shifted Functions. To disable the shifted functions, press the SHIFT button again. The SHIFT button's color is green and corresponds to the green lettering and symbols above the function buttons to identify shifted functions. All shifted functions readings are made by taking multiple measurements.

NOTE

The 3456A's Autozero feature (see Paragraph 3-48) is automatically enabled in front panel selectable shifted functions.

3-39. Ratio.

3-40. The -hp- Model 3456A can either make DCV/DCV, ACV/DCV, or ACV + DCV/DCV Ratio Measurements. This is done by taking a Signal, Reference High, and Reference Low Voltage reading which are all referenced to a common point, the VOLTS LOW terminal. The Signal Voltage is measured from the VOLTS HIGH terminal to the VOLTS LOW common. The Reference High Voltage is measured from the RATIO REF HIGH terminal to VOLTS LOW and the Reference Low Voltage is from the RATIO REF LOW terminal and VOLTS LOW. Refer to Figure 3-6 for a typical Ratio Measurement. Select the Ratio functions using the DCV, ACV, ACV + DCV function buttons in the shifted mode (press the SHIFT button). The green symbols above the function buttons identify the Ratio functions. Refer to Table 1-1 for accuracy specifications.
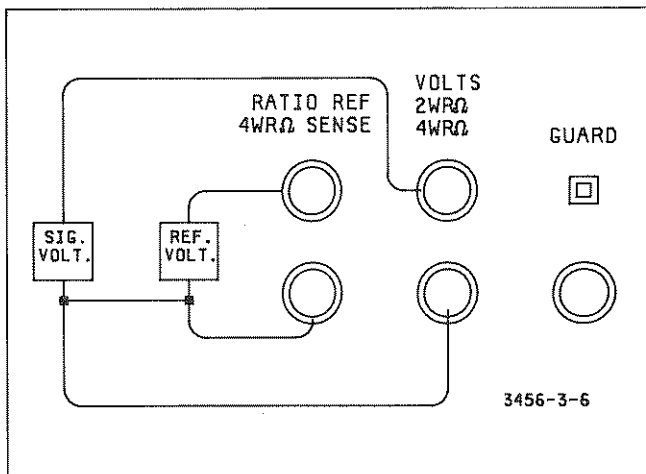

Figure 3-6. Ratio Connection.

a. Ratio Formula. A Ratio Measurement is a mathematical operation expressed in this formula:

$$\text{Ratio} = \frac{\text{Signal Voltage}}{\text{Reference Voltage}}$$

The 3456A Ratio Measurement formula is:

$$\text{Ratio} = \frac{\text{Signal Voltage}}{\text{Reference High - Reference Low}}$$

Remember, the three voltages are referenced to the VOLTS LOW terminal. The Reference Low voltage should be kept low for an accurate Ratio measurement (within ± 9% of Reference High Voltage). The voltage can be kept low by shorting or otherwise connecting the RATIO REF LOW and VOLTS LOW terminals to each other, either at the terminals or measuring point.

NOTE

For a three wire Ratio Measurement connect the REFERENCE LOW and VOLTS LOW terminals to each other.

b. Ratio Measurement. For a Ratio Measurement the Reference Voltage can be between 0 to ± 12 V dc. The 12 V level is the maximum Reference Voltage level the instrument is able to measure (the RATIO REF terminals are protected up to 350 V peak). The Signal Voltage, which is applied at the VOLTS terminals, can either be dc, ac, or ac + dc volts from 0 to 1000 V peak or 700 V RMS. In addition, the Analog Filter (see Paragraph 3-52) and Delay (see Paragraph 3-67) are not used for the Reference Measurement. These features can be selected for the Signal Voltage Measurement. The following is a typical Ratio Measurement procedure.

1. Measure your Signal and Reference Voltages and make sure they are within the range for a Ratio Measurement (refer to Table 1-1 for the limits). Use the instrument's unshifted functions for those measurements.

2. Connect the Reference Voltage between the HIGH and LOW REFERENCE terminals.

3. Connect the Signal Voltage between the HIGH and LOW VOLTS terminals and connect RATIO REF LOW to VOLTS LOW.

4. Set the 3456A to the desired range or to Autorange.

5. Place the instrument into the Ratio mode by pressing the appropriate button (DCV/DCV, ACV/DCV, or ACV + DCV/DCV in the shifted mode).

6. Read the Ratio reading on the display.

NOTE

It is important to remember that the RATIO REF LOW and VOLTS LOW terminals cannot be more than ± 12 V from each other.

c. Typical Ratio Measurement. Matching resistor values for an accurate voltage divider is one way to use the 3456A's Ratio feature. Try this by using the set up in Figure 3-7. Connect the instrument as indicated in the figure. Make sure that REFERENCE LOW is connected at the top of R2 and that Signal (Volts) Common is connected at the bottom of R1. Once the instrument is connected and placed in the DCV/DCV Ratio mode, a Ratio Measurement is made. The voltage drop across R1 and R2 is measured including any offset voltages between Signal Common and Reference Low. The offset voltage is used to compensate for any error causing voltages between the input and resistors. Once all the measurements are taken, the Ratio Measurement is displayed on the front panel. If the resistors are equal in value, the reading should be approximately "−1.00000".
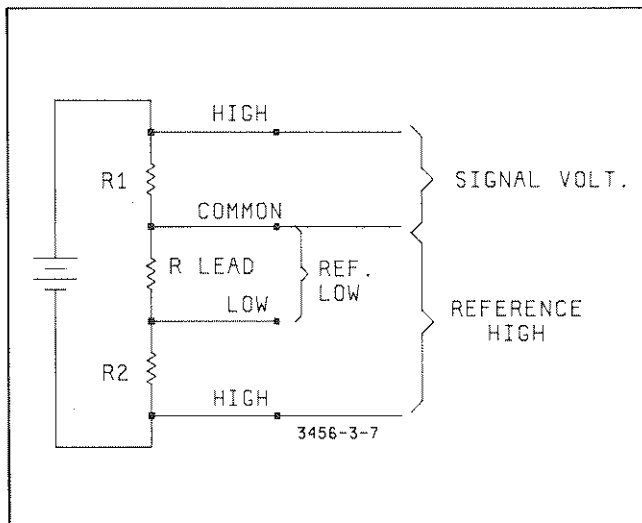

Figure 3-7. Typical Ratio Measurement.

3-41. Offset Compensated Ohms Measurement (O.C. Ohms).

3-42. This feature of the -hp- Model 3456A lets you take resistance measurements of components in the presence of small dc voltages. If this shifted function is selected, the instrument takes an ohms measurement and stores the reading into its internal memory. The ohms current source is then turned off and a dc reading is taken. This reading is subtracted from the previous reading and the resultant ohms reading is displayed on the front panel. Any small offset voltage on the measured component is compensated by the O.C. Ohms measurement. The maximum voltage level depends on the range selected (.01 V dc for the 100 ohm range, etc.). The O.C. Ohms ranges are from 100 ohm to 100 K ohm. Refer to Table 1-1 for the accuracy specifications.

NOTE

Due to internal switching in the 3456A, high capacitance(s) in parallel with the device or component being measured in the O.C. Ohms mode may cause erroneous readings.

3-43. You can use the O.C. Ohms feature of the 3456A to measure the contact resistance of a relay. Since some relay contacts may generate a small dc voltage (due to thermocouple effects), a normal ohms measurement technique may give incorrect readings. The O.C. Ohms feature subtracts this voltage from the ohms reading, and thereby gives an accurate resistance measurement of the relay.

3-44. Ranging.

3-45. The front panel range selection is controlled by three pushbuttons: the UPRANGE, DOWNRANGE, and AUTORANGE button. Their operation is as follows.

a. Uprange. The UPRANGE button's function is to set the 3456A to the next higher range, each time it is pressed. The highest selectable range depends on the function selected. For example, the 100 M ohm in the ohms function is not a valid range for the DCV or ACV functions and the 3456A defaults to the next highest valid range. The UPRANGE button is identified by an upward pointing arrow on its face.

b. Downrange. The function of the DOWNRANGE button is to set the 3456A to the next lower range, each time it is pressed. The lowest selectable range is the 100 mV or 100 ohms range. Similar to UPRANGE operation, the lowest range depends on the function. The ACV function, for example, has the 1 V range as the lowest range. If previously set to a lower range, the 3456A defaults to the 1 V range when the ACV function is selected. The DOWNRANGE button is identified by a downward pointing arrow on its face.

c. Autorange. With Autorange selected, the 3456A automatically selects the present reading's optimum range. Upranging is done when the reading is at or above 120% full scale. The downrange point is at or below 11% full scale. Try the following.

1. Place the 3456A into the Autorange mode; use a variable power supply and apply 1.0 V dc to the input. The range selected by the instrument is the 1 V range.

2. Increase the input voltage to > 1.2 V; the 3456A should then uprange to the 10 V range.

3. Decrease the input voltage to < 1.1 V; the instrument should then downrange back to the 1 V range.

d. Fast Autorange Feature. Autoranging by the 3456A is done quickly in both the upranging and downranging operations.

1. Upranging. When a voltage applied to the 3456A's input is higher than the range used at that time, an overload condition is detected. The overload condition is detected before the input measurement is complete. Upranging is done until the overload condition disappears and the optimum range is reached. Since the total measurement is never completed until the optimum range is reached, upranging is fast.

2. Downranging. Downranging is also done quickly by using a different method. When a non-overload measurement is made, the 3456A takes a complete measurement. Once the measurement is completed, the instrument then calculates the optimum range from the reading. A maximum of three ranges can be skipped at one time, enabling the 3456A to downrange quickly.

3-46. Instrument Trigger Modes.

3-47. The -hp- Model 3456A has four trigger modes: Internal Trigger, External Trigger, Single Trigger, and Hold. A description of each mode is as follows.

a. Internal Trigger. This trigger is internally generated by the 3456A and is used to initiate a measurement cycle. The instrument is placed into the Internal Trigger mode by pressing the INT (Internal Trigger) pushbutton located on the front panel. This trigger is also automatically selected when the RESET button is pressed and at turn on.

b. External Trigger. In the External Trigger mode, the instrument can be triggered by an externally applied trigger pulse. The pulse is applied to the External Trigger Input connector located on the rear panel and should be at least 500 nsec wide. The External Trigger Input is TTL compatible with actual instrument triggering occurring on the falling (negative) edge. By application of the pulse, the 3456A triggers and initiates a measurement cycle. After this cycle is completed, the instrument can be triggered again for a new cycle. If any triggering is done during the measurement cycle, the trigger is ignored until the cycle is completed. To start a new measurement, the 3456A has to be triggered again.

c. Single Trigger. The Single Trigger operation is similar to the External Trigger operation with triggering being accomplished by the front panel's SINGLE trigger pushbutton. Depressing the button first places the 3456A into the Signal Trigger mode (if the 3456A is in another trigger mode) and then triggers the instrument. A measurement cycle is then initiated. If the pushbutton is pressed again during the cycle, a new measurement cycle is started. The 3456A can be triggered again by depressing the SINGLE trigger pushbutton.

d. Hold. The Hold operation prevents the 3456A from accepting locally generated trigger commands, although an HP-IB trigger is accepted. Refer to the Remote Operation paragraphs for additional information on the HP-IB trigger.

3-48. Autozero.

3-49. The Autozero feature of the -hp- Model 3456A is used to compensate offsets in the dc input amplifier circuit of the instrument. Its main purpose is to correct for any zero drift in circuitry which may cause errors. The method used is to short the amplifier's input to circuit ground and take its offset reading. The reading is then stored in the instrument's internal memory and is later used to correct the following input measurement(s). Once the offset reading is taken, the short is removed and a regular input measurement is taken. As long as the Autozero feature is enabled, the 3456A takes an Autozero measurement and an input measurement. When the feature is disabled, an Autozero measurement is taken and is immediately stored into memory. No new Autozero measurements are made for the successive readings; only an input measurement is made. The stored Autozero reading is subtracted from the input measurement to correct the reading. Since only the input measurement is made, the 3456A's reading rate increases. This also makes the instrument more suitable for making measurements on high impedance circuitry, since no input switching is done. The 3456A's long term stability is affected (see Table 1-1) with the disabled feature, unless the Autozero reading is updated. Updating is done when any change in instrument state occurs. The only exception is that no updating is done by triggering, Front Panel SRQ, and HP-IB Local commands. The Autozero feature is enabled when the 3456A is first turned on and when pressing the RESET button.

3-50. Autozero Effects on 4-Wire Ohms Measurement.

3-51. The Autozero measurement is normally made with the input amplifier shorted to circuit ground. In the 4-Wire Ohms mode, the input amplifier is shorted to the 4-WRΩ SENSE Low terminal for the Autozero Measurement. With Autozero "ON", the Autozero reading is updated for each measurement cycle. With Autozero "OFF", the reading is not updated and causes an ohms measurement error if the measuring lead's impedance changes. To prevent this error, a new Autozero reading should be taken by changing or updating instrument state with the new measuring lead configuration. A disabled Autozero is useful in ohms measurements for a faster reading rate and where the 3456A's input switching may have affected the measurement.

3-52. Analog Filter.

3-53. The 3456A's Analog Filter is a 3 pole active filter with greater than 60 dB attenuation at frequencies of 50

Hz and higher. The filter is normally applied between the instrument's input terminals and input amplifier. An exception is when the 3456A is in the ACV or ACV + DCV unshifted or shifted functions. The filter is then applied between the output of the ac convertor and the input amplifier. In these modes, select the filter for accurate measurements below 400 Hz. Refer to Table 1-1 for the ACV and ACV/DCV accuracy specifications with the filter in or out. The Analog Filter is enabled (or disabled) by pressing the FILTER button.

3-54. NUMBERED KEYBOARD OPERATIONS.

3-55. Refer to Figure 3-8 for the 3456A's Numbered Keyboard selectable operations.

3-56. Storing Into Registers.

3-57. The next paragraphs explain the Number of Power Line Cycles Integrated, Number of Readings per Trigger, Settling Delay, and a variety of math operations. Except for math, other operations are changed by storing numbers into appropriate registers. The math operations are selected by pressing the appropriate math key. Table 3-2 gives a short description of the registers and math operations.
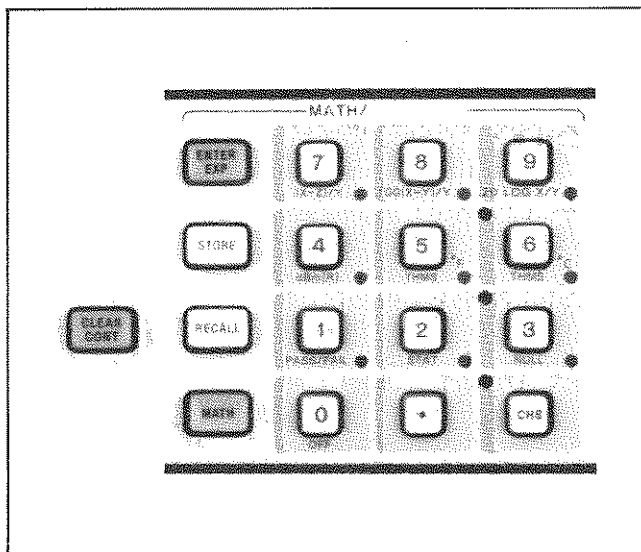

Figure 3-8. Front Panel Numbered Keyboard Area.

