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MAINTENANCE MANUAL

4002
DIGITAL MULTIMETER

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WARRANTY

Within one year of purchase, Racal-Dana will repair or replace your instrument, at our option, if in any way it is defective in material or workmanship. All parts and labor charges will be paid by Racal-Dana Instruments. Just call Racal-Dana Product Service (collect) at (714) 833-1234 in U.S.A., Windsor (07535) 69811 in England or 027-7575 in France for assistance. We will advise the proper shipping address for your prepaid shipment. Your instrument will be returned to you freight prepaid.

PROPRIETARY NOTICE

This document and the technical data herein disclosed, are proprietary to Racal-Dana Instruments, Inc., and shall not, without express written permission of Racal-Dana Instruments, Inc., be used, in whole or in part to solicit quotations from a competitive source or used for manufacture by anyone other than Racal-Dana Instruments, Inc. The information herein has been developed at private expense, and may only be used for operation and maintenance reference purposes or for purposes of engineering evaluation and incorporation into technical specifications and other documents which specify procurement of products from Racal-Dana Instruments, Inc.

FOR YOUR SAFETY

Before undertaking any maintenance procedure, whether it be a specific troubleshooting or maintenance procedure described herein or an exploratory procedure aimed at determining whether there has been a malfunction, read the applicable section of this manual and note carefully the WARNING and CAUTION notices contained therein.

The equipment described in this manual contains voltages hazardous to human life and safety and which is capable of inflicting personal injury. The cautionary and warning notes are included in this manual to alert operator and maintenance personnel to the electrical hazards and thus prevent personal injury and damage to equipment.

If this instrument is to be powered from the AC Mains through an autotransformer (such as a Variac or equivalent) ensure that the instrument common connector is connected to the ground (earth) connection of the power mains.

Before operating the unit ensure that the protective conductor (green wire) is connected to the ground (earth) protective conductor of the power outlet. Do not defeat the protective feature of the third protective conductor in the power cord by using a two conductor extension cord or a three-prong/two-prong adapter.

Maintenance and calibration procedures contained in this manual sometimes call for operation of the unit with power applied and protective covers removed. Read the procedures carefully and heed Warnings to avoid "live" circuit points to ensure your personal safety.

Before operating this instrument.

1. Ensure that the instrument is configured to operate on the voltage available at the power source. See Installation section.
2. Ensure that the proper fuse is in place in the instrument for the power source on which the instrument is to be operated.
3. Ensure that all other devices connected to or in proximity to this instrument are properly grounded or connected to the protective third-wire earth ground.

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SPECIFICATIONS

DC VOLTAGE

RANGE	MAXIMUM READING	ACCURACY (12 months) 18°-28°C ±(% rdg + digits)	MAXIMUM ALLOWABLE INPUT
200mV	199.99	0.04% + 3d	1200V momentary
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 except ±(0.006% + 0.4 digit)/°C on the 200mV range.
Input Resistance: 10MΩ ±0.1%

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.
Settling Time: 1 second to within 1 digit of final reading.

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
200mV	199.99	0.7% + 15d	0.07% + 2d	0.15% + 3d
2 V	1.9999	0.6% + 15d	0.07% + 2d	0.15% + 3d
20 V	19.999	0.5% + 15d	0.05% + 2d	0.05% + 2d
200 V	199.99	0.5% + 15d	0.05% + 2d	0.05% + 2d
1000 V	1000.0	0.5% + 15d	0.05% + 2d	0.05% + 2d

Extended Frequency Accuracy:
-(45Hz-100Hz) ±(0.7% + 15 digits)
(10kHz-20kHz) ±(0.8% + 15 digits) on the 20V and higher ranges, ±(1.5% + 15 digits) on the 2V range, ±(2% + 15 digits) on the 200mV range.
Response: True root mean square.
Crest Factor: 3.

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.
Settling Time: 2.5 seconds to within 10 digits of final reading.

DC AND TRMS AC CURRENT

RANGE	MAXIMUM READING	ACCURACY (12 months) 18°-28°C +(% rdg + digits) DC	AC 45Hz-10kHz (above 2000 counts)	MAXIMUM VOLTAGE BURDEN	SHUNT RESISTANCE
200μA	199.99	0.2% + 2d	1% + 15d	0.2 V	1kΩ
2mA	1.9999	0.2% + 2d	1% + 15d	0.2 V	100 Ω
20mA	19.999	0.2% + 2d	1% + 15d	0.2 V	10 Ω
200mA	199.99	0.2% + 2d	1% + 15d	0.25V	1 Ω
2000mA	1999.9	0.2% + 2d	1% + 15d	0.6 V	0.1 Ω

Maximum Input: 2A, 250V DC or rms (fuse protected).
Temperature Coefficient (0°-18° and 28°-55°C):
DC ±(0.01% + 0.2 digits)/°C.
AC ±(0.07% + 2 digits)/°C.

Crest Factor: 3
Analog Settling Time:
DC: 1 second to within 1 digit of final reading.
AC: 2.5 seconds to within 10 digits of final reading.

RESISTANCE

RANGE	MAXIMUM READING	ACCURACY (12 months) 18°-28°C ±(% rdg + digits) HI Ω	LO Ω	MAXIMUM VOLTAGE ACROSS UNKNOWN ON RANGE HI Ω	LO Ω	TEMPERATURE COEFFICIENT 0°-18° and 28°-55°C ±(% rdg + digits)/°C HI Ω	LO Ω	NOMINAL APPLIED CURRENT HI Ω	LO Ω
2kΩ	1.9999	—	0.15% + 15d	—	0.2V	—	0.02% + 2d	–	100μA
20kΩ	19.999	0.04% + 1d	0.15% + 15d	2V	0.2V	0.003% + 0.2d	0.02% + 2d	100μA	10μA
200kΩ	199.99	0.04% + 1d	0.15% + 15d	2V	0.2V	0.003% + 0.2d	0.02% + 2d	10μA	1μA
2000kΩ	1999.9	0.04% + 1d	0.15% + 15d	2V	0.2V	0.003% + 0.2d	0.03% + 2d	1μA	0.1μA
20MΩ	19.999	0.10% + 1d	—	2V	—	0.02 % + 0.2d	—	0.1μA	—

Maximum Allowable Input:
450V rms sustained, 1kV DC or peak AC momentary.
Maximum Open-Circuit Voltage: 5 volts.

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, (Option 06).
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. (3 lbs., 13 oz).
OVERRANGE INDICATION: Display blinks all zeros above 19999 counts.
MAXIMUM COMMON MODE VOLTAGE: 1400V peak.

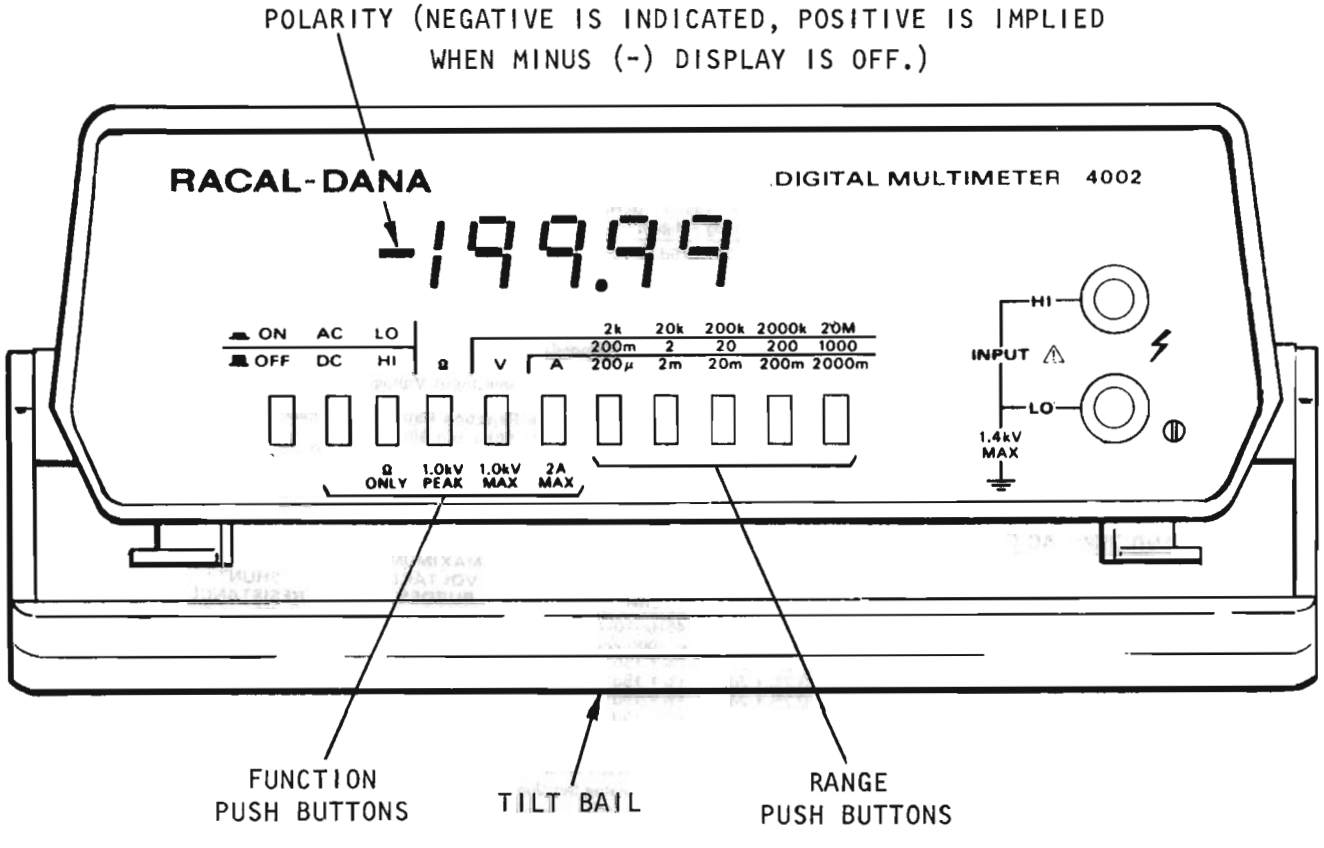


FIGURE 1-1. Front Panel.

SECTION 1. GENERAL INFORMATION.

1-1. INTRODUCTION. The Model 4002 DMM is a versatile digital multimeter useful for measurement of ac and dc voltage, ac and dc current and 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 4002 automatically indicates polarity and positions the decimal point.

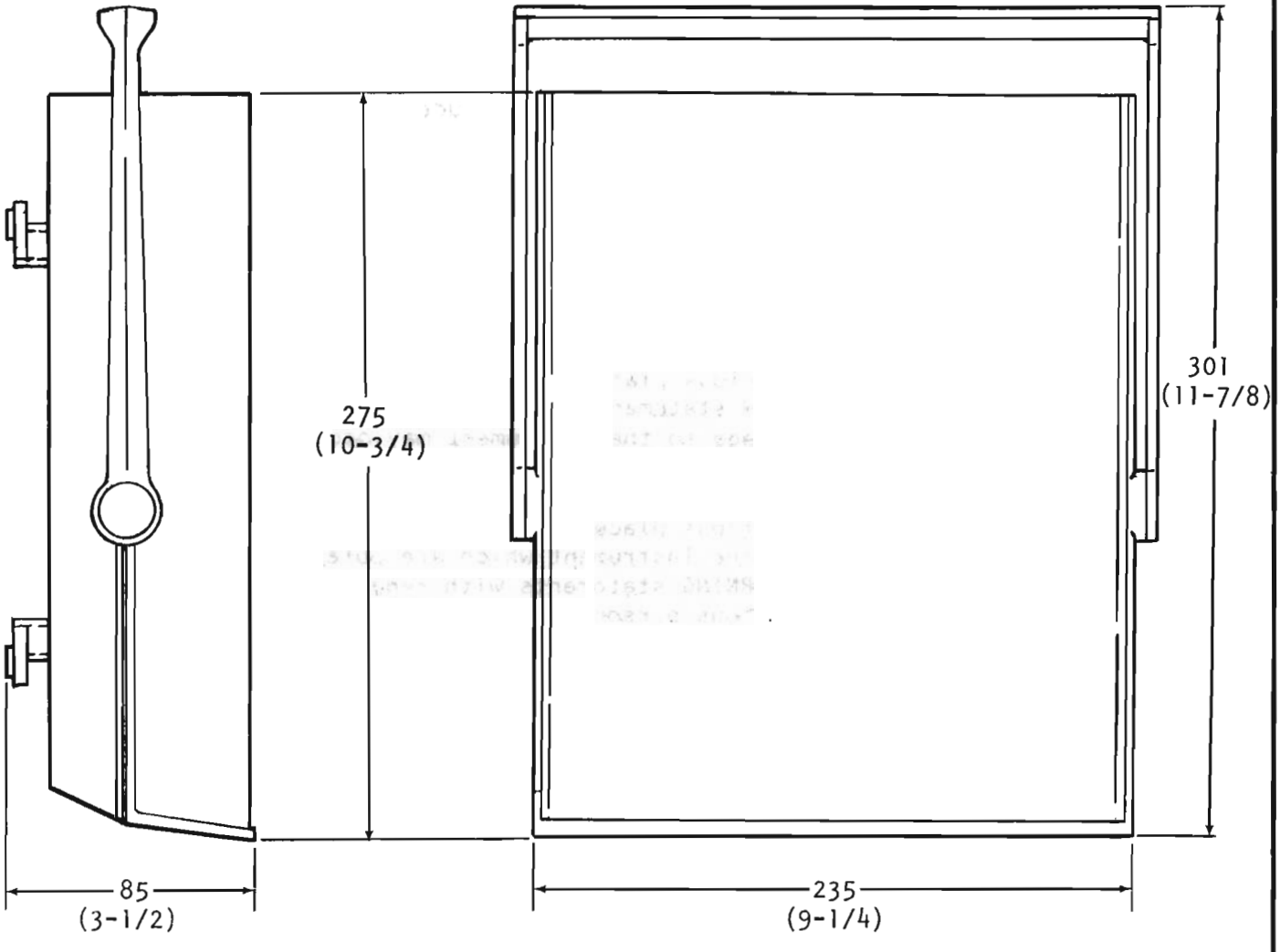
1-2. WARRANTY INFORMATION. The Warranty is given on the back of the title page of this Instruction Manual. If there is a need to exercise the Warranty, contact the Racal-Dana Representative in your area to determine the proper action to be taken. Racal-Dana maintains service facilities in the United Kingdom and France, as well as in the United States. A listing of Representatives and Service Centers is included in the back of this manual.

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.



