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DIGITAL MULTIMETER KIT

MODEL M-2665K

WIDE RANGE DIGITAL MULTIMETER WITH CAPACITANCE AND TRANSISTOR TESTING FEATURES

Assembly and Instruction Manual

Elenco™ Electronics, Inc.

Revised 2002 REV-P 753005

INTRODUCTION

Assembly of your M-2665K 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 circuit assembly.

Section E - Capacitance and transistor testing circuit assembly.

Section F - Final assembly.

THEORY OF OPERATION

A block diagram of the M-2665K 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 if 100VDC, it is reduced to 100mV DC by selecting a 1000:1 divider. Should the input be 100VDC, 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.

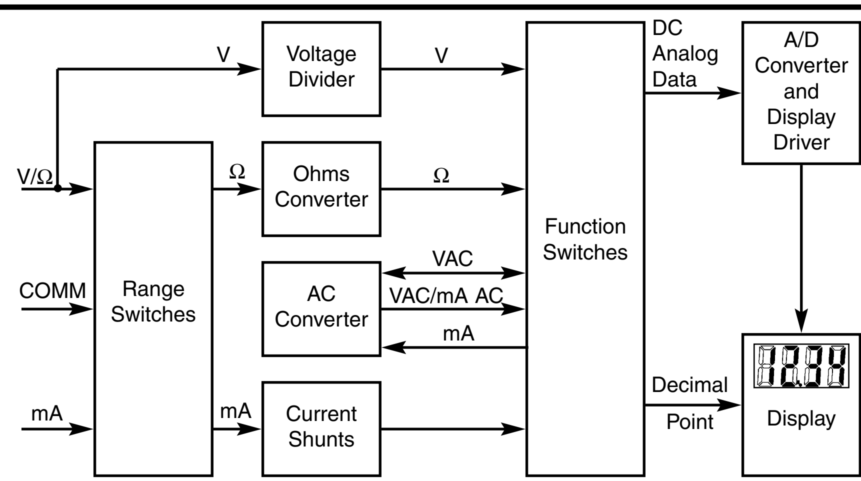


Figure 1 Simplified Block Diagram

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.

QUIZ

1. The function of the A/D converter is to . . .
   - ☐ A. convert digital to analog.
   - ☐ B. divide analog signal by 2.
   - ☐ C. convert analog to digital.
   - ☐ D. convert AC to DC.

2. What type of divider network is used for voltage measurements?
   - ☐ A. Divide by 20.
   - ☐ B. Capacitance.
   - ☐ C. Divide by 5.
   - ☐ D. Resistor.

3. When the AC voltage is measured, it is first . . .
   - ☐ A. divided down by 2.
   - ☐ B. converted to DC.
   - ☐ C. coupled to a halfwave rectifier.
   - ☐ D. low voltage.

4. When measuring current, the shunt resistors convert the current to . . .
   - ☐ A. +0.190 to –0.190.
   - ☐ B. –1.199 to +1.199.
   - ☐ C. –0.099 to +0.099.
   - ☐ D. –199 to +0.199.

5. Which IC drives the LCD?
   - ☐ A. 358.
   - ☐ B. LM324.
   - ☐ C. 7106R.
   - ☐ D. 1N5232.

6. Resistance measurements are made by . . .
   - ☐ A. comparing voltage drops in the unknown resistor and a reference resistor.
   - ☐ B. measuring the current in the unknown resistor.
   - ☐ C. measuring the current in the reference resistor.
   - ☐ D. equalizing the voltage drop in the unknown and reference resistor.

7. Measurement cycles performed by the A/D converter can be divided into what types of time periods?
   - ☐ A. Long, short.
   - ☐ B. Auto zero, integrate, read.
   - ☐ C. Zero, read, interphase.
   - ☐ D. Autozero, read, cycle phase.

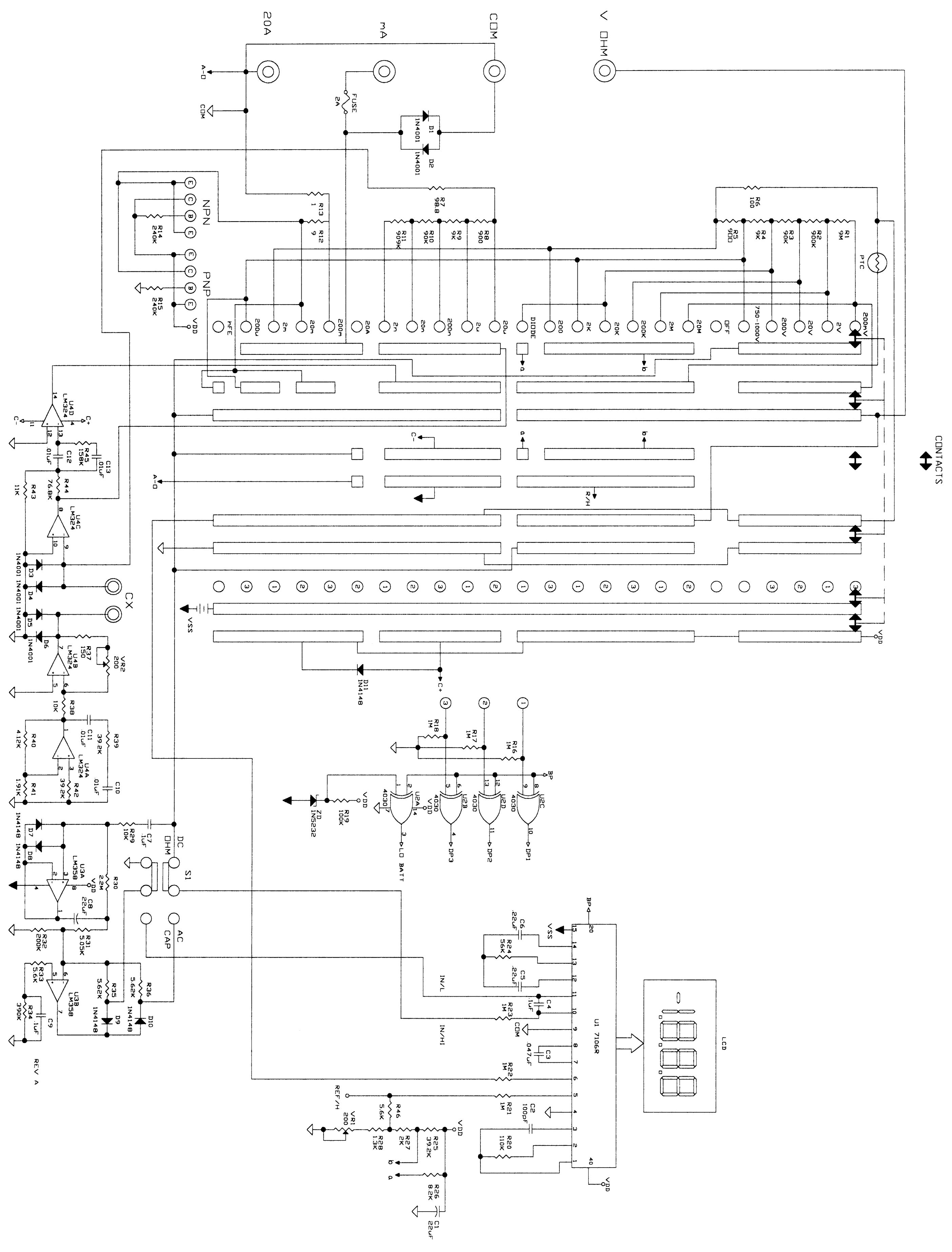
8. A resistor with band colors green-black-green-brown-green is what value?
   - ☐ A. 50.5kΩ ± 5%.
   - ☐ B. 5.15kΩ ± 10%.
   - ☐ C. 5.05kΩ ± .5%.
   - ☐ D. 5.05kΩ ± 1%.

9. When checking a transistor, the selector knob should be in the . . .
   - ☐ A. farad position.
   - ☐ B. ohm position.
   - ☐ C. diode position.
   - ☐ D. h_{FE} position.

10. Where do the leads need to be on the meter when measuring 450mA?
    - ☐ A. A20, COM.
    - ☐ B. V, COM.
    - ☐ C. A, A20.
    - ☐ D. A, COM.

Answers: 1. C, 2. D, 3. B, 4. B, 5. C, 6. A, 7. B, 8. C, 9. D, 10. A

SCHEMATIC DIAGRAM



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.

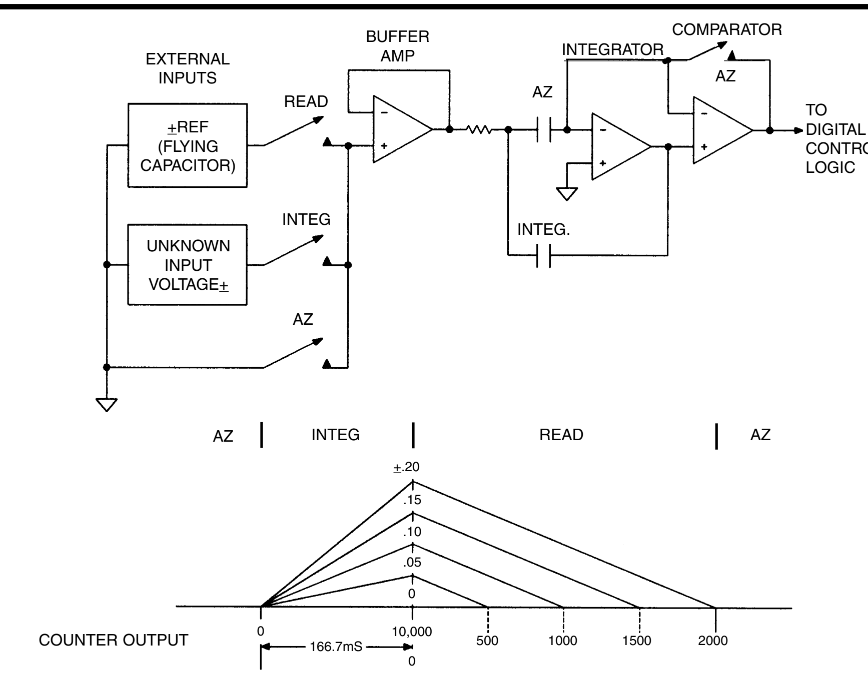


Figure 2 Dual Slope A/D Converter

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 unknown input voltage 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 withing –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.

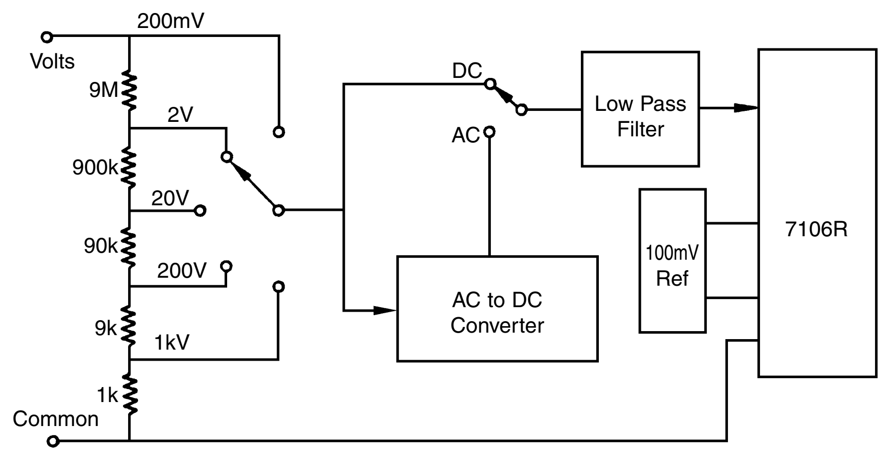


Figure 3 Simplified Voltage Measurement Diagram

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.

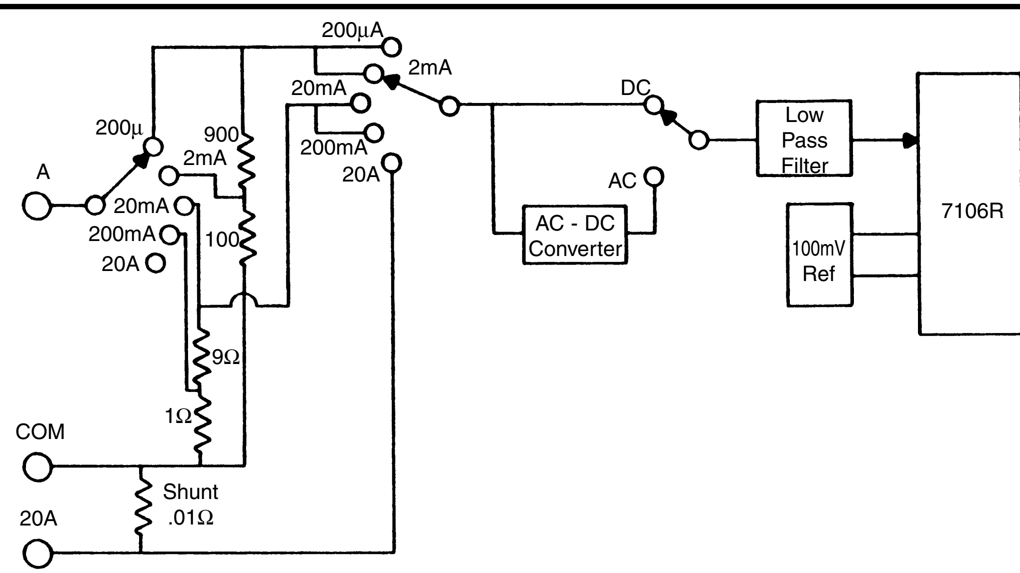


Figure 4 Simplified Current Measurement Diagram

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 (2A/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.

