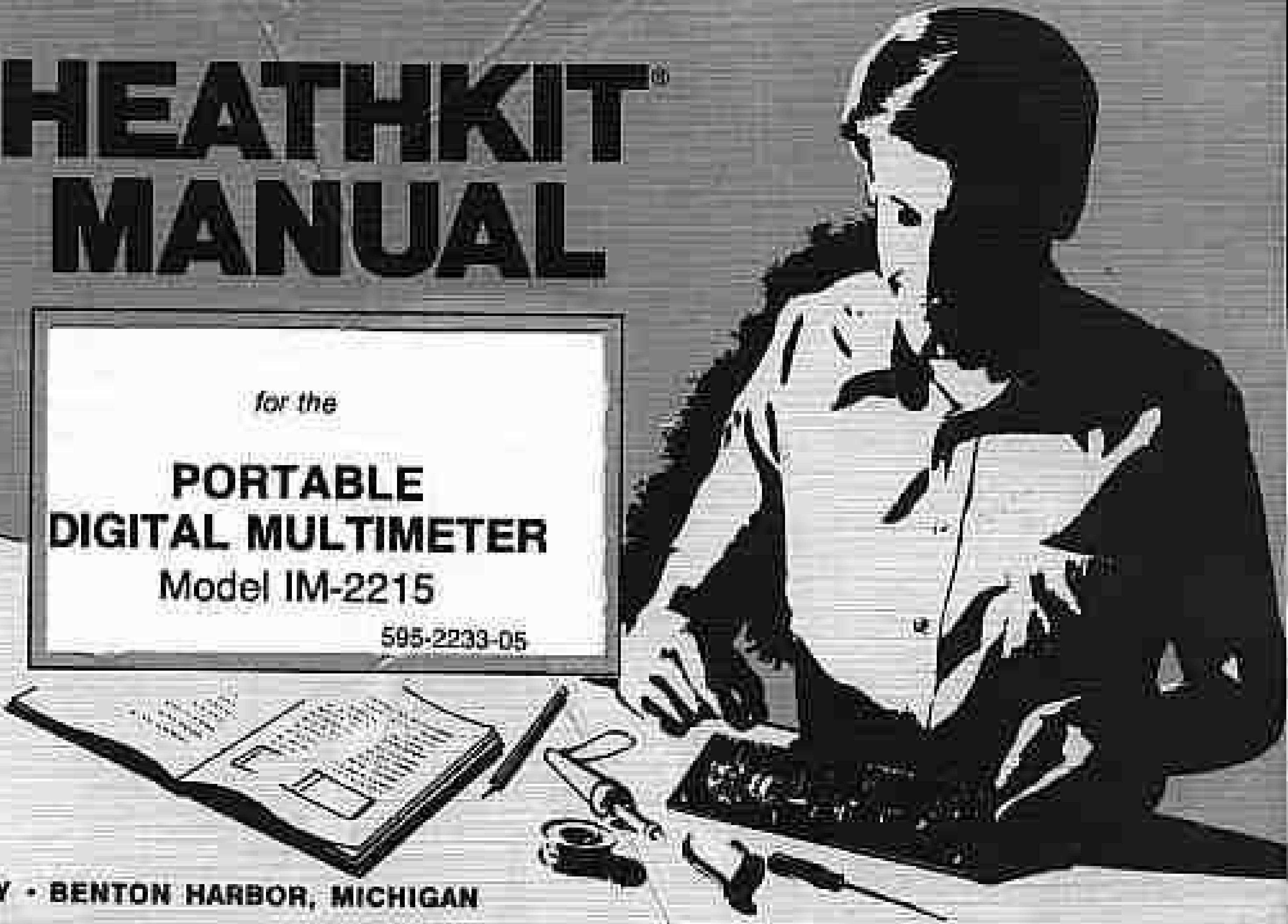
HEATHKIT® MANUAL

for the

PORTABLE DIGITAL MULTIMETER
Model IM-2215

595-2233-05



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INTRODUCTION

This Portable Digital Multimeter (DMM) is a compact, hand-held instrument designed for both field and laboratory use. Built-in references enable you to calibrate it to the accuracies listed in the Specifications section of this Manual. A 9-volt alkaline battery (not supplied) typically provides 200 hours of operation. You can also operate the Multimeter continuously from line voltage using one of the optional Heathkit converter/chargers* available for this kit.

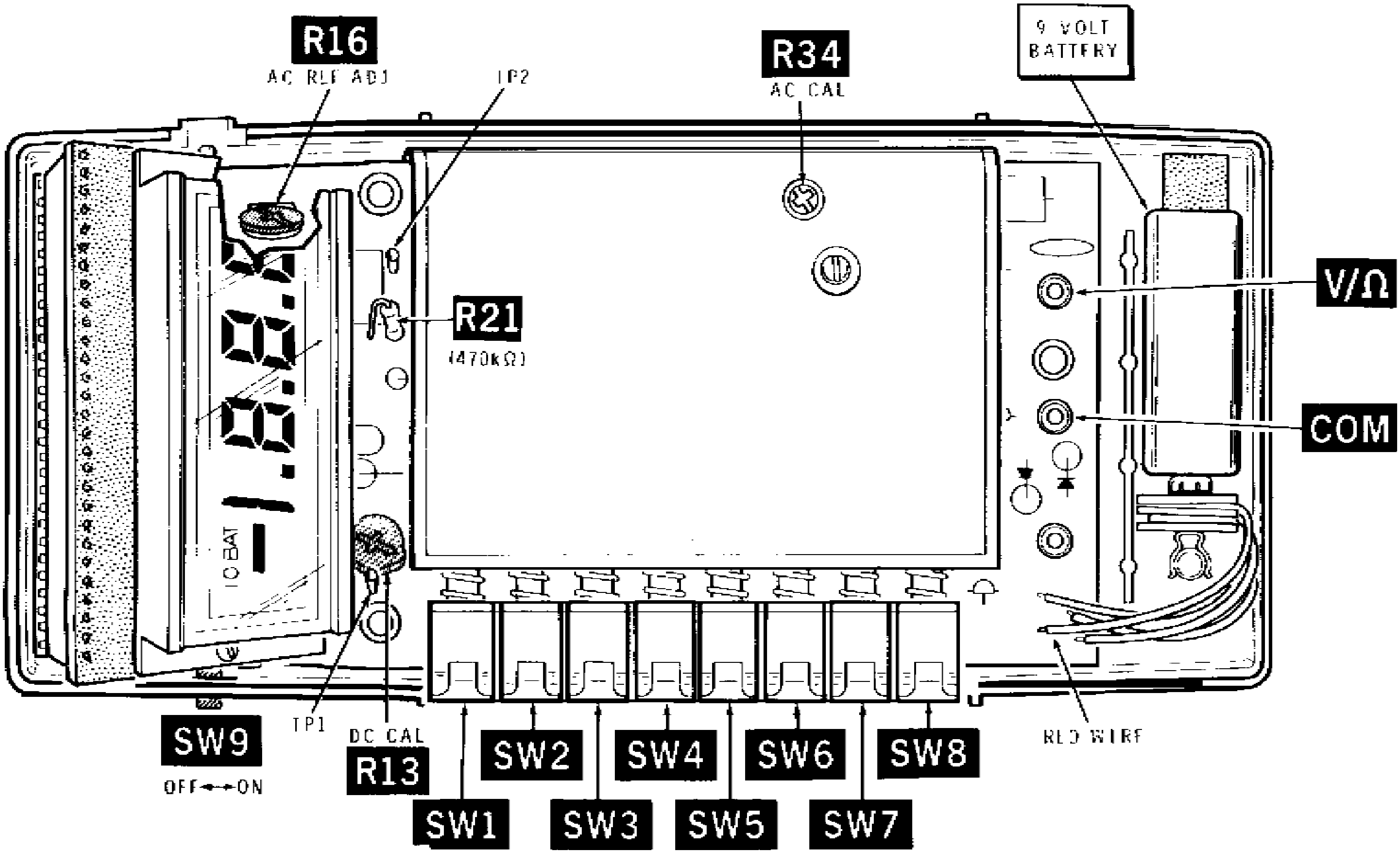
The 3-1/2 digit, liquid crystal display features large, easy-to-read numerals with automatic decimal point placement and polarity indication. Battery condition is continuously monitored and a warning ("LO BAT") is displayed during appproximately the last 20% of battery life. All of the dual-slope, analog-to-digital conversion circuitry, which provides extremely stable and accurate performance is contained in one MOS/LSI** integrated circuit.

Measurement functions include AC and DC voltages, AC and DC currents, and resistance. All functions are protected by fuse and diode against overload and transients. Voltage and current inputs are separated to protect the Multimeter and the circuitry being tested. The "full-scale" resistance test voltage alternates from high to low over the six ranges to allow both semiconductor testing and in-circuit resistance measurements.

This compact, lightweight instrument features pushbutton switching, which permits one-hand operation, leaving the other hand free for probe placement. A pivoting stand is used to support the front of the instrument at a more convenient viewing angle. This carefully designed Multimeter will provide long, reliable performance for your laboratory, workbench, or portable applications.

*Model PS-2350 for 120 VAC operation and Model PS-2450 for 220 VAC operation.

**Metal-oxide semiconductor/large scale integration.



PICTORIAL 4-1

ON-OFF SWITCH

Turns the instrument on and off.

RANGE SWITCHES

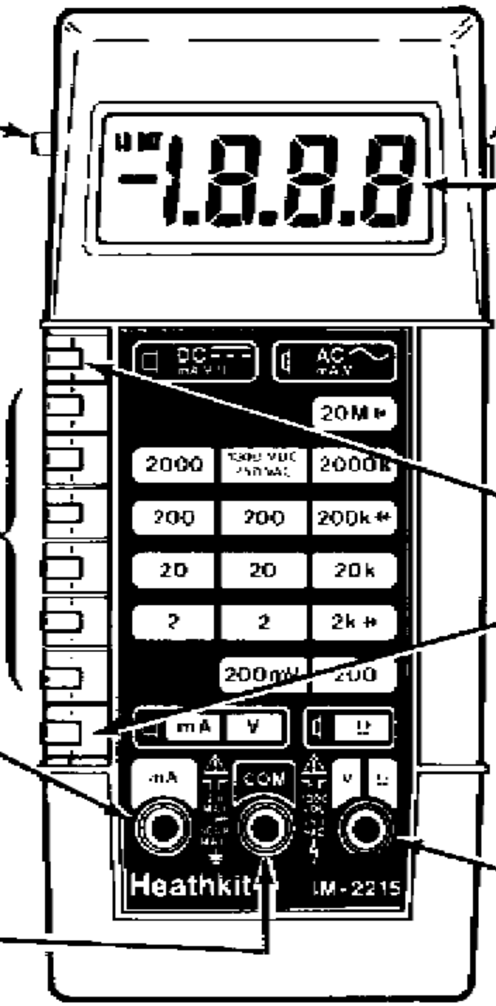
Selects desired range of operation.

CURRENT INPUT

Connect red test lead here when measuring current.

COMMON INPUT

Connect black test lead here for all measurements.



BATTERY ELIMINATOR JACK

Used for line-powered operation. Disconnects battery from Multimeter circuitry.

DISPLAY

Displays value of what is being measured. Decimal point position is determined by (RANGE switches (SW3 through SW7). Polarity indicators (implied for positive, "-" for negative) are displayed automatically. Overrange is indicated by a 1 in the most significant digit and the other digits blanked. LO BAT comes on when approximately 20% of battery capacity remains.

