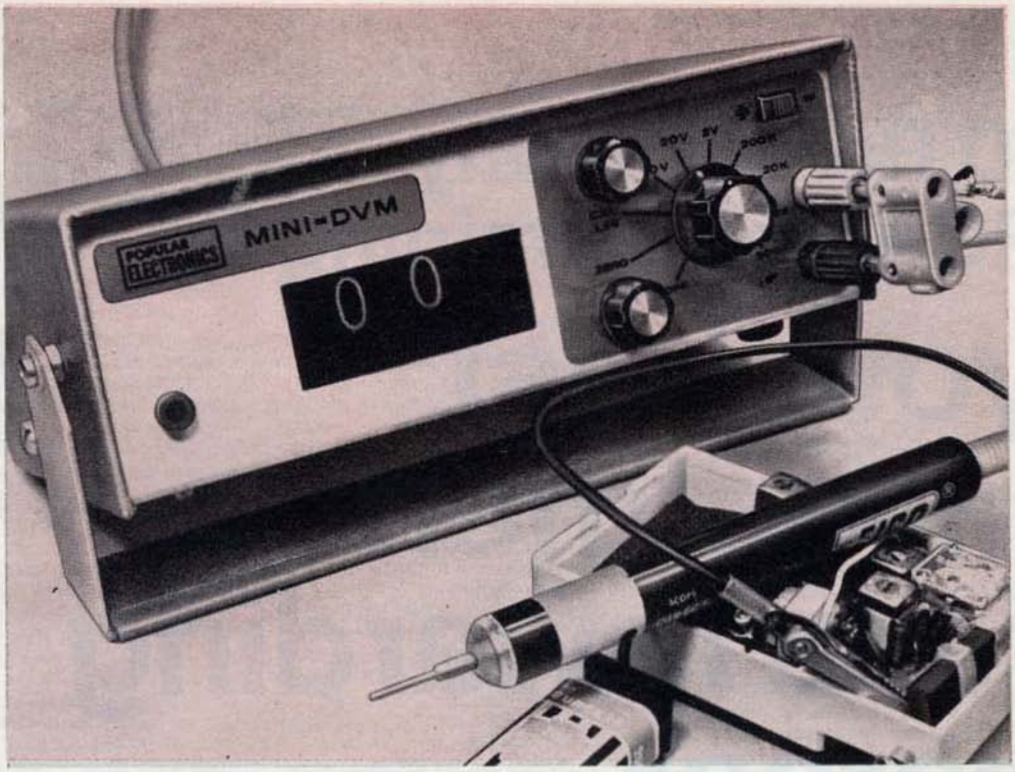


ASSEMBLING THE POPULAR ELECTRONICS

MINI-DVM

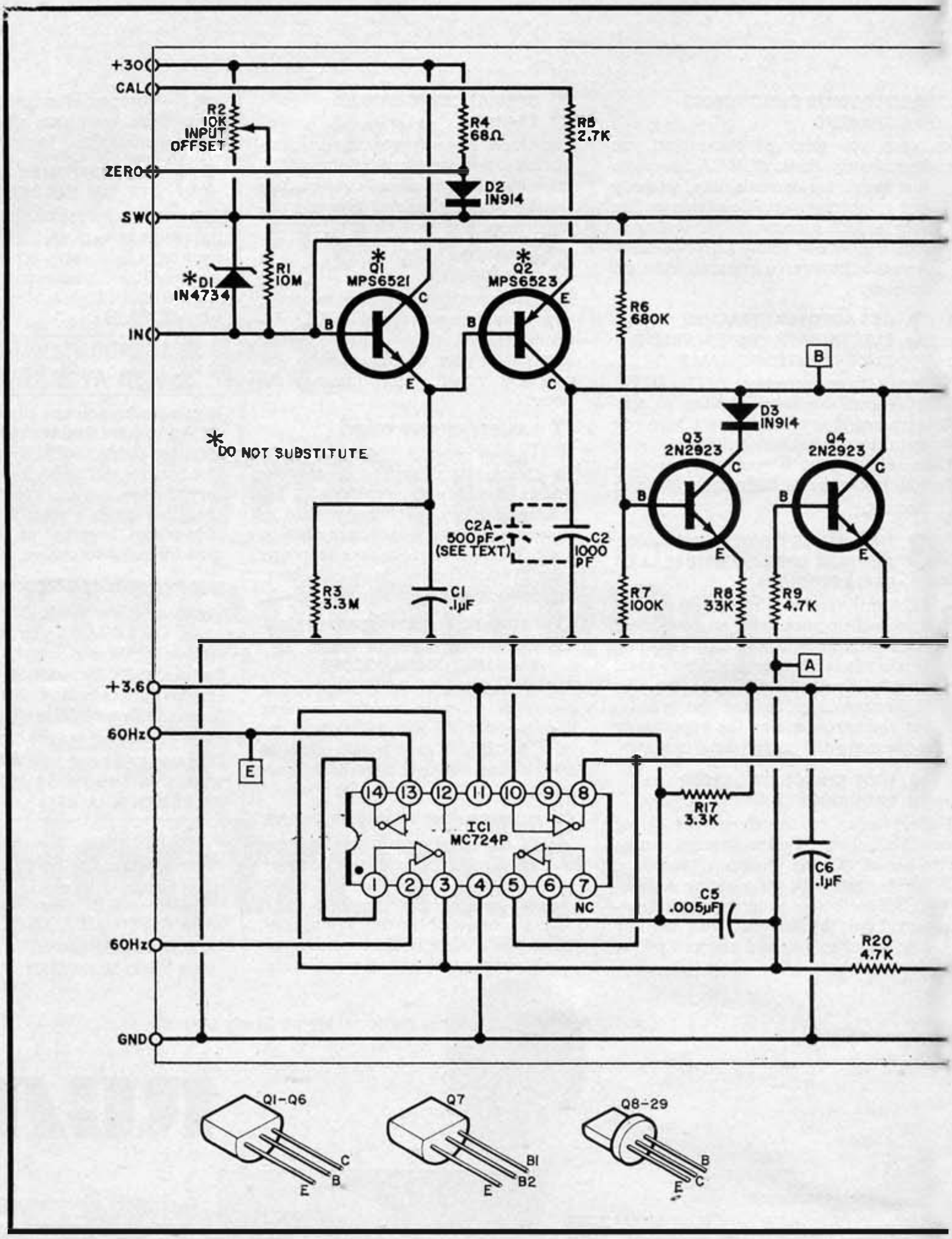
HIGH-QUALITY, LOW-COST MINIATURE DIGITAL VOLTOHMMETER

This is an up-graded version of the original Popular Electronics "Low-Cost Digital Voltohmmeter" that appeared in our December 1968 issue. Assembly has been eased, accuracy and stability improved, and the instrument may be constructed for a dollar outlay of less than the 1968 prototype. Detailed specifications appear on page 45. Full assembly details are published in this issue.