DIMENSIONS IN MILLIMETERS (INCHES)

FIGURE 1-2. Dimensional Data

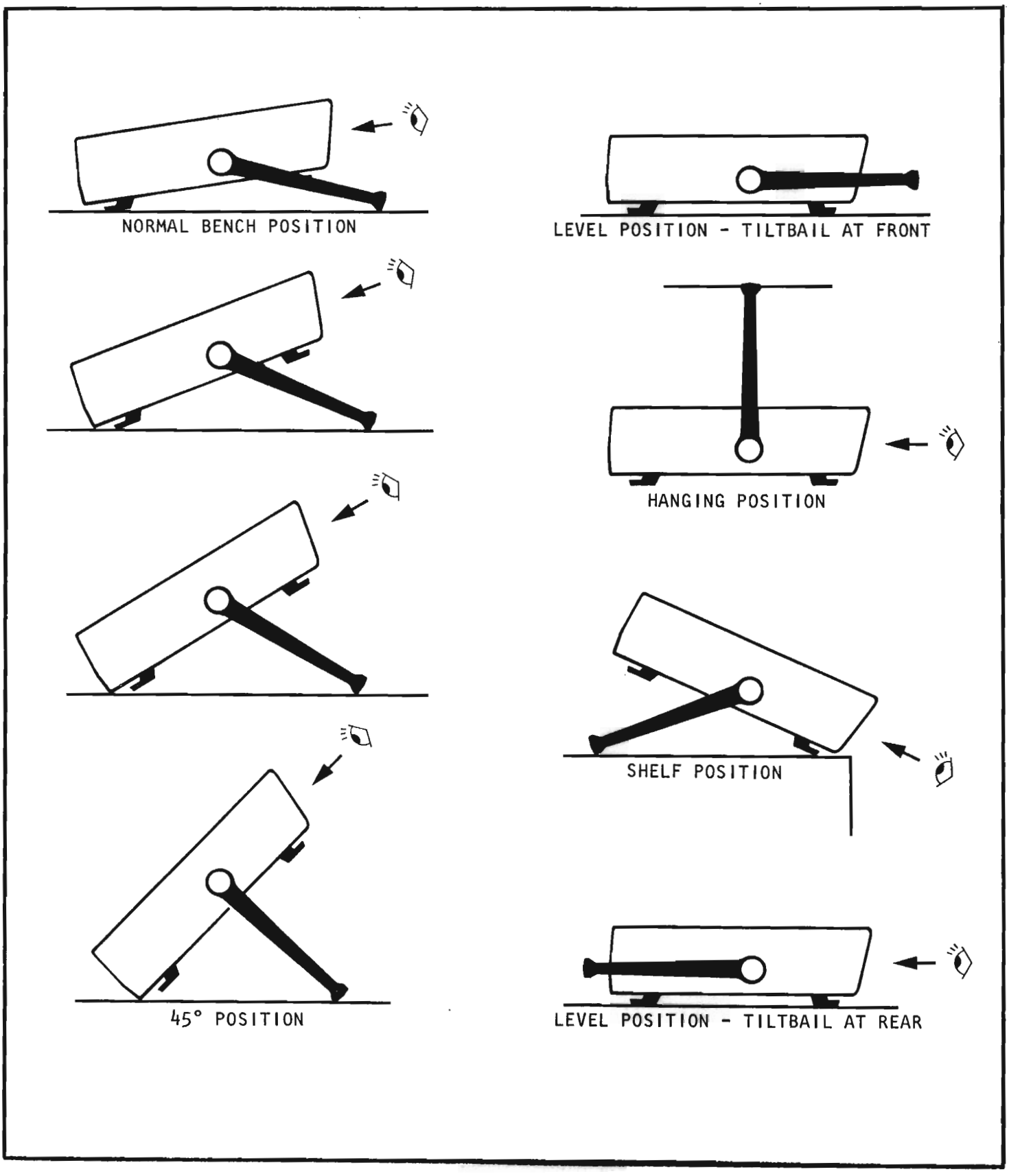


FIGURE 1-3. Tilt Bail Positions.

SECTION 2. OPERATION.

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

2-2. INSPECTION. The Model 4002 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 4002 is shipped ready-to-use. The instrument may be powered from line voltage or from rechargeable batteries (when the Option 06 Rechargeable Battery Set is installed).

2-4. OPERATION ON LINE POWER. The Model 4002 DMM 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 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 4002 DMM as described in SECTION 2-7.

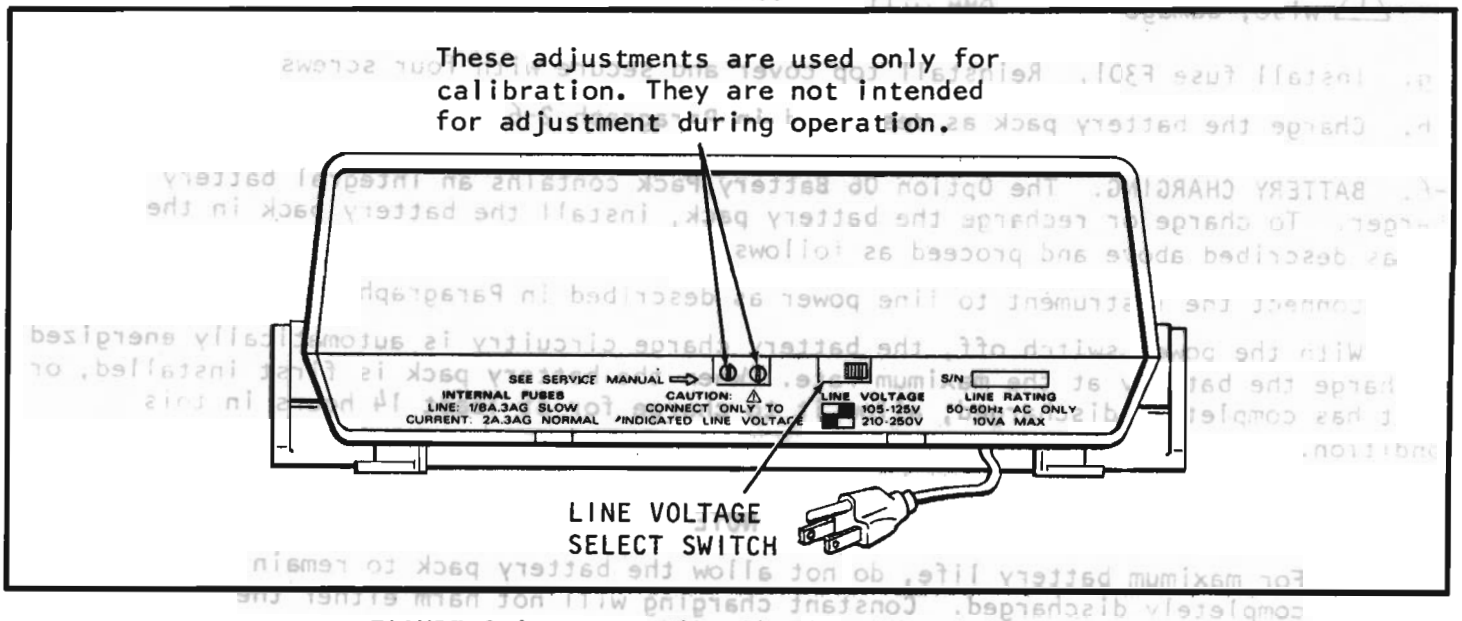


FIGURE 2-1. Rear View Showing Line Switch.

2-5. OPERATION ON BATTERY PACK POWER. The Model 4002 DMM may also be operated from rechargeable sealed lead-acid batteries contained in the Option 06 Battery Pack. The battery pack will operate the 4002 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 2-2 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 Option 06 Battery Pack contains an integral battery charger. To charge or recharge the battery pack, install the battery pack in the 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.

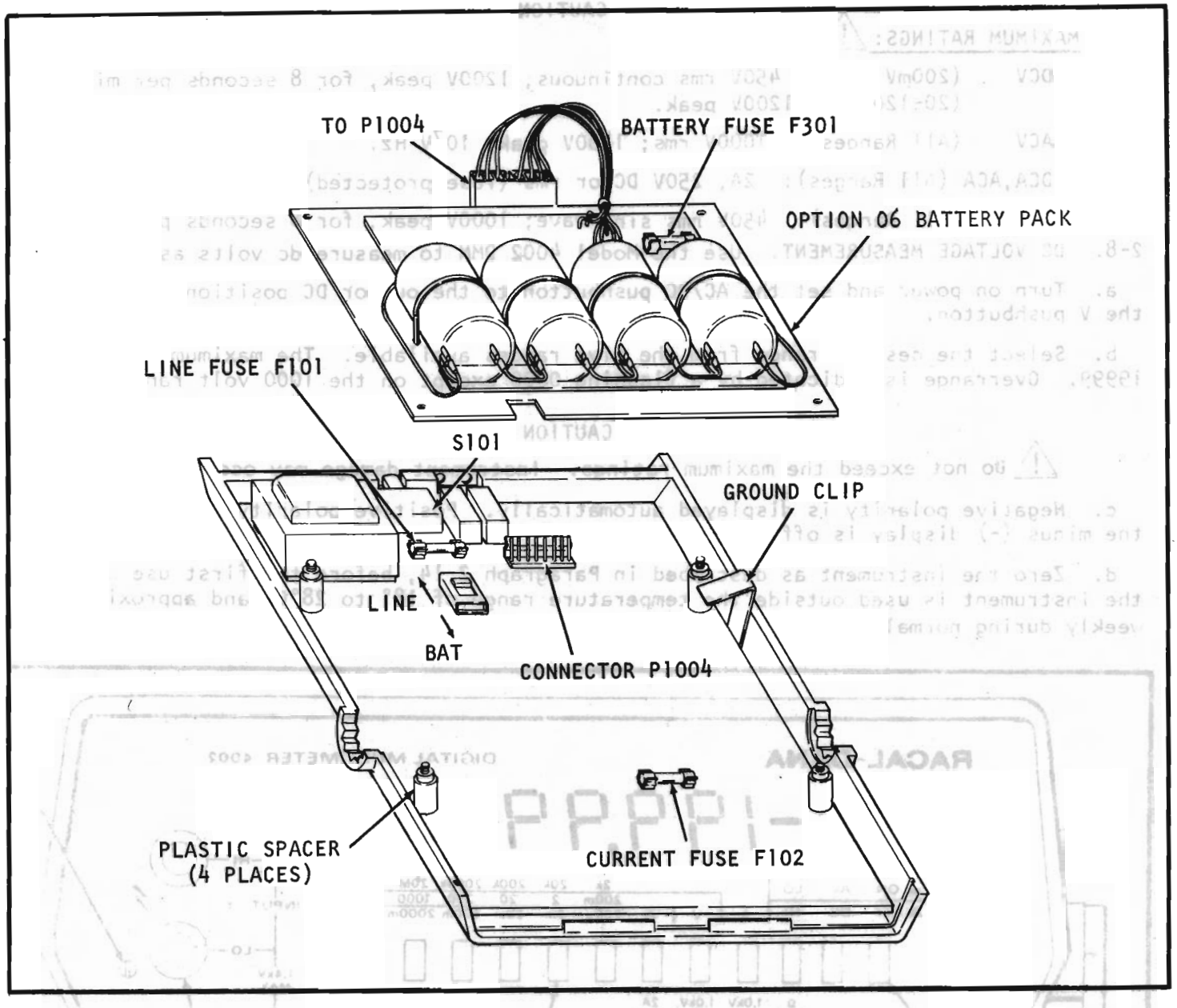


FIGURE 2-2. Battery Pack Installation

c. When the 4002 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 AC/DC, Ω, V, or A pushbuttons.

c. Select the range by depressing the appropriate pushbutton. For resistance measurements only, also set the LO/HI pushbutton as desired.

d. Connect the source to the INPUT terminals. Accessories described in Paragraph 2-15 should be used as required.

CAUTION

MAXIMUM RATINGS: ⚠

DCV (200mV, 2V): 450V rms continuous; 1200V peak, for 8 seconds per minute.
(20-1200V): 1200V peak.

ACV (All Ranges): 1000V rms; 1400V peak; 10^7V·Hz.

DCA,ACA (All Ranges): 2A, 250V DC or rms (fuse protected).

Ω (All Ranges): 450V rms sine wave; 1000V peak, for 8 seconds per minute.

2-8. DC VOLTAGE MEASUREMENT. Use the Model 4002 DMM to measure dc volts as follows:

a. Turn on power and set the AC/DC pushbutton to the out or DC position. Depress the V pushbutton.

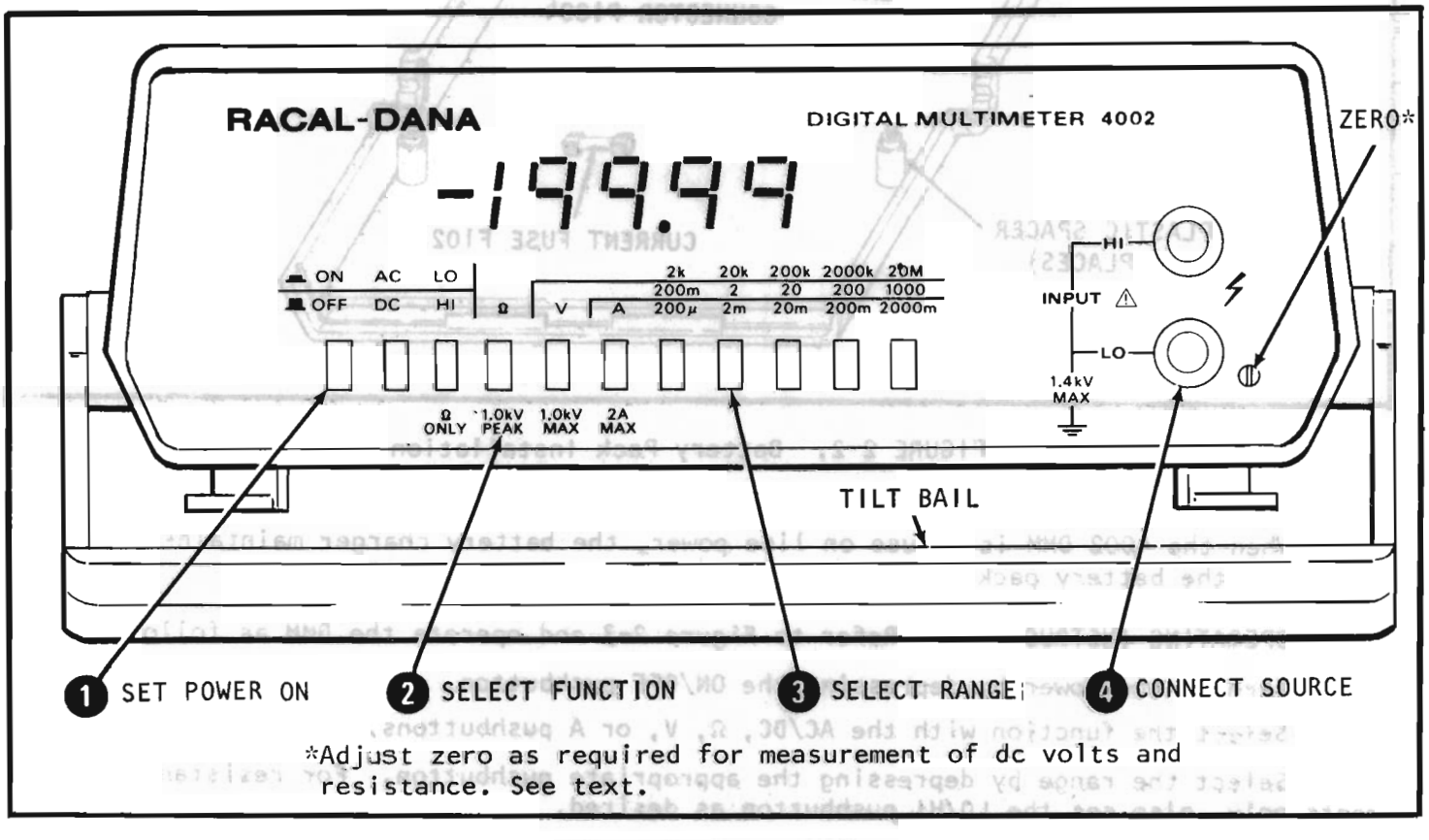
b. Select the desired range from the five ranges available. The maximum reading is 19999. Overrange is indicated by a flashing 0000 except on the 1000 volt range.

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 2-14, before the first use whenever the instrument is used outside the temperature range of 18° to 28°C, and approximately weekly during normal use.



*Adjust zero as required for measurement of dc volts and resistance. See text.

