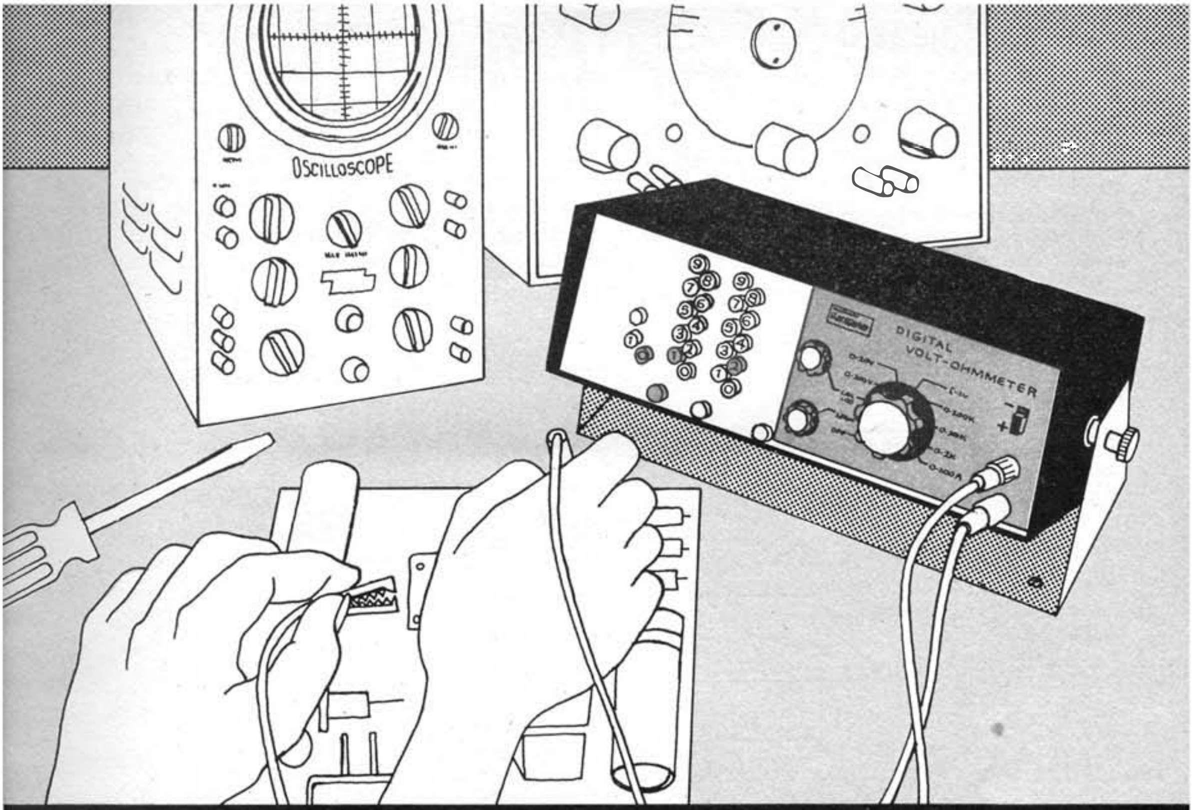



# Build the Popular Electronics Digital Volt-Ohmmeter


COMPLETE CONSTRUCTION DETAILS IN THIS ISSUE

**COVER STORY**
**BY DON LANCASTER**

For less than the price of many transistor multimeters, you can now build your own real digital volt-ohmmeter. Gone forever will be your days of having wobbly meter pointers, reading the wrong scales, or trying to read accurately from a cramped and highly nonlinear ohms scale. There will be no more problems caused by VOM circuit loading or bent or broken pointers resulting from circuit overload.

You can just clip the DVM to your circuit and read volts or ohms as they brightly and unquestionably pop up on the front panel of the instrument. Just clip and read—instantly! It's that simple.

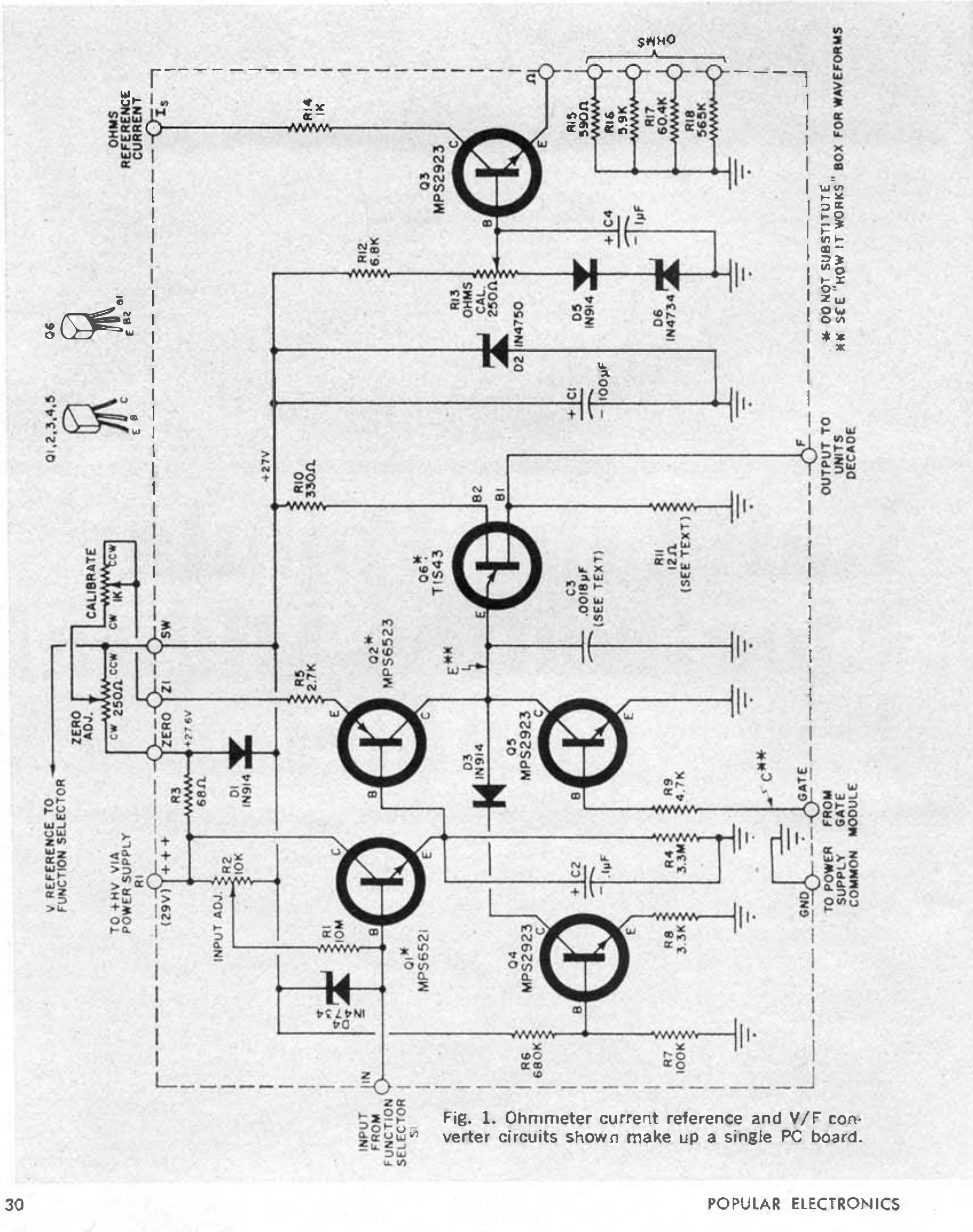



Fig. 1. Ohmmeter current reference and V/F converter circuits shown make up a single PC board.

