DIGITAL MULTIMETER KIT

MODEL M-2666K

WIDE RANGE DIGITAL MULTIMETER WITH CAPACITANCE AND TRANSISTOR TESTING FEATURES

Assembly and Instruction Manual

INTRODUCTION

Assembly of your M-2666 Digital Multimeter Kit will prove to be an exciting project and give much satisfaction and personal achievement. If you have experience in soldering and wiring technique, you should have no problems. For the beginner, care must be given to identifying the proper components and in good soldering habits. Above all, take your time and follow the easy step-by-step instructions. Remember, "An ounce of prevention is worth a pound of cure".

The meter kit has been divided into a number of sections to make the assembly easy and avoid major problems with the meter operation.

Section A - Meter display circuit assembly.

Section B - DC voltage and current circuit assembly.

Section C - AC voltage and current circuit assembly.

Section D - Resistance & buzzer circuit assembly.

Section E - Capacitance and transistor testing circuit assembly.

Section F - Final assembly.

THEORY OF OPERATION

A block diagram of the M-2666K is shown in Figure 1. Operation centers around a custom LSI chip. This IC contains a dual slope A/D converter, display, latches, decoder and the display driver. A block diagram of the IC functions is shown in Figure 6. The input voltage, current or ohm signals are conditioned by the function and selector switches to produce and output DC voltage between 0 and +199mV. If the input signal is 100VDC, it is reduced to 100mV DC by selecting a 1000:1 divider. Should the input be 100VAC, then after the divider it is processed by the AC converter to produce 100mVDC. If current is to be read, it is converted to a DC voltage via internal shunt resistors. For resistance measurements, an internal voltage source supplies the necessary 0-199mV voltage to be fed to the IC input.

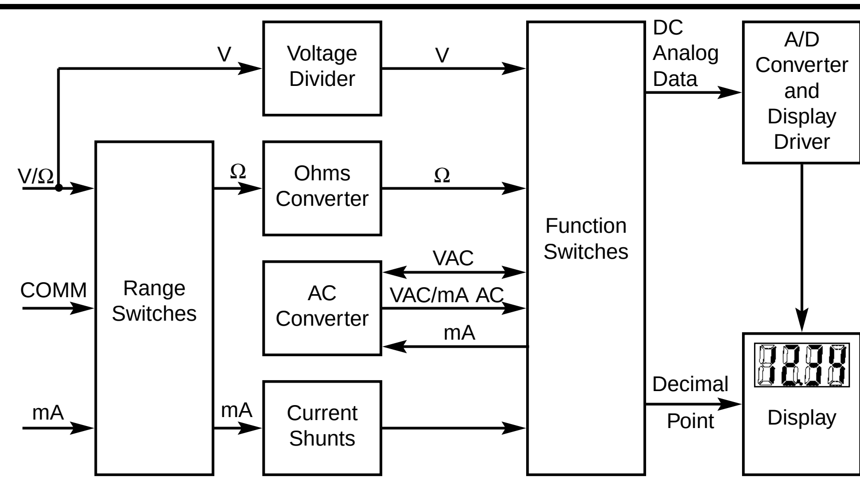


Figure 1 Simplified Block Diagram

The input of the 7106 IC is fed to an A/D (analog to digital) converter. Here the DC voltage amplitude is changed into a digital format. The resulting signals are processed in the decoders to light the appropriate LCD segment.

Timing for the overall operation of the A/D converter is derived from an external oscillator whose frequency is selected to be 40kHz. In the IC, this frequency is divided by four before it clocks the decade counters. It is further divided to form the three convert-cycle phases. The final readout is clocked at about three readings per second.

Digitized measurements data is presented to the display as four decoded digits (seven segments) plus polarity. Decimal point position on the display is determined by the selector switch setting.

A/D CONVERTER

A simplified circuit diagram of the analog portion of the A/D converter is shown in Figure 2. Each of the switches shown represent analog gates which are operated by the digital section of the A/D converter. Basic timing for switch operation is keyed by an external oscillator. The conversion process is continuously repeated. A complete cycle is shown in Figure 2.

Any given measurement cycle performed by the A/D converter can be divided into three consecutive time periods: autozero (AZ), integrate (INTEG) and read. Both autozero and integrate are fixed time periods. A counter determines the length of both time periods by providing an overflow at the end of every 1,000 clock pulses. The read period is a variable time, which is proportional to the unknown input voltage. The value of the voltage is determined by counting the number of clock pulses that occur during the read period.

