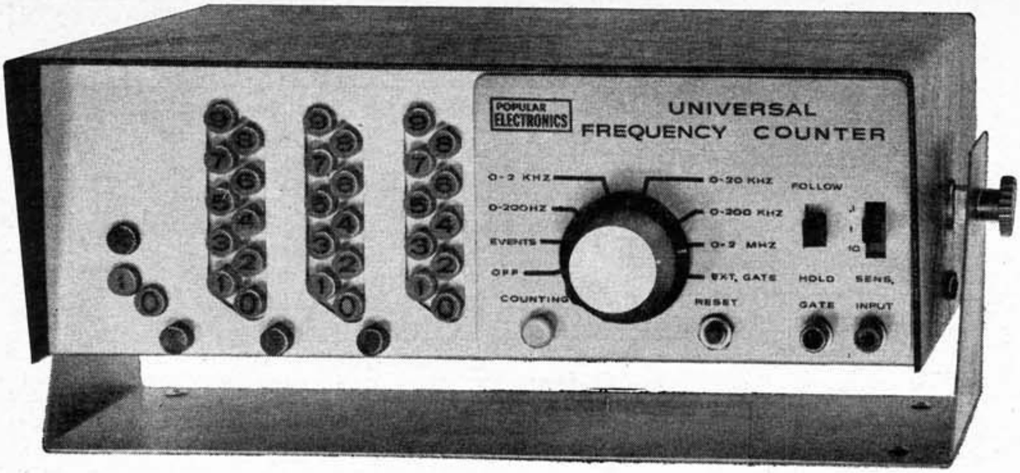

BUILD THE

Popular Electronics Universal Frequency Counter

HIGH-ACCURACY COUNTING TO 2 MHz

BY DON LANCASTER

PART 1 OF 2 PARTS

HOW OFTEN do you come across a frequency counter like this: maximum range—2 MHz; cost—less than \$200? The answer is very rarely, and that's why the POPULAR ELECTRONICS Universal Frequency Counter will be of prime interest to project builders in all areas. Its list of attributes doesn't end, however, with frequency range and price: it has seven counting ranges (200 Hz to 2 MHz), a choice of three automatically sequencing time bases (0.1, 1 and 10 seconds), and a comparator with built-in noise immunity and guarded input. The latter provides excellent sensitivity to sine waves, square waves or narrow pulses of either polarity, regardless of duty cycles. A special electronic synchronizer eliminates variations in the display of the last digit (known as bobble) and an overrange light indicates when the counter's capacity is exceeded.

With the Universal Frequency Counter, you can count events, measure frequencies from 0.1 Hz to over 2 MHz or you can gate the instrument externally so that it can be used as a stopwatch or to measure the ratio of two frequencies. The basic instrument has 0.1% accuracy with a 3½-digit display (3 digits plus overrange indication) and a line-operated time base similar to most commercial counters in the "under \$600" category.

