SERVICE MANUAL

Digital Multimeter

Model 178

FIRST PRINTING, FEBRUARY 1978, CLEVELAND, OHIO, U. S. A.
SECOND PRINTING, FEBRUARY 1979, CLEVELAND, OHIO, U. S. A.
DOCUMENT NO. 28970

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SPECIFICATIONS

DC VOLTAGE

RANGE	MAXIMUM READING	ACCURACY (12 months) 18°-28°C ±(% rdg + digits)	MAXIMUM ALLOWABLE INPUT
2 V	1.9999	0.04% + 1d	1200V momentary
20 V	19.999	0.04% + 1d	1200V
200 V	199.99	0.04% + 1d	1200V
1200 V	1200.0	0.04% + 1d	1200V

Temperature Coefficient (0°-18° and 28°-55°C): ±(0.006% + 0.2 digit)/°C
Input Resistance: 10MΩ ±0.1%
Settling Time: 1 second to within 1 digit of final reading.

Normal Mode Rejection Ratio: Greater than 60dB at 50Hz and 60Hz.
Common Mode Rejection Ratio (1kΩ unbalance): Greater than 120dB at DC, 50Hz and 60Hz.

AC VOLTAGE

RANGE	MAXIMUM READING	ACCURACY (12 months) (above 2000 counts) 18°-28°C; 100Hz-10kHz ±(% rdg + digits)	TEMPERATURE COEFFICIENT 0°-18° and 28°-55°C ±(% rdg + digits)/°C 45Hz-10kHz	10kHz-20kHz
2 V	1.9999	0.4% + 15d	0.04% + 0.5d	0.09% + 0.5d
20 V	19.999	0.3% + 15d	0.01% + 0.5d	0.03% + 0.5d
200 V	199.99	0.3% + 15d	0.01% + 0.5d	0.03% + 0.5d
1000 V	1000.0	0.3% + 15d	0.01% + 0.5d	0.03% + 0.5d

Extended Frequency Accuracy:
(45Hz-100Hz) ±(0.5% + 15 digits)
(10kHz-20kHz) ±(1.0% + 15 digits)
Response: Average responding calibrated in rms of a sinewave.
Settling Time: 2.5 seconds to within 10 digits of final reading.

Input Impedance: 1MΩ ±1% shunted by less than 75pF
Maximum Allowable Input Voltage: 1000V rms, 1400V peak, 10^7V•Hz maximum.
Common Mode Rejection Ratio (1kΩ unbalance): 60dB at DC, 50Hz and 60Hz.

RESISTANCE

RANGE	MAXIMUM READING	ACCURACY (12 months) 18°-28°C ±(% rdg + digits)	TEMPERATURE COEFFICIENT 0°-18° and 28°-55°C ±(% rdg + digits)/°C	NOMINAL APPLIED CURRENT
2 kΩ	1.9999	0.04% + 2d	0.003% + 0.2d	1mA
20 kΩ	19.999	0.04% + 1d	0.003% + 0.2d	100μA
200 kΩ	199.99	0.04% + 1d	0.003% + 0.2d	10μA
2000 kΩ	1999.9	0.04% + 1d	0.003% + 0.2d	1μA
20MΩ	19.999	0.10% + 1d	0.02 % + 0.2d	0.1μA

Maximum Allowable Input: 250V rms sine, 350V peak.
Maximum Voltage Across Unknown: 2V within range, 5V open circuit.

Settling Time: 1 second to within 1 digit of final reading except 2 seconds on the 20MΩ range.

GENERAL

DISPLAY: Five 0.5" LED digits, appropriate decimal position and polarity indication.
CONVERSION PERIOD: 400 milliseconds.
ENVIRONMENT:
Operating: 0°C to 55°C; 0% to 80% relative humidity up to 40°C.
Storage: -25°C to +65°C.

POWER: 105-125 or 210-250 volts (switch selected), 90-110V available. 50-60Hz, 7 watts. Optional 6 hour battery pack, Model 1788.
DIMENSIONS, WEIGHT: 85mm high x 235mm wide x 275mm deep (3-1/2 in. x 9-1/4 in. x 10-3/4 in.). Net weight: 1,7kg (3lbs., 13 oz).
OVERRANGE INDICATION: Display blinks all zeros above 19999 counts.
MAXIMUM COMMON MODE VOLTAGE: 1400V peak.

WARRANTY

Keithley Instruments, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from date of shipment.

Keithley Instruments, Inc. warrants the following items for 90 days from the date of shipment: probes, cables, rechargeable batteries, diskettes, and documentation.

During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

To exercise this warranty, write or call your local Keithley representative, or contact Keithley headquarters in Cleveland, Ohio. You will be given prompt assistance and return instructions. Send the product, transportation prepaid, to the indicated service facility. Repairs will be made and the product returned, transportation prepaid. Repaired or replaced products are warranted for the balance of the original warranty period, or at least 90 days.

LIMITATION OF WARRANTY

This warranty does not apply to defects resulting from product modification without Keithley's express written consent, or misuse of any product or part. This warranty also does not apply to fuses, software, non-rechargeable batteries, damage from battery leakage, or problems arising from normal wear or failure to follow instructions.

THIS WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR USE. THE REMEDIES PROVIDED HEREIN ARE BUYER'S SOLE AND EXCLUSIVE REMEDIES.

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KEITHLEY

Test Instrumentation Group, Keithley Instruments, Inc. • 28775 Aurora Road • Cleveland, Ohio 44139 • (216) 248-0400 • Fax: (216) 248-6168

CHINA:	Keithley Instruments, Inc. • Holiday Inn Lido • Office Building 404C • Beijing, China, 100004 • 861-4362871 • 861-4362871
FRANCE:	Keithley Instruments SARL • 3 Allée des Garays • B.P. 60 • 91122 Palaiseau Cédex • 01-60-11-51-55 • Fax: 01-60-11-77-26
GERMANY:	Keithley Instruments GmbH • Landsberger Str. 65 • 82110 Germering • 089-849307-0 • Fax: 089-84930759
GREAT BRITAIN:	Keithley Instruments, Ltd. • The Minster • 58 Portman Road • Reading, Berkshire RG30 1EA • 01734-575666 • Fax: 01734-596469
ITALY:	Keithley Instruments SRL • Viale S. Gimignano 38 • 20146 Milano • 02-48303008 • Fax: 02-48302274
JAPAN:	Keithley Instruments Far East KK • Sumiyoshi 24 Bldg., Room 201 • 2-24-2 Sumiyoshi-cho • Naka-ku, Yokohama 231 • 81-45-201-2246 • Fax: 81-45-201-2247
NETHERLANDS:	Keithley Instruments BV • Avelingen West 49 • 4202 MS Gorinchem • Postbus 559 • 4200 AN Gorinchem • 01830-35333 • Fax: 01830-30821
SWITZERLAND:	Keithley Instruments SA • Kriesbachstrasse 4 • 8600 Dübendorf • 01-821-9444 • Fax: 01-820-3081

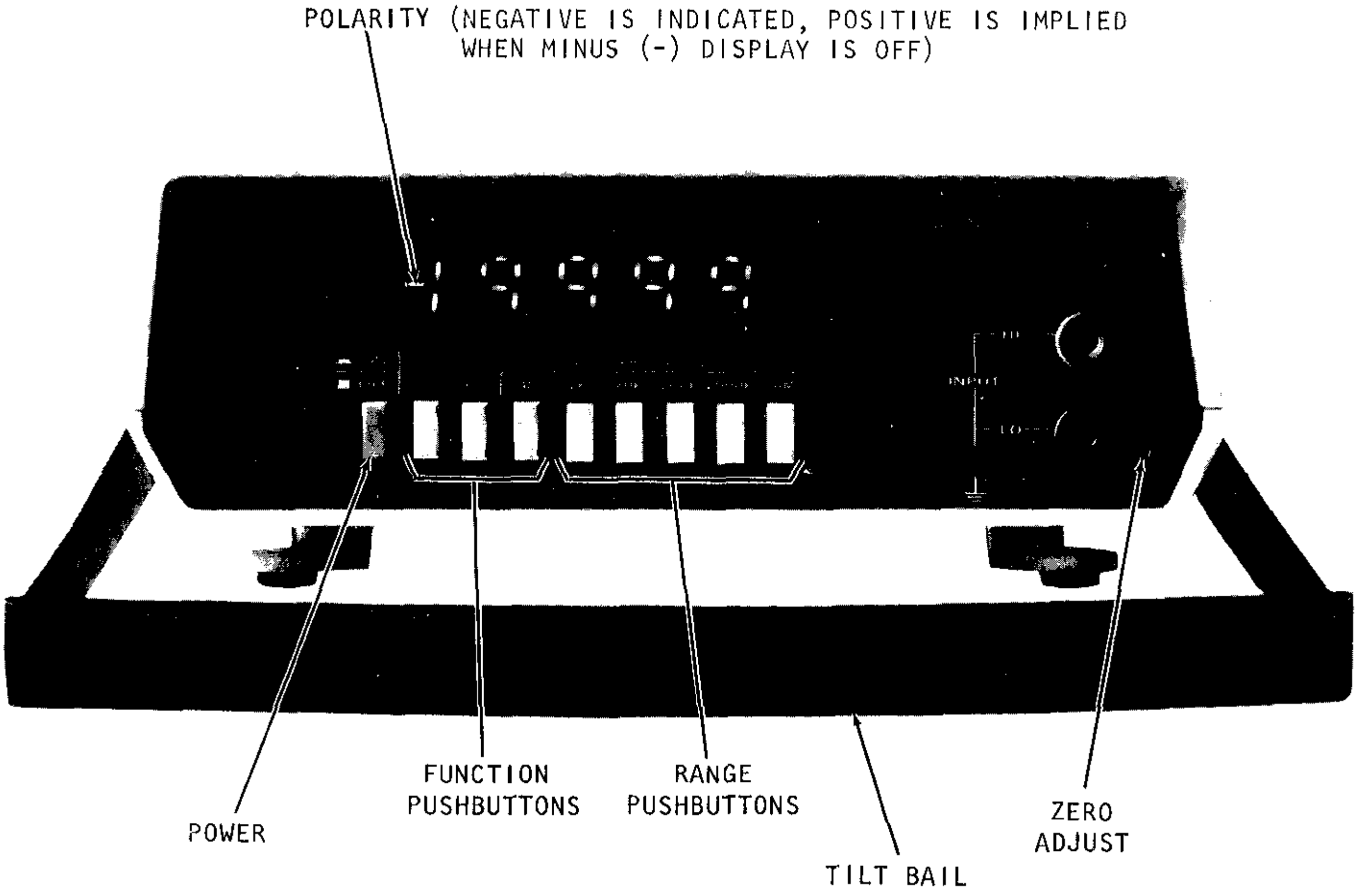


FIGURE 1-1. Front Panel.

SECTION 1. GENERAL INFORMATION

1-1. INTRODUCTION. The Model 178 DMM is a versatile digital multimeter useful for measurement of both ac and dc voltages as well as resistance. Ranges and accuracies are listed in the table of specifications on Page v. Ranges and functions are selected with pushbuttons on the front of the unit. The Model 178 automatically indicates polarity and positions the decimal point.

1-2. WARRANTY INFORMATION. The Warranty is given on the inside front cover of this Instruction Manual. If there is a need to exercise the Warranty, contact the Keithley Representative in your area to determine the proper action to be taken. Keithley maintains service facilities in the United Kingdom and West Germany, as well as in the United States. Check the inside front cover of this Instruction Manual for addresses.

1-3. CHANGE NOTICES. Improvements or changes to the instrument which occur after printing of the Instruction Manual will be explained on a Change Notice sheet attached to the inside back cover.

IMPORTANT

The ⚠ symbol can be found in various places in this Instruction Manual. Carefully read the associated CAUTION statements with regard to proper use and handling of the instrument. Damage to the instrument may occur if these precautions are ignored.

The ⚡ symbol can be found in various places in this Instruction Manual. This symbol indicates those areas on the instrument which are potential shock hazards. Carefully read the associated WARNING statements with regard to proper use and handling of the instrument. Serious personal injury may result if these precautions are ignored.