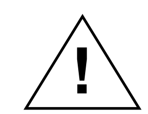
4-2 Calibration Procedure

It is normally not necessary to recalibrate for long intervals. If needed, adjustment should be done with highly accurate standards (setter than 0.1% accuracy).

Remove the two phillips head screws. Carefully remove the plastic back cover. With the instrument operating and set to the 200mV DC range (20µF capacitance range), apply 190mV DC (10µF) from an accurate source. With a small screwdriver inserted into the semi-fixed resistor VR1 (VR2: Capacitance), carefully turn the variable resistor until the reading reads 190mV (10µF).

NOTE: Be sure to proceed basic calibration by DC range first prior to capacitance.

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

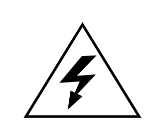
This WARNING sign denotes a hazard. It calls attention to a procedure, practice or the like, which if not correctly performed or adhered to, could result in personal injury.

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.

(D) Diode Test

1. Set the selector switch to the “Ohm” position.
2. Connect the red test lead to “V/Ω” input jack and the black one to the “COM” jack.
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. Set the selector switch to “DC”.
2. The transistor must be out of circuit. Set the rotary/function switch to the h_{FE} position.
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. Set the range selector knob to the “FARAD” position.
2. Set the range selector knob to the desired capacitance position.
3. Short the leads of the capacitor to be tested together to insure that there is no charge on the capacitor.
4. Insert the capacitor leads into the capacitor test socket. Note that there are two groups of holes. One lead must be inserted into one of group one, and the other lead must be inserted into one of the holes of group two.
5. Read the capacitance value on the digital display.

RESISTANCE MEASUREMENTS

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

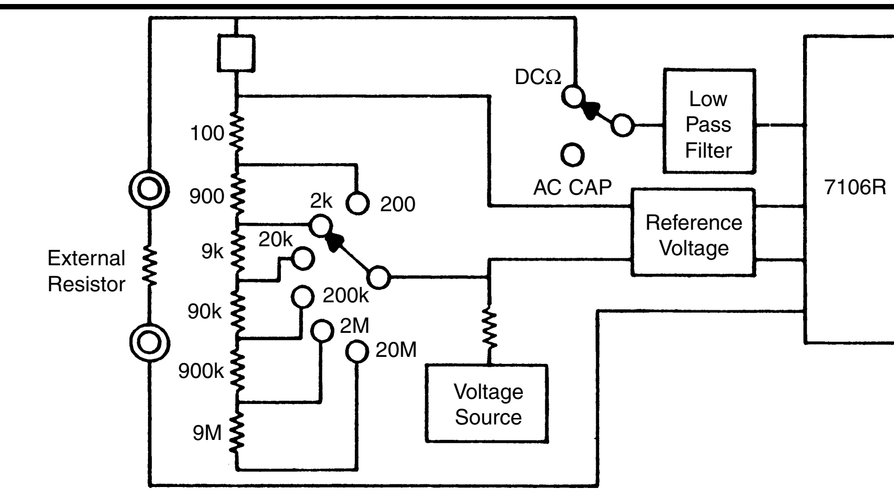


Figure 5 Simplified Resistance Measurement Diagram

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.

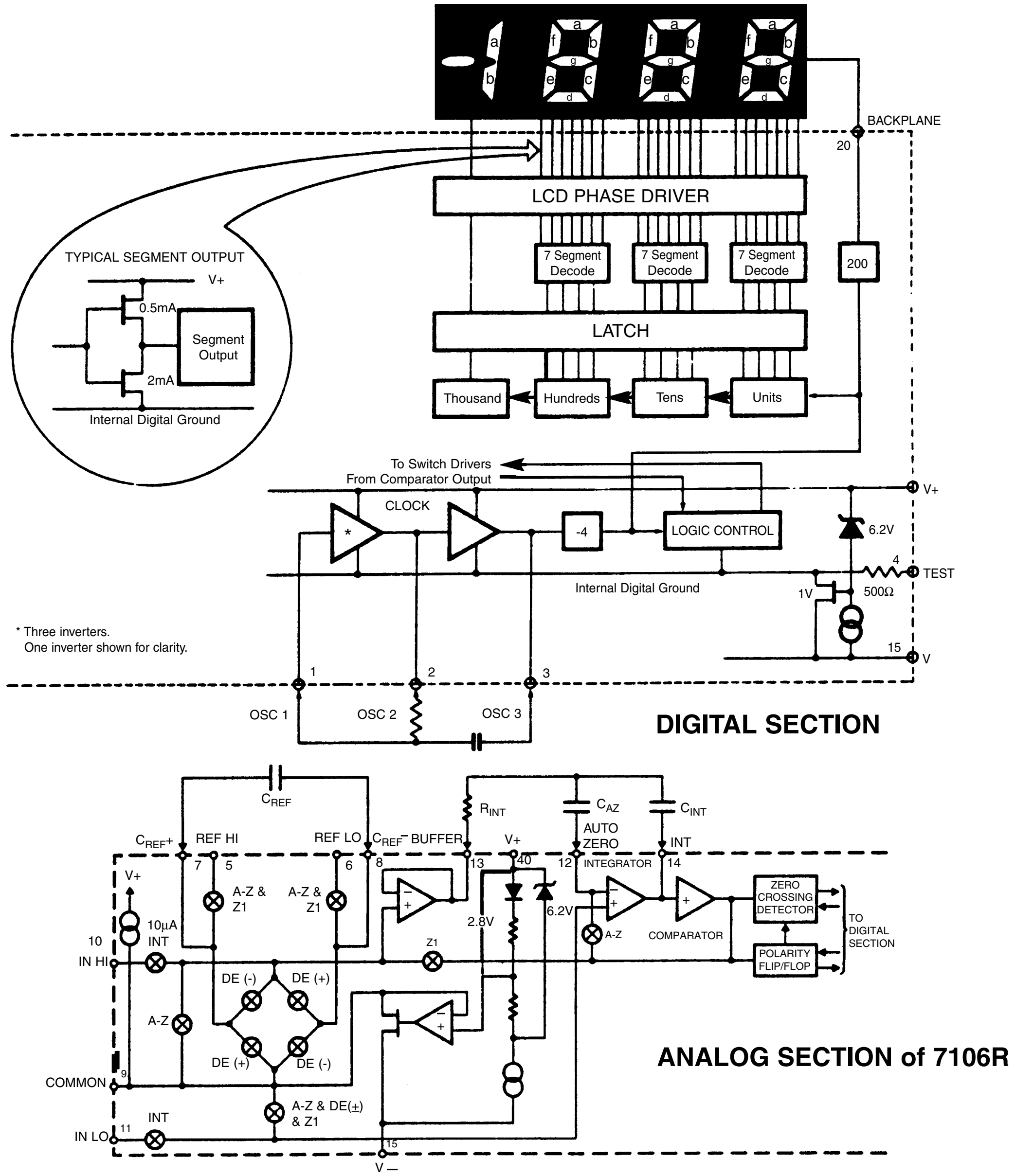
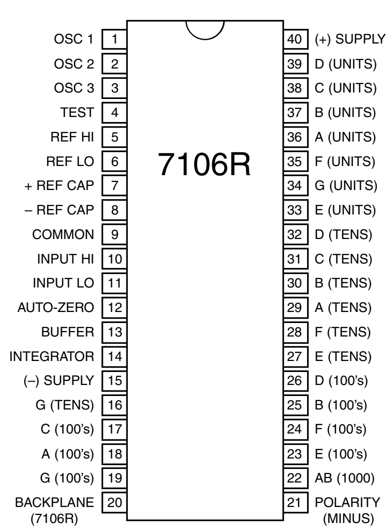


Figure 6 7106R Functions

Pin Configuration



7106R Pin Connections

3-3 Method of Measurement

(A) DC/AC Voltage Measurement

1. Set the selector switch to “DC” or “AC”.
2. Connect the red test lead to “V/Ω” input jack and the black one to the “COM” jack.
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. Set the selector switch to “DC” or “AC”.
2. Connect the red test lead to the “A” input jack for current measurement up to 200mA, and the black one to “COM”.
3. Set the range selector knob to the desired “Amp” current position.

   If the magnitude of current is not known, set the rotary/function switch 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 20A range, use the “20A” jack as the input jack. Be sure to measure within 10 seconds to avoid high-current hazard.

(C) Resistance Measurement

1. Set the selector switch to the “Ohm” position.
2. Connect red test lead to the “V/Ω” input jack and the black one to “COM”.
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.

Transistor h_{FE}

Range	Test Condition
NPN	10mA 2.8V
PNP	10mA 2.8V

Diode Test

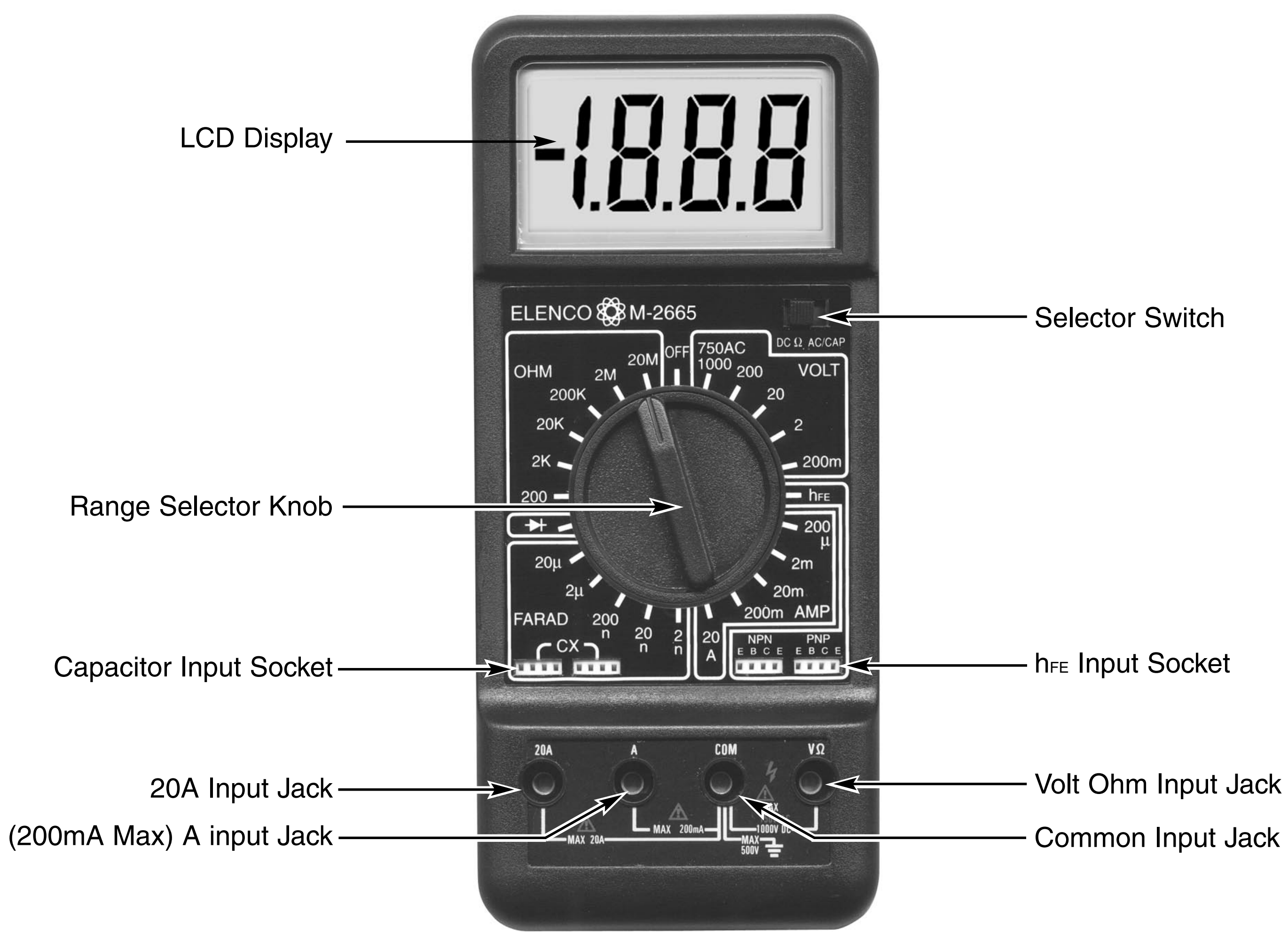
Measures forward resistance of a semiconductor junction in k Ohm at max. test current of 1.5mA.

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



ASSEMBLY

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

OPEN ONLY THOSE COMPONENT BAGS THAT ARE CALLED FOR IN YOUR ASSEMBLY PROCEDURE. DO NOT OPEN ANY OTHER BAGS.

Do not build more than one section of your meter at a time. Your instructor must approve the proper operation of the section you have built before you proceed to the next section. This procedure will minimize the problems you may have at the completion of the project.

Your kit program is divided into Sections “A – F”. The small parts bags will be marked accordingly. The sections are listed below.

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 circuit assembly.

Section E - Capacitance and transistor testing circuit assembly.

Section F - Final assembly.

IMPORTANT CONSTRUCTION NOTES

1. Wash your hands with soap and water before you assemble this kit. The high impedance areas on the circuit board can be contaminated by salt and oil from your skin. If these areas become contaminated, your completed multimeter may not meet the listed specifications. Handle the circuit board only by its edges.
2. Avoid any excessive accumulation of resin build-up whenever you solder a connection.
3. Take your time assembling the circuit board. Work at a slow pace. Remember that accuracy is far more important than speed.
4. When you perform the steps in assembly, identify each respective component before you install it. Then position it over its outline on the top legend side of the PC board, unless otherwise indicated.
5. Check for the proper polarity of ICs, diodes, electrolytic capacitors, battery snap and LCD.