FIGURE 2-3. Operating Controls.

2-9. AC VOLTAGE MEASUREMENT. Use the Model 4002 DMM to measure ac volts as follows:

a. Turn on power and set the AC/DC pushbutton to the in or AC position. Depress the V 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 except on the 1000 volt range. The instrument measures the true root mean square of a signal within the frequency range of 45 to 20k hertz. Maximum crest factor for rated accuracy is 3.

c. Refer to Paragraph 2-13 for TRMS measurements of a signal with both ac and dc components.

2-10. RESISTANCE (Ω) MEASUREMENT. Use the 4002 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 00000. Use the LO/HI pushbutton as follows:

1) Use the HI mode for measurements in the 20k, 200k, 2000k and 20M ohm ranges. Full range voltage drop is 2 volts and is sufficient to cause forward conduction of semiconductor junctions. The HI terminal is positive.

2) Use the LO mode for measurements in the 2k, 20k, 200k and 2000k ohm ranges. Full range voltage drop is 200 millivolts. Depressing 2k automatically selects LO mode; 20M selects HI mode. Maximum open circuit voltage is 5V on all ranges.

c. Zero the instrument as described in Paragraph 2-14 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. DC CURRENT MEASUREMENT. Use the 4002 DMM to measure dc current as follows:

a. Turn on power and set the AC/DC pushbutton to the out or DC position. Depress the A pushbutton.

CAUTION

⚠ Do not install a larger fuse than the one originally supplied (2A). Current fuse F102 protects the instrument against overcurrent.

b. Select the desired range from the five ranges available. The maximum reading is 19999. Overrange is indicated by a flashing 0000. Overload is protected by fuse F102, a 2 amp 3AG normal-blow fuse.

2-12. AC CURRENT MEASUREMENT. Use the 4002 DMM to measure ac current as follows:

a. Turn on power and set the AC/DC pushbutton to the in or AC position. Depress the A pushbutton.

CAUTION

⚠ Do not install a larger fuse than the one originally supplied. Current fuse F102 protects the instrument against overcurrent.

b. Select the desired range from the five available ranges. The maximum reading is 19999. Overrange is indicated by a flashing 0000. The instrument measures the true root mean square of a waveform in the frequency range of 45 to 10k hertz. Overload is protected by fuse F102, a 2 amp 3AG fuse.

2-13. TRMS MEASUREMENT. The Model 4002 measures the ac component of a waveform and does not measure the dc component. For ac + dc measurements, use the procedure discussed in a. below.

NOTE

Accuracy is specified for 2000 counts and above. The method of calibrating the converter may yield an offset up to 50 digits with the input shorted. This does not affect the instrument accuracy.

a. Use the 4002 DMM to measure TRMS on a signal which has both ac and dc components as follows:

1. Turn on the power. Measure and record the ac and dc components separately.
2. Compute the rms value from the following equation:

$$E_{RMS} = \sqrt{E_{DC}^2 + E_{AC}^2}$$

b. The crest factor (CF) is the ratio of the peak voltage to the rms voltage as follows:

$$CF = \frac{V_{PEAK}}{V_{RMS}}$$

1. Typical crest factors are as follows:

Sine wave	$CF = \sqrt{2}$
Square wave	$CF = 1$
Triangular wave	$CF = \sqrt{3}$
Positive pulse train (duty cycle for CF = 3 is 0.11)	$CF = 1/\sqrt{\text{duty cycle}}$

NOTE

There will be some additional measurement error for signals with a crest factor greater than 3 (CF>3).

2-14. ZERO ADJUSTMENT. The front panel zero adjustment nulls input offset on the 20, 200 and 1200 dc voltage 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 the instrument as follows:

a. Turn on the power and select LO Ω and the 200k range.

b. Plug in test leads and short them. Adjust the zero adjustment pot (R149) to obtain a reading of 0000 ±3 digits.

NOTE

The zero adjustment may also be used for lead compensation on a particular Ω range.

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 Racal-Dana 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 PRODECURE. Use the following procedures to verify the basic accuracy of the Model 4002 DMM for voltage, resistance and current 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
E	Current Source	100µA, 1mA, 10mA, ±0.006%	Fluke	3330B
F	Current Source	100mA, 1A, ±0.02%	Fluke	382A

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 internal temperatures to stabilize for one hour minimum at the environmental conditions specified in Paragraph 3-3.

2) Turn-on the 4002 DMM and allow it to warm up for 10 minutes. The instrument may be 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.

3) Zero the instrument as described in Paragraph 2-14.

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 readings with the AC/DC and V pushbuttons.

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

3) Select the 200mV range, and apply positive 100 mVdc 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
200 mV	100.00 mV	99.93 to 100.07
2 V	1.0000 V	0.9995 to 1.0005
20 V	10.000 V	9.995 to 10.005
200 V	100.00 V	99.95 to 100.05
1200 V	1000.0 V	999.5 to 1000.5

c. AC Volts Checkout.

1) Select ac voltage readings with the AC/DC and V pushbuttons.

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

3) Set the DMM to the 200 mV range and apply 100 mV ac 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 volts ac rms and verify that the DMM readings is within the specified limits.

TABLE 3-3.
AC Voltage Performance Check

Range	Applied Voltage	Allowable Readings at 18° to 28°C
200 mV	100.00 mV	99.15 to 100.85 mV
2 V	1.0000 V	0.9925 to 1.0075 V
20 V	10.000 V	9.935 to 10.065 V
200 V	100.00 V	99.35 to 100.65 V
1000 V	1000.0 V	993.5 to 1006.5 V

d. Resistance Checkout.

1) Select resistance readings by pressing the Ω pushbutton.

2) Set the HI/LO pushbutton to HI and select the 20k Ω 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 19.000 kΩ. Verify that the reading is within the limits specified in Table 3-4.

6) Select the next range and measure the next resistance as specified in Table 3-4. Verify that each reading is within specifications. Test each item in the table, switching the HI/LO pushbutton as indicated.

TABLE 3-4.
Resistance Performance Check

HI/LO	Range	Resistance	Allowable Reading at 18° to 28°C
HI	20 kΩ	19.000 kΩ	18.990 to 19.010 kΩ
HI	200 kΩ	190.00 kΩ	189.90 to 190.10 kΩ
HI	2000 kΩ	1.9000 MΩ	1899.0 to 1901.0 kΩ
HI	20 MΩ	19.000 MΩ	18.980 to 19.020 MΩ
LO	2 kΩ	1.9000 kΩ	1.8957 to 1.9043 kΩ
LO	20 kΩ	19.000 kΩ	18.957 to 19.043 kΩ
LO	200 kΩ	190.00 kΩ	189.57 to 190.43 kΩ
LO	2000 kΩ	1900.0 kΩ	1895.7 to 1904.3 kΩ

e. DC Current Checkout.

1) Select dc current readings with the AC/DC and A pushbuttons.

2) Connect the dc current source (Item E or F, Table 3-1) to the DMM.

3) Select the 200 µA range and apply a current of 100.00 µA to the DMM. The reading must be within the limits in Table 3-5.

4) Select each range and apply the required current as specified in Table 3-5. Verify that the reading is within specifications.

f. Analysis. If the instrument is out of specified limits at any point in Tables 3-2 through 3-5, calibrate the DMM as described in Section 4. If the unit is still under warranty, refer to the note in Paragraph 3-1.

TABLE 3-5.
DC Current Performance Check

Range	Applied Current	Allowable Reading at 18° to 28°C
200 uA	100.00 µA	99.88 to 100.22 µA
2 mA	1.0000 mA	0.9988 to 1.0022 mA
20 mA	10.000 mA	9.988 to 10.022 mA
200 mA	100.00 mA	99.88 to 100.22 mA
2000 mA	1000.0 mA	998.8 to 1002.2 mA

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 4002 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 Racal-Dana representative 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 179 DMM and restore its operation to specified limits.

a. Calibration Shield Installation. If the Option 06 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 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.

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 perform the listed adjustments in the sequence indicated. Note that the step sequence is also indicated on the calibration shield by boxed numerals. The sequence must be followed exactly because the adjustments are interrelated and dependent on the preceeding steps.

2) If the indicated adjustment cannot be made to obtain the specified reading, refer to Section 2-5 for Troubleshooting Information.

TABLE 4-2.

Calibration Procedure

Step	Function	Range	Input	Adjustment Point	Desired Reading	Test Equipment*
1	DC V	2 V	+1.9 V	R107	1.9000	DC Calibrator (A)
2	DC V	200 mV	+190 mV	R108	190.00	DC Calibrator
3	DC V	2 V	+1.9 V	R107	1.9000	DC Calibrator
4	Ω LO	200 kΩ	Short	R149	Set Front Panel Zero to Mechanical Center.	None
5	Ω LO	200 kΩ	Short	R112	00.0 ±10 digits	None
6	Ω LO	200 kΩ	Short	R149	00.00 ±2 digits	None
7	Ω HI	200 kΩ	190 kΩ	R127	190.00	Decade Resistor(C)
8	Ω LO	2 kΩ	1.9 kΩ	R129	1.9000	Decade Resistor
9	DC V	200 V	+190 V	R103	190.00	DC Calibrator
10	DC V	20 V	+19 V	R126	19.000	DC Calibrator
11	DC V	1000 V	+1000 V	R128	1000.0	DC Calibrator
12	AC V	20 V	1 V at 1 kHz	R142	1.000	AC Calibrator (B)
13	AC V	20 V	10 V at 1 kHz	R143	10.000	AC Calibrator
14	AC V	20 V	1 V at 1 kHz	R142	1.000	AC Calibrator
15	AC V	20 V	10 V at 1 kHz	R143	10.000	AC Calibrator
16	AC V	200 V	100 V at 10 kHz	C106	100.00	AC Calibrator
17	AC V	20 V	10 V at 10 kHz	C112	10.000	AC Calibrator
18	AC V	2 V	1 V at 10 kHz	C111	1.0000	AC Calibrator

* 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.

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.

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 conditionings. Check these circuits per Tables 5-4 and 5-3, respectively.

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

e. Check the dc voltage attenuator 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. If problems occur with current readings, check the current shunts and related circuits per Table 5-9.

g. 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 VR104.
7	VR104, IN C108-2200µF (+)	+7 volts Minimum.	Output of CR101, input to VR104.
8	+15V pad*	+15 volts ±10%.	Output of VR102.
9	TP1*	+17.5 volts minimum.	Output of CR102, input to VR102.
10	-15V pad*	-15 volts ±10%.	Output of VR101.
11	TP2*	-17.5 volts minimum.	Output of CR102, input to VR101. 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 500mA 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 5-10 for adjustment of battery charge voltage.
6	Each battery cell voltage during 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 CR101.
8	C304 +	+17.5 volts minimum.	Output of CR102. 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 & 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	VR104, IN	+7 volts minimum.	Battery voltage input to VR104.
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 fully charged bat.).	Inverter Output, input to VR101 & VR102

TABLE 5-3.
Display

Step	Item/Component	Required Condition	Remarks
1		Turn on power. Any function or range except OHMS.	
2	+5V* or J1001, pin 5	+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 segment decoder/driver.
5	U201, pin 4	Positive-going signal lasting for 200 clock pulses.	Leading digit suppression. Output of U107A.
6	J1002, pin 9	Polarity line (SIGN) HI = off LO = -.	NOTE: Polarity output (in at J1002, pin 9) is inverted for VDC on 20 volt and higher ranges. Polarity output is disabled on AC and Ω.
7	J1001, pins 1, 2, 3 and 4.	Appropriate DP line high (on).	

* On main printed circuit board.

TABLE 5-4.
A/D Converter

Step	Item/Component	Required Condition	Remarks
1		Turn on Power. Select 2 volt DC range and short inputs.	On this function and range (also on 200 mV DC), input HI connects thru R106, R136, and R135G to A/D, without attenuation.
2	Display	.0000 ±1 digit.	
3	TP10*	0.0000 volts.	A/D signal input.
4	TP8*	+1.00 volt.	Reference output.
5	TP3*	+100 millivolts.	Reference output.
6	TP4*	6.3 ±0.25 volts.	Reference zener voltage.
7	U106, pin 7	+1.00 volt.	Reference input to U106.
8	CLK*	0 to +5V square wave at 100 kHz.	Clock input.
9	TP6*	+1.0 ±0.1 volt.	Stored autozero voltage.
10	U103, pin 11	+1.0 ±0.1 volt.	Σ-node voltage to integrator in U103.
11	TP7*	-1.2 ±0.2 volt.	U103 integrator output voltage.
12	U104, pins 2, 3, and 6	+1 volt.	Buffer voltage on U104.
13	External voltage source	Apply +1.9000 volts. Display must read 1.9000 ±1 digit.	Calibration point.
14	TP7*	Waveform per Figure 5-1.	Integrator output.
15	U103, pin 2	Waveform per Figure 5-1 during ramping of integrator output.	Comparator output.
16		Select 200 mV range and short inputs.	
17	Display	00.00 ±3 digits.	Proceed if out-of-limits. Change selected value of R145 if tests 18-26 meet required conditions.
18	TP10*	0.0000 volts.	A/D signal input.

* On main printed circuit board.

TABLE 5-4.
A/D Converter, continued

Step	Item/Component	Required Condition	Remarks
19	U106, pin 7	+0.100 volt.	Reference input to U106.
20	U103, pin 11	+1.000 ±0.1 volt.	Σ-node voltage to integrator in U103.
21	TP7*	-1.2 ±0.2 volts.	U103 integrator output voltage.
22	U104, pins 2, 3	+100 millivolts.	Buffer voltage on U104.
23	U104, pin 6	+1 volt.	Buffer voltage.
24	External voltage source	Apply +190 millivolts. Display must read 190.00 ±1 digit.	Calibration point.

* On main printed circuit board.