IT ISN'T OFTEN that you see a small, compact digital voltohmmeter with Nixie® tube readout that doesn't cost at least several hundred dollars. The "Mini-DVM" described here is a seven-range, high-impedance digital voltohmmeter with 1% accuracy that can be built for about the cost of a better-grade analog multimeter. It uses 2½-decade Nixie-tube numeric display to indicate—brightly and unambiguously—any d.c. voltage from 10 millivolts to 200 volts or any resistance value from 1 to 200,000 ohms. It has internal self-calibration and zeroing.

The Mini-DVM can be assembled in its own case or the internal electronics can be used as a 0-199 digital counter or panel meter to indicate digitally any quantity that can be converted into a 0-2-volt d.c. signal driving a 1-megohm load. Complete technical specifications are given in the Table. The instrument consists of a counter module, a power module, and some case-mounted controls and components.

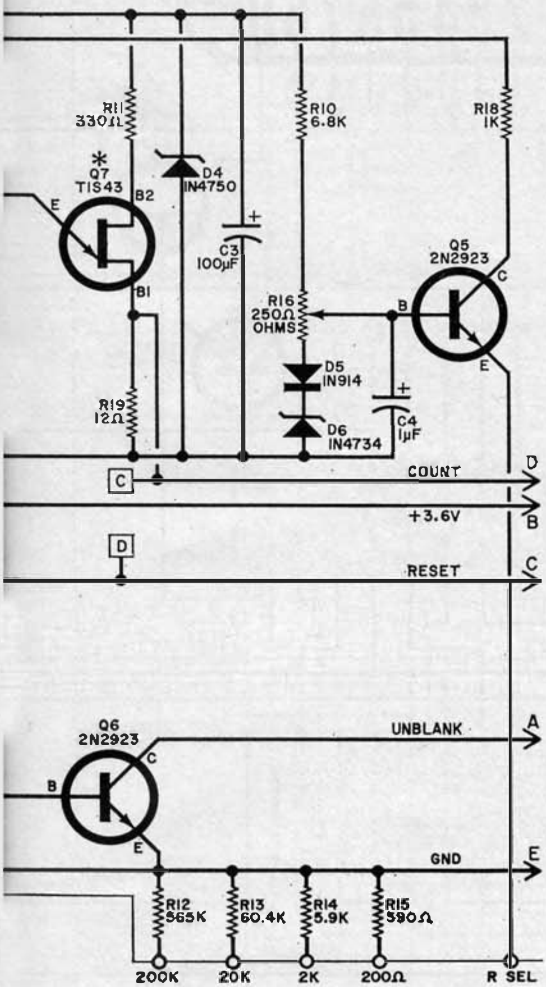
COVER STORY BY DON LANCASTER



Counter Module Construction. The schematic of the counter module is shown in Fig. 1. A printed circuit board is essential for this module. You can purchase one as mentioned in the Parts List or you can make your own using the etching guide shown in Fig. 2 and the drilling instructions in Fig. 3.

In laying out the components as shown in Fig. 4, make sure that the jumpers (#24 wires) are positioned exactly as shown and that insulated sleeving is used where it is needed.

Note particularly the orientation of the semiconductors, diodes, IC's, etc. There are three different kinds of basing involved on the transistors used. All transistors "point" the same way, except for *Q6*. The IC's are identified by a dot and notch. Note that *IC5*