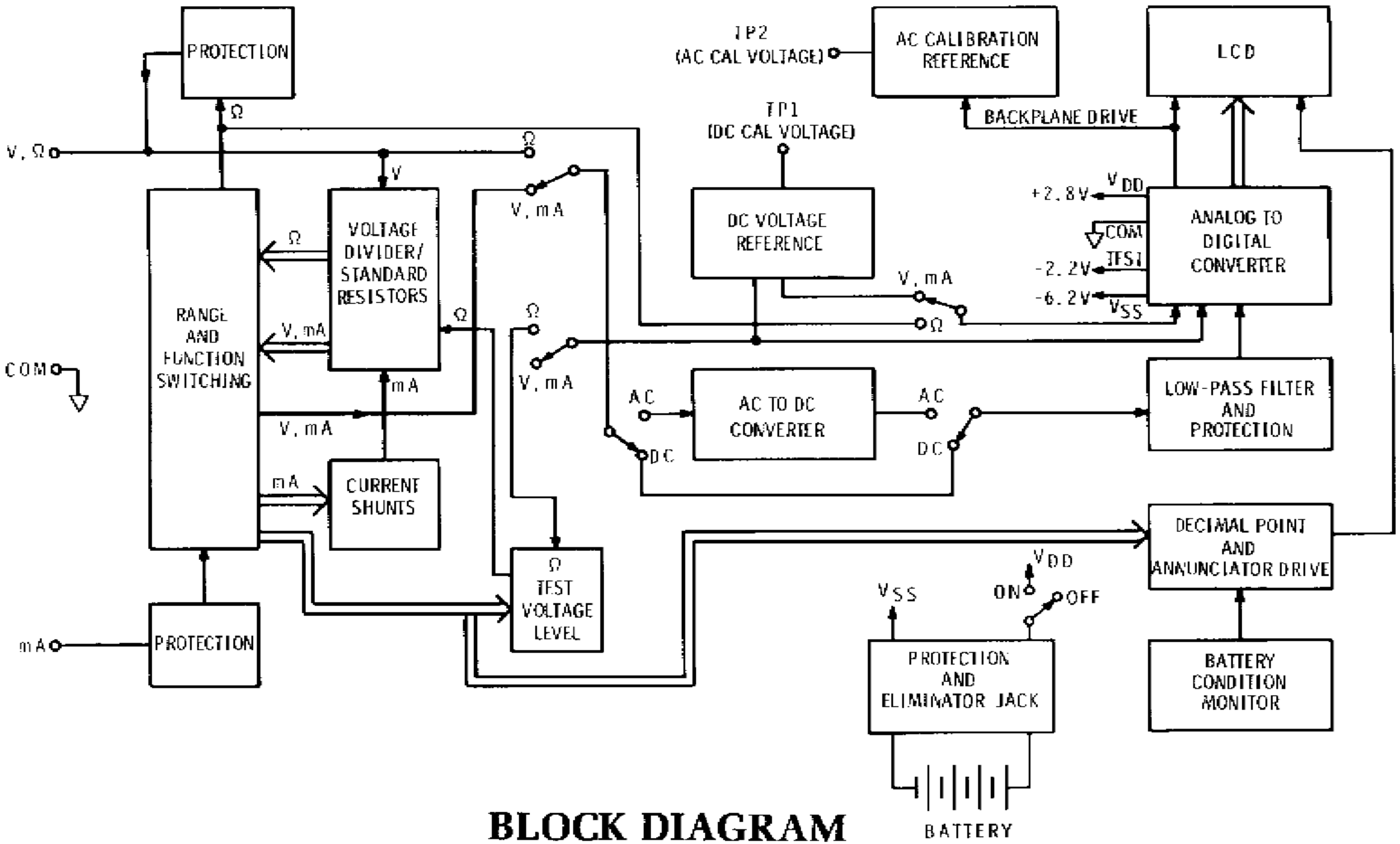
FUNCTION SWITCHES

Selects proper circuits to measure AC or DC current, or resistance.

VOLTAGE/RESISTANCE INPUT

Connect red test lead here when measuring voltage or resistance.

PICTORIAL 6-1



BLOCK DIAGRAM

CALIBRATION

NOTES:

1. New Multimeters may exhibit a small amount of calibration drift due to component "aging". Therefore, we suggest that you re-calibrate your Multimeter after an initial period of use; six months, for example. You may also wish to recalibrate your Multimeter regularly at six to twelve months intervals, or as required, to insure optimum accuracy during use.

2. If you do not obtain the correct indication in any of the following steps, refer to the "In Case of Difficulty" section. Locate and repair any problem before you continue with the calibration.

( ) Make sure the converter/charger is disconnected from your Multimeter.

The following characteristics of the display, which occur during calibration, are normal:

1. Overrange is indicated by a "1" in the left-end digit with the remaining digits blanked.

2. When you select an AC voltage range, the display reading may take several seconds to settle.

NOTE: Two methods of calibration are provided in this section of the Manual. The first method ("Built-in Standards Method") uses the internal, supplied references. The second method (on Page 48) uses laboratory-grade standard references.

To perform the calibration with laboratory-grade standard references, you will need the following equipment:

1. A DC voltage standard that provides plus and minus 190 mV DC with an accuracy greater than ± .05%.

2. An AC voltage standard that provides 190 mV AC rms with an accuracy within ±.1%. The output must be a low distortion 100 Hz sine-wave.

Choose one of the calibration methods and perform the steps for that method only.

Built-In Standards Method

DC CALIBRATION

Refer to Pictorial 4-1 (Illustration Booklet, Page 15) for the following steps.

( ) Locate the DC calibration label; it will be used in the following steps.

( ) Plug the red test lead into the V/Ω jack.

( ) Select the 2VDC range by depressing SW6 only.

( ) Slide the OFF-ON switch to ON.

( ) Touch the red test probe tip to TP1 on the component side of the main circuit board and adjust the DC CAL control (R13) so the meter displays the number on the DC calibration label. NOTE: An occasional variation of ±1 digit is acceptable.

( ) Remove the probe tip from TP1.

AC CALIBRATION

Refer to Pictorial 4-1 (Illustration Booklet, Page 15) for the following steps.

( ) Set the AC REF ADJ control fully counterclockwise, as viewed from the front of the control.

( ) Select the 200 mV DC range by selecting SW7 only.

( ) Touch the red test probe tip to TP2 and adjust the AC REF ADJ control (R16) for a reading of 171.2. NOTE: An occasional flash of ± 2 digits is acceptable.

( ) Select the 200 mV AC range by depressing SW1 and SW7 only.

NOTE: Allow sufficient time for the display to stabilize before you proceed to the next step.

( ) Touch the red test probe tip to TP2 and adjust the AC CAL control (R34) for a reading of 190.0 NOTE: An occasional variation of ±2 digits is acceptable.

( ) Remove the probe tip from TP2.

This completes the "Calibration" of your Multimeter. However, after it has been in use for some time – six months for example – you may wish to touch up the calibration to remove any small "aging" drift.

Laboratory Standards Method

Make sure that your calibration standards are at least 5 times more accurate than the Laboratory Standards Accuracy Specification on Pages 70 and 71. For example, to obtain an accuracy of ±.25%, the Laboratory Standard must be accurate to within ±.05%.

DC CALIBRATION

Refer to Pictorial 4-1 (Illustration Booklet, Page 15) for the following steps.

( ) Select the 200 mV DC range by depressing SW7 only.

( ) Slide the OFF-ON switch to ON.

( ) Connect the black test lead to the COM jack and the red test lead to the V/Ω jack.

( ) Connect the Multimeter test leads to a +190.0 mV source.

( ) Adjust the DC CAL control (R13) for display reading of 190.0 NOTE: An occasional variation of ±1 digit is acceptable.

( ) Disconnect the test leads from the +190.0 mV source.

AC CALIBRATION

Refer to Pictorial 4-1 for the following steps.

( ) Select the 200 mV AC range by depressing SW1 and SW7 only. Allow the Multimeter display time to stabilize.

( ) Connect the Multimeter test leads to a 190.0 mV, 100 Hz source.

( ) Adjust the AC CAL control (R34) for a display reading of 190.0. NOTE: An occasional variation of ±1 digit is acceptable.

( ) Disconnect the test leads.

This completes the "Calibration" of your Multimeter. However, after it has been in use for some time — six months for example — you may wish to touch up the calibration to remove any small "aging" drift.

Proceed to "Final Assembly."

OPERATION

This portion of the Manual is divided into three parts. The first part, "General," provides information concerning various precautions you must observe when using the Multimeter. The second part, "Operating Characteristics," includes operating information that applies to the various functions of the Multimeter. The third part, "Measurements," provides specific operating instructions for each function of the Multimeter, along with guidelines and techniques for providing optimum measurement accuracy.

NOTE: Be sure you read all of the "General" and "Operating Characteristics" sections before you use the Multimeter.

General

Refer to Pictorial 6-1 (Illustration Booklet, Page 18) for a brief description of each switch and input jack.

The front of the Multimeter has two standard operator warnings. These are:

This symbol advises the operator to familiarize himself with the operation section of this Manual.

This symbol warns the operator that there may be dangerously high voltage at this location, or that there is a voltage limitation to be considered when using this terminal.

Specific limitations of the Multimeter are included in the VDC, VAC, mA DC, and mA AC portions of the "Measurement" section concerning these symbols.

SAFETY PRECAUTIONS

You may often use your Multimeter to check, maintain, and repair electronic equipment that contains DANGEROUSLY HIGH VOLTAGES. Because of this danger, always observe the safety procedures listed below.

1. Always handle the test probe by the insulated portion only. Be careful not to touch the exposed tip.

2. When you measure high voltages, turn off the power to the equipment to be tested before you connect the test leads. If this is not possible, be very careful to avoid accidental contact with any object that could provide a ground return (circuit completion) path.

3. If at all possible, use only one hand when you make tests on equipment that is turned on. Keep one hand in your pocket or behind your back to help avoid accidental shock.

4. If possible, insulate yourself from ground while you make measurements. Stand on a properly insulated floor or floor covering.

LIQUID CRYSTAL DISPLAY

The liquid crystal display (LCD) is a rugged and reliable device which should provide years of service. You can extend the display lifetime by observing the following practices:

A. Protect the display from extended exposure to bright sunlight.

B. Do **NOT** store your Multimeter in extremely hot, humid, or cold environments. Refer to the "Storage Temperature" specification on Page 74 of this Manual.

C. Do **NOT** apply excessive pressure or stresses to the LCD.

POWER SOURCES

You may use either of two power sources for the Multimeter. We recommend an **alkaline** power cell, NEDA type # 1604 for battery power. You may purchase the optional 9-volt Heathkit Converter/Charger, Model PS-2350 for 120 VAC operation or Model PS-2450 for 220 VAC operation, if you wish to power the Multimeter without a battery or if you intend to use both.

When you have access to a conventional AC power source, and if you have the proper Converter/Charger, merely push the subminiature phone plug into PCB jack J4 and connect the line cord plug to an AC outlet. NOTE: In this Multimeter, the Converter/Charger is used as a **Battery Eliminator**; it will **not** charge your battery, which is disconnected from the Multimeter circuitry when the Converter/Charger is connected to J4.

BATTERY LIFE

Your Multimeter is designed to operate on an inexpensive 9-volt battery (NEDA 1604). If you use an alkaline battery, you can expect a typical operating life of up to 200 hours. A zinc-carbon battery will provide 100-150 hours of operation.

CAUTION: You should replace the battery annually or when it is discharged to protect your Multimeter from battery leakage or rupture. Several battery manufacturers will repair any device damaged by their batteries — it is advisable to use a battery with such a guarantee. It is further advisable to remove the battery during extended storage.

Operating Characteristics

The LCD provides a continuous indication of your Multimeter's operating status: overload, low battery, and normal operation.

INPUT OVERLOAD PROTECTION

All functions are protected against input overloads, either by resistor-diode networks, or through fuse action as long as the overload is within the specified limits. (See Page 70).

OVERLOAD/OVERRANGE INDICATION

An overload/overrange condition is indicated when all display digits, except the most significant digit ("1"), are blanked. This does not necessarily mean that the Multimeter is being exposed to a damaging input condition. For example, when you measure resistance, an open-input condition will cause an overload/overrange condition.