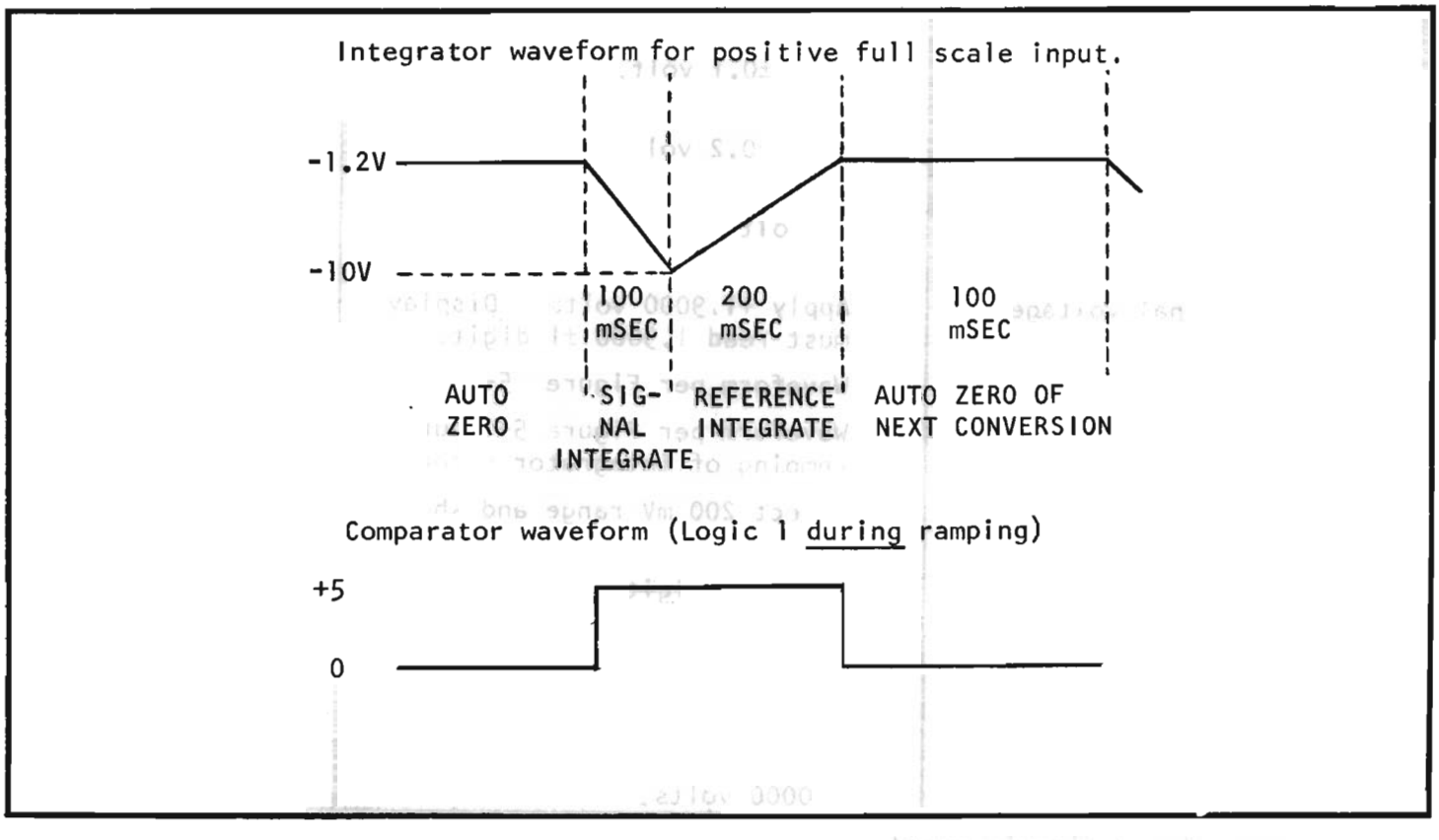


FIGURE 5-1. Integrator and Comparator Waveforms.

TABLE 5-5.
DC Volts Attenuator

Step	Item/Component	Required Condition	Remarks
1		Turn on power. Select 20 VDC range, and short inputs.	
2	R149	Front panel adjustment must zero the display.	
3	U101, pin 2	0.000 ±0.005 volts.	
4	External voltage source	Apply +10 volts from HI to LO.	Calibrated input.
5	TP5*	-1 volt	Output of U101.
6	External voltage source	(Apply +100 and +1000 volts on 200 and 1000 volt ranges.	Calibrated input.
7	TP5*	-1 volt	Output of U101 and feedback components, including relays.

* On main printed circuit board.

TABLE 5-6.
AC Volts Attenuator and X10 Amplifier

Step	Item/Component	Required Condition	Remarks
1		Turn on power. Select 2 VAC range.	NOTE: Full scale inputs should produce ≃2 volts output at TP9.
2	External voltage source	Apply 1 volt rms at 1 kHz.	Calibrated input.
3	TP9* & TP5	1 volt rms.	Output of U101 and feedback components.
4	External voltage source	10, 100 and 1000 volts rms on 20, 200 and 1000 volt ranges.	Calibrated input.
5	TP9* & TP5	1 volt rms on all ranges except 200 millivolts.	Output of U102 and feedback components, including relays.
6	External voltage source	Apply 1, 10, 100V @ 20kHz on 2, 20 and 200V ranges respectively.	C106, C111, C112, C113, and C114.
7	External voltage source	Apply 10V @ 45Hz on 20V range.	C105, C115, C116.
8		Select 200 mV range.	
9	External voltage source	100 millivolts at 1 kHz.	Calibrated input.
10	TP5*	100 millivolts rms.	Output of U101 and feedback components.
11	TP9*	1 volt rms.	Output of U102.

* On main printed circuit board.

TABLE 5-7.
Resistance Circuit.

Step	Item/Component	Required Condition	Remarks
1		Turn on power. Select Ω, HI and 200k range. Short inputs.	
2	U101, pin 2	Continuity to input HI.	K105.
3	TP10*	0.0 volt.	A/D input.
4	Ω switch, pin 11	+1 volt.	Reference voltage.
5	INPUT HI to LO	Remove short and measure open circuit voltage; must be +2 to +5 volts.	R150 & R151.
6	100k resistor	Apply to input.	Calibrated resistance.
7	TP10*	-1 volt.	A/D input.
8		Select LO range.	
9	Ω switch, pin 11	+100 millivolts.	Reference voltage.
10	TP10*	-100 millivolts.	A/D input.
11		Test other ranges in similar manner as needed.	NOTE: Reference loading by the current setting resistor does not affect readout since A/D converter is ratiometric.

* On main printed circuit board.

TABLE 5-8.
AC Converter

Step	Item/Component	Required Condition	Remarks
1		Turn on power. Select 20 VAC range.	
2	External voltage source	10 volts rms, 1 kHz.	Calibrated input.
3	TP9*	1 volt rms (approximate).	Input to converter.
4	U105, pin 6 or TP10*	+1 volt DC.	Output of U105.
5	R143	Gain adjustment must operate.	
6	Repeat steps 4 & 5	10 volts rms, 45 Hz.	Low frequency response.
7	Repeat steps 4 & 5	10 volts rms, 20 kHz.	High frequency response.

* On main printed circuit board.

TABLE 5-9.
Current Shunts

Step	Item/Component	Required Condition	Remarks
1	F102	Continuity.	
2	R123, R124, R137, R138, R139	Correct shunt value for specified range. See schematic.	Measure with ohmmeter.
3		Turn on power. Select DCA and 200 µA range.	
4	External voltage source	0 to 3 volts.	Clamping must occur at ±2 volts.

TABLE 5-10.
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 min. 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 4002 DMM and for the Option 06 Battery Pack. An overall block diagram of signal flow is provided in Figure 6-1. The overall schematic diagram, drawing 28992E, is contained in the back of this manual.

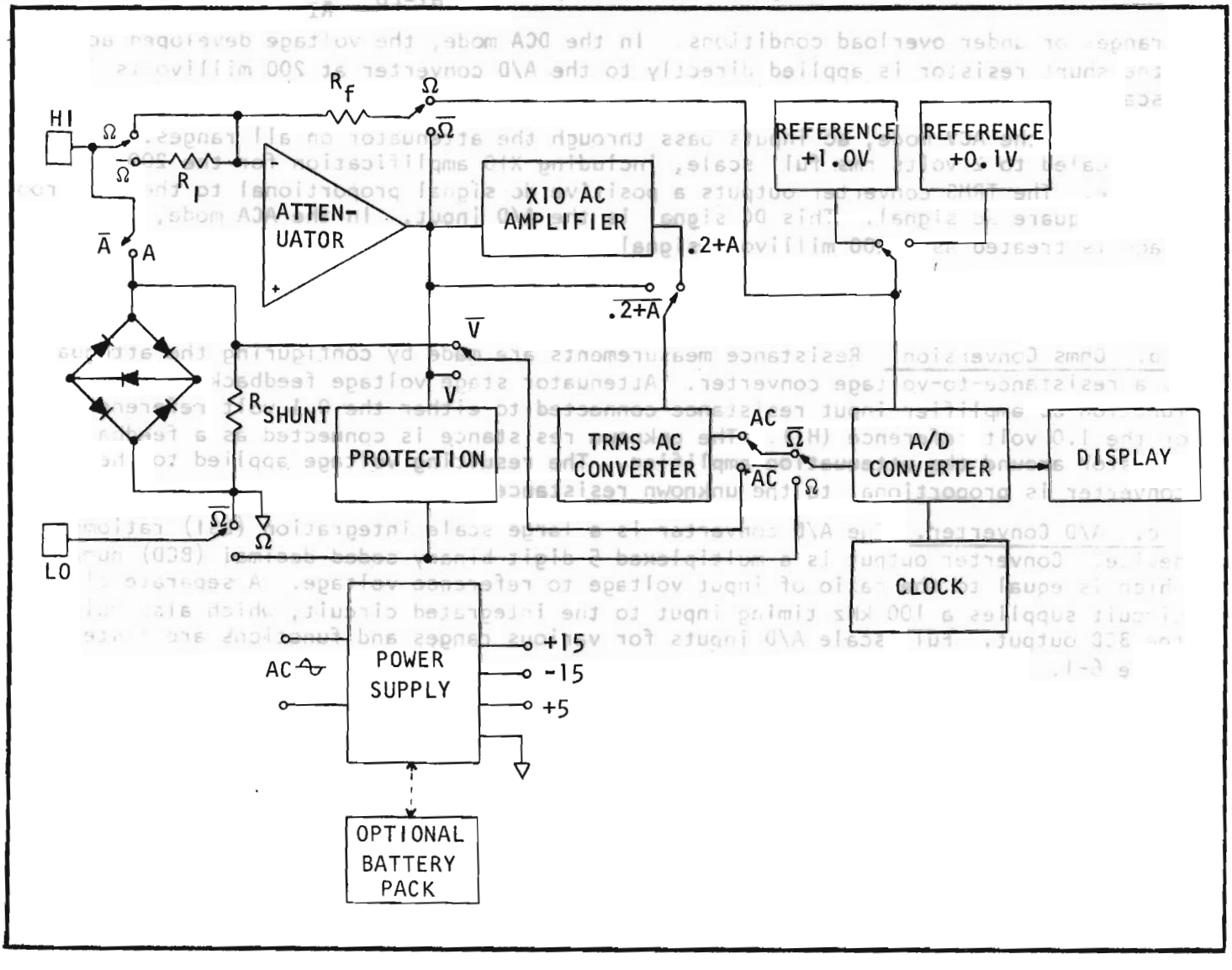


FIGURE 6-1. Simplified Signal Flow Block Diagram.

6-2. OVERALL OPERATION. The Model 4002 DMM uses a 2-volt or 200-millivolt 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 voltage and current measurements over 5 decades, and to measure resistance over 5 ranges.

a. Signal Conditioning. Signal conditioning includes dc attenuation (except on the 2 volt and 200 millivolt ranges), ac attenuation and X10 amplification, ac-to-dc conversion, ohms conversion and current shunts as shown in Figure 6-2.

1) In the DCV mode, signal conditioning to the A/D converter is an active attenuator, except on the two lowest ranges. The A/D input is $-V_{HI-LO} \cdot \frac{Rf}{RI}$, except on the lowest ranges or under overload conditions. In the DCA mode, the voltage developed accross the shunt resistor is applied directly to the A/D converter at 200 millivolts full scale.

2) In the ACV mode, ac inputs pass through the attenuator on all ranges. The input is scaled to 2 volts rms full scale, including X10 amplification for the 200 millivolt range. The TRMS converter outputs a positive dc signal proportional to the true root mean square ac signal. This DC signal is the A/D input. In the ACA mode, shunt voltage is treated as a 200 millivolt signal.

b. Ohms Conversion. Resistance measurements are made by configuring the attenuator as a resistance-to-voltage converter. Attenuator stage voltage feedback resistors R_f function as amplifier input resistance connected to either the 0.1 volt reference (LO) or the 1.0 volt reference (HI). 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 (BCD) 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. Full scale A/D inputs for various ranges and functions are listed in Table 6-1.

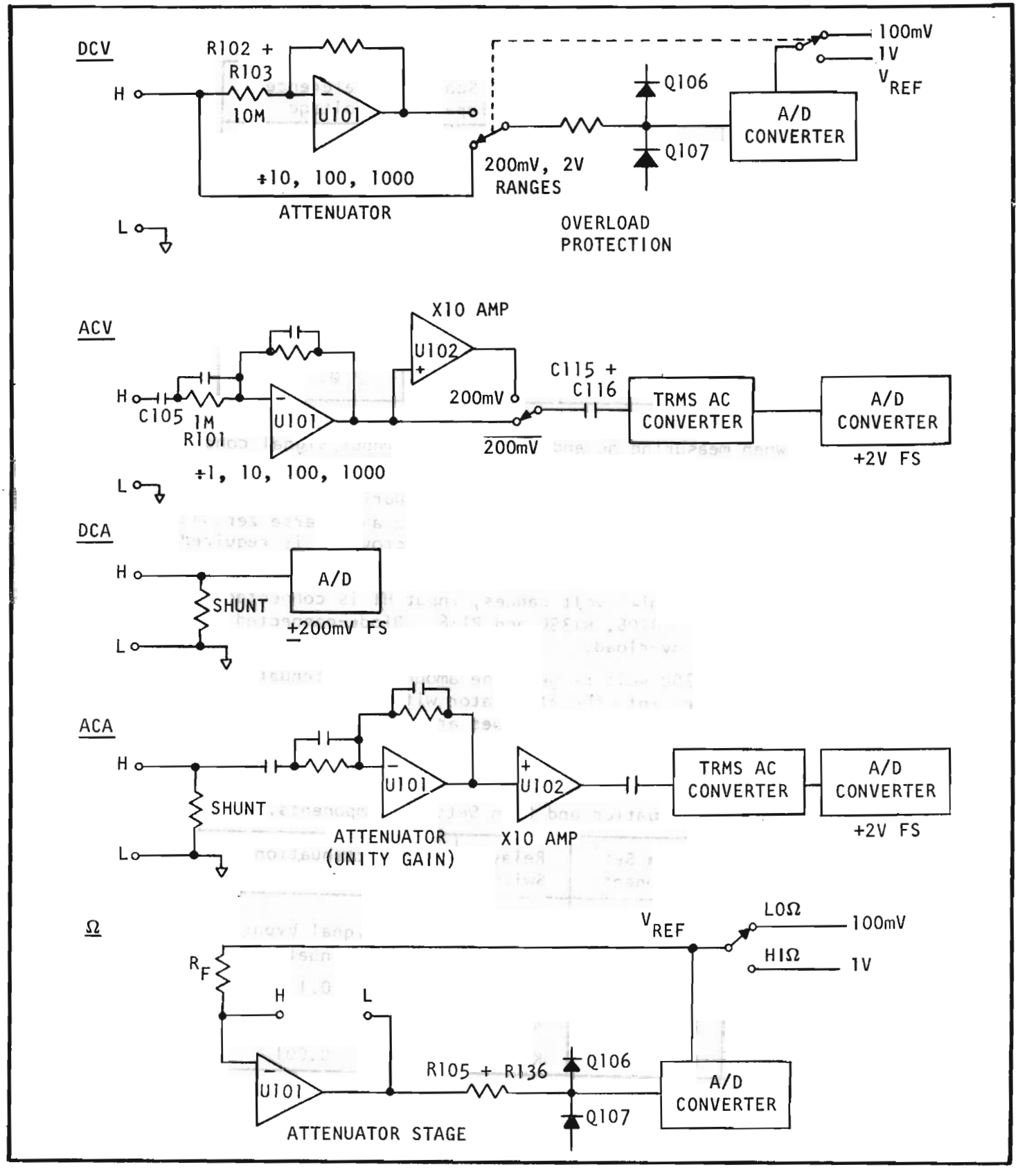


FIGURE 6-2. Attenuation and Ohms Conversion.

TABLE 6-1.
Full Scale A/D Inputs.

Function	Range	Full Scale A/D Input	Reference Voltage
DCV	200 mV	200 mV	0.1 V
DCV	2, 20, 200 1200 V	2 V	1.0 V
ACV	All	2 V	1.0 V
DCA	All	200 mV	0.1 V
ACA	All	2 V	1.0 V
Ω	HI	2 V	1.0 V
	LO	200 mV	0.1 V

6-3. ATTENUATION. When measuring ac and dc voltages, input signal conditioning is provided by inverting amplifier U101 and additional components as described below.

a. DC. Input resistance is set by R102 and R103. During calibration, R103 is adjusted to obtain a total input resistance of 10 MΩ. Both fine and coarse zero adjustments are provided since an amplifier output resolution of 10 microvolts is required for LO resistance measurements.