CONSTRUCTION

Introduction

The most important factor in assembling your M-2665K Digital Multimeter Kit is good soldering techniques. Using the proper soldering iron is of prime importance. A small pencil type soldering iron of 25 - 40 watts is recommended. **The tip of the iron must be kept clean at all times and well tinned.**

Safety Procedures

- Wear eye protection when soldering.
- Locate soldering iron in an area where you do not have to go around it or reach over it.
- **Do not hold solder in your mouth.** Solder contains lead and is a toxic substance. Wash your hands thoroughly after handling solder.
- Be sure that there is adequate ventilation present.

Assemble Components

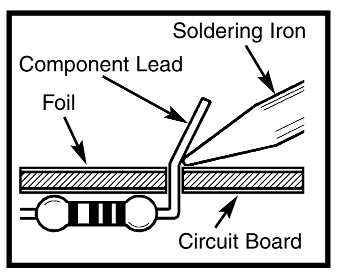
In all of the following assembly steps, the components must be installed on the top side of the PC board unless otherwise indicated. The top legend shows where each component goes. The leads pass through the corresponding holes in the board and are soldered on the foil side.
Use only rosin core solder of 63/37 alloy.

DO NOT USE ACID CORE SOLDER!

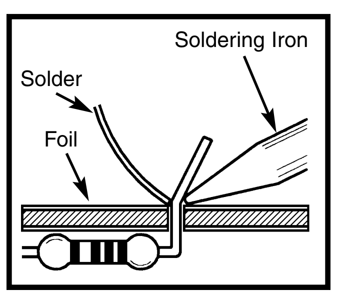
What Good Soldering Looks Like

A good solder connection should be bright, shiny, smooth, and uniformly flowed over all surfaces.

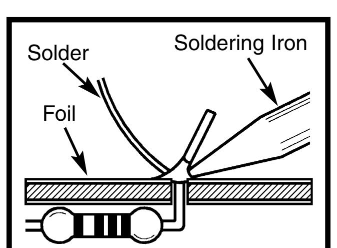
1. Solder all components from the copper foil side only. Push the soldering iron tip against both the lead and the circuit board foil.



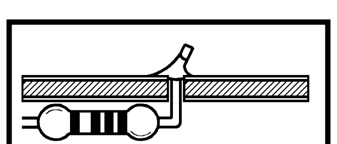
2. Apply a small amount of solder to the iron tip. This allows the heat to leave the iron and onto the foil. Immediately apply solder to the opposite side of the connection, away from the iron. Allow the heated component and the circuit foil to melt the solder.



3. Allow the solder to flow around the connection. Then, remove the solder and the iron and let the connection cool. The solder should have flowed smoothly and not lump around the wire lead.

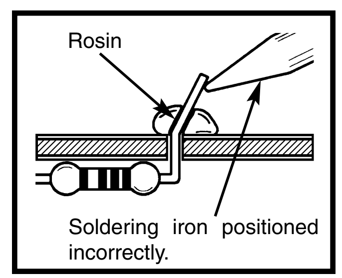


4. Here is what a good solder connection looks like.

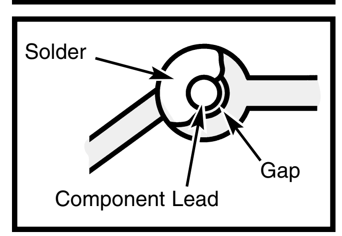


Types of Poor Soldering Connections

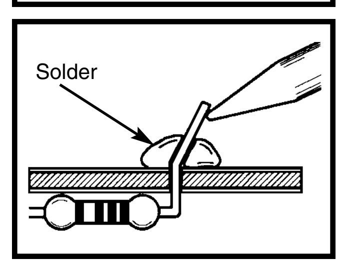
1. **Insufficient heat** - the solder will not flow onto the lead as shown.



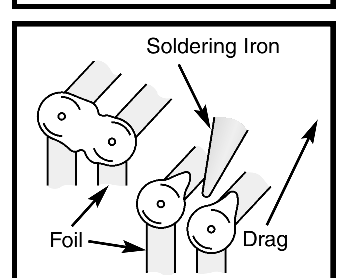
2. **Insufficient solder** - let the solder flow over the connection until it is covered. Use just enough solder to cover the connection.



3. **Excessive solder** - could make connections that you did not intend to between adjacent foil areas or terminals.



4. **Solder bridges** - occur when solder runs between circuit paths and creates a short circuit. This is usually caused by using too much solder. To correct this, simply drag your soldering iron across the solder bridge as shown.



AC Voltage

Range	Resolution	Accuracy	Maximum Input
200mV	100µV	±1.2% of rdg ± 2dgt	AC 750V maximum 50Hz - 400Hz
2V	1mV	±1.2% of rdg ± 2dgt	
20V	10mV	±1.2% of rdg ± 2dgt	
200V	100mV	±1.2% of rdg ± 2dgt	
750V	1V	±1.2% of rdg ± 2dgt	

Resistance

Range	Resolution	Accuracy	Test Current	Input Protection
200Ω	0.1Ω	±0.8% of rdg ± 2dgt	Approximately 1.2mA	Protected By PTC
2kΩ	1Ω	±0.8% of rdg ± 2dgt		
20kΩ	10Ω	±0.8% of rdg ± 2dgt		
200kΩ	100Ω	±0.8% of rdg ± 2dgt		
2MΩ	1kΩ	±1.0% of rdg ± 3dgt		
20MΩ	10kΩ	±3.0% of rdg ± 4dgt		

Maximum open circuit voltage: 2.8V

DC Current

Range	Resolution	Accuracy	Protection
200µA	100nA	±0.5% of rdg ± 2dgt	Protected by 250V/2A Fuse
2mA	1µA	±0.5% of rdg ± 2dgt	
20mA	10µA	±0.5% of rdg ± 2dgt	
200mA	100µA	±0.5% of rdg ± 2dgt	
20A	10mA	±1.0% of rdg ± 3dgt	

AC Current

Range	Resolution	Accuracy	Protection
200µA	100nA	±1.2% of rdg ± 3dgt	Protected by 250V/2A Fuse
2mA	1µA	±1.2% of rdg ± 3dgt	
20mA	10µA	±1.2% of rdg ± 3dgt	
200mA	100µA	±1.2% of rdg ± 3dgt	
20A	10mA	±3.0% of rdg ± 3dgt	

Capacitance

Range	Resolution	Accuracy	Protection
2nF	1pF	±3.0% of rdg ± 3dgt	Test frequency 400Hz±3.0% Test Voltage 120mV
2nF	10pF	±3.0% of rdg ± 3dgt	
200nF	100pF	±3.0% of rdg ± 3dgt	
2µF	1nF	±3.0% of rdg ± 3dgt	
20µF	10nF	±3.0% of rdg ± 3dgt	

1. FEATURES

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

2. SPECIFICATIONS

2-1 General Specifications

Display	3 1/2 LCD 0.95” 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^oC to 50^oC. less than 80% relative humidity up to 35^oC. less than 70% relative humidity from 35^oC to 50^oC.
Storage Temperature	-15^oC to 50^oC
Temperature Coefficient	0^oC to 18^oC and 28^oC to 50^oC. 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	3.47” (88mm) (W) x 7.52” (191mm) (L) x 1.42” (36mm) (H).
Weight	Approximately 10.4oz. (300g.)
Accessories	Safety Test Lead 1 pair

2-2 Measurement Ranges (Accuracy: 1 year 18^oC to 28^oC)

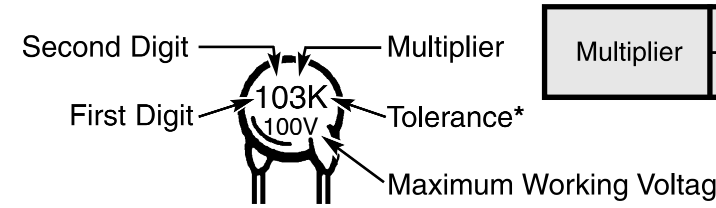
DC Voltage

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	±0.5% of rdg ± 2dgt	

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

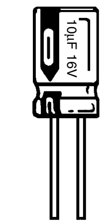
IDENTIFYING CAPACITOR VALUES

Capacitors will be identified by their capacitance value in pF (picofarads), nF (nanofarads), or µF (microfarads). Most capacitors will have their actual value printed on them. Some capacitors may have their value printed in the following manner. The maximum operating voltage may also be printed on the capacitor.



The value is 10 x 1,000 =
10,000pF or .01µF 100V

Multiplier	For the No.	0	1	2	3	4	5	8	9
	Multiply By	1	10	100	1k	10k	100k	.01	0.1



Note: The letter “R” may be used at times to signify a decimal point; as in 3R3 = 3.3

*The letter M indicates a tolerance of ±20%
The letter K indicates a tolerance of ±10%
The letter J indicates a tolerance of ±5%

IDENTIFYING RESISTOR VALUES

Use the following information as a guide in properly identifying the value of resistors.

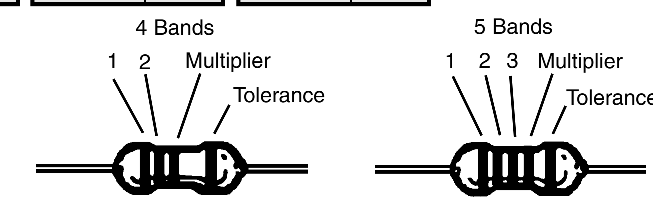
BAND 1 1st Digit Color	Digit
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

BAND 2 2nd Digit Color	Digit
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

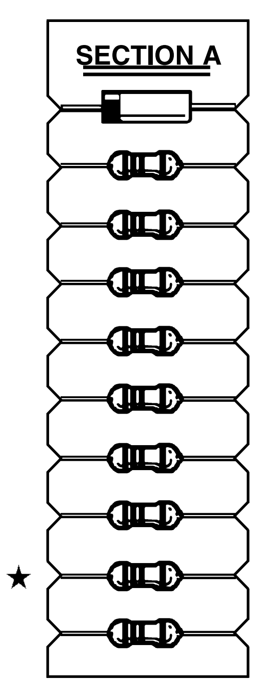
BAND 3 (if used) 3rd Digit Color	Digit
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

Multiplier Color	Multiplier
Black	1
Brown	10
Red	100
Orange	1,000
Yellow	10,000
Green	100,000
Blue	1,000,000
Silver	0.01
Gold	0.1

Resistance Tolerance Color	Tolerance
Silver	±10%
Gold	±5%
Brown	±1%
Red	±2%
Orange	±3%
Green	±0.5%
Blue	±0.25%
Violet	±0.1%



PART IDENTIFICATION CARDS



★ EXAMPLE

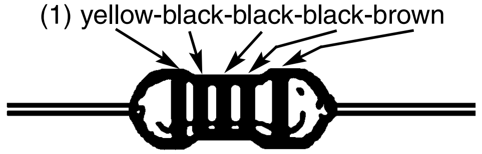
To help identify the resistors and diodes used in the construction of your digital multimeter we have mounted the diodes and resistors of each section onto a card. The card will help you find the diodes and resistors quickly. THE PARTS WILL NOT NECESSARILY BE LISTED IN THE ORDER SHOWN IN THE PARTS LIST SECTION OR IN THE ASSEMBLY PROCEDURE.

When you are ready to assemble the meter kit, follow the procedure shown. For an example refer to page 11 for assembly of Section “A”. The first resistor called for is R-20, 110kΩ resistor (brown-brown-yellow-gold). Locate it on the card (★), verify that it is the correct value. Some resistors may be mounted backwards on the card so you must be certain that you are reading the resistors correctly. When the correct value has been established, only then will you mount it into its correct position on the PC board.

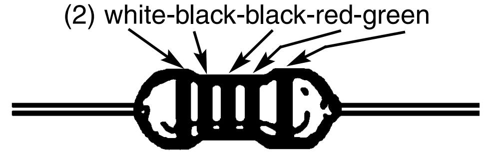
RESISTOR READING EXERCISE

Before starting assembly of your digital multimeter project, you should be thoroughly familiar with the 5 band color code system. Many of the resistor values will be identified by color bands and it is easy to mistake their value if you read the colors incorrectly or read the value from the wrong end. Do the following exercise in resistor values. Place your answer in the box beneath the resistor. Answers are on the bottom of this page.