3-58. The Numbered Keyboard is very similar to those in pocket calculators with some keys performing more than two functions. Refer to the front panel. Note that the differences in key color, and the labeling above and below the keys determine the key's function. The blue color identifies the math operation, the white color identifies registers, and the black color identifies numbers, decimal point, and polarity. The white and blue color buttons located to the keyboard's left corresponds to the math and register operations.

3-59. Various LEDs on the keyboard annunciate which math function has been selected and which register contains a non-default number. For example, the LED next to the PASS/FAIL label lights if you select this math operation.

3-60. Storing numbers into registers:

a. Store. Numbers stored into registers changes the instrument's operation. For example, select the 100 Power Line Cycles Integrated mode (10 Line Cycles is the default value). To do this, "100" has to be stored into register N CYC INT. Try the following procedure.

1. Press the "1" key and the "0" key twice. These keys are on the Numbered Keyboard.

2. A "100" should now be displayed on the front panel.

3. Next press the white STORE button and then the CHS key (note, the white label above the CHS key is N CYC INT). The CHS key, which is normally the Change of Sign key, becomes the N CYC INT register key when the STORE button is pressed. (The CHS key is normally used to change the polarity of a number which is typed in from the keyboard, before storing into a register.)

4. The 3456A is now set to 100 Power Line Cycles Integrated. Use the same method to store numbers into the other registers.

Using this method you can select a six digit number (and a "1" as the overrange number) of any value and store it into a register. When a number is entered from the keyboard, the number is displayed before it is stored into a register. There is one important thing to remember when storing numbers. Some registers only accept certain numbers. The N DIG DISP (Number of Digits Displayed), for example, only accepts either a 3, 4, 5, or 6, since these are the only number of digits the 3456A can display. If you try to store an illegal number, Error 4 will be displayed.

NOTE

Since only a six digit number and overrange number can be entered, any additional numbers will be ignored.

b. EXP (Exponential). There are two ways to store numbers into registers using the Numbered Keyboard, Fixed Point and Floating Point. One way is to enter a number digit by digit and the other way is using the EXP (Exponential) key. A digit to digit entry looks like this: Enter "2". "0", "0", "0" to display "2000"

or

Enter "." "0", "2" to display ".02"

To enter the same numbers using the EXP key, first enter all of the number's significant digits and then press the ENTER EXP button. Once this is done, the displayed number is then stored into the desired register. The exponent can also be changed from a "+" to a "-" by pressing the CHS key. This is done before or after you enter the exponent and after pressing the ENTER EXP key. To enter "2000", do this:

Enter "2", press ENTER EXP key, and enter "3" displaying "2 + 3". The same as "2000"

To enter the number ".02" do this:

Enter "2", press the ENTER EXP button, enter "2", and press the CHS key displaying "2 -2". The same as ".02"

Table 3-2. Registers and Math Listing.

Key	Register	Registers Default Values	Description
CHS	N CYC INT	10	Used for changing and determining the Number of Power Line Cycles Integrated
·	VARIANCE	-00.000-3	Used for storing the varience value determined from Statistics Math Operation
0	MEAN	199999 + 9	Used for storing the Mean Value determined from the Statistics Math operation.
1	LOWER	-1999999 + 9	Used for storing the lower value for the Pass/Fail Math operation or the lowest reading taken in the Statistics Math operation.
2	UPPER	1999999 + 9	Used for storing the upper value for the Pass/Fail Math operation or the highest reading taken in the Statistics Math operation.
3	DELAY SEC	0	Used for changing and determining the 3456A's Settling Delay.
4	R	600	Used for storing the resistor value for the dBm Math operation or for recalling readings taken in the 3456A's Reading Storage mode.
5	COUNT	0	Used for storing the number of readings taken while in the Statistics Math operation.
1	N RD/TRIG	1	Used for changing and determining the Number of Readings taken or are to be taken per Trigger.
7	Z	0	Used for storing a number value for the Scale Math operation and stores the first statistics Reading.
1	Y	1	Used for storing a number value for the Scale and %Error Math operation.
9	N DIG DISP	5	Used for changing and determining the 3456A's Number of Digits Displayed.
Math			
CHS	—		
·	—		
0	OFF		Disables Math operation.
1	PASS/FAIL		Used to determine if a reading(s) is within set limits.
2	STATS		Used to calculate the Mean, Variance, Upper, Lower, and Count of a reading(s).
3	NULL		Used for offset compensation of the following reading(s) taken.
4	DBM		dBm calculation.
5	THMS F		Used in calculating a Thermistor reading(s) in degrees Fahrenheit.
6	THMS C		Used in calculating a Thermistor reading in degrees Celsius.
7	(X-Y)/Y		Used for the Scale calculation.
8	100 (X-Y)/Y		Used for the %Error calculation.
9	20 LOG X/Y		Used for the dB calculation.

NOTE

Pressing the EXP key before entering a number will display 1 + 0.

c. Recall. Any of the Registers can be recalled at any time. By pressing the RECALL button and the key for the Register to be displayed. (Remember, the registers are in white.) The Register's value is then displayed on the front panel.

d. Clear-Continue. The CLEAR-CONTINUE button, when pressed, clears the display and continues with the previous operation. This can be useful when accidently entering an incorrect number from the keyboard. The Clear-Continue feature clears the incorrect number and starts a new measurement cycle. This feature can also be used when a register is recalled and no changes in the register are desired.

3-61. Number of Power Line Cycles Integrated.

3-62. This feature of the -hp- Model 3456A allows you to select the integration time from .01 to 100 power line cycles in multiples of 10. Since a power line cycle of "1" has a time period of 1/60 second, 1/50 for the 50 Hz option, the intergration time is 1/60 or 1/50 second. The Number of Power Line Cycles Integrated determines measurement time. The slowest integration time of the 3456A is 100 Power Line Cycles Integrated and the fastest is .01 line cycles. For good power line frequency noise rejection (Normal Mode Rejection), use integration times of either 1, 10, or 100 power line cycles. Use the Store method in Paragraph 3-60 to select the various integration times (Number of Power Line Cycles). The default value of the Number of Power Line Cycles Integrated is 10 (at Turn-on and Reset).

3-63. Digits Displayed.

3-64. The 3456A can display either a 3, 4, 5, or 6 digit reading. Select any of these digits using the Store method in Paragraph 3-60. The Number of Power Line Cycles Integrated determines the maximum number of digits the 3456A can display. If the 1 to 100 Power Line Cycles Integrated are used, the 3456A can display from 3 to 6 digits. With .01 Integration Time the maximum number of digits then is 4 and with .1 Line Cycles Integrated the maximum is 5. Five is also the number of digits displayed at Turn-On or when the RESET button is pressed.

3-65. Number of Readings per Trigger.

3-66. The Model 3456A is capable of taking from 1 to 9999 Readings per Trigger. Selection of the Number of Readings per Trigger is accomplished by using the Store method in Paragraph 3-60. The selected number of readings are executed each time the instrument is triggered. Although the Internal, External, and Single Trigger modes will take the selected number of readings, it

may be advantageous to use the External or Single Trigger modes. Using these modes, if a Single Trigger is sent the 3456A starts taking the readings and stops when all the readings are taken. Another trigger repeats the same operation. An Internal Trigger also does the same thing, but automatically triggers again when all readings are taken. The default value of the Number of Readings per Trigger at Turn-On or at Reset is "1".

3-67. Settling Delay.

3-68. This feature of the -hp- Model 3456A can be used to delay the 3456A's input measurement for a preselected time, before a measurement cycle (A/D operation) is started. The amount of Settling Delay is selected by using the Store method in Paragraph 3-60. In some modes (ACV, OHMS, and Analog Filter), a delay value is selected by the instrument. These selected delays are defined in Table 3-3 and can be changed to another value by using the Store method. Any number value from .001 second to 999.999 seconds (including 0) can be chosen for a delay in any mode. To return a 3456A selected delay to its default value store any negative number into the DELAY register.

Table 3-3. Default Delays.

3456A Set-Up Condition	Delay (in second)
DCV, Filter On	.650
ACV or ACV + DCV, Filter Off	.060
ACV or ACV + DCV, Filter On	.800
Ohms, 100 K Range	.001
Ohms, 1 M Range	.008
Ohms, 10 M Range	.080
Ohms, 100 M Range	.080
Ohms, 1 G Range	.080

3-69. Optimizing the Reading Rate.

3-70. The previous paragraph stated that the Number of Power Line Cycles Integrated has an effect on the Number of Digits displayed. In addition to that, the measurement accuracy and power line frequency noise rejection (NMR) are also affected. You can select a faster reading rate with a low Number of Power Line Cycles Integrated. But keep in mind that the 3456A's measurement error increases and that the ability to reject power line frequency noise rejection is lessened. Table 3-4 gives some ideas on how to optimize the 3456A's reading rate.

3-71. MATH FEATURE.

3-72. A variety of math operations can be done by the Model 3456A. Use the instrument's Numbered Keyboard to select a math operation and to enter values into registers used by the math operations. Refer to the Numbered Keyboard for the following discussion and make sure you know how to store values into registers

Table 3-4. Optimizing Reading Rate.

OPTIMIZING YOUR READING RATE

Your maximum reading rate with the 3456A is influenced by a large number of factors, not the least of which is the signal you are trying to measure. These factors can be divided into two categories; signal related and voltmeter related. Among signal related factors are:

- desired accuracy (or resolution)
- nature of the signal (dcv, acv, or ohms)
- signal environment (line related and broadband noise)

Among voltmeter related factors are:

- method of measurement transfer (Packed Output, Reading Storage, System Output)
- number of convenience features selected (Math operations, Autorange)

For all operations, an equally important consideration is what you're trying to accomplished by measuring fast. Are you

- scanning a large number of points so that faster readings mean a better picture of what is happening at a single point in time?
- trying to read fast so that you do not use up valuable computer time waiting for the measurement operation to complete?
- trying to digitize waveforms?

The 3456A can solve these application problems in many different ways.

AT TURN-ON

For most bench and system applications, the preprogrammed settling times assure accurate readings regardless of the signal and signal environment. However, knowledge about your signal and/or signal environment can let you achieve up to 330 rds/s (at 60 Hz) with noise rejection and 10 microvolt sensitivity.

YOUR SIGNAL ENVIRONMENT

Your signal is subject to line related and broadband noise which can interfere with the measurement. There are two ways of rejecting noise on the 3456A; integration and input filtering.

Integration is a process where the affect of line related noise is averaged to zero over the period of an integer number of Power Line Cycles (PLC) during the A to D conversion. The basic integrator is an Op Amp with a (integrator) capacitor in its feedback loop. The signal is connected to the input of the Op Amp for a period of the line frequency. This configuration theoretically provides infinite noise rejection at integer multiples of the inverse of the integration period and single pole roll-off (20 dB of amplitude attenuation for every decade increase in frequency above the knee frequency) for broadband noise. Refer to the graph for more detail.

The input filter provides excellent noise rejection. The price you pay is an additional 650 ms settling time which allows the filter output to settle to a final value before the input is measured. The fastest possible reading rate measuring widely varying signals with line rejection is provided by 1 PLC integration time. But, if you are looking at a slowly varying signal or scanning similar signals, you can get faster readings by overriding the preprogrammed settling

time selecting 0.01 or 0.1 PLC integration time and the filter. The trade-off is less accuracy and resolution as well as more uncertainty about the filtered input.

SPEEDING THE MEASUREMENT CYCLE

The thermal stability of the measurement environment is important. By simply keeping the temperature of the 3456A at a fixed value, you can nearly double the reading rate by turning Auto Zero off. The 3456A is slightly less accurate but the faster reading rate may be worth it. In addition, any range, function, or filter change that takes place is automatically accompanied by an Auto Zero update which removes any accumulated offsets. Of course, if the measurement environment is quiet enough to omit NMR then only the accuracy and resolution of your desired measurement are the factors and you can achieve up to 210 or 330 rds/s with .1 and .01 PLC respectively (60 Hz).

Further, you can speed the measurement cycle by selecting a fixed range instead of using the Autorange function. Even at 1 PLC integration time there is a 10% reduction of the reading rate with Autorange on. Of course, if your signal is changing, Autorange is far faster than letting your software range the 3456A over the HP-IB.

AC Volts requires some special attention. With the filter off, you can measure signals of greater than 400 Hz frequency at a rate of 12 rds/s with the preprogrammed settling time of 60 ms. If you are monitoring a slowly changing ac signal or scanning similar signals, you can minimize the settling time to achieve up to 330 rds/s. Keep in mind that the input could change drastically before your readings would indicate a large change.

For signals of less than 400 Hz the input filter is connected in series with the ac converter to slow the signal response to the A to D converter. Again, you can override the preprogrammed settling time of 800 ms but beware! Large changes in the input signal level may let you read numerous wrong readings while the ac converter and the input filter are settling to a final value.

The 3456A can read resistance measurements as fast as dc volts up to the 10 K ohm range, but you can not use the input filter. Above the 10 K ohm range, additional settling time is required for stable resistance measurements. If all you want is an indication of the actual resistance above 10 K ohm, you can override the preprogrammed settling times. However, just considering the size of the resistance you are trying to measure and any associated stray capacitance in the measuring circuit, you may want to add settling time between reading for best accuracy.

Offset Compensated Ohms is very slow (10 rds/s) by comparison with a standard ohms measurement. But, for a single input reading, it is the fastest way to measure low value resistances accurately in the presence of thermally generated voltage offsets.

Before leaving the topic of Speeding the Measurement Cycle, it is important to ask why you would use 100 or 10 PLC integration times. The answer is increased accuracy and reduced internal noise. If you really need all the accuracy and repeatability you can get, the 100 PLC is the place you want to be.

SPEEDING THE READING TRANSFER

You might make many accuracy compromises to attain an acceptable reading rate and still not be able to read as fast

Table 3-4. Optimizing Reading Rate (Cont'd).

as you could. Why? Because you have not optimally handled the transfer of data over the bus from the 3456A to your computer.