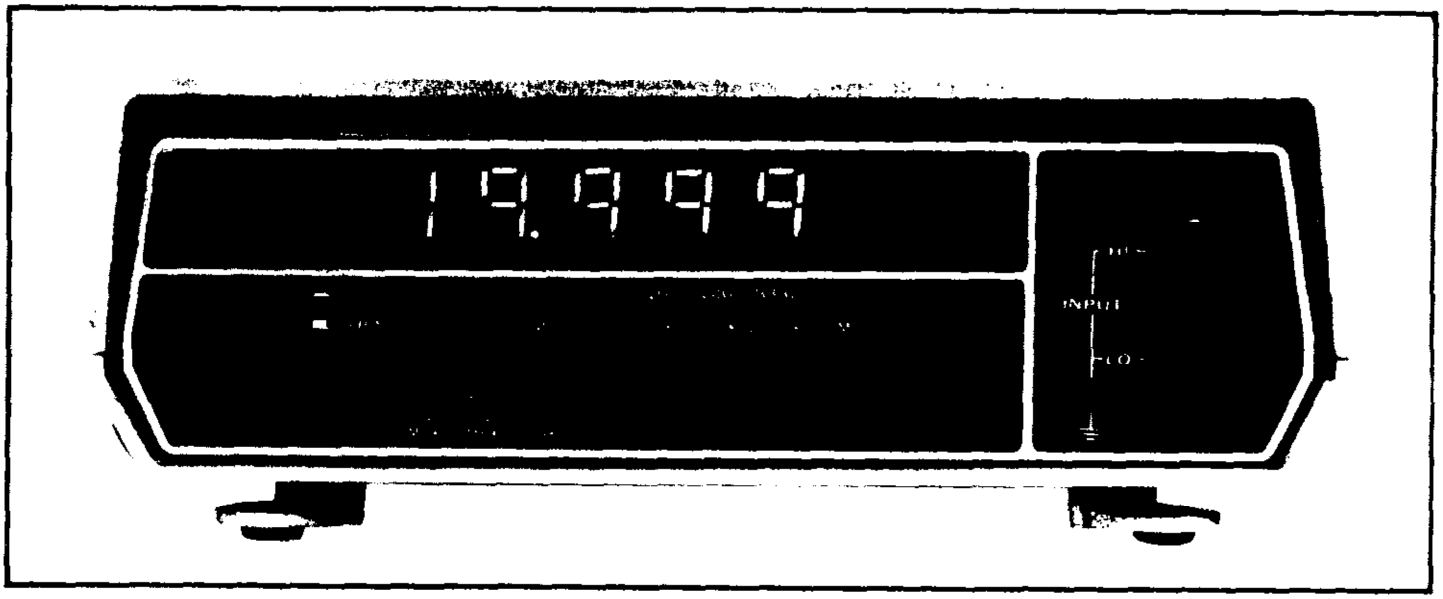


FIGURE 1-1. Front Panel

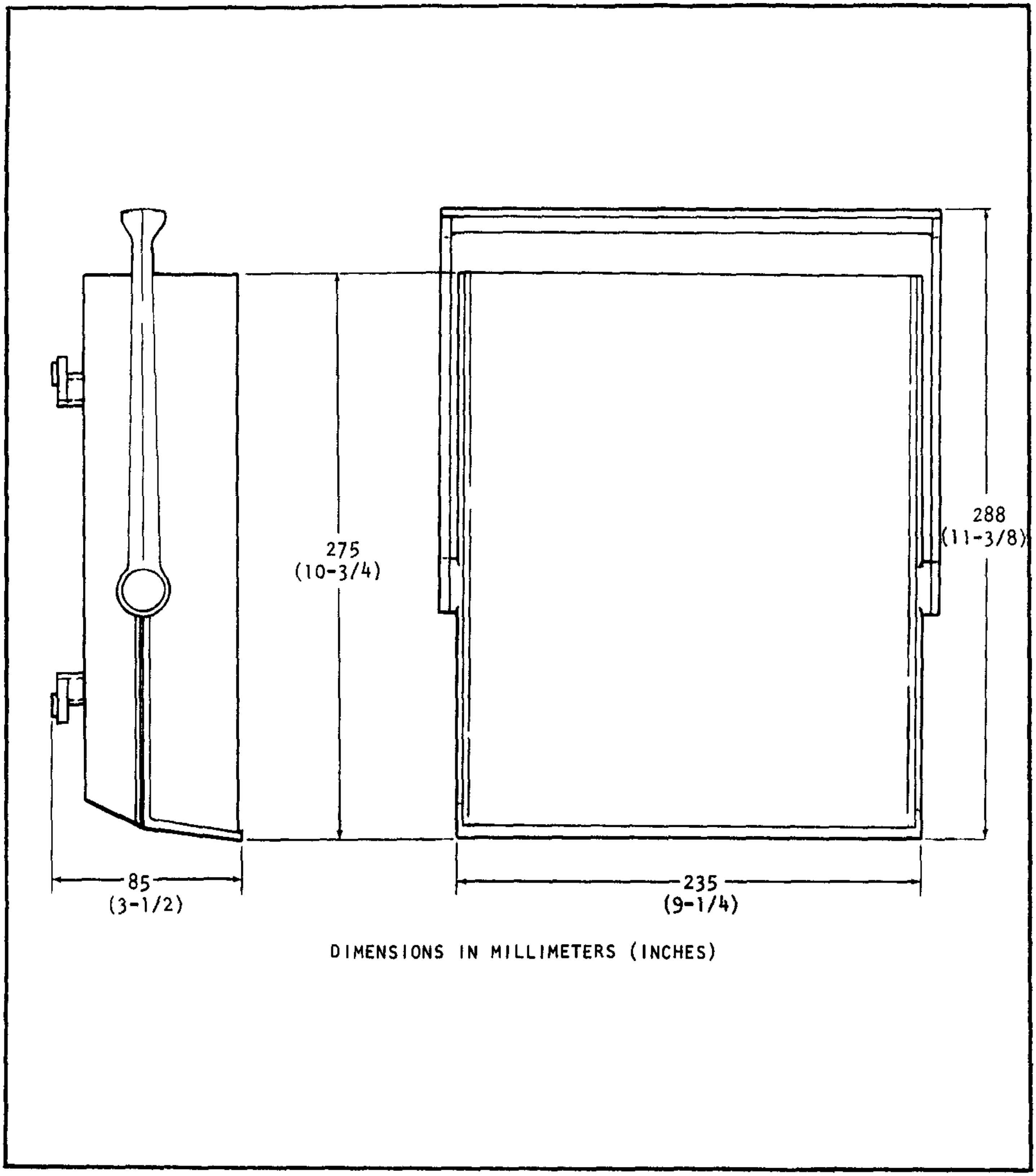


FIGURE 1-2. Dimensional Data

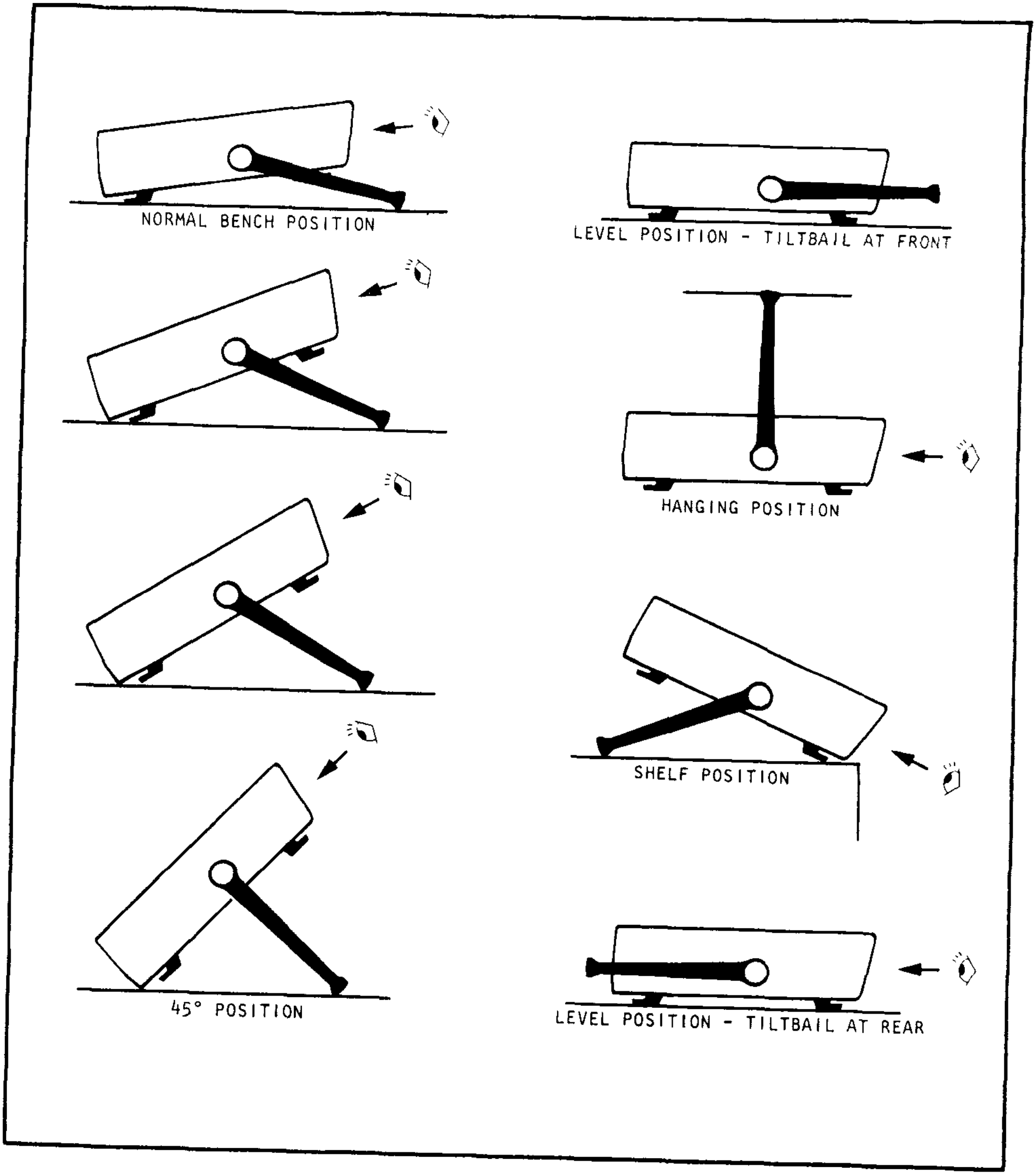


FIGURE 1-3. Tilt Bail Positions.

SECTION 2. OPERATION

2-1. GENERAL. This section provides information needed for incoming inspection and preparation for use.

2-2. INSPECTION. The Model 178 was carefully inspected both mechanically and electrically before shipment. Upon receiving the instrument, check for any obvious damage which may have occurred during transit. Report any damages to the shipping agent. To verify the electrical specifications, follow the procedures given in Section 3.

2-3. PREPARATION FOR USE. The Model 178 is shipped ready-to-use. The instrument may be powered from line voltage or from rechargeable batteries (when the optional Model 1788 Rechargeable Battery Set is installed).

2-4. OPERATION ON LINE POWER. The Model 178 is provided with a three-wire line cord which mates with third-wire grounded receptacles. Connect the instrument to ac line power as follows:

CAUTION

Connect only to the line voltage selected. Application of incorrect voltage can damage the instrument.

a. Set the LINE VOLTAGE switch on the back of the instrument to correspond to the line voltage available. Ranges are 105 to 125 volts ac and 210 to 250 volts ac as shown in Figure 2-1.

WARNING

Ground the instrument through a properly grounded receptacle before operation. Failure to ground the instrument can result in severe injury or death in the event of short circuit or malfunction.

b. Plug the power cord into a properly grounded outlet. Operate the 178 DMM as described in Section 2-7.

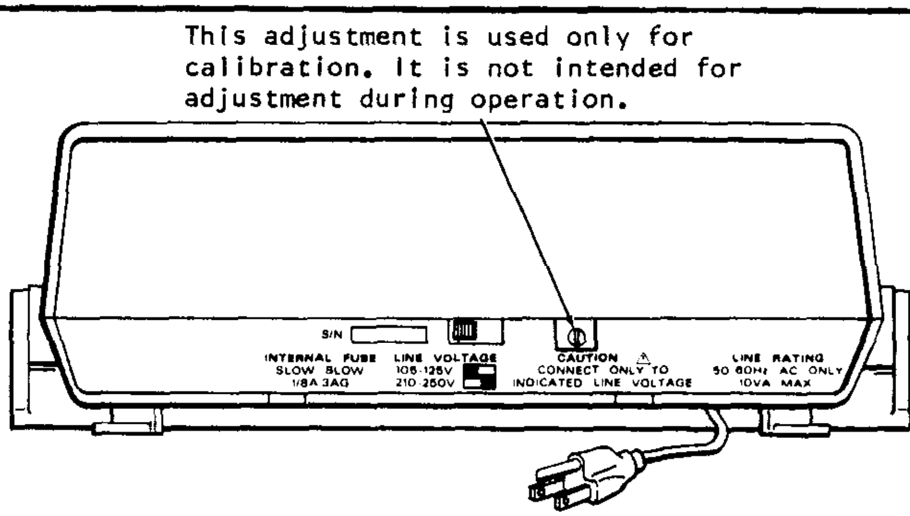


FIGURE 2-1. Rear View Showing Line Switch

2-5. OPERATION ON BATTERY PACK POWER. The Model 178 DMM may also be operated from rechargeable sealed lead-acid batteries contained in the optional Model 1788 Battery Pack. The pack will operate the 178 DMM for up to 6 hours. Circuits within the battery pack will automatically shut down the instrument when the battery charge is insufficient to maintain accurate readings. Refer to Figure 2-1 and install the battery pack as follows:

WARNING

Disconnect the line cord before removing the case cover.

a. Turn off the power and disconnect the line cord. Remove four screws from the bottom of the case and separate the top cover from the bottom cover.

b. Lift off the calibration shield, and save it for later use. The four plastic spacers must remain in place on the upright studs projecting through the main circuit board.

NOTE

Do not discard the calibration shield. This shield must be installed during calibration as described in Section 4.

c. Set the BAT/LINE switch to the BAT position shown in Figure 2-2. Note that the battery pack will not operate properly if this switch is not in the BAT position.

d. Remove fuse F301 on the battery pack.

e. Install the battery pack in the instrument so that it rests on the plastic spacers. The ground clip must make contact with the upper side of the battery pack plate.

f. Carefully align the battery pack plug with connector P1004 on the circuit board. Push the plug firmly onto the connector until the lip on the plug engages the lip on the connector to lock the plug in place.

CAUTION

Make sure the connector is aligned so that all pins mate properly, otherwise, damage to the DMM will result.

g. Install fuse F301. Reinstall top cover and secure with four screws.

h. Charge the battery pack as described in Paragraph 2-6.

2-6. BATTERY CHARGING. The Model 1788 Battery Pack contains an integral battery charger. To charge or recharge the battery pack, install the battery pack in the 178 DMM as described above and proceed as follows:

a. Connect the instrument to line power as described in Paragraph 2-4.

b. With the power switch off, the battery charge circuitry is automatically energized to charge the battery at the maximum rate. When the battery pack is first installed, or if it has completely discharged, allow it to charge for at least 14 hours in this condition.

NOTE

For maximum battery life, do not allow the battery pack to remain completely discharged. Constant charging will not harm either the battery pack or the instrument.

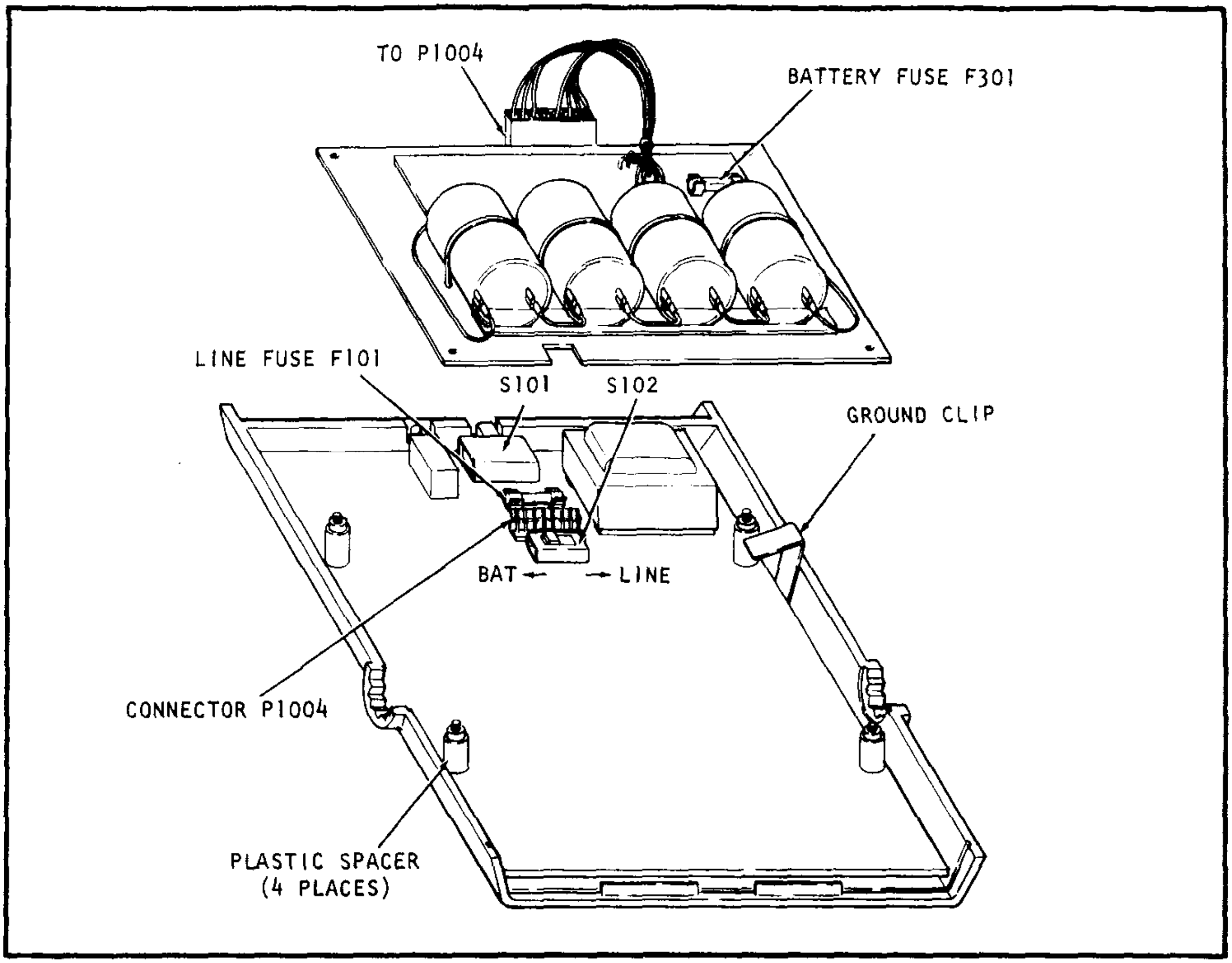


FIGURE 2-2. Battery Pack Installation.

c. When the 178 DMM is in use on line power, the battery charger maintains a trickle charge on the battery pack.

2-7. OPERATING INSTRUCTIONS. Refer to Figure 2-3 and operate the DMM as follows:

a. Turn on the power by depressing the ON/OFF pushbutton.

b. Select the function with the DCV, ACV or Ω pushbutton.

c. Select the range by depressing the appropriate pushbutton. For ac and dc voltage measurements there are four ranges available. For resistance measurements there are five ranges. The pushbuttons are interlocked to avoid improper settings.

d. Connect the source to the INPUT terminals.

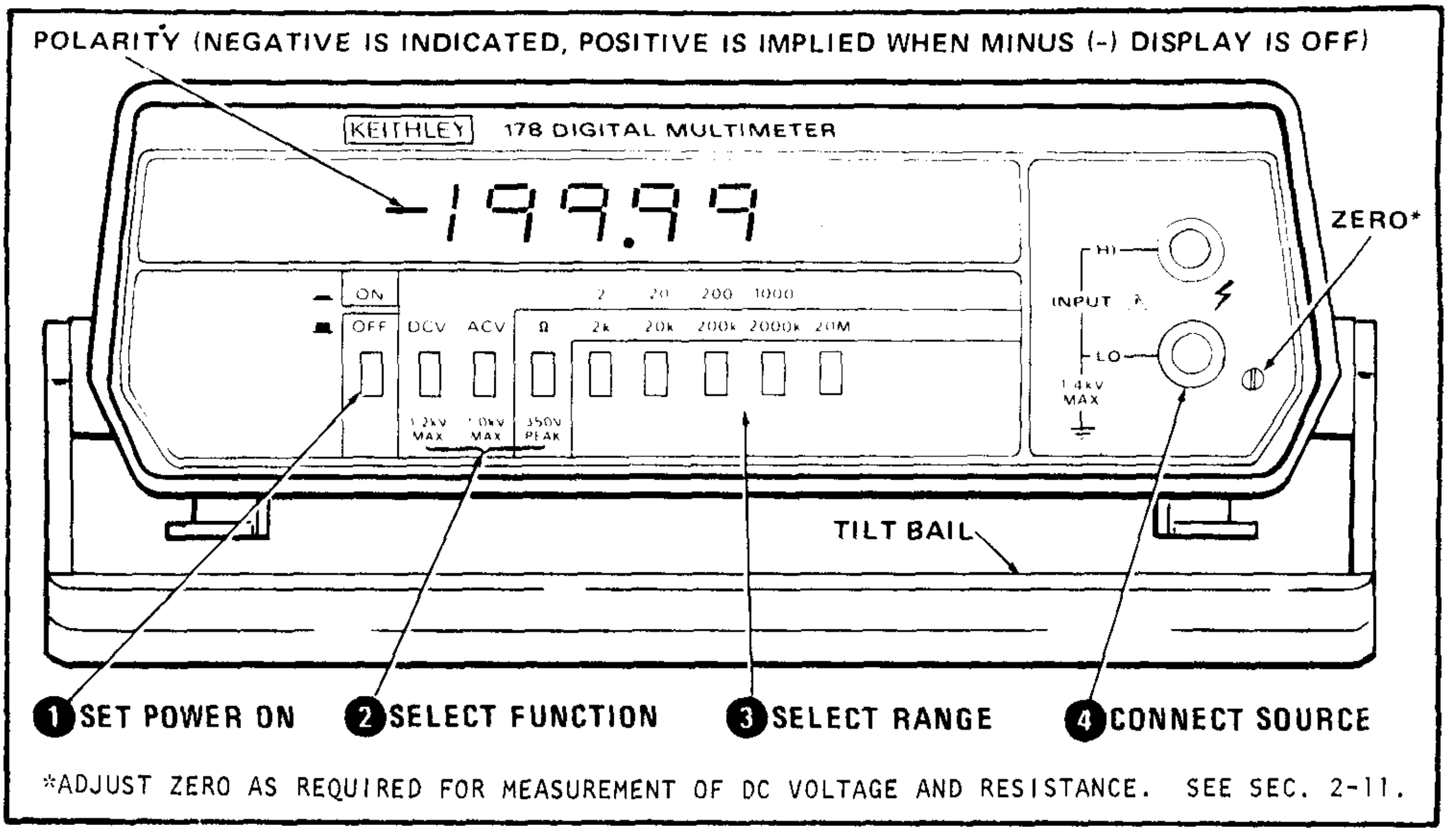


FIGURE 2-3. Operating Controls.

CAUTION

MAXIMUM RATINGS: ⚠

DCV:	(2V):	450V rms continuous; 1200V peak, for 8 seconds per minute.
	(20-1200V):	1200V peak.
ACV:	(All Ranges):	1000V rms; 10^7V•Hz.
Ω:	(All Ranges):	250V rms sine wave or 350V peak.

e. Accessories described in Paragraph 2-12 should be used as required.

2-8. DC VOLTAGE MEASUREMENT. Use the Model 178 DMM to measure dc volts as follows:

a. Turn on power and depress the DCV pushbutton.

b. Select the desired range from the four ranges available. The maximum reading is 19999. Overrange is indicated by a flashing 0000 except on the 1000-volt range.

CAUTION

⚠ Do not exceed the maximum ratings. Instrument damage may occur.

c. Negative polarity is displayed automatically. Positive polarity is implied when the minus (-) display is off.

d. Zero the instrument as described in Paragraph 2-11 before the first use, whenever the instrument is used outside the temperature range of 18° to 28°C, and approximately weekly during normal use.

2-9. AC VOLTAGE MEASUREMENT. Use the Model 178 DMM to measure ac volts as follows:

a. Turn on power and depress the ACV pushbutton.

CAUTION

⚠ Do not exceed the maximum ratings. Instrument damage may occur.

b. Select the desired range from the four ranges available. The maximum reading is 19999. Overrange is indicated by a flashing 0000 except on the 1000-volt range. The instrument reads the root mean square value of a sine wave with a frequency of 45 to 20 kHz.

c. The Model 1682 RF Probe (see Paragraph 2-12e) should be used to measure ac voltages with a frequency of 20kHz to 100MHz.

2-10. RESISTANCE (Ω) MEASUREMENT. Use the 178 DMM to measure resistance as follows:

a. Turn on power and depress the Ω pushbutton.