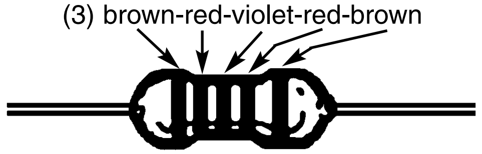
(1) yellow-black-black-black-brown



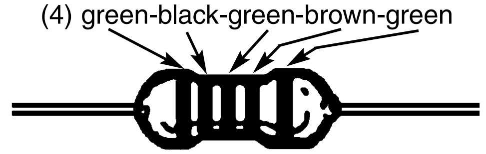
(2) white-black-black-red-green



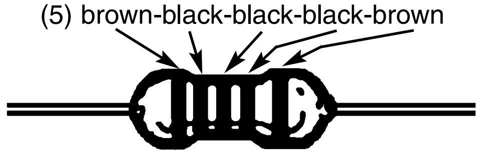
(3) brown-red-violet-red-brown



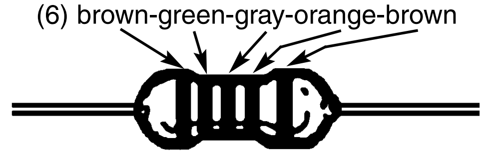
(4) green-black-green-brown-green



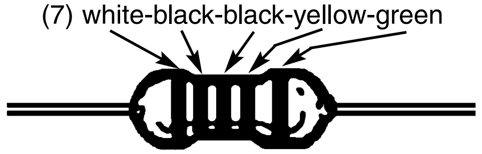
(5) brown-black-black-black-brown



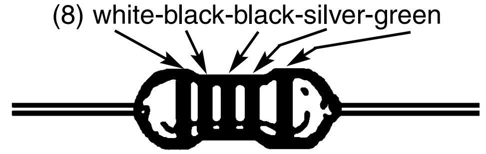
(6) brown-green-gray-orange-brown



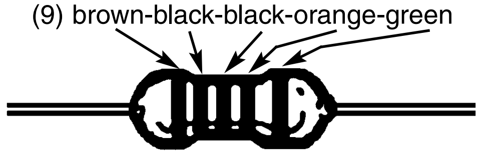
(7) white-black-black-yellow-green



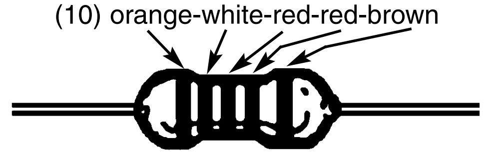
(8) white-black-black-silver-green



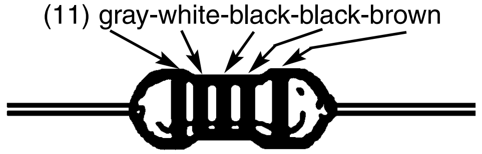
(9) brown-black-black-orange-green



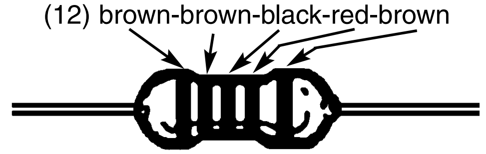
(10) orange-white-red-red-brown



(11) gray-white-black-black-brown



(12) brown-brown-black-red-brown



Answers to Resistor Reading Exercise: 1) 400Ω±1%; 2) 90KΩ±.5%; 3) 12.7KΩ±1%; 4) 5.05KΩ±.5%; 5) 100Ω±1%; 6) 158KΩ±1%; 7) 9MΩ±.5%; 8) 9Ω±.5%; 9) 100KΩ±.5%; 10) 39.2KΩ±1%; 11) 890Ω±1%; 12) 11KΩ±1%;

REINSTALLATION OF THE RANGE SELECTOR KNOB

If you removed the range selector knob for troubleshooting, then follow the instructions below to reinstall it.

Place the PC board over the range selector knob and fasten the knob to the PC board with a M2.3 x 8 screw. **CAUTION:** Do not overtighten the screw. The knob should be snug, but not loose. Turn back the M2.3 x 8 screw 1/2 turn. Slip the two shims under the knob (see Figure L). If they do not slip in, turn back the screw another 1/4 turn. Tighten the screw just enough so that the shims can be pulled out. You should now have the proper tension to hold the knob and contacts in place and rotate the knob to the desired positions.

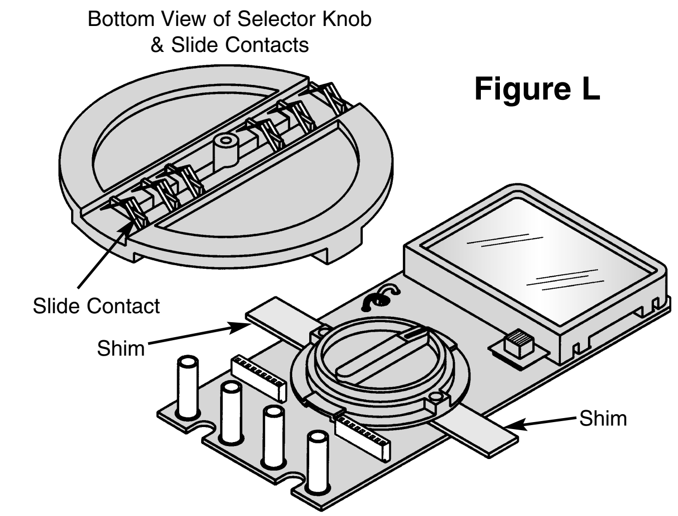


Figure L

USING THE DIGITAL MULTIMETER

Familiarize yourself with your new digital meter by taking readings of known resistances and voltages. You will find that the readings will not be as accurate on certain ranges for a given measurement. For example, when measuring a low resistance on a high range, the reading will show a short 0.00. When measuring a high resistance on a low range, the reading will show infinity 1. Likewise, it is important to use the correct range when measuring voltages.

Table 1 shows an example of the readouts for different values of resistance. Table 2 shows an example of the readouts for 117VAC and 100VDC. The shaded area indicates the most accurate range. It must be remembered that the readings will shift slightly when switching to a different range.

MEASURED RESISTANCE	RANGE SETTING					
	200Ω	2kΩ	20kΩ	200kΩ	2MΩ	20MΩ
SHORT (LEADS TOUCHING)	* 00.1	.000	0.00	00.0	.000	0.00
INFINITY	1 .	1.	1 .	1 .	1.	1 .
47Ω	52.1	.052	0.05	00.0	.000	0.00
270Ω	1 .	.267	0.26	00.2	.000	0.00
10kΩ	1 .	1.	10.18	10.2	.010	0.01
47kΩ	1 .	1.	1 .	52.7	.052	0.05
470kΩ	1 .	1.	1 .	1 .	.472	0.47
2.2MΩ	1 .	1.	1 .	1 .	1.	2.12

* RESISTANCE OF TEST LEADS

Table 1

Table 2

MEASURED VOLTAGE	200mV	2V	20V	200V	1000V
117VAC	1 .	1.	1 .	117.0	117
100VDC	1 .	1.	1 .	100.0	100

Amps Section

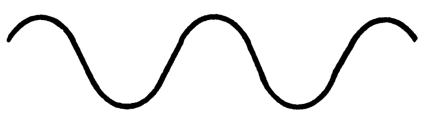
1. 200mA scale not working:
   - A. Check fuse.
   - B. Measure across (A) terminal and (COM) terminal for 1Ω (set meter in 200mA).
     1. Lower or higher than 1Ω, Check R13.
2. 20mA scale not working:
   - A. Check fuse.
   - B. Measure between (A) terminal and (COM) for 10Ω (set meter in 20mA).
     1. Lower or higher than 10Ω, check R12 and R13.

Capacitance Section

1. Place .001µF cap in the socket and check pin 7 and pin 8 of U4 with a scope (meter set to 2N).

Pin 7 370Hz - 400Hz .12Vpp.

Pin 14 370Hz - 400Hz .3Vpp.



- A. No signal at pin 14.
  1. Check D3, D4 and shorts.
- B. No signal at pin 7 but present at pin 1.
  1. Check D5 and D6.

h_{FE} Section

1. Check for shorts on socket pins.
2. Measure across B terminal to COM terminal for 251kΩ.
   - A. Lower or higher than 251kΩ; Check R14 and R15.

Decimal Point Section

1. Displays two decimal points.
   - A. Shorted output on U2.
2. No decimal points displayed.
   - A. Check U2 325.

Diode

1. Measure voltage across V OHM and COM terminal (set in diode mode) = 1.3V.
   - A. Low voltage, check R26.

Battery Low Indicator

1. Not working.
   - A. Check ZD1, R19 and U2.

SECTION A

Meter Display Circuit

PARTS LIST - SECTION A

If any parts are missing or damaged, see instructor or bookstore. **DO NOT** contact your place of purchase as they will not be able to help you.
Contact Elenco™ Electronics (address/phone/e-mail is at the back of this manual) for additional assistance, if needed.

RESISTORS

Qty.	Symbol	Description	Color Code	Part #
☐ 1	R24	56kΩ 5% 1/4W	green-blue-orange-gold	155600
☐ 1	R19	100kΩ 5% 1/4W	brown-black-yellow-gold	161000
☐ 1	R20	110kΩ 5% 1/4W	brown-brown-yellow-gold	161100
☐ 6	R16, 17, 18, 21, 22, 23	1MΩ 5% 1/4W	brown-black-green-gold	171000

Note: Resistor tolerance (last band) of 5-band resistors may be green instead of brown.

CAPACITORS

Qty.	Symbol	Value	Description	Part #
☐ 1	C2	100pF (101)	Ceramic Capacitor	221017
☐ 1	C3	.047µF (473)	Mylar Capacitor	244717
☐ 1	C4	.1µF (104)	Mylar Capacitor	251017
☐ 2	C5, C6	.22µF (224)	Mylar Capacitor	252217

SEMICONDUCTORS

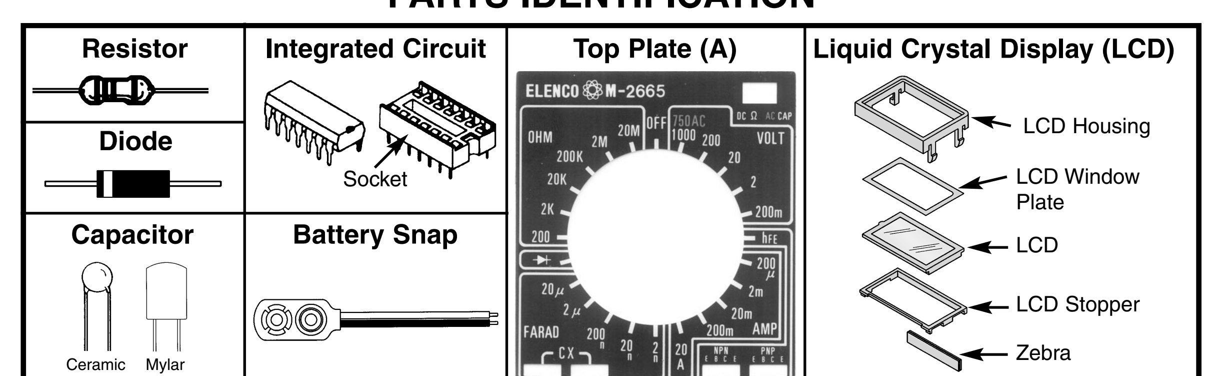
Qty.	Symbol	Value	Description	Part #
☐ 1	ZD	1N5232/1N752	Zener Diode	315232
☐ 1	U2	4030/4070	Integrated Circuit	334030
☐ 1	U1	7106R	Integrated Circuit	337106R

MISCELLANEOUS

Qty.	Description	Part #	Qty.	Description	Part #
☐ 1	Liquid Crystal Display (LCD)	35114A	☐ 1	LCD Stopper	629005
☐ 1	Zebra	500000	☐ 1	LCD Housing	629007
☐ 1	PC Board	516000A	☐ 2	M2.3 x 6 Screw	642360
☐ 1	Solder Roll	551135	* ☐ 1	M2.3 x 8 Screw	642430
☐ 1	Battery Snap (BAT)	590098	☐ 1	IC Socket 40-Pin	664040
☐ 1	Battery	590009	* ☐ 6	Slide Contact	680016
☐ 1	LCD Window Plate	621002A	☐ 1	Top Plate (A)	724001A
* ☐ 1	Range Selector Knob	622003	☐ 2	Shims (see page 26)	780006
* ☐ 1	Bushing	624004			

* Parts installed on PC board already.

PARTS IDENTIFICATION



ASSEMBLE THE FOLLOWING COMPONENTS TO THE PC BOARD

In all of the following steps **the components must be installed on the top legend side of the PC board. The board is turned to solder the component leads on the selector switch side**.

Figure A

Align the notch on the socket (if any) with the notch marked on the PC board. Solder the socket to the PC board. Insert the IC into the socket with the notch as shown below. **Note: If the IC is already inserted into the socket, do not attempt to pull it out, as this will damage the IC and socket. Instead, solder the socket to the PC board with the IC in it.**

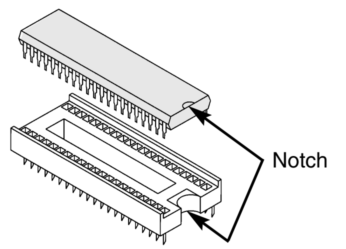


Figure B

Lay resistor flat against the PC board.

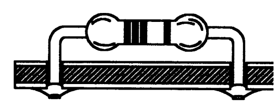
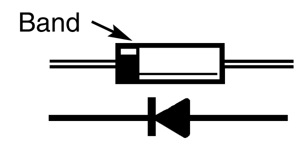
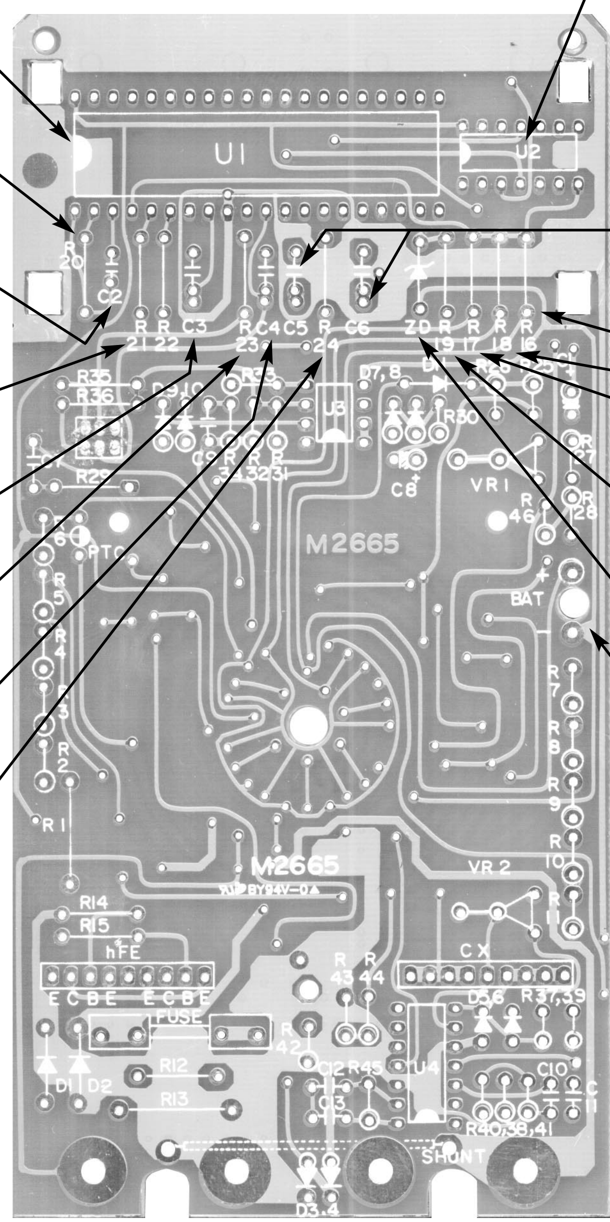


Figure C

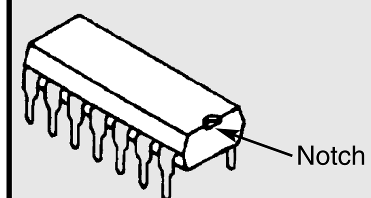
Mount the diodes with the band in the correct direction as shown on the top legend.