This DVM is no slouch on performance either. It has better than ±1 percent accuracy over most portions of the seven available scales. It is self-zeroing and automatically self-calibrating. Three voltage scales, 0-2, 0-20, and 0-200 volts are provided, each at reasonably high impedances—in fact, you can read down to 10 millivolts with ease. Four ohmmeter scales, useful from one ohm to over 200,000 ohms, are also available. If you like, you can easily add extra outside circuits to measure digitally anything you can convert into a 0-2-volt d.c. signal, including a.c. voltage and current, d.c. current, speed, and temperature.

Like its far more expensive brothers, this DVM is a multiple-slope integrating device. This means it averages the input signal over a relatively long measuring time. It's done in a way that automatically rejects all a.c. line-induced hum and noise and also eliminates practically all other high-frequency noise that may be present. The instrument is essentially "blind" to 60-Hz hum and only measures the d.c. component of the input, even if hum or noise is present. All this is done automatically—all you do is watch a continuous output display that updates its readings fifteen times a second.

While not a beginner's project, the extensive use of integrated circuits makes the construction of the DVM relatively straightforward and easy on a module-by-module basis. A complete kit is available as well as individual circuit boards, dialplates, and individual module kits. If you'd rather build things on your own, all parts are obtainable on the market, and complete preparation details of all the circuit boards are given here. Either way, when you're done, you'll have a real DVM—at a fraction of the cost of commercial equivalents and with performance untouched by anything analog.

### V/F MODULE PARTS LIST

*C1—100-μF, 25-volt electrolytic capacitor*
*C2—0.1-μF, 35-volt Mylar or tantalum capacitor*
*C3—0.0018-μF, 50-volt Mylar or polystyrene capacitor (see text)*
*C4—1-μF electrolytic capacitor*
*D1, D3, D5—1N914 silicon computer diode or equivalent*
*D2—1N4750 1-watt, 27-volt zener diode*
*D4, D6—1N4734 1-watt, 5.6-volt zener diode*
*Q1—Transistor (Motorola MPS6521, do not substitute)*
*Q2—Transistor (Motorola MPS6523, do not substitute)*
*Q3-Q5—Transistor (Motorola MPS2923)*
*Q6—Unijunction transistor (Texas Instruments TIS43, do not substitute)*
*R1—10-megohm*
*R3—68-ohm*
*R4—3.3-megohm*
*R5—2700-ohm*
*R6—680,000-ohm*
*R7—100,000-ohm*
*R8—3300-ohm*
*R9—4700-ohm*
*R10—330-ohm*
*R11—12-ohm*
*R12—6800-ohm*
*R14—1000-ohm*
*R15—590-ohm*
*R16—5900-ohm*
*R17—60,400-ohm*
*R18—565,000-ohm*
*(R1–R18: all resistors ¼-watt; R15–R18: 1% precision)*
*R2—10.000-ohm trimmer potentiometer (CTS type U-201 or similar)*
*R13—250-ohm trimmer potentiometer (CTS type U201 or similar)*
*Misc.—3" x 3-¼" PC board, PC terminals or eyelets (14) (optional), aluminum mounting bracket (see Fig. 11) with hardware, solder.*
*Note:—The following are available from Southwest Technical Products, 219 W. Rhapsody, San Antonio. Texas 78216: etched and drilled printed circuit board, #155V, $3.25: complete kit of all above required parts, #CV-155, $16 postpaid in USA.*

**Construction.** The project has been broken down into five modules plus the case and some panel components. Module 1 is the voltage-to-frequency (V/F) converter. Modules 2 and 3 are decimal counting units (DCU's) described in the February 1968 issue of POPULAR ELECTRONICS, or you can use the improved, low-power versions described in the Winter 1969 ELECTRONIC EXPERIMENTER'S HANDBOOK.

Module 4 is the gate circuit, which simultaneously provides the 0, 1, and overrange counting needed to complete the digital display. Module 5 is the power supply.*

It is best to construct each module separately following the details very carefully. Each module has its own parts list and schematic. If you prefer to purchase circuit boards or partial kits, details are given in the parts lists.

*Voltage/Frequency Converter.* This circuit, shown in Fig. 1, is the "heart" of the DVM and converts the input d.c.

---

**Important: The circuits labeled GND throughout this project are not actually ground connections and should not be connected to the metal case. They are common connections constituting an individual circuit and grounding them to the case may produce circulating currents which interfere with the operation of the meter. The metal case should be either left floating or connected to the SW terminal on the V/F module. This is one side of the input signal and is actually the reference point for the system.*


Fig. 2. If you make your own V/F converter-ohmmeter current reference PC board, carefully copy this actual-size etching guide.

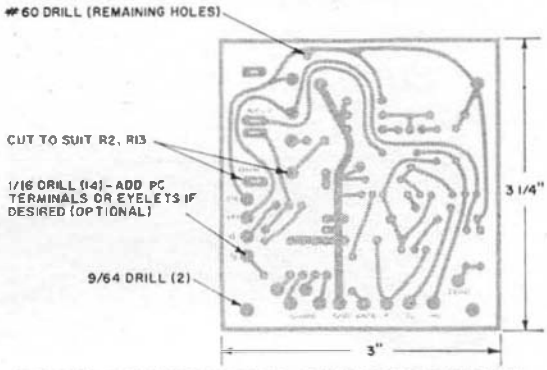



Fig. 3. Place etched and cleaned board foil-side up on a block of scrap wood, carefully locate and mark hole centers, and drill all the way through from foil side.

On the cover, just behind the Digital Volt-Ohmmeter, can be seen another advanced experimenter's test set using POPULAR ELECTRONICS' low-cost digital readout (see our February 1968 issue or the 1969 Winter Edition of ELECTRONIC EXPERIMENTER'S HANDBOOK). This particular unit is a frequency counter capable of indicating from 1 Hz to 2 MHz in five ranges. It is now in the final design stage and complete construction details will appear in a forthcoming issue of this magazine.

signal to a series of pulses that are counted by the DCU's.

You can purchase the printed-circuit board for this module or you can make one using the actual-size layout shown in Fig. 2 and following the drilling details of Fig. 3. File or multiple-drill the slots required for the two trimming potentiometers (*R2* and *R13*). If you wish, you can add optional terminals or eyelets to make wiring easier.

Components are installed on the board as shown in Fig. 4. Be sure to install all semiconductors properly and double-check electrolytic capacitor polarities. Be especially careful not to interchange *R2* with *R13*.

*Gate Module.* This is actually the control center of the DVM. The start and stop signals for the V/F converter and the reset signals for the various counting circuits are generated in this module. The schematic for this module is shown in Fig. 5.