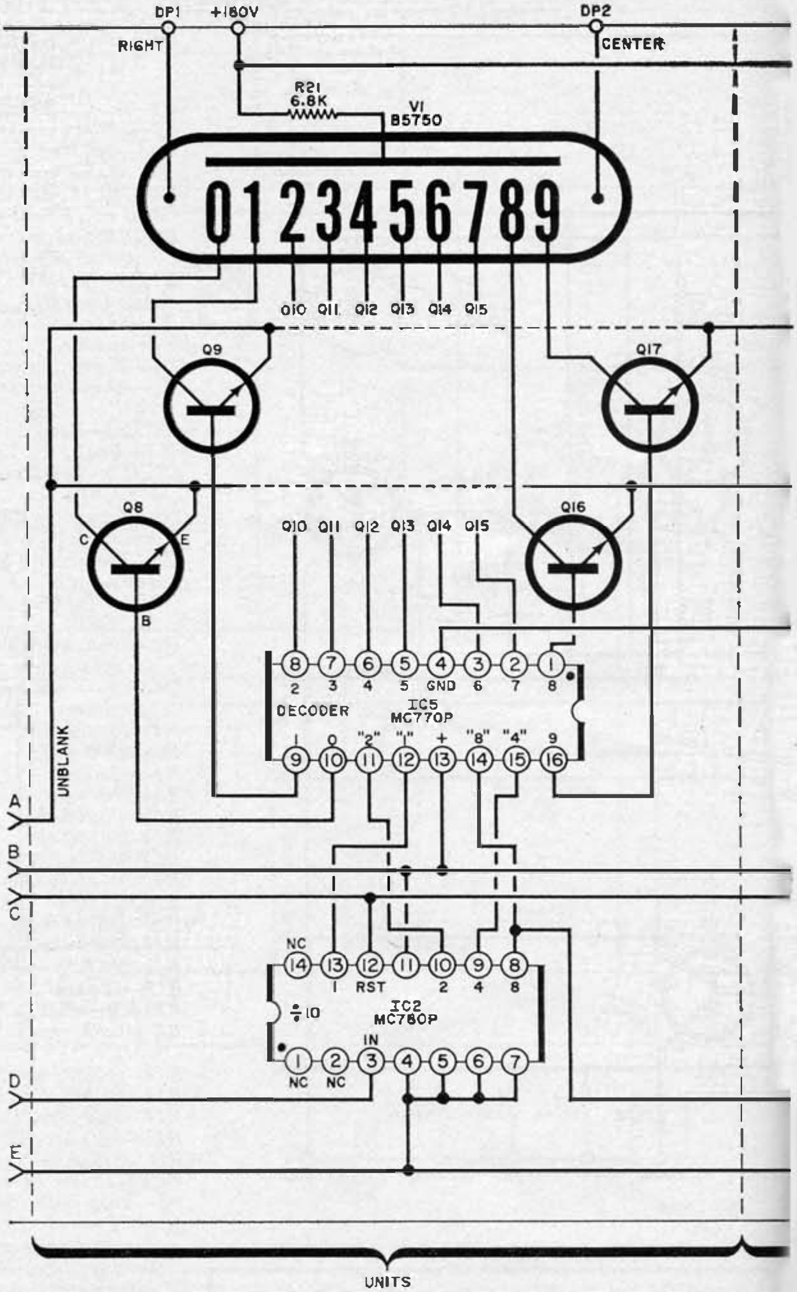


and *IC6* go in "upside down" with respect to *IC1-IC4*. Also, be careful not to mix up the two calibration potentiometers, *R2* and *R16*. The warning, "Do Not Substitute," on some parts in the Parts List should be observed since subtle changes in performance may result from apparently reasonable alternatives. Use a low-wattage soldering iron and fine solder to install all components.

PARTS LIST COUNTER MODULE

C1—0.1-µF, 50-volt Mylar capacitor
C2—1000-pF polystyrene or mica capacitor
C2A—0-800-pF polystyrene or mica capacitor as needed (see text)
C3—100-µF, 50-volt electrolytic capacitor
C4—1-µF, 10-volt electrolytic capacitor
C5—0.005-µF disc ceramic capacitor
C6—0.1-µF, 10-volt disc ceramic capacitor
D1,D6—1N4734 5.6-volt zener diode (do not substitute D1)
D2,D3,D5—Silicon computer diode (1N914 or similar)
D4—27-volt, 1-watt zener (1N4750 or similar)
IC1—Quad two-input gate (Motorola MC-724P)
IC2,IC3—Decade counter (Motorola MC780P)
IC4—Dual JK Flip-flop (Motorola MC791P)
IC5,IC6—Low-level 1/10 decoder (Motorola MC770P)
Q1—Transistor (Motorola MPS6521, do not substitute)
Q2—Transistor (Motorola MPS6523, do not substitute)
Q3-Q6—Transistor (Motorola MPS2923 or 2N2923)
Q7—Transistor (Texas Instruments TIS43, do not substitute)
Q8-Q29—Transistor (Sprague 2N3877, do not substitute)
R1—10-megohm
R3—3.3-megohm
R4—68-ohm
R5—2700-ohm
R6—680,000-ohm
R7—100,000-ohm
R8,R23,R24,R27—33,000-ohm
R9,R20—4700-ohm
R10,R21,R22—6800-ohm
R11—330-ohm
R17—3300-ohm
R18,R28,R29—1000-ohm
R19—12-ohm
R25,R26—68,000-ohm
(All resistors ¼-watt)
R2—10,000-ohm, PC-mount linear potentiometer
R12—565,000-ohm, 1% precision resistor
R13—60,400-ohm, 1% precision resistor
R14—5900-ohm, 1% precision resistor
R15—590-ohm, 1% precision resistor
R16—250-ohm, PC-mount linear potentiometer
V1,V2—Nixie tube (Burroughs B-5750)
V3—Neon bulb (Signalite A-261)
Misc—Printed circuit terminals (21, optional); #24 solid wire for jumpers; insulated sleeving; snap-in mounting spacers (8); solder; etc.
Note—The following is available from Southwest Technical Products, Box 16297, San Antonio, TX 78216: etched and drilled PC board, $6.75, postpaid, insurance extra.

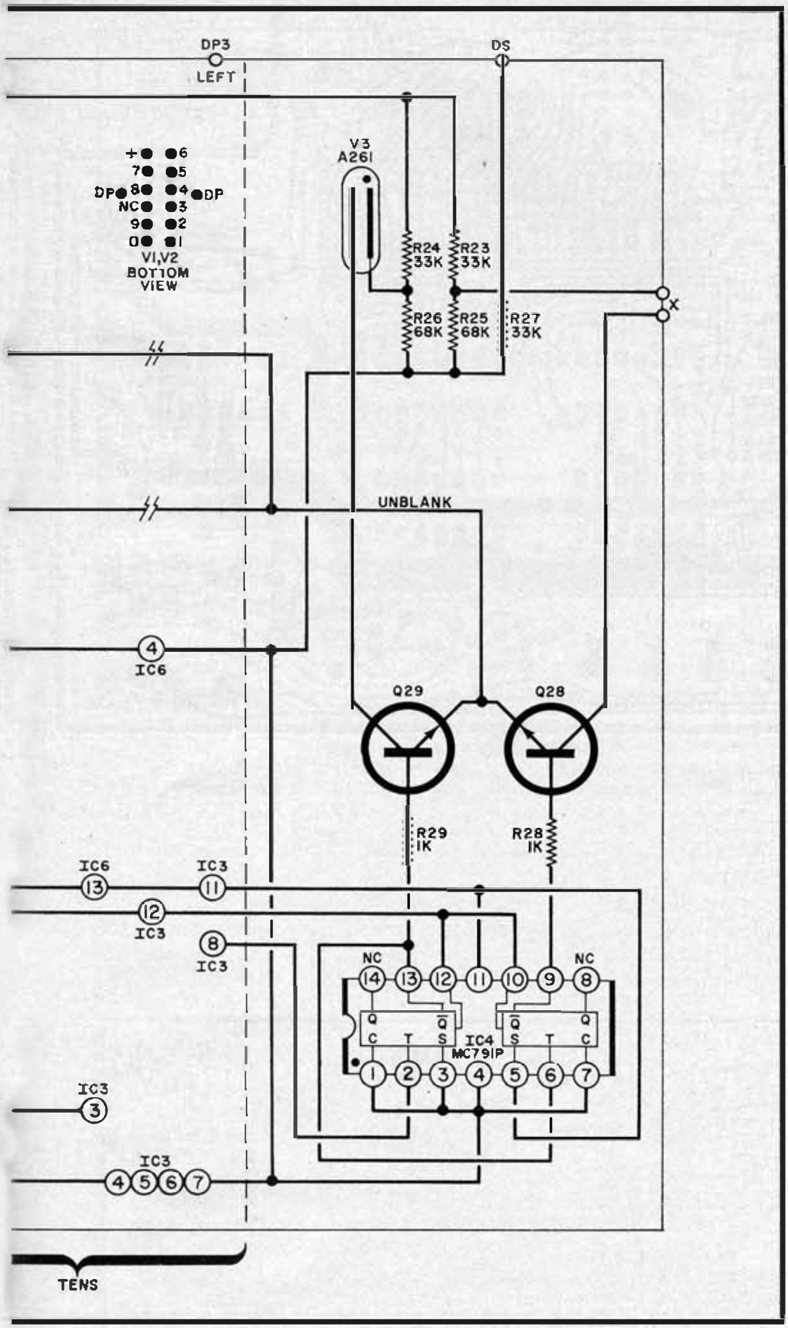
Fig. 1. The schematic has been broken into two parts. This section contains the voltage-to-frequency converter, the reset and unblanking circuit, and the ohms constant-current source. Circuit continued overleaf.