CAUTION

⚠ Do not exceed the maximum ratings. Instrument damage may occur.

b. Select the desired range from the five ranges available. The maximum reading is 19999. Overrange is indicated by a flashing 0000. The letter k refers to kilohms, and M refers to megohms.

c. The HI input terminal is positive and causes forward conduction of semiconductor junctions.

d. Two volts is applied at full range with 5 volts maximum under open circuit conditions.

e. Zero the instrument as described in Paragraph 2-11 before the first use, whenever the instrument is used outside the temperature range of 18° to 28°C, and approximately weekly during normal use.

2-11. ZERO ADJUSTMENT. The zero adjustment nulls input offset on the 20, 200 and 1200 volt ranges and on all resistance ranges. Typically, this adjustment need not be performed more often than once a week unless the instrument is operated at ambient temperatures outside the range of 18° to 28°C. Zero adjustment may also be used for lead compensation on the Ω function. Zero the instrument as follows:

a. Turn on the power and select DCV and the 20 range.

b. Plug in test leads and short them. Adjust the zero adjust (pot R132) from the front panel with a small screwdriver to obtain a reading of 0000 or -0000.

2-12. ACCESSORIES. A wide range of accessories is available to facilitate use of the Model 178 DMM, extend its range and adapt it for additional uses.

a. Model 1600 High Voltage Probe. The Model 1600 High Voltage Probe (shown in Figure 2-4) extends the measurable dc voltage range up to 40 kilovolts. It has a 1000:1 division ratio, so that a reading of 1 volt on the DMM corresponds to 1 kilovolt (1000 volts). To use the probe, select DCV and the required range, connect the high voltage probe banana plug to the instrument, connect the alligator clip to source low and touch the probe tip to source high.

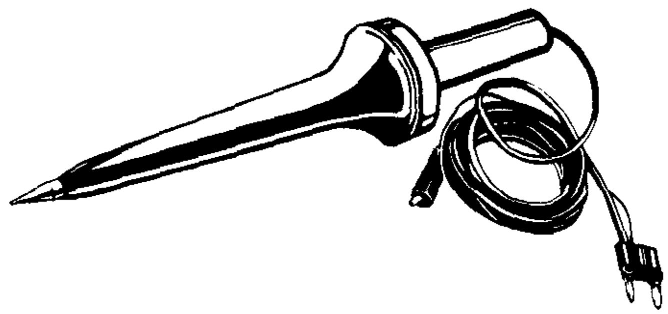


FIGURE 2-4. Model 1600 High Voltage Probe.

SPECIFICATIONS:

Voltage Range: 0 to 40,000 volts DC.
Input Resistance: 1000 megohms.
Division Ratio: 1000:1
Ratio Accuracy:
±1.5% at 25kV, decreasing to
±2.0% at 20kV and 30kV,
±3.0% at 10kV and 40kV, and
±4.0% at 1kV.
Ratio Stability: ±0.01% per °C; ±0.1% per year.
Heating Effects: Self-heating due to application of high voltage for period in excess of 1 minute will cause a maximum of 0.2% additional error at 40kV (error is less at lower voltage).

WARNING

Be sure the alligator clip is connected to source low before touching probe tip to source high. A shock hazard or damage to instrument may result.

b. Model 1651 50-Ampere Shunt. The Model 1651 50-Ampere Shunt (shown in Figure 2-5) permits current measurements of up to 50 amperes ac or dc. The shunt has a resistance of 0.001 ohm ±1%, so that a 50-ampere current will correspond to a reading of 50 millivolts (0.0500 volt). Set the DMM to ACV or DCV and select the required range. To use the shunt, connect the leads furnished with the shunt from the shunt screw terminals to the DMM input terminals. Use separate leads (not furnished) to connect the source to the hex head bolts. Be sure to use leads with a capacity of 50 amperes, or as needed.

c. Model 1681 Clip-On Test Lead Set. This set (shown in Figure 2-5) contains two leads with banana plugs at one end and spring-action clip-on probes at the other end. Plug the leads into the DMM and attach the probes to the source.

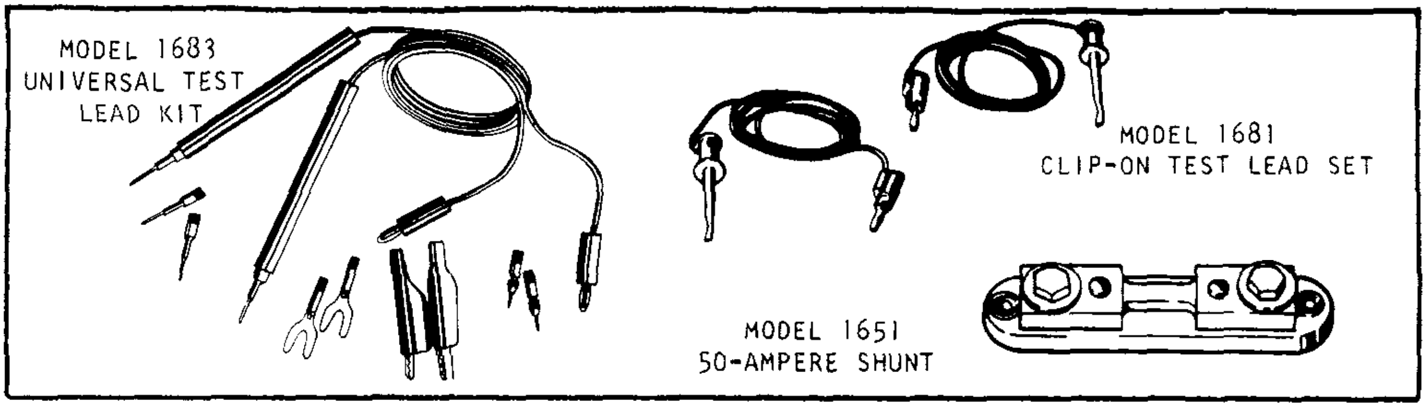


FIGURE 2-5. Accessories.

d. Model 1683 Universal Test Lead Kit. This kit (shown in Figure 2-5) contains 2 test leads, 14 tips, 2 probes, 4 banana plugs 2 spade lugs and 2 pnone tips to permit connection of the DMM to virtually any source within its range.

e. Model 1682 RF Probe. The Model 1682 RF Probe (shown in Figure 2-6). permits measurement of ac voltages at frequencies of 20 kilohertz to 100 megahertz. Connect the probe to the input terminals and select ACV and the appropriate range.

SPECIFICATIONS:

Voltage Range: 0.25 to 30 volts rms.
Transfer Accuracy: ±0.5dB, 100kHz to 100MHz peak responding calibrated in rms of a sinewave.
Input Impedance: 4 megohm shunted by 3pF.
Maximum Allowable Input: 30V rms AC, 200V DC.
Accessories Supplied: straight tip, hook tip, ground clip, hi adapter, banana plug adapter.

f. Model 1685 Clamp-On AC Current Probe. The Model 1685 Clamp-On AC Current Probe (shown in Figure 2-6) permits measurement of ac current by clamping around a single conductor, eliminating the need to interrupt the current path. Plug the ac current probe into the DMM and select ACV and the appropriate range. The DMM will display 0.1 volt rms per ampere.

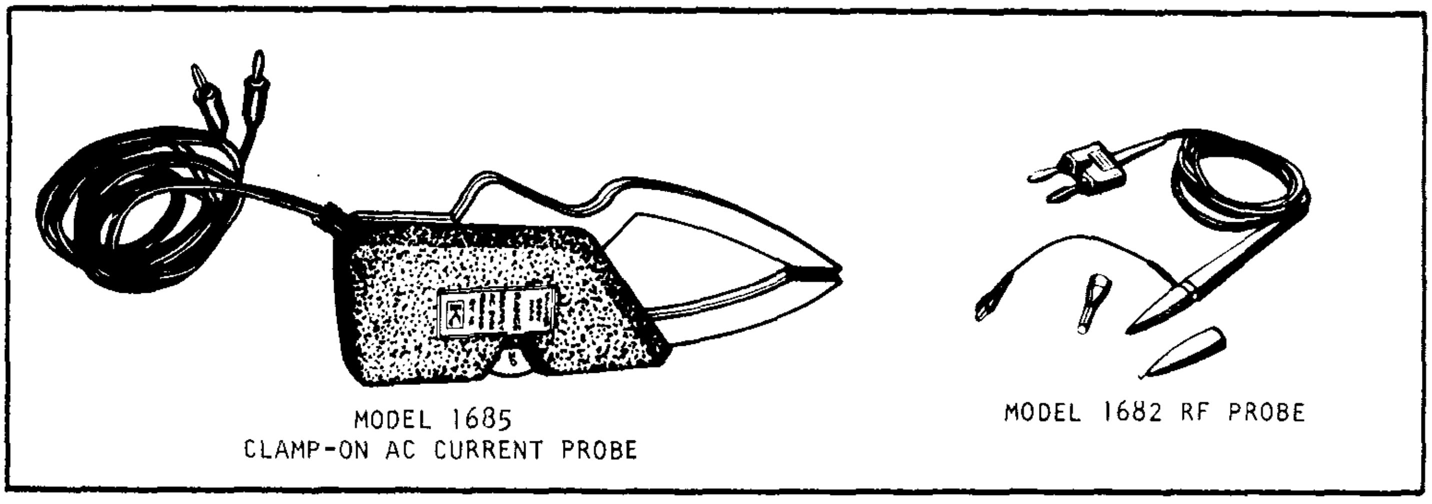


FIGURE 2-6. Model 1682 RF Probe and Model 1685 Clamp-On AC Current Probe.

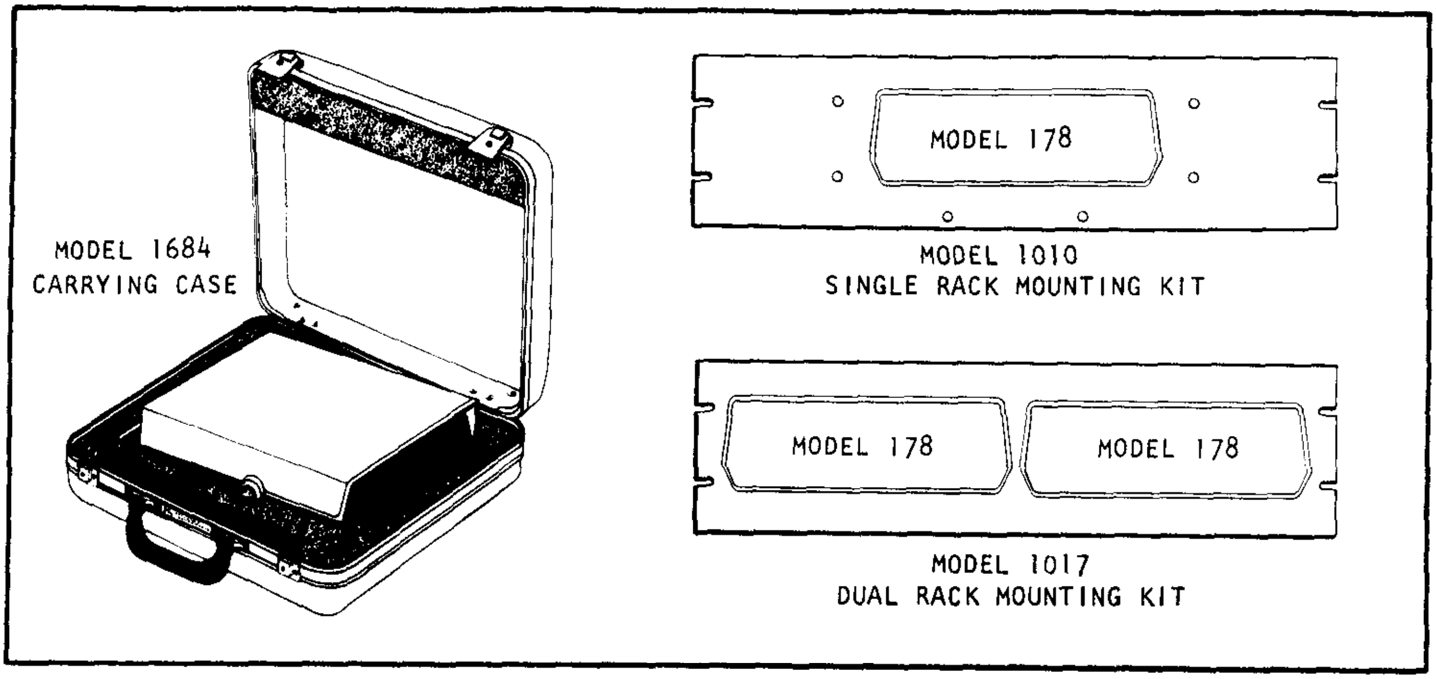


FIGURE 2-7. Carrying Case and Rack Mounting Kits.

SPECIFICATIONS:

Range: 2, 20 and 200 amperes rms.
Accuracy: ±4% of range at 60Hz. ±6% of range at 50Hz.
Temperature Coefficient: ±0.05%/°C on the 20 and 200 ampere ranges. ±0.3%/°C on the 2 ampere range.
Maximum Allowable Current: 300 amperes rms.
Maximum Conductor Voltage: 600 volts rms.
Conversion Ratio: 0.1 volt rms per ampere.

g. Model 1684 Carrying Case. The Model 1684 Carrying Case (Shown in Figure 2-7) is a hard vinyl case with a fitted foam insert to help protect the Model 178 DMM from damage. There is also room in the case for this instruction manual and other small accessories.

h. Models 1010 and 1017 Rack Mounting Kits. The rack mounting kits (shown in Figure 2-7) permit mounting one or two Model 179 DMM's in a rack for convenient viewing.

SECTION 3. PERFORMANCE VERIFICATION.

3-1. GENERAL. Performance verification should be performed upon receipt of the instrument to ensure that no damage or misadjustment has occurred during transit. Verification may also be performed whenever there is question of the instrument's accuracy and following calibration, if desired.

NOTE

For instruments that are still under warranty (less than 12 months since date of shipment), if the instrument's performance falls outside specifications at any point, contact your Keithley representative or the factory immediately.

3-2. RECOMMENDED TEST EQUIPMENT. Recommended test equipment for performance verification is listed in Table 3-1. Alternate test equipment may be used. However, if the accuracy of the alternate test equipment is not at least 10 times better than the instrument specifications, additional allowance must be made in the readings obtained.

3-3. ENVIRONMENTAL CONDITIONS. All measurements should be made at an ambient temperature within the range of 18° to 28°C (65° to 82°F), and a relative humidity of less than 80%.

3-4. PERFORMANCE VERIFICATION PROCEDURE. Use the following procedures to verify the basic accuracy of the Model 178 DMM for voltage and resistance measurements. If the instrument is out of specifications at any point, perform a complete calibration as described in Section 4, unless the instrument is still under warranty, as noted above.

TABLE 3-1.
Recommended Test Equipment for Performance Verification.

Item	Description	Specification	Mfr.	Model
A	DC Calibrator	0.1V, 1V, 10V, 100V, 1000V ±0.002% or 20µV	Fluke	343A
B	AC Calibrator	0.1V, 1V, 10V, 100V ±0.022%	H-P	745A
C	AC Calibrator/Amplifier	1000V @ ±0.04%	H-P	745A/746A
D	Decade Resistor	1.9kΩ, 19kΩ, 190kΩ 1.9MΩ, 19MΩ, ±0.01%	ESI	RS725

NOTE

Performance verification should be performed by qualified personnel using accurate and reliable test equipment.

a. Initial Conditions. Before beginning the verification procedure the instrument must meet the following conditions:

1) If the instrument has been subjected to extremes of temperature, allow the internal temperatures to stabilize for one hour minimum at the environmental conditions specified in Paragraph 3-3.

1) Turn on the 178 DMM and allow it to warm up for 10 minutes. The instrument may by operated from either line power or from battery pack power, as long as the battery pack has been fully charged as described in Paragraph 2-6.

2) Zero the instrument as described in Paragraph 2-11.

WARNING

Some procedures require the use of high voltage. Take care to prevent contact with live circuits which could cause electrical shock resulting in injury or death.

b. DC Volts Checkout.

1) Select dc voltage by pushing the DCV pushbutton.

2) Connect the DC Calibrator (Item A, Table 3-1) to the instrument.

3) Select the 2V range and apply positive 1.0000V to the DMM. The reading must be within the limits specified in Table 3-2.

4) Select each remaining range and apply the required voltage as specified in Table 3-2. Verify that the reading is within specifications.

5) Repeat all checks with negative voltage.

TABLE 3-2.
DC Voltage Performance Check.

Range	Applied Voltage	Allowable Readings at 18° to 28°C
2V	1.0000V	0.9995 to 1.0005V
20V	10.000V	9.995 to 10.005V
200V	100.00V	99.95 to 100.05V
1200V	1000.0V	999.5 to 1000.5V

c. AC Volts Checkout.

1) Select ac voltage by pushing the ACV pushbutton.

2) Connect the AC Calibrator (Item B, Table 3-1) to the DMM. Set the calibrator frequency to 1kHz.

3) Set the DMM to the 2V range and apply 1.0000V to the DMM. The reading must be within the limits specified in Table 3-3.

4) Select the 2, 20 and 200 volt ranges and apply the required voltages as specified in Table 3-3. Verify that the readings are within specifications.

5) To check the 1000 volt range, connect the AC Calibrator/Amplifier (Item C, Table 3-1) to the output of the AC Calibrator per the manufacturer's instructions. Set it for an output of 1000.0V rms and verify that the DMM reading is within the specified limits.

TABLE 3-3.
AC Voltage Performance Check.

Range	Applied Voltage	Allowable Readings at 18° to 28°C
2V	1.0000V	0.9945 to 1.0055V
20V	10.000V	9.955 to 10.045V
200V	100.00V	99.55 to 100.45V
1000V	1000.0V	995.5 to 1004.5V

d. Resistance Checkout.

1) Select resistance readings by pressing the Ω pushbutton.

2) Push the 2kΩ button to select the required range.

3) Connect the Decade Resistor (Item D, Table 3-1) to the DMM.

4) Set the Decade Resistor to zero and measure the resistance of the test leads. Subtract this reading from the displayed reading in all of the following steps.

5) Set the Decade Resistor to 1.9000kΩ. Verify that the reading is within the specified limits in Table 3-4.

6) Select each remaining range and measure the next resistance as specified in Table 3-4. Verify that each reading is within specifications. The displayed reading must fall within specified limits for each resistance.