A printed-circuit board is suggested for this module. You can purchase one (see Parts List for Fig. 5), or you can etch and drill your own following the actual-size layout shown in Fig. 6 and the drilling information shown in Fig. 7. Don't forget to install the two jumpers on the component side of the board as shown in Fig 7. Do not use a drill larger than #67 for the IC mounting holes. Optional eyelets or PC terminals can be added where indicated.

Mount the components as shown in Fig. 8. Use a low-wattage soldering iron and fine solder when mounting the IC's. The rectangular IC's are identified by a notch and dot at one end, while the round IC's have either a flat or a dot at pin 8.

*Power Supply.* The power supply is not assembled on a PC board, but is wired point-to-point at one end of the chassis. The schematic is shown in Fig. 9. A conventional tube-type transformer is used. The 250-volt, center-tapped secondary has two functions. It provides the 125-volt a.c. reference, and its output is

## HOW IT WORKS

### V/F CONVERTER

The block diagram for this module appears here while the complete schematic is shown in Fig. 1. The waveforms are keyed to test points shown on the diagrams.

The 0-2-volt input from the function selector is subtracted from a +27-volt supply generated by the power supply module and regulated by zener diode *D2*. Thus the input voltage at the V/F converter actually varies from +27 to +25 volts as the instrument input goes from 0 to +2 volts. *Note that all input signals are referenced to +27 volts and not to the power supply common (GND).*

Diode *D4* provides reverse polarity and overload protection for the circuit. Transistor *Q1* is an emitter follower that provides a high input impedance. Transistor *Q2* is a complementary emitter follower that bucks out the offset produced by *Q1* and causes a voltage identical to the input voltage to appear across *R5* and the front-panel CAL 1.35 control. The current through these resistors can be set for a constant input voltage by adjusting the CAL 1.35 control. Practically the same current appears at *Q2*'s collector as flows through *R5* and the CAL 1.35 control. Transistor *Q2*'s output current is then proportional to the original input voltage. Transistor *Q2*'s output current drives a conventional unijunction sawtooth oscillator consisting of UJT *Q6* and integrating capacitor *C3*. A series of pulses at *B1* of *Q2* changes in *frequency* as the input voltage changes in *amplitude*. These output pulses are sent to the 0-199 digital counter and display modules.

The UJT oscillator is turned on and off by gating transistor *Q5*. This transistor is driven by the Gate module and allows the oscillator to run for 16.7 milliseconds and then shorts it out for the next 50 milliseconds and keeps this up continuously, recycling 15 times a second. The frequency produced by the oscillator is determined by the input voltage. The time this frequency is produced is determined only by the Gate module and *Q5*. As a result, the oscillator generates 0 to 199 pulses for a 0-1.99-volt input signal, once each measurement interval. This is how the digital display appears to be reading the actual value of the input signal.

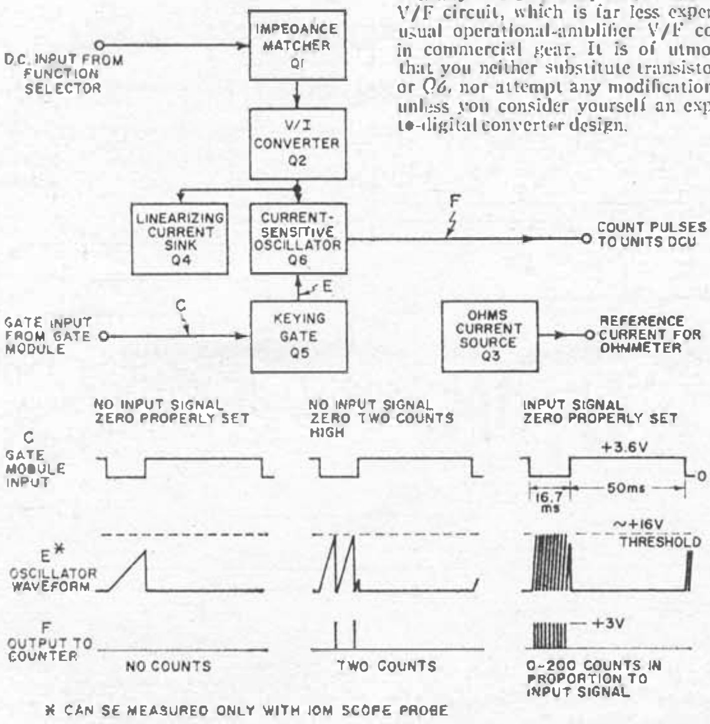
There would be a slight linearity problem if the current on *Q2* were allowed to go down to zero. Thus a little more emitter voltage (about 0.3 volts) is added by the front-panel ZERO potentiometer to remove a correspondingly constant amount of collector current (about 100 microamperes) all the time. This shifts the operating point of *Q2* to a more linear region but still lets 0-2 volts of input produce 0-200 pulses per 16.7 milliseconds at the output.

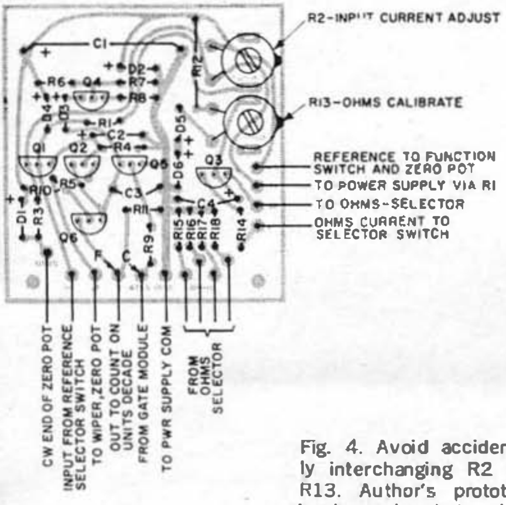
The extra 100 microamperes of current is "dumped" into the collector of *Q5*, which is biased to act as a current sink.

The current source for the ohmmeter is also on the V/F board, but it is a completely separate circuit. The collector current of transistor *Q3* is either 0.01, 0.1, 1, or 10 milliamperes, depending on the resistor selected for its emitter circuit (*R15*, *R16*, *R17*, or *R18*). These resistors are not quite decade multiples of each other, because they compensate for slight circuit nonlinearities.

Base current for *Q3* is regulated by *D6*, temperature-compensated by *D5*, and adjusted over a limited range by *R13*. Resistor *R14* prevents oscillation but otherwise does not affect the output current.

Many hours of design went into this particular V/F circuit, which is far less expensive than the usual operational-amplifier V/F converters used in commercial gear. It is of utmost importance that you neither substitute transistors for *Q1*, *Q2*, or *Q6*, nor attempt any modification of the circuit unless you consider yourself an expert in analog-to-digital converter design.