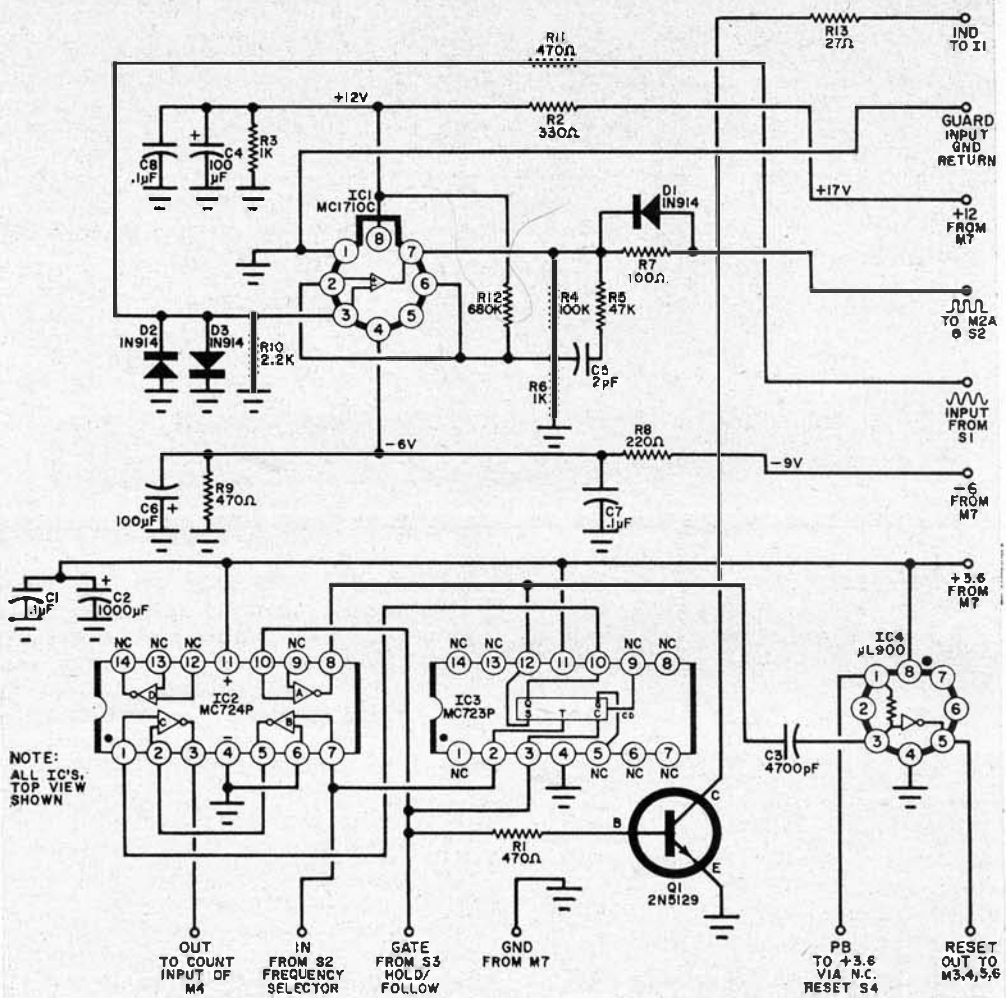

Fig. 1. The comparator module actually contains three separate circuits: input signal comparator (IC1), signal-time base synchronizing circuit (IC2 and IC3), and automatic reset generator IC4.

PARTS LIST
COMPARATOR MODULE

C1, C7, C8—0.1-μF, 10-volt disc ceramic capacitor
C2—1000-μF, 3-volt electrolytic capacitor
C3—4700-pF polystyrene, Mylar, or disc ceramic capacitor
C4, C6—100-μF, 15-volt electrolytic capacitor
C5—2-pF mica capacitor
D1-D3—1N914 silicon computer diode or equivalent
IC1—Operational amplifier (Motorola MC1710CG)
IC2—Quad two-input gate (Motorola MC724P)
IC3—JK flip-flop (Motorola MC723P)
IC4—RTL buffer (Fairchild μL900)
Q1—Transistor (National 2N5129)
R1, R9, R11—470-ohm
R2—330-ohm
R3, R6—1000-ohm
R4—100,000-ohm
R5—47,000-ohm
R7—100-ohm
R8—220-ohm
R10—2200-ohm
R12—680,000-ohm
R13—27-ohm

All resistors ¼-watt

Misc.—PC terminal (USECO 1310B, optional, not provided in kits, 13), #24 wire for jumper, solder.
Note:—The following are available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216: etched and drilled fiberglass circuit board, #M1b, $3.20: complete kit of all parts required, #M-1, $14.65, plus postage, 6 oz.