TABLE 3-4.
Resistance Performance Check

Range	Resistance	Allowable Reading at 18° to 28°C
2kΩ	1.9000kΩ	1.8989 to 1.9011kΩ
20kΩ	19.000kΩ	18.990 to 19.010kΩ
200kΩ	190.00kΩ	189.90 to 190.10kΩ
2000kΩ	1.9000MΩ	1899.0 to 1901.0kΩ
20MΩ	19.000MΩ	18.980 to 19.020MΩ

SECTION 4. CALIBRATION

4-1. GENERAL. Calibration should be performed yearly (every 12 months) or whenever performance verification (see Section 3) indicates that the Model 178 DMM is out of specifications. If any step in the calibration procedure cannot be performed properly, refer to Section 5 for troubleshooting information, or contact your Keithley representstive or the factory.

4-2. RECOMMENDED TEST EQUIPMENT. Recommended test equipment for calibration is listed in Table 4-1. Alternate test equipment may be used. However, the accuracy of the alternate test equipment must be at least 10 times better than the instrument specification, or equal to Table 4-1 specifications.

Table 4-1.
Recommended Test Equipment for Calibration

Item	Description	Specification	Mfr.	Model
A	DC Calibrator	0.1V, 1V, 10V, 100V, 1000V ±0.002% or 20μV	Fluke	343A
B	AC Calibrator	0.1V, 1V, 10V, 100V ±0.022%	H-P	745A
C	Decade Resistor	1.9kΩ, 190kΩ, ±0.01%	ESI	RS725

4-3. ENVIRONMENTAL CONDITIONS. Calibration should be performed under laboratory conditions having an ambient temperature of 20° to 26°C (68° to 78°F), and a relative humidity of less than 80%.

4-4. CALIBRATION PROCEDURE. Perform the following adjustments to calibrate the Model 178 DMM and restore its operation to specified limits.

a. Calibration Shield Installation. If the Model 1788 Battery Pack is installed in the instrument it must be removed and the calibration shield reinstalled before calibration.

WARNING

Disconnect the line cord before removing the case cover.

1) Turn off the power and disconnect the line cord. Remove the four screws from the bottom of the case, and separate the top cover from the bottom cover.

2) Push back the ground clip (shown in Figure 2-2) from the upper side of the battery pack, and remove the battery pack from the spacers.

3) Calibration may be performed on battery power as long as the battery pack is sufficiently charged. Leave the battery pack plugged into the instrument, but set the battery pack behind the DMM on the bench or table. If the battery pack is not sufficiently charged, operate from line power.

4) Set the calibration shield in place on the spacers. The shield should read correctly when viewed from the front of the instrument.

5) Slide the ground clip over the top of the calibration shield so that it contacts the upper surface of the shield.

6) If battery power is not to be used, plug in the line cord.

b. Calibration Instructions

WARNING

Some procedures require the use of high voltage. Take care to prevent contact with live circuits which could cause electrical shock resulting in injury or death.

1) Refer to Table 4-2 and to the calibration shield, and perform the listed adjustments in the sequence indicated. The sequence must be followed exactly because the adjustments are interrelated and are dependent on the preceding steps.

2) If the indicated adjustment cannot be made to obtain the specified reading, refer to Section 5 for troubleshooting information.

Table 4-2.
Calibration Procedure.

Step	Function	Range	Input	Adjustment Point	Desired Reading	Test Equipment*
1	DCV	20V	Short	R132	0.000	None
2	ACV	20V	Short	R115	0.000	None
3	Ω	2kΩ	1.9kΩ	R128	1.9000	Decade Resistor (C)
4	Ω	200kΩ	190kΩ	R126	190.00	Decade Resistor (C)
5	DCV	2V	+1.9V	R113	1.9000	DC Calibrator (A)
6	DCV	200V	+190V	R101	190.00	DC Calibrator (A)
7	DCV	20V	+19V	R125	19.000	DC Calibrator (A)
8	DCV	1000V	+1000V	R127	1000.0	DC Calibrator (A)
9	ACV	2V	1V@1kHz	R116	1.0000	AC Calibrator (B)
10	ACV	200V	100V@10kHz	C119	100.00	AC Calibrator (B)
11	ACV	20V	10V@10kHz	C115	10.000	AC Calibrator (B)
12	ACV	2V	1V@10kHz	C113	1.0000	AC Calibrator (B)

* See Table 4-1

SECTION 5. TROUBLESHOOTING

5-1. GENERAL. The troubleshooting instructions contained in this section are intended for qualified personnel having a basic understanding of analog and digital electronic principles and components used in a precision electronic test instrument. Instructions have been written to assist in isolating the defective circuit or subcircuit. Isolation of the specific defective component has been left to the technician.

5-2. TROUBLESHOOTING PROCEDURE. This section contains tables listing step-by-step checks of the major DMM circuits described in Section 6, Theory of Operation. Proceed as follows:

a. In general, start troubleshooting with Table 5-1, Line Power Checks, to verify that the power supplies are providing the specified voltage to the electronic components.

b. If trouble occurs on battery power only, or if battery operating time is substantially less than 6 hours after overnight charging, test the batteries and charging circuit per Table 5-2.

c. Proper operation of the A/D converter display should be verified before troubleshooting the signal conditioning. Check these circuits per Tables 5-4 and 5-3, respectively.

d. Problems with ac voltage ranges may involve either the ac attenuator or the ac converter. Check these circuits per Tables 5-6 and 5-8.

e. Check the dc voltage attenutator per Table 5-5 if problems occur with the dc voltage ranges. Check the resistance circuit per Table 5-7 if resistance measurements are erratic.

f. All measurements are referenced to analog common (ground clip).

Table 5-1.
Line Power Checks

Step	Item/Component	Required Condition	Remarks
1	S101 line switch	Must be set to 105-125V or 210-250V as appropriate.	
2	S102 LINE/BAT switch	Must be set to BAT for use with battery pack.	
3	F101 line fuse	Continuity.	
4	P1007 line cord	Plugged into live receptacle.	
5		Turn on power.	
6	+5V pad*	+5 volts ±10%.	Output of VR103.
7	TP7*	+7 volts minimum.	Output of CR105, input to VR103.
8	+15V pad*	+15 volts ±10%.	Output of VR101.
9	TP1*	+17.5 volts minimum.	Output of CR106, input to VR101.
10	-15V pad*	-15 volts ±10%.	Output of VR102.
11	TP2*	-17.5 volts minimum.	Output of CR106, input to VR102. NOTE: Hot regulator may indicate shorted load.

* On main printed circuit board.

TABLE 5-2.
Battery Power Checks.

Step	Item/Component	Required Condition	Remarks
1		Check AC line power per Table 5-1.	
2		Turn off power.	
3	S102 line/bat switch	Move to BAT.	
4	P1007 line cord	Plugged into live receptacle.	Charge circuit checks.
5	F301	Remove fuse and connect ammeter to fuse clip. 0 to 500 mA charging rate, varies with line voltage and battery state of charge.	No charge, see step 5A. Correct charging but short battery operating time, see step 6.
5A	BT301 batteries	Full charge is ≈9.8 volts over 4 cells. R301 adjusts charging rate (float voltage).	If voltage is low and adjustment of R301 does not start charging, see steps 7 and following. If voltage is low and adjustment of R301 does start charging, see Table 5-9 for adjustment of battery charge voltage.
6	Each battery cell voltage <u>during</u> charging.	Less than 3 volts for any cell.	High voltage or zero indicates damaged cell.
7	Q301 anode	Full wave rectified voltage, 15 VDC nominal.	Output of CR105.
8	C304 +	+17.5 volts minimum.	Output of CR106. Triggers Q301 gate thru R306 and CR301 unless Q302 is on.
9	Q302	Should saturate only when battery approaches full charge.	
10	VR301	8.2V zener.	
11		Unplug line cord and turn power on.	Discharge checks.
12	P1004 pin 8 or U301 pin 11.	100 kHz; 5V square wave.	Clock input. If no input, see step 12A.
12A	TP7*	+7 volts minimum.	Battery voltage input to VR103.
13	Q307 and Q308 base	Square wave, ±0.7 volts at 25 kHz.	Output of U301, ÷ 4.
14	Q307, Q308 collector.	Must oscillate from saturation to twice battery voltage (≈19 volts) at 25 kHz.	Inverter.
15	C304, C305	±17.5 volts minimum (±25 volts typical with full charged batteries).	Inverter output; Input to VR101 and VR102.

* On main printed circuit board.

TABLE 5-3.
Display

Step	Item/Component	Required Condition	Remarks
1		Turn on power. Any function or range, except OHMS.	
2	+5V*	+5 volts ±10%.	If low, check per Table 5-1.
3	U202, pins 2, 6, 7, 9 and 13.	Digit drive. Low = enabled.	LED cathode.
4	U201, pins 1, 2, 6 and 7	HI = enabled.	BCD input to U201 segment decoder/drive.
5	U201, pin 4	Positive-going signal lasting for 200 clock pulses.	Leading digit suppression. Output of U104A.
6	J1002, pin 9	Polarity line (sign). HI = off LO = -	Polarity output is inverted for 2VDC.
7	J1001, pins 1, 2, 3 and 4.	Appropriate DP line high (on).	

* On main printed circuit board.

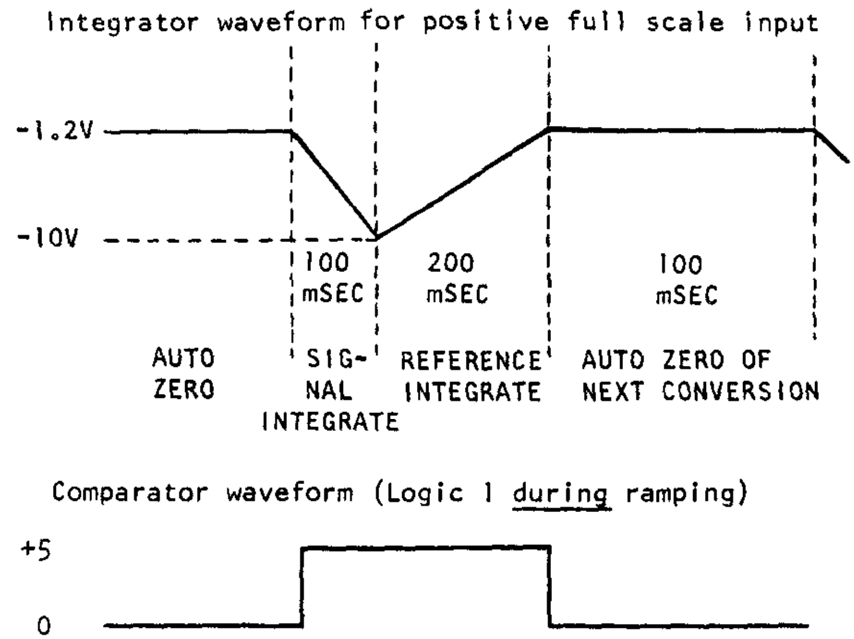


FIGURE 5-1. Integrator and Comparator Waveforms.

TABLE 5-4.
A/D Converter.

Step	Item/Component	Required Condition	Remarks
1		Turn on power. Select 2 VDC range.	On this function and range, input HI connects thru R124 and R117 to A/D, without attenuation.
2	Display	.0000 ±1 digit.	
3	TP8*	0.0000 volts.	Input to U106.
4	TP10*	+1.00 volt.	Reference output.
5	TP3*	6.3 ±.25V.	Reference zener voltage.
6	CLK*	0 to +5 volt square wave at 100 kHz.	Clock input.
7	TP9*	+1.0 ±0.1 volts.	Stored autozero voltage.
8	U105, pin 11	+1.0 ±0.1 volts.	Σ-node voltage to integrator in U105.
9	TP11*	-1.2 ±0.2 volts.	U105 integrator output voltage.
10	U105, pin 13	+1 volt.	U105 buffer input.
11	U105, pin 9	+1 volt.	U105 buffer output.
12	External voltage source.	Apply +1.9000 volts.	Calibration point.
13	Display.	1.9000 ±1 digit.	If different, check U106 input.
14	TP8*	1.0000 volt.	Input to U106.
15	TP11	Waveform per Figure 5-1.	Integrator output.
16	U105-2	Waveform per Figure 5-1. during ramping of integrator output.	Comparator output.

* On main printed circuit board.

Table 5-5.
DC Volts Attenuator

Step	Item/Component	Required Condition	Remarks
1		Turn on power. Select 20 VDC range, and short inputs.	
2	R132	Front panel adjustment must zero the display.	
3	U103, pin 2	0.000 ±0.005 volts.	
4	External voltage source	Apply +10 volts from HI to LO.	Calibrated input.
5	TP5*	-1 volt (display must read 1.0000).	
6	External voltage source	apply +100 and + 1000 volts on 200 and 1000 volt ranges.	Calibrated input.
7	TP5*	-1 volt.	Output of U103 and feedback components, including relays.

* On main printed circuit board.

TABLE 5-6.
AC Volts Attenuator

Step	Item/Component	Required Condition	Remarks
1		Turn on power. Select 2 VAC range.	
2	External voltage	Apply 1 volt rms at 1 kHz.	Calibrated input.
3	TP5*	1 volt rms.	Output of U103 and feedback components. NOTE: Full scale inputs should produce ≈2 volts output, all ranges.
4	External voltage source.	Apply 10, 100 and 1000 volts rms on 20, 200 and 1000 volt ranges.	Calibrated input.
5	TP5*	1 volt rms on all ranges.	Output of U103 and feedback components, including relays.
6	External voltage source.	Apply 1, 10, 100V @ 20 kHz on 2, 20 and 200V ranges respectively.	C113, C115, C116, C117 and C119.
7	External voltage source.	Apply 10V @ 45Hz on 20V range.	C121.

* On main printed circuit board.

Table 5-7.
Resistance Circuit

Step	Item/Component	Required Condition	Remarks
1		Turn on power. Select Ω, 200K range.	Voltage attenuation feedback resistors are amplifier input resistors on Ω function.
2	INPUT HI to LO	5 volts maximum open circuit.	R118 and Q102 should limit open circuit volts.
3	U103 pin 2	Continuity to input HI.	K105.
4	Ω switch pin 11	+1V.	Reference voltage.
5	Short input TP8	0V.	A/D input.
6	100K resistor	Apply to input.	
7	TP8*	-1V.	A/D input.

* On main circuit board.

TABLE 5-8.
AC Converter.

Step	Item/Component	Required Condition	Remarks
1		Turn on power. Select 20 VAC range and short inputs.	
2		0.0000 display.	Calibration point.
3		Remove input short.	
4	External voltage source.	10 volts rms, 1 kHz	Calibrated input.
5	CR103 cathode.	Half-wave rectification of input (use scope): gain ≈ 2.	Output of U102 and CR103.
6	TP8*	Average value of rectified waveform ≈ 1 volt dc.	Converter output.
7	Repeat steps 5 and 6.	10 volts rms, 45 Hz.	Low frequency response.
8	Repeat steps 5 and 6.	10 volts rms, 20 kHz	High frequency response.

* On main printed circuit board.

TABLE 5-9.
Adjustment of Battery Charge Voltage.

Step	Item/Component	Required Condition	Remarks
1		Instrument off.	
2	R301	Turn full CCW. (maximum charge rate).	
3	BT301	Monitor battery voltage for > 9.8V.	Fully charged cells require several minutes to reach this level. Discharged cells require several hours. ⚠ CAUTION - charging to > 10V for longer than 30 minutes will reduce battery life.
4	R301	When cells reach 9.8V, turn DMM on and adjust to maintain 9.8V across BT301.	

SECTION 6. THEORY OF OPERATION

6-1. GENERAL. This section contains circuit descriptions for the Model 178 DMM and for the Model 1788 Battery Pack. An overall block diagram of signal flow is provided in Figure 6-1. The overall schematic diagram, drawing 28991E, is contained in the back of this manual.

6-2. OVERALL OPERATION. The Model 178 DMM uses a 2-volt full scale analog-to-digital (A/D) converter with a 4-1/2 digit multiplexed display. Signal conditioning permits the A/D converter to handle full scale ac and dc voltages over 4 decades and to measure resistance over 5 ranges.

a. Signal Conditioning. Signal conditioning includes dc attenuation (except on the 2-volt range), ac attenuation, ac-to-dc conversion and ohms conversion as shown in Figure 6-2.

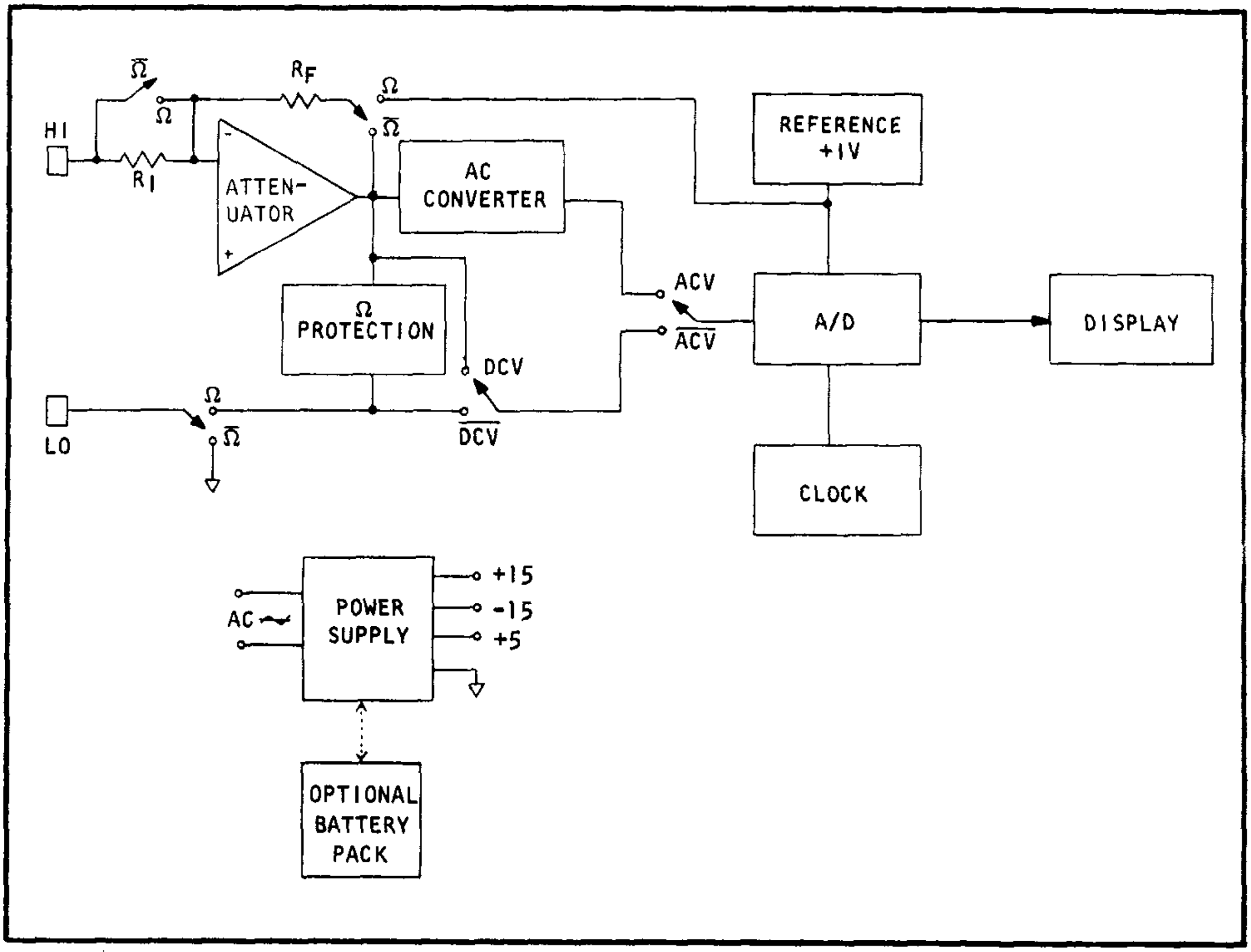


FIGURE 6-1. Signal Flow Block Diagram, Model 178 DMM.