NOTE: The minus sign (−) may flash momentarily as your Multimeter recovers from an overload/overrange condition. You will most likely see this in the ohms mode when the open circuit test leads are connected across an in-range resistor. If the minus sign remains on for in-range ohms readings, a voltage is present at the input terminals due to charged capacitors, etc. For this reason, you will observe incorrect resistance readings.

LOW BATTERY INDICATION

When approximately 80% of the useful battery life has been exhausted, a "LO BAT" indication will appear in the upper left-hand corner of the display. When the low battery indication first appears, at least 20 hours of operating time will remain before the accuracy of your Mulitmeter will be affected (if an alkaline battery is being used).

OPEN INPUT DISPLAY

A significant voltage may be displayed on the lowest VDC or VAC ranges if the test leads are not connected to a measurement point (or to each other). This is normal and will not produce a measurement error when the leads are connected to a low impedance (less than 1 MΩ for VDC, or 100 kΩ for VAC) measurement point.

± 1 COUNT

It is normal for the right-hand digit of the display to alternate one digit above and below a reading on successive conversions.

USE WITH ACCESSORY PROBES

High Voltage Probe

You can use this Multimeter with a high voltage probe on VDC only. The probe must be designed for a meter that has a 10 MΩ input impedance. (A high voltage probe of this type is available from the Heath Company.) The probe should be connected between the V/Ω and COM sockets. The Multimeter should be set for a range governed by the voltage division ratio of the probe. If, for example, you are using a 100:1 probe and you expect the voltage to measure approximately 14,000 VDC, the Multimeter should be set to its 200 VDC range. The display reading must now be multiplied by 100. If you do not know the voltage to be expected, start with the 1000 VDC range.

CAUTION: Do not exceed the voltage rating of the probe.

RF Probe

You can also use an RF probe with this Multimeter. It should be connected between V/Ω and COM sockets. Consult the manufacturer's suggestion for which VDC range provides the best accuracy; then set the Multimeter to that range.

CAUTION: Do not exceed the voltage rating of the probe.

FUSE REPLACEMENT

The Multimeter is protected in the mA DC and mA AC modes by the mA fuse which is installed in the fuseholder. Replace it only with a 2A, 250 V, 8AG regular blow fuse. Use of a higher current-rated fuse may cause Multimeter damage.

Measurements

This section deals first with general, then with specific measurement techniques. In addition, it contains some application information to help you obtain valid measurements in harsh environments.

Included are:

- Interpreting the Display
- Connecting the Multimeter
- VDC Measurements
- VAC Measurements
- mA DC Measurements
- mA AC Measurements
- Ω Measurements

INTERPRETING THE DISPLAY

On all ranges of all functions, the measurement display is direct-reading. Correct positioning of the decimal point is automatic.

For voltage measurements, the display reading is in millivolts or volts. On VDC negative polarity is indicated when the "−" sign is displayed. Positive polarity is indicated when the "−" sign is absent ("+" sign is implied). On VAC, no sign is displayed, except during recovery from extreme overloads.

For current measurements, the display reading is in mA. On mA DC negative polarity is indicated when the "−" is displayed. Positive polarity is indicated when the "−" sign is absent ("+" sign is implied). On mA AC, no sign is displayed, except during recovery from extreme overloads.

For resistance readings, the display reading is in Ω, kΩ, or MΩ. No polarity sign is displayed for these measurements, except possibly when the Multimeter is connected to an energized circuit.

CONNECTING THE MULTIMETER

Before you make any measurements with the Multimeter, be sure (if possible) that the measurement will not exceed the limits indicated in the voltage, current, or resistance sections which follow.

Never use uninsulated, cracked, or frayed test leads. Replace or repair any questionable test leads.

All inputs to the Multimeter are made at the three front panel banana jacks identified as V/Ω, mA, and COM. These will accommodate separate banana plugs or a "dual" banana plug (3/4" centers). You may use the test leads supplied with the Multimeter, or you may make up your own test leads. For low-level VDC or VAC measurements, you may find that using "twisted pair" test leads or coaxial, shielded, cable provides more stable, accurate, measurements. For high current or low resistance measurements, use good quality, stranded, copper wire.

VDC MEASUREMENTS

WARNING: For any VDC measurement, do not connect the COM socket (black test lead) to a voltage that exceeds 500 volts (DC plus peak AC) or 350 volts rms above earth (power line) ground. This can present a safety hazard, or damage the Multimeter when used with the battery eliminator.

CAUTION: 1000 volts (DC plus peak AC) is the maximum voltage allowable between the V/Ω and COM sockets.

1. Select the operating power for the Multimeter (line or battery). Connect the connector/charger to an AC outlet and the converter/charger's plug to the Multimeter if you selected line operation.

2. Release pushbuttons SW1 and SW8.

3. Depress the pushbutton (SW3 through SW7) that selects the desired range. If you are not sure, select the highest range.

4. Connect the test leads to the Multimeter V/Ω and COM sockets.

5. Connect the black test lead to circuit ground or the "−" point.

6. Touch the red test lead probe tip to the measurement point and observe the display.

7. Select a higher range if an overload is indicated. For readings less than 200 counts, you may select a lower range for increased resolution.

The following table indicates the display limits for each VDC range:

VDC Range	Minimum Display	Maximum Display
± 200 mV	00.0	199.9
± 2	.000	1.999
± 20	0.00	19.99
± 200	00.0	199.9
± 1000	000	1000

NOTE: Inputs of up to ± 1000 VDC to any range, including the 200 mV DC range, will not damage the Multimeter.

Additional considerations:

A. To determine measurement accuracy, keep in mind that the accuracy specification for VDC is ± (.25% of reading + 1 digit). For example, a display reading of 1.000 VDC from a low impedance source will have an uncertainty of ± .0035 VDC.

B. The input resistance of the Multimeter on all VDC ranges is 10 MΩ. Measurements at relatively high source resistances could cause a significant reading error. The amount of error due to Multimeter loading can be determined by the following:

$$\%\ \text{Error} = -\left(\frac{R_s}{R_s + 10\ \text{M}\Omega}\right) \times 100$$

For example, a source resistance (Rs) of 10 kΩ will result in a loading error of −0.1%. The error will always have a "−" sign, since the loading will always reduce the voltage under "load" from its "unloaded" value.

NOTE: Loading error will become very significant for source resistances above 100 kΩ.

C. When the Multimeter inputs are open-circuited on the 200 mV DC range, several counts will be displayed due to bias currents in the measuring circuitry. This is normal and will not produce a measurement error when the leads are connected to a low resistance (less than 1 MΩ) source.

VAC MEASUREMENTS

WARNING: For any VAC measurement, do not connect the COM socket (black test lead) to a voltage that exceeds 500 volts (DC plus peak AC) or 350 volts rms above earth (power line) ground. This can present a safety hazard or damage the Multimeter when used with the battery eliminator.

CAUTION: 750 volts AC rms (1000 volts peak AC plus DC) is the maximum voltage allowable between the V/Ω and COM sockets.

NOTES:

A. When you measure AC voltage, any input other than a pure sine wave will cause an error because the AC converter is average-sensing and rms (sine wave) calibrated. Square waves, sawtooth waves, etc. can be measured best with an oscilloscope.

B. After you have first selected the VAC function, allow the Multimeter several seconds to stabilize before you make any measurements. This also applies after a severe overload has occurred.

C. On VAC ranges, the input signal is AC coupled (capacitive) to the measurement circuitry so that DC is blocked.

D. The Multimeter will display the measured voltage within rated accuracy within a few seconds, but it may take a few additional seconds to obtain a stable (±1 count) display.

1. Select the operating power for the Multimeter (line or battery). If you selected line operation, connect the converter/charger to an AC outlet and the converter/charger's plug to the Multimeter.
2. Depress pushbutton SW1.
3. Release pushbutton SW8.
4. Depress the pushbutton (SW3 through SW7) that selects the desired range.
5. Connect test leads to the Multimeter V/Ω and COM sockets.
6. Connect the black test lead to circuit ground or low point.
7. Touch the red test lead probe tip to the measurement point and observe the display.
8. Select a higher range if an overload is indicated. For readings less than 200 counts, you may select a lower range for increased resolution.

The following table indicates the display limits for each VAC range.

VAC Range	Minimum Display	Maximum Display
200 mV	00.0	199.9
2	.000	1.999
20	0.00	19.99
200	00.0	199.9
750	000	750

NOTE: Applying 750 VAC or less to any range, except the 200 mV AC range, will not damage the Multimeter. An overload that does not exceed 300 VAC (rms) can be applied to the 200 mV AC range indefinitely, and for a maximum of 15 seconds when over 300 VAC.

A. To determine measurement accuracy, keep in mind that the combined accuracy specification for VAC is ± (1.5% of reading + 3 digits) over the frequency range applicable to the VAC range being used. For example, a display reading of 1.000 VAC from a low impedance source will have an uncertainty of ± .018 VAC over the frequency range of 40 Hz to 1000 Hz.

B. The input impedance of the Multimeter on all VAC ranges is frequency dependent, and can be represented as 10 MΩ in parallel with approximately 100 pF. This corresponds to approximately 9.36 MΩ at 60 Hz. Measurements at relatively high source resistances could cause a significant reading error. The Multimeter input impedance at other frequencies may be determined by the following expression:

$$Z_{in} = \frac{10\ M\Omega}{\sqrt{1 + (6.28 \times f)^2}}$$

where Z_{in} = effective Multimeter input impedance, and

f = frequency in kHz.

Source loading error can be determined as follows:

$$\%\ \text{Error} = -\left(\frac{Z_{source}}{Z_{source} + Z_{in}}\right) \times 100$$

Loading error at low frequencies (<100 Hz) can be very significant for source impedance (resistances) above 100 kΩ; and at higher frequencies (in the order of 1 kHz) for source impedance even as low as 20 kΩ. The error will always have a " − " sign, since the loading will always reduce the voltage under load from its unloaded value.

C. When the Multimeter inputs are open-circuited on the 200 mV AC or 2 VAC ranges, there will be a significant amount of counts displayed, due to stray line voltage radiation. This is normal and will not produce a measurement error when the leads are connected to a low impedance source.

mA DC MEASUREMENTS

WARNINGS:

A. For any mA DC measurement, do not connect the COM socket (black test lead) to a voltage exceeding 500 volts (DC plus peak AC) or 350 volts rms above earth (power line) ground. This can present a safety hazard or damage the Multimeter when used with a battery eliminator.

B. Operator injury or instrument damage may result if the fuse opens while measuring current in a circuit with an open-circuit voltage greater than 250 V.

CAUTION: The Multimeter is fuse-protected for a 2-ampere maximum DC current on the mA DC ranges. If this is exceeded, the fuse will open, the display will read zero, and the circuit under test will be opened. (See "Fuse Replacement" on Page 53).

1. Select the operating power for the Multimeter (line or battery). If you selected line operation, connect the converter/charger to an AC outlet and the converter/charger plug to the Multimeter.

2. Release pushbuttons SW1 and SW8.

3. Depress the pushbutton (SW3 through SW6) that selects the desired range. If you are not sure, select the highest range.

4. Connect test leads to the Multimeter mA and COM sockets.

5. Connect the test leads into the circuit under test, and observe the display.

6. Select a higher range if an overload is indicated. For readings less than 200 counts, you may select a lower range for increased resolution.

The following table indicates the display limits for each mA DC range:

mA DC Range	Minimum Display	Maximum Display
± 2	.000	1.999
± 20	0.00	19.99
± 200	00.0	199.9
± 2000	000	1999

NOTE: Inputs of up to ± 2000 mA DC to any range, will not damage the Multimeter.

Additional Considerations:

A. To determine measurement accuracy, keep in mind that the accuracy specification for mA DC is ± (.75% of reading + 1 digit). For example, a display reading of 1.000 mA DC will have an uncertainty of ±.0085 mA DC.