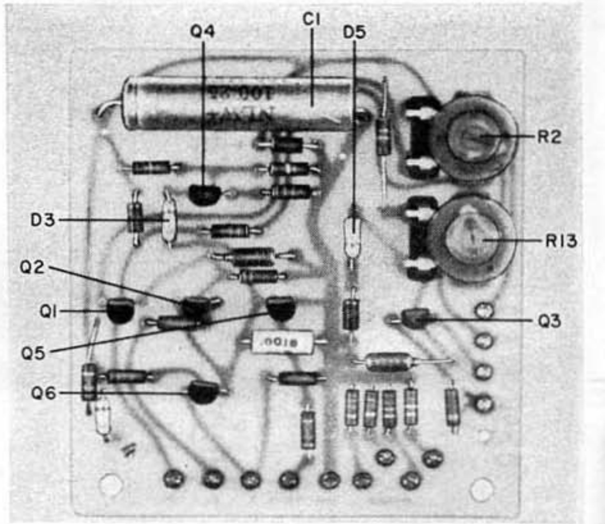
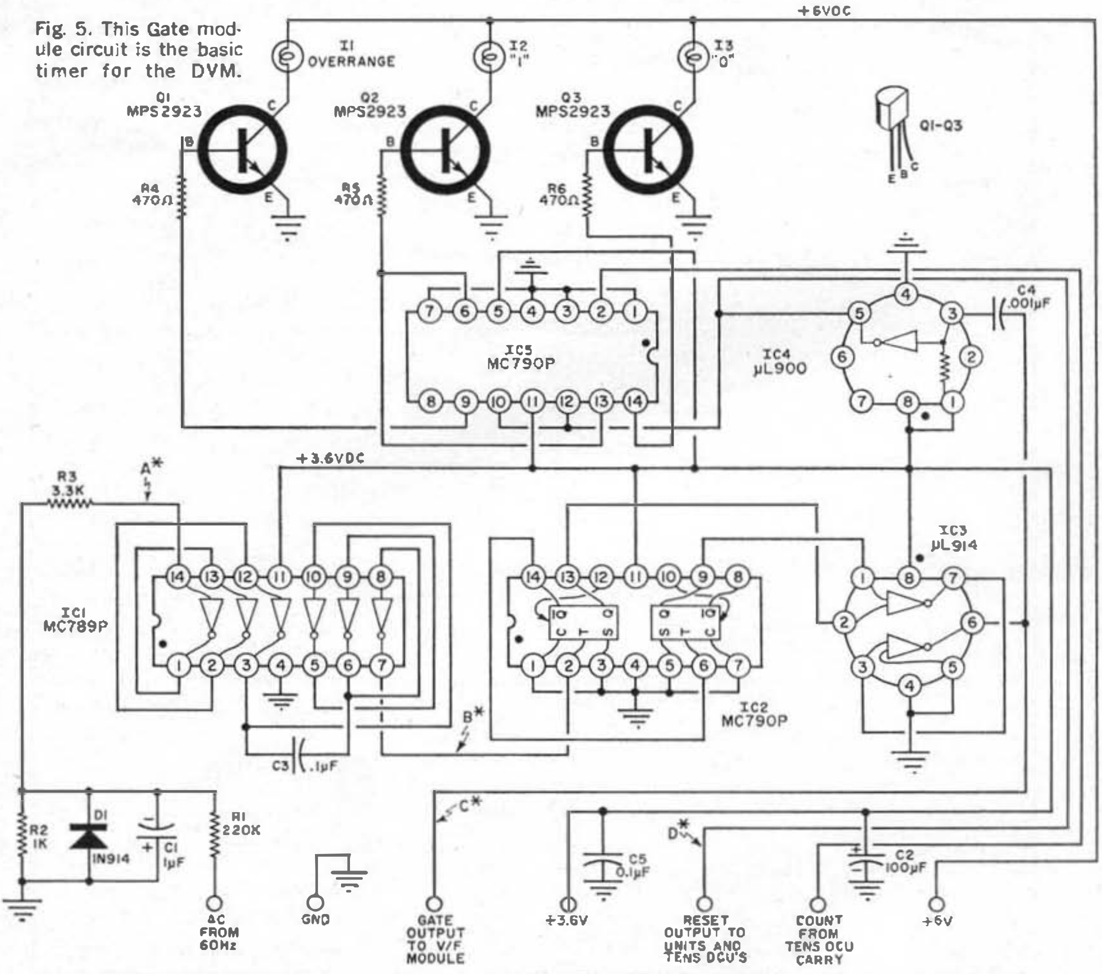




Fig. 4. Avoid accidentally interchanging R2 and R13. Author's prototype is shown in photo, right.

Fig. 5. This Gate module circuit is the basic timer for the DVM.



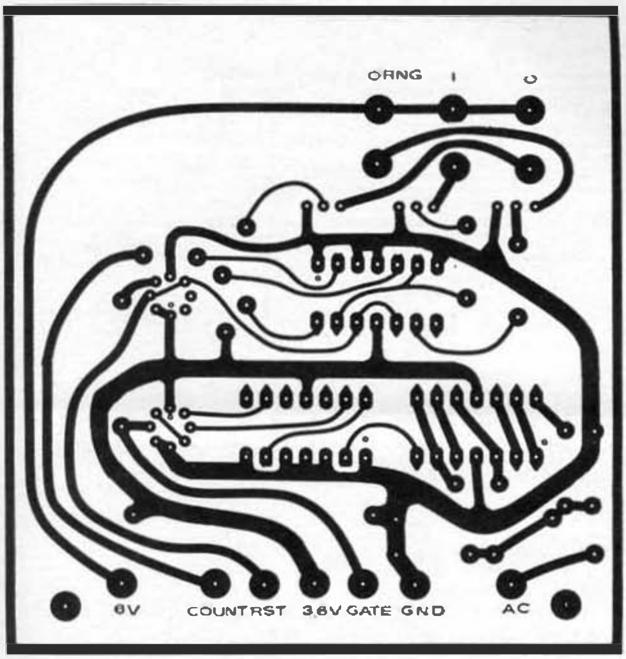
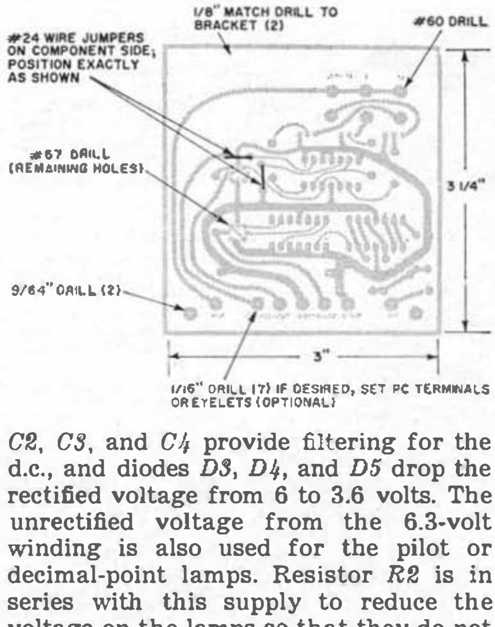



Fig. 6. Actual-size etching guide must be copied exactly as shown to insure proper component fit. Small dots near solder terminals indicate IC indexes.

Fig. 7. Proper location of hole centers and selection of drills are critical for the Gate module board. Once holes are drilled, immediately install jumpers.




also rectified to provide a 30-volt d.c. supply. Resistor *R1* is a voltage dropping resistor which dissipates a large amount of power and must be located where the heat produced will do no damage.