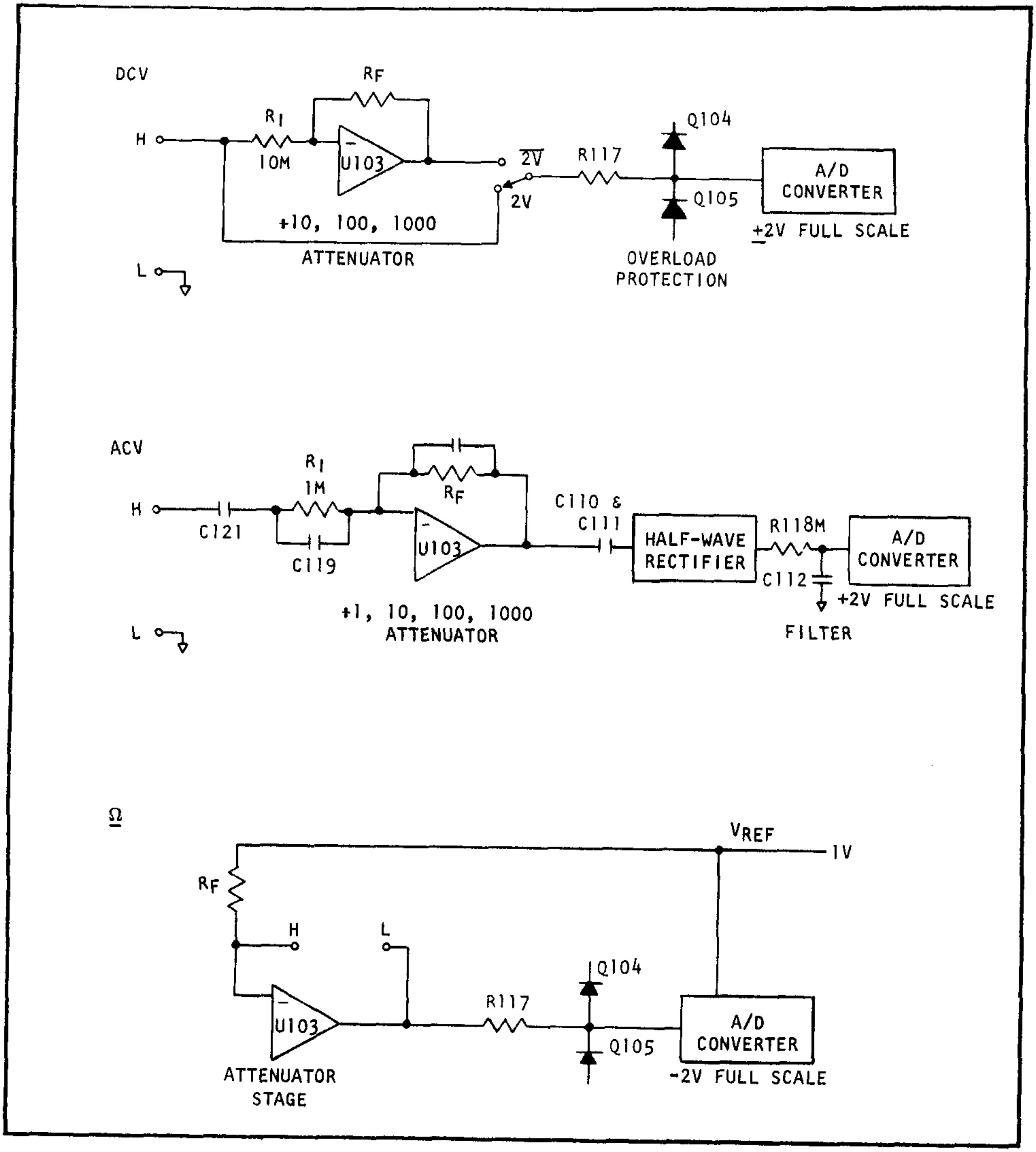


FIGURE 6-2. Attenuation and Ohms Conversion.

1) In the DCV mode, signal conditioning to the A/D converter is an active attenuator. The A/D input is $-V_{HI-LO} \cdot \frac{R_f}{R_I}$, except on the 2-volt range or under overload conditions.

2) In the ACV mode, ac inputs pass through the attenuator on all ranges. The input is scaled to 2-volts rms full scale and is applied to a half-wave rectifier. An RC filter averages the signal before it is applied to the A/D converter.

b. Ohms Conversion. Resistance measurements are made by configuring the attenuator section as a resistance-to-voltage converter. Attenuator stage voltage feedback resistors R_f function as amplifier input resistance connected to the reference voltage. The unknown resistance is connected as a feedback resistor around the attenuation amplifier. The resulting voltage applied to the A/D converter is proportional to the unknown resistance.

c. A/D Converter. The A/D converter is a large scale integration (LSI) ratiometric device. Converter output is a multiplexed 5-digit binary coded decimal number which is equal to the ratio of input voltage to reference voltage. A separate clock circuit supplies a 100 kHz timing input to the integrated circuit, which also multiplexes the BCD output.

6-3. ATTENUATION. When measuring ac and dc voltages, input signal attenuation is provided by inverting amplifier U103 and additional components as described below.

a. DC Volts. Input resistance is set by resistors R101 and R111. During calibration, R101 is adjusted to obtain a total input resistance of 10 MΩ. Additional conditioning is as follows:

1) On the 2-volt range, input HI is connected to the A/D converter input through protection resistors R117 and R124. Diode-connected FETs Q104 and Q105 clamp the A/D input during overload.

2) On the 20, 200 and 1200 volt ranges, the amount of attenuation is selected by switching feedback resistors into the attenuator with relays K101, K102 and K103. Gain setting components and attenuation values are listed in Table 6-1.

TABLE 6-1.
DC Attenuation Gain Setting Components

Range	Gain Set Components	Relay Energized	Attenuation
2 V	None	None	None
20 V	R119, R125	K101	0.1
200 V	R120, R126	K102	0.01
1200 V	R121, R127	K103	0.001

b. AC Volts. Input resistance is 1 MΩ (R110). Shunt capacitance is typically less than 75pF. Additional conditioning is as follows:

1) On all ac voltage ranges, the amount of attenuation is selected by switching feedback resistors into the attenuator with relays K101 through K104. Gain setting components and attenuation values are listed in Table 6-2.

TABLE 6-2.
AC Attenuation Gain Setting Components.

Range	Gain Set Components	Relay Energized	Attenuation	Frequency Compensation Capacitors
2 V	R119, R125	K101	1	C113, C119
20 V	R120, R126	K102	0.1	C115, C119
200 V	R121, R127	K103	0.01	C116, C119
1000 V	R122, R123, R128	K104	0.001	C117, C119

2) On the 2-volt and 20-volt ranges, high frequency compensation is adjusted with with capacitors C113 and C115, respectively, as shown in Table 6-2. On the 200-volt and 1000-volt ranges, adjustment is performed with C119. Low frequency rolloff is determined by input blocking capacitor C121 and ac converter input capacitors C110 and C111.

6-4. AC CONVERSION. The ac converter is a conventional half-wave, average responding circuit which is calibrated to the root mean square (rms) of a sine wave. Feed-forward compensation of amplifier U102 establishes a high unity-gain crossover frequency of approximately 10 MHz, which minimizes high frequency errors. Potentiometer R116 corrects gain errors in both the ac converter and the ac attenuator.

6-5. OHMS CONVERSION. During calibration, the 10 MΩ input resistance (R101 and R111) and all attenuator feedback resistors are adjusted for both ratio and absolute value. Therefore, these resistors can also serve as reference (current setting) for resistance measurements. In the Ω mode, the attenuation (feedback) resistors are disconnected from the output of the attenuation amplifier (U103) and are connected instead to the A/D converter reference voltage.

a. Range Selection. Operation of the range pushbuttons selects range resistors to provide the reference current (I_{REF}) listed in Table 6-3.

TABLE 6-3.
Resistance Range Setting Components

Range	Range Resistors	Effective Relay/Switch	Nominal V_{REF}	Nominal I_{REF}
2 kΩ	R122, R123, R128	K104	1 volt	1 mA
20 kΩ	R121, R127	K103	1 volt	100 μA
200 kΩ	R120, R126	K102	1 volt	10 μA
2000 kΩ	R119, R125	K101	1 volt	1 μA
20 MΩ	R101, R111	20M switch, pins 8 & 9.	1 volt	0.1 μA

b. Ω Circuit. For resistance measurements, relay K105 and terminals 4, 5 and 6 of the Ω pushbutton connect the input HI terminal directly to the amplifier summing node. Input LO is disconnected from ground and is connected to the amplifier output through the overload protection components described below. The unknown resistance (R_X) then becomes the amplifier feedback resistance.

1) Current flow in the unknown resistance is from input HI to input LO. At full scale, the voltage across R_X is 2 volts. Reference source loading does not affect accuracy since the A/D converter is ratiometric.

2) Protection for the instrument is provided by Q101, Q102, CR104, CR112 and the collector junction of Q103. Under normal conditions, Q103 is saturated. Overloads with input HI positive are sustained by CR104; Q103 and CR112 sustain negative overloads. Input HI terminal is clamped to analog common by Q101 and Q102. Network resistors R118C, R118D and R118E keep open circuit terminal voltage below 5 volts.

6-6. A/D CONVERTER. The A/D converter operates on the dual slope principle. The timing is divided into 3 periods as described below.

a. Auto-Zero. The auto-zero period (A, Figure 6-3) is 100 milliseconds in length, which corresponds to 10,000 clock pulses. During this period, the reference voltage (V_{REF}) is stored on capacitor C122. Capacitor C124 stores $V_{REF} + V_{OS1} - V_{OS2}$

b. Signal-Integrate. The signal-integrate period (B, Figure 6-3) is also 100 milliseconds in length. The A/D input is buffered and integrated by U105. Positive signals generate a negative-going ramp at the integrator output (Pin 14), while negative signals produce a positive-going ramp. The level of the integrated signal at the end of the signal - integrate period is proportional to the average of the applied signal during this period. Since signal integration continues for 100 milliseconds, the A/D converter exhibits high normal mode rejection for ac signals in multiples of 10 Hz, particularly the 50 and 60 Hz line frequencies.

c. Reference-Integrate. The reference-integrate period (C or D, Figure 6-3) is 200 milliseconds, or 20,000 counts in length. During this period, the integrator is returned to baseline level by applying a reference voltage of a polarity opposite to that of the signal. A positive-going ramp is obtained by grounding the buffer input, while a negative-going ramp is produced by the integration of 2 x V_{REF} (that is, V_{REF} + the voltage stored on C122). The time, or number of clock pulses, required for discharge is proportional to the signal input. Digital output is from latches within U106 which store the number of clock pulses required for the integrator to return to baseline level. The maximum count during this period is 20,000, which corresponds to a discharge period of 200 milliseconds, or full scale input. V_{REF} is provided by a divider across a temperature-compensated zener diode. Operational amplifier U101 provides the zener with a self-regulating bias.

6-7. DISPLAY. Five light-emitting diodes (LED) are driven by U201, which is a CMOS BCD-to-seven segment decoder/driver with bipolar current-sourcing outputs. Segment currents are limited to approximately 20 milliamperes peak by resistor network R202. The LED readout is a multiplexed, common-cathode configuration with Darlington array U202 sequentially sinking current from each digit. Blanking of the overrange digit is accomplished by gates U104A and U104B. Emitter-follower Q106 ensures that CMOS-compatible levels are maintained on U104A, pin 1, regardless of the loading of U202. The minus polarity readout is blanked on ac voltage and resistance ranges by a normally closed contact on the DCV pushbutton.

6-8. AC POWER SUPPLY. When the DMM is operated from ac line power, the power supply furnished +5, +15 and -15 volts from regulators VR103, VR101 and VR102, respectively. Full-wave rectified ac from bridge rectifiers CR105 and CR106 is filtered by reservoir capacitors C103, C101, and C102 and is applied to the linear voltage regulators.

6-9. MODEL 1788 BATTERY PACK. When the Model 1788 Battery Pack is installed in the DMM, S102 must be set to the BAT position to provide additional secondary voltage for battery charging. S102 also switches the input to VR103 from bridge rectifier CR105 to batteries BT301. Four 2-volt, 2.5 ampere-hour lead-acid cells supply approximately 9.8 volts at full charge. After six hours of use on battery power, the battery pack should be recharged to ensure long battery life.

a. Battery Charging Circuit. While the DMM is plugged into line power and the battery pack is installed, battery charging proceeds as follows:

1) Full-wave rectified voltage from CR105 is applied to the anode of Q301, which is an SCR which regulates charging voltage. When Q301 is triggered on by a sufficient gate-cathode voltage differential, the batteries receive charge. Charging continues as long as the bridge output voltage exceeds battery voltage by 1 volt or more. Resistor R304 limits charging current when recharging a set of completely discharged cells. A filtered positive output from CR106 (or T301) provides the necessary gate turn-on bias through R306 and diode CR301. Resistor R303 ensures proper high-temperature operation of Q301.

2) When the battery voltages reach the preset float voltages of 9.8 volts, zener VR301 conducts sufficient current to turn on Q302 and thus remove the gate trigger voltage from Q301. Float voltage is adjusted with R301. This is a factory adjustment which will normally not need field readjustment.

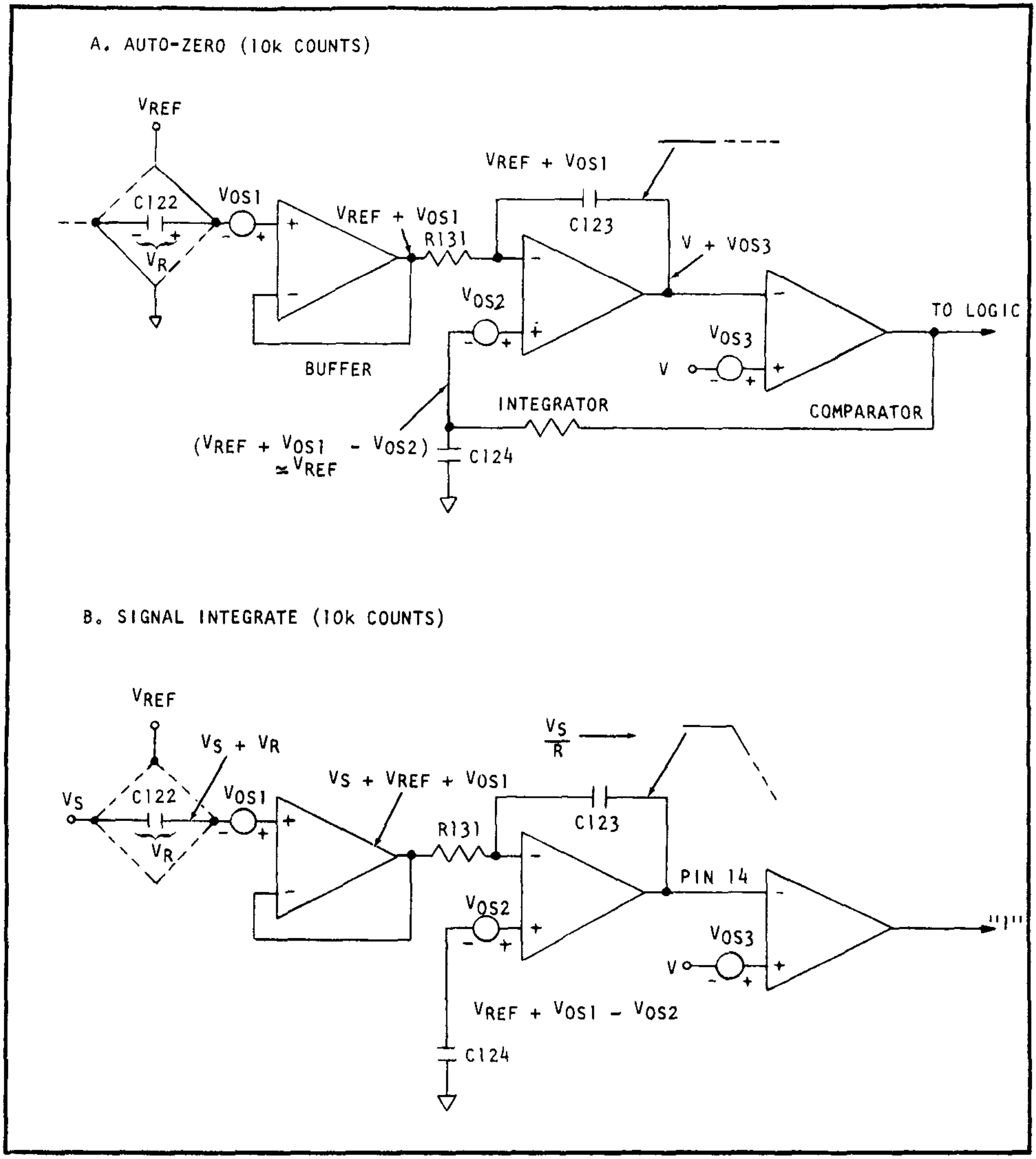
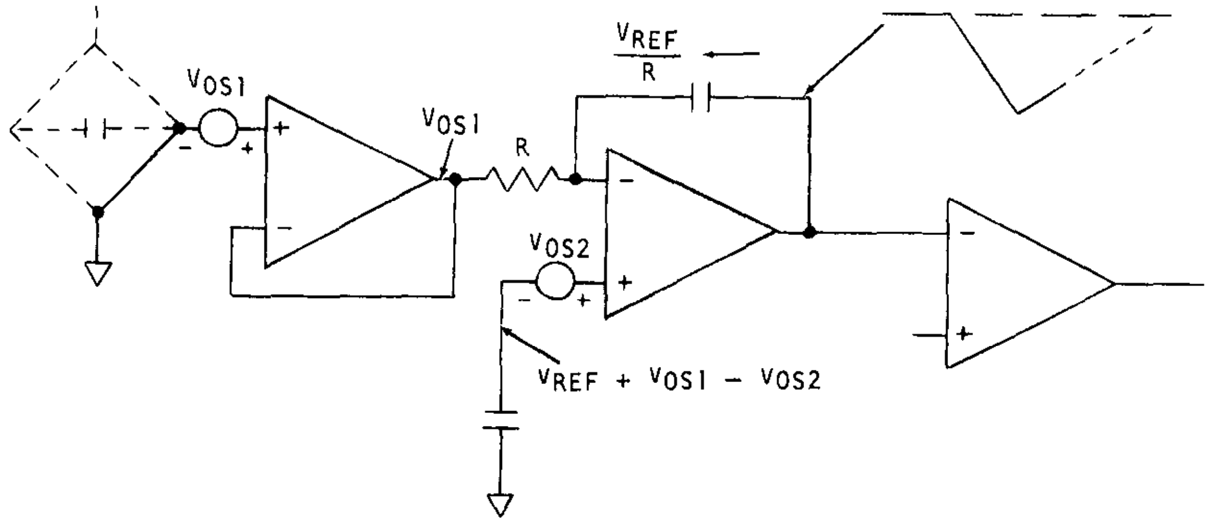