1) On the 2 volt and 200 millivolt ranges, input HI is connected to the A/D converter through protection resistors R106, R135G and R136. Diode-connected FET's Q106 and Q107 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 6-2.

TABLE 6-2.
DC Attenuation and Gain Setting Components.

Range	Gain Set Components	Relay/ Switch	Attenuation
200 mV			Signal bypasses attenuator
2 V			
20 V	R118, R126	K101	0.1
200 V	R119, R127	K102	0.01
1200 V	R120, R128	K103	0.001

b. AC Volts. Input resistance is 1MΩ (R101). Shunt capacitance is typically less than 75 pF. Additional conditioning is as follows.

1) For all ranges except the 200 millivolt range, the amount of attenuation is selected by switching feedback resistors into the attenuator with relays K101 through K104. For the 200 millivolt range, non-inverting X10 amplifier U102 boosts the signal to 2 volts full scale. Gain setting components and attenuation values are listed in Table 6-3.

TABLE 6-3.
AC Attenuation Gain Setting Components

Range	Gain Set Components	Relay Energized	Attenuation	Freq. Comp. Capacitors
200 mV	R118, R126	K101	1 (X10*)	C106, C111
2 V	R118, R126	K101	1	C106, C111
20 V	R119, R127	K102	0.1	C106, C112
200 V	R120, R128	K103	0.01	C106, C113
1000 V	R121, R122, R129	K104	0.001	C106, C114

* Signal applied to X10 ac amplifier U102.

2) On the 200 millivolt and 2 volt ranges, high frequency compensation is adjusted with capacitor C111, as shown in Table 6-3. On the 20 volt range, adjustment is performed with C112. On the 200 and 1000 volt ranges, adjustment is performed with C106. Some low frequency rolloff is introduced by input blocking capacitor C105, and ac converter input capacitors C115 and C116.

6-4. AC CONVERSION. The ac converter is a monolithic TRMS module. Output $V_{dc} = \sqrt{Avg(Vin)^2}$. Potentiometer R143 provides gain adjustment, and R142 establishes output zero. Settling time and ripple are determined by C110 and C120. Low frequency rolloff is a function of C120.

6-5. OHMS CONVERSION. During calibration, the 10 MΩ input resistance (R102 and R103) 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 (U101) and are connected instead to the A/D converter reference voltage. Since two reference voltages and two A/D converter gains are available, the Model 4002 DMM provides the option of measuring resistance with the sense current reduced by a factor of 10.

a. Range Selection. Operation of the range pushbuttons selects range resistors to provide the reference current listed in Table 6-4. Operation of the HI/LO pushbutton selects the 1 volt or 0.1 volt reference, respectively. Relay K105 is always energized in the Ω mode.

TABLE 6-4,
Resistance Range Setting Components

Range	Range Resistors	Relay/Switch	Nom. I_{REF} in HI Ω	Nom. I_{REF} in LO Ω
2 kΩ	R121, R122, R129	K104	-	100μA
20 kΩ	R120, R128	K103	100μA	10μA
200 kΩ	R119, R127	K102	10μA	1μA
2000 kΩ	R118, R126	K101	1μA	0.1μA
20 MΩ	R102, R103	1000 switch, pins 17, and Ω 8, 9.	0.1μA	-

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 A/D converter input through the 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 either 2 volts (HI) or 200 millivolts (LO). Reference source loading does not affect accuracy since the A/D converter is ratiometric.

2) The HI terminal is clamped to analog common by Q101 and Q102. The instrument protection network at the amplifier output consists of a pulldown resistance (R104 and CR103, CR104 and CR105). R104 sinks approximately 150 microamps. During in-range measurements, this current is supplied by the reference voltage through CR105 and voltage through the amplifier (U101) and CR104. Overloads with input HI positive are sustained by CR105; diodes CR103 and CR104 sustain negative overloads. Open circuit voltage is set to less than 5V by R150 and R151 through CR103 and CR105. A/D protection in Ω is the same as in V except R105 is substituted for R106.

6-6. A/D CONVERTER. The A/D converter operates on the dual slope principle. The timing is divided into three periods as described below. Operation with high and low reference voltages is described separately in subparagraph d.

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, reference voltage V_{REF} (see subparagraph d) is stored on capacitor C124. Capacitor C117 stores $V_{REF} + V_{OS1} - V_{OS2}$.

b. Signal-Integrate. The signal-integrate period (B, Figure 6-3) is 100 milliseconds in length. The A/D input is buffered by U104 (see subparagraph d) and integrated by U103. 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 hertz, particularly the 50 and 60 hertz 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 C124). 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.

d. Reference Voltages. Reference voltage V_{REF} may be either 1 volt or 0.1 volt. Switching through the pushbuttons turns on either Q104 (for 1 volt) or Q103 (for 0.1 volt). The voltages are provided by a divider across a temperature compensated zener diode. An operational amplifier on U103 provides the zener with a self-regulating bias. Use of the 0.1 volt reference increases converter sensitivity to 200 millivolts full scale, permitting accurate LO ohms operation, 10 microvolt resolution on dc voltage measurements, and dc amperage measurements with a full scale burden of 200 millivolts. Increased sensitivity is accomplished by switching input buffer U104 into a gain-of-10 configuration by turning on Q105. Auto-zero charging on C124 is to a 100 millivolt reference instead of a 1 volt reference. Integrator and comparator voltage levels are unaffected by buffer gain. Buffer offset voltage is zeroed, and resistors R146 plus R144 or R145, which are selected at test, null any remaining zero offset on the 200 millivolt range.

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 U107A and U107B. Emitter-follower Q108 ensures that CMOS-compatible levels are maintained on U107A, pin 1, regardless of the loading of U202. The minus polarity readout is blanked on ac voltage and resistance ranges by contacts on the pushbutton switch. Proper decimal point position is determined by the combination of function and range selected.

6-8. CURRENT MEASUREMENTS. In the A mode, the signal is switched into one of five current shunts ahead of the attenuator section. For dc current measurements, the shunt voltage drop is applied directly to the A/D converter input at 200 millivolts full scale. For ac current measurements, the shunt voltage drop is treated as a 200 millivolt ac signal and passes through the ac attenuator and the X10 ac amplifier. Overload clamping occurs at three diode drops which is a level high enough to permit high crest factor current waveforms.

6-9. AC POWER SUPPLY. When the DMM is operated from ac line power, the power supply furnishes +5, +15, and -15 volts from regulators VR104, VR102 and VR101, respectively. Full-wave rectified ac from bridge rectifiers CR101 and CR102 is filtered by reservoir capacitors C108, C104 and C103 and is applied to the linear voltage regulators.

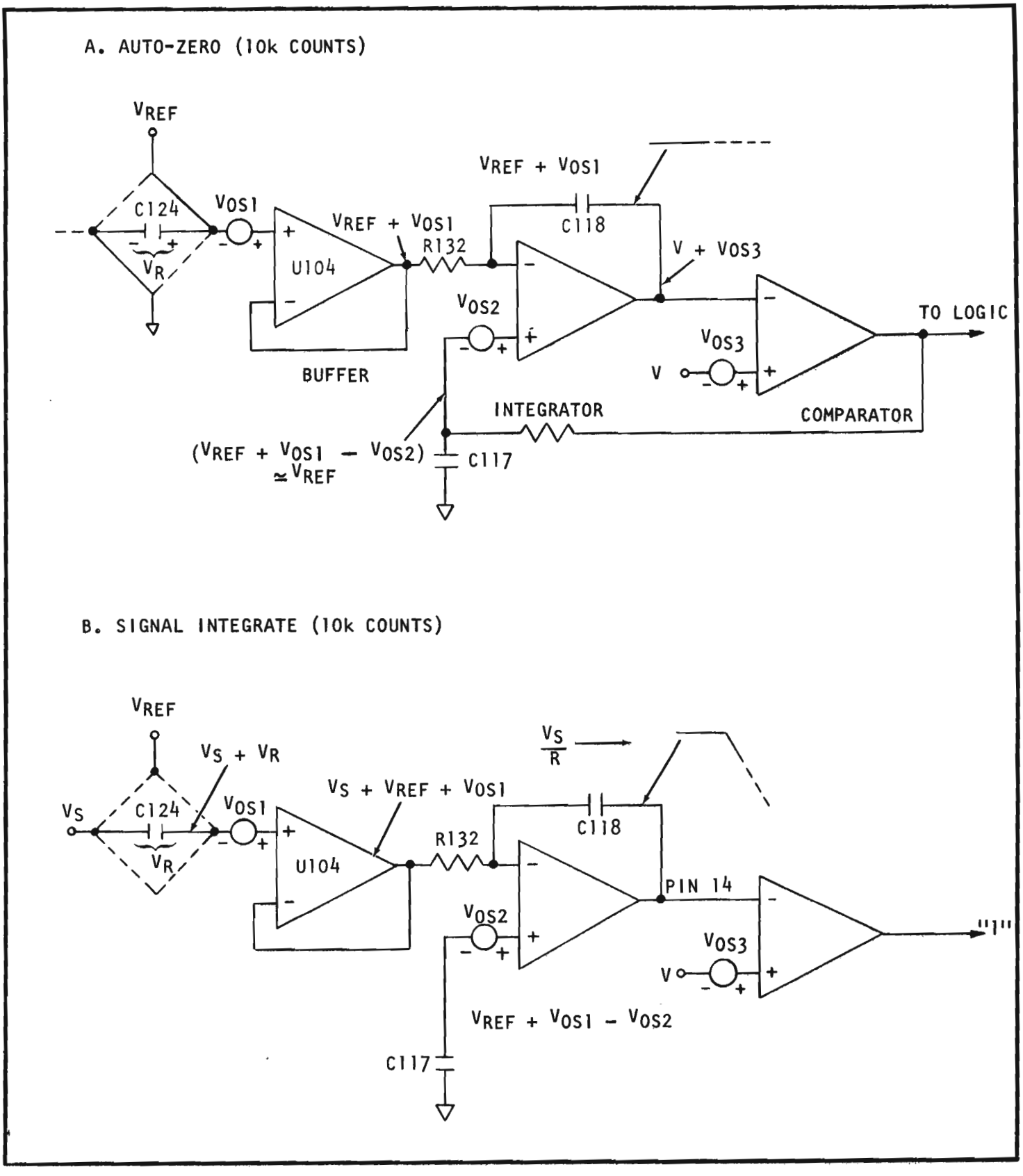


FIGURE 6-3. A/D Converter Function (Sheet 1 of 2)

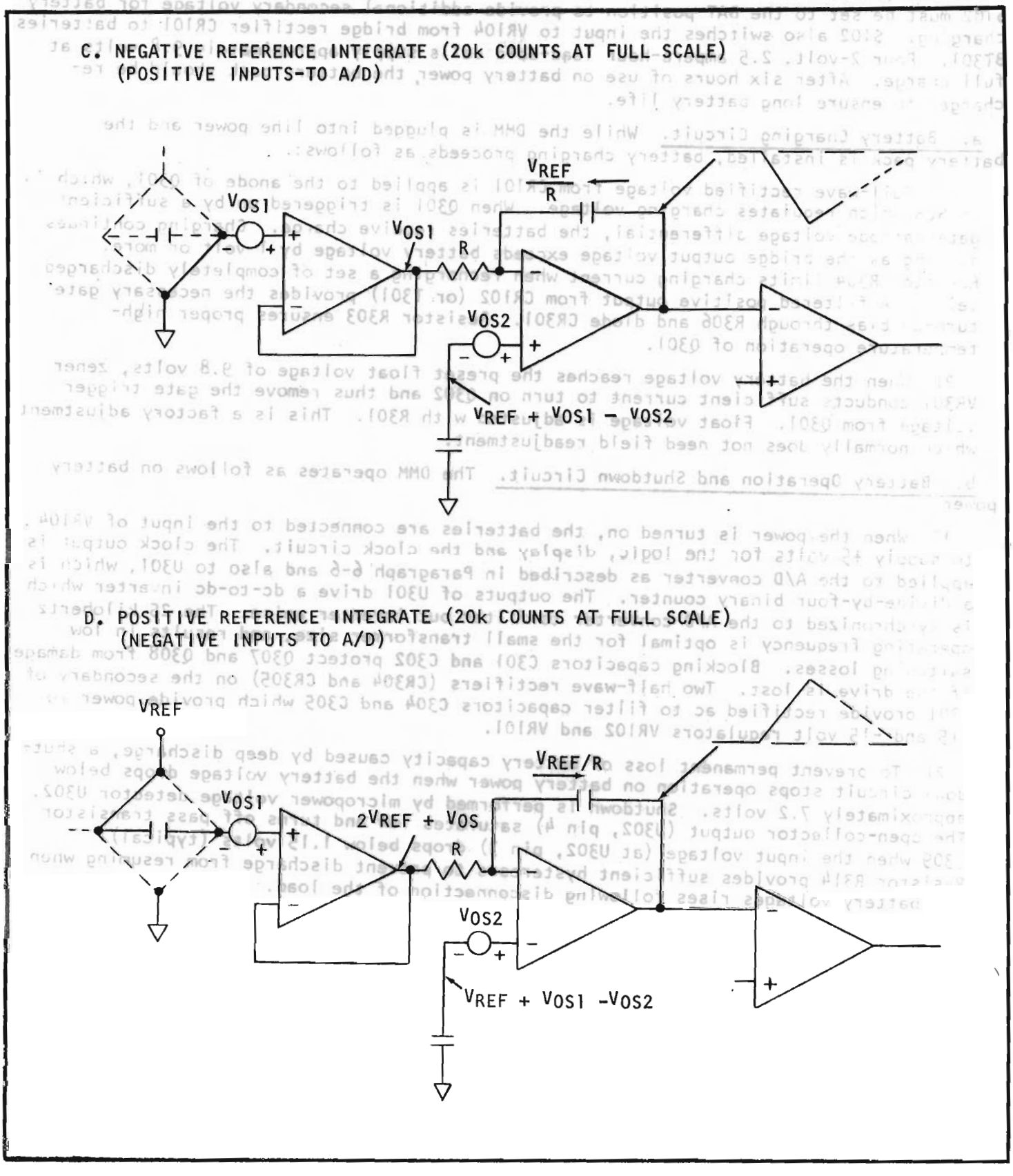


FIGURE 6-3. A/D Converter Function (Sheet 2 of 2)

6-10. OPTION 06 BATTERY PACK. When the Option 06 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 VR104 from bridge rectifier CR101 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 CR101 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 CR102 (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 voltage reaches the preset float voltage 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 normally does not need field readjustment.

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 VR104 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 also to U301, which is a divide-by-four binary counter. The outputs of U301 drive a dc-to-dc inverter which is synchronized to the A/D converter to filter out inverter noise. The 25 kilohertz 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 VR102 and VR101.

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 voltages 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 Racal-Dana Instruments, Irvine, California 92713, (714) 833-1234. When ordering, include the following information:

a. Instrument Model Number.

b. Instrument Serial Number.

c. Part Description.

d. Circuit Designation (if applicable).

e. 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 4002 DMMs. Specify Part Number 29197A when ordering.

TABLE 7-1.
Model 4002 Maintenance Kit.

Qty.	Part Number	Schematic Callout
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	V107
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
2	TG-128	Q101, 102, 106, 107

7-4. SCHEMATIC.

a. Model 4002 4-1/2 Digit TRMS Multimeter: Schematic No. 28992E (Page 7-10). This schematic also describes the Option 06 Rechargeable Battery Pack.