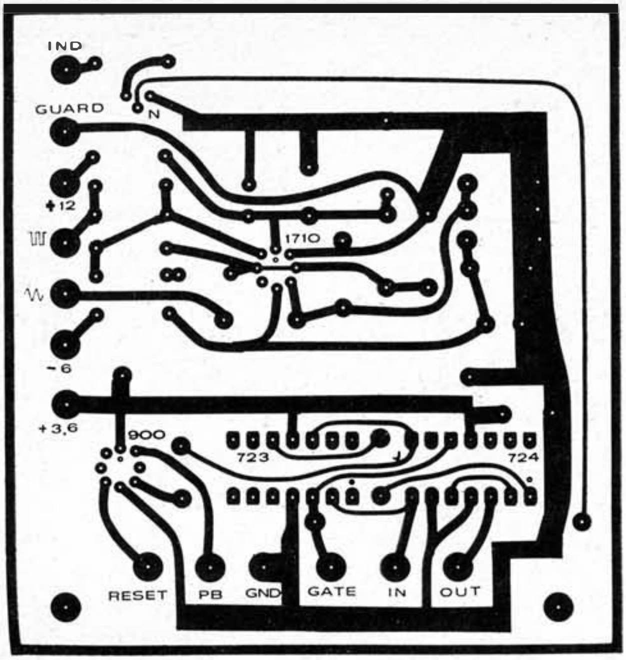

Fig. 2. Actual-size printed board for the comparator module. Because of the complexity of the circuit, printed boards are a must for this project.

Modular construction permits easy addition of extra decades or use of a more accurate, crystal time base. For instance, the time base used in POPULAR ELECTRONICS' Electronic Stopwatch (March 1968) and Sports Timer (October 1968) can be easily adapted for use in the counter. It is also possible to add divide-by-ten scalers to extend the counter's basic range to 20 or 200 MHz, direct reading.

While the Universal Frequency Counter is probably the most complex construction project ever presented in a hobby electronics magazine, the extensive use of integrated circuits and modular construction greatly simplifies the project. It is not a project for beginners but the procedure is relatively simple and straightforward. Parts and a complete kit are readily available as noted in the parts lists.

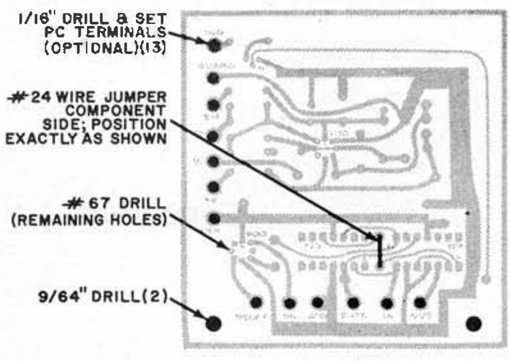

Fig. 3. Drill the board as shown here, and install the single jumper on the component side of board.

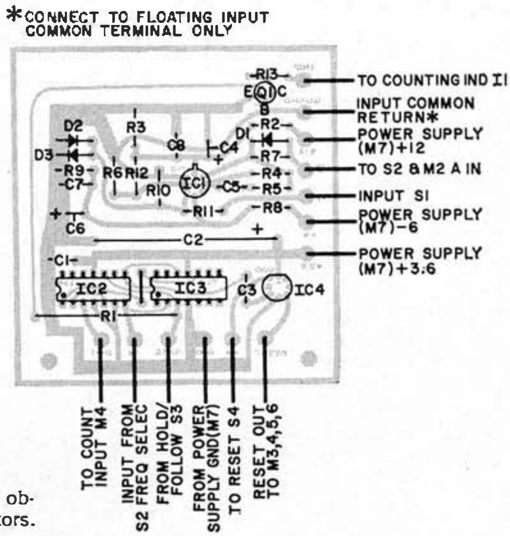

Fig. 4. Install the components taking care to observe polarities of semiconductors and capacitors.

HOW IT WORKS
COMPARATOR MODULE

There are actually three circuits in the Comparator module: a comparator, a synchronizing circuit, and a reset generator.

The comparator (*IC1*) is a high-gain operational amplifier that compares two input signals and provides a digital output signal generated by the difference between the signal input and a reference signal. The reference is derived from the output of the comparator by positive feedback and is either 10 or 30 millivolts positive. When the instantaneous value of the input signal is more than 30 millivolts, the output of the comparator goes to ground, helped along by a dropping reference voltage through positive feedback. If the input signal drops below 10 millivolts, the comparator output goes positive, again aided by feedback. This two-level action is called hysteresis, and it permits the comparator to operate with inputs that are noisy or are very low-frequency sine waves without producing a noisy output.

The comparator is protected on the input side by diodes *D2* and *D3*, which also act to restore the d.c. level for narrow pulse inputs. Feedback is provided by *R4*, *R5*, and *C5* and is both a.c. and d.c. Other components in the comparator circuit provide power supply decoupling and output load matching.