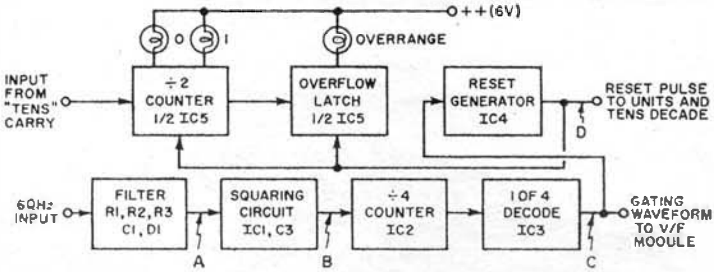
The power from the "filament" winding of *T1* is rectified to provide 6-volt and 3.6-volt d.c. supplies. Rectifier *RECT1* is a full-wave bridge. Capacitors *C2*, *C3*, and *C4* provide filtering for the d.c., and diodes *D3*, *D4*, and *D5* drop the rectified voltage from 6 to 3.6 volts. The unrectified voltage from the 6.3-volt winding is also used for the pilot or decimal-point lamps. Resistor *R2* is in series with this supply to reduce the voltage on the lamps so that they do not glow brighter than the counting lamps.

Most of the power supply components can be mounted on terminal strips or a component board as shown in Fig. 10. The rest of the components are mounted on the chassis.

## GATE MODULE PARTS LIST

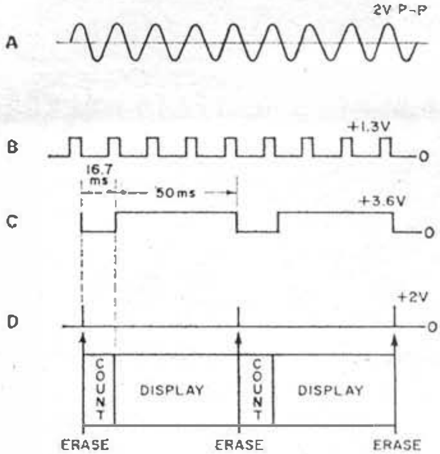
*C1—1-μF, 25-volt electrolytic capacitor*
*C2—100-μF, 10-volt electrolytic capacitor*
*C3—0.1-μF, 10-volt ceramic disc capacitor*
*C4—0.001-μF, 50-volt Mylar capacitor*
*C5—0.1-μF capacitor*
*D1—1N914 silicon computer diode or equivalent*
*I1-I3—6.3-volt, 50-mA pilot lamp and lens assembly, two orange and one red (Southwest Technical Products #O-6.3 and #R-6.3 respectively, or equivalent)*
*IC1—Integrated circuit (Motorola MC789P)*
*IC2, IC5—Integrated circuit (Motorola MC790P or MC791P)*
*IC3—Integrated circuit (Fairchild μL914)*
*IC4—Integrated circuit (Fairchild μL900)*
*Q1-Q3—2N5129 transistor or Motorola MPS2923*
*R1—220,000-ohm, ½-watt resistor*
*R2—1000-ohm, ¼-watt resistor*
*R3—3300-ohm, ¼-watt resistor*
*R4-R6—470-ohm, ¼-watt resistor*
*Misc.—PC board, 3" x 3-¼", PC terminals or eyelets (7) (optional), #24 jumpers (2), solder, lamp bracket (see Fig. 12), mounting bracket and hardware (see Fig. 11).*
*Note:—The following Gate module parts are available from Southwest Technical Products, 219 W Rhapsody, San Antonio, Texas 78216: etched and drilled printed circuit board #155G, $3; complete kit of all necessary parts #CG-155, $10.85 postpaid in U.S.A.*

**Assembly.** To mount the modules in the chassis, aluminum support brackets such




# HOW IT WORKS

## GATE MODULE




This module is a three-in-one board. First, it's a gate generator that produces the on-for-one, off-for-three gating waveform used in the V/F; it's also a reset generator that automatically provides a short pulse the instant the V/F is told to start producing a new count; and finally, it contains an 0, 1, overrange counter used to complete the 0-199 digital display. The complete schematic is shown in Fig. 5.

The gate waveform is generated by filtering the 60-Hz supply to obtain a smooth sine wave. The filter removes any noise from the power line that might cause inaccuracies, while *IC1*, a hex inverter, produces a rectangular wave with a fall time sufficiently steep to trigger the next stage. Capacitor *C3* provides positive feedback to improve the square-wave form.

The next stage, *IC2*, is a divide-by-four counter consisting of two JK flip-flops connected as cascaded binary dividers. Dual-gate *IC3* is a 1-of-4 decoder producing a gating waveform that is grounded for 16.7 milliseconds (one 60-Hz period), and positive for the next 50 milliseconds (three 60-Hz periods). Since this process takes up four 60-Hz cycles, the frequency of the composite waveform is ¼ of 60 Hz, or 15 Hz; hence the 15 measurements per second.

The gate output is routed to the V/F converter and to a half-monostable reset generator consisting of *C4* and buffer *IC4*. This circuit generates a very brief (about 2 microseconds) reset pulse which erases the display before the V/F converter can produce its first output pulse. The reset pulse goes to the two decimal counters as well as resetting the 0, 1, overrange portion of this module.

The 0, 1, overrange counter, *IC5*, has two flip-flops. One is a binary divider; the second is a latch that goes on when full scale is reached, regardless of how many more counts arrive. This counter takes the output of the ten's DCU and converts what would be an 0-99 display into an 0-199 plus overrange capability.

A power-line gate may be expected to be accurate to ±0.05%, while the digital 0-199 display used is only inherently accurate to ±0.5%. Thus, the instrument accuracy is determined by the display and the V/F accuracy. Without a far more expensive V/F circuit, extra decade modules or a more precise time base will not increase the instrument's accuracy.

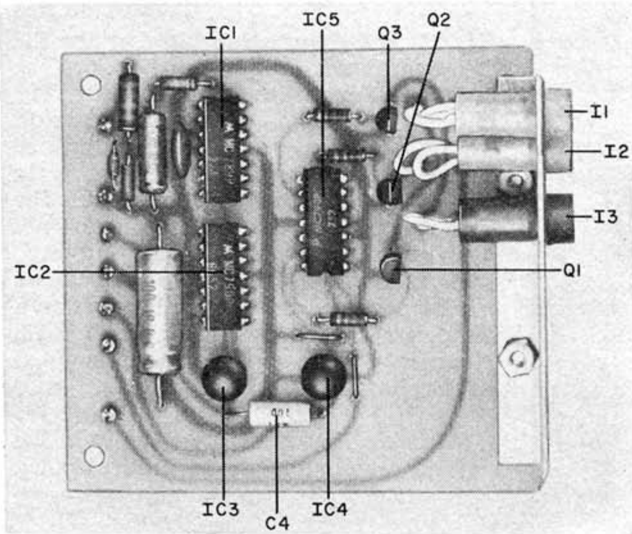



Photo of author's prototype shows properly wired Gate module board with indicator lamps and bracket in place and optional solder terminals at left; external wiring can be soldered directly to board.