B. When you measure current, your Multimeter will, to some degree, affect the operation of the circuit you are testing. This effect, known as "insertion loss," causes a voltage drop. This will reduce the actual circuit current to the current displayed on the Multimeter. This error should be considered if the source resistance of the circuit under test is not at least 1000 times the shunt resistor for the range being used. For example, on the 2 mA DC range, the shunt resistor is 100 Ω; therefore, a source resistance of 10 kΩ would result in an insertion loss error of approximately 1% of the reading. You can determine insertion loss error for other source resistances with the following formula:

$$\%\ \text{Error} = -\left(\frac{R_{shunt} + .25\ \Omega^{*}}{R_{source} + R_{shunt} + .25\ \Omega^{*}}\right) \times 100$$

Where R_{shunt}	=	100 Ω	on the 2 mA DC range
		10 Ω	on the 20 mA DC range
		1 Ω	on the 200 mA DC range
		.1 Ω	on the 2000 mA DC range

* .25 Ω is the maximum fuse and wiring resistance of the Multimeter.

The error will always have a " − " sign, since the "inserted" current will always be less than the "not inserted" current. To reduce this effect, use the highest range possible consistent with the measurement resolution required.

C. When you attempt to measure DC current with a substantial AC or pulse component superimposed on it, no significant error will result if the peak-to-peak variation in current does not exceed three times the full-scale DC current of the range being used (2.0 amperes peak AC plus DC on 2000 mA DC range). A higher range, will minimize this error.

mA AC MEASUREMENTS

WARNINGS:

A. For any mA AC measurement, do not connect the COM socket (black test lead) to a voltage exceeding 500 volts (DC plus peak AC) or 350 volts rms above earth (power line) ground. This can present a safety hazard or damage the Multimeter when used with a battery eliminator.

B. Operator injury or instrument damage may result if the fuse opens while measuring current in a circuit with an open-circuit voltage greater than 250 V.

CAUTION: The Multimeter is fuse-protected for a 2-ampere maximum AC current on the mA AC ranges. If this is exceeded, a fuse will open, the display will read zero, and the circuit under test will be opened. (See "Fuse Replacement" on Page 53).

NOTES:

A. When you measure AC current, any input other than a pure sine wave, will cause an error because the AC converter is average-sensing and rms (sine wave) calibrated. Square waves, sawtooth waves, etc. can be measured best with an oscilloscope.

B. After you have first selected the VAC function, allow the Multimeter several seconds to stabilize before you make any measurements. This also applies after a severe overload has occurred.

C. On mA AC ranges, the input signal is AC coupled (capacitively) to the measurement circuitry so that DC is blocked.

D. The Multimeter will display the measured current within rated accuracy, within a few seconds, but it may take a few additional seconds to obtain a stable (± 1 count) display.

1. Select the operating power for the Multimeter (line or battery). If you selected line operation, connect the converter/charger to an AC outlet and the converter/charger's plug to the Multimeter.

2. Depress pushbutton SW1.

3. Release pushbutton SW8.

4. Depress the pushbutton (SW3 through SW8) that selects the desired range.

5. Connect the test leads to the Multimeter mA and COM sockets.

6. Connect the test leads into the circuit under test and observe the display.

7. Select a higher range if an overload is indicated. For readings less than 200 counts, you may select a lower range for increased resolution.

The following table indicates the display limits for each mA AC range:

mA AC Range	Minimum Display	Maximum Display
2	.000	1.999
20	0.00	19.99
200	00.0	199.9
2000	000	1999

NOTE: Inputs of up to 2000 mA AC to any range will not damage the Multimeter.

Additional Considerations.

A. To determine measurement accuracy, you should keep in mind that the accuracy specification for mA AC is ± (1.5% of reading + 3 digits) from 40 to 1000 Hz on the 20, 200, and 2000 mA ranges and ± (1.5% of reading + 3 digits) from 40 to 200 Hz on the 2 mA range. Then, as an example, a display reading of 1.000 mA AC will have an uncertainty of ± .018 mA AC.

B. When you measure current, your Multimeter will, to some degree, affect the operation of the current you are testing. This effect, known as "insertion loss," causes a voltage drop. This will reduce the actual circuit current to the current displayed on the Multimeter. This error should be considered if the source resistance of the circuit under test is not at least 1000 times the shunt resistor for the range being used. For example, on the 2 mA AC range, the shunt resistor is 100 Ω; therefore, a source resistance of 10 kΩ would result in an insertion loss error of approximately 1% of the reading. You can determine the insertion loss error for other source resistances with the following formula:

$$\%\ \text{Error} = -\left(\frac{R_{shunt} + .25\ \Omega^*}{R_{source} \times R_{shunt} \times .25\ \Omega^*}\right) \times 100$$

Where R_{shunt}	=	100 Ω	on the 2 mA AC range
		10 Ω	on the 20 mA AC range
		1 Ω	on the 200 mA AC range
		.1 Ω	on the 2000 mA AC range

* .25 Ω is the maximum fuse and wiring resistance of the Multimeter.

The error will always have a " – " sign since the "inserted" current will always be less than the "not inserted" current. To reduce this effect, use the highest range possible consistent with the measurement resolution required.

Ω MEASUREMENTS

CAUTION: Before you make in-circuit resistance measurements, make sure you disconnect power to the circuit. Also discharge all capacitors.

NOTES:

A. The resistance of the test leads may affect the accuracy on the 200 Ω range of your Multimeter. To determine this error, first short the test leads together and read the lead resistance. Then subtract the lead resistance (typically .1 to .3 Ω) from the reading for the unknown resistor.

B. When you make resistance measurements on the two highest ranges, the test leads may pick up stray line-noise, which may result in erratic behavior of the last digit in the display. You can minimize this effect by using one or more of the following methods.

1. Twist the test leads together.
2. Place the unknown resistor directly across the input jacks.
3. Operate the Multimeter on the internal battery.
4. Keep your hands away from the test leads.

C. If an overrange condition occurs while you make resistance measurements on the two highest ranges, it may take several seconds before the display shows the correct, measured value.

D. You can make in-circuit resistance measurements by using the 200 Ω, 20 kΩ, and 2000 kΩ ranges, since full-scale measurement voltages on these ranges are not sufficient to forward-bias silicon junctions. Therefore, you can make resistance measurements without having to remove diodes and transistors from the circuit.

E. On the 2 kΩ, 200 kΩ, 20 MΩ ranges, the Multimeter produces a measurement voltage that is sufficient to forward-bias silicon junctions. These ranges are useful when you check and match diodes and transistors.

The following table indicates the approximate voltage and current characteristics for each resistance range.

Range	Full Scale Voltage (typical)	Short Circuit Current (typical)	Open Circuit Test Voltage (typical)
20 MΩ ⊣◀⊢	800 mV	.12 μA	1.2 V
2000 kΩ	200 mV	.35 μA	.35 V
200 kΩ ⊣◀⊢	800 mV	12 μA	1.2 V
20 kΩ	200 mV	35 μA	.35 V
2 kΩ ⊣◀⊢	1 V	.75 mA	2.2 V
200 Ω	75 mV	.40 mA	1.2 V

IN CASE OF DIFFICULTY

NOTE: It is important that you read the entire "General Troubleshooting Information" sections which follow, before you attempt to service your Multimeter.

This section of the Manual is divided into four parts. The first part, titled "General Troubleshooting Information," describes what to do about the difficulties that may occur right after your Multimeter is assembled.

The second section, titled "Troubleshooting Precautions," points out the care that is required when you service the Multimeter to prevent damage to the components.

The third part, titled "Troubleshooting Chart," is provided to assist you in servicing the Multimeter if the "General Troubleshooting Information" fails to clear up the problem, or if difficulties occur after your Multimeter has been in use for some time. The "Troubleshooting Chart" lists a number of possible difficulties that could arise along with several possible solutions to those difficulties. Refer to the "Circuit Board X-Ray Views" on Pages 88 and 89 for the physical location of parts on the circuit boards.

The fourth part, "Circuit Board Cleaning," should be used only as a "last resort" to clean a contaminated main circuit board.

General Troubleshooting Information

CAUTION: Always be sure the foil side of the circuit board is positioned on an insulated surface; otherwise, the Multimeter can be damaged.

1. Recheck the wiring. It is often helpful to have a friend check your work. Someone who is not familiar with the unit may notice an error that was consistently overlooked by the builder.

2. About 90% of the kits that are returned for repair do not function properly due to poor connections and soldering. Therefore, you can eliminate many troubles by checking all connections to make sure that they are soldered correctly. Reheat the connections, if necessary, but be careful so you do not create any solder bridges.

3. Check the values of all the parts. Be sure that the proper part has been installed at each location on the circuit board. Refer to the "Circuit Board X-Ray Views" for the physical location of parts on the circuit board.

4. Check for bits of solder, wire ends, or other foreign matter which may be lodged in the components on the circuit board.

5. Check very carefully to be sure there are no solder bridges between different circuit board foils. If you are not sure a solder bridge exists, compare the circuit board foil with the "Circuit Board X-Ray Views" on Pages 88 and 89 in this Manual. Remove any solder bridges by holding a clean, hot soldering iron tip between the two points that are bridged until the excess solder flows down onto the tip.

If you still cannot locate and correct the trouble after you have completed the checks listed above, and if a voltmeter is available, check the voltages in the Multimeter against the Schematic. A review of the "Circuit Description" and Schematic may also help you to locate any difficulties in the kit.

In an extreme case where you are unable to resolve a difficulty, refer to the "Customer Service" information inside the rear cover of the Manual. Your Warranty is located inside the front cover.

Troubleshooting Precautions

- Integrated circuits U3 and U4 are MOS (metal-oxide semiconductor) devices and they can be damaged by static electricity. Therefore, make sure you remove these IC's in the same manner that you installed them. Refer to Pages 38 and 39 for the correct technique.
- Be sure you do not short any adjacent terminals or foils when you make tests or voltage measurements. If a probe or test lead slips for example, and shorts together two adjacent connections, it is very likely to cause damage to one or more IC's, transistors, or diodes.
- Be especially careful when you test any circuit that contains an IC or a transistor. Although these components have almost unlimited life when used properly, they are much more vulnerable to damage from excessive voltage or current than many other parts.
- In several areas of the circuit board, the foil patterns are quite narrow. When you unsolder a part to check or replace it, avoid excessive heat while you remove the part. A suction-type desoldering tool will make removal considerably easier. You may also use the desoldering braid supplied with this kit to remove the solder.

Troubleshooting Charts

These charts list the condition and possible causes of several malfunctions. If a particular part is mentioned (U4 for example) as a possible cause, check that part to see if it was installed correctly. Also check it and the parts connected to it for poor connections. It is also possible, on rare occasions, for a part to be faulty and require replacement.

PROBLEM	POSSIBLE CAUSE
1. No part of the display lights on any function or range.	A. Dead battery. B. SW9. C. ZD1. D. U4. E. LCD1. F. J4. G. Open wiring to battery.
2. LO BAT is displayed.	A. Low battery voltage. B. Q3. C. R25, R26, or R27. D. U3 or U4.
3. One or more display segments do not light.	A. Interconnection between U4 and LCD1. B. LCD1. C. U4.
4. One or more digits do not light.	A. U4.

PROBLEM	POSSIBLE CAUSE
5. One or more display segments are always lit.	A. U4.
6. Improper decimal point operation.	A. SW2 through SW7. B. U3. C. R18, R19, or R21. D. D7.
7. Negative sign improperly displayed.	A. U4.
8. L or X segments of display are lit (see Schematic).	A. Interconnection between display circuit board and LCD1.
9. Display does not respond to any input changes on the 200 mV DC range.	A. U1 or U4. B. C4, C12, C13, C14, C15, or C16. C. R4, R9, R24, or R35 to R38. D. Open in SW1 to SW8 circuit.
10. Readings are out of tolerance on the 200 mV DC range.	A. DC CAL control (R13) improperly adjusted. B. U1. C. R8, R9, R11, R12. D. Q2.
11. Displayed reading is greater than ±.001 on the 2 VDC range with COM and V/Ω inputs shorted.	A. Main circuit board is contaminated. See "Circuit Board Cleaning" on Page 70. B. U4. C. C16. D. Q4 or Q5.