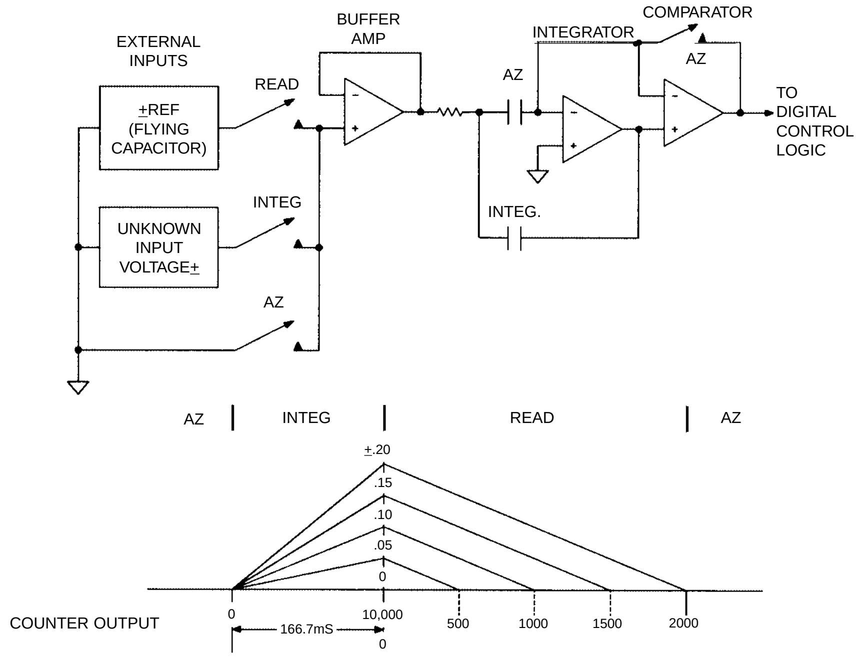


Figure 2 Dual Slope A/D Converter

During autozero, a ground reference is applied as an input to the A/D converter. Under ideal conditions the output of the comparator would also go to zero. However, input-offset-voltage errors accumulate in the amplifier loop, and appear at the comparator output as an error voltage. This error is impressed across the AZ capacitor where it is stored for the remainder of the measurement cycle. The stored level is used to provide offset voltage correction during the integrate and read periods.

The integrate period begins at the end of the autozero period. As the period begins, the AZ switch opens and the INTEG switch closes. This applies the unknown input voltage to the input of the A/D converter. The voltage is buffered and passed on to the input of the A/D converter. The voltage is buffered and passed on to the integrator to determine the charge rate (slope) on the INTEG capacitor. At the end of the fixed integrate period, the capacitor is charged to a level proportional to the unknown input voltage. This voltage is translated to a digital indication by discharging the capacitor at a fixed rate during the read period, and counting the number of clock pulses that occur before it returns to the original autozero level.

As the read period begins, the INTEG switch opens and the read switch closes. This applies a known reference voltage to the input of the A/D converter. The polarity of this voltage is automatically selected to be opposite that of unknown input voltage, thus causing the INTEG capacitor to discharge as fixed rate (slope). When the charge is equal to the initial starting point (autozero level), the read period is ended. Since the discharge slope is fixed during the read period, the time required is proportional to the unknown input voltage.

The autozero period and thus a new measurement cycle begins at the end of the read period. At the same time, the counter is released for operation by transferring its contents (previous measurement value) to a series of latches. This stored stat is then decoded and buffered before being used for driving the LCD display.

VOLTAGE MEASUREMENT

Figure 3 shows a simplified diagram of the voltage measurement function.

The input divider resistors add up 10MΩ with each step being a division of 10. The divider output should be within –0.199 to +0.199V or the overload indicator will function. If the AC function is selected, the divider output is AC coupled to a full wave rectifier and the DC output is calibrated to equal the rms level of the AC input.