The second half of the circuit contains the units, tens, 1, and overrange indicators. Only the units decade is shown in detail as the tens decade is similar. The overrange indicator is connected to terminal marked "X".

The Nixie indicators may be mounted either using the plastic basing guide as an insertion aid; or the leads may be cut diagonally so that progressively shorter leads can be inserted two at a time until the tube is seated. Be careful to have both Nixie tubes vertical when you finally solder them in place. Also be sure that the tube leads are pulled all the way through the PC board; a bent or shorting lead inside the plastic insertion guide can be very difficult to fix after the tube is soldered in place.

Power Module Construction. The com-



ter module requires 3.6 volts at 400 mA, 180 volts at 5 mA and 30 volts at 35 mA for power. These are provided by the power module which is driven by a power transformer. The power module (see Fig. 5) has a full-wave center-tapped rectifier for the high voltage and a similar one for the low voltage, with 30 volts derived through a dropping resistor. Watch the diode polarity; and, if different breakdown voltage ratings are used for the low-voltage diodes, be sure not to interchange them.

While a printed circuit board is not essential for the power module, it is convenient.

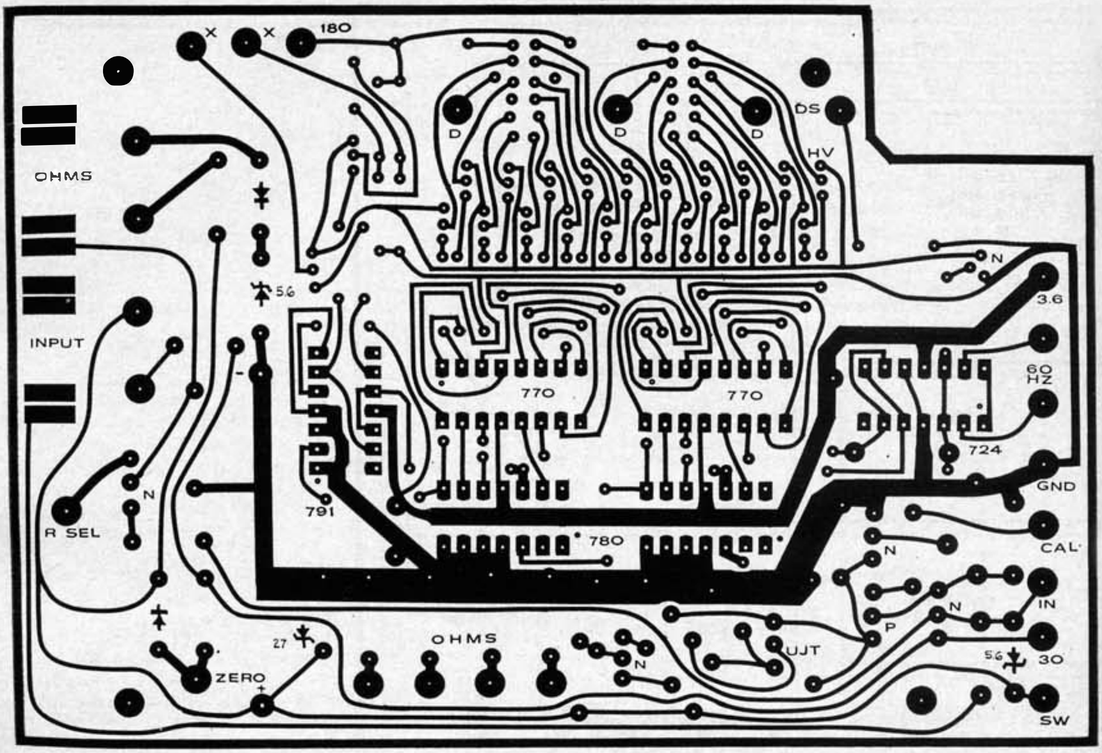


Fig. 2. Actual size foil pattern can be duplicated if you are very careful or use photography. If you don't feel up to it, a commercially made, pre-drilled board is available.

An etching guide and drilling instructions are shown in Figs. 6 and 7 respectively. Components are mounted as shown in Fig. 8. Watch the polarities on the diodes and the electrolytic capacitors. Be certain that *R1* is spaced well away from the electrolytics since actual contact can shorten the capacitor's life.

Assembly. Four plastic spacers are used to mount the power supply module over the counter module (see Fig. 9). The spacers

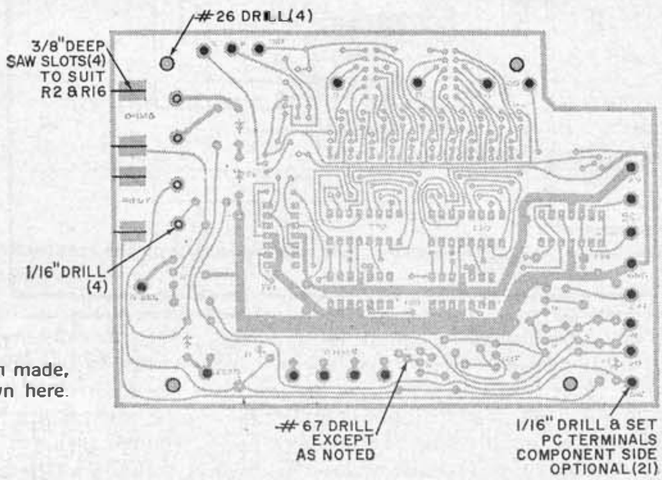


Fig. 3. Once board has been made, drill various holes as shown here.