The synchronizing circuit consists of four gates and a JK flip-flop. The circuit delays the input measure command until the first input signal arrives and holds the measure command until one more input signal passes through the switch, *after* the measure command ceases. In this way, the measuring interval is locked to the signal to be counted. This eliminates a one-count bobble that might take place if the measurement command were turned on at random either just before or just after an input signal arrived. Transistor *Q1* is used to drive the COUNTING indicator light.

The reset generator, *IC4*, is a buffer connected as a half-monostable circuit. It generates a 2-microsecond reset pulse at the beginning of the measure command to reset the counters to zero. Operation of the RESET pushbutton, interrupts the positive supply to pin 1 of *IC4* and provides a longer positive output voltage. Either the automatic pulse or the manual reset causes the readouts to drop to zero.

Construction. The Universal Frequency Counter consists of seven modules, plus the case and some panel components. Module 1 is the comparator, module 2 is the Scaler, module 6 is the Gate, and module 7 is the Power Supply. The construction of these modules is given in detail here. Modules 3, 4, and 5 are decimal counting units that are fully described in the Winter 1969 ELECTRONIC EXPERIMENTER'S HANDBOOK and the details of their construction will not be given here.

It is advisable to build each module separately following the instructions carefully. Each module has its own schematic, parts list, and circuit board pattern. Note that round IC's are identified by a tab, flat, or color dot beside pin 8, while the rectangular (inline) units have a notch or dot at one end. In the schematic diagrams, they are shown from the top and the pins are numbered counterclockwise from the identifying mark. Be sure that all IC's are properly positioned before soldering connections. Also be careful to observe the polarities of diodes and electrolytic capacitors. Use fine solder and a low-power (25-35 watts) soldering iron.

Comparator (M1) The schematic for this module is shown in Fig. 1. A printed circuit board is a must. You can make your own, using the foil pattern in Fig. 2 or purchase one etched and drilled (see Parts List for Fig. 1). Install the single jumper on the component side as shown in Fig. 3. To mount the components on the board, follow the layout in Fig. 4.

Scaler (M2) The schematic for the Scaler is shown in Fig. 5. Construction will be greatly simplified by use of the circuit board whose pattern is shown in Fig. 6. Install the 12 jumpers on the component side of the board as shown in Fig. 7. The four jumpers marked with an asterisk should be insulated with small pieces of sleeving. Install the nine IC's and two capacitors as shown in Fig. 8.

Gate (M6) The Gate module schematic is shown in Fig. 9. Once again, construction will be greatly simplified by the use of a PC board. You can make your own using the pattern in Fig. 10. Mount the four jumpers on the component side as

A NOTE ON DCU'S

The Universal Frequency Counter can only use the new, low-power decimal counting units described fully in the Winter 1969 edition of ELECTRONIC EXPERIMENTER'S HANDBOOK. Module kits sold by Southwest Technical Products since October 1968 are of the new type.

Here's how to tell what you have: (1) if your DCU has only three IC's, you have the new unit; (2) if it has four IC's but no 1-watt resistors, you have a medium-power unit, modification of which is suggested but not essential; (3) if it has four IC's and two 1-watt resistors, you have the original version which must be modified if it is to be used in the counter. Modification kits with complete instructions are available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216, for $1 per module.