Let's take a closer look at the reasons for fast reading rates:

- High speed scanning
- Data Throughput
- Waveform Characterization

HIGH SPEED SCANNING

Typical applications of high speed scanning include temperature and strain profiling where a large number of measurements must be taken very quickly to "freeze" the phenomenon at some point in time. For this type measurement, data transfer from the voltmeter to the computer is not really required to go fast. As long as the scanner data does not exceed 350 measurements, the built-in memory can store all the measurements for one scanned sequence and transfer the data at the end of acquisition. In conjunction with Reading Storage, three other 3456A features make high speed scanning particularily easy to do:

- Program Memory
- Voltmeter Complete
- External Trigger

Program Memory can be used to store a series of measurement sequences and operate on the acquired data. For example, in a high speed scanning situation you could acquire the measurements as fast as possible in the Reading Store mode. Flag the computer and then output the data, perhaps already scaled, in ASCII format. It is almost a 10 to 1 savings in time during acquisition and the results are just as easy to use as if you load, acquire, and transfer individual readings. Voltmeter Complete can be used to increment the scanner sequentially without software interaction between the voltmeter, the scanner, and the computer.

To close the loop, the scanner can output a signal to the 3456A's internal trigger. The result is that once the measurements are initiated by your computer there is no additional need for computer interaction until the measurement sequence is complete.

The fastest possible reading rate for any integration time is achieved when:

- Autorange, Auto Zero, Math, Display and Filter are off.
- Measurements are stored in the built-in memory using internal trigger and the packed format mode.

Since the packed mode and Display off are functions only available over the HP-IB, the maximum reading rate is achievable only with remote operation. If your trigger source is fast enough, external triggering is just as fast as internal triggering.

Transferring the measurements in packed format over the bus to a 9825A Calculator using a Fast Read/Write Buffer transfer reduces the maximum reading rate by 10% and you have to unpack the stored data. But, you can store many more measurements using the computer's memory.

DATA THROUGHPUT

The 3456A solves many of the data throughput problems because Reading Store and Program Memory remove the constant control necessity from the computer. The ability to flag the computer from the front panel of the 3456A,
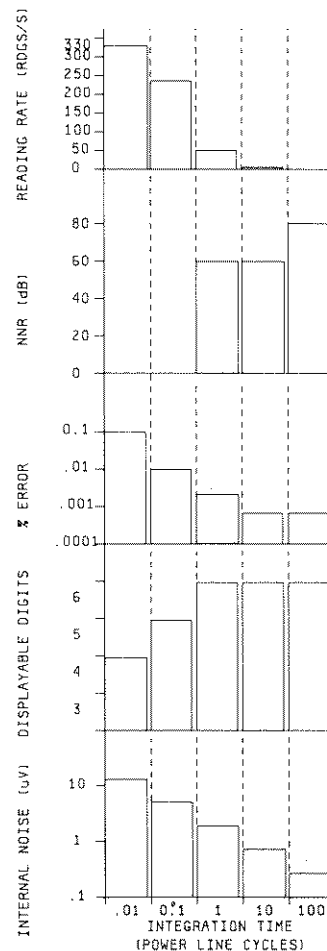
store measurement sequences in its memory, and flag the computer when it is done, lets you use both the 3456A and the computer to their best advantage. To avoid overrunning the computer with data from the 3456A, you can select the Systems Output mode which updates the output only after handshake.

WAVEFORM CHARACTERIZATION

The 3456A can digitize sinewaves up to about 100 Hz with fairly good accuracy. All the high speed modes must be used to acquire at least two samples per cycle. The Delay generator gives you about 1% timing accuracy.

Waveform characterization should be performed with a System Voltmeter. These voltmeters use a sample and hold technique which allows the waveform to be "frozen" at a well-defined point in time. An integrating-type voltmeter, like the 3456A, will always average the waveform over its integration period giving less accurate results. System voltmeters also typically have higher speed, greater bandwidth, and much more precise delay generation.

To summarize, let's look at the fastest reading rate set up again. Note that all convenience and accuracy features are eliminated and that the data is stored internally in the packed mode. This may not be right for your use. You may want a final answer which the Math functions could provide without computer interaction.

3456 TABLE 3-4

(read Paragraph 3-56). Figure 3-8, the Numbered Keyboard figure may also be helpful for the following discussion of the math operation. They are:

%Error
Scale
Pass/Fail (Limit Test)
dB
dBm
Null
Thermistor
    in Degrees C
    in Degrees F
Statistics
    Mean
    Variance
    Count
    Limits

3-73. Math operations can only be done on instrument acquired measurement data.

3-74. A Math operation is selected by first pressing the front panel's blue MATH button and then pressing the desired math key. The blue label below the front panel's numbered keys shows the various math operations. An LED, located to the center and below the display also lights when a math operation is selected. The registers used in the math operations are identified by the white labels above the numbered keys. The range of numbers you can store into the registers or use in math is from $\pm\ 0.000000 \times 10^{-9}$ to 1999999×10^9. The 3456A does, however, do internal calculations using 9 digit floating point numbers. If any of the math calculations are out of range, an "LL" is displayed. The following describes the 3456A's math operations.

3-75. %Error.

3-76. The %Error math feature of the 3456A can best be described by the formula:

$$\text{Results in percent} = \frac{X - Y}{Y} \times 100$$

where "X" is the present measurement value and "Y" is the value in register Y. This formula gives the percent difference between the reading taken by the 3456A and the value in register Y. The default (Turn-On or Reset)) value in register Y is 1. The %Error feature is selected by the "8" [100 (X - Y/Y)] key. Refer to Table 1-1 for the %Error accuracy specifications.

3-77. You can use the %Error function to determine the percent difference between an ideal voltage and a measured voltage. For example, you may wish to know the %Error of a 10 V dc measurement. The first thing to do is to store 10 into register Y. Then set the 3456A to the %Error math function and take a 10 V measurement. If the reading is exactly 10 V a "0" is displayed.

If the reading is, for example, 10.1 V, the result becomes:

$$\text{Result} = \frac{X - Y}{Y} \times 100 = \frac{10.1 - 10}{10} \times 100 = .01 \times 100 = 1$$

showing that the measured value is 1% higher than the ideal value. The number displayed on the front panel would be "1".

3-78. Scale.

3-79. The Scale feature of the -hp- Model 3456A lets you modify a measurement value by a selected value. The modification can be done either by addition, subtraction, multiplication, or division, depending on how the Scale function is used. The Scale mode is represented by the formula:

$$\text{Results} = \frac{X - Z}{Y}$$

where "X" is the present measurement value, "Y" is the value in register Y and "Z" is the value in register Z. The default (Turn-On/Reset) values in register Y and Z are 1 and 0, respectively. The Scale math feature is selected by the "7" [(X - Z)/Y] key. Refer to Table 1-1 for Scale accuracy specifications.

3-80. To do an addition or a subtraction, first enter a "1" into register Y. If you wish to perform an addition, enter a negative number into register Z. If a subtraction is desired, enter a positive number into register Z. The Scale formula then becomes:

$$\text{Results} = \frac{X - (\pm Z)}{1} = X - (\pm Z)$$

To perform a division, enter a "0" into register Z and the divisor value into register Y. The Scale formula then becomes:

$$\text{Results} = \frac{X - 0}{Y} = \frac{X}{Y}$$

Multiplication is performed by dividing the measured value by the inverse of the multiplier value (a fraction). Here again, a "0" is to be entered into register Z with the inverse value going into register Y.

3-81. Pass/Fail (Limit Test).

3-82. The Pass/Fail math operation can be used to make a voltage or ohms measurement and then determine if the reading falls within certain limits. The limits are selectable from the 3456A's front panel and should be stored into the instrument's UPPER and LOWER registers. Once the limits are stored and the Pass/Fail math operation is selected, the 3456A can then be set for a regular volts or ohms measurement. If the measured reading is within the selected limits, the reading will be

displayed. If the reading is above the upper limit, "HI" will be displayed. If the reading is below the lower limit, "LO" will be displayed. The default (Turn-On/Reset) values of the UPPER and LOWER registers are $+1999999+9$ and $-1999999+9$, respectively. The Pass/Fail feature is selected by the "1" (PASS/FAIL) key. Refer to Table 1-1 for the Pass/Fail accuracy specificaitons.

3-83. A way to use the Pass/Fail feature, is to make sure that a certain number of 1 K ohm resistors are within a 1% tolerance. To do this, you first should store the upper and lower accuracy limits into the 3456A's respective registers. In this case "1010" is stored into the UPPER register and a "990" is stored into the LOWER register. The next step is to select the ohms function and the 1 K ohms range. After you have done this, select the Pass/Fail math feature and start to measure the resistors one at a time. If the resistor value is within the 1% tolerance, in other words between 1.01 K ohms and .99 K ohms, the actual value of the resistor will be displayed on the front panel. "HI" will be displayed for any readings above 1.01 K ohms and "LO" will be displayed for any readings below .99 K ohms.

3-84. dB.

3-85. This feature of the 3456A is a Ratio Measurement of two voltages which is calculated and displayed in Decibels (dB). The dB formula is:

$$dB = 20 \text{ Log} \left| \frac{X}{Y} \right|$$

where "X" is the present measurement value and "Y" is the value in register Y. The default (Turn-On/Reset) value in register Y is 1. The dB feature is selected by the "9" (20 LOG X/Y) key. Refer to Table 1-1 for the dB accuracy specifications.

3-86. You can use the dB feature to measure the voltage gain of an amplifier. First measure the input voltage to the amplifier and store it into register Y. (You can store the reading directly into Y without re-entering the reading from the keyboard.) For this example a voltage reading of .1 V is assumed. The next step is to measure the amplifier's output voltage and set the 3456A to the dB math operation. The gain of the amplifier is then displayed in decibels. Assuming that the amplifier's output voltage is 10 V, the dB equation becomes:

$$dB = 20 \text{ Log } \frac{X}{Y} = 20 \text{ Log } \frac{10}{.1} = 20 \text{ Log } 100 = 40$$

giving you a gain of 40 decibles.

3-87. dBm.

3-88. The dBm feature of the 3456A is used to calculate a power ratio using a resistance as the reference. The

dBm equation is:

$$dBm = 10 \text{ Log} \left| \frac{X^2/R}{1 \text{ mW}} \right|$$

where "X" is the present measured value, "1 mW" is the power reference, and "R" is the resistance reference value to be entered by you. The default (Turn-On/Reset) value in register R is 600 ohms. The dBm math feature is selected by the "4" [dBm (R)] key. Refer to Table 1-1 for the dBm accuracy specifications.

3-89. The dBm feature can be used to measure the input power of a speaker. In this example we assume an 8 ohm speaker load and an input voltage of 10 volts. The formula now becomes:

$$dBm = 10 \text{ Log} \left| \frac{100/8}{.001} \right| = 40.97$$

giving you a value of 40.97 dBm.

3-90. Null.

3-91. The Null feature of the 3456A is described by the formula:

$$\text{Displayed Results} = X - X_1$$

where "X_1" is the first measurement taken after the Null feature has been selected and where "X" is the reading(s) after the first reading. When the "X_1" reading is first taken it is stored into register Z. That reading is then subtracted from the following reading(s) with the net present result displayed on the front panel. Since the first reading is stored in register Z, you can recall its value by recalling the register. The Null math feature is selected by the "3" (NULL) key.

3-92. The Null feature can be used to make more accurate 2-Wire Ohms measurements. To do this, short the input leads together at the measuring point and place the 3456A into the Null and 2-Wire Ohms mode. The first reading taken, which is the lead resistance, is stored into register Z. Remove the short from the input leads and take the unknown resistance measurement. The displayed reading is the total resistance measurement minus the lead resistance, giving you an accurate 2-Wire Ohms Measurement. The Null formula becomes.

$$\text{Unknown Resistance} = X - X_1 = X - R$$

where "X" is the total unknown resistance (including "R") and where "R" is the lead resistance.

3-93. Thermistor.

3-94. The 3456A makes temperature measurements using an externally connected thermistor, when selecting this mode. To correctly do this operation, set the 3456A

to the ohms function. It is advisable to first select an ohms range which corresponds closely to the resistance value of the thermistor for the temperature to be measured. When the Thermistor operation is selected, the ohms reading (thermistor resistance) is then calculated by the instrument and can be displayed either in degrees C or degrees F dependent on which math feature is selected. The Thermistor math operation with the results displayed in degrees C is selected by the "6" (°C) key. The "5" (°F) key is used for degrees F. Refer to Table 1-1 for the Thermistor accuracy specifications. The recommended Thermistor can be ordered by -hp Part Number 0837-0164. A package of 4 thermistors is also available under Accessory Number 44414A. The thermistor's corresponding resistor value at high and low temperature limits and at nominal room temperature is:

Temperature	Resistance
150°C	92.7 Ohms
25°C	5000 Ohms
-80°C	3684 K Ohms

3-95. Keep a couple of things in mind when using the Thermistor mode. Choosing an optimum ohms range for the termperature measurement has been mentioned in the preceding paragraph. This is important for a stable reading. You can use other ranges or autorange, but the reading may be unstable. To demonstrate this, choose a high ohms range for the thermistor. An ohms reading is still taken and the temperature is still calculated; but since a higher range is more sensitive for low ohms values, the reading is not as stable. Autorange may have the same effects, since there may be a difference from range to range. Another thing to keep in mind is lead resistance. If 2-Wire Ohms is used, any lead resistance is added to the thermistor resistance causing an inaccurate temperature reading.

3-96. Statistics.

3-97. The Statistics math feature of the -hp- Model 3456A is used to make a Mean and Variance calculation of reading(s) taken in any function. These calculations are made when the instrument is set to the Statistics (STAT) mode and after a measurement cycle is completed. The Mean value is then stored into the MEAN register with the number of readings taken stored into the COUNT register. The Variance value is stored into the VARIANCE register with highest reading taken stored into the UPPER register and the lowest reading into the LOWER register. In addition, the first reading taken is also stored into register Z. Except for the Variance calculation, all other statistics calculations are done after the first measurement cycle is completed. The Variance calculation needs at least two readings to calculate its value. The default values of the MEAN, VARIANCE, COUNT, UPPER, LOWER, and Z registers are 199999 +9, −00.000 −3 (0), 0, 1999999 +9, −1999999 +9, and 0 respecitvely. The Statistic

mode is selected by the "2" (STAT) key. To reset the registers to their default values without pressing the 3456A's RESET button or cycling power, select the statistics function again by pressing the MATH button and STAT key. Refer to Table 1-1 for the Statistics Accuracy Specifications.

<div align="center">NOTE</div>

Since the math calculations are made to 9 digits, certain accuracy limitations as shown in Table 1-1 should be kept in mind.

3-98. **Mean.** The Mean (Average) value is calculated by the formula:

$$\text{Mean (M)} = X_1 + \frac{1}{C} \sum_{i=1}^{C} (X_i - X_1) = \overline{X}$$

Where "X_i is the "ith" reading taken after enabling statistics, "X_1" is the first reading taken after enabling Statistics, and "C" is the total number of readings taken with the present reading (X) displayed on the front panel. The present Mean value is in the MEAN register and it, along with the other registers used in the Statistics mode, can be recalled at any time by recalling the appropriate register.