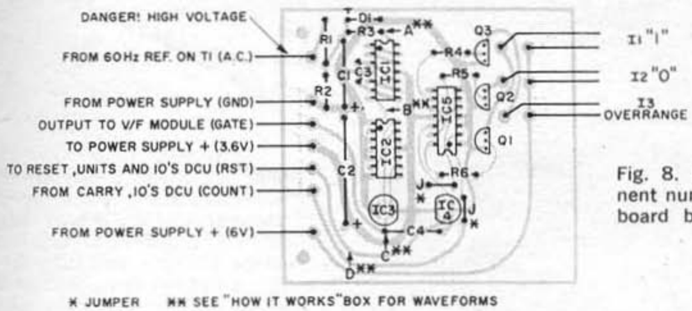



Fig. 8. Double and triple check component numbers, values, and orientation on board both before and after soldering.

as those shown in Fig. 11 can be used. The photos show how these brackets are used for support.

A three-hole bracket is required for the indicator lamps of the gate module. This can be fabricated as shown in Fig. 12. (One of the brackets supplied with the DCU kit can be used as a guide.) Use orange plastic covers for the 0 and 1 bulb, and a red one for the overrange indicator.

The complete schematic for the DVM is shown in Fig. 13. The photos show the assembly used by the author, although any other similar neat arrangement can be used. While layout is not critical, be sure to keep the instrument neat and compact to minimize the chance of wiring error. Be sure to use very short, heavy ground connectors. A ground buss of #12 solid wire between modules is strongly recommended.

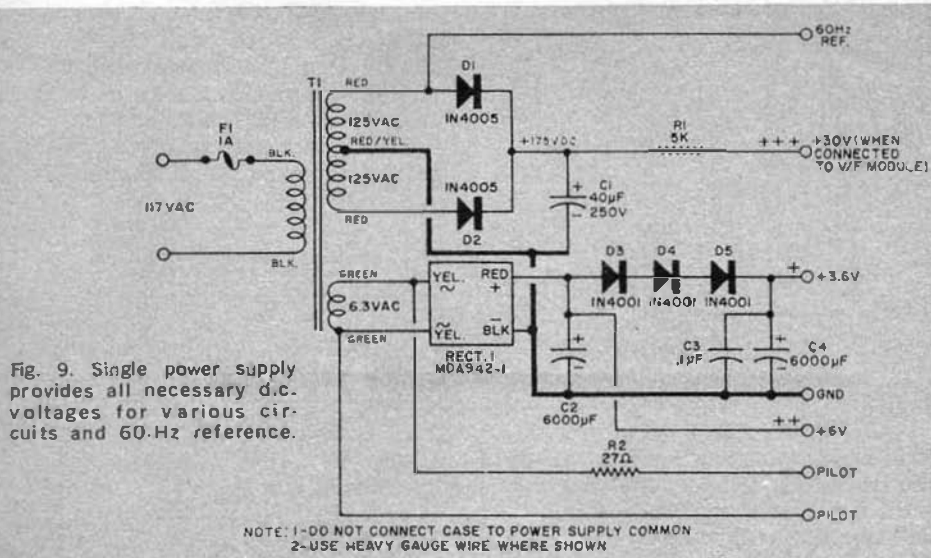



Fig. 9. Single power supply provides all necessary d.c. voltages for various circuits and 60-Hz reference.

## POWER SUPPLY PARTS LIST

*C1—40-µF, 250-volt electrolytic capacitor*
*C2, C4—6000-µF, 10-volt electrolytic capacitor*
*C3—0.1-µF, 10-volt ceramic disc capacitor*
*D1, D2—1-ampere, 600-volt silicon diode (Motorola 1N4005 or similar)*
*D3-D5—1-ampere, 50-volt silicon diode (Motorola 1N4001 or similar)*
*RECT1—1.5-ampere, 50-volt, full-wave silicon molded bridge assembly (Motorola MDA942-1 or similar)*
*F1—1-ampere fuse and fuseholder*
*R1—5000-ohm, 10-watt resistor*
*R2—27-ohm, ½-watt resistor*
*T1—Power transformer, secondary 250 volts CT @ 25 mA, 6.3 volts 1 ampere (Knight 54E-2008, Stancor PS8416, Thordarson 22R39 or similar)*
*Misc.—16-point (8 on each side) terminal board assembly with mounting hardware, a.c. line cord, strain relief, mounting hardware for T1 and F1, wire, solder, mounting clips for capacitors, etc.*
*Note:—Complete kit of all power supply parts available from Southwest Technical Products, 219 W. Rhapsody, San Antonio, Texas 78216. #CS-155, $10.70 postpaid in U.S.A.*

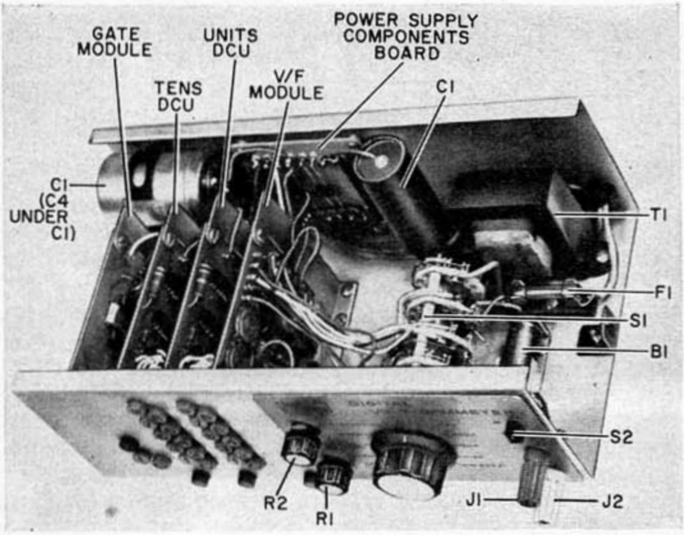



Fig. 10. Power supply circuit is located along rear apron of chassis. Modules are at left, while CAL and ZERO controls, range/function switch, polarity selector are at right.

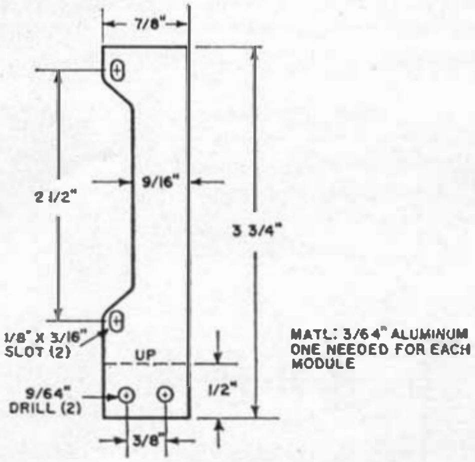



Fig. 11. If necessary, to avoid interference with components or wiring, deepen the notched cutout.

It is best to use color-coded wiring to minimize wrong connections and facilitate any possible troubleshooting. The resistors associated with *S1* may be assembled directly on the switch before installation. Also, use green-colored lenses on the decimal-point indicators.