PROBLEM	POSSIBLE CAUSE
12. Readings are out of tolerance on any (or all) VDC and VAC ranges except the 200 mV range.	A. RN1 or RN2. B. R2 or R3. C. Q4 or Q5.
13. Readings are out of tolerance on the 200 mV AC range for full-scale values only at 60 Hz.	A. U2. B. D5 or D6. C. C9.
14. Readings are out of tolerance on the 200 mV AC range for low values only at 60 Hz.	A. C7 or C8. B. D8 or D9. C. R23.
15. Readings are out of tolerance on the 200 mV AC range for any value at 60 Hz.	A. AC CAL control (R34) improperly adjusted. B. R29, R32, or R33.
16. Readings are out of tolerance on the 200 mV AC range for low frequencies (less than 60 Hz)	A. C5 through C9 or C16. B. R22.
17. Readings are out of tolerance on the 200 mV AC range for high frequencies.	A. U2. B. R4 or R14. C. C11.

PROBLEM	POSSIBLE CAUSE
18. Frequency response is not flat on higher AC voltage ranges.	A. C2 or C3. B. Shield is not grounded.
19. Readings are out of tolerance on the 200 Ω resistance range only.	A. R5.
20. Readings are out of tolerance on the higher resistance ranges.	A. R5. B. RN1.
21. Readings are out of tolerance on the 2000 kΩ and 20 MΩ resistance ranges only.	A. Main circuit board is contaminated. See "Circuit Board Cleaning" on Page 70. B. RN1. C. C1
22. Readings are unstable on all resistance ranges.	A. RT1.
23. Full-scale voltages on all resistance ranges are not as specified.	A. Q1. B. R6 or R7. C. D3 or D4.
24. Displayed reading remains unchanged regardless of current into the mA input.	A. F1 (or wiring). B. D1 or D2. C. Open in SW3, SW4, or SW5 circuit.

PROBLEM	POSSIBLE CAUSE
25. Readings are out of tolerance on the 200 mA or 2000 mA current ranges.	A. RN2.
26. Readings are out of tolerance on all current ranges.	A. R2 or R3. B. RN2.
27. DC CAL control (R13) is turned to either limit.	A. U1. B. R8, R9, R11, R12, or R13.
28. AC CAL control (R34) is turned to either limit.	A. U2. B. D8 or D9. C. R29, R32, R33, or R34. D. C7.
29. AC REF ADJ control (R16) is turned to either limit.	A. U4. B. D10. C. R15, R16, or R17.

Circuit Board Cleaning

Use the following "last resort" procedure to clean a contaminated main circuit board.

1. Remove the bezel, the liquid crystal display, and the LCD holder from the display circuit board.

2. Use demineralized water and a soft brush to clean the entire circuit board and the pushbutton switch assembly. CAUTION: Avoid getting excessive amounts of water in the switches.

3. Bake at 150°F for 5 hours. CAUTION: Allow the circuit board time to cool down before you reassemble the instrument.

SPECIFICATIONS

NOTE: The accuracy of this Multimeter depends on whether you calibrated it using the built-in references or laboratory standards. specifications are listed for both methods of calibration, where applicable, at 25°C.

DC VOLTAGE

Ranges	± 200 mV, ± 2V, ± 20V, ± 200V, ± 1000V.
Accuracy	Laboratory standards: ± (.25% of reading + 1 count). Built-in standards: ± (.35% of reading + 1 count).

Input Impedance	10 MΩ on all ranges.
Overvoltage Protection	1000 VDC, 750 VAC on all ranges.
NMRR* (line and battery operation)	Greater than 40 dB on all ranges. (@ DC, 50 and 60 Hz AC).
CMRR** (line and battery operation)	Greater than 100 dB on all ranges. (@ DC, 50 and 60 Hz AC).

AC VOLTAGE (Average-responding, rms-calibrated)

Ranges	100 mV, 2 V, 20 V, 200 V, 750 V.
Basic Accuracy (50 and 60 Hz)	Laboratory standards: ± (.5% of reading + 3 counts). Built-in standards: ± (.6% of reading + 3 counts).
Frequency Response (@ 25°C ± 10° C referenced to 60 Hz reading).	200 mV, 2V, 20V, 200 V ranges: ±(1% of reading), 40 Hz to 1 kHz. 750 V range: ±(1% of reading), 40 to 400 Hz.

*Normal Mode Rejection Ratio.
**Common Mode Rejection Ratio.

Input Impedance	10 MΩ shunted by approximately 100 pF on all ranges.
Overvoltage Protection	2 V, 20 V, 200 V, 750 V ranges: 1000 VDC, 750 VAC.
	200 mV range: 1000 VDC; 15 seconds maximum over 300 VAC.

DIRECT CURRENT

Ranges	± 2 mA, ± 20 mA, ± 200 mA, ± 2000 mA.
Accuracy	± (.75% of reading + 1 count) on all DC ranges.
Voltage Drop (maximum)	±2 mA, ±20 mA, ±200 mA ranges: .25 VDC at maximum display.
	±2000 mA range: .7 VDC at maximum display.
Overcurrent Protection	2000 mA maximum on all ranges, protected by fuse and clamp diodes in circuits with open circuit voltage less than 250 volts.

ALTERNATING CURRENT (Average-responding, rms-calibrated)

Ranges	2 mA, 20 mA, 200 mA, 2000 mA.
Accuracy	20 mA, 200 mA, 2000 mA ranges: ± (1.5% of reading + 3 counts), 40 Hz to 1 kHz.
	2 mA range: ± (1.5% of reading + 3 counts), 40 to 200 Hz.
Voltage Drop (maximum)	2 mA, 2o mA, 200 mA ranges: .25 VAC at maximum display.
	2000 mA range: .7 VAC at maximum display.
Overcurrent Protection	2000 mA maximum on all ranges, protected by fuse and clamp diodes in circuits with open circuit voltage less than 250 volts.

RESISTANCE

Ranges	200 Ω, 2 kΩ, 20 kΩ, 200 kΩ, 2000 kΩ, 20 MΩ.

Accuracy	200 Ω range: ± (.3% of reading + 3 counts). 2 kΩ, 20 kΩ, 200 kΩ, 2000 kΩ ranges: ± (.25% of reading + 1 count). 20 MΩ range: ± (2% of reading + 1 count).
Voltage @ max. display	200 Ω, 20 kΩ, 2000 kΩ ranges (low test voltage): Less than .25 VDC. 2 kΩ, 200 kΩ, 20 MΩ ranges (high test voltage): Greater than .7 VDC.
Overvoltage Protection	300 volts DC or AC on all ranges.

GENERAL

Operating Temperature Range	0°C to 50°C (32°F to 122°F).
Storage Temperature	−20°C to 60°C (−4°F to 140°F).
Temperature Coefficient	± (.1 × applicable accuracy)/°C.
Power Requirements	9-volt battery (NEDA 1604) or Heath PS-2350 or PS-2450 Converter/Charger.

Battery Life (typical)	Alkaline 200 hours; carbon-zinc 100 to 150 hours.
Battery Indicator	Displays "LO BAT" when approximately 20% of battery life remains.
Polarity Indication	Automatic negative, implied positive on VDC, mA DC.
Overrange Indication	All digits except most significant digit blanked.
Maximum Resolution (low range)	Voltage: 100 μV. Current: 1 μA. Resistance: .1 Ω.
Display Rate	Approximately 2-1/2 per second.
Display	3-1/2 digit (1999 maximum count) liquid crystal.
Dimensions	2" H × 3-1/4" W × 7-1/2" L (5.1 × 8.3 × 19.1 cm)
Weight	14 oz. (400g) with battery.

The Heath Company reserves the right to discontinue products and to change specifications at any time without incurring any obligation to incorporate new features in products previously sold.

CIRCUIT DESCRIPTION

Refer to the Schematic Diagram, the Block Diagram (Illustration Booklet, Page 18), and the following Pictorials as you read this "Circuit Description."

BASIC METER CIRCUIT

The analog-to-digital (A/D) converter, liquid crystal display (LCD), and DC voltage reference make up the basic meter circuit, which provides a digital indication for DC input voltages between − 199.9 millivolt and + 199.9 millivolt. The MOS/LSI integrated circuit (U4) contains all of the active analog, digital, timing, and display drive circuits required for the 3-1/2 digit A/D conversion.

U1 is a temperature-compensated, 1.23 volt DC reference, which is used to establish a reference voltage for the A/D conversion process. U1 also provides a known DC voltage at TP1 for calibration purposes. R8 sets the reverse current through U1 at about 1 mA. Shunt capacitor C4 prevents U1 from oscillating; thus, ensuring reference stability under all operating conditions. R11, R12, and R13 form a resistive voltage divider, which establishes a 100.0 millivolt voltage drop across R11 when R13 is properly adjusted.

The reference voltage across R11 is applied to A/D REF HI and REF LO inputs in the voltaage and current modes of operation. This voltage charges reference capacitor C14 once every conversion cycle (once every .4 second). R24 and C14 provide low-pass filtering of the reference voltage, reducing noise effect. When the Multimeter is operated in the resistance mode, the reference circuit is used as a voltage source for resistance measurements (see "Resistance Measurements").

C15 and R38 are oscillator components which determine the A/D converter's oscillator frequency of approximately 40 kHz. This frequency provides 2-1/2 conversions per second and helps suppress 50 and 60 Hz noise. The entire conversion timing sequence is controlled by this oscillator.

U4 is powered by a 9-volt battery, which is connected across V_{DD} and V_{SS}. An internal regulator on U4 sets V_{DD} (pin 1) at approximately + 2.8 volts with respect to the COM pin (32). The COM pin is used as analog ground. The TEST pin (37) is about −2.2 volts with respect to COM and is used as the digital ground for U4 and the decimal and annunciator drives circuitry.

IN LO (pin 30) and IN HI (pin 31) are the analog signal inputs to the A/D converter. R35 and C16 provide low-pass filtering of the input signal to suppress AC line and noise signals from the input DC signal. Transistors Q4 and Q5 are connected as clamp diodes to protect U4 against excessive positive or negative input voltages. Under overload conditions, R35 limits the current passing through Q4 and Q5, while R36 limits the current to U4.

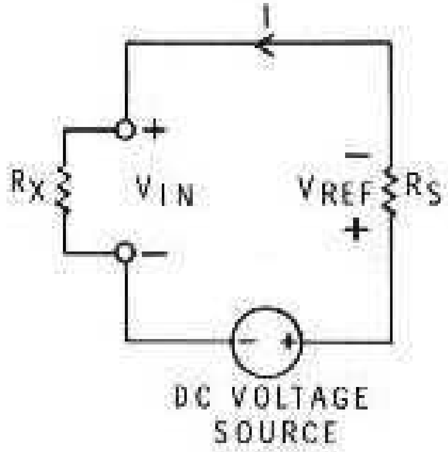
C13 is charged by internally generated voltages to compensate for offset voltages in the analog circuitry of U4. This "automatic zeroing" ensures that the digital display will be zero for a zero voltage input to the A/D converter input.

Integrating resistor R37 and integrating capacitor C12 are used in conjunction with the internal circuitry of U4 to integrate the analog input voltage over a fixed time interval. After integration, the voltage across the reference capacitor is used to return the integrator output to zero. The time required for the output to return to zero is proportional to the analog input signal. Specifically,

$$\text{Display reading} = 1000 \left[\frac{V_{IN\ HI} - V_{IN\ LO}}{V_{REF\ HI} - V_{REF\ LO}} \right]$$

RESISTANCE MEASURING CIRCUIT

Resistance measurements are accomplished with a ratiometric technique which compares the voltage across a standard resistor with the voltage across the resistor being measured. This is possible since the A/D converter produces a display that is proportional to the ratio of the A/D analog input voltage (V_{in}) to the A/D reference input voltage (V_{ref}). Specifically, the digital value displayed is: $1000 \left(\frac{V_{in}}{V_{ref}}\right)$. Therefore, if V_{in} and V_{ref} are equal, 1000 would be displayed.