3-99. **Variance.** The Variance value is calculated by the formula:

Variance (V) =

$$\frac{\sum\limits_{i=1}^{C} (X_i - X)^2 - \frac{1}{C} \left[\sum\limits_{i=1}^{C} (X_i - X_1) \right]^2}{C - 1}$$

Where "X_i" is the "ith" reading taken after enabling statistics, "X_1" is the first reading taken after enabling Statistics and "C" is the total number of readings taken with the present reading (X) displayed on the front panel. The present Variance value is in the VARIANCE register and it, along with the value(s) in the other register(s), can be recalled at any time by recalling the appropriate register.

3-100. **Statistics Example.** One way to use the Statistics feature is to calculate the average value of a number of resistors. Start by setting the 3456A to the ohms function and Single Trigger mode. Then select the Statistics Math mode. Next connect the first resistor to the input terminals and trigger the instrument (push the SINGLE trigger button). Do the same for the other resistors after the measurement cycle is completed. When all of the resistors are measured, you can determine the average value of the resistors by recalling the MEAN register. The Variance of the register values can be recalled by the VARIANCE register. To doublecheck the number of resistors you have measured, recall the COUNT

register. For the lowest value, recall the LOWER register and the UPPER register for the highest value.

3-101. READING STORAGE.

3-102. The Reading Storage feature of the 3456A allows you to store into the instrument's internal memory a certain number of readings. The memory size is 1400 bytes and since each reading takes 4 bytes of memory up to 350 readings can be stored, depending on available memory space. This is because the Program Memory Operation of the 3456A (see Paragraph 3-200) also uses the internal memory and, if used, reduces memory space allowing fewer readings to be stored. The number of storable readings can be determined by this formula:

Memory Size - Memory Used = Memory Available
(rounded off to the lowest value)

For example, if you use 85 bytes of memory for the Program Memory operation the total number of readings you can store is:

$$\frac{1400 - 85}{4} = 328.75$$

allowing you enough space for 328 readings.

3-103. The Reading Storage feature is enabled by pressing the front panel's RDGS STORE button. The LED next to the button then lights and the instrument starts storing a reading when triggered. The LED turns off when the feature is disabled or when the 3456A's internal memory is full. To turn the Reading Storage feature off, press the RDGS STORE button a second time. The readings in the memory are cleared when the Reading Storage is first turned on and the 3456A is triggered, by the Self Test mode, and at Turn-On.

3-104. Readings are stored into memory with the most recent reading as reading #1 and the preceding readings as #2, #3, and so on. For example if you take 350 readings, the reading taken after enabling the feature is #350 and the last reading taken is #1. The reading order is important to keep in mind when recalling the reading(s). Any or all of the readings can be recalled either one at a time or they can be scrolled. These two methods operate as follows.

a. Recalling Single Readings. To recall a single reading from memory

1. Set the 3456A to Trigger Hold and then turn Reading Storage on. The Trigger is set to Hold because a trigger restarts the Reading Storage, when enabled, and the previously stored readings are cleared.

2. Next store the number corresponding to the reading you wish to recall into register R (use store method in Paragraph 3-60).

3. Then recall the R register (by pressing the RECALL button and key "4").

The reading is then displayed on the front panel. When you press the RECALL button again without pressing the "4" key, the following reading is then displayed. Press the button again and the next reading is displayed, and so on. Try the following example in which reading #3 through #1 are recalled.

1. Press the HOLD trigger button and then press the RDGS STORE button.

2. Store "3" into register R by pressing the STORE button and then key 4.

3. Recall the register by pressing the RECALL button and key 4. Reading #3 is now displayed on the front panel.

4. Press the RECALL button again and reading #2 is displayed.

5. Reading #1 is next displayed when the RECALL button is again pressed.

b. Scroll Readings. This procedure is very similar in recalling a single reading. The only difference is that the reading number is entered into register R as a negative number. When that register is then recalled the reading which corresponds to the stored number is then displayed. The display time is determined by the DELAY register value. The next reading is then displayed and then the next reading and so on. Since the time between readings is very short and makes it impossible to see the readings, store a delay into the DELAY register. A 1 second delay, for example, will display each reading for 1 second. The last reading to be displayed is reading #1 and remains until the 3456A's operation is changed.

3-105. The 3456A can also perform other operations while recalling readings. When recalling a single reading, the reading number is displayed before displaying the actual reading. But since the display time is determined by the value in the DELAY register, the reading number may not be seen. Here again, a delay has to be stored into the DELAY register. The reading number is then displayed for a time determined by the delay. Another operation you can do is to select a math operation while the recalled readings are scrolled. For instance, select the Statistics math operation to find the Mean, Variance, Upper, Lower, and Count values of the stored readings. An example on how to use this feature with 350 stored readings is as follows.

a. Press the HOLD trigger button and then the RDGS STORE button.

b. Enter "-350" into the R register to scroll the readings starting with reading #350.

3-17

c. Select the Statistics math operation by pressing the MATH button and then the "2" (STAT) key.

d. Recall the R register by pressing the RECALL button and then the "4" (R register) key. The scrolled readings should now be displayed.

e. When the scrolling is completed (no updating of the display), the reading's Mean, Variance, and Count values can now be determined by recalling register MEAN, VARIANCE, and COUNT respectively.

3-106. VOLTMETER COMPLETE.

3-107. The voltmeter complete connector is a BNC connector which outputs a sync signal during the measurement cycle . The signal itself is composed of an approximately 330 nanosecond wide negative going TTL level pulse. One way to use the sync signal is to advance a scanner, like the -hp- Model 3497A. To do this, connect the 3456A's voltmeter complete output to the scanner's channel advance input. Once the connection is made, the scanner advances to the next channel during the 3456A's measurement cycle. The voltmeter complete output is designed to drive at least one TTL input.

3-108. GUARDING.

3-109. General.

3-110. The Guarding Terminals on the -hp- Model 3456A can be used to reduce or cancel error causing common-mode voltages. Figure 3-9 gives three methods of making guard connections. A Guard Terminal on the 3456A is used to make the connections. Both the front panel and the rear panel have a Guard Terminal. For most measurements the terminal should be connected to the common (Low) input terminal. This is done internally in the instrument when the Guard Switch is in the IN position. Each of the Guard Terminals use a separate switch for a connection to each of the common terminals, with the switches located above their respective Guard Terminals.

3-111. Guarding Information.

3-112. Detailed information on guarding methods and the purpose of guarding can be found in -hp- Application Note Number 123, "Floating Measurements and Guarding". This application note is available through your nearest -hp- Sales and Service Office.

3-113. FRONT/REAR SWITCH LOCKOUT.

3-114. The Model 3456A is provided with an interlock for the Front/Rear Switch. This has been provided for you to lock the switch either for the front or rear terminals, preventing any quick changes from front to rear. The switch is locked in the front position when the arrow marked on the lock is pointing toward the FRONT lettering. In the rear position the arrow is point

3-18

to the REAR lettering. A procedure to install and remove the lock is given in Appendix B.

3-115. REMOTE OPERATION.

3-116. General.

3-117. The following gives instrument dependent information necessary to remotely operate the -hp- Model 3456A over the Hewlett-Packard Interface Bus (HP-IB). Directions for mechanical interface connections to the HP-IB are given in Section II (see Paragraph 2-18) of this Manual. You should be familiar with the front panel (local) operation of the instrument before attempting to use the 3456A in the remote (HP-IB) operating mode. The front panel operational information is located in the Operating Characteristics paragraphs (starting with Paragraph 3-10) in this section of the Manual.

NOTE

HP-IB is Hewlett-Packard's implementation of IEEE Std. 488-1975, "Standard Digital Interface for Programmable Instrumentation".

3-118. HP-IB Description (in Appendix A).

3-119. A general description of the HP-IB is in this Manual's Appendix A. Refer to it for any non-3456A related HP-IB information. Included in the appendix is a worksheet you can use to tabulate the 3456A's HP-IB capabilities and of other Bus compatible devices. It is assumed, in the following paragraphs, that you are knowledgeable about the HP-IB.

3-120. 3456A Response to Bus Messages.

3-121. The following paragraphs deal with the implementation of the HP-IB using the 3456A. The instrument's Bus capabilities are listed in Table 3-5. The following also explains the 3456A's response to Bus Messages, also known as Meta Messages.

Table 3-5. Interface Functions.

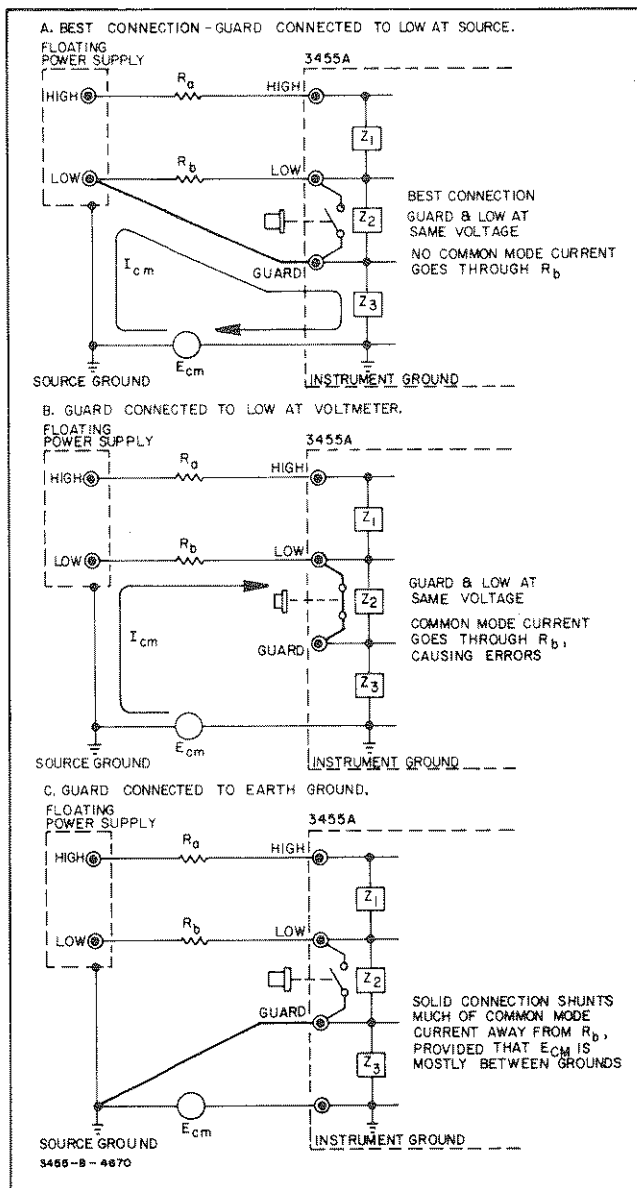| Mnemonic	Interface Function Name
SH1	Source Handshake Capability
AH1	Acceptor Handshake Capability
T5	Talker (Basic Talker, Serial Poll, Talk Only Model, Unaddressed to Talk if Addressed to Listen)
L4	Listener (Basic Listener, Unaddressed to Listen if Addressed to Talk)
SR1	Service Request Capability
RL1	Remote/Local Capability
PPO	No Parallel Poll Capability
DC1	Device Clear Capability
DT1	Device Trigger Capability
CO	No Controller Capability
E1	Open Collector Bus Drivers

Figure 3-9. Guard Connection.

3-122. Data.

3-123. The Data Message is used to transfer information between the 3456A and the controller. It is used either to send data or receive data. A description is as follows.

a. Send Data is the 3456A's set up information (set to DCV, etc.). The instrument has to be in Remote and Listen (a listener) and the controller a Talker.

b. Receive Data is the 3456A's output. This includes readings and instrument status. To send the data, the 3456A is the talker and the controller is a listener.

3-124. Trigger.

3-125. The Trigger Message causes the 3456A to initiate

a measurement cycle. It is an HP-IB Trigger and triggers the instrument in any front panel Trigger mode, since it has priority over other trigger conditions. If the 3456A is triggered during a measurement cycle, the cycle is aborted. If the instrument is executing a measurement cycle, it will be aborted upon receipt of a Bus Trigger. The 3456A has to be programmed to "listen" to execute the trigger.

3-126. Clear.

3-127. The Clear Message sets the 3456A to the turn-on state. This action is similar to pressing the RESET button on the instrument's front panel. The Clear, Turn-On, and Reset differences are listed in Table 3-6.

Table 3-6. 3456A Clear, Home, and Reset Differences.

	Status Byte Byte Reset	HP-IB Address Reset	Hardware Reset	Program Memory and Reading Storage Clear	Time
Power-On	Y	Y	Y	Y	= 3 sec
Reset	Y	Y	N	N	< .5 sec
Clear	Y	N	N	N	< 5 msec
Home	Y	N	N	N	< 5 msec
Note: Y = YES, N = NO					

3-128. Remote.

3-129. The 3456A is in the local front panel mode when first turned on. A Remote Message allow the 3456A to be controlled over the HP-IB. In Remote, the front panel controls are disabled (except the LOCAL button) and are then controllable over the HP-IB. The instrument's initial set up is determined by the front panel setting before being placed in remote.

3-130. Local.

3-131. This message clears the remote operation of the 3456A and enables the front panel operation. Pressing the front panel LOCAL button also sets the instrument to local, provided the button has not been disabled by the Local Lockout Message (see next paragraph).

3-132. Local Lockout.

3-133. This message disables the 3456A's Local Front Panel controls, including the LOCAL button. The message is in effect until the message is cleared over the HP-IB or power is cycled.

3-134. Clear Lockout and Set Local.

3-135. This message places the 3456A to local and clears the Lockout.

3-136. Require Service (SRQ).

3-137. The Require Service Message (SRQ) is indepen-

dent of all other HP-IB activity and is sent on a single line called the SRQ line. Its state is either true or false, with low being true and high being false. When the Require Service Message is sent and more than one device on the HP-IB has the capability to send this message, the user must decide which device is sending the message. This is done by conducting a "Serial Poll" for the device(s) on the Bus. The device polled responds by sending a Status Byte. The Status Byte indicates whether the device has requested service and if so, for what reason. If the device polled shows that it did not send the Require Service Message, the other devices would typically be polled. Paragraph 3-140 describes the 3456A's Status Byte.

3-138. When the 3456A sends a Require Service Message, the front panel SRQ LED is on. The message and LED are cleared when the 3456A is polled, although some of the messages are cleared by the instrument (i.e. Front Panel SRQ, Program Memory Complete, and Data Ready). The following are the conditions that can cause a Require Service Message.