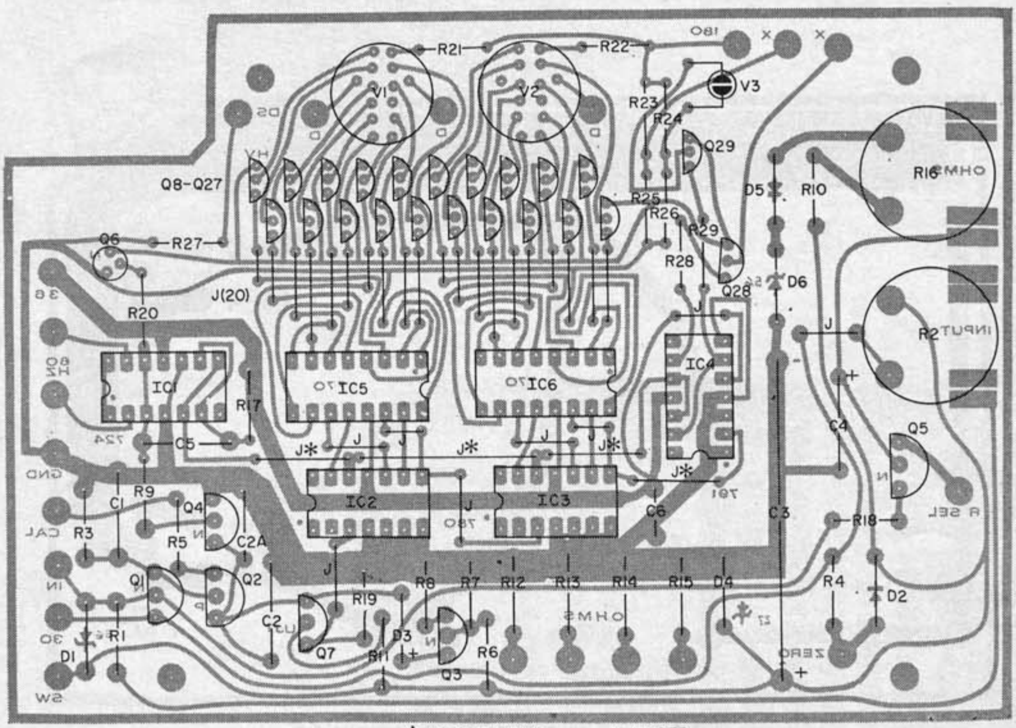
TECHNICAL SPECIFICATIONS MINI-DVM

Ranges	D.c. volts: 0-2, 20, 200 Ohms: 0-200, 2000, 20,000, 200,000 Range extendable to anything that can be represented by a variable 0-2-volt d.c. signal.
Input Impedance (voltmeter)	0-2 volts: 1 megohm 0-20 volts: 1 megohm 0-200 volts: 10 megohms
Input Current (ohmmeter)	0-200 ohms: 10 mA maximum 0-2000 ohms: 1 mA maximum 0-20,000 ohms: 100 μA maximum 0-200,000 ohms: 10 μA maximum
Resolution	One part in 200, any range ±5 mV, 0-2-volt range ±0.5 ohms, 0-200-ohm range
Accuracy	Better than ±1% over most portions of most ranges Internal calibration with 1.35-volt diode standard
Stability	Less than 1 count drift per 20 minutes after 15-minute warmup
Noise Rejection	Dual input filter plus fixed phase measurement with respect to power line hum and noise
Update Time	60 measurements per second. Instrument integrates input for 8.33 milliseconds and displays for 8.33 milliseconds.

should have shoulders on both ends and suitable holes may be drilled in both PC boards.

The over-all wiring of the Mini-DVM is shown in Fig. 10. While the photographs show the prototype mounted in an 8″ × 2¾″ × 4¼″ two-piece metal enclosure, any other type of housing may be used, as long as a 2½″ × 1″ opening for the readout is provided.

Five-way binding posts, spaced ¾″ apart should also be provided on the front panel for input terminals *J1* and *J2*. In addition, holes



*USE SLEEVING J=JUMPER

Fig. 4. Take your time when installing the components to make sure you insert the IC's and transistors properly. Certain jumpers are insulated to remove the possibility of shorts when all components are installed.

HOW IT WORKS

The Mini-DVM consists of two elements: a counter module and a power supply module. The operation of the power supply is straightforward and will not be discussed here. On the counter module there are two principal circuits: the counter and the 2½-decade display. In the following discussion, reference should be made to Fig. 1 as well as the diagrams shown here.

The counter circuit is made up of a timing gate generator (*IC1*), a display unblanker (*Q6*), a voltage-to-current converter (*Q1, Q2, Q3*), a gated oscillator (*Q4, Q7*), an ohmmeter current source (*Q5*), and a 1.35-volt calibration reference source.

The timing gate generator takes a split-phase 60-Hz reference from the power line via *T1* (waveform E) and uses it to drive a set-reset flip-flop in *IC1*. This produces a sharp-rise square wave that is initially grounded for 8.33 milliseconds and then is positive for 8.33 milliseconds (waveform A).

At the beginning of each measure cycle, the square wave suddenly drops to zero, producing a reset output pulse that "erases" any number that was in the counter and readout, thus resetting the counter to 000. At the same time, drive is removed from the unblanking transistor (*Q6*), which turns the display off. Simultaneously, drive is removed from the gating transistor (*Q4*), allowing the oscillator to operate.

Thus, for the first half cycle, the gated oscillator is allowed to run and the initially reset counter accumulates the desired 0-199 counts in proportion to the input voltage. On the second half of the cycle, the V/F converter is stopped and the display is unblanked, or turned on. The counter "keeps" the total count presented to it on the first half cycle and the display in turn presents it as a visual output.

The *time* that the gated oscillator is allowed to run is a constant 8.33 milliseconds. The *frequency* is determined by the input current to the gated oscillator, which in turn is proportional to the input signal voltage. By suitable scaling, the total *number* of counts per measurement interval is made to relate to the input voltage. As a result, for example, an input of 1.35 volts produces 135 counts.

The input voltage is applied to impedance matcher *Q1* and voltage-to-current converter *Q2*. The input signal is protected by *D1* and an input offset compensation is provided by *R1* and *R2*. Transistor *Q3* is a current sink that constantly removes 100 microamperes of *Q2*'s collector current to make the conversion process very linear. The zero input current is determined by the front-panel ZERO potentiometer, while the scaling or gain is controlled by the CAL potentiometer and *R5*.