7-5. COMPONENT LAYOUT.

a. Model 4002 4-1/2 Digit TRMS Multimeter (Page 7-11).

b. Option 06 Rechargeable Battery Pack (Page 7-13).

TABLE 7-1.
Cross-Reference of Manufacturers

MFR. CODE	NAME AND ADDRESS	FED. SUPPLY CODE
A-B	Allen-Bradley Corp Milwaukee, WI 53204	01121
A-D	Analog Devices Inc. Norwood, MA 02026	24355
ACI	American Components, Inc. Conshohocken, PA 19428	14298
AMP	Amphenol Broadview, IL 60153	02660
APX	Amperex Elkgrove Vlg, IL 60007	73445
BEC	Beckman Inst. Inc. Fullerton, CA 92634	73138
BLD	Belden Mfg. Co. Chicago, IL 60644	70903
BRG	Berg Electronics Inc. New Cumberland, PA 17070	22526
BRN	Bourns, Inc. Riverside, CA 92507	80294
BUS	Bussman Mfg. Div. St. Louis, MO 63017	71400
C-I	Components, Inc. Biddeford, ME 04005	06751
C-W	Continential-Wirt Elec. Corp. Warminster, PA 18974	79727
CAD	Caddock Riverside, CA. 92507	19647
CAN	ITT Cannon Electric Santa Ana, CA 92702	71468
CLB	Centralab Division Milwaukee, WI 53201	71590
CLR	Clarostat Mfg. Co., Inc. Dover, NH 03820	12697
CTS	CTS Corporation Elkhart, IN 46514	71450
DIC	Dickson Electronics Corp. Scottscale, AZ 85252	12954
DLE	Dale Electronics Inc. Columbus, NE 68601	91637
DTN	Dielettron (Consolidated) New York City, NY 10013	
ECI	Electro Cube Inc. San Gabriel, CA 91776	14752
EDI	Electronic Devices, Inc. Yonkers, NY 10710	83701
EFJ	E. F. Johnson Co. Waseca, MN 56093	74970
ERI	Erie Technological Prod. Erie, PA 16512	72982
F-I	Fairchild Inst. Corp. Mountain View, CA 94043	07263
FUS	Bussman Mfg. (Fusetron) St. Louis, MO 63107	71400
G-E	General Electric Company Syracuse, NY 13201	03508
G-I	General Instrument Corp. Newark, NJ 07104	72699
GLD	Gould, Inc. St. Paul, MN 55165	52431
H-P	Hewlett-Packard Palo Alto, Ca 94304	50434
INT	Intersil Inc. Cupertino, CA 95014	32293
IRC	IRC Division Burlington, IA 52601	07716
L-F	Littlefuse, Inc. Des Plaines, IL 60016	75915
MOL	Molex Downers Grove, IL 60515	27264
MOT	Motorola Semi Prod. Inc. Phoenix, AZ 85008	04713
NAT	National Semi Corp. Santa Clara, CA 95051	27014

TABLE 7-1. (Cont'd)

MFR. CODE	NAME AND ADDRESS	FED. SUPPLY CODE
NCI	National Components, Inc. West Palm Beach, FL	
NEL	Northern Engr. Labs Burlington, WI 53105	00815
P&B	Potter & Brumfield Princeton, IN 47670	12300
PAK	Paktron Vienna, VA 22180	
POM	Pomona Electric Pomona, CA 91766	05276
QTN	Q-Tron Santa Ana, CA 92705	25525
R-D	Racal-Dana Instruments Irvine, Ca. 92713	21793
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
TEP	Tepro Electric Corp. Rochester, NY 14606	02985
TPL	Temple Tecate, CA 92080	29505
TRW	TRW Capacitor Div. Ogallala, NB 69153	84411
VIS	Vishay Resistor Products Malvern, PA 19355	18612
VRN	Vernitron Laconia, NH 03246	13150
WAB	Wabash-Magnetics Wabash, IN 46992	01101

REPLACEABLE PARTS LIST

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Part No.
	CAPACITORS (C)					
	"100" Series (Sch. 28992E-Pg. 7-10) (PC-Board 448-Pg. 7-11)					
C101	4.7µF, 20V, ETT	D-7	D-4	NCI	KNS475A020K	C-179-4.7
C102	4.7µF, 20V, ETT	D-7	D-4	NCI	KNS475A020K	C-179-4.7
C103	470µF, 35V, EAL	C-8	D-4	NIC	35ELA470	C-289-470
C104	470µF, 35V, EAL	C-8	E-4	NIC	35ELA470	C-289-470
C105	0.1µF, 1000V. MPF	C-3	F-4	STD	M2W-F-0.1µF	C-285-.1
C106	.25-1.5pF, 2000V, Teflon Trimmer.	D-2	F-4	EFJ	273-101	C184
C107	1000pF, 500V, ±5%, Polystyrene	D-3	F-4	CLB	CPR-1000	C-138-1000
C108	2200µF, 15V, EAL	C-7	D-3	NAC	16FLA2200	C-290-2200
C109	3.3pF, ±0.5pF, 50VDC, CerD	E-2	E-3	NAC	DT200-3R3	C-291-3.3P
C110	1µF, 100V, ±10%, MPF	G-2	E-3	POT	4309C-105K	C-294-1
C111	.25-1.5pF, 2000V, Teflon Trimmer.	D-2	E-3	EFJ	273-1-1	C-184
C112	1.9-15.8pF, 250V, Trimmer	D-2	E-3	EFJ	187-0109-005	C-284
C113	1100pF, 500VDC, ±1%, Silver Mica	D-2	E-3	G-1	RDM19FD112F03	C-278-110P
C114	1100pF, 500VDC, ±1%, Silver Mica.	D-1	F-3	G-1	RDM19FD111F03	C-278-1100P
C115	33µF, 15V, ETT.	F-2	E-2	NCI	KNS336D015K	C-228-33
C116	33µF, 15V, ETT.	F-2	E-2	NCI	KNS336D015K	C-228-33
C117	1µF, 100V, ±10%, MPF.	J-3	D-2	POT	4309C-105K	C-294-1
C118	.22µF, 200VDC, ±10%, MPF	J-2	D-2	POT	22-200-10-X363UW	C-269-.22
C119	NOT USED		---			
C120	1µF, 100V, ±10%, MPF	F-3	D-1	POT	4309C-105K	C-294-1
C121	4.7µF, 20V, ETT	D-8	D-2	NCI	KNS475A020K	C-179-4.7
C122	4.7µF, 20V, ETT	D-8	D-2	NCI	KNS475A020K	C-179-4.7
C123	.1µF, 200V, 20%, MPF.	G-4	E-2	ECI	625B1C104	C-221-.1
C124	4µF, 100V, 20%, MPF	H-2	E-1	POT	0109-5432	C-294-4
C125	100pF, 1000V, CerD.	F-5	F-2	CLB	DD-101	C-64-100P
	"200" Series (Sch. 28992E-Pg. 7-10) (PC-Board 449-Pg. 7-12)					
C201	4.7µF, 20V, ETT	K-7	F-3	NCI	KNS475A020K	C-179-4.7
	"300" Series (Sch. 28992E-Pg. 7-10) (PC-Board 451-Pg. 7-13)					
C301	4.7µF, 35V, EAL	F-7	E-3	NCI	KNS475A020K	C-179-4.7
C302	4.7µF, 35V, EAL	F-7	E-3	NCI	KNS475A020K	C-179-4.7
C303	1.0µF, 250V, MPY.	F-7	E-3	AMP	C280AE/A1M	C-256-1
C304	100µF, 35VC	F-8	F-4	NIC	35-ULA-100	C-295-100
C305	100µF, 35VC	F-8	F-3	NIC	35-ULA-100	C-295-100

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Part No.
	DIODES (CR)					
	"100" Series (Sch. 28992E-Pg. 7-10) (PC-Board 448-Pg. 7-11)					
CR101	Bridge Rectifier, 100V, 2A	C-6	D-5	EDI	PD10	RF-36
CR102	Bridge Rectifier, 1A, 400V	C-7	D-5	EDI	PF40	RF-46
CR103	Silicon Rectifier, 1A, 1000V.	E-3	F-5	T-I	IN4007	RF-50
CR104	Silicon Rectifier, 1A, 1000V.	E-3	F-5	T-I	IN4007	RF-50
CR105	Silicon Rectifier, 1A, 1000V.	E-3	F-5	T-I	IN4007	RF-50
CR106	Rectifier, 75mA, 75V.	D-8	D-3	T-I	IN914	RF-28
CR107	Rectifier, 75mA, 75V.	J-2	C-1	T-I	IN914	RF-28
CR108	Rectifier, 75mA, 75V.	J-2	C-2	T-I	IN914	RF-28

DIODES (CR) (CON'T)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Part No.
CR109	Rectifier, 75mA, 75V.	K-3	E-2	T-I	IN914	RF-28
CR110	Rectifier, 75mA, 75V.	J-3	E-2	T-I	IN914	RF-28
CR111	Bridge Rectifier, 5A, 50V	A-3	G-2	EDI	PE05	RF-48
CR112	Rectifier, 3A, 50V.	A-4	G-2	SOL	3A50	RF-34
CR113	Rectifier, 75mA, 75V.	H-I	C-2	T-I	IN914	RF-28
	"300" Series (Sch. 28992E-Pg. 7-10) (PC-Board 451-Pg. 7-13)					
CR301	Rectifier, 75mA, 75V.	E-6	D-4	T-I	IN914	RF-28
CR302	Rectifier, 75mA, 75V.	F-7	E-3	T-I	IN914	RF-28
CR303	Rectifier, 75mA, 75V.	F-7	E-3	T-I	IN914	RF-28
CR304	Rectifier, 75mA, 75V.	E-8	F-4	T-I	IN914	RF-28
CR305	Rectifier, 75mA, 75V.	E-8	F-4	T-I	IN914	RF-28

DISPLAYS (DS)
"200" Series (Sch. 28992E-Pg, 7-10)
(PC-Board 449-Pg. 7-12)

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

FUSES (F)
"100" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 448-Pg. 7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Part No.
F101	Fuse, Slo-Blo, 1/8A, 250V, 3AG.	B-7	D-4	BUS	MDL	FU-20
F102	Fuse, 2A, 250V, 3AG	A-3	F-3	LIT	312002	FU-13
	"300" Series (Sch. 28992E-Pg. 7-10) (PC-Board 451-Pg. 7-13)					
F301	2A, 250V, 3AG, Quick	F-6	C-3	L-F	312002	FU-13

CONNECTORS (J)
"100" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 449-Pg. 7-12)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Part No.
J1001	11-Pin Right Angle	H-7	B-3	MOL	22-15-2111	CS-348-2
J1002	6-Pin Right Angle	H-6	F-3	MOL	22-15-2061	CS-348-1
J1003	3-Pin	B-8	---	MOL	2139-3	CS-287-3
J1004	8-Pin	D-8	D-5	MOL	2139-8	CS-287-8
J1005	Banana Jack, Black.	A-5	---	POM	1581	BJ-11-0
J1006	Banana Jack, Red.	A-3	---	POM	1581	BJ-11-2
J1007	NOT USED					

RELAYS (K)
"100" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 448-Pg. 7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Part No.
K101	5V, Reed Type	B-8	E-4	COT	UF-40097	RL-56
K102	5V, Reed Type	B-8	E-4	COT	UF-40097	RL-56
K103	5V, Reed Type	A-8	E-4	COT	UF-40102	RL-59
K104	5V, Reed Type	A-8	F-4	COT	UF-40102	RL-59
K105	5V, Reed Type	A-8	F-4	COT	UF-40102	RL-59

CONNECTORS (P)
"1000" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 448-Pg. 7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Part No.
P1001	6-Pin	H-7	G-5	MOL	22-03-2061	CS-247-1
P1002	11-Pin.	H-6	G-2	MOL	22-03-2061	CS-347-2
P1003	MALE.	B-8	C-5	MOL	A-2391-3A	CS-288-3
P1004	MALE.	D-5	D-3	MOL	A-2391-8A	CS-288-8
P1005	NOT USED					
P1006	NOT USED					
P1007	Line Cord	B-8	---	R-D	---	CO-9

TRANSISTORS (Q)
"100" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 448-Pg. 7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Part No.
Q101	N-Chan, JFET.	D-3	E-4	INT	ITE4392	TG-77
Q102	N-Chan, JFET.	D-3	E-4	INT	ITE4392	TG-77
Q103	N-Chan, JFET.	H-2	C-2	INT	ITE4392	TG-77
Q104	N-Chan, JFET.	H-2	C-2	INT	ITE4392	TG-77
Q105	N-Chan, JFET.	J-3	D-2	INT	ITE4392	TG-77
Q106	N-Chan, JFET.	G-3	E-2	R-D	---	TG-128
Q107	N-Chan, JFET.	G-4	E-2	R-D	---	TG-128
Q108	NPN, Switch	H-6	G-2	MOT	2N3904	TG-47

"300" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 451-Pg. 7-13)

Q301	Thyristor, SCR	D-6	C-4	MOT	106F1	TG-132
Q302	NPN, Switch	E-7	C-3	MOT	2N3904	TG-47
Q303	NPN, Switch	E-7	D-4	MOT	2N3904	TG-47
Q304	NPN, Switch	E-7	E-4	MOT	2N3904	TG-47
Q305	NPN, Switch	E-8	E-4	MOT	2N3904	TG-47
Q306	PNP, Silicon, TO-92 Case	E-7	E-4	R-D	---	TG-53
Q307	NPN, Switch	F-7	E-3	MOT	2N3725	TG-131
Q308	NPN, Switch	F-7	E-3	MOT	2N3725	TG-131
Q309	PNP, Silicon	E-6	D-3	MOT	MPS-WA5	TG-133
Q310	PNP, Silicon, TO-92 Case.	E-6	D-3	R-D	---	TG-53

RESISTORS (R)
"100" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 448-Pg. 7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Part No.
R101	1MΩ, ±0.5%, 2W, MtF	D-3	E-5	ACI	PME80T9	R-267-1M
R102	9.88M, ±0.5%, .5W, 1200V, MtF	D-2	E-4	TRW	AR90T10	R-265-9.88M
R103	200KΩ, 10%, Cermet Trimmer.	C-2	E-5	BEC	89P	RP-89-200K
R104	100KΩ, 10%, 2W, Comp.	E-4	F-5	A-B	HB	R-2-100K
R105	47KΩ, 10%, 2W, Comp	G-4	F-5	A-B	HB	R-3-47K
R106	47KΩ, 10%, 2W, Comp	D-4	G-5	A-B	HB	R-3-47K
R107	100Ω, 10%, Cermet Trimmer	J-1	C-3	BRN	30-69-P	RP-64-100
R108	200Ω, 10%, Cermet Trimmer	J-1	C-3	BRN	30-69-P	R-64-200
R109	MATCHED SET WITH VR105.	J-1	C-3	TRW	MAR-5	R-263-99.8K (28798A)
R110	MATCHED SET WITH VR105.	J-1	C-3	TRW	MAR-5	R-263-4.59K (28798A)
R111	931Ω, 1%, 1/8W, MtF	J-1	C-3	IRC	CEA-T0-931	R-88-931
R112	50KΩ, 10%, Cermet Trimmer	E-3	D-3	BEC	72PMR	RP-97-50K
R113	200KΩ, 1%, 1/8W, MtF.	D-3	D-3	IRC	CEA-T0-200K	R-88-200K
R114	1.8M, 10%, 1/4W, Comp	D-3	D-3	MEP	CR25, 5%	R-76-1.8M
R115	100Ω, 1%, 1/8W, MtF	D-3	D-3	IRC	CEA-T0-100	R-88-100