Front Panel SRQ (can be cleared by the 3456A)
Program Memory Execution Complete (can be cleared by the 3456A)
Data Ready (can be cleared by the 3456A)
Trigger Too Fast
Illegal Instrument State/Internal Error/Syntax Error
Program Memory Error
Limits Failure

3-139. The 3456A requires service only if told to do so. It has to be programmed to output the Require Service Message for the previously listed conditions. This is done by setting the Service Request Mask. The mask is set by sending certain program codes to the 3456A and is explained in Paragraph 3-169.

3-140. Status Byte.

3-141. The Status Byte Message is output by the 3456A in response to a Serial Poll. Each bit represents a message. Table 3-7 lists the bits which are defined as follows.

NOTE

Remember to set the SRQ mask to output the Require Service Message.

a. Front Panel SRO. A Require Service Message can be output when pressing the 3456A's front panel SRQ button. The button is only enabled in Local operation.

b. Program Memory Execution Complete. A Require Message is output when the 3456A's internally programmed operation, called Program Memory, is completed. Information on the Program Memory Operation is in Paragraph 3-200.

Table 3-7. Status Byte Definition.

Octal Code	Decimal Code	Bit	Definition
101	65	0	Front Panel SRQ - When the front panel SRQ button is pressed, this Require Service is output. Pressing the button a second time will clear the Service Request.
102	66	1	Program Memory Execution Complete -Indicates to the controller that all the program codes in the 3456A's internal memory are executed. The Require Service condition is cleared when the Program Memory is executed again.
104	68	2	Data Ready - Indicates to the controller that measurement data is ready to be output. The Require Service is cleared when a new measurement cycle is initiated.
110	72	3	Trigger Too Fast - Indicates that the 3456A was triggered while executing a measurement cycle. This only occurs in External Trigger.
120	80	4	Illegal Instrument State - Indicates that the 3456A is unable to do an operation because of an invalid set-up (e.g. 10 M ohm range in DCV) Internal Error - Indicates a failure in the 3456A Syntax Error - Indicates to the controller that invalid Program Code(s) where sent to the 3456A (e.g. code F9)
140	96	5	Program Memory Error - Indicates that the Program Memory Execution command or the Test function was stored in memory, or an overflow of memory occurred while loading into memory.
300	192	7	Limits Failure - Indicates that the Pass/Fail measurement made is out of the selected limits.

Note: Bit 6 is not in this table, because it is the SRQ bit.

c. Data Ready. A Require Service Message is output when the 3456A's measurement cycle is completed (e.g. a DCV reading is taken). More information on Data Ready is in Paragraph 3-206.

d. Trigger Too Fast. This Require Service Message is output if the 3456A is triggered while outputting data over the HP-IB. This can only be caused by the External Trigger.

e. Illegal Instrument State/Internal Error/Syntax Error. This Message is output for the following conditions:

1. Illegal Instrument State. An Illegal Instrument State is when the 3456A is, for example, unable to complete internal operations. An example is programming the instrument to the 10 M ohm range while in the DCV function. This range is invalid in the DCV function.

2. Internal Error. An Internal Error occurs is when a digital failure occurs in the 3456A. If this may happen, refer the instrument to a Service Trained Person.

3. Syntax Error. A Syntax Error is when invalid programs codes are sent to the 3456A. An invalid program code is F9.

f. Program Memory Error. This error occurs under the following two conditions.

1. When trying to execute the program memory from memory (program codes X1 in program memory) and when enabling the Internal Test from memory (program codes TE1 in memory). Both conditions terminate the Program Memory Operation.

2. When exceeding internal memory space during program memory loading (storing more than 1400 bytes into memory).
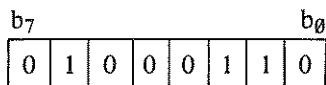
g. Limits Failure. A Limits Failure occurs when a limit is exceeded in the 3456A's Pass/Fail math operation. More information on the Pass/Fail feature is in Paragraph 3-81.

3-142. The Status Byte Message in Figure 3-10 is represented in octal code. Each bit, except for bit 6, indicates a particular Require Service condition. Bit 6 (seventh bit) is the Service Request bit and is true when service is required. The bit lets the controller know that a Require Service condition exists. Remember, set the SRQ mask to output the Require Service Message.

3-143. If the SRQ mask has been set for more than one condition, more than one bit of the Status Byte Message may be true. For example:

a. A Require Service condition sets bits 1, 2, and 6 true. (Remember, bit 6 is true for any Require Service.) The conditions are caused by Program Memory Execution Complete and Data Ready.
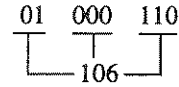
b. The Status Byte looks like:

b_7 b_0

0	1	0	0	0	1	1	0

NOTE

A "1" in this example indicates a true condition.

c. The byte is output in octal code and the corresponding octal number is:

$$\underbrace{01}\ \underbrace{000}_{106}\ \underbrace{110}$$

The resultant decimal number of octal 106 is 70.

3-144. Status Bit.

3-145. The 3456A does not respond to a Parallel Poll.

NOTE

The Status Bit is not part of the Status Byte Message and should not be confused with the bits in the Status Byte Message.

3-146. Pass Control.

3-147. The 3456A does not have controller capabilities.

3-148. Abort (Interface Clear).

3-149. All HP-IB communication is terminated, including the 3456A's Bus communication. Control is returned to the system controller. The Abort Message does not remove the 3456A from remote control.

3-150. 3456A Addressing.

3-151. HP-IB requires that a device on the Bus needs to be identified as a Listener or a Talker, in order to execute the Bus Messages and commands. Because of this requirement, each device on the HP-IB has a unique "listen" and "talk" address to distinguish themselves from each other. The device is then able to receive programming instructions when addressed to listen or sent data when addressed to talk.

3-152. The 3456A's address is set by the address switch located at the instrument's rear panel. The switch is a seven section "DIP" switch with five switches used for

			b7	b6	b5	b4	b3	b2	b1	b0		

Limits Failure ———
Service Request ———
Program Memory Error ———
Illegal Instrument State ———
Internal Error ———
Syntax Error ———

——— Front Panel SRQ
——— Program Memory Execution Complete
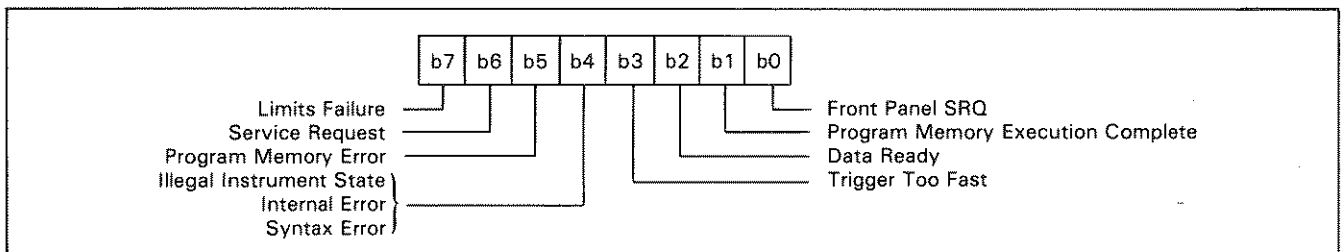——— Data Ready
——— Trigger Too Fast

Figure 3-10. Status Byte.

address selection, as shown in Table 3-8. The sixth switch is not used and the seventh switch sets the instrument to the "Talk-Only" mode (see Paragraph 3-154). The 3456A's allowable address settings are listed in Table 3-8. Its factory address setting is a listen address of 22 decimal (ASCII character "6") and a talk address of 54 decimal (character "V").

NOTE

Setting the 3456A's Address Switch to the Listen Address' corresponding decimal code will also set the Talk Address.

3-153. Instrument address commands are usually in this form:

universal unlisten, device talk, device listen.

Table 3-8. 3456A Address Codes.

```
                    INSTRUMENT
                     ADDRESS
          TALK      ┌───────┐
          ONLY     5         1
                    · · · · ·

              ┌──────────────────┐
              │ ▯ ▯▯▯▯▯ ▯ │
              └──────────────────┘

0 POSITION (DOWN)                  1 POSITION (UP)

              NOT USED
```

ASCII Code Character		Address Switches					5-bit Decimal Code	
Listen	Talk	A5	A4	A3	A2	A1		
SP	@	0	0	0	0	0	00	
!	A	0	0	0	0	1	01	
''	B	0	0	0	1	0	02	
#	C	0	0	0	1	1	03	
$	D	0	0	1	0	0	04	
%	E	0	0	1	0	1	05	
&	F	0	0	1	1	0	06	
'	G	0	0	1	1	1	07	
(	H	0	1	0	0	0	08	
)	I	0	1	0	0	1	09	
*	J	0	1	0	1	0	10	
+	K	0	1	0	1	1	11	
,	L	0	1	1	0	0	12	
–	M	0	1	1	0	1	13	
.	N	0	1	1	1	0	14	
/	O	0	1	1	1	1	15	
0	P	1	0	0	0	0	16	
1	Q	1	0	0	0	1	17	
2	R	1	0	0	1	0	18	
3	S	1	0	0	1	1	19	
4	T	1	0	1	0	0	20	
5	U	1	0	1	0	1	21	3456A
6	V	1	0	1	1	0	22◄	FACTORY
7	W	1	0	1	1	1	23	Setting
8	X	1	1	0	0	0	24	
9	Y	1	1	0	0	1	25	
:	Z	1	1	0	1	0	26	
;	[	1	1	0	1	1	27	
<	\	1	1	1	0	0	28	
=	]	1	1	1	0	1	29	
>	~	1	1	1	1	0	30	

The universal unlisten command removes all listeners from the HP-IB to allow only the addressed listener to receive information. The information is sent by a talker which is designated by the device talk code.

3-154. Talk-Only (No Controller).

3-155. Setting the 3456A to the "Talk-Only" mode can provide measurement data to another device, like a printer, without a Bus controller. The 3456A is placed to the "Talk-Only" mode by setting the rear "DIP" switch to the mode (set the seventh switch to "1"). Once this is done measurement data is output after each trigger. Instrument set up (function, range, etc.) is done from the front panel.

3-156. 3456A HP-IB Programming.

3-157. Now that the basic HP-IB operation is known, the next thing is to program and use the 3456A over the Bus. First, determine the measurement or instrument operation you want. Then determine the 3456A's program codes. The codes are ASCII characters transmitted over the HP-IB to the instrument.

3-158. Once you have defined the instrument criteria and program codes, next write an algorithm on how to make the measurement. When you have done this, convert the Algorithm to controller language. Refer to your controller's operating manual for the language.

3-159. Algorithm.

3-160. The algorithm should show exactly how to set up and use the instrument in a certain function. To simplify the algorithm, use the twelve Bus Messages as key words in the algorithm. The messages are repeated here for your reference.

1. DATA
2. TRIGGER
3. CLEAR
4. REMOTE
5. LOCAL
6. LOCAL LOCKOUT
7. CLEAR LOCKOUT AND SET LOCAL
8. REQUIRE SERVICE
9. STATUS BYTE
10. STATUS BIT
11. PASS CONTROL
12. ABORT

3-161. The definitions of the Bus Messages are given in this manual's Appendix A, Paragraph A-11. Remember, refer to your controller manual to convert the messages. If you have an -hp- Model 9825A Controller, the controller's Extended I/O Manual (-hp- Part Number 09825-90025) has a listing of the codes. For the 9835A/B, refer to the I/O Programming Manual (-hp- Part Number 09835-90060). If your controller manual does not have a code conversion chart, you may be able

to use the technical description of the messages located in Appendix A.

3-162. Here is an example Algorithm for the 3456A. Note that only the key words are used, not the codes.

 a. In this algorithm, the 3456A is set up to make a DCV measurement, output it over the HP-IB and print the reading. The program ends if the 3456A sends a Require Service Message. The algorithm is as follows.

1. ABORT all previous operations

2. Set the 3456A to REMOTE

3. CLEAR the 3456A

4. LOCAL LOCKOUT the Instrument

5. Send DATA to set up the 3456A to

 a) the dc function
 b) autorange
 c) hold trigger
 d) set SRQ mask to Illegal Instrument State, Internal Error, and Syntax Error.

6. TRIGGER the 3456A

7. Send the measurement DATA to the controller and store in a variable

8. Check the 3456A to see if it REQUIRE's SERVICE

9. If REQUIRE SERVICE, check the STATUS BYTE; otherwise skip the next step

10. If the 3456A sent the STATUS BYTE, it did REQUIRE SERVICE and the program is ended

11. Print out the DATA from the variable

12. CLEAR LOCKOUT AND SET LOCAL
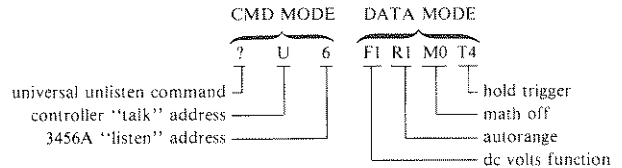
13. End program

3-163. Programming the 3456A over the HP-IB.

3-164. Programming the 3456A is done by DATA messages. Remember, DATA is sent or received. The DATA received by the 3456A is for instrument set up (function, range, etc.). The DATA sent by the 3456A is output data. Included in the following paragraph are programming examples of the Bus Messages and the algorithm. They are given in the HP-IB format, HPL (9825A Controller Language), and Enhanced Basic (9835A/B and 9845B Controller Language).

3-165. Program Codes (Data received by the 3456A).

3-166. Program codes are used for the 3456A's set up information. A listing of the codes is in Table 3-9. The instrument must be in "remote" and "listen" to receive the codes. An example is as follows.

 a. HP-IB Format:

 b. HPL (9825A Controller Language).

 wrt 722,"F1 R1 M0 T4"

 c. Enhanced Basic (9835A/B, 9845B Controller Language).

 OUTPUT 722;"F1 R1 M0 T4"

NOTE

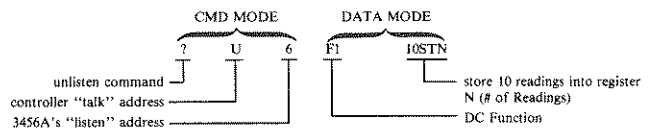*The "7" in the "722" address code is the 9825A, 9835A/B and 9845B Controllers I/O Card select code.*

NOTE

The spaces between the program codes (F1spaceR1, etc.) shown in the example are not necessary. They are only included to separate the different program codes.

3-167. Storing into Registers (Y, Z, Delay, etc.) over the HP-IB.

3-168. Storing into register is similar to the front panel method. First enter the number to be stored and then store it into the register. The following examples shows how to do it, by storing "10" into the Number of Readings/Trigger register. The DCV function's program codes is also included in the example to show that other than register program codes can be in the same string.

 a. HP-IB Format.

 b. HPL (9825A Controller Language).

 wrt 722,"F1 10STN"

Table 3-9A. 3456A Program Codes.