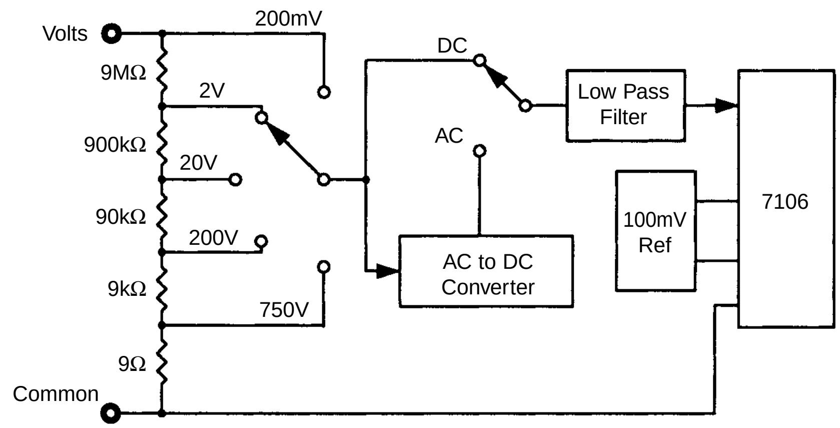


Figure 3 Simplified Voltage Measurement Diagram

CURRENT MEASUREMENT

Figure 4 shows a simplified diagram of the current measurement positions.

Internal shunt resistors convert the current to between –0.199 to +0.199V which is then processed in the 7106 IC to light the appropriate LCD segments. If the current is AC in nature, the AC converter changes it to the equivalent DC value.

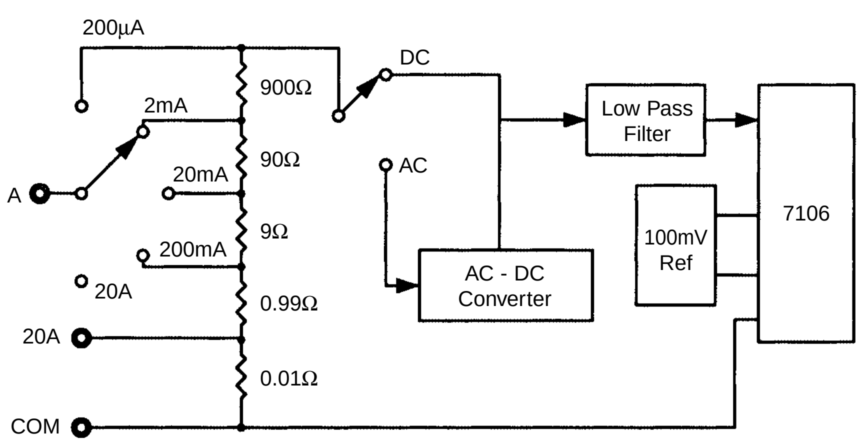


Figure 4 Simplified Current Measurement Diagram

RESISTANCE MEASUREMENTS

Figure 5 shows a simplified diagram of the resistance measurement function.

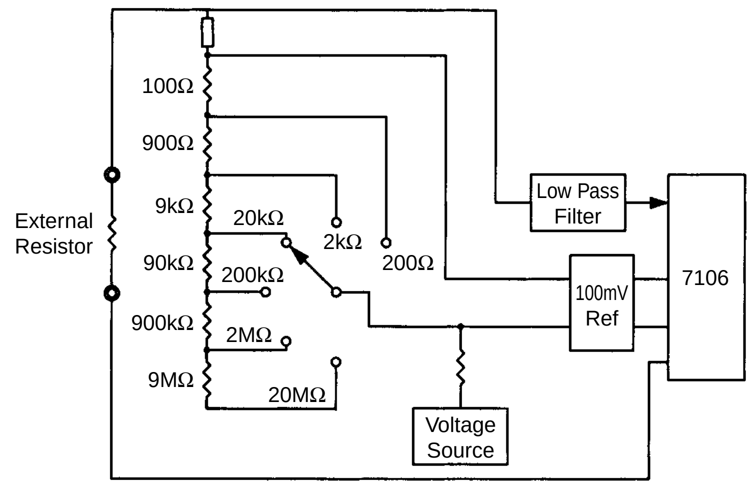


Figure 5 Simplified Resistance Measurement Diagram

A simple series circuit is formed by the voltage source, a reference resistor from the voltage divider (selected by range switches), and the external unknown resistor. The ratio of the two resistors is equal to the ratio of their respective voltage drops. Therefore, since the value of one resistor is known, the value of the second can be determined by using the voltage drop across the known resistor as a reference. This determination is made directly by the A/D converter.