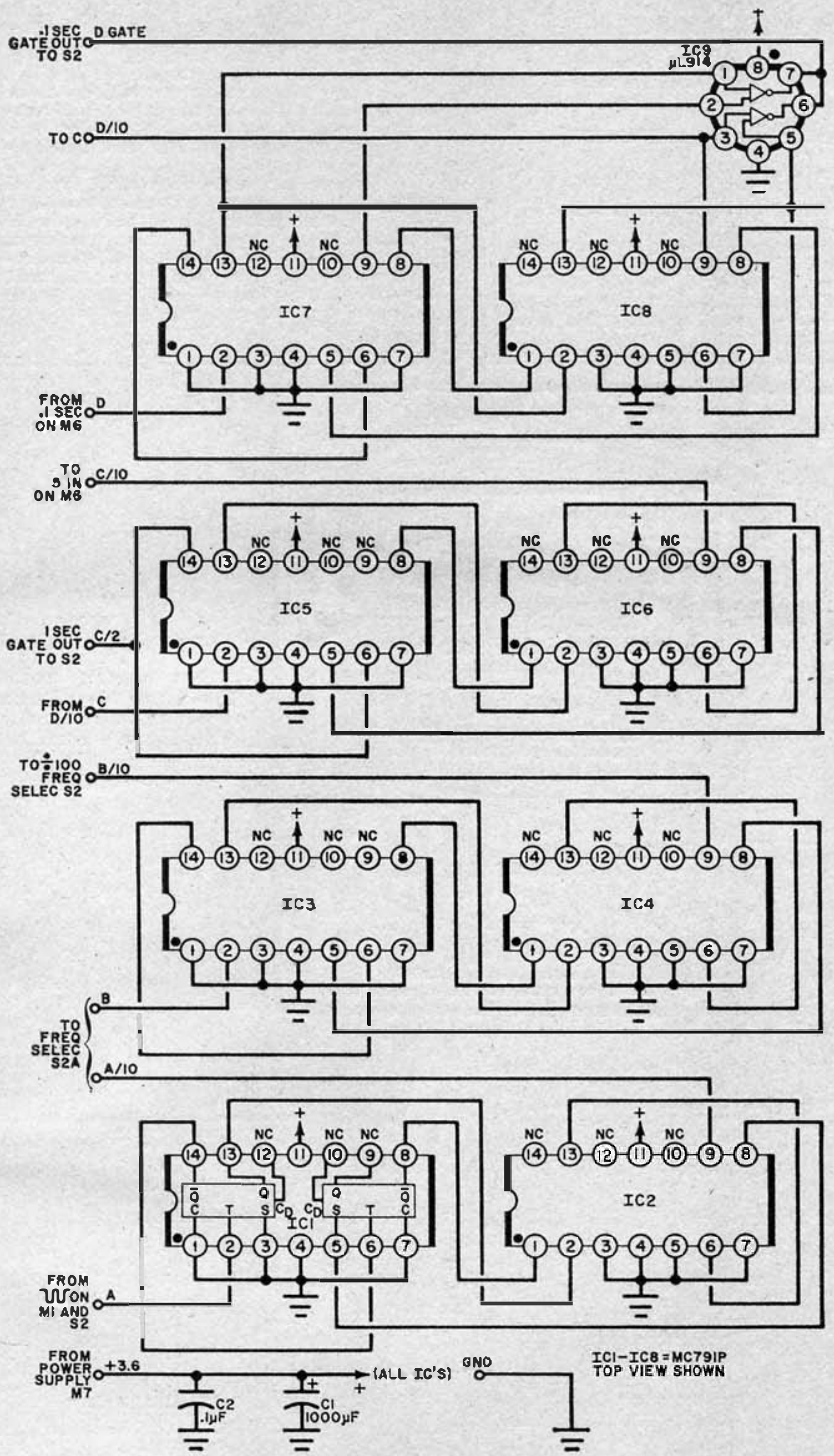

Fig. 5. The scaler module contains four independent divide-by-10 circuits, with IC1-IC4 scaling (divide by 10 or 100) the input frequency, while IC5-IC8 does the same for the timer circuit.

PARTS LIST
SCALER MODULE

C1—1000-µF, 3-volt electrolytic capacitor
C2—0.1-µF, 10-volt disc ceramic capacitor
IC1-IC8—MRTL dual JK flip-flop (Motorola MC791P)
IC9—RTL dual two-input gate (Fairchild µL914)
Misc.—#24 wire (12 jumpers), insulated sleeving for jumpers (4), PC terminals (USECO 1310B, optional, 12, not provided in kit), solder.
Note:—The following are available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216: etched and drilled fiberglass circuit board, #M-2b, $2.85; complete kit of all parts required, #M-2, $21.90, plus postage, 6 oz.

HOW IT WORKS
SCALER MODULE

There are four independent divide-by-ten or decade counters in the Scaler module. Each counter, or scaler, consists of four JK flip-flops in a "modulo-10 minimum-hardware" circuit, the simplest possible decade divider.