FIGURE 6-3. A/D Converter Function (Sheet 1 of 2)

C. NEGATIVE REFERENCE INTEGRATE (20k COUNTS AT FULL SCALE)
(POSITIVE INPUTS-TO A/D)



D. POSITIVE REFERENCE INTEGRATE (20k COUNTS AT FULL SCALE)
(NEGATIVE INPUTS TO A/D)

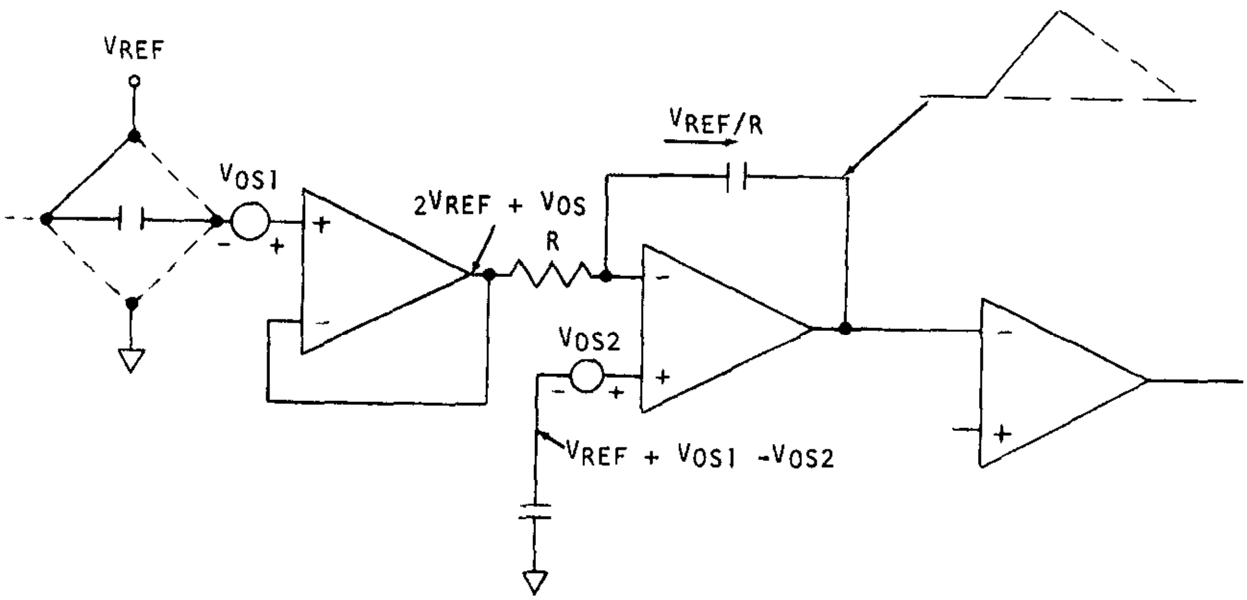


FIGURE 6-3. A/D Converter Function (Sheet 2 of 2)

b. Battery Operation and Shutdown Circuit. The DMM operates as follows on battery power:

1) When the power is turned on, the batteries are connected to the input of VR103 to supply +5 volts for the logic, display and the clock circuit. The clock output is applied to the A/D converter as described in Paragraph 6-6, and U301 which is a divide-by-four binary counter. The outputs of U103 drive a dc-to-dc inverter which is synchronized to the A/D converter to filter out inverter noise. The 25 kHz operating frequency is optimal for the small transformer size and results in low switching losses. Blocking capacitors C301 and C302 protect Q307 and Q308 from damage if the drive is lost. Two half-wave rectifiers (CR304 and CR305) on the secondary of T301 provide rectified ac to filter capacitors C304 and C305, which provide power to +15 and -15 volt regulators VR101 and VR102.

2) To prevent permanent loss of battery capacity caused by deep discharge, a shutdown circuit stops operation on battery power when the battery voltage drops below approximately 7.2 volts. Shutdown is performed by micropower voltage detector U302. The open-collector output (U302, pin 4) saturates low and turns off pass transistor Q309 when the input voltage (at U302, pin 3) drops below 1.15 volts (typical). Resistor R314 provides sufficient hysteresis to prevent discharge from resuming when the battery voltage rises following disconnection of the load.

SECTION 7. REPLACEABLE PARTS.

7-1. GENERAL. This section contains information for ordering replacement parts. The parts list is arranged in alphabetical order of their Circuit Designations.

7-2. ORDERING INFORMATION. To place an order or to obtain information concerning replacement parts, contact your Keithley representative or the factory. See the inside front cover for addresses. When ordering, include the following information.

a. Instrument Model Number.

b. Instrument Serial Number.

c. Part Description.

d. Circuit Designation (if applicable).

e. Keithley Part Number.

7-3. MAINTENANCE KIT. A Maintenance Kit is available that contains a complement of spare parts that will maintain up to ten Model 178 DMMs. Specify Part Number 29197A when ordering.

TABLE 7-1.
Model 178 Maintenance Kit.

Qty.	Keithley P/N	Schematic Designation Model 178
1	C-294-4	C124
2	DD-16	DS202, 203, 204, 205
1	DD-17	DS201
5	FU-13	F102
2	FU-20	F101
1	IC-93	VR104
1	IC-102	U107
2	IC-165	U101, 102
1	IC-168	U201
1	IC-169	U202
1	IC-170	VR102
1	IC-174	VR101
1	LSI-11	U106
1	LSI-12	U103
2	RL-59	K101, 102, 103, 104, 105
1	TF-G3	R118
1	TG-93	Q103
2	TG-128	Q101, 102, 106, 107

7-4. FACTORY SERVICE. If the instrument is to be returned to the factory for service, please complete the Service Form which follows this section and return it with the instrument.

7-5. SCHEMATIC.

a. Model 178 4-1/2 Digit Multimeter: Schematic No. 28991E (Page 7-10). This schematic also describes the Model 1788 Rechargeable Battery Pack.

7-6. COMPONENT LAYOUT.

a. Model 178 4-1/2 Digit Multimeter (Page 7-11).

b. Display Board PC-485 (Page 7-12).

c. Model 1788 Rechargeable Battery Pack (Page 7-13).

TABLE 7-1.
Cross-Reference of Manufacturers

MFR. CODE	NAME AND ADDRESS	FED. SUPPLY CODE	MFR. CODE	NAME AND ADDRESS	FED. SUPPLY CODE
A-B	Allen-Bradley Corp Milwaukee, WI 53204	01121	DLE	Dale Electronics Inc. Columbus, NE 68601	91637
A-D	Analog Devices Inc. Norwood, MA 02026	24355	DTN	Dielettron (Consolidated) New York City, NY 10013	
ACI	American Components, Inc. Conshohocken, PA 19428	14298	ECI	Electro Cube Inc. San Gabriel, CA 91776	14752
AMP	Amphenol Broadview, IL 60153	02660	EDI	Electronic Devices, Inc. Yonkers, NY 10710	83701
APX	Amperex Elkgrove Vlg, IL 60007	73445	EFJ	E. F. Johnson Co. Waseca, MN 56093	74970
BEC	Beckman Inst. Inc. Fullerton, CA 92634	73138	ERI	Erie Technological Prod. Erie, PA 16512	72982
BLD	Belden Mfg. Co. Chicago, IL 60644	70903	F-I	Fairchild Inst. Corp. Mountain View, CA 94043	07263
BRG	Berg Electronics Inc. New Cumberland, PA 17070	22526	FUS	Bussman Mfg. (Fusetron) St. Louis, MO 63107	71400
BRN	Bourns, Inc. Riverside, CA 92507	80294	G-E	General Electric Company Syracuse, NY 13201	03508
BUS	Bussman Mfg. Div. St. Louis, MO 63017	71400	G-I	General Instrument Corp. Newark, NJ 07104	72699
C-I	Components, Inc. Biddeford, ME 04005	06751	GLD	Gould, Inc. St. Paul, MN 55165	52431
C-W	Continential-Wirt Elec. Corp. Warminster, PA 18974	79727	H-P	Hewlett-Packard Palo Alto, Ca 94304	50434
CAD	Caddock Riverside, CA 92507	19647	INT	Intersil Inc. Cupertino, CA 95014	32293
CAN	ITT Cannon Electric Santa Ana, CA 92702	71468	IRC	IRC Division Burlington, IA 52601	07716
CLB	Centralab Division Milwaukee, WI 53201	71590	K-I	Keithley Instruments, Inc. Cleveland, Ohio 44139	80164
CLR	Clarostat Mfg. Co., Inc. Dover, NH 03820	12697	L-F	Littlefuse, Inc. Des Plaines, IL 60016	75915
CTS	CTS Corporation Elkhart, IN 46514	71450	MOL	Molex Downers Grove, IL 60515	27264
DIC	Dickson Electronics Corp. Scottscale, AZ 85252	12954	MOT	Motorola Semi Prod. Inc. Phoenix, AZ 85008	04713

TABLE 7-1. (Cont'd)

MFR. CODE	NAME AND ADDRESS	FED. SUPPLY CODE	MFR. CODE	NAME AND ADDRESS	FED. SUPPLY CODE
NAT	National Semi Corp. Santa Clara, CA 95051	27014	TEP	Tepro Electric Corp. Rochester, NY 14606	02985
NCI	National Components, Inc. West Palm Beach, FL		TPL	Temple Tecate, CA 92080	29505
NEL	Northern Engr. Labs Burlington, WI 53105	00815	TRW	TRW Capacitor Div. Ogallala, NB 69153	84411
P&B	Potter & Brumfield Princeton, IN 47670	12300	VIS	Vishay Resistor Products Malvern, PA 19355	18612
PAK	Paktron Vienna, VA 22180		VRN	Vernitron Laconia, NH 03246	13150
POM	Pomona Electric Pomona, CA 91766	05276	WAB	Wabash-Magnetics Wabash, IN 46992	01101
QTN	Q-Tron Santa Ana, CA 92705	25525			
RAY	Raytheon Company Quincy, MA	94144			
RCA	RCA Corporation Moorestown, NJ 08050	02734			
RCL	RCL Electronics, Inc. Manchester, NJ 03102	01686			
SIE	Siemens Corporation Iselin, NJ 08830	25088			
SIG	Signetics Corp. Sunnyvale, CA 94086	18324			
SIL	Siliconix Inc. Santa Clara, CA 95054	17856			
SPG	Sprague Electric Co. Visalia, CA 93278	14659			
SOL	Solitron Devices Inc. San Diego, CA 92123	22229			
STD	Standard Condensor Chicago, IL	97419			
T-I	Texas Instruments, Inc. Dallas, TX 75231	01295			
TEL	Tel Labs Manchester, NH 03102	94322			

REPLACEABLE PARTS LIST

BATTERIES (BT)
Model 1788 Battery Pack
"300" Series (Sch. 28992E-Pg. 7-10)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
BT301	Set of four "D" Cells, 8V	F6	---	*		
*	Lead-acid "D" cell, 2V, 2.5AH (Used for BT301, four required)			G-E	GE0225	BA-33

CAPACITORS (C)
"100" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 492-Pg. 7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
C101	470µF, 35V, EAL	F-7	D-5	NAC	35ELA470	C-289-470
C102	470µF, 35V, EAL	F-8	D-5	NAC	35ELA470	C-289-470
C103	2200µF, 15V, EAL	F-6	E-4	NAC	16FLA2200	C-290-2200
C104	1µF, 100V, ±10%, MPF	E-2	E-4	POT	4309C-105K	C-294-1
C105	4.7µF, 20V, ETT	D-2	E-4	NCI	KNS475A020K	C-179-4.7
C106	4.7µF, 20V, ETT	D-3	E-4	NCI	KNS475A020K	C-179-4.7
C107	150pF, 1000V, CerD	D-2	E-4	CLB	DD-151	C-64-150P
C108	4.7µF, 20V, ETT	G-6	E-4	NCI	KNS475A020K	C-179-4.7
C109	4.7µF, 20V, ETT	G-6	E-4	NCI	KNS475A020K	C-179-4.7
C110	33µF, 15V, ETT	D-2	E-3	NCI	KNS335D015K	C-228-33
C111	33µF, 15V, ETT	C-2	E-3	NCI	KNS336D015K	C-228-33
C112	.12µF, 100V, 20%, MPF	E-3	E-3	POT	4039C	C-294-.12
C113	.25-1.5pF, 2000V, Teflon Trimmer	C-2	F-3	EFJ	273-101	C184
C114	100pF, 1000V, CerD	D-5	F-2	CLB	DD-101	C-64-100P
C115	1.9-15.7pF, 500VDC, 250V, Trimmer	C-2	F-3	EFJ	187-0109-005	C-284
C116	110pF, 500VDC, ±1%, Silver Mica	C-2	F-3	G-1	RDM19FD112F03	C-278-110P
C117	1100pF, 500VDC, ±1%, Silver Mica	B-1	G-3	G-1	RDM19FD111F03	C-278-1100P
C118	.12, 100V, 20%, MPF	E-4	G-3	POT	4039C	C-294-.12
C119	1.25-1.5pF, 2000V, Teflon Trimmer	B-2	G-4	EFJ	273-1-1	C-184
C120	1000pF, 500V, ±5%, Polystyrene	B-3	G-3	CLB	CPR-1000	C-138-1000
C121	0.1µF, 1000V, MPF	B-3	G-3	STD	M2W-F-0.1µF	C-285-.1
C122	4µF, 100V, 20%, MPF	F-3	G-2	POT	0109-5432	C-294-4
C123	.22µF, 200VDC, ±10%, MPF	G-3	G-2	TRW	22-200-10-X363UW	C-269-.22
C124	1µF, 100V, ±10%, MPF	F-3	G-2	POT	4309C-105K	C-294-1

"200" Series (Sch. 28991E-Pg. 7-10)
(PC-Board 485-Pg. 7-12)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
C201	4.7µF, 20V, ETT	K-2	F-3	NCI	KNS475A020K	C-179-4.7

"300" Series (Sch. 28991E-Pg. 7-10)
(PC-Board 451-Pg. 7-13)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
C301	4.7µF, 20V, ETT	J-6	E-3	NCI	KNS475A020K	C-179-4.7
C302	4.7µF, 20V, ETT	J-7	E-3	NCI	KNS475A020K	C-179-4.7
C303	1.0µF, 250V, MPy	K-7	E-3	AMP	C280AE/A1M	C-256-1
C304	100µF, 35VC	H-7	F-4	NIC	35-ULA-100	C-295-100
C305	100µF, 35VC	H-8	F-3	NIC	35-ULA-100	C-295-100

DIODES (CR)
"100" Series (Sch. 28991E-Pg. 7-10)
(PC-Board 447-Pg. 7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
CR101	Rectifier, 75mA, 75V	G-7	E-5	T-I	IN914	RF-28
CR102	Rectifier, 75mA, 75V	E-2	E-5	T-I	IN914	RF-28
CR103	Recitifer, 75mA, 75V	E-2	E-5	T-I	IN914	RF-28
CR104	Recitifer, 1A, 800V	C-3	G-5	MOT	IN914	RF-38
CR105	Bridge Rectifier, 100V, 2A	F-6	E-2	EDI	PD10	RF-36
CR106	Bridge Rectifier, 1A, 400V	F-7	E-2	EDI	PF40	RF-46
CR107	NOT USED					
CR108	Silicon Rectifier, 1A, 1000V	F-3	F-2	T-I	IN4007	RF-50
CR109	Rectifier, 75mA, 75V	F-3	F-2	T-I	IN914	RF-28
CR110	Rectifier, 75mA, 75V	F-2	F-2	T-I	IN914	RF-28
CR111	Rectifier, 75mA, 75V	F-2	G-2	T-I	IN914	RF-28
CR112	Rectifier, 1A, 800V	C-3	G-5	MOT	IN4006	RF-38

DIODES (CR) (CON'T)
"300" Series (Sch. 28991E-Pg.7-10)
(PC-Board 451-Pg.7-13)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
CR301	Rectifier, 75mA, 75V.	H-6	D-4	T-1	1N914	RF-28
CR302	Rectifier, 75mA, 75V.	J-6	E-3	T-1	1N914	RF-28
CR303	Rectifier, 75mA, 75V.	J-7	E-3	T-1	1N914	RF-28
CR304	Rectifier, 75mA, 75V.	H-7	F-4	T-1	1N914	RF-28
CR305	Rectifier, 75mA, 75V.	H-8	F-4	T-1	1N914	RF-28

DISPLAYS (DS)
"200" Series (Sch. 28991E-Pg.7-10)
(PC-Board 485-Pg.7-12)

Circuit Desig.	Description	Sch. Location	PCB Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
DS201	± 1 LED Digit.	H-2	C-2	F-1	FND561	DD-17
DS202	7-Segment LED Digit	H-2	D-2	F-1	FND560	DD-16
DS203	7-Segment LED Digit	H-2	D-2	F-1	FND560	DD-16
DS204	7-Segment LED Digit	J-2	D-2	F-1	FND560	DD-16
DS205	7-Segment LED Digit	H-2	D-2	F-1	FND560	DD-16

FUSES (F)
"100" Series (Sch. 28991E-Pg.7-10)
(PC-Board 447-Pg.7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
F101	Slo-Blo, 1/8A, 250V, 3AG.	D-7	D-3	BUS	MDL	FU-20

"300" Series (Sch. 28991E-Pg.7-10)
(PC-Board 451 Pg.7-13)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
F301	2A, 250V, 3AG, Quick.	K-5	C-3	L-F	312002	FU-13