	Control	Program Code
FUNCTION	Shift Function Off (Unshifted)	S0
	DCV	F1
	ACV	F2
	ACV + DCV	F3
	2 Wire K Ohms	F4
	4 Wire K Ohms	F5
	Shift Function On (Shifted)	S1
	DCV/DCV Ratio	F1
	ACV/DCV Ratio	F2
	ACV + DCV/DCV Ratio	F3
	O.C. 2 Wire K Ohms	F4
	O.C. 4 Wire K Ohms	F5
RANGE	Auto	R1
	100 mV or .1 K Ohms	R2
	1000 mV or 1 K Ohms	R3
	10 V or 10 K Ohms	R4
	100 V or 100 K Ohms	R5
	1000 V or 1 M Ohms	R6
	10 M Ohms	R7
	100 M Ohms	R8
	1000 M Ohms	R9
TRIGGER	Internal	T1
	External	T2
	Single	T3
	Hold	T4
AUTOZERO	On	Z1
	Off	Z0
FILTER	On	FL1
	Off	FL0
TEST	On	TE1
	Off	TE0
REGISTERS	Storing into Registers	ST
	Recalling Registers	RE
	Number of Readings	N
	Number of Digits Displayed	G
	Number of Power Line Cyc. Int.	I
	Delay	D
	Mean Register (Read only)	M
	Varience Register (Read only)	V
	Count Register (Read only)	C
	Lower Register	L
	R Register	R
	Upper Register	U
	Y Register	Y
	Z Register	Z
MATH	Off	M0
	Pass/Fail	M1
	Statistic (Mean, Variance, Count)	M2
	Null	M3
	dBm	M4
	Thermistor (°F)	M5
	Thermistor (°C)	M6
	Scale [(X - Z)/Y]	M7
	%Error [(X - Y)/Y x 100]	M8
	dB (20 Log X/Y)	M9
READING STORAGE	On	RS1
	Off	RS0
SYSTEM OUTPUT MODE	On	SO1
	Off	SO0
DISPLAY	On	D1
	Off	D0
OUTPUT FORMAT	Packed Format On	P1
	Packed Format Off (ASCII Format)	P0
CLEAR-CONTINUE	Active	CL1
NUMERIC SEPARATOR	Separates Numbers (e.g. F1W10STN)	W
HOME COMMAND	Software Reset	H
FRONT/REAR SWITCH SENSE	1 = Front, 0 = Rear	SW1
EOI	Enable	O1
	Disable	O∅
PROGRAM MEMORY	Load Program (Syntax) On	L1
	Load Program (Syntax) Off	Q
	Execute Program Memory	X1

c. Enhanced Basic (9835A/B, 9845B Controller Language).
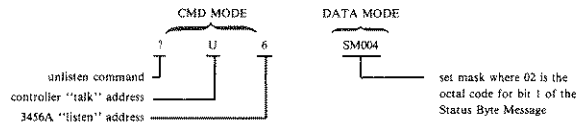
OUTPUT 722;"F1 10STN"

In the example, "F1" and "10STN" is separated by a space to keep the numbers apart. This is not necessary but may be less confusing. You can, however, enter a "W" instead of a space. The "W" is ignored by the 3456A but can be used to separate numerical entries from commands. The same program string with "W" looks like this:

"F1W10STN"

3-169. Programming the SRQ Mask.

3-170. Program codes are used to set the SRQ Mask. Use the programming procedure in Paragraph 3-165 to send the codes. Remember, the 3456A has to be in "remote" and "listen" to receive the codes. Since the Status Byte Message is in octal, the mask is programmed in octal by using the corresponding octal codes of the message. For example, bit 2 (Data Ready) is to be set and is done by sending its octal code, 004. The following example illustrates this.

a. HP-IB Format.

b. HPL (9825A Controller Language).

wrt 722, "SM004"

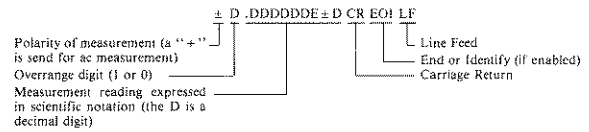c. Enhanced Basic (9835A/B, 9845B Controller Language).

OUTPUT 722; "SM004"

3-171. Any, all, or combinations of the Require Service conditions can be set by programming the SRQ mask. All the bits can be disabled by programming the mask to "000".

3-172. 3456A's Measurement DATA (Data sent by the 3456A).

3-173. 3456A measurement data can be sent to the controller in two different formats, ASCII or Packed Format. The following explains the formats.

3-174. ASCII Format.

3-175. Output Statement. The 3456A's output data in the ASCII Format consists of 14 bytes and is in this form:

NOTE

The decimal point in the output statement is "free field" and can move to any place on the left side of the "E" and the right of the overrrange digit.

Each character in the output statement is one byte and adds up to 14 bytes (the Carriage Return and Line Feed are one character each). The first digit (D) is the overrange digit and is either "1" or "0". The decimal point can be anywhere between the right of the overrange digit (shown in this example) and the left of the exponent ("E"). The Carriage Return and Line Feed are used to terminate the output statement. The End or Identify (EOI) line is normally set by the 3456A prior to the Line Feed if enabled. The EOI statement can be disabled over the HP-IB (see Paragraph 3-186).

3-176. Overload Output Statement. The output statement from an overload condition is in this form:

The overload polarlity depends on the type of overload condition. A " + " is normally output when a measurement overload is present. A "-" can be output when a math overload condition is present.

3-177. Multiple Reading Output. The output statement for multiple readings (Number of Readings per Trigger feature) is similar to the normal output statement. The only difference is that no Carriage Return (CR), Line Feed (LF), and End or Identify (EOI) is output until all readings are taken. A comma (,) is used in their place to separate the readings. An example for 3 multiple readings is as follows:
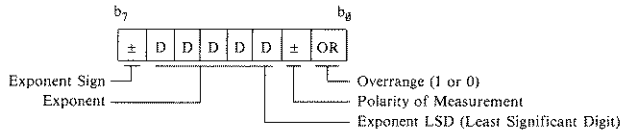
+ D.DDDDDDE + D,-DD.DDDDE + D,
+ DDD.DDDDE-D CR EOI LF

3-178. Packed Format.

3-179. Unlike the ASCII Format, the Packed Format outputs 4 bytes instead of 14. A faster reading transfer is possible using the Packed Format. Before the 3456A can output readings in the packed mode, it must be remotely programmed. The codes are "P1" (see Table 3-9) to enable and "P0" to disable the Packed Format. The ASCII Format is automatically selected at turn-on.

3-180. Output Statement. Once the 3456A is programmed to output data in the Packed Format, each measurement is output in 4 bytes. Each byte shows a certain part of the measurement data. Here is a graphic description of the packed mode.
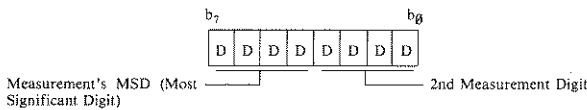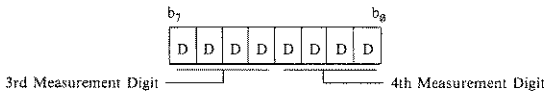
First Byte

NOTE

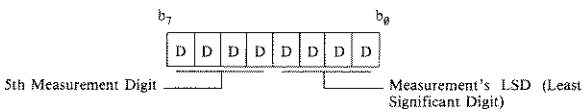*The decimal point in the Packed Format is implied to the Overrange Digit's left.*

Second Byte

Third Byte

Fourth Byte

The sign (polarity) is indicated with "+" as a "0" and "-" as a "1". The exponent and the measurement digits are in packed Binary Coded Decimal (BCD). The decimal point is implied to the overrange digit's left. The End or Identify (EOI) line is normally set prior to the 4th byte.

3-181. Overload Output Statement. The Overload Output Statement in the Packed Format follows the same number convention as the ASCII overload statement. The difference is that the numbers representing the overload condition is output in the Packed mode.

3-182. Multiple Reading Output. No delimiters are used between the readings with the End or Identify (EOI) being suppressed. The EOI will not be activated until all readings are output.

3-183. Unpacking the Packed Output. Since only four bytes of data is output in the Packed Format, some sort

of unpacking should be done for the reading(s) to make sense. This is done simply by converting each 8 bit binary number to a decimal number. An unpacking program using Enhanced Basic (9835A/B, 9845B Controller Language) is in Appendix A.

3-184. Reading the 3456A's Output Data.

3-185. First choose the output format you wish to use. The ASCII Format is chosen in this example. To output data, the 3456A has to be addressed to "talk" and the device receiving the data is the listener. Here is an example.

a. HP-IB Format.

b. HPL (9825A Controller Language).

red 722,A

c. Enhanced Basic (9835A/B, 9845B Controller Language).

ENTER 722;A

NOTE

Although it is not specified in the HP-IB Format, the output of the 3456A is normally stored in a variable. This is the reason why variable "A" is used in the controller language examples.

3-186. Disabling the End or Identify (EOI) Statement.

3-187. The End or Identify (EOI) statement can be disabled over the HP-IB for a faster transfer of readings. This is done by sending program codes "O0" to the 3456A using the programming procedure in Paragraph 3-165. Disabling the EOI statement and using the 3456A's Internal Trigger mode allows the faster possible reading transfer. The EOI statement is enabled by sending codes "O1" and at turn-on.

3-188. System Output Mode.

3-190. With the 3456A's System Output Mode enabled, a new measurement cycle is not initiated until the present reading is output by the instrument. The reading is output by addressing the 3456A to "talk". Once this is done, a new measurement cycle is started. As long as the System Output mode is enabled and no reading is output, the instrument does not take any new readings. The mode is an advantage when using controllers slower than the 3456A. For example, if the Number of
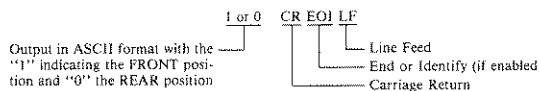
Readings per Trigger operation is selected to output readings, the readings are output one after another. A slow controller may not be able to accept the readings at the 3456A's output speed and loose some or all readings. The System Output mode prevents this from happening. The 3456A waits until the controller is able to receive data. The mode is enabled by sending program codes "SO1" and disabled by codes "SO0". Use the programming procedure in Paragraph 3-165 to send the codes.

3-191. Home Command.

3-192. The Home Command is used to reset the 3456A to the same conditions as sending the CLEAR message, except faster. The differences between Home, Clear, Reset, and Turn-On are listed in Table 3-6. The Home Command is sent by program code "H" using the programming procedure in Paragraph 3-165.

3-193. Front/Rear Switch Position.

3-194. The Front/Rear Switch position can be remotely determined over the HP-IB. This is done by sending program codes "SW1" to the 3456A and then reading its output. If "0" is output, the switch is set to REAR and "1" indicates FRONT. Use the programming procedure in Paragraph 3-165 to send the codes and the procedure in Paragraph 3-184 to read the output data (switch position). The output is as follows:

```
                     1 or 0   CR EOI LF
Output in ASCII format with the ───┘      │ │  └── Line Feed
"1" indicating the FRONT posi-            │ └───── End or Identify (if enabled
tion and "0" the REAR position            └─────── Carriage Return
```

3-195. Complete Program Example.

3-196. After you know how to program the 3456A using the HP-IB, the next step is to write a program of the algorithm in Paragraph 3-162. Again, the program is given in the HP-IB Format, HPL (9825A Controller Language), and Enhanced Basic (9835A/B, 9845B Controller Language).

a. HP-IB Format.

1. Interface clear	ABORT all previous operation
2. ?U6	REMOTE the 3456A
3. ?U6 *004*	CLEAR the instrument
4. *021*	LOCAL LOCKOUT the 3456A (including the other devices on the controller's select code)
5. ?U6 F1R1T4SM020 *15 12*	Send DATA to set up the instrument to the dc function, autorange, hold trigger, and set SRQ bit 4 mask (15 is CR and 12 is LF)
6. ?U6 *010*	TRIGGER the 3456A

7. ?U5V +D.DDDDDDE+D *015* EOI *012*	Send the measurement DATA to the controller and store in a variable
8. ?5V *030*	If REQUIRE SERVICE, check the STATUS BYTE; otherwise skip the next step (the 030 is the Serial Poll enable)
9, 10. *031*	No STATUS BYTE is sent by the 3456A (the 031 is the Serial Poll disable)
11. Controller Language	Print out the DATA in variable A
12. ?U, *001*	CLEAR LOCKOUT AND SET LOCAL (in this case, only for the 3456A)
13. Controller Language	Ends the program

b. HPL (9825A Controller Language).

0: cli 7	ABORT
1: rem 722	REMOTE 3456A
2: clr 722	CLEAR 3456A
3: llo 7	LOCAL LOCKOUT
4: wrt 722, "F1R1T4SM020"	DATA. Set up instrument
5: trg 722	TRIGGER 3456A
6: red 722,A	DATA.Output of 3456A into variable
7: rds (722) → S	REQUIRE SERVICE?
8: if S = 0; gto 10	If no STATUS BIT, skip the next line
9: stp	Stop the program
10: prt A	Print output DATA in variable
11: lcl 722	CLEAR LOCKOUT AND SET LOCAL (3456A)
12: end	Ends the program

c. Enhanced Basic (9835A/B, 9845B Controller Language).

10 ABORTIO 7	ABORT
20 REMOTE 722	REMOTE 3456A
30 CLEAR 722	CLEAR 3456A
40 LOCAL LOCKOUT 7	LOCAL LOCKOUT
50 OUTPUT 722; "F1R1T4SM020"	DATA. Set up instrument
60 TRIGGER 722	TRIGGER 3456A
70 ENTER 722;A	DATA. Output of 3456A into variable
80 STATUS 722;S	REQUIRE SERVICE?
90 IF S = 0 THEN GOTO 110	If no STATUS BIT, skip the next line
100 STOP	Stop the program
110 PRINT A	Print output DATA in variable

| 120 LOCAL 722 | CLEAR LOCKOUT AND SET LOCAL |
| 130 END | Ends the program |

3-197. The information you have received in the preceding paragraphs should give you a good start in programming the 3456A over the HP-IB. The following paragraphs explain some more unique remote operations.
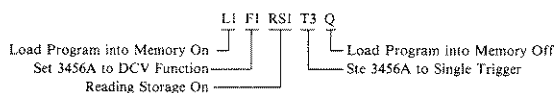
3-198. Front Panel SRQ.

3-199. The Front Panel SRQ feature of the 3456A outputs a Require Service Message when the Front Panel SRQ button is pressed. Before this can take place, set bit 0 on the SRQ mask (refer to Paragraph 3-169 to set the mask). Once this is done, press the SRQ button. The front panel SRQ LED will turn on and the Require Service Message is output. This condition will remain until the SRQ button is pressed a second time or a Serial Poll is done by the controller.