PICTORIAL 7-1

In Pictorial 7-1, the DC voltage source forces a current to pass through unknown resistor R_x and standard resistor R_S. This current produces a voltage drop across each resistor such that:

$$V_{in} = R_x I \quad \text{and} \quad V_{ref} = R_s I.$$

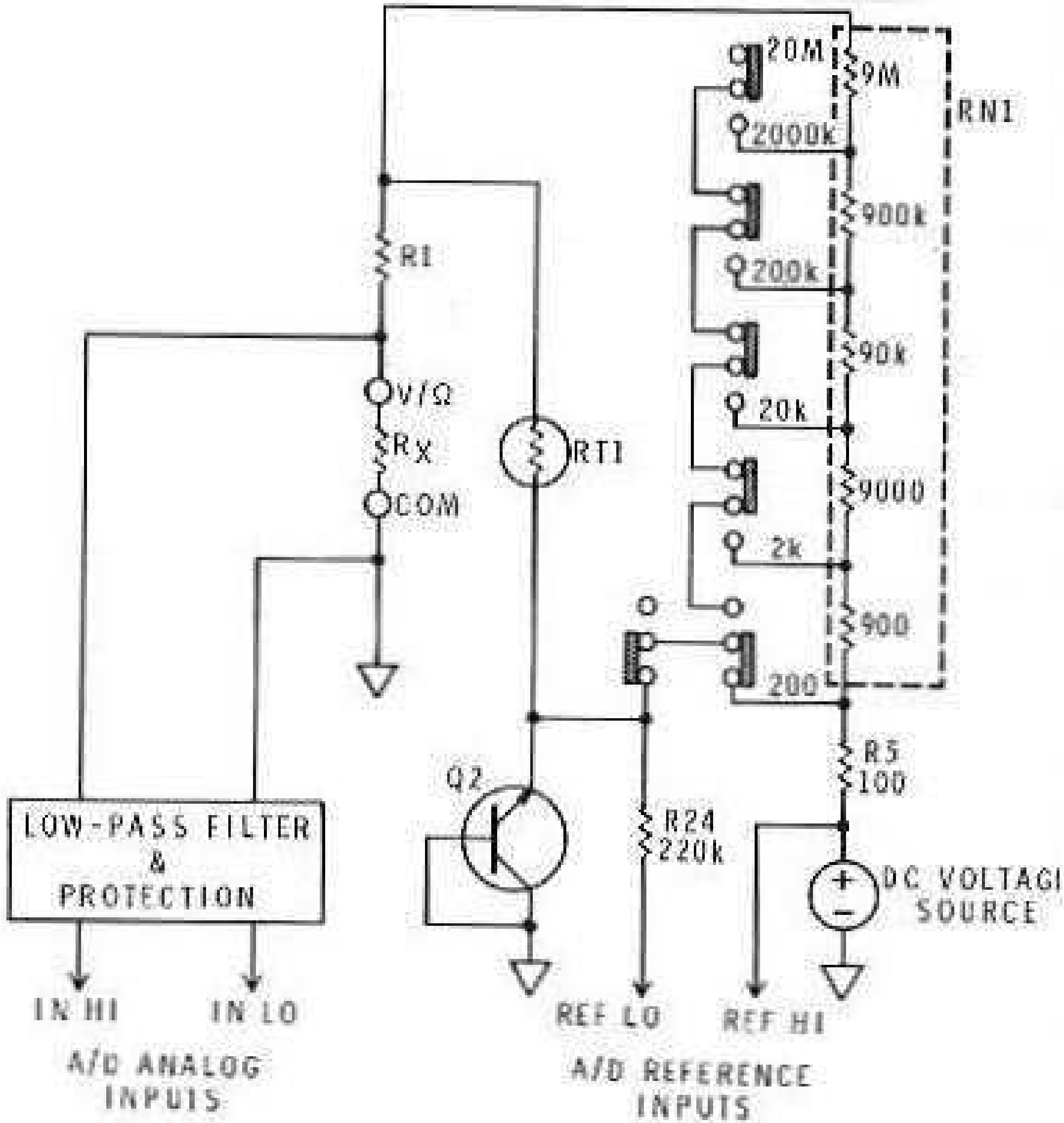
If these equations are substituted for V_{in} and V_{ref} in the previous A/D equation, the displayed value will be:

$$\left(\frac{V_{in}}{V_{ref}}\right) = 1000 \frac{R_x I}{R_s I} = 1000 \frac{R_x}{R_s}$$

Since the value of R_s is chosen to be some power of 10, the displayed value is equal to the unknown resistance times a power of 10 scaling factor.

As shown in Pictorial 7-2, the voltage across unknown resistor R_x is applied to A/D converter inputs IN HI and IN LO through a low-pass filter and protection circuitry. The voltage across standard resistor R_s (RN1 and R5) is applied to A/D converter inputs REF HI and REF LO through a low-pass filter made up of R24 and C14. Transistor Q2 is connected as a zener diode; therefore , its emitter-collector voltage is limited to approximately 9 volts when the "diode" is reverse-biased by a positive overload voltage. When the "diode" is forward -biased by a negative overload voltage, the emitter-collector voltage of Q2 is approximately −.7 volt. In either case, a current path exists through Q2, RT1, R1, and the source of the overload. RT1 acts as a linear resistor until the current through it exceeds 12 mA. Above this value its resistance increases rapidly in a non-linear manner, limiting the current to some value less than 12 mA. This provides protection for the A/D reference inputs as well as for the DC voltage source.

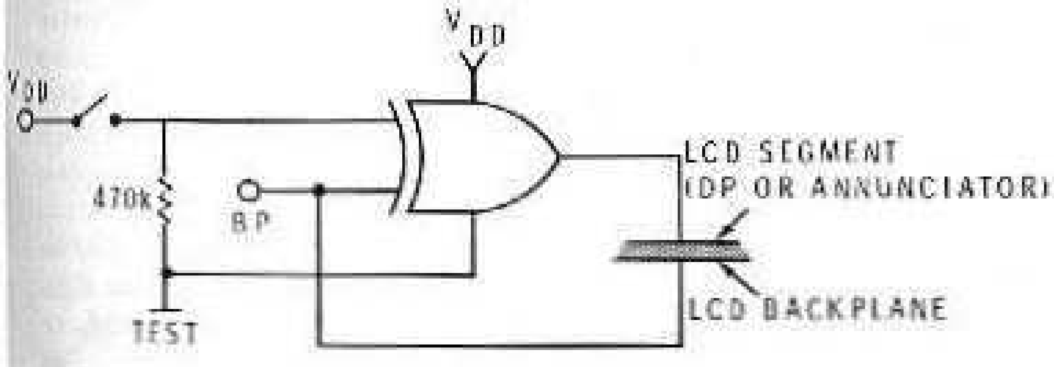
U1 is used as a DC voltage source for ohms measurements. The exact value of the voltage is not important since the same current passes through both the unknown resistor and the standard resistor for any value. It is this current that establishes the ratiometric voltages. Transistor Q1 is driven into saturation on the 20 kΩ and 2000 kΩ ranges, effectively reducing the DC test voltage at the bottom of the standard resistor string (junction of R5 and R6). On the 200 Ω range, considerable voltage drops across R9, RT1, and R1 provide the desired low test voltage condition.



PICTORIAL 7-2

DECIMAL POINT AND ANNUNCIATOR DRIVE

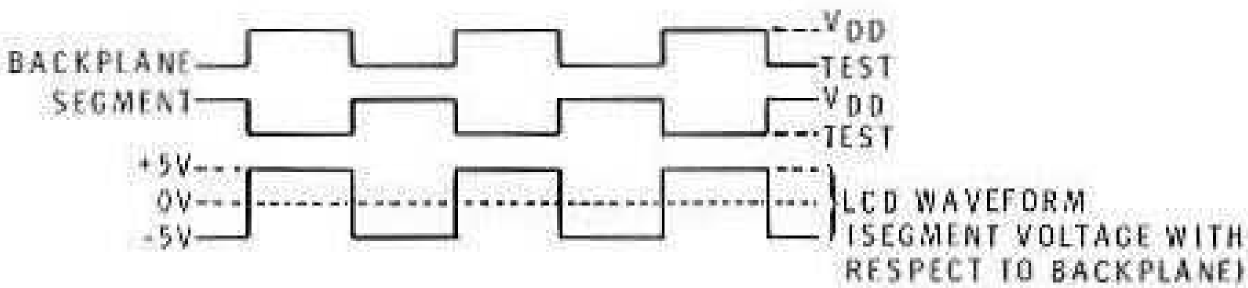
One input of each of the Exclusive OR gates in U3 is connected to the backplane (BP) pin of U4 (see Pictorial 7-3). The other inputs are normally "pulled down" to digital ground by resistors R18, R19, R21, and R26. When these inputs are pulled down, the LO BAT annunciator and the decimal points (DPs) are blanked (off), since the back plane and segment waveforms are in phase and the net voltage from LCD backplane to segment is zero.



PICTORIAL 7-3

When the switch is closed, the gate input is "pulled up" to V_{DD} and the segment waveform is shifted 180° with respect to the backplane waveform. This results in a net LCD drive waveform with a 5 volts rms or 10 volts peak-to-peak value (see Pictorial 7-4).

When the battery voltage (V_{DD} - V_{SS}) is higher than approximately 7.2 volts, Q3 is saturated and pin 2 of U3 is pulled near digital ground, so the LO BAT annunciator is blanked. When the battery voltage drops to about 7.2 volts, pin 2 of U3 is pulled to V_{DD}. This turns the annunciator on, at which time approximately 20% of the battery capacity remains before the accuracy of Multimeter falls off.



PICTORIAL 7-4

VOLTAGE DIVIDER/STANDARD RESISTORS

RN1, R2, R3, and RN2 form a decade resistive divider network for attenuating input voltages. Range switches select the proper tap in the divider network. On the 200 mV range, the input voltage is applied directly to the AC/DC or A/D converter through R4, which provides current limiting for the AC/DC converter. C2 and C3 are voltage divider compensation capacitors, which extend the AC frequency response of the Multimeter. RN1 and R5 are used as standard resistors for resistance measurements.

CURRENT SHUNTS

R2, R3, and RN2 are used as current shunts for DC and AC current measurements. RN2 provides four-terminal measurement on the 200 and 2000 mA ranges; therefore, errors are reduced due to switch and contact resistances. D1 and D2 are voltage clamps which, together with F1, protect the shunts from voltage and current overloads.

AC/DC CONVERTER

Voltages from the divider taps are applied to C5, which blocks any DC or low frequency AC components. D5 and D6 are protection diodes which clamp any excessive input voltage. R14 limits the peak current through D5 and D6. Capacitor C6 blocks any DC voltage present at the junction of D5 and D6, so that the DC operating point of U2 does not shift during an overload condition. R22 references the very high input resistance of U2 to ground. Due to the high value of R22, it has a very small loading effect on the divider resistance with respect to ground.

The U2 circuitry has two separate feedback paths; one for DC and one for AC. The DC feedback signal, through R23, causes the DC output level at pin 6 of U2 (by virtue of its high gain) to track the DC voltage at pin 3. If the output varies from this point, a correction signal to pin 2 counteracts the variation.