CONNECTORS (J)
"1000" Series (Sch. 28991E-Pg.7-10)
(PC-Board 485-Pg.7-12)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
J1001	6-Pin Right Angle	H-2	B-3	MOL	22-15-2061	CS-348-1
J1002	11-Pin Right Angle.	H-3	F-3	MOL	22-15-2111	CS-348-2
J1003	3-Pin	D-8	D-5	MOL	2139-3	CS-287-3
J1004	8-Pin	H-5	D-5	MOL	2139-8	CS-287-8
J1005	Banana Jack, Black.	A-4	---	POM	1581	BJ-11-0
J1006	Banana Jack, Red.	A-3	---	POM	1581	BJ-11-2

RELAYS (K)
"100" Series (Sch. 28991E-Pg.7-10)
(PC-Board 447-Pg.7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
K101	5V, Reed Type	B-2	E-4	COT	UF-40097	RL-56
K102	5V, Reed Type	B-2	E-4	COT	UF-40097	RL-56
K103	5V, Reed Type	B-1	E-4	COT	~~UF-40097~~	~~RL-56~~ RL-59
K104	5V, Reed Type	B-1	E-4	COT	~~UF-40097~~	~~RL-56~~ RL-59
K105	5V, Reed Type	B-3	F-4	COT	~~UF-40097~~	RL-56 RL-59

CONNECTORS (P)
"1000" Series (Sch. 28991E-Pg.7-10)
(PC-Board 447-Pg.7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
P1001	6-Pin	H-2	H-5	MOL	22-03-2061	CS-347-1
P1002	11-Pin	H-3	H-2	MOL	22-03-2061	CS-347-2
P1003	MALE	D-8	D-4	MOL	A-2391-3A	CS-288-3
P1004	MALE	H-5	E-3	MOL	A-2391-3A	CS-288-3
P1005	NOT USED					
P1006	NOT USED					
P1007	Line Cord	D-8	---	K-1	---	CO-9

TRANSISTORS (Q)
"100" Series (Sch. 28991E-Pg.7-10)
(PC-Board 447-Pg.7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
Q101	N-Chan, JFET	B-2	F-4	INT	ITE4392	TG-77
Q102	N-Chan, JFET	B-2	F-4	INT	ITE4392	TG-77
Q103	N-Chan, JFET	C-3	G-5	INT	ITE4392	TG-77 TG-93
Q104	N-Chan, JFET	D-4	G-3	K-1	---	TG-128
Q105	N-Chan, JFET	E-5	G-3	K-1	---	TG-128
Q106	NPN Switch	H-4	H-2	MOT	2N3904	TG-47

"300" Series (Sch. 28991E-Pg.7-10)
(PC-Board 451-Pg.7-13)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
Q301	Thyristor, SCR	H-5	C-4	MOT	106F1	TG-132
Q302	NPN Switch	H-6	C-2	MOT	2N3904	TG-47
Q303	PNP, Silicon, TO-92 Case	J-6	D-4	MOT	2N3905	TG-53
Q304	NPN, Switch	J-6	E-4	MOT	2N3904	TG-47
Q305	NPN, Switch	J-7	E-4	MOT	2N3904	TG-47
Q306	PNP, Silicon, TO-92 Case	J-7	E-3	MOT	2N3905	TG-53
Q307	NPN, Switch	K-6	E-3	MOT	2N3725	TG-131
Q308	NPN, Switch	K-7	E-3	MOT	2N3725	TG-131
Q309	PNP, Silicon	J-5	D-3	MOT	MPS-WA5	TG-133
Q310	PNP, Silicon, TO-92 Case	J-5	D-3	MOT	2N3905	TG-53

RESISTORS (R)
"100" Series (Sch. 28991E-Pg.7-10)
(PC-Board 447-Pg.7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
R101	200KΩ, 10%, Cermet Trimmer	B-2	F-5	BEC	89P	RP-89-200K
R102	120KΩ, 10%, 1/4W, Comp.	H-1	H-5	MEP	CR25, 5%	R-76-120
R103	9.88K, .1%, 1/4W, MtF	E-2	E-5	TRW	MAR-5	R-263-9.88K
R104	10KΩ, 10%, 1/4W, Comp	E-2	E-5	A-B	CB-100-10%	R-76-10K
R105	402Ω .1%, 1/4W, MtF	E-2	E-5	TRW	MAR-5	R-263-402
R106	PART OF 27699A.	F-2	E-5	TRW	MAR-5	R-263-*
R107	806Ω, 1%, 250V, 1/8W.	F-1	E-5	IRC	CEA-TO-806	R-88-806
R108	6.49KΩ, 1%, 250V, 1/8W.	F-1	F-5	IRC	CEA-TO-6.49K	R-88-6.49K
R109	3.65KΩ, 1%, 250V, 1/8W.	F-1	F-5	IRC	CEA-TO-3.65K	R-88-3.65K
R110	1MΩ, ±0.5%, 2W, MtF	B-3	F-4	PYF	PME80T9	R-267-1M
R111	9.88M, ±0.5%, .5W, 1200V, MtF	B-2	F-5	PYF	PME80	R-265-9.88M
R112	NOT USED					
R113	50KΩ, 20%, .75W, POT.	E-2	D-4	HEL	77PR-50K	RP-64-50
R114	4.44K, .1%, 1/4W, MtF	D-2	E-4	TRW	MAR-5	R-263-4.44K
R115	50KΩ, 10%, Cermet Trimmer	D-3	E-4	BEC	72PMR	RP-97-50K
R116	100Ω, 0.5W, POT	D-2	E-4	BEC	72PMR-100	RP-97-100
R117	100KΩ, 10%, 2W, Comp.	D-4	G-4	HB	01121	R-3-100K
R118(A-H)	Thick Film	CDEF-3&4	E-3	CTS	SPECIAL	TF-63
R119	998KΩ, .1%, 1/4W, MtF	C-2	F-3	TRW	MAR-7, T13	R-264-998K
R120	99.8KΩ, .1%, 1/4W, MtF.	C-2	F-3	TRW	MAR-5, T13	R-263-99.8K

RESISTORS (R) (CON'T)
"100" Series (Sch. 28991E-Pg. 7-10)
(PC-Board 447-Pg. 7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
R121	9.98KΩ, .1%, 1/10W, MtF	C-1	F-3	TRW	MAR-5, T13	R-263-9.98K
R122	120Ω, 10%, 1/4W, Comp	C-1	F-3	MEP	CR25, 5%	R-76-120
R123	1.002KΩ, .1%, 1/10W, MtF.	C-1	F-3	TRW	MAR-5, T13	R-263-1.002K
R124	100KΩ, 10%, 2W, Comp.	B-3	G-3	H-B	01121	R-3-100K
R125	5KΩ, 10%, Cermet Trimmer.	C-2	E-2	BEC	72PMR	RP-97-5K
R126	500Ω, 10%, Cermet Trimmer	C-2	F-2	BEC	72PMR	RP-97-500
R127	50Ω, 10%, Cermet Trimmer.	C-1	F-2	BEC	72PMR	RP-97-50
R128	50KΩ, 10%, Cermet Trimmer	C-1	F-2	BEC	72PMR	RP-97-50K
R129	22M, 10%, 1/4W, Comp.	E-5	F-2	MEP	CR25, 5%	R-76-47K
R130	47KΩ, 10%, 1/4W, Comp	D-5	F-2	MEP	CR25, 5%	R-76-47K
R131	100KΩ, 1%, 1/10W, MtF	F-2	F-2	IRC	CEA-TO-100K	R-88-100K
R132	856KΩ, .1%, 1/10W, MtF.	C-3	H-1	TRW	MAR-5, T13	R-263-856
R133	6.8M, 10%, 1/4W, Comp	C-5	F-4	A-B	CB-682-10%	R-76-6.8M
R134	PART OF 27699A.	E-1	E-5	K-1	SPECIAL	R-88-*

"200" Series (Sch. 28991E-Pg. 7-10)
(PC-Board 485-Pg. 7-12)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
R201	120Ω, 10%, 1/4W, Comp	H-2	C-2	A-B	CB-121-10%	R-76-120
R202	Thick Film	J-2	E-2	DLE	LDP14-01-4706	TF-64

"300" Series (Sch. 28991E-Pg. 7-10)
(PC-Board 451-Pg. 7-13)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
R301	20KΩ, 0.5W, POT	H-6	C-3	BEC	72PMR-20K	RP-97-20K
R302	330Ω, 10%, 1/4W, Comp	H-6	C-3	MEP	CR25, 5%	R-76-330
R303	1KΩ, 10%, 1/4W, Comp.	H-6	D-4	MEP	CR25, 5%	R-76-1K
R304	3.9KΩ, ±20%, 3W, WW	H-6	D-4	TEP	TS3	R-268-3.9
R305	4.7KΩ, 10%, 1/4W, Comp.	H-6	D-3	MEP	CR25, 5%	R-76-4.7K
R306	33KΩ, 10%, 1/4W, Comp	H-7	C-3	A-B	CB-332-10%	R-76-3.3K
R307	82KΩ, 10%, 1/4W, Comp	J-6	E-3	MEP	CR25, 5%	R-76-82
R308	82KΩ, 10%, 1/4W, Comp	J-7	E-3	MEP	CR25, 5%	R-76-82
R309	10Ω, 10%, 1/4W, Comp.	H-8	F-4	A-B	CB-100-10%	R-76-10
R310	10Ω, 10%, 1/4W, Comp.	H-7	F-4	A-B	CB-100-10%	R-76-10
R311	100KΩ, 1%, 1/8W, MtF.	J-5	E-3	A-B	CB-104-10%	R-76-100K
R312	100KΩ, 1%, 1/8W, MtF.	J-5	E-3	A-B	CB-104-10%	R-76-100K
R313	100KΩ, 1%, 1/8W, MtF.	J-5	E-3	A-B	CB-104-10%	R-76-100K
R314	6.8M, 10%, 1/4W, Comp	J-5	E-3	A-B	CB-68R-10%	R-76-6.8M
R315	576KΩ, 1%, 1/8W, MtF	J-5	E-3	IRC	CEA-TO-576K	R-88-576K
R316	100KΩ, 1%, 1/8W, MtF.	J-5	E-3	IRC	CEA-TO-100K	R-88-100K

SWITCHES (S)
"100" Series (Sch. 28991E-Pg. 7-10)
(PC-Board 447-Pg. 7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
S101	Line Selector	D-6	D-3	C-W	GG350PCDPDT	SW-318
S102	Line Battery.	E-5	E-3	K-1	SPECIAL	SW-397
S103	Switch	B-4	H-4	CTL	PB-10	SW-401

TRANSFORMERS
"100" Series (Sch. 28991E-PG. 7-10)
(PC-Board 447-Pg. 7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
T101	Transformer, Power.	E-5	D-2	K-1	---	TR-168
T101	Transformer, Power (100/200V)	E-5	D-2	K-1	---	TR-169

"300" Series (Sch. 28991E-Pg. 7-10)
(PC-Board 451-Pg. 7-13)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
T301	Transformer, Power	K-6	F-3	K-1	---	TR-170

TEST POINTS (TP)
(Sch. 28991E-Pg.7-10)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
TP1	Test Point.	F-7	---	K-1	---	---
TP2	Test Point.	F-8	---	K-1	---	---
TP3	Test Point.	F-1	---	K-1	---	---
TP4	Test Point.	E-2	---	K-1	---	---
TP5	Test Point.	C-2	---	K-1	---	---
TP6	Test Point.	D-3	---	K-1	---	---
TP7	Test Point.	G-6	---	K-1	---	---
TP8	Test Point.	D-4	---	K-1	---	---
TP9	Test Point.	F-3	---	K-1	---	---
TP10	Test Point.	E-1	---	K-1	---	---
TP11	Test Point.	G-2	---	K-1	---	---

INTEGRATED CIRCUITS (U)
"100" Series (Sch. 28991E-Pg.7-10)
(PC-Board 447-Pg.7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
U101	8-Pin Op-Amp, DIP	F-1	E-5	F-1	UGT7741393	IC-42
U102	8-Pin Op-Amp, DIP	D-2	E-4	NAT	LM301AN	IC-167
U103	8-Pin Op-Amp, TO-5.	C-2	F-4	NAT	LH0022CH	IC-165
U104(A-C)	4011 CMOS Unbuffered.	G-4,K-4	F-2	MOT	MC14011CP	IC-102
U105	4-1/2 Digit Analog-Processor.	F-3	G-2	INT	3052A	LSI-12
U106	4-1/2 Digit Logic Processor	F-4	G-2	INT	7103A	LSI-11-1

"200" Series (Sch. 28991E-Pg.7-10)
(PC-Board 485-Pg.7-12)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
U201	Segment Drive	K-2	F-2	MOT	4511	IC-168
U202	Digit Driver.	H-3	F-2	T-1	75492	IC-169

"300" Series (Sch. 28991E-Pg.7-10)
(PC-Board 451-Pg.7-13)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
U301	Dual D-Type Flip-Flop, 14-Pin DIP .	J-7	D-3	RCA	CD4013AE	IC-103
U302	1.1V Micro-Power Detector	K-5	E-3	INT	ICL8211CPA	IC-177

VOLTAGE REGULATORS (VR)
"100" Series (Sch. 28991E-Pg.7-10)
(PC-Board 447-Pg.7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
VR102	+15V, 3-Term, LO-Power.	F-7	E-5	MOT	MC7915CT	IC-174
VR101	+15V, 3-Term, LO-Power.	E-2	E-5	MOT	MC78L15CP	IC-170
VR103	+5V, 3-Term, TO-220	G-6	E-4	MOT	MC7805CI	IC-93
VR104	(PART OF 27699A).	F-1	F-5	C-D	1N4577	DZ-58

"300" Series (Sch. 28911E-Pg.7-10)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
VR301	8.2 Volt, Zener.	H-6	C-3	MOT	1N765A	DZ-61

CRYSTAL (Y)
"100" Series (Sch. 28991E-Pg.7-10)
(PC-Board 447-PG.7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Keithley Part No.
Y101	Quartz, ±0.01%, 100kHz.	D-5	E-2	NEL	NE34PE	CR-8

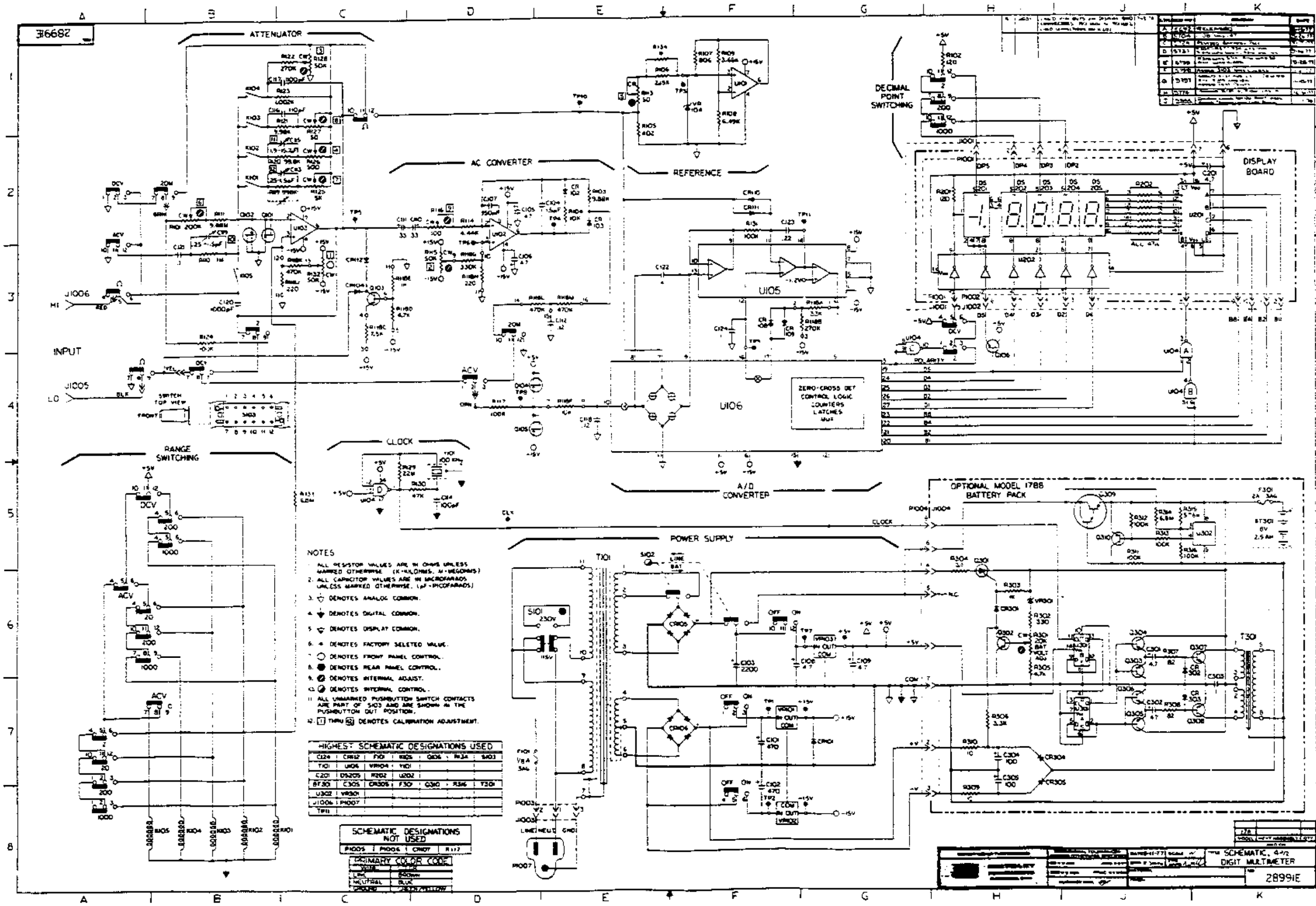


FIGURE 7-1. Schematic Diagram - Model 178 Digit Multimeter.