Of the four scalers, units A and B are used to divide the input frequency by a factor of 10 or 100 as necessary. Scalers C and D are used in the timing circuit to generate measure commands. Scaler C has a divide-by-two output, which provides the 1-second measure command; scaler D has a 1-of-10 decoder (*IC9*), which provides the 0.1-second measure command.

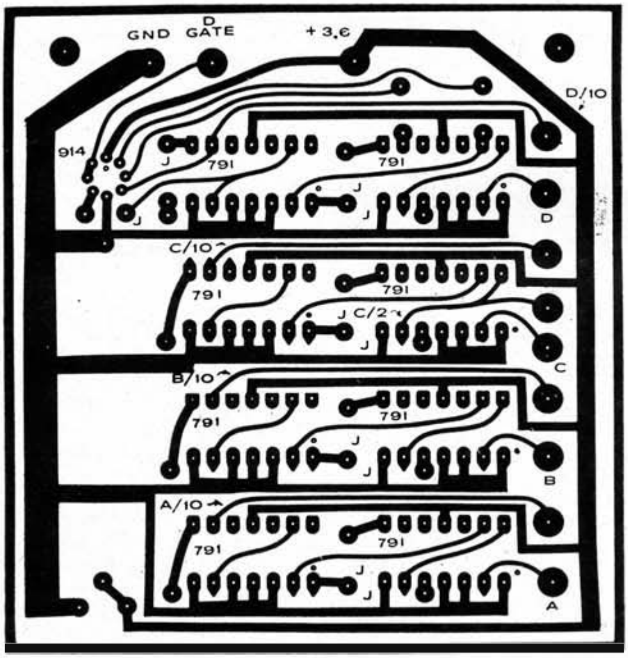

Fig. 6. Actual-size foil pattern for scaler module. This board, like all others is available etched and drilled (see Parts List).

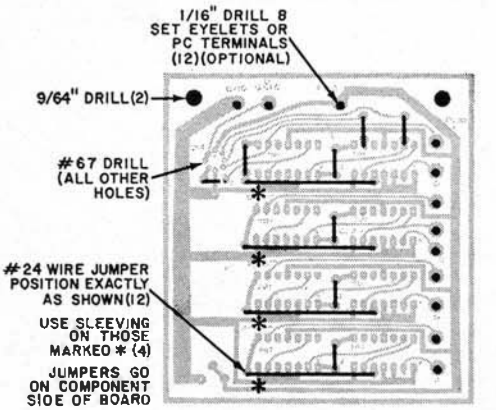

Fig. 7. After drilling the PC board, install the 12 jumpers on the component side in positions shown.

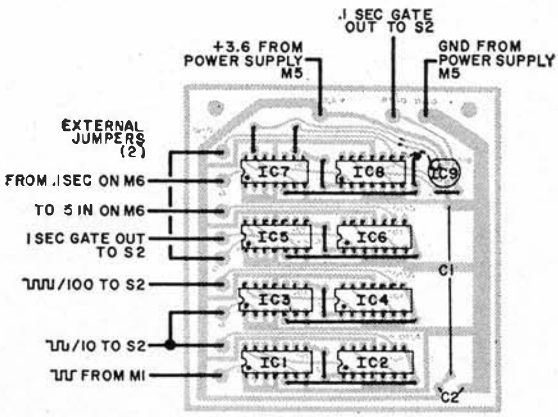

Fig. 8. When installing in-line IC's, observe the notch and code dot. Round IC has a flat at pin 8.