The 1.35-volt reference cell (*B1*) is mounted wherever convenient within the chassis. Note that there are two types of mercury cell: those for general-purpose use and those for standard or voltage-reference purposes. Make sure that you get the latter. The accuracy of the DVM will be no better than the accuracy of the calibration standard.

**Setup and Calibration.** After a careful wiring check, the DVM may be plugged in and *S1* placed in the ZERO position. One digit in each column should light brightly and continuously. Turning the ZERO control through its entire range should change the display from 000 to 030. At about the mid-point of the control, the reading should be 001.

The proper setting of the ZERO control is the position immediately before

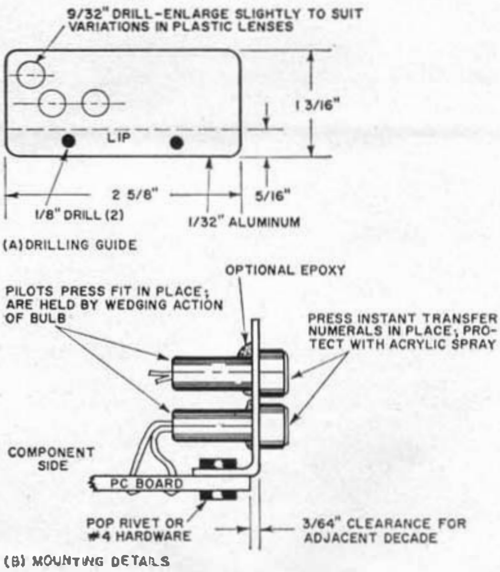



Fig. 12. Arrange lamp mounting holes in two closely spaced, staggered columns to obtain small size.

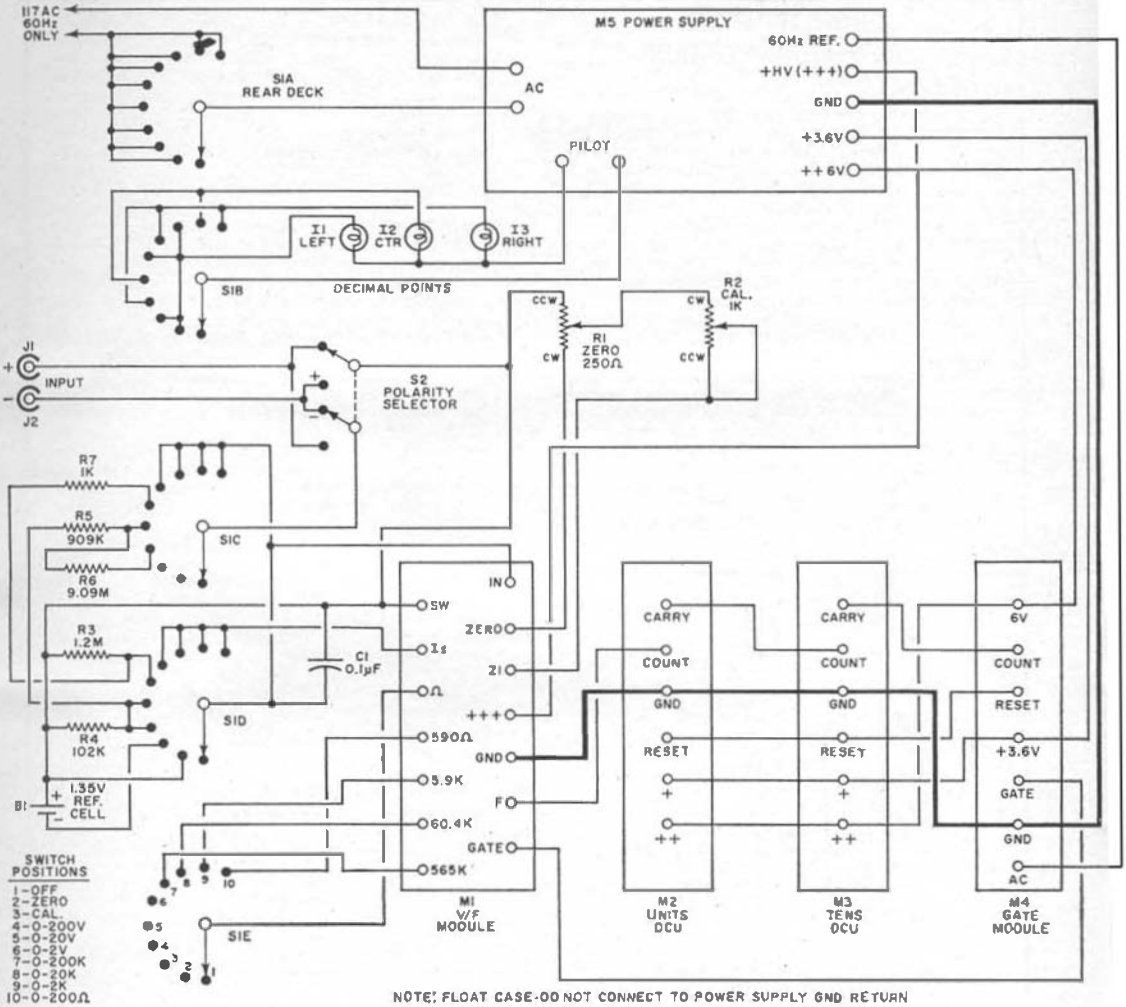



Fig. 13. The heavy line connecting the GND terminals in this overall wiring diagram is NOT a chassis ground; it is a convenient floating common bus.

## COMPLETE DVM PARTS LIST

*B1—1.35-volt AA mercury reference cell*
*C1—0.1-µF, 50-volt Mylar capacitor*
*I1-I3—6.3-volt, 50-mA pilot lamp.*
*J1, J2—5-way binding post, (red and black)*
*M1—V/F module (see text)*
*M2, M3—Decimal counting unit. See POPULAR ELECTRONICS February 1968 or Winter 1969 ELECTRONIC EXPERIMENTER'S HANDBOOK (see note).*
*M4—Gate module (see text)*
*M5—Power supply (see text)*
*R1—250-ohm, 2-watt linear potentiometer*
*R2—1000-ohm, 2-watt linear potentiometer*
*R3—1.2-megohm, ¼-watt resistor*
*R4—102,000-ohm, ¼-watt, 1% precision resistor*
*R5—909,000-ohm, ¼-watt, 1% precision resistor*
*R6—9.09-megohm, ¼-watt, 1% precision resistor or series resistor combination*
*R7—1000-ohm, ¼-watt resistor*
*S1—Five-deck, five-pole, ten-position, nonshorting rotary switch*
*S2—D.p.d.t. slide switch*
*Misc.—Vinyl clad aluminum case and support assembly, ¾" knobs (2), 1-½" knob (1), backup plate for controls, dialplate (optional), mounting hardware, brackets for M2, M3, (see Fig. 11), wire, solder, 1300- to 1500-ohm precision resistor, green jewels (2), etc.*
*Dialplate:—Hard anodized aluminum dialplate available from Reill's Photo Finishing, 4627 N. 11th St., Phoenix, Ariz. 85014. In black and silver, $3.00; in red, gold, or copper, $3.45, postpaid in USA. Stock #DVM-1.*
*Note—Kits for the decimal counting units are available from Southwest Technical Products, 219 W. Rhapsody, San Antonio, Texas 78216 for $12 each, postpaid in USA. A complete kit of all above parts, including a punched and machined, vinyl-clad case and support assembly, but less dialplate and B1 is available from the same source for $79.50 plus postage for 6½ pounds.*