The gated oscillator performs the current-to-frequency conversion. The output of unijunction transistor *Q7* consists of pulses appearing across *R19* (waveform C). Transistor *Q4* provides the gating that determines whether *Q7* is allowed to oscillate. Waveform B can be measured only with a 10-megohm scope probe.

The display circuit is an improved version of the circuit used in the "Numeric Glow Tube DCU" described in POPULAR ELECTRONICS, February 1970.

The first two decades are identical to each other. They start with a decimal counter (*IC2* or *IC3*) driving a 1-of-10 low-level decoder (*IC5* or *IC6*). The decoder drives ten high-voltage transistors (*Q8-Q17* or *Q18-Q27*) which, in turn, drive the Nixie tube.

The overflow counter uses a single dual flip-flop to serve both as a 100-up counter and a 200-up overflow latch. Each half drives a neon lamp—the first one aligned with the Nixies to produce a "1" and the second mounted on the front panel behind a red "overrange" lens.

The ohmmeter current source is *Q5*, whose base voltage is fixed by *D6* (adjusted slightly by *R16*) and temperature-compensated by *D5*.

Emitter resistors are selected to get the four values of ohmmeter current needed (0.01, 0.1, 1, and 10 mA), as well as the 10 mA for the 1.35-volt calibrate diode. The emitter is left unconnected to disable the current source for the input voltage ranges. A resistance measurement is made by delivering the selected amount of current to the resistor under test and then using the Mini-DVM to measure the resultant voltage drop. This method provides a great convenience over the normally cramped and highly nonlinear ohmmeter scales common to most analog multimeters.

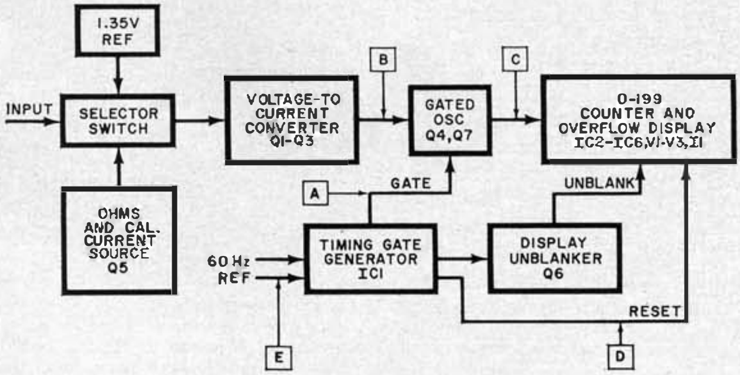
With *S1* in any of the ohms positions, the input is connected directly to the counter module and the ohmmeter current source is switched to provide the proper current.

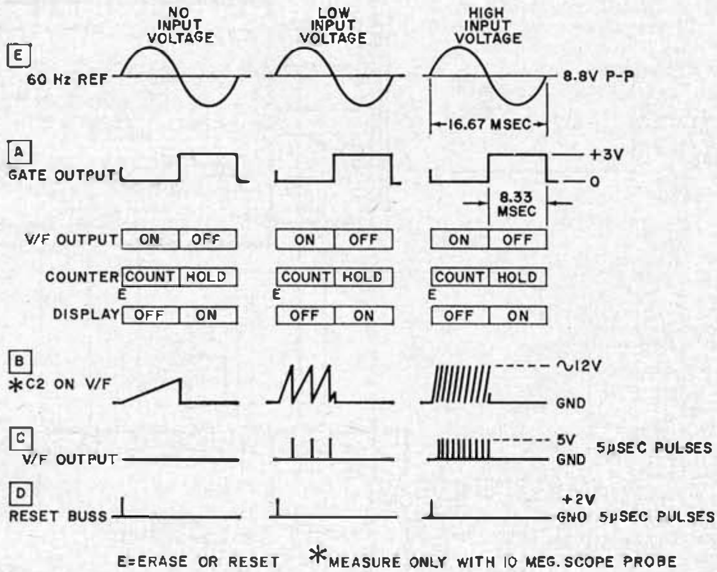
The fifth deck of *S1* is a snap-action power switch (*S1E*) which turns the power input to the meter on and off.

Power transformer *T1* mounts on the bottom of the chassis, behind the selector switch, while the fuseholder fits on the rear wall of the chassis. After all mechanical parts are mounted, wire the Mini-DVM together as shown in Fig. 10. The two modules are attached to the bottom of the chassis using four plastic supports.

Put four non-skid rubber feet on the bottom of the chassis, making sure that the back ones are directly along the rear wall. This permits standing the case on the swivel handle. The handle is fabricated as shown in the photographs and should be attached to the chassis so that it can swing and be used either as a carrying handle or a support.

A polarized orange filter should be glued





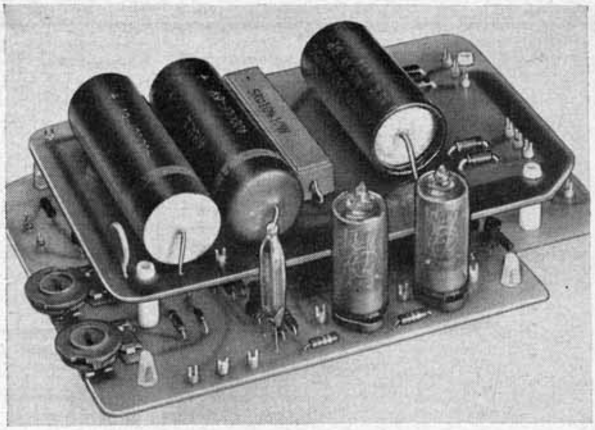
with epoxy to the back of the display opening. The filter orientation is critical and the filter should be installed to provide the darkest possible interior when the interior is illuminated and viewed from the outside.

Checkout and Calibration. With the selector switch off, plug the Mini-DVM into a 117-volt, 60-Hz power source. Now place the selector switch on ZERO and note that the two Nixie tubes glow with some number. If the instrument has been properly wired, varying the ZERO control should cause the display to vary from 0.00 to about 0.40 with the 0.01 indication at about the middle of the range control. The proper setting for the ZERO control is just before the numeral one is lit on the right-hand side.