- □ U1 - IC Socket 40-pin
- □ U1 - 7106R IC (see Figure A)
- □ R20 - 110kΩ 5% 1/4W Res. (brown-brown-yellow-gold) (see Figure B)
- □ C2 - 100pF (101) Ceramic Cap. (see Figure D)
- □ R21 - 1MΩ 5% 1/4W Res.
- □ R22 - 1MΩ 5% 1/4W Res. (brown-black-green-gold) (see Figure B)
- □ C3 - .047µF (473) Mylar Cap. (see Figure D)
- □ R23 - 1MΩ 5% 1/4W Res. (brown-black-green-gold) (see Figure B)
- □ C4 - .1µF (104) Mylar Cap. (may be marked 104) (see Figure D)
- □ R24 - 56kΩ 5% 1/4W Res. (green-blue-orange-gold) (see Figure B)

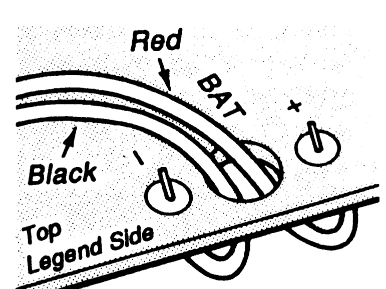


- □ U2 - 4030 IC or 4070
  No IC socket used



Solder the IC to the PC board with the notch in the direction shown on the top legend.

- □ C5 - .22µF (224) Mylar Cap
- □ C6 - .22µF (224) Mylar Cap. (see Figure D)
- □ R16 - 1MΩ 5% 1/4W Res.
- □ R18 - 1MΩ 5% 1/4W Res.
- □ R17 - 1MΩ 5% 1/4W Res. (brown-black-green-gold) (see Figure B)
- □ R19 - 100kΩ 5% 1/4W Res. (brown-black-yellow-gold) (see Figure B)
- □ ZD - 1N5232 Diode (see Figure C)
- □ BAT - Battery Snap
  Insert both wires through the hole and mount the red wire to the (+) hole and the black wire to the (–) hole. Solder the wires from the top legend side.



Mount the capacitors with 1/4" of space between the body and the PC board. Bend cap over as shown.

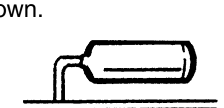


Figure D

TROUBLESHOOTING GUIDE

If the meter is not working, perform the U1 (7106R) Voltage Test first. This test is to verify that the IC and Reference Voltage are operational. Then perform the tests that pertain to the Function that is not working on your meter.

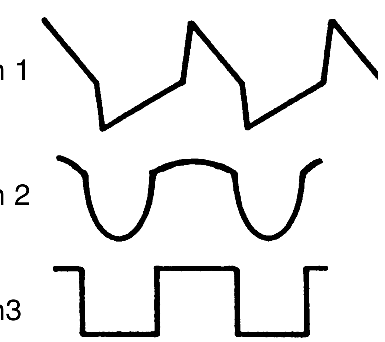
U1 (7106R) Voltage Test

1. Measure the voltage across pin 40 and pin 15 on U1 (7106R) for 9V.
   - A. Check the battery connection.
   - B. Check for a 9V and GND short.
     1. One of the ICs may be bad. Remove one IC at a time and check voltage again between pins 40 - 15.
2. Measure the voltage across pin 40 and pin 9 on U1 for 3V.
   - A. U1 is defective.
3. Check the Main Oscillator on U1 (7106R) pins 1, 2, 3.

Pin 1

Pin 2

Pin3



4. Measure the voltage across pin 5 and pin 6 on U1 (7106R) for 70mV - 105mV (reference voltage).
   - A. Adjust VR1 so the the junction of R46, R27 and R28 equal to 100mV.
     1. Can't set to 100mV.
        - a. VR1 wrong value or defective.
        - b. R25, R27 and R28 wrong value.
   - B. Can't obtain 100mV between pin 5 and pin 6.
     1. Check R21 and R46.

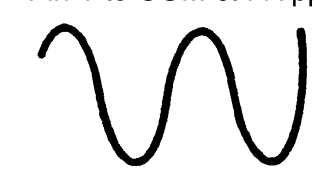
Voltage/OHM Section

1. Measure across V OHM terminal and COM terminal for 10MΩ (set meter in 200mV) battery installed.
   - A. Lower or higher than 10MΩ.
     1. Check resistors R1 - R6.
2. LCD readings floating.
   - A. Measure across the COM terminal to pin 6 on U1 (7106R) for 1MΩ.
     1. R22 open or defective.

AC Voltage Section

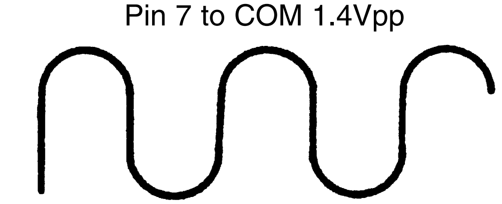
1. Apply 15VAC to meter and measure pin 1 and pin 7 of U3 (358) to COM terminal with a scope (meter on 20VAC scale).

Pin 1 to COM 0.44Vpp



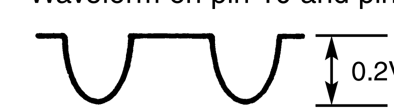
   - A. Check DC/AC switch
   - B. Check C7, R29 - R32, D7, D8 and U3.

Pin 7 to COM 1.4Vpp



   - A. Check R33 - R36, D9, D10, C9 and U3.
2. Check pin 10 and pin 11 of U1 (7106R) with a scope.

Waveform on pin 10 and pin 11.



   - A. Check C4 and R23.

Testing Procedure SECTION C - AC voltage and current circuit

Measure an AC voltage with a known accurate meter. Now measure the voltage with the kit meter. The meters should be the same voltage.

Connect the kit meter and another meter of known accuracy in series. Set the meters in the 200mA position. Construct a circuit for an AC current and measure the circuit current. Both meters should have close to the same readings. If the meters do not agree, check the parts just added. Do not re-adjust VR1 this will change the voltage reading set in step 1. Check the 200µ - 200mA scales. The 20A scale requires, a circuit of 1 - 10 amps. If the tests are not working, check for cold solder joints and part values. **DO NOT PROCEED TO SECTION F WITHOUT INSTRUCTORS APPROVAL.**

Testing Procedure SECTION F

Set the meter in one of the farad scales. Make sure that SW1 is in the AC/Cap position. Measure a cap with another meter and then insert the same cap into the kit meters CX connectors. Adjust VR2 so that the meter reads the same as the accurate one. This calibrates capacitance circuit of meter. Using two or three different value capacitors, check each scale. Compare the kit meter readings with another meter. Turn the meter off and remove the battery.

Set the meter in the h_{FE} scales. Place an NPN transistor into the socket. Make sure that the transistor is in correctly. Depending on the type of transistor, the meter will range from 20 to 550. Place a PNP transistor into the PNP socket, the range will also be 20 to 550. If the tests are not working, check for cold solder joints and part values.

ASSEMBLE THE LCD

- ☐ Assemble the LCD into the housing with the parts shown in Figure E. The LCD must be put in with the notch in the direction shown in Figure E. Peel off the clear protective film on top of the LCD (see Figure G), then place the LCD plate into the housing with the two curved corners on the inside of the plate in the same direction as the two curved corners on the housing. Wipe off zebra edges with a lint-free cloth.
- ☐ Mount the LCD unit to the PC board. Insert the two pins on the side shown in Figure E into the holes on the PC board. Then push the other end down until it snaps into place.
- ☐ Screw the LCD housing to the PC board with two M2.3 x 6 screws as shown in Figure E.

Testing Procedure

Placing the top plate (A) over the knob will assist in obtaining the correct knob position when doing tests.

Connect the 9V battery and turn the range selector. The LCD will display random numbers. As you turn the knob clockwise, the decimal point will move also. Check that all of the segments that make up the certain number are displayed. If the LCD is working correctly, move the knob to the off position and remove the battery. If the tests are not working, check for cold solder joints, part values and if the LCD is assembled correctly. **DO NOT PROCEED TO SECTION B WITHOUT INSTRUCTOR'S APPROVAL.**

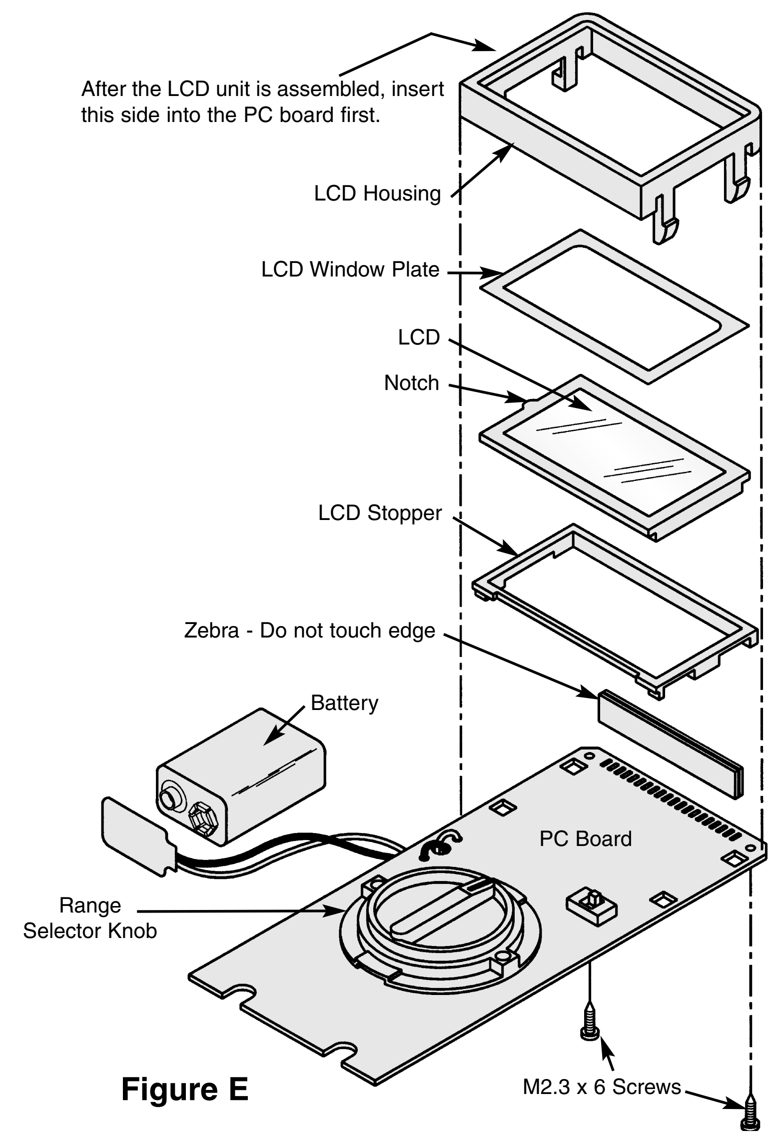


Figure E

NOTE: If the range selector switch becomes hard to turn, then loosen the M2.3 x 8 screw slightly.

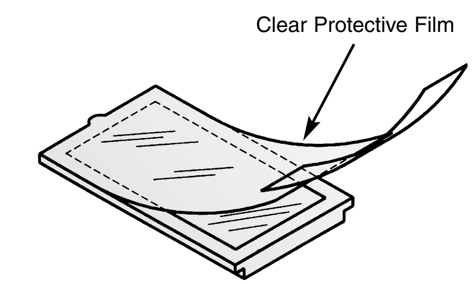


Figure F

SECTION B
DC Voltage & Current Circuit

PARTS LIST - SECTION B

RESISTORS

Qty.	Symbol	Description	Color Code	Part #
☐ 1	R13	1Ω .5% 1/2W	brown-black-gold-green / OR brn-blk-blk-sil-grn	111051
☐ 1	R12	9Ω .5% 1/4W	white-black-black-silver-green	119050
☐ 1	R6	100Ω .5% 1/4W	brown-black-black-black-green	131050
☐ 1	R5	900Ω .5% 1/4W	white-black-black-black-green	139050
☐ 1	R28	1.3kΩ 1% 1/4W	brown-orange-black-brown-brown	141230
☐ 1	R27	2kΩ 1% 1/4W	red-black-black-brown-brown	142030
☐ 1	R46	5.6kΩ 5% 1/4W	green-blue-red-gold	145600
☐ 1	R26	8.2kΩ 5% 1/4W	gray-red-red-gold	148200
☐ 1	R4	9kΩ .5% 1/4W	white-black-black-brown-green	149050
☐ 1	R25	39.2kΩ 1% 1/4W	orange-white-red-red-brown	153930
☐ 1	R3	90kΩ .5% 1/4W	white-black-black-red-green	159050
☐ 1	R2	900kΩ .5% 1/4W	white-black-black-orange-green	169050
☐ 1	R1	9MΩ .5% 1/2W	white-black-black-yellow-green	179051
☐ 1	VR1	200Ω / 220Ω	Potentiometer	191320

★ **Note:** Some resistors may not have a color coding, but they will have the value imprinted on them.