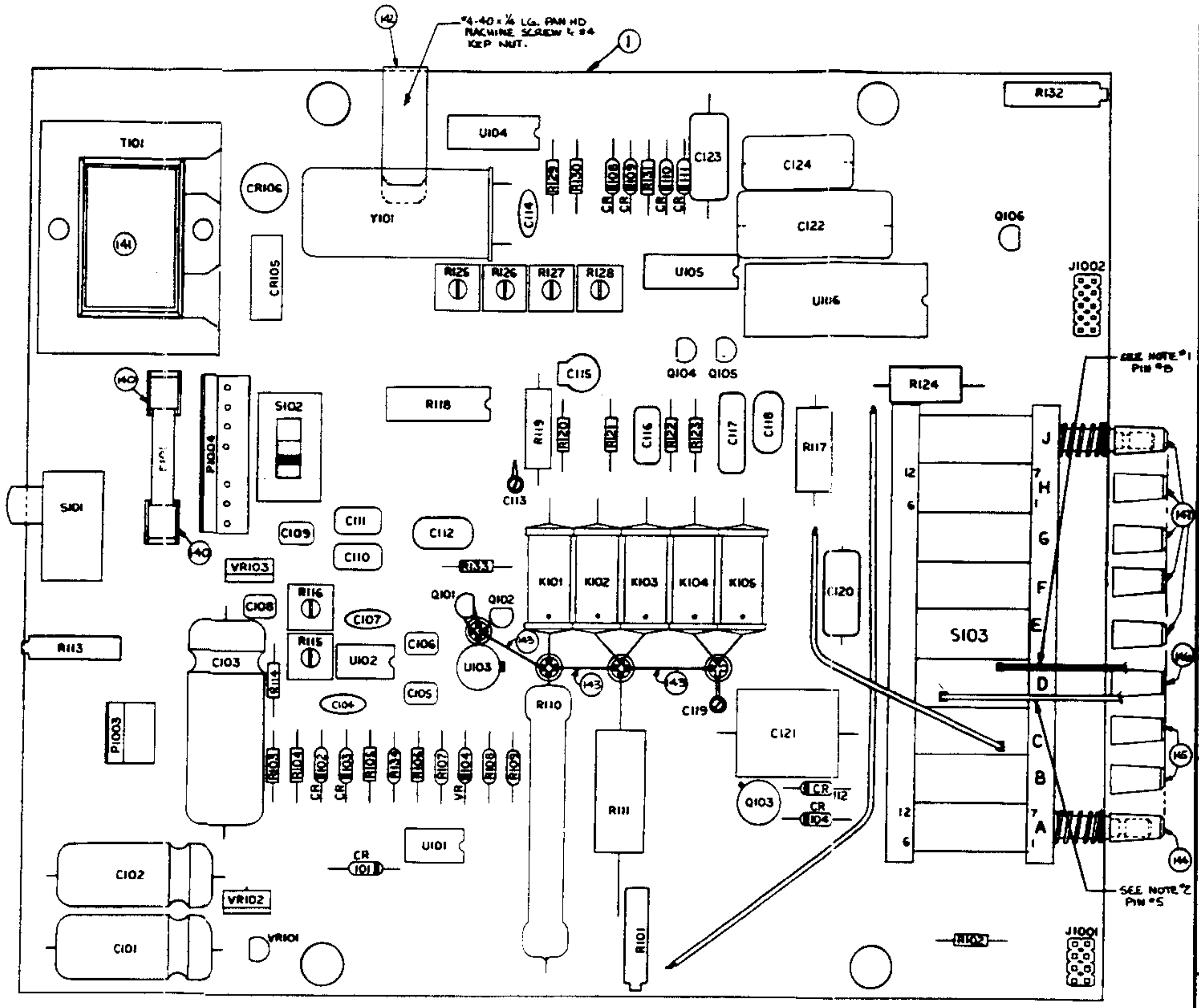
006962 D

ZONE	LTR	ECO NO.	REVISION	DATE
	A	6631	RELEASED	7-13-78
	B	5079	Changed Artwork From Rev. A To Rev. B	9-9-78
	C	7255	" " " B " C	1/25/79

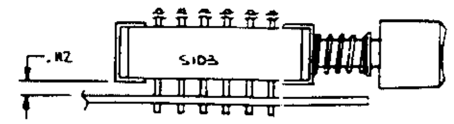
ITEM	PART NO	SCHEM DESIG	ZONE
1	29689B	STAKING	
2			
3	C-289-470	C101	D5
4	"	C102	D5
5	C-290-2200	C103	E4
6	C-291-1.5pF	C104	E4
7	C-179-4.7	C105	E4
8	"	C106	E4
9	C-64-150pF	C107	E4
10	C-179-4.7	C108	E4
11	"	C109	E3
12	C-228-33	C110	E3
13	"	C111	E3
14	C-294-.12	C112	E3
15	C-184	C113	F3
16	C-64-100pF	C114	F2
17	C-284	C115	F3
18	C-278-110pF	C116	F3
19	C-278-1100pF	C117	G3
20	C-294-.12	C118	G3
21	C-184	C119	G4
22	C-138-1000pF	C120	G4
23	C-285-.1	C121	G4
24	C-294-4	C122	G2
25	C-269-.22	C123	G2
26	C-294-1	C124	G2
27			
28			
29			
30	RF-28	CR101	E5
31	"	CR102	E5
32	"	CR103	E5
33	RF-38	CR104	G5
34	RF-36	CR105	E2
35	RF-46	CR106	E2
36			
37	RF-28	CR108	F2
38	"	CR109	F2
39	"	CR110	F2
40	"	CR111	G2
41	RF-38	CR112	G5
42			
43			
44			
45	FU-20	F101	D3
46			
47			
48			
49	RL-56	K101	E4
50		K102	E4
51	RL-59	K103	E4
52		K104	E4
53		K105	F4
54			
55			
56			
57	CS-356-4	J1001	H5
58	CS-356-5	J1002	H2
59	CS-288-3	P1003	D4
60	29467A	P1004	E3
61			
62			
63			
64	TG [illegible]	Q101	F4
65		Q102	F4
66	TG 93	Q103	G5
67	TG 128	Q104	G3
68		Q105	G3
69	TG 41	Q106	H2
70			
71			
72			
73	[illegible] 200K	[illegible]	F5
74	[illegible]	[illegible]	H5
75	R-263-[illegible]K	[illegible]	F5

ITEM	PART NO	SCHEM DESIG	ZONE
76	R-76-10K	R104	E5
77	R-263-402	R105	E5
78	R-263-2.15K	R106	E5
79	R-88-806	R107	E5
80	R-88-6.49K	R108	F5
81	R-88-3.65K	R109	F5
82	R-267-1M	R110	F4
83	R-265-9.88M	R111	F5
84			
85	RP-64-50	R113	D4
86	R-263-4.44K	R114	E4
87	RP-97-50K	R115	E4
88	RP-97-100	R116	E4
89	R-3-100K	R117	G3
90	TF-63	R118	E3
91	R-264-998K	R119	F3
92	R-263-99.8K	R120	F3
93	R-263-9.98K	R121	F3
94	R-76-270K	R122	F3
95	R-263-1.002K	R123	F3
96	R-3-100K	R124	G3
97	RP-97-5K	R125	E2
98	RP-97-500	R126	F2
99	RP-97-50	R127	F2
100	RP-97-50K	R128	F2
101	R-76-22M	R129	F2
102	R-76-47K	R130	F2
103	R-88-100K	R131	F2
104	RP-89-50K	R132	H1
105	R-76-6.8M	R133	F4
106	R-88-4(27699A)	R134	E5
107			
108			
109			
110	SW-318	S101	D3
111	SW-397	S102	E3
112	27695B/SW-401	S103	H4
113			
114			
115			
116	TR-168 #	T101	D2
117			
118			
119			
120	IC-42	U101	E5
121	IC-167	U102	E4
122	IC-165	U103	F4
123	IC-102	U104	F2
124	LSI-12	U105	G2
125	LSI-11	U106	G2
126			
127			
128			
129	IC-170	VR101	E5
130	IC 174 or IC 195	VR102	E5
131	IC-93	VR103	E4
132	DZ 58 (27699A)	VR104	F5
133			
134			
135			
136	CR-8	Y101	E2
137			
138			
139			
140	FH-12 ¼	—	D3
141	MC 221	—	D2
142	28776A	—	E2
143	#22 GA. BARE BUSS WIRE	3 REQ'D	F4
144	29465C-3		H5
145	29465C-6	2 REQ'D	H4,5
146	29465C-7		H4
147	29465C-2	3 REQ'D	H3,4

NOTE:
△ FOR 100V JAPANESE VERSION SUBSTITUTE TR-168 FOR ITEM 116, TR-168



NOTES:
1. BLACK WIRE FROM SWITCH (SW401) TO BE CONNECTED TO BLACK BANANA JACK (BJ-11-0) ON FRONT PANEL.
2. RED WIRE FROM SWITCH SW-401 TO BE CONNECTED TO RED BANANA JACK (BJ-11-2) ON FRONT PANEL.



MODEL	NEXT ASSEMBLY	QTY
174A		1

USED ON

DO NOT SCALE THIS DRAWING

KEITHLEY INSTRUMENTS CLEVELAND OHIO

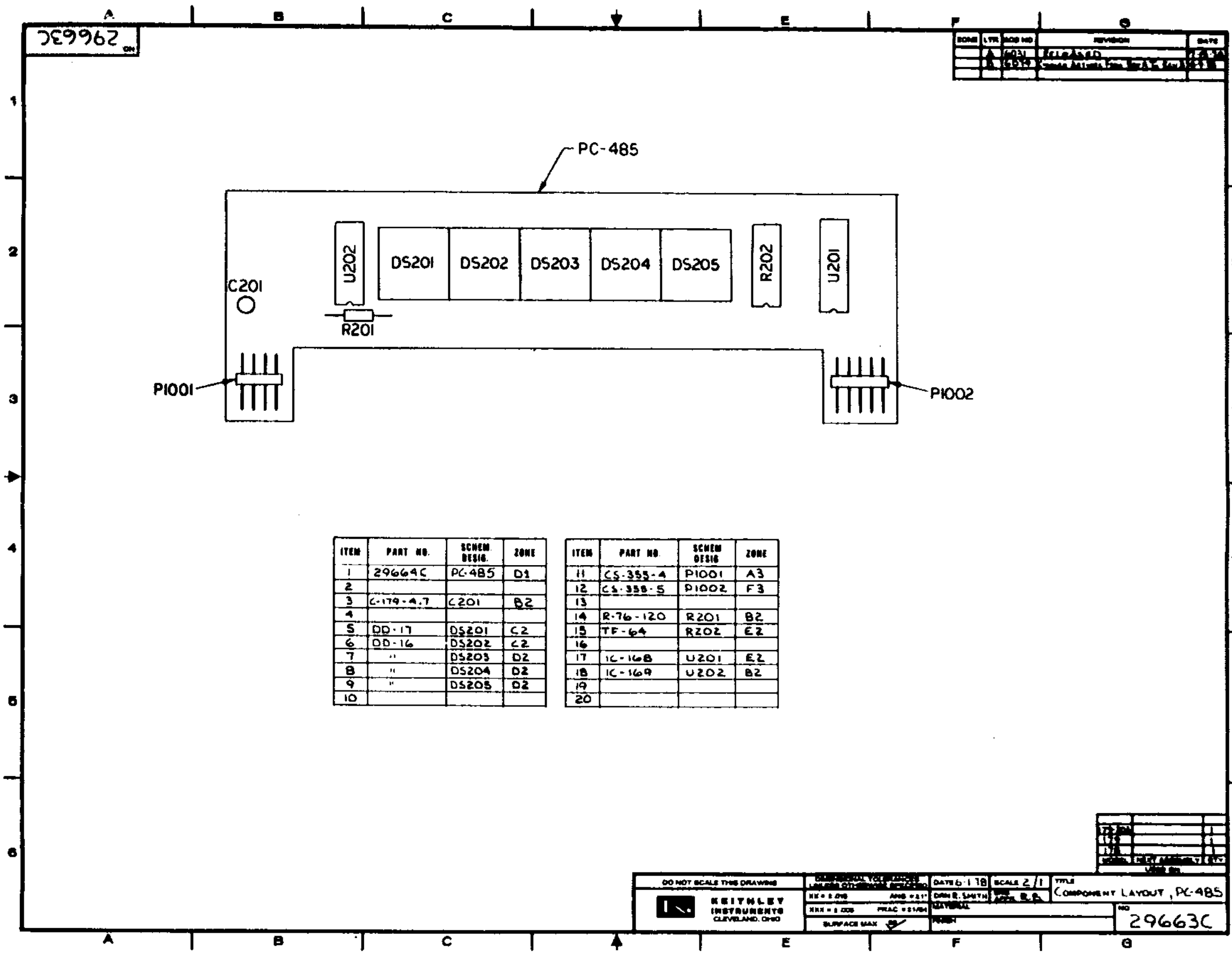
DATE 7-11-78 | SCALE 2:1 | DRN D.J.K. | APPR R.B.

TITLE COMPONENT LAYOUT, PC-491

NO. 29690 D

FORM 205110

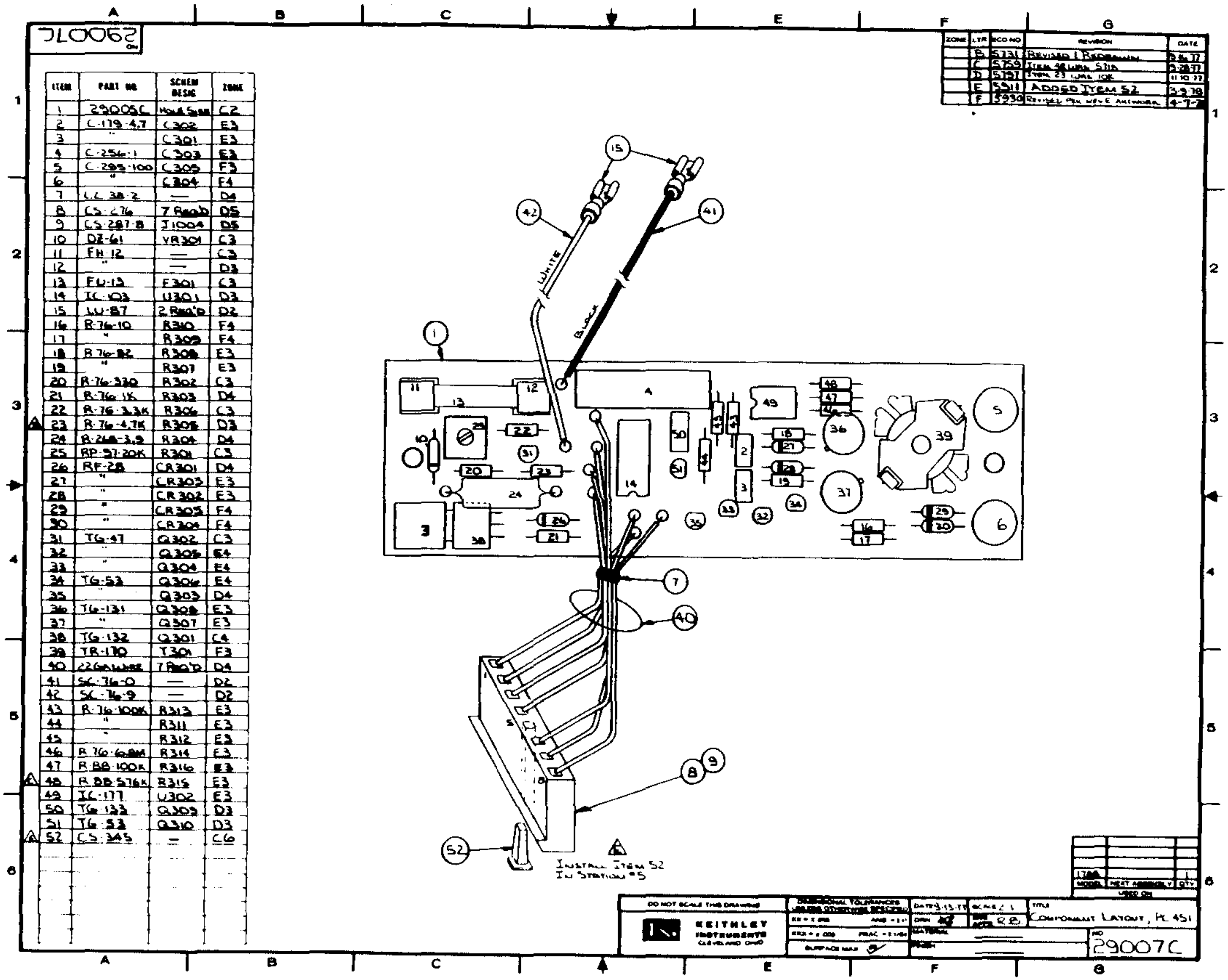
FIGURE 7-2. Component Layout, PC-491, Mother Board.



ITEM	PART NO.	SCHEM DESIG.	ZONE
1	29664C	PC-485	D1
2			
3	C-179-4.7	C201	B2
4			
5	DD-17	DS201	C2
6	DD-16	DS202	C2
7	"	DS203	D2
8	"	DS204	D2
9	"	DS205	D2
10			

ITEM	PART NO.	SCHEM DESIG.	ZONE
11	CS-355-4	P1001	A3
12	CS-358-5	P1002	F3
13			
14	R-76-120	R201	B2
15	TF-64	R202	E2
16			
17	IC-168	U201	E2
18	IC-169	U202	B2
19			
20			

FIGURE 7-3. Componen _ayout, PC-485, Display Board.



ITEM	PART NO.	SCHEM DESIG	ZONE
1	29005C	Hold Seal	C2
2	C-179-4.7	C302	E3
3	"	C301	E3
4	C-256-.1	C303	E3
5	C-295-100	C305	F3
6	"	C304	F4
7	LC-38-2	—	D4
8	CS-276	7 Req'd	D5
9	CS-287-8	J1004	D5
10	DZ-61	VR301	C3
11	FH-12	—	C3
12	"	—	D3
13	FU-13	F301	C3
14	IC-103	U301	D3
15	LU-87	2 Req'd	D2
16	R-76-10	R310	F4
17	"	R309	F4
18	R-76-82	R308	E3
19	"	R307	E3
20	R-76-330	R302	C3
21	R-76-1K	R303	D4
22	R-76-3.3K	R306	C3
23	R-76-4.7K	R305	D3
24	R-246-3.9	R304	D4
25	RP-97-20K	R301	C3
26	RF-28	CR301	D4
27	"	CR303	E3
28	"	CR302	E3
29	"	CR305	F4
30	"	CR304	F4
31	TG-47	Q302	C3
32	"	Q305	E4
33	"	Q304	E4
34	TG-53	Q306	E4
35	"	Q303	D4
36	TG-131	Q308	E3
37	"	Q307	E3
38	TG-132	Q301	C4
39	TR-170	T301	F3
40	22Ga Wire	7 Req'd	D4
41	SC-76-0	—	D2
42	SC-76-9	—	D2
43	R-76-100K	R313	E3
44	"	R311	E3
45	"	R312	E3
46	R-76-6.8M	R314	E3
47	R-88-100K	R316	E3
48	R-88-576K	R315	E3
49	IC-177	U302	E3
50	TG-133	Q309	D3
51	TG-53	Q310	D3
52	CS-345	—	C6

FIGURE 7-4. Component Layout, PC-451, Battery Pack Board.