3-200. Instrument Program memory Operation.

3-201. With this feature, you can store into the 3456A's internal memory any valid remote operations (excluding Test and Program Memory Execution) using program codes. Total available memory size is 1400 bytes. Because a program code takes one byte of memory you can store 1400 codes. The memory is also used with Reading Storage and any stored codes takes space away for storing readings.

3-202. **Storing Program Codes.** The 3456A has to be told to store into its internal memory. The program used are "L1" to enable the storage and "Q" to disables the storage. This is illustrated in the following example.

Program codes "L1" and "Q" are not stored into memory. The total memory used is 7 bytes. The codes remain in memory until the 3456A is turned off (Reset, Clear, and Home do not clear the memory). The memory can be cleared by sending codes "L1Q".

NOTE

Unlike regular remote operation, program memory only ignores blanks. Other invalid characters can produce a Syntax Error during program memory execution.

3-203. **Program Execution.** Once the program codes are stored in memory they can be executed. This is done by sending program codes "X1" to the 3456A. The instrument then performs the operation. In the previous

example, when Program Memory is executed, a dc reading is taken and stored into memory.
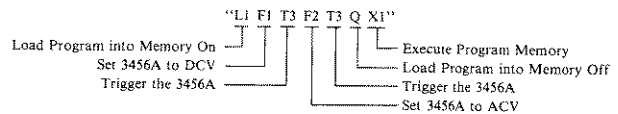
NOTE

The Execute (X1) and Internal Test (TE1) codes can cause a program memory execution error.

NOTE

With Home (H) command stored in program memory while executing the memory the 3456A is reset to the Turn-On state and stops the program memory operation.

3-204. **Multiple Operations.** You can store and execute more than one remote operation into memory. For example, the 3456A can be programmed to do a DCV measurement, Trigger it, do an ACV measurement, Trigger it, and so on. The next example illustrates this.

3-205. **Recall of Readings from Memory.** Readings are remotely recalled and output from memroy similar to the front panel recall operation (see Paragraph 3-104). This is done by storing into register R the corresponding number of the reading you wish to recall. Then recall the register and output the reading. The following procedure illustrates this operation. In the procedure, reading #1 and #2 are to be recalled.

a. Set the 3456A to listen. Sent the program codes for Hold Trigger, Reading Storage On, and store a "1" (reading #1) into register R.

"T4 RS1 1STR"

b. Sent program codes to recall the R register.

"RER"

c. Set the 3456A to talk. Output the reading (#1) over the HP-IB.

d. Set the 3456A to listen. Sent the program codes to store a "2" (reading #2) into register R.

"2STR"

e. Sent program codes to recall the R register.

"RER"

f. Set the 3456A to talk. Output the reading (#2) over the HP-IB.

NOTE

Make sure the 3456A is programmed to Hold or Single Trigger when recalling readings.

The remote recall operation is similar to the front panel operation. Scrolling is also done similar to front panel operation. An example to scroll the readings, starting with #10, is as follows.

a. Set the 3456A to listen. Sent program codes for Hold Trigger, Reading Storage On, and store "-10" into register R. (The -10 is used to scroll the readings starting with reading #10.)

"T4 RS1 -10STR"

b. Sent program codes to recall the R register.

"RER"

c. Set the 3456A to talk. The readings are now output over the HP-IB starting with reading #10 and ending with #1.

In the example, multiple readings are output the same as explained in paragraph 3-177. A program example using HPL (9825A Controller Language) and Enhanced Basic (9835A/B and 9845B Controller Language) is given in Appendix A.
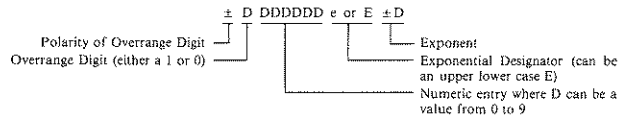
3-206. Data Ready.

3-207. The Data Ready feature, when enabled, outputs a Require Service Message for a completed measurement cycle. The SRQ mask has to be set before the message is output. Set the mask by sending program codes "SM004" (for bit 2 of the Status Byte). When the Require Service message is sent, the front panel SRQ LED is on. The LED remains on until a new measurement cycle is started (the 3456A is triggered), when the present reading is output over the HP-IB, or when the 3456A is polled (Serial Poll). If the 3456A is set up to take a number of readings per trigger, the require service condition will be true, at the end of each reading,

for about $320\mu s$. The condition will remain true and the SRQ LED turns on, after all the readings are taken.

3-208. 3456A's Numeric Entry Format and other Input Considerations.

3-209. The 3456A's Numeric Entry Format (used in program codes) are in this form:

The decimal point is optional and ranges from the right of the overrange digit to the Exponential Designator's left.

3-210. When sending data to the 3456A in remote, all lower case (except "e") alpha characters, spaces, carrage return, and line feed are ignored. All other invalid ASCII characters are illegal. The optional "W" character can be used as a prefix to a numeric string like this"

F1W10STN

3-211. OPERATOR'S CHECK.

3-212. The following is an Operator's Check you can perform to check the major DCV, ACV, Ohms, and Digital circuitry. The checks are not used to verify performance accuracy. They are only used to check the operating capabilities of the 3456A. The following can be used as the Operator's Check.

a. Remove everything from the 3456A's input terminals.

b. press the TEST button. The display should go blank while doing an internal test. When the test passes and is completed, $+1.8.8.8.8.8.+8.$ is displayed including all of the front panel LEDs. The cycle will then be repeated. If a negative integer is displayed, refer the 3456A to a service trained person. Press the TEST button a second time.

APPENDIX A

A-1. INTRODUCTION.

A-2. The following chapters in this appendix contain certain general and specific HP-IB information. The general information is non-controller dependent but may be dependent on the 3456A. The specific information is controller and/or instrument dependent.

A-3. GENERAL HP-IB DESCRIPTION.

A-4. The Hewlett-Packard Interface Bus (HP-IB) is a carefully defined interface which simplifies the integration of various instruments, calculators, and computers into systems. The interface provides for messages in digital form to be transferred between two or more HP-IB compatible devices. A compatible device can be an instrument, calculator, computer, or peripheral device that is designed to be interfaced using the HP-IB.

A-5. The HP-IB is a parallel bus of 16 active signal lines grouped into three sets, according to function, to interconnect up to 15 instruments. A diagram of the Interface Connections and Bus Structure is in Figure A-1.

A-6. Eight signal lines, termed as DATA lines, are in the first set. The Data lines are used to transmit data in the form of coded messages. These messages are used to program instrument function, transfer measurement data, coordinate instrument operation, and to manage the system. This allows you to set-up the instrument and read its measurement data. Input and output of messages in bit-parallel, byte-serial form are also transferred in the Data lines. A 7-bit ASCII code normally represents each piece of DATA.

A-7. Data is transferred by means of an interlocking "handshake" technique which permits data transfer (asynchronously) at the rate of the slowest active device used in that particular transfer. The three DATA BYTE CONTROL lines coordinate the transfer and form the second set of lines.

A-8. The remaining five GENERAL INTERFACE MANAGEMENT lines are used to manage the devices on the HP-IB. This includes activating all connected devices at once, clearing the interface, and others. A condensed description of the HP-IB is available in the
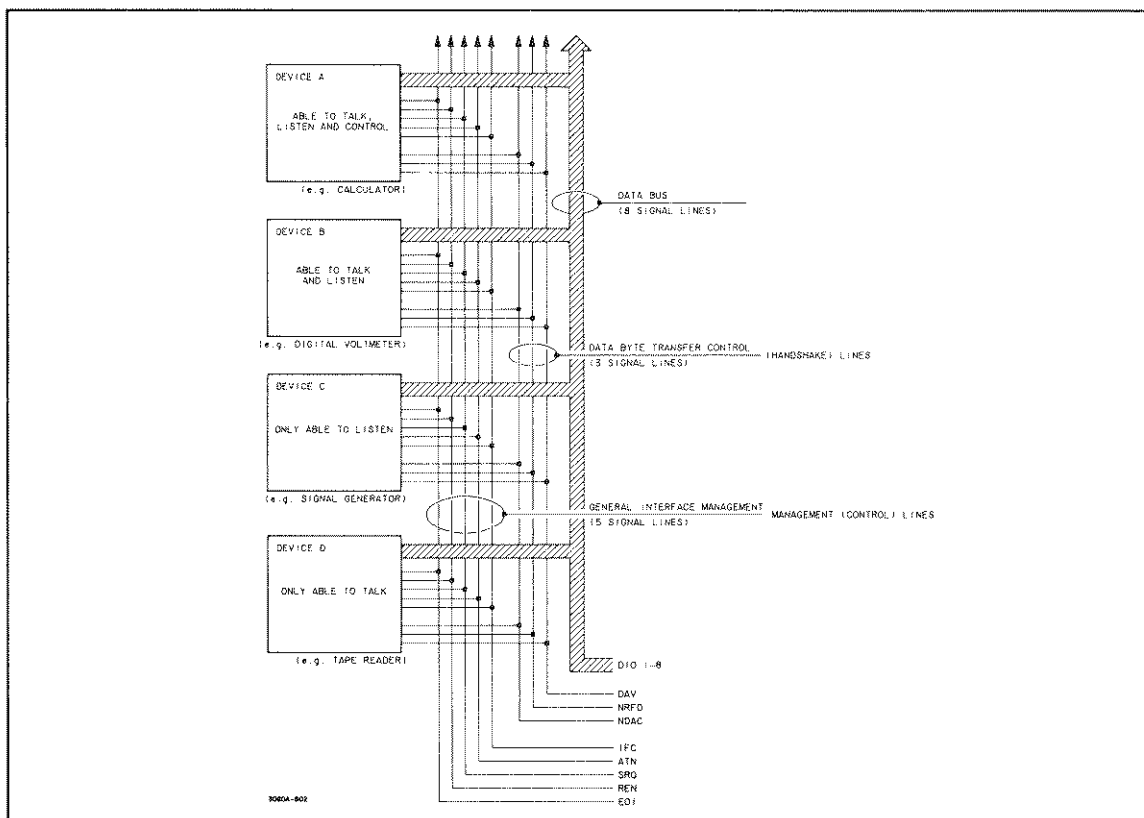

Figure A-1. Interface Connection and Bus Structure.

Condensed Description of the Hewlett-Packard Inter-
face Bus Manual, -hp- Part Number 59401-90030. The
manual is available through your nearest -hp- Sales and
Service Office.

A-9. HP-IB SYSTEM OVERVIEW.

A-10. The following chapters define the terms and con-
cepts used to describe HP-IB (Bus) system operations.

A-11. HP-IB System Terms.

a. Address: The characters sent by a controlling
device to specify which device will send information on
the HP-IB and which device(s) will receive that informa-
tion. Addressing may also be accomplished by hardwir-
ing a device to only send information or only receive in-
formation.

b. Byte: A unit of information consisting of 8 binary
digits (bits).

c. Device: A unit that is compatible with the IEEE
Standard 488-1975.

d. Device Dependent: An action a device performs
in response to information sent over the HP-IB. The ac-
tion is characteristic of an individual device and may
vary from device to device.

e. Polling: This process typically is used by a con-
troller to locate a device that needs to interact with the
controller. There are two types of polling, as follows:

1. Serial Poll: This method obtains one byte of
   operational information about an individual
   device in the system. The process must be repeated
   for each device from which information is desired.

2. Parallel Poll: This method obtains information
   about a group of devices simultaneously.

A-12. Basic Device Communication Capabilities.

A-13. Devices which communicate along the interface
bus can be classified into three basic categories:

a. Talker: Any device that is able to send informa-
tion over the HP-IB, when it has been addressed. Only
one talker may be active at a time; usually the one that is
currently directed to send data. All HP-IB type
calculators and computers are generally talkers.

b. Listener: Devices which receive information over
the HP-IB, when they have been addressed. A device
may or may not be both a talker and a listener.
Calculators or computers are generally both a talker and
a listener (at different times).

c. Controller: The device that can specify which

devices(s) on the Bus is a talker or a listener. There can
be two types of controllers, an Active Controller and a
System Controller. The Active Controller is the current
controlling device. The System Controller can,
however, take control of the HP-IB even if it is not the
active controller. There can also be only one controller
at a time, even if several controllers are on the Bus.

A-14. HP-IB Messages.

A-15. Different types of information can be passed
over the HP-IB to one or more devices. Some of this in-
formation is in the form of messages, most of which can
be separated into two parts. One part can be classified
as the address portion specified by the controller and the
information that comprises the messages. The second
part can be classified as HP-IB management messages.
These messages are comprised of twelve messages and
are called meta messages. In this manual they are refer-
red to as Bus Messages and are defined as follow.

a. Data: The actual information (binary bytes) sent
by a talker to one or more listener. The information
(data) can either be in a numeric form or a character
string.

b. Trigger: The trigger message causes the listening
device or devices to perform a device dependent action
when addressed.

c. Clear: The clear message causes the listening
device(s) or all of the devices on the HP-IB to return to
their predefined device-dependent state.

d. Remote: This message causes the listening
device(s) to switch from local front panel control to
remote program control when addressed to listen.

e. Local: This message clears the REMOTE message
from the listening device(s) and returns the device(s) to
local front panel control.

f. Local Lockout: This message prevents a device
operator from manually inhibitating remote program
control.

g. Clear Lockout and Set Local: With this mesage,
all devices are removed from the local lockout mode and
revert to local. The remote message is also cleared for all
devices.

h. Require Service: A device can send this message at
any time to signify the device needs some type of in-
teraction with this controller. The message is cleared by
the device's STATUS BYTE message if the device no
longer requires service.

i. Status Byte: A byte that represents the status of a
single device on the HP-IB. One bit indicates whether
the device sent the required service message and the re-

maining seven bits indicate operational conditions defined by the device. This byte is sent from the talking device in response to a "Serial Poll" operation performed by the controller.

j. Status Bit: A byte that represents the operational conditions of a group of devices on the HP-IB. Each device responds on a particular bit of the byte thus identifying a device dependent condition. This bit is typically sent by devices in response to a parallel poll operation.

k. Pass Control: The bus management responsibility is transferred from the active controller to another controller by this message.

l. Abort: The system controller sends this message to unconditionally assume control of the HP-IB from the active controller. The message will terminate all bus comunication but does not implement the CLEAR message.

A-16. HP-IB WORKSHEET.

A-17. The HP-IB Worksheet (Table A-1) can be used to determine the HP-IB capabilities of the other HP-IB compatible instruments may have. The sheet may be filled in with the Bus messages applicability for your controller and each HP-IB device. The Bus capability of the 3456A has already been filled in. Refer to your controller manual and the manual(s) of your other device(s) for their Bus Messages capabilities. Once the sheet is filled out, you should then have the HP-IB capabilities of your device(s).

Table A-1. HP-IB Worksheet.