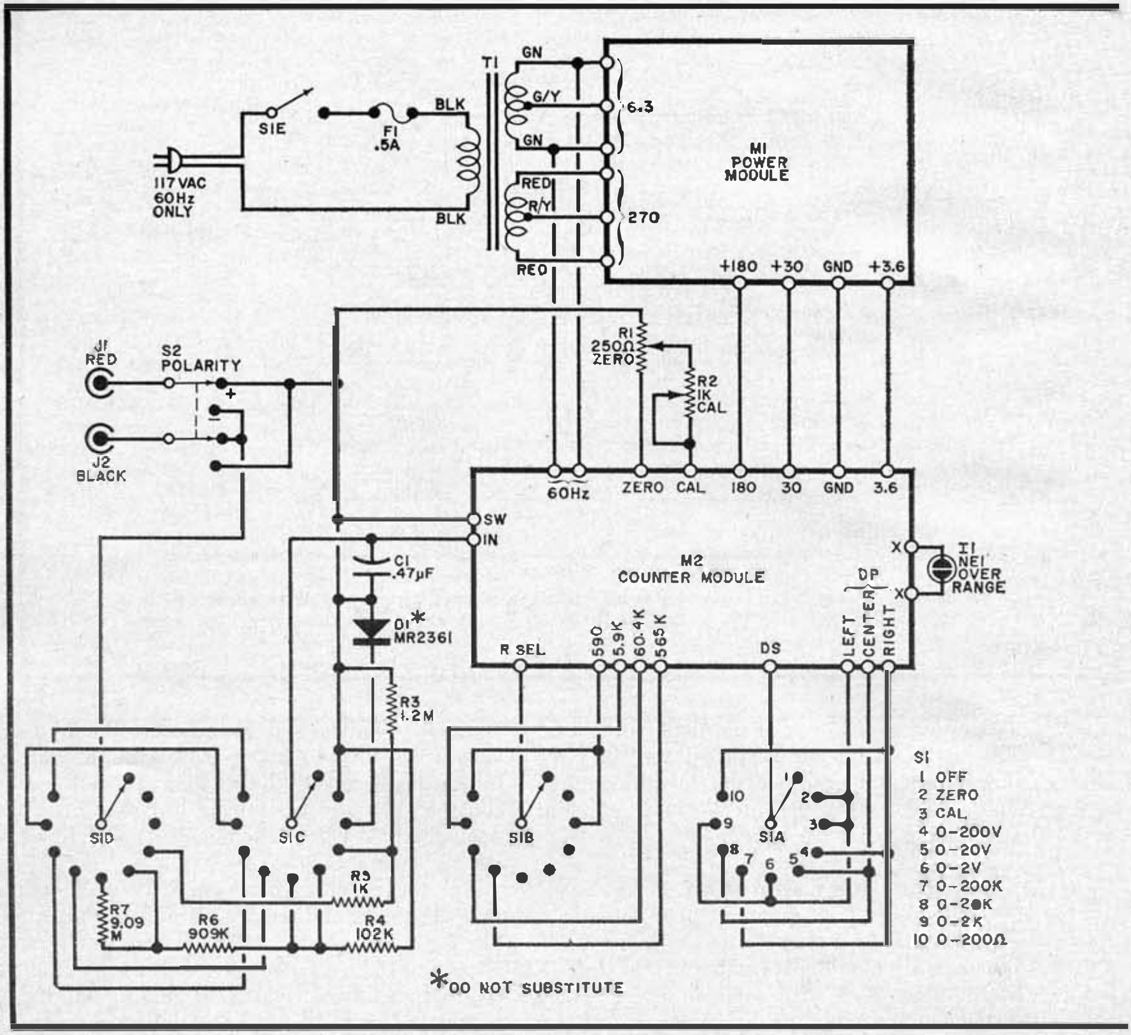
Put the selector switch on CAL and note that the Nixies and the neon 1 indicator are all lit. With the selector switch in this position, adjusting the CAL control can vary the reading by about 60 counts, depending on the particular unit. If the operation seems normal. add up to 800 pF of capacitance as needed across *C2* (on the counter PC board) until 1.35 can be obtained at about the midpoint of the rotation of the CAL potentiometer. (Be sure that the zero adjustment has been properly set previously.)

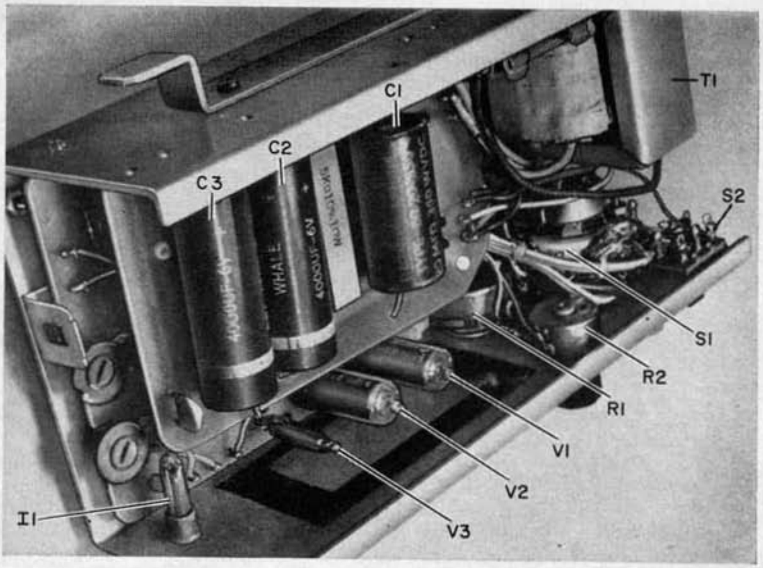
The input offset potentiometer (*R2*) on the counter module is set next. Put the selector switch on ZERO and adjust the front-panel ZERO control to obtain an indication of 0.01 on the display. Place the selector switch on 2V and short the input jacks together. The display should not change from the 0.01 indication. Remove the short, and, if necessary, adjust the input offset potentiometer (*R2*) to regain the 0.01 indication. Place the selector switch on ZERO and reset the ZERO control to get a 0.00 display.

Obtain a 1% precision resistor with a value



Power supply is joined to counter board via plastic spacers. Make sure both Nixies and the "1" neon lamp are vertical. Photograph is into viewing plane.