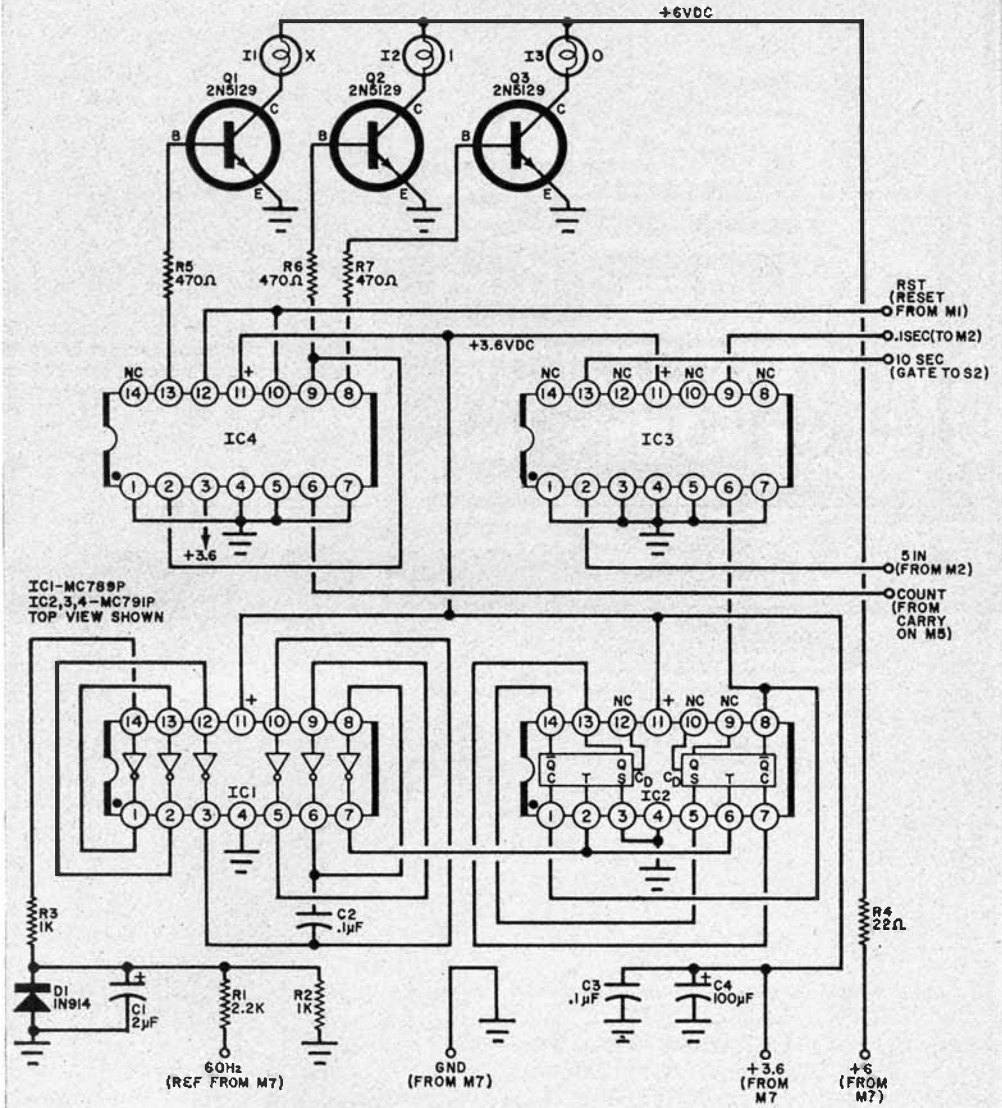

Fig. 9. The gate module performs three functions: accepts, shapes, and converts 60 Hz to 20 Hz; produces .1- and 10-second gates (IC3); and mounts 0-1 and overflow circuit (IC4, Q1, Q2, Q3).

PARTS LIST GATE MODULE

C1—2-μF, 10-volt electrolytic capacitor
C2, C3—0.1-μF, 10-volt disc ceramic capacitor
C4—100-μF, 15-volt electrolytic capacitor
D1—1N914 silicon computer diode
I1-I3—6.3-volt, 50-mA indicator lamp assembly, two orange, one red (Southwest Technical 0-6.3 and R-6.3, respectively, or similar)
IC1—MRTL hex inverter (Motorola MC789P)
IC2-IC4—MRTL dual JK flip-flop (Motorola MC791P)
Q1-Q3—Transistor (National 2N5129)
R1—2200-ohm
R2, R3—1000-ohm
R4—22-ohm
R5-R7—470-ohm
All resistors ¼-watt
Misc.—#24 wire (4 jumpers), insulated sleeving (1 inch), bracket and mounting hardware for lamps, PC terminals (USECO 1310B, optional, 9, not provided in kit), solder.
Note:—The following are available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216: etched and drilled circuit board, #M-6b, $2.35; complete kit of all parts required, #M-6, $13.85, plus postage, 5 oz.