When 200 mV AC is applied to pin 3 of U2, the positive and negative half cycles of the sine wave are routed through different circuits at the output of U2. These half cycles are recombined in a manner as described next. For the positive half cycle, the pin 6 output is driven positive by the gain of U2. This output variation, which is coupled through C8, forward biases D9 and a positive current is forced through R32 to R33 and R34. The voltage produced at the junction of R32 and R33 by this current is coupled by C7 back to pin 2 of U2. The positive half cycle of the AC voltage at pin 2 is forced by the high gain of U2 to be equal to the positive half-cycle of the AC voltage at pin 3. During the negative half cycle, the AC output at C8 biases D8 on and, in a similar manner as just described, the negative half-cycle at R33 is coupled back to pin 2 and is the same as the negative half-cycle at pin 3.

During the positive half-cycle, the peak voltage out of D9 to R32 is divided down by the R32 through R34 circuit. However, since the voltage at R33 must be equal to the peak voltage at pin 3, the peak voltage at R32 is higher. R32 has, in fact, approximately a .63 volt peak value when the input at pin 3 (200 mV AC) has a .28 volt peak value. Likewise, the output of D8 has a −.63 volt peak value. During the positive half-cycle, the positive peak voltage from D9 charges C9 through R31. During the negative half-cycle, C9 is discharged somewhat (through R32) by the −.28 volt peak signal at R33. However, the net charge during a complete cycle results in a positive charge on C9.

Adjustment of the gain of this circuit is made at R34 such that, for example, a 190 mV AC signal applied to the Multimeter on the lowest range produces +190 mV DC at the junction of R31 and C9. This is measured by the A/D circuit.

C11 provides a peaking of the high-frequency response of this circuit by increasing the circuit gain for frequencies above 500 Hz.

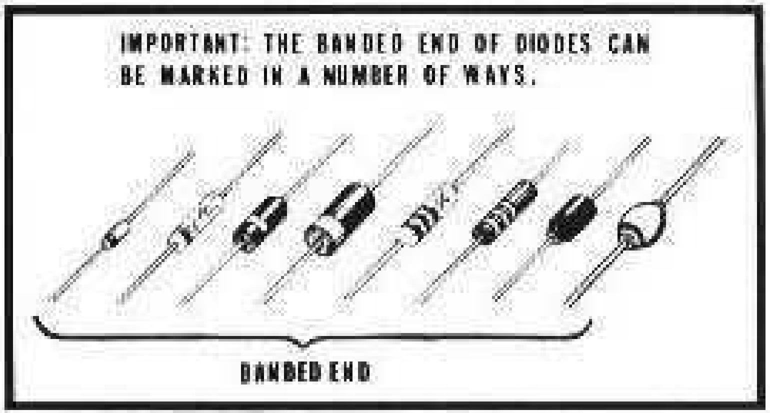
INTERNAL REFERENCES

U1 is extremely stable with respect to temperature, bias current variations, and aging. Its reverse breakdown voltage has been measured accurately and then recorded for use as a "reference" voltage for DC calibration.

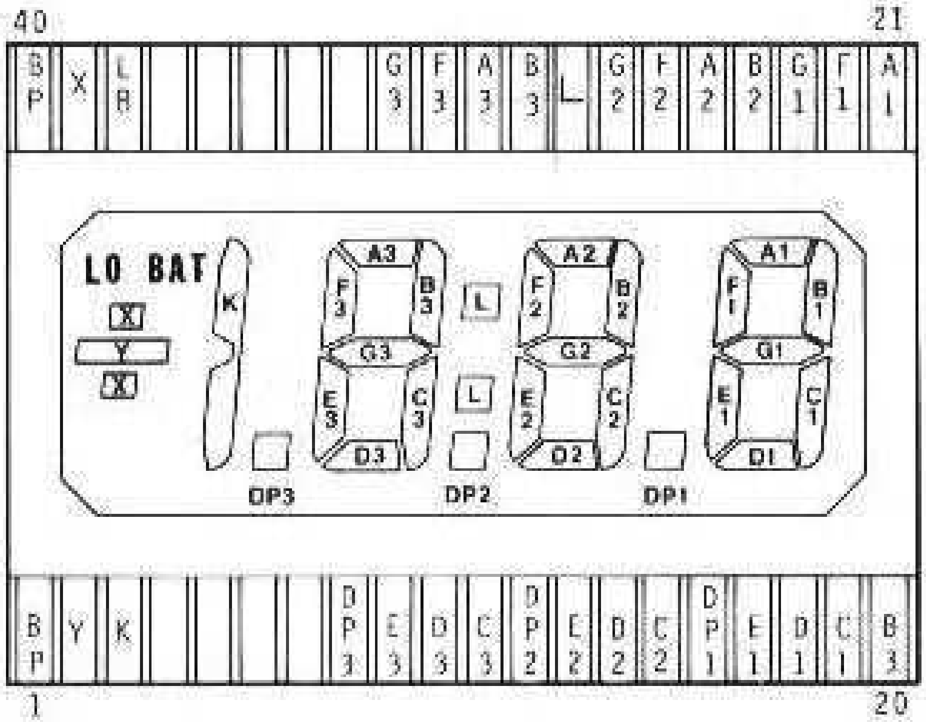
The backplane signal of U4 is a high quality, 50 Hz square wave which can be used for calibrating the AC/DC converter. A known ratio exists between the values displayed for AC and DC mode measurements of the voltage at TP2. D10 rectifies the backplane signal. R15, R16 and R17 form a voltage divider. In the DC mode, R16 is adjusted for a voltage of 171.2 mV at TP2. The AC mode is then selected and R34 is adjusted for a reading of 190.0 mV.

SEMICONDUCTOR IDENTIFICATION CHARTS

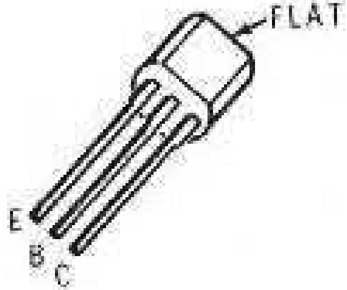
DIODES

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
D3, D4, D7 D8, D9, D10	56-56	1N4149	
ZD1	56-90	1N4742A	
D5, D6	56-652	1N4448	
D1, D2	57-613	selected 1N5624	

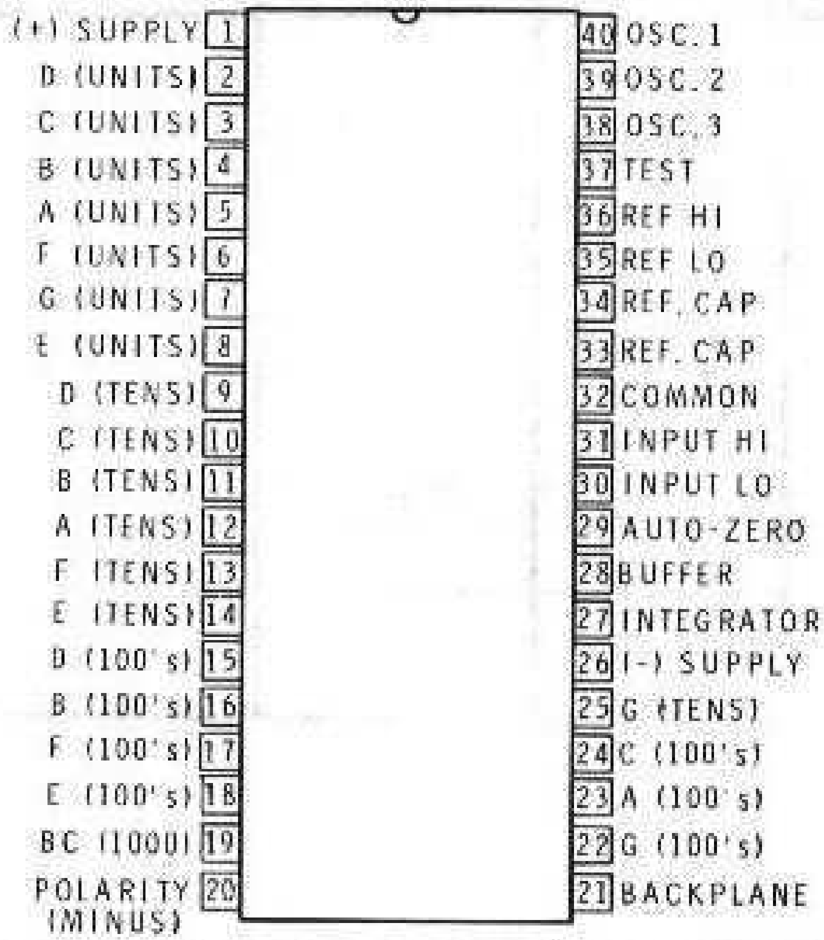
DISPLAY

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
LCD1	411-843	AND FE0203 or BECKMAN 739-02050 or HAMLIN 3933-363-159	

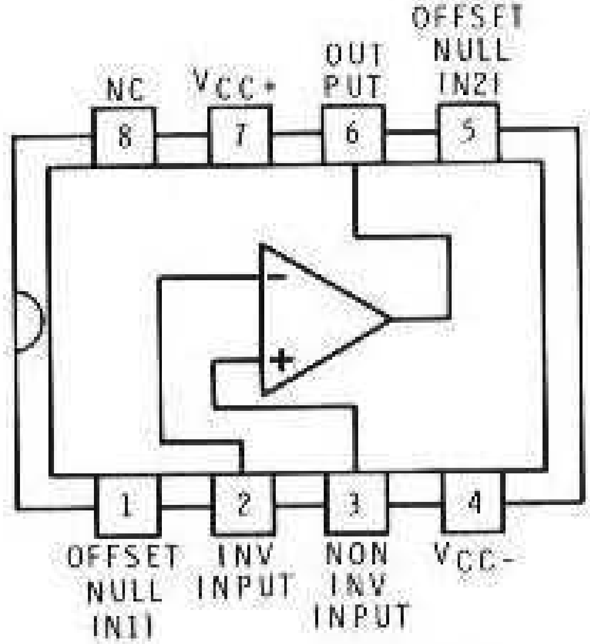
TRANSISTORS

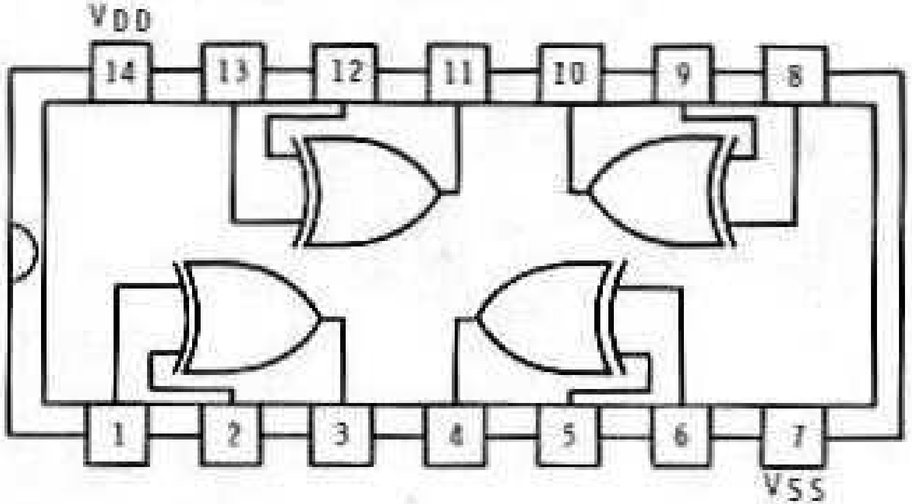
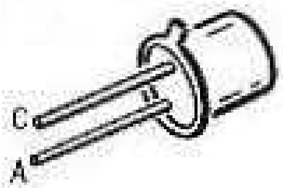
CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
Q2	417-864	MPSA05	
Q1, Q3 Q4, Q5	417-875	2N3904	

INTEGRATED CIRCUITS

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION (TOP VIEW)
U4	442-678	ICL7106CPL	

Integrated Circuits (cont'd.)