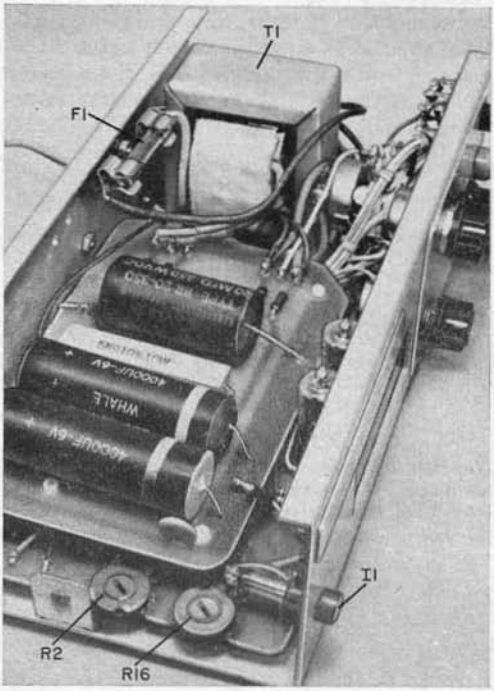


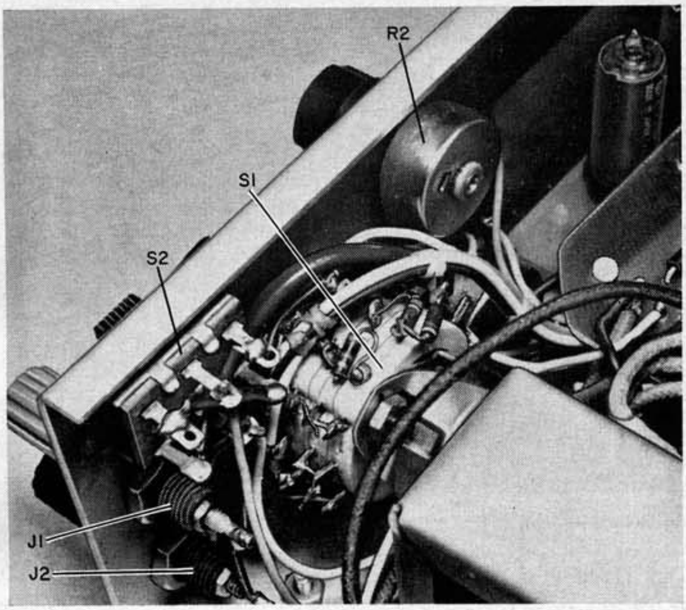
PARTS LIST COMPLETE MINI-DVM

C1—0.47-µF, 50-volt Mylar capacitor (do not substitute an electrolytic)
D1—1.35-V, 10-mA reference diode (Motorola MR2361)
F1—0.5-ampere fuse and fuseholder
I1—Neon lamp and overrange lens (A261 or NE-2)
J1,J2—Banana jack or 5-way binding post (one red, one black)
M1—Power module
M2—Counter module
R1—250-ohm linear potentiometer
R2—1000-ohm linear potentiometer
R3—12-megohm, ½-watt resistor
R4—102,000-ohm, 1% precision resistor
R5—1000-ohm, ½-watt resistor
R6—909,000-ohm, 1% precision resistor
R7—9.09-megohm, 1% precision resistor
S1—Four-pole, ten-position, non-shorting rotary switch with s.p.s.t snap switch attached to make on positions 2-10.
S2—D.p.d.t. slide switch
T1—Transformer; primary, 117 V; secondary #1, 6.3 VCT at 500 mA; secondary #2, 270 VCT at 40 mA
Misc.—Case with three-way handle; line cord with strain relief; ⅝" knobs (2); 1" knob; circularly polarized orange viewing filter; rubber feet (4); mounting and stand-off hardware; solder; sleeving; wire; etc.
Note—The following is available from Southwest Technical Products, Box 16297, San Antonio, TX 78216: complete kit of all above parts, #MDVM-K, $69.95; postpaid, insurance extra. Any and all individual parts also available.

Fig. 10. The overall DVM showing module interconnections. This system is to be used on 60-Hz power only as the counting circuit will have to be changed for other power-line frequencies.

The two photos above and below show how the DVM is assembled within its low-profile case. The viewing window should be large enough to show the readouts clearly and covered with optical filter as explained in text. The small bracket visible at the rear of the chassis is used to wind up the power line. The overrange indicator is isolated from the display so as to be very eye catching when it comes on.

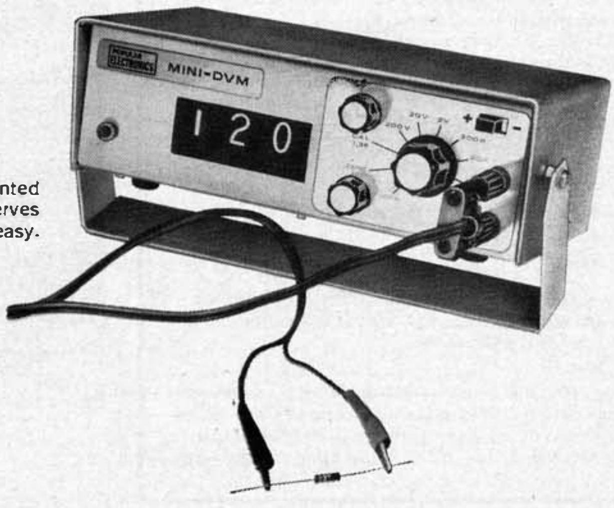




The various front-end resistors are wired point-to-point directly on the switch. This can be done before the switch is mounted, but be sure to double check the assembly before installation. Keep all wiring short and make sure no part shorts against the metal chassis.

between 1200 and 1400 ohms. Using test leads, connect this resistor to the input jacks. After zeroing and calibrating, place the selector switch in the 2K position. Adjust the Ohms potentiometer (*R6*) on the counter module until the display indicates the exact resistance value (in kilohms). Potentiometers *R2* and *R6* will rarely, if ever, need re-adjustment.

In using the Mini-DVM, allow a minute or two for warmup before making any measurements. Then check both the ZERO and CAL positions of the selector switch and make any necessary front-panel adjustments. There is a slight interaction between these two controls so double check their operation. Calibration of the Mini-DVM can always be checked by switching back to the ZERO and CAL positions of the selector switch. -30-



The handle is optional if the DVM is mounted on a shelf. Otherwise, the handle also serves as a tilting support to make the viewing easy.