RESISTORS (R) (CON'T)
"100" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 448-Pg. 7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Part No.
R116	4.99KΩ, .1%, 1/10W, MtF	E-2	D-3	TRW	MAR-5, T13	R-263-4.99K
R117	44.9KΩ, .1%, 1/10W, MtF	E-2	D-3	TRW	MAR-5, T13	R-263-44.9K
R118	998KΩ, .1%, 1/4W, MtF	D-2	E-3	TRW	MAR-7, T13	R-264-998K
R119	99.8KΩ, .1%, 1/4W, MtF.	D-2	E-3	TRW	MAR-5, T13	R-263-99.8K
R120	9.98KΩ, .1%, 1/10W, MtF	D-2	E-3	TRW	MAR-5, T13	R-263-9.98K
R121	1.002KΩ, .1%, 1/10W, MtF.	D-1	E-3	TRW	MAR-5, T13	R-263-1.002K
R122	270KΩ, 10%, 1/4W, Comp.	D-1	F-3	MEP	CR25, 5%	R-76-270K
R123	.898Ω, .1%, 5W, WW.	B-4	F-3	TEP	TS5-.898	R-232-.898
R124	.1Ω, .1%, 7.5W, WW, 5-Terminal	B-4	F-2	TEL	SPECIAL	R-262-.1000
R125	120Ω, 10%, 1/4W, Comp	G-7	G-3	MEP	CR25, 5%	R-76-120
R126	5KΩ, 10%, Cermet Trimmer.	D-2	E-3	BEC	72PMR	RP-97-5K
R127	500Ω, 10%, Cermet Trimmer	D-2	E-3	BEC	72PMR	RP-97-500
R128	50Ω, 10%, Cermet Trimmer.	D-2	E-3	BEC	72PMR	RP-97-50
R129	50KΩ, 10%, Cermet Trimmer	E-1	E-3	BEC	72PMR	RP-97-50K
R130	143KΩ, .1%, 1/10W, MtF.	J-2	C-2	TRW	MAR-5, T13	R-263-143
R131	856KΩ, .1%, 1/10W, MtF.	J-2	C-2	TRW	MAR-5, T13	R-263-856
R132	100KΩ, 1%, 1/10W, MtF	J-2	D-2	IRC	CEA-TO-100K	R-88-100K
R133	26.7Ω, 1%, 1/8W, MtF.	J-2	D-2	IRC	CEA-TO-26.7K	R-88-26.7K
R134	3.01Ω, 1%, 1/8W, MtF.	J-3	D-2	IRC	CEA-TO-3.01K	R-88-3.01K
R135 (A-J)	Thick Film Network.	SEVERAL	E-2	R-D	---	TF-65
R136	47KΩ, 10%, WW, Comp	F-4	F-2	A-B	HB	R-3-47K
R137	9Ω, 0.5W, 0.1%, WW	B-4	F-2	TEL	SA3	R-252-9
R138	900Ω, 0.1%, 1/2W, MtF	C-4	F-2	DLE	MFF-1/2-T0-900	R-169-900
R139	90Ω, 1/2W, .1%, MtF	B-4	F-2	DLE	MFF-1/2-T0-90	R-169-90
R140	11KΩ, 1%, 1/8W, MtF	J-1	C-1	IRC	CEA-T0-11K	R-88-11K
R141	19.6KΩ, 1%, 1/8W, MtF	J-2	C-1	IRC	CEA-T0-19.6K	R-88-19.6K
R142	50K, 10%, Cermet Trimmer.	G-3	D-2	BEC	72PMR	RP-97-50K
R143	500Ω, 10%, Cermet Trimmer	G-2	D-2	BEC	72PMR	RP-97-500
R144	Optional, Factory Selected.	H-4	E-2	MEP	CR25, 5%	R-76-* (SEL)
R145	Optional, Factory Selected.	H-5	E-2	MEP	CR25, 5%	R-76-* (SEL)
R146	1Ω, 5%, 1/4W, Comp.	H-5	E-2	MEP	CR25, 5%	R-76-1
R147	47KΩ, 10%, 1/4W, Comp	F-5	F-2	MEP	CR25, 5%	R-76-47K
R148	22M, 10%, 1/4W, Comp.	F-5	F-2	MEP	CR25, 5%	R-76-22M
R149	200K, 10%, Cermet Trimmer	D-3	G-1	BEC	89P	RP-89-200K
R150	3.3KΩ, 5%, 1/4W, Comp	E-3	F-5	MEP	CR25, 5%	R-76-3.3K
R151	12KΩ, 5%, 1/4W, Comp.	F-3	F-5	MEP	CR25, 5%	R-76-12K
R152	(Part of 28798A).	J-1	C-3	R-D	---	R-88-*
R153	(Part of 28798A).	J-1	C-3	R-D	---	R-88-*

"200" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 448-Pg. 7-11)

R201	120Ω, 1/4W, Comp.	H-7	C-2	MEP	CR25, 5%	R-76-120
R202	47Ω, Thick Film Network	J-7	E-2	BEC	899-3-R47	RF-64

"300" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 451-Pg. 7-13)

R301	20KΩ, 0.5W, POT	E-7	C-3	BEC	72PMR-20K	RP-97-20K
R302	330Ω, 10%, 1/4W, Comp	E-7	C-3	MEP	CR25, 5%	R-76-330
R303	1KΩ, 10%, 1/4W, Comp.	E-6	D-4	MEP	CR25, 5%	R-76-1K
R304	3.9KΩ, 20%, 3W, WW	D-6	D-4	TEP	TS3	R-268-3.9
R305	4.7KΩ, 10%, 1/4W, Comp.	E-7	D-3	MEP	CR25, 5%	R-76-4.7K
R306	33KΩ, 10%, 1/4W, Comp	D-8	C-3	A-B	CB-332-10%	R-76-3.3K
R307	82KΩ, 10%, 1/4W, Comp	F-7	E-3	MEP	CR25, 5%	R-76-82
R308	82KΩ, 10%, 1/4W, Comp	F-7	E-3	MEP	CR25, 5%	R-76-82
R309	10Ω, 10%, 1/4W, Comp.	D-8	F-4	A-B	CB-100-10%	R-76-10
R310	10Ω, 10%, 1/4W, Comp.	D-8	F-4	A-B	CB-100-10%	R-76-10
R311	100KΩ, 5%, 1/4W, Comp	E-6	E-3	MEP	CR25, 5%	R-76-100K
R312	100KΩ, 5%, 1/4W, Comp	E-6	E-3	MEP	CR25, 5%	R-76-100K
R313	6.8MΩ, 5%, 1/4W, Comp	F-6	E-3	MEP	CR25, 5%	R-76-6.8M
R314	6.8MΩ, 5%, 1/4W, Comp	F-6	E-3	MEP	CR25, 5%	R-76-6.8M
R315	576KΩ, 1%, 1/8W, Comp	F-6	E-3	IRC	CEA-T0-576K	R-88-576K
R316	100KΩ, 1%, 1/8W, Comp	F-6	E-3	IRC	CEA-T0-100K	R-88-100K

SWITCHES (S)
"100" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 448-Pg. 7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Part No.
S101	Line Voltage Selector	B-7	C-4	C-W	GG350PCDPDT	SW-318
S102	Line/Battery.	C-6	D-4	R-D	---	SW-397
S103	11 Station Pushbutton	A-5	G-4	R-D	---	SW-402 (27696A)

TRANSFORMERS (T)
"100" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 448-Pg. 7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Part No.
T101	Transformer, Power	C-6	D-5	R-D	---	TR-168
T101	Transformer, Power (100/200 V)	C-6	D-5	R-D	---	TR-169

"300" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 451-Pg. 7-13)

T301	Transformer, Power	F-7	F-3	R-D	---	TR-170

TEST POINTS (TP)
(Sch. 28992E-Pg. 7-10)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Part No.
TP1	Test Point	C-8	---	R-D	---	---
TP2	Test Point	C-8	---		---	---
TP3	Test Point	H-2	---		---	---
TP4	Test Point	J-1	---		---	---
TP5	Test Point	E-3	---		---	---
TP6	Test Point	J-3	---		---	---
TP7	Test Point	J-2	---		---	---
TP8	Test Point	H-2	---		---	---
TP9	Test Point	F-2	---		---	---
TP10	Test Point	G-3	---	R-D	---	---

INTEGRATED CIRCUITS (U)
"100" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 448-Pg. 7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Part No.
U101	Operational AMP 8-Pin, TO-5	D-3	E-3	NAT	LH0022CH	IC-165
U102	Operational AMP 8-Pin, DIP	E-2	D-3	NAT	LM301AN	IC-167
U103	4-1/2 Digit Analog-Processor	K-2	D-2	INT	8052A	LSI-12
U104	Operational AMP 8-Pin, TO-5	H-2	E-2	NAT	LH0042CH	IC-175
U105	TRMS Converter	F-2	D-2	A-D	AD536J	IC-172
U106	4-1/2 Digit Logic Processor	J-4	E-2	INT	7103A	LSI-11
U107(A-D)	4011 CMOS Unbuffered	SEVERAL	F-2	MOT	MC14011CP	IC-102

"200" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 449-Pg. 7-12)

U201	Segment Drive	K-7	F-2	MOT	4511	IC-168
U202	Digit Driver	H-6	F-2	T-I	75492	IC-169

"300" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 451-Pg. 7-13)

U301	Dual D-Type Flip-Flop, 14-Pin DIP	E-7	D-3	RCA	CD4013AE	IC-103
U302	1.1V Micro-Power Detector	F-6	E-3	INT	ICL8211CPA	IC-177

VOLTAGE REGULATORS (VR)
"100" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 448-Pg. 7-11)

Circuit Desig.	Description	Sch. Location	PC-Board Location	Mfr. Code	Mfr. Desig.	Part No.
VR101	-15V, 3-Term	C-8	E-5	MOT	MC7915CT	IC-174
VR102	+15V, 3-Term, LO-Power	C-8	E-5	MOT	MC78L15CP	IC-170
VR103	NOT USED					
VR104	+5V, 3-Term, TO-220	D-7	D-4	MOT	MC7805CT	IC-93
VR105	Reference Zener	J-2	C-2	R-D	---	(28798A)

"300" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 451-Pg. 7-13)

VR301	8.2 Volt, Zener	E-6	C-3	MOT	1N765A	DZ-61

CRYSTAL (Y)
"100" Series (Sch. 28992E-Pg. 7-10)
(PC-Board 448-Pg. 7-11)

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

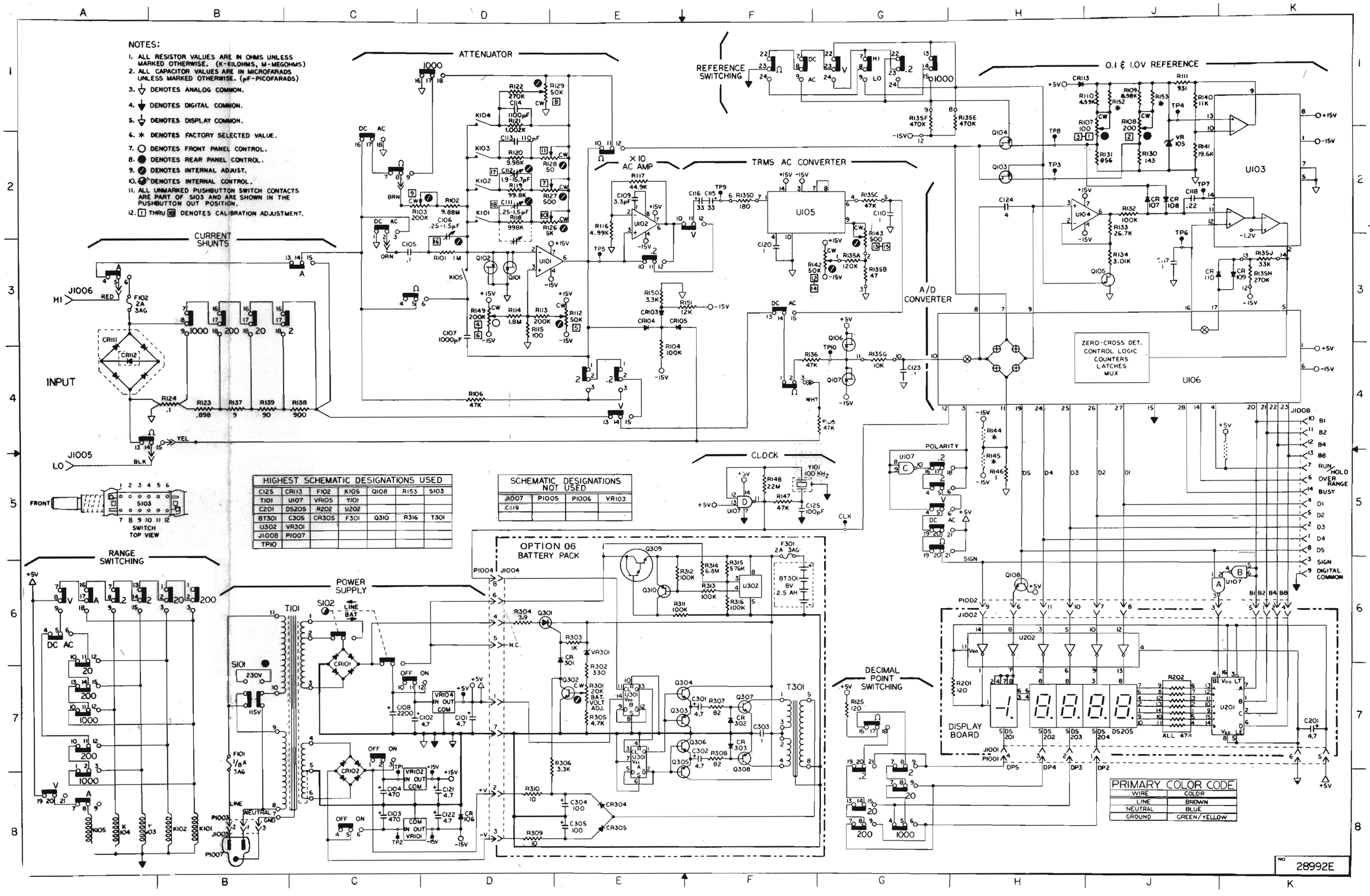
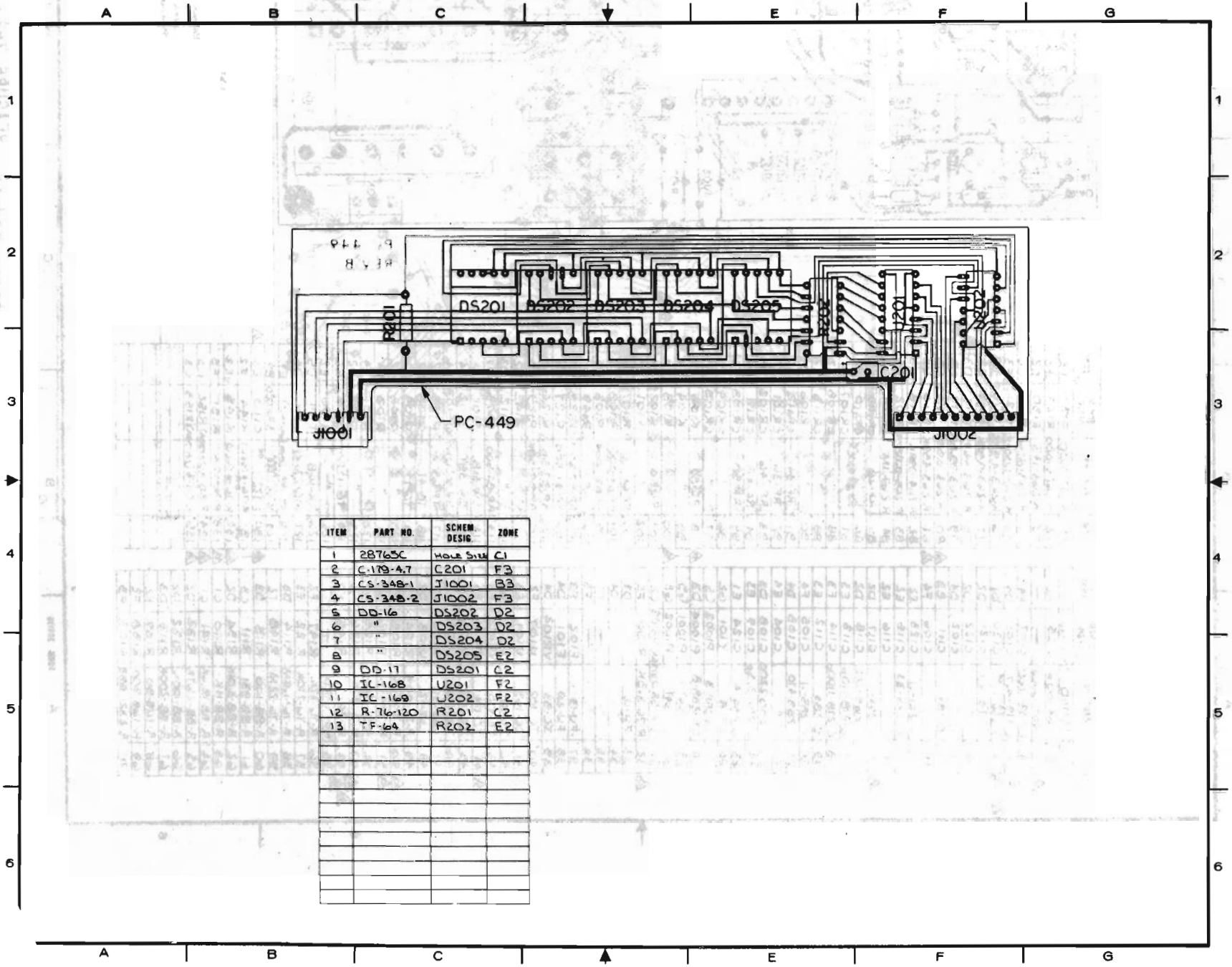