Note: Resistor tolerance (last band) of 5-band resistors may be green instead of brown.

CAPACITORS

Qty.	Symbol	Value	Description	Part #
☐ 1	C1	22μF	Electrolytic (Lytic)	272244

SEMICONDUCTORS

Qty.	Symbol	Value	Description	Part #
☐ 2	D1, D2	1N4001 or 1N4007	Diode	314001

MISCELLANEOUS

Qty.	Symbol	Description	Part #
☐ 1		Shunt Wire M1.6 x 60	100069
☐ 1		Fuse 2A	533020
* ☐ 1	SW1	Slide Switch	541104
☐ 1		Slide Switch Knob	622004
☐ 2		Fuse Holder Clips	663003
☐ 4		Input Socket	664000
☐ 1		Test Lead Set	RWTL14

* Part installed on PC board already

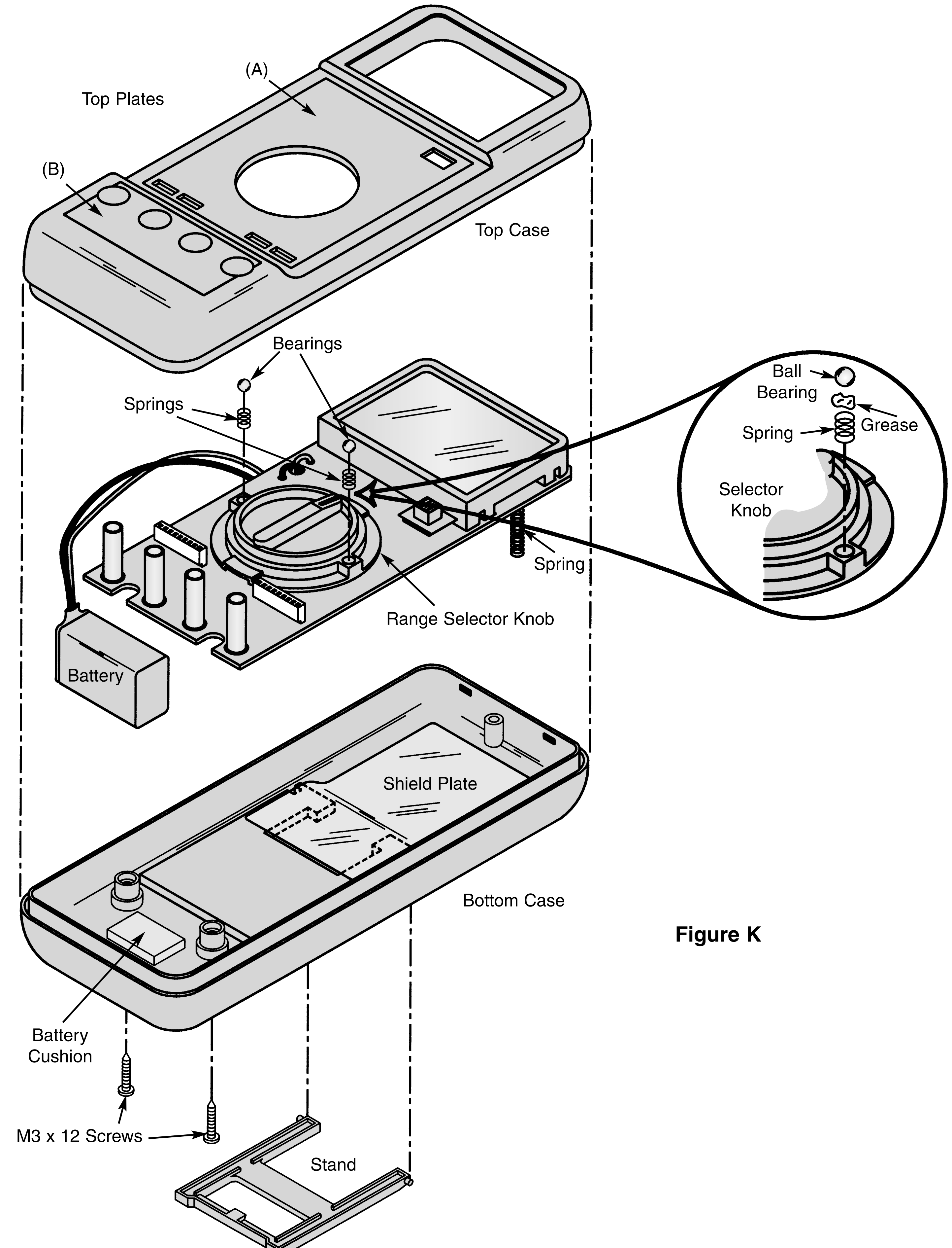


Figure K

FINAL ASSEMBLY

☐ Solder the spring to the PC board as shown in Figure Ja.

See Figure K for the following steps.

☐ Peel off the protective backing on the top plates (A) and (B) and stick them to the top case. Peel off the protective backing on the battery cushion and stick it onto the bottom case. **(These may be installed on the case already)**.

☐ Turn the selector knob screw one full turn out as shown in the figure.

☐ Place the PC board on a standard piece of paper (8 1/2” x 11”). Insert the two springs into the holes on the range selector knob. Put grease on top of the springs and then place a ball bearing on each spring. Press the top case onto the PC board. Using both hands, slide your fingers under the paper. Press your thumbs down on the top case and then flip the board. Be sure to hold the PC board to the case firmly or the ball bearings will fall out. Fasten the PC board to the top case with three M2.3 x 6 screws in the places shown in Figure J.

☐ Connect the battery and place it in the cavity of the top case.

☐ Place the bottom case onto the top case. Hold the two sections together with two M3 x 12 screws.

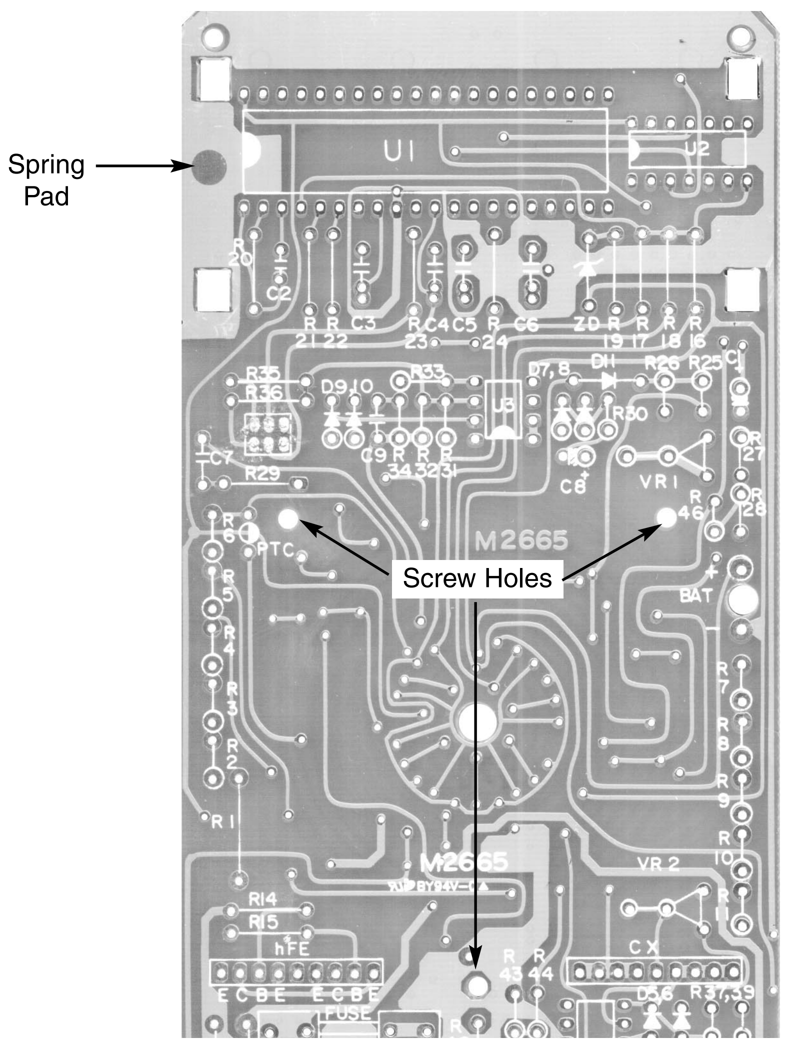


Figure J

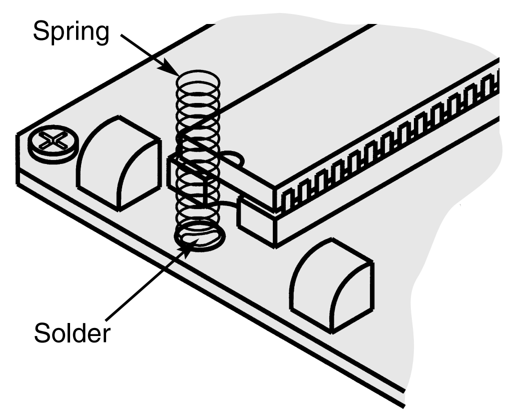


Figure Ja

ASSEMBLE THE FOLLOWING COMPONENTS TO THE PC BOARD

In all of the following steps **the components must be installed on the top legend side of the PC board. The board is turned to solder the component leads on the selector switch side**.

Figure E

Stand resistor on end as shown with the body inside the white circle.

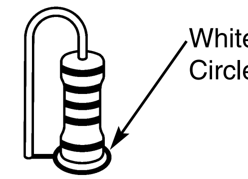
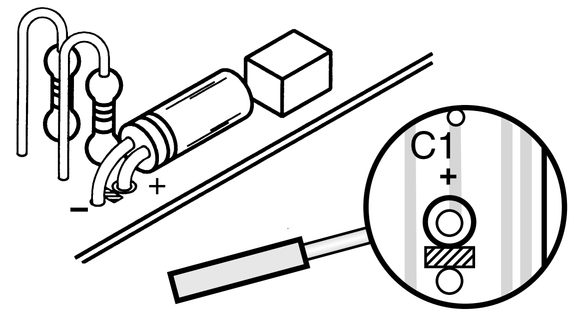


Figure F

Lytics have a polarity marking on them indicating the negative lead, the opposite lead is positive. The PC board is marked to show the positive (+) lead position. Mount the capacitor with the positive (+) lead in the hole marked on the PC board. Bend the capacitor over.



☐ R6 - 100Ω .5% 1/4W Res. (brown-blk-blk-blk-green) (see Figure E)

☐ R5 - 900Ω .5% 1/4W Res. (white-blk-blk-blk-green) (see Figure E)

☐ R4 - 9kΩ .5% 1/4W Res. (white-blk-blk-brown-green) (see Figure E)

☐ R3 - 90kΩ 1/4W .5% Res. (white-blk-blk-red-green) (see Figure E)

☐ R2 - 900kΩ .5% 1/4W Res. (white-blk-blk-orange-green) (see Figure E)

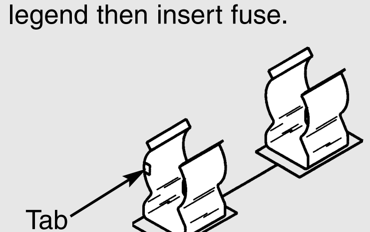
☐ R1 - 9MΩ .5% 1/2W Res. (white-blk-blk-yellow-green) (see Figure B)

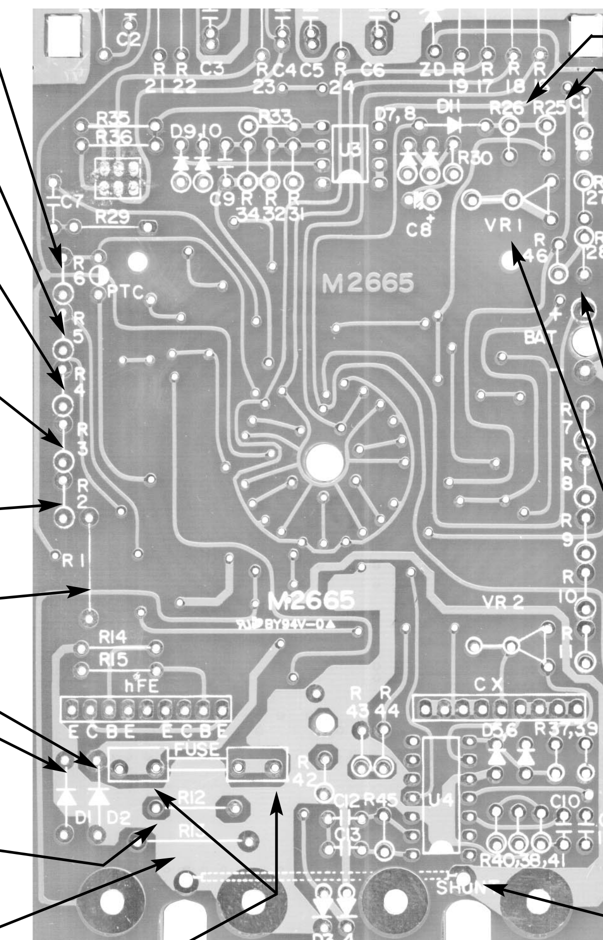
☐ D1 - 1N4001 Diode
☐ D2 - 1N4001 Diode
(see Figure C)

☐ R12 - 9Ω 1/4W .5% Res. (white-blk-blk-silver-green) (see Figure B)

☐ R13 - 1Ω .5% 1/2W Res. (brown-black-gold-green) (see Figure B)

☐ Fuse Holder Clips
☐ Fuse 2A
Mount holders with the tab side as shown on the top legend then insert fuse.