Overall operation of the A/D converter during a resistance measurement is basically as described earlier in this section, with one exception. The reference voltage present during a voltage measurement is replaced by the voltage drop across the reference resistor. This allows the voltage across the unknown resistor to be read during the read period. As before, the length of the read period is a direct indication of the value of the unknown.

h_{FE} MEASUREMENT

Figure 6 shows a simplified diagram of the h_{FE} measurement function. Internal circuits in the 7106 IC maintain the COMMON line at 2.8 volts below V+. When a PNP transistor is plugged into the transistor socket, base to emitter current flows through resistor R49. The voltage drop in resistor R49 due to the collector current is fed to the 7106 and indicates the h_{FE} of the transistor. For an NPN transistor, the emitter current through R50 indicates the h_{FE} of the transistor.

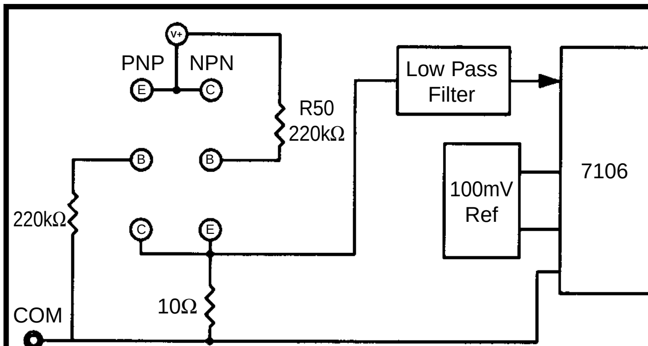


Figure 6

CAPACITANCE MEASUREMENT

The capacitor circuit consists of four op-amps. IC3 D& A form an oscillator, which is applied to the test-capacitor through the test leads. The capacitor couples the oscillator to pin 6 of IC3B. The amount of voltage developed at pin 6 is indicative of the capacitors ESR value. IC3B and C amplify the signal which is seen at pin 8. The AC signal is then converted to a DC voltage and displayed on the meter.