## HOW IT WORKS
### OVERALL OPERATION

The function selector includes switch *S1* and its associated circuits. Here all input signals are converted to 0-2-volt d.c. voltages across a one-megohm resistance. When measuring 2 volts d.c. or less, the signal is applied directly to the remainder of the circuit. Above 2 volts, the signal is attenuated by 10 or 100. For ohms measurement, a calibrated and temperature-compensated current source supplies 0.01, 0.1, 1, or 10 mA to the input terminals. The voltage drop across the resistance (between 0 and 2 volts) is then an accurate measure of the resistance. For example, 1 mA of current through a 1600-ohm resistor produces a voltage drop of 1.6 volts. Because maximum ohmmeter current is only 10 mA on the lowest range (less on the higher resistance ranges), you can safely measure most current-sensitive devices without fear of damage.

For calibrating and zeroing the instrument, the function selector switch connects either a 1.35-volt mercury standard battery or a short circuit to the input.

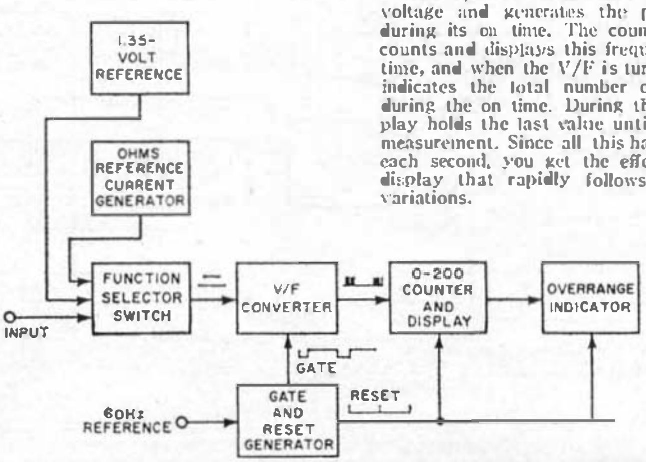
The 0-2-volt d.c. signal from the function selector is fed to a voltage-to-frequency (V/F) converter. This is a current-driven unijunction oscillator whose output frequency is proportional to the input voltage. Unlike industrial V/F converters, this one runs "open loop" and relies on calibration and inherent linearity rather than on complex and expensive feedback schemes for accuracy. Linearity, range, and resolution are more than adequate for the one-part-in-200 digital display used.

The output of the V/F converter drives a 0-199 counter/display (DCU's) and turns on a red overrange indicator when full scale is exceeded.

If this were the entire circuit, the digital display would be a blur of numbers that would just keep on adding up the output pulses from the V/F converter. Additional circuitry, called the gate-and-reset generator, continuously turns the V/F converter off and on and erases the old display before presenting an up-dated one.

In the gate and reset generator, the 60-Hz power from the line is used to generate a signal that turns the V/F converter on for one-fourth of the time and allows the display to show the results for three-fourths of the time. Immediately after the V/F converter is turned on, a very brief reset pulse is generated to erase the counter display before the new results can arrive at the DCU's.

The V/F converter then averages the input voltage and generates the pertinent frequency during its on time. The counter/display module counts and displays this frequency during the on time, and when the V/F is turned off, the display indicates the total number of pulses generated during the on time. During the off time, the display holds the last value until reset for the next measurement. Since all this happens fifteen times each second, you get the effect of a continuous display that rapidly follows the input-voltage variations.




you get the 001 reading. If you turn the control down all the way, you'll pick up some serious low-scale errors.

After zeroing, switch to the CAL 1.35 position. When the CAL potentiometer is turned through its entire range, the indicator should go from about 1.20 to about 1.50 with 1.35 at about the middle of the range. If you cannot get the readings low enough, or if 1.35 is at the *lower* end of the control, add one or two 500-pF mica capacitors across integrating capacitor *C3* in the V/F module till you get the proper range.

Very rarely, it may be necessary to change the value of *R11*. This occurs because of variations in the characteristics of *Q6*, the unijunction transistor. If the V/F converter oscillates but does not drive the counter, either increase or decrease the value of *R11* (in a range of 6.8 to 22 ohms) until proper operation is obtained.

Always rezero the instrument before calibrating. The settings will be remarkably stable after a few minutes' warmup. A slight interaction between the CAL 1.35 and the ZERO controls is normal, so always recheck the ZERO setting after calibrating.

To check zeroing, short test leads together, and misadjust zero control to get an 001 reading. Switch *S1* to 0-2 range. The reading should stay at 001. Remove the short. If the reading

(*Continued on page* 108)

## VOLT-OHMMETER

*(Continued from page 40)*

changes, adjust *R2* on the V/F module to get an identical 001 reading with the input test leads either open or shorted. Center the adjustment on the 001 reading and then adjust it slightly lower, favoring the 000 reading.

### DIGITAL VOLTMETER SPECIFICATIONS

**Ranges:** D.c. volts: 0-2, 0-20, 0-200. Ohms: 0-200, 0-2000, 0-20,000, 0-200,000. Range extendable to anything that can be represented by a variable 0-2-volt d.c. signal.

**Input Impedance (Voltmeter):** 0-2, 1 megohm; 0-20, I megohm; 0-200, 10 megohms.

**Maximum Ohmmeter Current:** 0-200,000 ohms, 10 μA; 0-20,000 ohms, 100 μA; 0-2000, 1 mA; 0-200, 10 mA.

**Resolution:** One part in 200, any range. ±5 millivolts on 0-2-volt range, ±0.5 ohms on 0-200-ohm range.

**Accuracy:** Better than ±1% of full scale, ±1 count over most portions of most ranges. Internal calibration with 1.35-volt secondary mercury standard.

**Stability:** Less than 1 count drift per 20 minutes after 15-minute warmup.

**Noise Rejection:** Instrument is a fully integrating, multiple slope type and is essentially "blind" to any 60-Hz line-borne hum or noise and has a high degree of rejection to all other high-frequency noise.

**Update Time:** 15 measurements per second; instrument integrates input for 16.7 milliseconds and displays for 50 milliseconds.

**Miscellaneous:** Automatic overrange indicator, floating decimal points for "actual value" indication; zener input protection; polarity reversal switch; internally self-calibrating; useful accuracy to 200% of full scale.

To calibrate the ohmmeter portion, ZERO and CALibrate the DVM as described above. Then place the test leads across a precision 1% resistor between 1300 and 1500 ohms (do not use higher or lower values) and switch to the 0-2K resistance range. If the DVM does not read exactly the resistance being measured, adjust *R13* on the V/F module till it does. The instrument is now fully calibrated on all scales.

Readjust the ZERO and CALibrate 1.35 front-panel controls any time you like. This gives you an instant check on how the DVM is doing. The internal trimmers will rarely if ever need readjustment. —30—