☐ R26 - 8.2kΩ 5% 1/4W Res. (gray-red-red-gold) (see Figure E)

☐ R25 - 39.2kΩ 1% 1/4W Res. (orange-white-red-red-brown) (see Figure E)

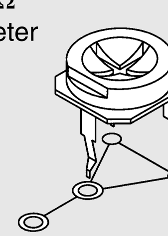
☐ C1 - 22µF Lytic Capacitor (see Figure F)

☐ R27 - 2kΩ 1% 1/4W Res. (red-blk-blk-brown-brown) (see Figure E)

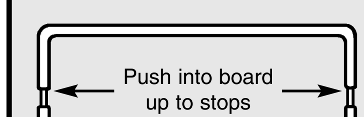
☐ R28 - 1.3kΩ 1% 1/4W Res. (brn-orange-blk-brn-brn) (see Figure E)

☐ R46 - 5.6kΩ 5% 1/4W Res. (green-blue-red-gold) (see Figure E)

☐ VR1 - 200Ω Potentiometer



☐ Shunt



☐ Push the four input sockets into the PC board holes from the selector switch side until they stop (see Figure G). Turn the board over as shown in Figure Ga and solder the sockets in place from the top legend side. Apply enough heat to allow the solder to flow around the input sockets (see Figure Gb).

☐ Push on the slide switch knob.

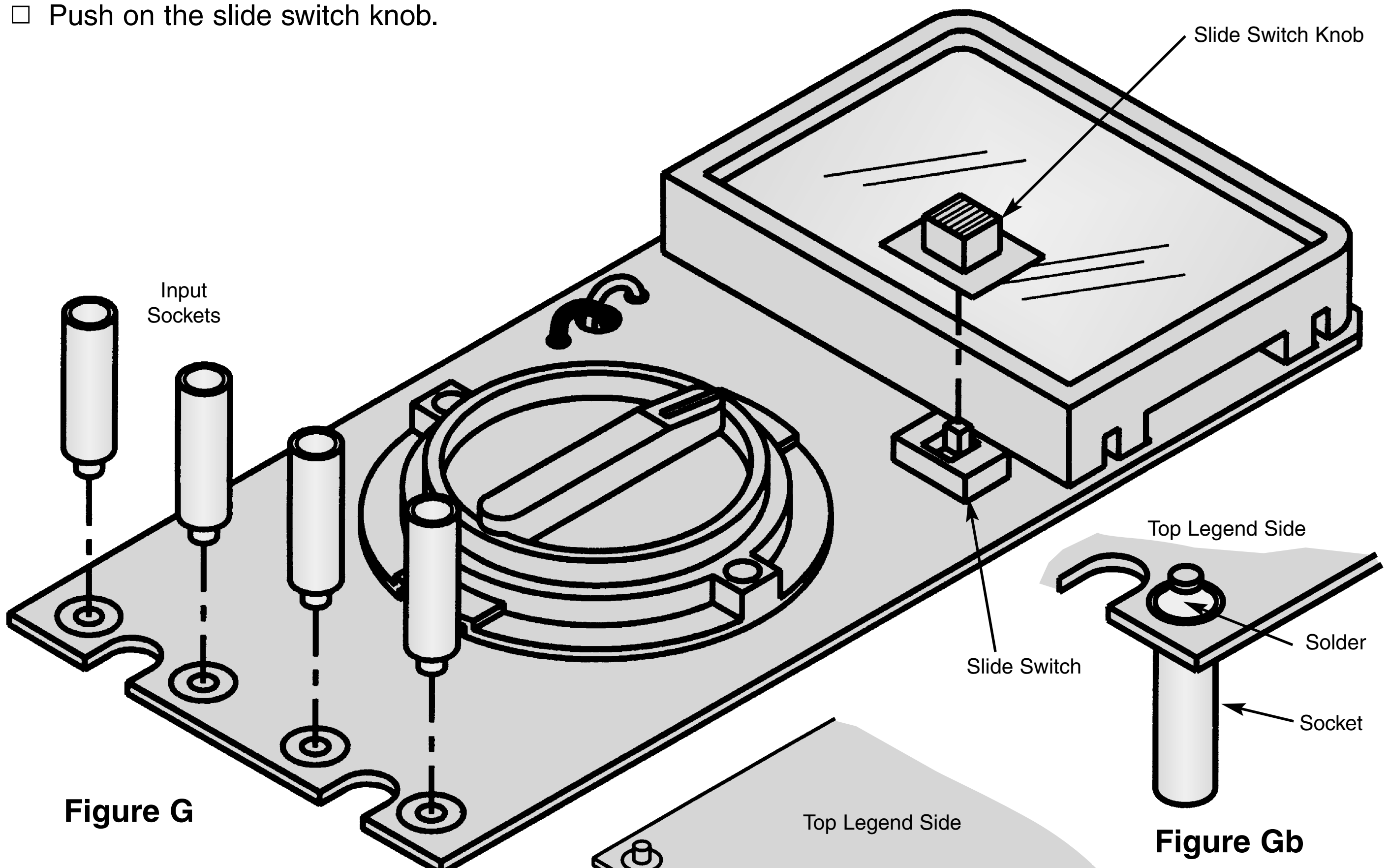


Figure G

Figure Gb

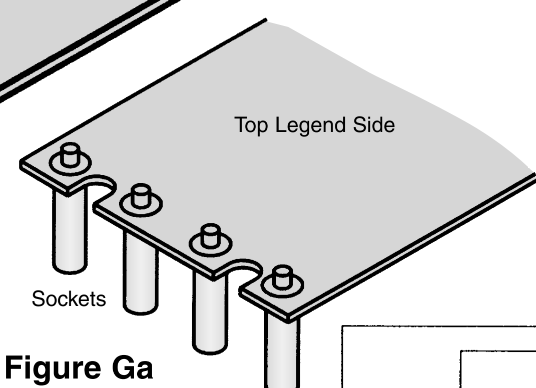


Figure Ga

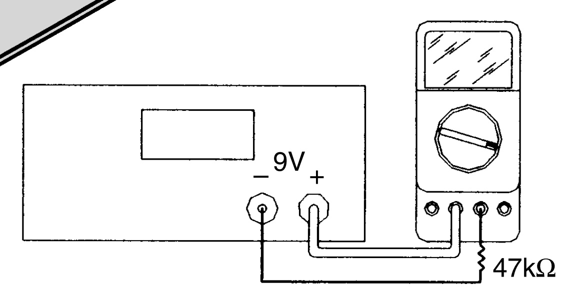


Figure Gc

Testing Procedure

Voltage Test

Connect the 9V battery to the meter. Turn the range selector knob to the 20V position and connect the test leads (red lead to VΩ and black to COM). Using another meter of known accuracy, measure a DC voltage less than 20V (such as a 9 volt battery). You will calibrate the kit meter by measuring the same voltage source and adjusting VR1 until the kit meter reads the same as the accurate meter. When the two meters agree, the voltage circuit is calibrated. Turn the range selector knob to the off position.

Current Test

Connect the kit meter and another meter of known accuracy in series. Set the meters in the 200μA position. Construct a circuit for a DC current (for example 9V and a 47kΩ resistor for 190μA) and measure the circuit. Both meters should have close to the same readings. If the meters do not agree, check the parts just added. Do not readjust VR1 for this will change the voltage reading set in step 1. Check that 200μA - 200mA scales. The 20A scale requires a circuit of 1 - 10 amps. If the tests are not working, check for cold solder joints and part values. Turn the meter off and remove the battery and test leads. **DO NOT PROCEED TO SECTION C WITHOUT YOUR INSTRUCTOR'S APPROVAL.**

☐ Mount the two 9-pin component sockets to the PC board with the notch at the base of the socket in the direction shown in Figure I. Solder the sockets in place from the top legend side.

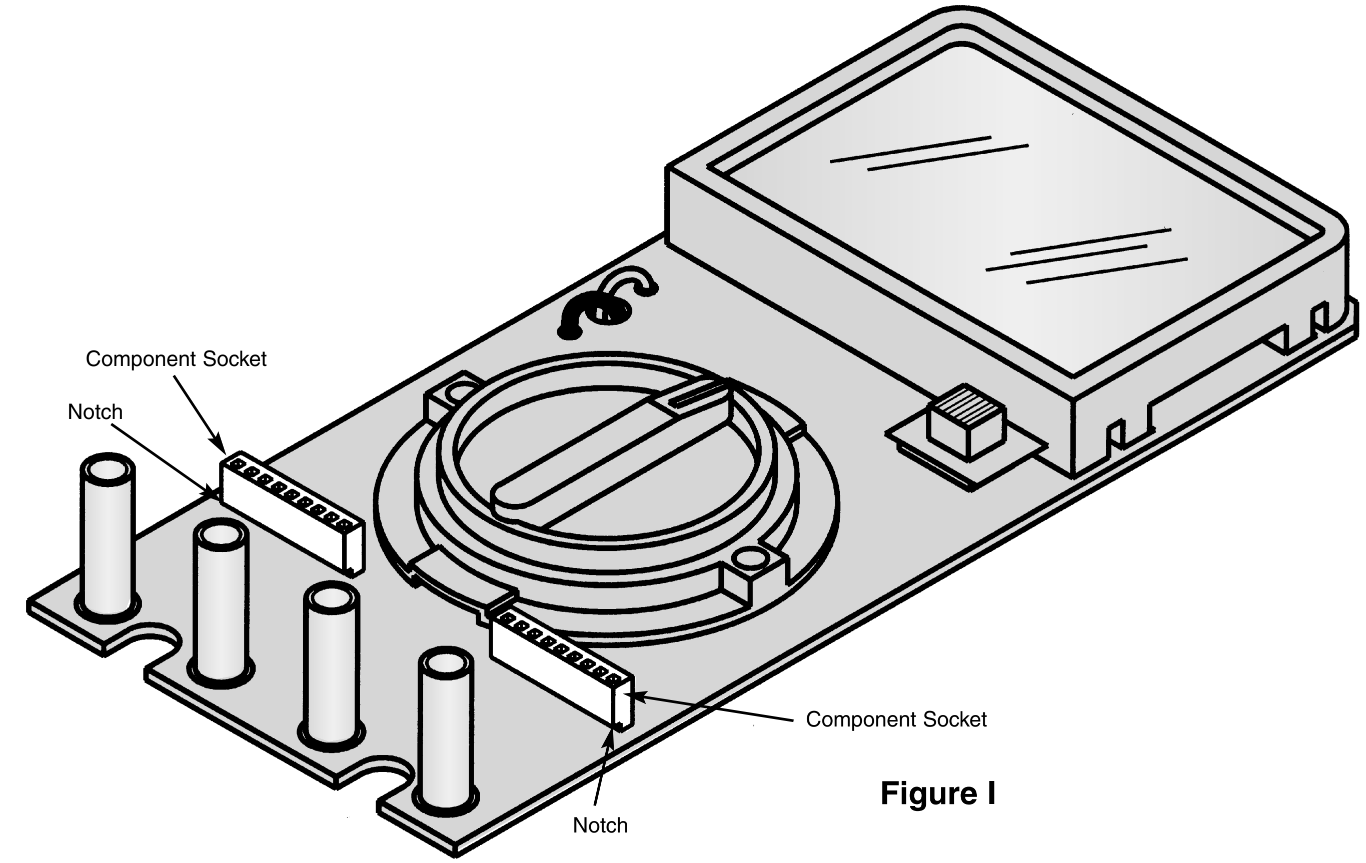
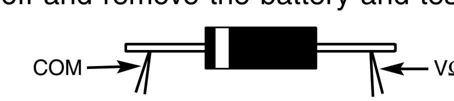


Figure I

Testing Procedure

Connect the 9V battery and test leads to the meter (red to VΩ and black to COM). Set the range selector knob to the diode scale and set SW1 in the DC Ohm position. Connect a diode to the test leads with the correct polarity (see figure below). The meter will range for 100 - 950. If the tests are not working, check for cold solder joints and part values. Turn the meter off and remove the battery and test leads.



DO NOT PROCEED TO SECTION E WITHOUT INSTRUCTOR'S APPROVAL.

SECTION F
Final Assembly

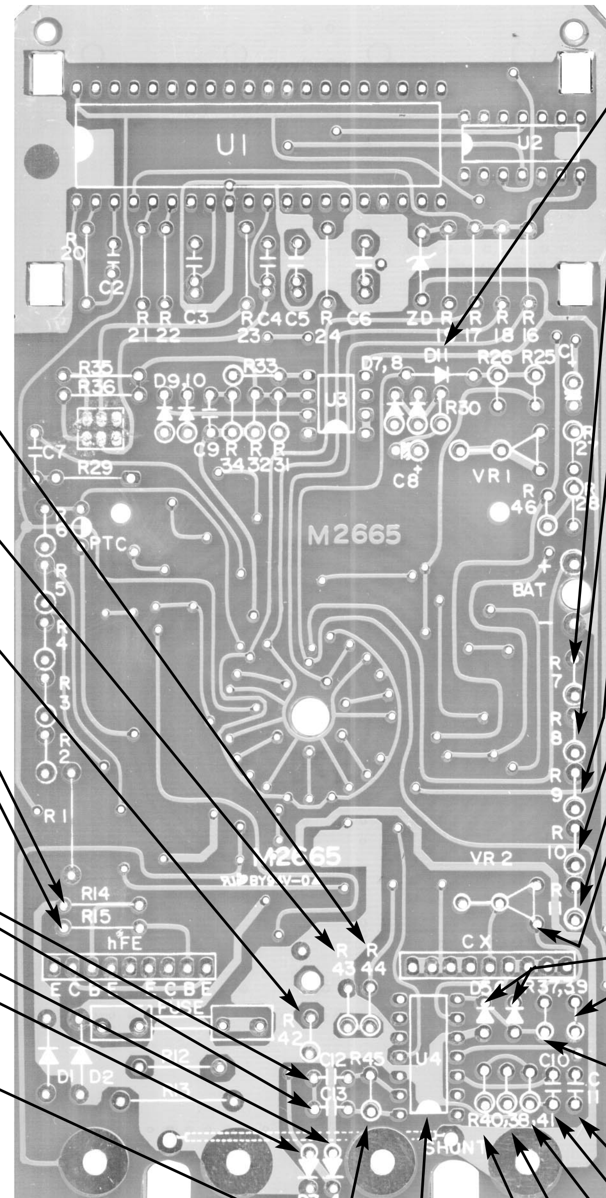
PARTS LIST - SECTION F

Qty.	Description	Part #	Qty.	Description	Part #
☐ 1	Battery Cushion	620001	☐ 1	Shield Spring	680008
☐ 1	Top Case	623101A	☐ 2	Knob Spring	680009
☐ 1	Bottom Case w/Stand	623200A	☐ 1	Top Plate (B)	724000A
☐ 3	Screw M2.3 x 6	642360	☐ 1	Shield	780008
☐ 2	Screw M3 x 12	642367	☐ 1	Grease	790004
☐ 2	Bearing	666001			

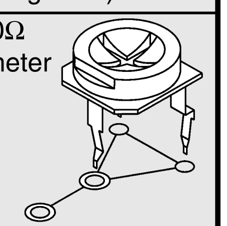
Note: The shield and battery cushion may be installed already.