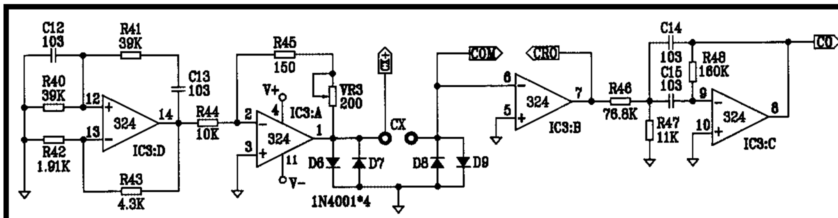


Figure 7

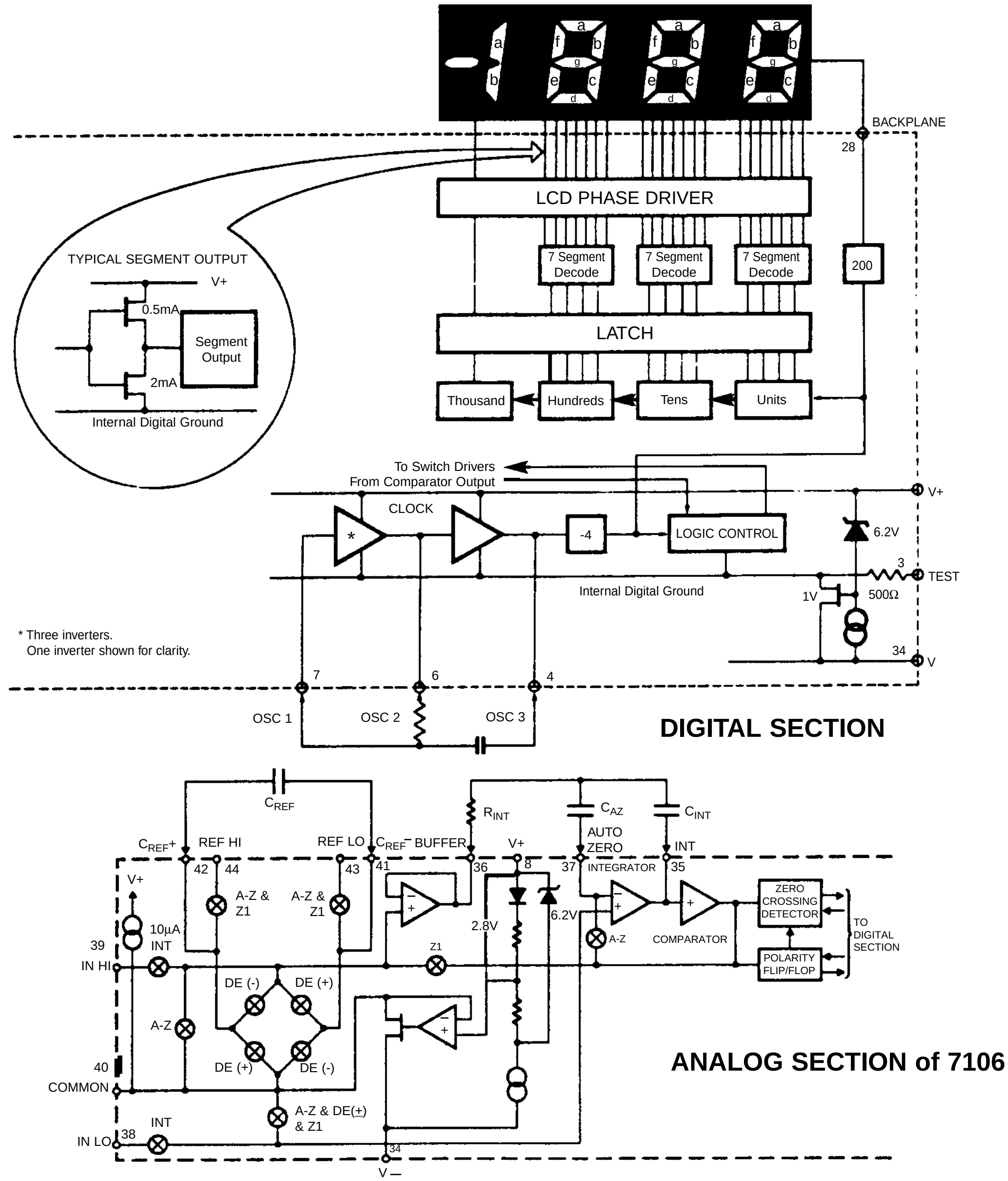
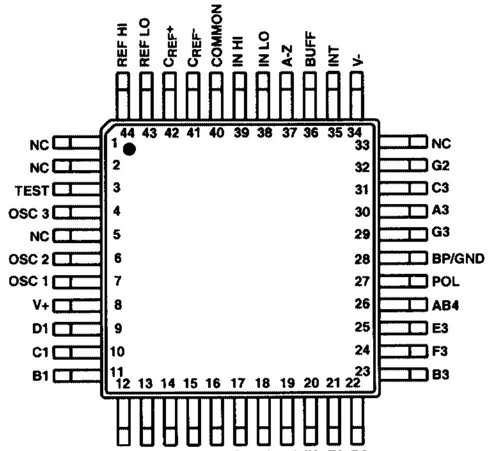


Figure 8 7106 Functions

ICL7106, ICL7107 (MQFP)
TOP VIEW



1. FEATURES

- Wide measuring ranges: 34 ranges for AC/DC Voltage and Current, Resistance, Capacitance, TR h_{FE}, Diode Test, and Continuity Buzzer.
- 10MΩ Input Impedance
- Big LCD for easy reading
- Tilt Stand
- Rubber Holster

2. SPECIFICATIONS

2-1 General Specifications

Display	3 1/2 LCD 0.9” height, maximum reading of 1999.
Polarity	Automatic “–” sign for negative polarity.
Overrange Indication	Highest digit of “1” or “–1” is displayed.
Low Battery Indication	“BAT” lettering on the LCD readout.
Operating Temperature	0°C to 50°C. less than 80% relative humidity up to 35°C. less than 70% relative humidity from 35°C to 50°C.
Storage Temperature	–15°C to 50°C
Temperature Coefficient	0°C to 18°C and 28°C to 50°C. less than 0.1 x applicable accuracy specification per degree C.
Power	9V alkaline or carbon zinc battery (NEDA 1604).
Battery Life (typical)	100 hours with carbon zinc cells. 200 hours with alkaline cells.
Dimensions (w/o holster)	3.55” (90.2mm) (W) x 7.6” (193mm) (L) x 1.78” (45.2mm) (H).
Weight (w/o holster)	Approximately 10.4oz. (300g.)
Accessories	Safety Test Leads 1 pair