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
U2	442-679	TL061CP	

CIRCUIT COMPONENT NUMBER	HEATH PART NUMBER	MAY BE REPLACED WITH	IDENTIFICATION
U3	443-917	CD4030AE	
U1	SELECTED (PART OF 100-1757)		

CIRCUIT BOARD X-RAY VIEWS

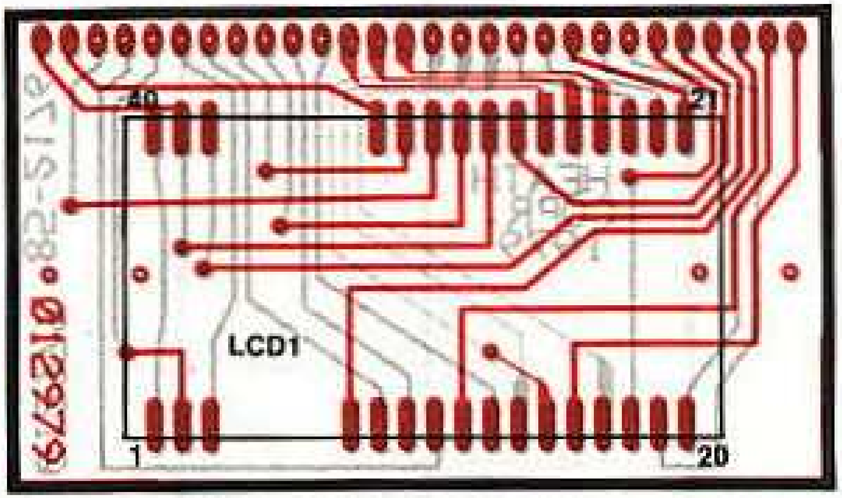
NOTE: To find the PART NUMBER of a component for the purpose of ordering a replacement part:

A. Find the circuit component number (R5, C3, etc.) on the X-Ray View.

B. Locate this same number in the "Circuit Component Number" column of the "Parts List" in the front of this Manual.

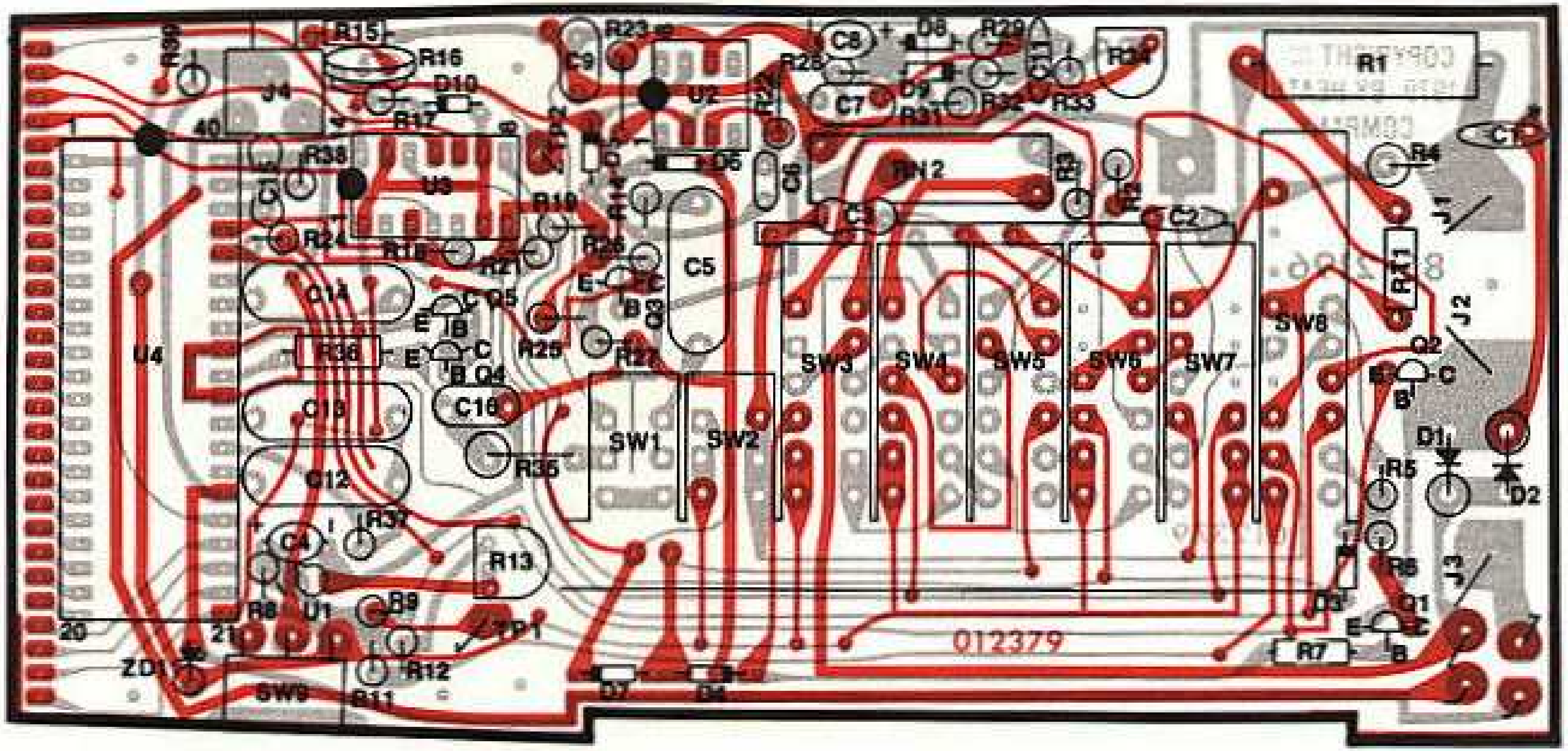
C. Adjacent to the circuit component number, you will find the PART NUMBER and DESCRIPTION which must be supplied when you order a replacement part.

DISPLAY CIRCUIT BOARD



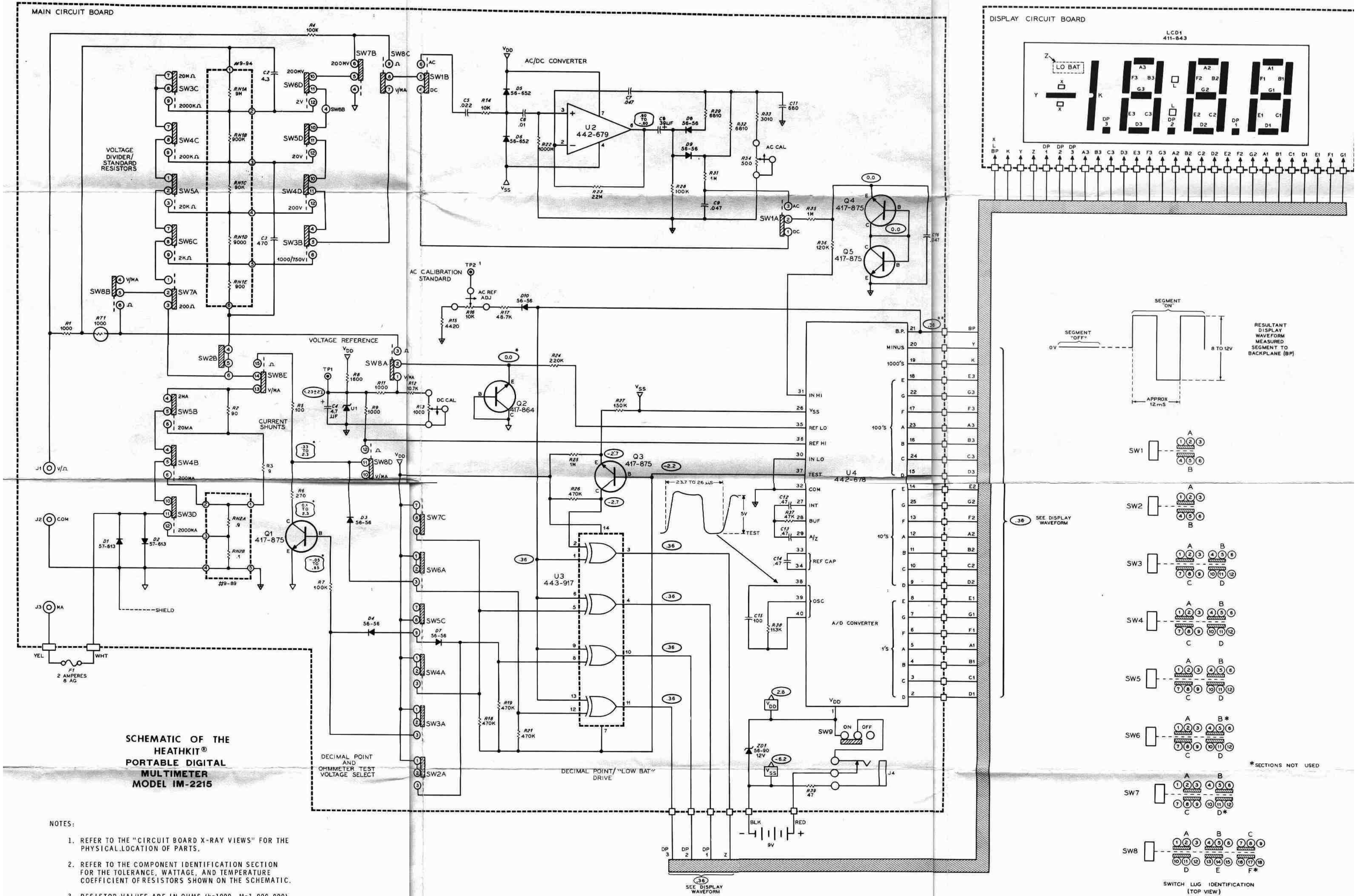
(Viewed from the component side)

MAIN CIRCUIT BOARD



*Not used.

(Viewed from the component side)



SCHEMATIC OF THE HEATHKIT® PORTABLE DIGITAL MULTIMETER MODEL IM-2215

NOTES:

1. REFER TO THE "CIRCUIT BOARD X-RAY VIEWS" FOR THE PHYSICAL LOCATION OF PARTS.
2. REFER TO THE COMPONENT IDENTIFICATION SECTION FOR THE TOLERANCE, WATTAGE, AND TEMPERATURE COEFFICIENT OF RESISTORS SHOWN ON THE SCHEMATIC.
3. RESISTOR VALUES ARE IN OHMS (k=1000, M=1,000,000).
4. CAPACITOR VALUES LARGER THAN 1.0 ARE IN pF AND CAPACITOR VALUES LESS THAN 1.0 ARE IN µF UNLESS OTHERWISE SPECIFIED.
5. ▽ INDICATES POWER GROUND.
6. ▽ INDICATES LOW-NOISE GROUND.
7. ▭ INDICATES A WIRE CONNECTION TO A CIRCUIT BOARD.
8. ◉ INDICATES A TEST POINT.
9. ◯ INDICATES DC VOLTAGE MEASUREMENT WITH V/Ω AND COM INPUT JACKS SHORTED. VOLTAGES ARE MEASURED WITH RESPECT TO INPUT COMMON (J2).
10. ◯* INDICATES DC VOLTAGE MEASUREMENT WITH SW8 IN OHMS POSITION AND V/Ω AND COM INPUT JACKS SHORTED. VOLTAGES ARE MEASURED WITH RESPECT TO INPUT COMMON (J2).
11. SWITCHES ARE SHOWN IN THE 200MV DC POSITION.

NOTE: ALL VOLTAGES WERE MEASURED AT NOMINAL BATTERY VOLTAGE (9V) WITH A 10 MΩ INPUT IMPEDANCE VOLTMETER. VOLTAGES MAY VARY ±20% EXCEPT AS NOTED. ALL WAVEFORMS WERE MEASURED AT NOMINAL BATTERY VOLTAGE (9V) WITH LOW-CAPACITANCE, 10MΩ PROBE. LEVELS MAY VARY ±10%

Part of 595-2233-05