MESSAGE	HP-IB BUS IMPLEMENTATION WORKSHEET DEVICE								
INSTRUMENT IDENTIFICATION AND HP-IB ADDRESS	MODEL 3456A				MODEL				
	LISTEN YES				LISTEN				
	TALK YES				TALK				
	5 BIT VALUE 22				5 BIT VALUE				
DATA	S & R								
TRIGGER	R								
CLEAR	R								
LOCAL	R								
REMOTE	R								
LOCAL LOCKOUT	R								
CLEAR LO & SET LOCKOUT	R								
REQUIRE SERVICE	S								
STATUS BYTE	S								
STATUS BIT	N								
PASS CONTROL	N								
ABORT	N								

S = SEND ONLY   R = RECEIVE ONLY   S & R = SEND AND RECEIVE   N = NOT IMPLEMENTED

A-18. UNPACKING PROGRAM.

A-19. The following is an unpacking program used to unpack the 3456A's readings taken in the Packed mode.

The program is given in the Enchanced Basic (9835A/B and 9845B Controller) Language.

Unpacking Program

```
10    ! The following program illustrates one method for unpacking data from
20    ! the 3456A.  You can program this routine to take "any" number of readings
30    ! by changing the DIM statement in line 20 , the 3456A programming syntax
40    ! in line 30, and the buffered transfer statement in line 40.  The
50    ! numerical array Out is dimensioned to contain the number of readings that
60    ! will be taken The string variable In$ is dimensioned to 4 times the
70    ! number of readings taken.  That is, a packed reading contains 4 bytes of
80    ! data per reading.
90    !
100   ! In this particular example, the 3456A is programmed to the following
110   ! states:
120   ! Function: DCV (F1)
130   ! Data Output Format: Packed (P1)
140   ! Range: Autorange (R1)
150   ! Delay: 0 (0STD)
160   ! Integration Time: .1 Line Cycles (.1STI)
170   ! Number of Readings: 9 (9STN)
180   ! System Output Mode: On (SO1)
190   ! Trigger: Single (T3)
200   !
210   ! You can follow the comment statements on each line of the program to
220   ! understand the basic operation .  Explaining the operation of the
230   ! unpacking subprogram is beyond the scope of this manual.
240   !
250   !
260   OPTION BASE 1  ! Specifies first element in numeric array Out is Out(1).
270   DIM In$[36],Out(9)  ! Dimensions the string variable and numeric array.
280   OUTPUT 722;"P1F1R10STD.1STI9STNSO1T3"  ! Programs the 3456A.
290   ENTER 722 BFHS 36 NOFORMAT;In$ ! Enters 36 data bytes into the string In$.
300   CALL Unpk56(In$,Out(*)) ! Calls Unpacking routine; passes the packed data.
310   FOR I=1 TO 9  ! Sets up loop to print out the number of readings taken.
320   PRINT "NUMBER ";I;" VOLTAGE READING = ";Out(I)
330   NEXT I
340   END
350   SUB Unpk56(In$,Out(*))
360   INTEGER N,J,I,B1,B2,B3,B4
370   N=LEN(In$)
380   J=0
390   FOR I=1 TO N STEP 4
400   J=J+1
410   B1=NUM(In$[I])
420   B2=NUM(In$[I+1])
430   B3=NUM(In$[I+2])
440   B4=NUM(In$[I+3])
450   Out(J)=.1*BIT(B1,0)+.01*SHIFT(B2,4)+.001*BINAND(B2,15)+.0001*SHIFT(B3,4)+.
00001*BINAND(B3,15)+.000001*SHIFT(B4,4)+.0000001*BINAND(B4,15)
460   Out(J)=Out(J)*(1-2*BIT(B1,1))*10↑((1-2*BIT(B1,7))*SHIFT(BINAND(B1,124),2))
470   NEXT I
480   SUBEND
```

A-20. MULTIPLE READING TRANSFER PROGRAMS.

A-21. The following programs show how to transfer multiple readings from the 3456A to the controller. The programs are given in the HPL(9825A Controller) and Enhanced Basic (9835A/B and 9845B Controller) Language. The programs do the following.

a. The 3456A is set up to do this:

1. Clear the 3456A and set SRQ Mask to bit 1 (Program Memory Execution Complete).

2. Enter into memory to enable Reading Storage, select 10 Number of Readings per Trigger, and Single Trigger.

3. Execute Program Memory.

b. Read 3456A Status and remain in a loop until Program Memory has completed its execution.

c. Set up the 3456A to enable its System Output Mode and scroll the internally stored readings starting with #10.

d. Store readings into variables.

HPL Program.

```
0: dim A[10]
1: wrt 722,"HSM002L1RS110STNT3QX1"
2: if rds(722)#66;jmp 0
3: wrt 722,"SO1-10STRRER"
4: for I=1 to 10
5: red 722,A[I]
6: next I
7: for I=1 to 10
8: prt A[I]
9: next I
10: end
*22514
```

Enhanced Basic Program

```
10    OPTION BASE 1
20    DIM A(10)
30    OUTPUT 723;"HSM002L1RS110STNT3QX1"
40    STATUS 723;S
50    IF S<>66 THEN GOTO 40
60    OUTPUT 723;"SO1-10STRRER"
70    ENTER 723;A(*)
80    MAT PRINT A
90    END
```

A-22. BUS MESSAGE IMPLEMENTATION.

A-23. The following figures provide a description on the implementation of the Bus Messages using the 3456A. The codes used in the figures are:

T = True
F = False
X = Don't Care
oct = Octal Code

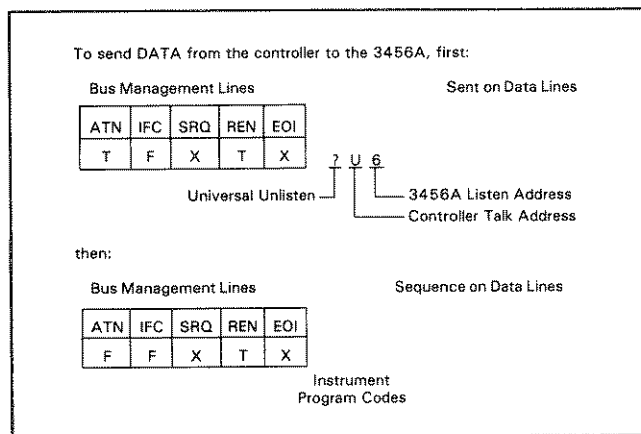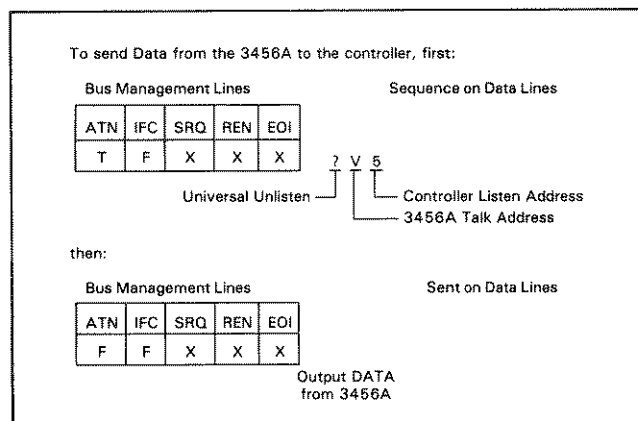**Figure A-2. Data Message (Controller to 3456A).**

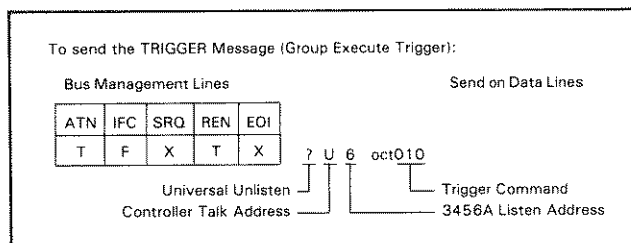**Figure A-3. Data Message (3456A to Controller or Other Device(s).**

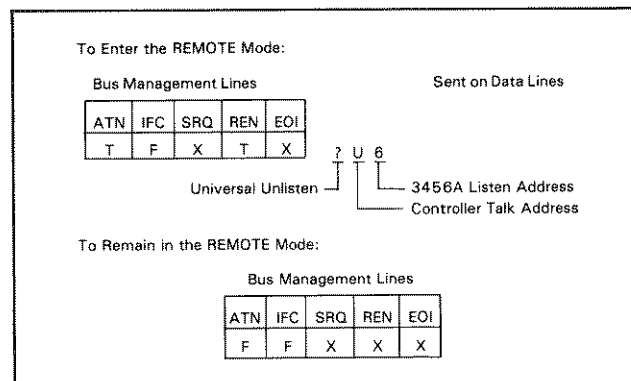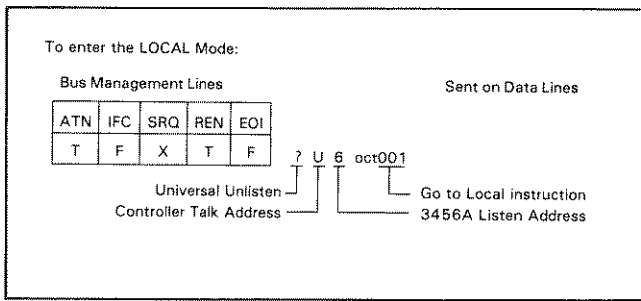**Figure A-4. Trigger Message (from Controller do Device(s)).**

Figure A-5. Remote Message.

To enter the LOCAL Mode:

Bus Management Lines   Sent on Data Lines

ATN	IFC	SRQ	REN	EOI
T	F	X	T	F

? U 6 oct001

Universal Unlisten ┘
Controller Talk Address ──────

Go to Local instruction
3456A Listen Address

Figure A-6. Local Message.

To enable LOCAL LOCKOUT:

Bus Management Lines   Sent on Data Lines

ATN	IFC	SRQ	REN	EOI
T	F	X	T	F

oct 021

Local Lockout instruction

to maintain LOCAL LOCKOUT:

Bus Management Lines

ATN	IFC	SRQ	REN	EOI
X	X	X	T	X

Figure A-7. Local Lockout Message.

To CLEAR LOCAL LOCKOUT and set LOCAL:

Bus Management Lines

ATN	IFC	SRQ	REN	EOI
X	X	X	T	X

Figure A-8. Clear Lockout/Set Local Message.

To send REQUIRE SERVICE MESSAGE:

Bus Management Lines

ATN	IFC	SRQ	REN	EOI
X	X	T	X	X

Figure A-9. Require Service Message.

To Serial POLL the 3456A (obtain Status Byte):

Bus Management Lines   Sent on Data Lines

ATN	IFC	SRQ	REN	EOI
T	F	X	X	F

? 6 oct030 V 5

Universal Unlisten ┘
3456A Listen Address ──────
Serial Poll Enable ──────────

Controller Listen Address
3456A Talk Address

then:

Bus Management Lines   Sent on Data Lines

ATN	IFC	SRQ*	REN	EOI
F	F	X	X	F

3456A Status Byte

*If SRQ was true, it will switch to the false state.

and finally:

Bus Management Lines   Sent on Data Lines

ATN	IFC	SRQ	REN	EOI
T	F	F	X	F

oct 031

Serial Poll Disable

Figure A-10. Status Byte Message.

To send the CLEAR Message:

Bus Management Lines   Sent on Data Lines

ATN	IFC	SRQ	REN	EOI
T	F	X	X	X

oct004

Clear Command

To send the CLEAR MESSAGE Only to the 3456A:

Bus Management Lines   Sent on Data Lines

ATN	IFC	SRQ	REN	EOI
F	F	X	T	X

? 6 oct 004

Universal Unlisten ┘
3456A Listen Address ──────

Clear Command

Figure A-11. Clear Message.

To send the ABORT Message:

Bus Management Lines

ATN	IFC	SRQ	REN	EOI
X	T	X	X	X

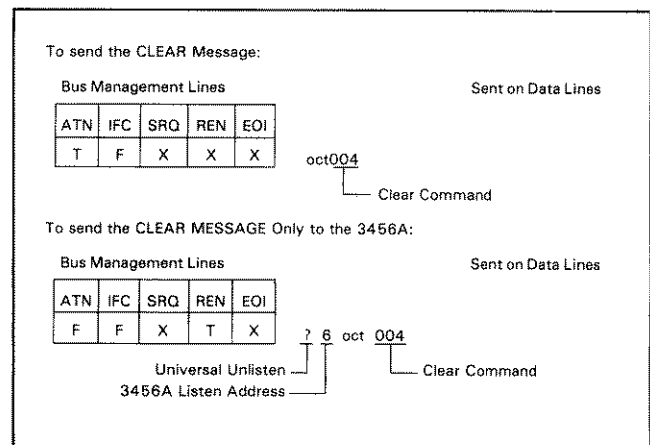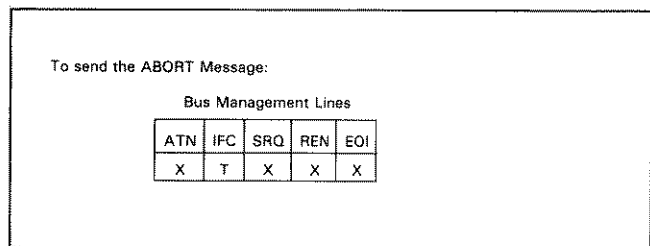**Figure A-12. Abort Message.**

APPENDIX B

B-1. FRONT/REAR SWITCH LOCK PROCEDURE.

B-2. The Front/Rear Switch can be locked in either the FRONT or REAR position by the installation of a lock. The following procedures show how to install and remove the lock.

  a. Lock Installation Procedure.

  1. Locate the front panel section located at the front panel's input terminals.

  2. Remove the front panel section by loosening the hold down screws located to the left and right of the panel. (Note: The screws are fastened to the panel section and should not be forced out of the section.)

  3. Remove the switch cap from the Front/Rear Switch. The cap can be removed by holding the cap between the index finger and thumb and pulling it away from the switch.

  4. Set the Front/Rear Switch to the desired position (FRONT or REAR).

  5. Locate the Locking Cap and front panel section. Install the cap into the panel section's slot marked FRONT and REAR until it snaps in place. Make sure the arrow on the cap points to the lettering which corresponds to the Front/Rear Switch position.

  6. Reinstall the front panel section into the front panel and tighten the screws.

  b. Lock Removal Procedure.

  1. Do step a and b of the Lock Installation Procedure.

  2. Remove the lock from the front panel section. Do this by squeezing the cap's locking fingers and push the lock out of the slot. A pair of needlenose pliars or something similar can be used.

  3. Locate the cap which was removed from the Front/Rear Switch when the lock was installed. Reinstall it on the Front/Rear Switch.

  4. Reinstall the front panel section into the front panel and tighten the screws.

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