2-2 Measurement Ranges (Accuracy: 1 year 18°C to 28°C)

DC Voltage

Range	Resolution	Accuracy	Maximum Input
200mV	100µV	±0.5% of rdg ± 2dgt	DC 1000V or peak AC
2V	1mV	±0.5% of rdg ± 2dgt	
20V	10mV	±0.5% of rdg ± 2dgt	
200V	100mV	±0.5% of rdg ± 2dgt	
1000V	1V	±0.8% of rdg ± 2dgt	

Normal Mode Rejection Ratio: Greater than 46dB at 50Hz 60Hz (1k unbalance)

AC Voltage

Range	Resolution	Accuracy	Maximum Input
200mV	100µV	±1.5% of rdg ± 2dgt	
2V	1mV	±1% of rdg ± 2dgt	
20V	10mV	±1% of rdg ± 2dgt	AC 750V maximum 50Hz - 400Hz
200V	100mV	±1% of rdg ± 2dgt	
750V	1V	±1.5% of rdg ± 2dgt	

Resistance

Range	Resolution	Accuracy	Test Current	Input Protection
200Ω	0.1Ω	±1% of rdg ± 2dgt		
2kΩ	1Ω	±0.8% of rdg ± 2dgt		
20kΩ	10Ω	±0.8% of rdg ± 2dgt	Approximately	Protected By
200kΩ	100Ω	±0.8% of rdg ± 2dgt	1.2mA	PTC
2MΩ	1kΩ	±0.8% of rdg ± 3dgt		
20MΩ	10kΩ	±2.0% of rdg ± 4dgt		

Maximum open circuit voltage: 2.8V

DC Current

Range	Resolution	Accuracy	Protection
200µA	100nA	±1.5% of rdg ± 2dgt	
2mA	1µA	±1.5% of rdg ± 2dgt	Protected by
20mA	10µA	±1.5% of rdg ± 2dgt	250V/2A Fuse
200mA	100µA	±2% of rdg ± 2dgt	
20A	10mA	±2.5% of rdg ± 3dgt	

AC Current

Range	Resolution	Accuracy	Protection
200µA	100nA	±1% of rdg ± 3dgt	
2mA	1µA	±1% of rdg ± 3dgt	Protected by
20mA	10µA	±1% of rdg ± 3dgt	250V/2A Fuse
200mA	100µA	±1.5% of rdg ± 3dgt	
20A	10mA	±2.0% of rdg ± 3dgt	

Capacitance

Range	Resolution	Accuracy	Protection
2nF	1pF	±2.5% of rdg ± 3dgt	
2nF	10pF	±2.5% of rdg ± 3dgt	
200nF	100pF	±2.5% of rdg ± 3dgt	Test frequency 400Hz
2µF	1nF	±2.5% of rdg ± 3dgt	
20µF	10nF	±2.5% of rdg ± 3dgt	
200µF	100nF	±5% of rdg ± 3dgt	

Transistor h_{FE}

Range	Test Condition
NPN	2mA 3V
PNP	2mA 3V

Diode Test

Measures forward resistance of a semiconductor junction in k Ohm at max. test current of 1mA.

3. OPERATION

3-1 Preparation and caution before measurement

1. If the function must be switched during a measurement, always remove the test leads from the circuit being measured.
2. If the unit is used near noise generating equipment, be aware that the display may become unstable or indicate large errors.
3. Avoid using the unit in places with rapid temperature variations.
4. In order to prevent damage or injury to the unit, never fail to keep the maximum tolerable voltage and current, especially for the 20A current range.
5. Carefully inspect the test lead. If damaged, discard and replace.

3-2 Panel Description

3-3 Method of Measurement

(A) DC/AC Voltage Measurement

1. Connect the red test lead to “VΩCAP” input jack and the black one to the “COM” jack.
2. Turn the meter on by pressing the power switch.
3. Set the range selector knob to the desired volt position. If the magnitude of the voltage is not known, set the range selector knob to the highest range and reduce until a satisfactory reading is obtained.
4. Connect the test leads to the device or circuit being measured.
5. Turn on the power to the device or circuit being measured. The voltage value will appear on the digital display along with the voltage polarity.
6. Turn off the power to the device or circuit being tested and discharge all of the capacitors prior to disconnecting the test leads.