FIGURE 7-1 Schematic Diagram - Model 4002 TRMS Multimeter.

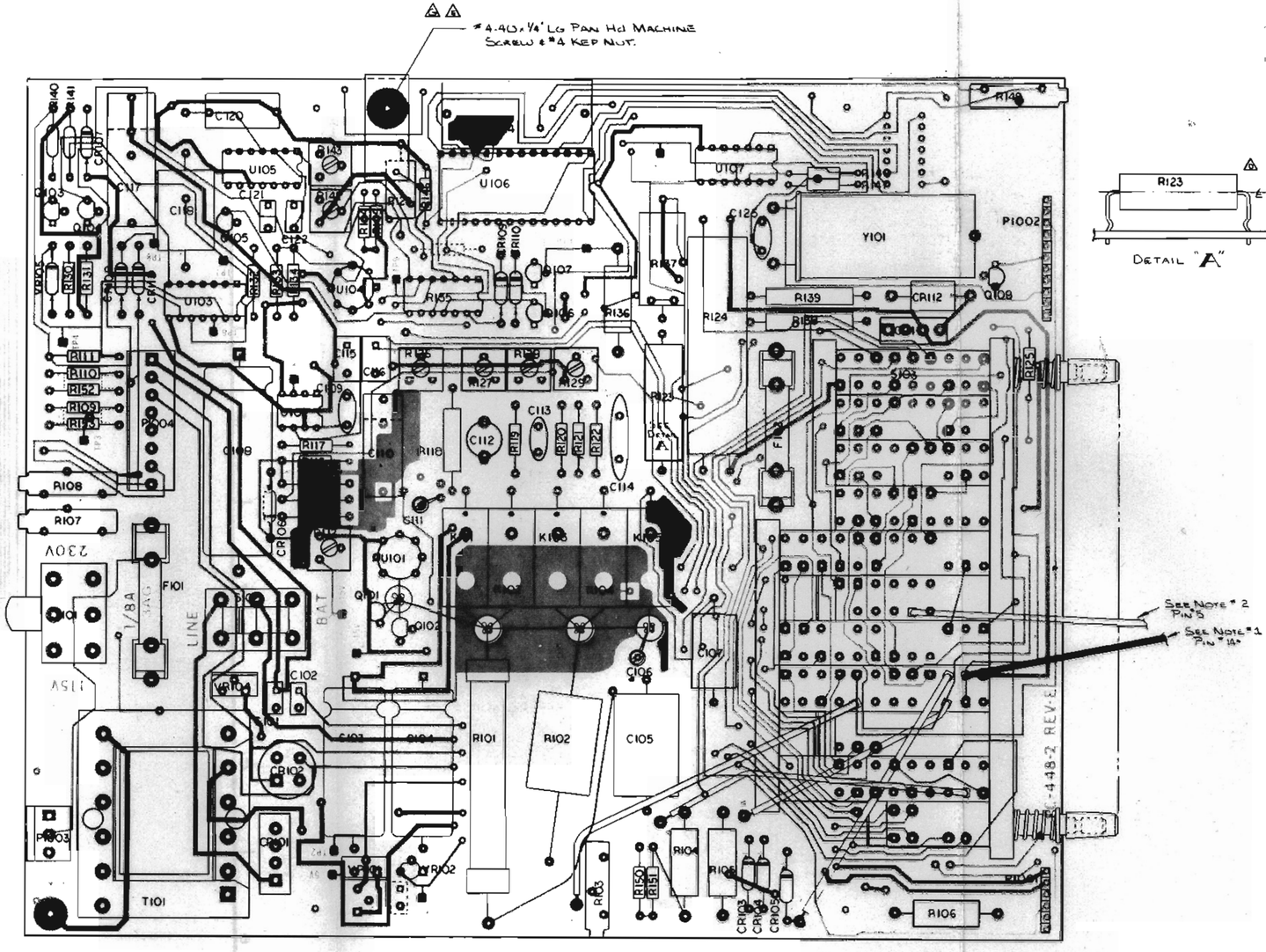


ITEM	PART NO.	SCHEM. DESIG.	ZONE
1	28765C	HOLE SIZE	C1
2	C-179-4.7	C201	F3
3	CS-348-1	J1001	B3
4	CS-348-2	J1002	F3
5	DD-16	DS202	D2
6	"	DS203	D2
7	"	DS204	D2
8	"	DS205	E2
9	DD-17	DS201	C2
10	IC-168	U201	F2
11	IC-168	U202	F2
12	R-76-120	R201	C2
13	TF-64	R202	E2

FIGURE 7-3. Component Layout, PC-449, Display Board.

ITEM	PART NO.	SCHEM. DESIG.	ZONE
1	28715D STAKING		
2	C-64-100p	C125	F2
3	NOT USED	—	—
4	C-138-1000	C107	F4
5	C-179-4.7	C101	D4
6	C-294-1 OR C-294-1	C120	D1
7	C-179-4.7	C121	D2
8	"	C122	D2
9	"	C102	D4
10	C-184	C111	E3
11	"	C106	F4
12	C-221-.1	C123	E2
13	C-228-33	C115	E2
14	"	C116	E2
15	C-294-1	C117	D2
16	C-269-.22	C118	D2
17	C-278-110p	C113	E3
18	C-278-1100p	C114	F3
19	C-284	C112	E3
20	C-285-.1	C105	F4
21	C-289-470	C103	D4
22	"	C104	E4
23	C-290-2200	C108	D3
24	C-291-3.3p	C109	E3
25	C-294-4	C124	E1
26	CR-8	Y101	G2
27	CS-288-3	P1003	C5
28	CS-288-8	P1004	D3
29	CS-347-1	P1001	G5
30	CS-347-2	P1002	G2
31	DZ-5B (zener)	VR105	C2
32	R-76-3.3K	R150	F5
33	FH-12	—	D3
34	"	—	D4
35	"	—	F3
36	"	—	F3
37	FU-13	F102	F3
38	FU-20	F101	D4
39	IC-93	VR104	D4
40	IC-102	U107	F2
41	IC-165	U101	E3
42	IC-167	U102	D3
43	IC-170	VR102	E5
44	IC-174	VR101	E5
45	IC-172	U105	D2
46	IC-175	U104	E2
47	LSI-11	U106	E2
48	LSI-12	U103	D2
49	R-3-100K	R104	F5
50	R-3-47K	R105	F5
51	R-3-47K	R106	G5
52	R-76-120	R125	G3
53	R-3-47K	R136	F2
54	R-76-1	R146	E2
55	NOT USED	—	—
56	R-76-47K	R147	F2
57	R-76-270K	R122	F3
58	R-76-1.8M	R114	D3
59	R-76-22M	R148	F2
60	R-88-100	R115	D3
61	R-88-931	R111	C3
62	R-88-3.01K	R134	D2
63	R-88-11K	R140	C1
64	R-88-19.6K	R141	C1
65	R-88-26.7K	R133	D2
66	R-88-100K	R132	D2
67	R-88-200K	R113	D3
68	R-169-90	R139	F2
69	R-169-900	R138	F2
70	R-232-.898	R123	F3

ITEM	PART NO.	SCHEM. DESIG.	ZONE
71	R-252-9.00	R137	F2
72	R-262-.1000	R124	F2
73	R-263-143	R130	C2
74	R-263-856	R131	C2
75	R-263-1.002K	R121	E3
76	R-263-4.99K	R116	D3
77	R-263-9.98K	R120	E3
78	R-263-44.9K	R117	D3
79	R-263-99.8K	R119	E3
80	R-263-8.98K	R109	C3
81	R-263-4.99K	R110	C3
82	R-264-998K	R118	E3
83	R-265-9.88M	R102	E4
84	R-267-1M	R101	E5
85	RF-28	CR109	E2
86	"	CR110	E2
87	"	CR107	C1
88	"	CR108	C2
89	"	CR113	C2
90	"	CR106	D3
91	RF-34	CR112	G2
92	RF-36	CR101	D5
93	RF-46	CR102	D5
94	RF-48	CR111	G2
95	RF-50	CR103	F5
96	"	CR104	F5
97	"	CR105	F5
98	RL-59	K105	F4
99	"	K104	F4
100	"	K103	E4
101	RL-56	K102	E4
102	"	K101	E4
103	RP-64-100	R107	C3
104	RP-64-200	R108	C3
105	RP-89-200K	R103	E5
106	"	R149	G1
107	RP-97-50	R128	E3
108	RP-97-500	R127	E3
109	RP-97-5K	R126	E3
110	RP-97-50K	R129	E3
111	"	R142	D2
112	"	R112	D3
113	RP-97-500	R143	D2
114	SW-318	S101	C4
115	SW-397	S102	D4
116	SW-402 (2765A/B)	S103	G4
117	TF-65	R135	E2
118	TG-47	Q108	G2
119	TG-77	Q104	C2
120	"	Q103	C2
121	"	Q102	E4
122	"	Q101	E4
123	"	Q105	D2
124	TG-128	Q107	E2
125	"	Q106	E2
126	TR-168	T101	D5
127	MC-221	—	D5
128	28776A (GOLD CONTACT)	—	E1
129	22 GA BARE BUSS WIRE	3 REQ'D	E4
130	C-294-1 OR C-294-1	C110	E3
131	R-76-X (SEL.) OR	R144	E2
132	R-76-X (SEL)	R145	E2
133	R-76-12K	R151	F5
134	R-88-X (28735A)	R152	C3
135	R-88-X (28735A)	R153	C3



NOTES:

1. BLACK WIRE FROM SWITCH (SW-402) TO BE CONNECTED TO BLACK BANANA JACK (BJ-11-0) ON FRONT PANEL.
2. RED WIRE FROM SWITCH (SW-402) TO BE CONNECTED TO BANANA JACK (BJ-11-2) ON FRONT PANEL.

FIGURE 7-2. Component Layout, PC 448, Mother Board.

ITEM	PART NO.	SCHEM. DESIG.	ZONE
1	29005C	HOLE SIZE	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	CC-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 68-3.9	R304	D4
25	RP-91 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	1 REQ'D	D4
41	SC 76-0	—	D2
42	SC 76-9	—	D2
43	K 16 100K	R313	E3
44	"	R311	E3
45	"	R312	E3
46	R 76-6.8M	R314	E3
47	R-88-100K	R316	E3
48	K 88-5.76K	R315	E3
49	IC-177	U302	E3
50	TG-133	Q309	D3
51	TG-53	Q310	D3

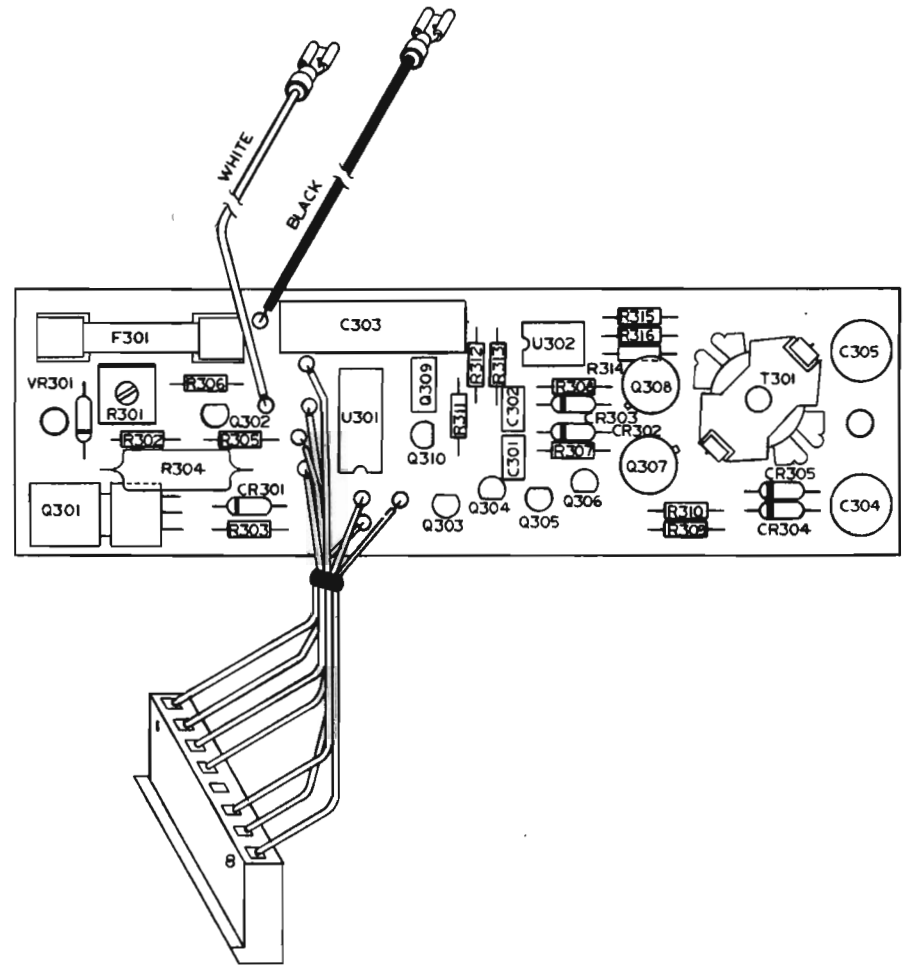


FIGURE 7-4. Component Layout, PC-451, Battery Pack Board.