ASSEMBLE THE FOLLOWING COMPONENTS TO THE PC BOARD

In all of the following steps **the components must be installed on the top legend side of the PC board. The board is turned to solder the component leads on the selector switch side**.



- ☐ D11 - 1N4148 Diode (see Figure C)
- ☐ R7 - 98.8Ω 1% 1/4W Res. (wht-gray-gray-gold-brn) (see Figure E)
- ☐ R8 - 900Ω 1% 1/4W Res. (wht-blk-blk-blk-brn) (see Figure E)
- ☐ R9 - 9kΩ 1% 1/4W Res. (wht-blk-blk-brn-brn) (see Figure E)
- ☐ R10 - 90kΩ 1% 1/4W Res. (wht-blk-blk-red-brn) (see Figure E)
- ☐ R11 - 909kΩ 1% 1/4W Res. (wht-blk-wht-org-brn) (see Figure E)
- ☐ VR2 - 200Ω Potentiometer

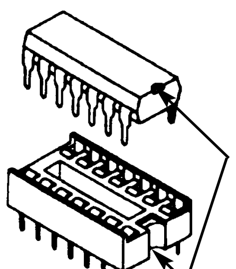


- ☐ D5 - 1N4001 Diode
- ☐ D6 - 1N4001 Diode (see Figure H)
- ☐ R39 - 39.2kΩ 1% 1/4W Res. (org-wht-red-red-brn) (see Figure E)
- ☐ R37 - 150Ω 5% 1/4W Res. (brn-grn-brn-gold) (see Figure E)
- ☐ C11 - .01µF (103) Mylar Cap.
- ☐ C10 - .01µF (103) Mylar Cap.
- ☐ R41 - 1.91kΩ 1% 1/4W Res. (brn-wht-brn-brn-brn) (see Figure E)
- ☐ R38 - 10kΩ 1% 1/4W Res. (brn-blk-blk-red-brn) (see Figure E)
- ☐ R40 - 4.12kΩ 1% 1/4W Res. (yel-brn-red-brn-brn) (see Figure E)

- ☐ R44 - 76.8kΩ 1% 1/4W Res. (violet-blue-gray-red-brown) (see Figure E)
- ☐ R43 - 11kΩ 1% 1/4W Res. (brown-brown-blk-red-brn) (see Figure E)
- ☐ R42 - 39.2kΩ 1% 1/4W Res. (orange-white-red-red-brn) (see Figure E)
- ☐ R14 - 240kΩ 5% 1/4W Res.
- ☐ R15 - 240kΩ 5% 1/4W Res. (red-yellow-yellow-gold) (see Figure B)
- ☐ C12 - .01µF (103) Mylar Cap.
- ☐ C13 - .01µF (103) Mylar Cap.
- ☐ D3 - 1N4001 Diode
- ☐ D4 - 1N4001 Diode (see Figure H)
- ☐ R45 - 158kΩ 1% 1/4W Res. (brown-grn-gray-orange-brn) (see Figure E)

- ☐ U4 - IC Socket 14-pin
- ☐ U4 - 324 Integrated Circuit

Align the notch on the socket (if any) with the notch marked on the PC board. Solder the socket to the PC board. Insert the IC into the socket with the notch as shown below.



SECTION C

AC Voltage & Current Circuit

PARTS LIST - SECTION C

RESISTORS

Qty.	Symbol	Description	Color Code	Part #
☐ 1	R31	5.05kΩ .5% 1/4W	green-black-green-brown-green	145050
☐ 1	R33	5.6kΩ 5% 1/4W	green-blue-red-gold	145600
☐ 2	R35, 36	5.62kΩ .5% 1/4W	green-blue-red-brown-green	145650
☐ 1	R29	10kΩ 5% 1/4W	brown-black-orange-gold	151000
☐ 1	R32	200kΩ 5% 1/4W	red-black-yellow-gold	162000
☐ 1	R34	390kΩ 5% 1/4W	orange-white-yellow-gold	163900
☐ 1	R30	2.2MΩ 5% 1/4W	red-red-green-gold	172200

Note: Resistor tolerance (last band) of 5-band resistors may be green instead of brown.

CAPACITORS

Qty.	Symbol	Description	Color Code	Part #
☐ 1	C9	.1µF (104)	Ceramic	251010
☐ 1	C7	.1µF (104)	Mylar	251017
☐ 1	C8	22µF	Electrolytic (Lytic)	272244

SEMICONDUCTORS

Qty.	Symbol	Description	Color Code	Part #
☐ 4	D7 - D10	1N4148	Diode	314148
☐ 1	U3	358/17358	Integrated Circuit	330358

MISCELLANEOUS

Qty.	Symbol	Description	Color Code	Part #
☐ 1	U3	IC Socket 8-pin		664008

ASSEMBLE THE FOLLOWING COMPONENTS TO THE PC BOARD

In all of the following steps **the components must be installed on the top legend side of the PC board. The board is turned to solder the component leads on the selector switch side**.

- ☐ D9 - 1N4148 Diode
- ☐ D10 - 1N4148 Diode (see Figure H)
- ☐ R35 - 5.62kΩ .5% 1/4W Res.
- ☐ R36 - 5.62kΩ .5% 1/4W Res. (green-blue-red-brn-green) (see Figure B)
- ☐ C7 - .1µF (104) Mylar Cap.
- ☐ R29 - 10kΩ 5% 1/4W Res. (brown-black-orange-gold) (see Figure B)
- ☐ R34 - 390kΩ 5% 1/4W Res. (orange-white-yellow-gold) (see Figure E)
- ☐ R32 - 200kΩ 5% 1/4W Res. (red-black-yellow-gold) (see Figure E)
- ☐ R31 - 5.05kΩ .5% 1/4W Res. (green-blk-green-brn-green) (see Figure E)

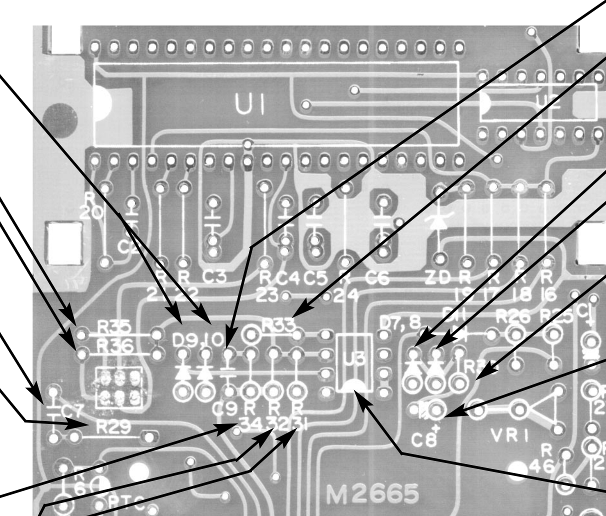


Figure H

Mount the diode with the band in the direction of the arrow on the top legend.

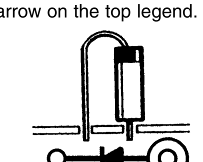
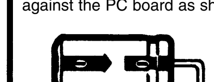
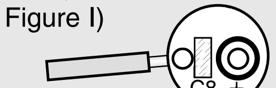


Figure I

Mount the capacitor with the negative (–) lead in the negative hole and the positive (+) lead in the positive hole marked on the PC board. Lay the capacitor flat against the PC board as shown.

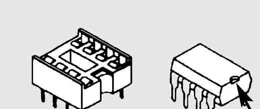


- ☐ C9 - .1µF (104) Ceramic Cap.
- ☐ R33 - 5.6kΩ 5% 1/4W Res. (green-blue-red-gold) (see Figure E)
- ☐ D7 - 1N4148 Diode
- ☐ D8 - 1N4148 Diode (see Figure H)
- ☐ R30 - 2.2MΩ 5% 1/4W Res. (red-red-green-gold) (see Figure E)
- ☐ C8 - 22µF Lytic Capacitor (see Figure I)



- ☐ U3 - IC Socket 8-pin
- ☐ U3 - 358 Integrated Circuit

Align the notch on the socket (if any) with the notch marked on the PC board. Solder the socket to the PC board. Insert the IC into the socket with the notch as shown below.



SECTION D

Resistance Circuit

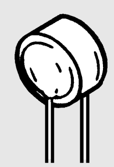
PARTS LIST - SECTION D

Qty	Symbol	Description	Part #
□ 1	PTC	1kΩ Thermister	190415

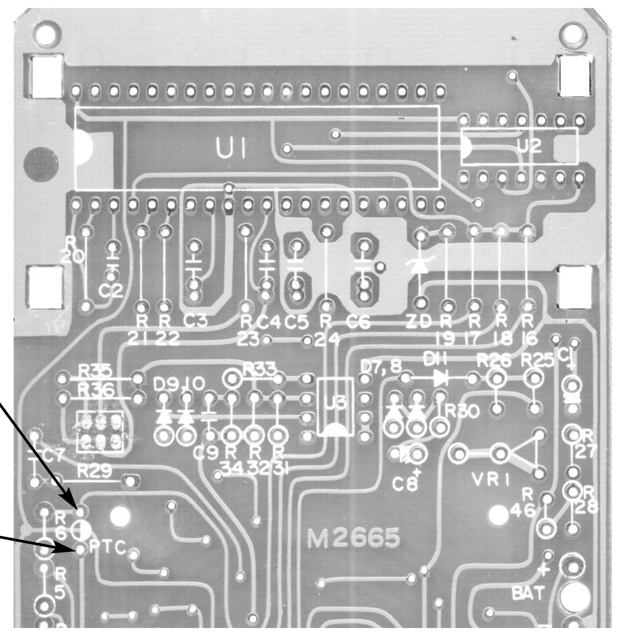
ASSEMBLE THE FOLLOWING COMPONENT TO THE PC BOARD

The other components for this section have been installed already.

□ PTC - Thermister 1kΩ



Mount part in holes shown only



Testing Procedure

Connect the 9V battery and test leads to the meter (red to VΩ and black to COM). Set the range selector knob to one of the Ohm scales. Make sure that SW1 is in the DC/Ohm position. Using two or three different value resistors, check each scale. Compare the kit meter readings with another meter of known accuracy. If the tests are not working, check for cold solder joints, part values, and the contacts on the selector knob to make sure that they are intact. Turn the meter off and remove the battery and test leads.

DO NOT PROCEED TO SECTION E WITHOUT INSTRUCTOR'S APPROVAL.

SECTION E

Capacitance and Transistor Testing Circuit

PARTS LIST - SECTION E

RESISTORS

Qty.	Symbol	Description	Color Code	Part #
□ 1	R7	98.8Ω 1% 1/4W	white-gray-gray-gold-brown	129830
□ 1	R37	150Ω 5% 1/4W	brown-green-brown-gold	131500
□ 1	R8	900Ω 1% 1/4W	white-black-black-black-brown	139030
□ 1	R41	1.91kΩ 1% 1/4W	brown-white-brown-brown-brown	141930
□ 1	R40	4.12kΩ 1% 1/4W	yellow-brown-red-brown-brown	144130
□ 1	R9	9kΩ 1% 1/4W	white-black-black-brown-brown	149030
□ 1	R38	10kΩ 1% 1/4W	brown-black-black-red-brown	151030
□ 1	R43	11kΩ 1% 1/4W	brown-brown-black-red-brown	151130
□ 2	R39, R42	39.2kΩ 1% 1/4W	orange-white-red-red-brown	153930
□ 1	R44	76.8kΩ 1% 1/4W	violet-blue-gray-red-brown	157630
□ 1	R10	90kΩ 1% 1/4W	white-black-black-red-brown	159030
□ 1	R45	158kΩ 1% 1/4W	brown-green-gray-orange-brown	161530
□ 2	R14, R15	240kΩ 5% 1/4W	red-yellow-yellow-gold OR red-yellow-black-orange-green	162400
□ 1	R11	909kΩ 1% 1/4W	white-black-white-orange-brown	169060
□ 1	VR2	200Ω / 220Ω	Potentiometer	191320

Note: Resistor tolerance (last band) of 5-band resistors may be green instead of brown.

CAPACITORS

Qty.	Symbol	Value	Description	Part #
□ 4	C10 - C13	.01μF (103)	Mylar	241017

SEMICONDUCTORS

Qty.	Symbol	Value	Description	Part #
□ 1	U4	324 / 17324	Integrated Circuit	330324
□ 4	D3 - D6	1N4001 or 1N4007	Diode	314001
□ 1	D11	1N4148	Diode	314148

MISCELLANEOUS

Qty.	Symbol	Description	Part #
□ 2	h_{FE}, CX	9-pin Socket	664009
□ 1	U4	IC Socket 14-pin	664014