(B) DC/AC Current Measurement

1. Connect the red test lead to the “A” input jack for current measurement up to 200mA, and the black one to “COM”.
2. Turn the meter on by pressing the power switch.
3. Set the range selector knob to the desired “Amp” current position.

   If the magnitude of current is not known, set the range selector knob to the highest range and reduce until a satisfactory reading is obtained.
4. Open the circuit to be measured, and connect the test leads in series with the load in which current is to be measured.
5. Read the current value on the digital display.
6. Turn off all power to the circuit being tested and discharge all of the capacitor prior to disconnecting the test lead.
7. To measure in the 10A range, use the “10A” jack as the input jack. Be sure to measure within 10 seconds to avoid high-current hazard.

(C) Resistance Measurement

1. Connect red test lead to the “VΩCAP” input jack and the black one to “COM”.
2. Turn the meter on by pressing the power switch.
3. Set the range selector knob to desired “Ohm” position.
4. If the resistance being measured is connected to a circuit, turn off the power to the circuit being tested and discharge all capacitors.
5. Connect the test leads to the circuit being measured. When measuring high resistance, be sure not to contact adjacent point even if insulated, because some insulators have a relatively low insulation resistance, causing the measured resistance to be lower than the actual resistance.
6. Read resistance value on digital display.

(D) Diode Test

1. Connect the red test lead to “VΩCAP” input jack and the black one to the “COM” jack.
2. Turn the meter on by pressing the power switch.
3. Set the range selector knob to the “ —▶|— ” position.
4. If the semiconductor junction being measured is connected to the circuit, turn off the power to the circuit being tested and discharge all of the capacitors.
5. Connect the test leads to the device and read forward value on the digital display.
6. If the digital reads overrange (1), reverse the lead connections.

   The placement of the test leads when the forward reading is displayed indicates the orientation of the diode.

   The red lead is positive and the black lead is negative.

   If overrange (1) is displayed with both lead connections, the junction is open.

(E) Transistor h_{FE} Measurement

1. The transistor must be out of circuit. Set the rotary selector knob to the h_{FE} position.
2. Turn the meter on by pressing the power switch.
3. Plug the emitter, base and collector leads of the transistor into the correct holes in either the NPN of the PNP transistor test socket, whichever is appropriate for the transistor you are checking.
4. Read the h_{FE} (beta or DC current gain) on the display.

(F) Capacitance Measurement

1. Connect red test lead to the “VΩCAP” input jack and the black one to “COM”.
2. Turn the meter on by pressing the power switch.
3. Set the rotary selector knob to the “FARAD” position.
4. Set the rotary selector knob to the desired capacitance position.
5. Short the leads of the capacitor to be tested together to insure that there is no charge on the capacitor.
6. Connect the leads to the capacitor and read the capacitance value on the digital display.

4. OPERATION MAINTENANCE

4-1 Battery and Fuse Replacement

CAUTION

BEFORE ATTEMPTING BATTERY REMOVAL OR REPLACEMENT, DISCONNECT THE TEST LEADS FROM ANY ENERGIZED CIRCUITS TO AVOID SHOCK HAZARD.

The fuse rarely needs replacement and blow almost always as a result of operator error. To replace the battery and fuse (200mA/250V), remove the two screws in the bottom of the case. Simply remove the old battery or fuse and replace with a new one.

Be sure to observe the polarity when replacing the battery.

5. SAFETY SYMBOLS

This marking adjacent to another marking or a terminal operating device indicates that the operator must refer to an explanation in the operating instructions to avoid damage to the equipment and/or to avoid personal injury.

WARNING

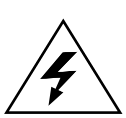
This WARNING sign denotes a hazard. It calls attention to a procedure, practice or the like, which if not correctly performed or adhered to, could result in personal injury.

CAUTION

This CAUTION sign denotes a hazard. It calls attention to a procedure, practice or the like, which if not correctly adhered to, could result in damage to or destruction of part or all of the instrument.

500V max.

This marking advises the user that the terminal(s) so marked must not be connected to a circuit point at which the voltage, with respect to earth ground, exceeds (in this case) 500 volts.



This symbol adjacent to one or more terminals identifies them as being associated with ranges that may in normal use be subjected to particularly hazardous voltages. For maximum safety, the instrument and its test leads should not be handled when these terminals are energized.

SCHEMATIC DIAGRAM