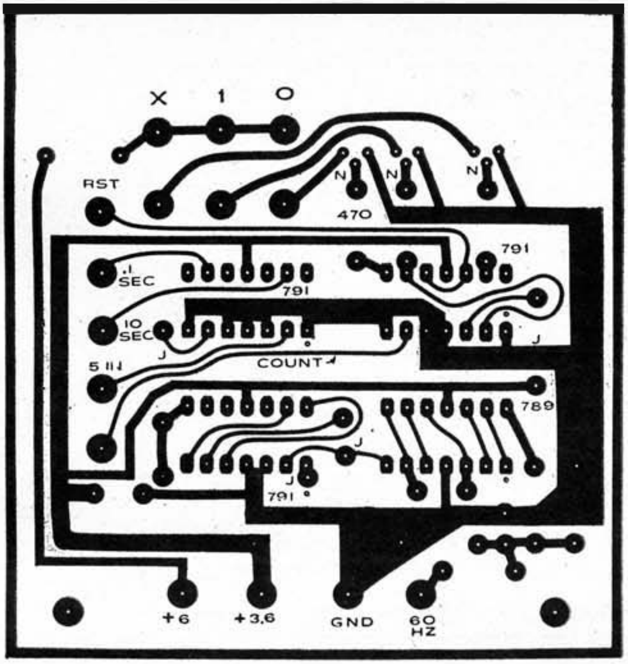

Fig. 10. Actual-size foil pattern for the gate module. As in the other foil patterns, each input-output termination and semiconductors are marked.

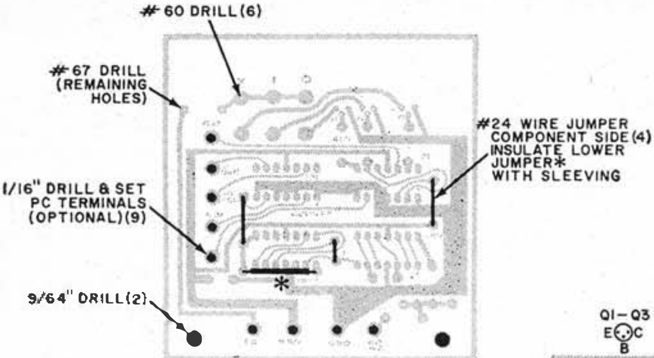

Fig. 11. Mount four jumpers on the component side of the board, making sure the indicated jumper is insulated to prevent short circuiting IC2.

shown in Fig. 11. Insulate the lower jumper with suitable sleeving. Mount the components as shown in Fig. 12.

A mounting bracket is required for this module to hold the three indicator lights. Details for this part appear in "Low-Cost Counting Unit," ELECTRONIC EXPERIMENTER'S HANDBOOK, Winter 1969 and "Digital Volt-Ohmmeter," POPULAR ELECTRONICS, December 1968. The bracket is mounted by match drilling to the PC board, then pop-riveting using #4 hardware. An orange plastic lens can be used for both the 0 and 1 indicators and a red lens for the overrange indicator.

Power Supply (M7) Most of the power supply, whose schematic is shown in Fig. 13, is assembled on the PC board shown

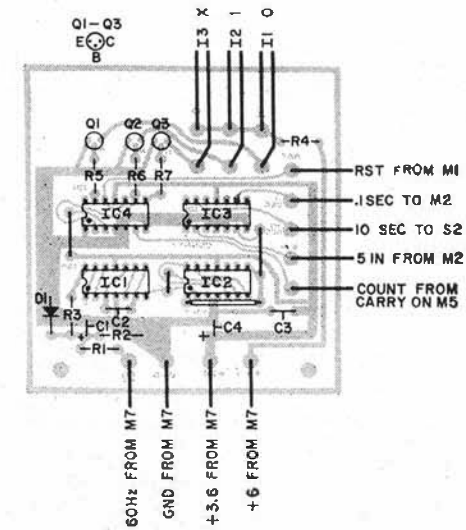

Fig. 12. Mount the board components as shown here, once again taking care to observe all polarities.

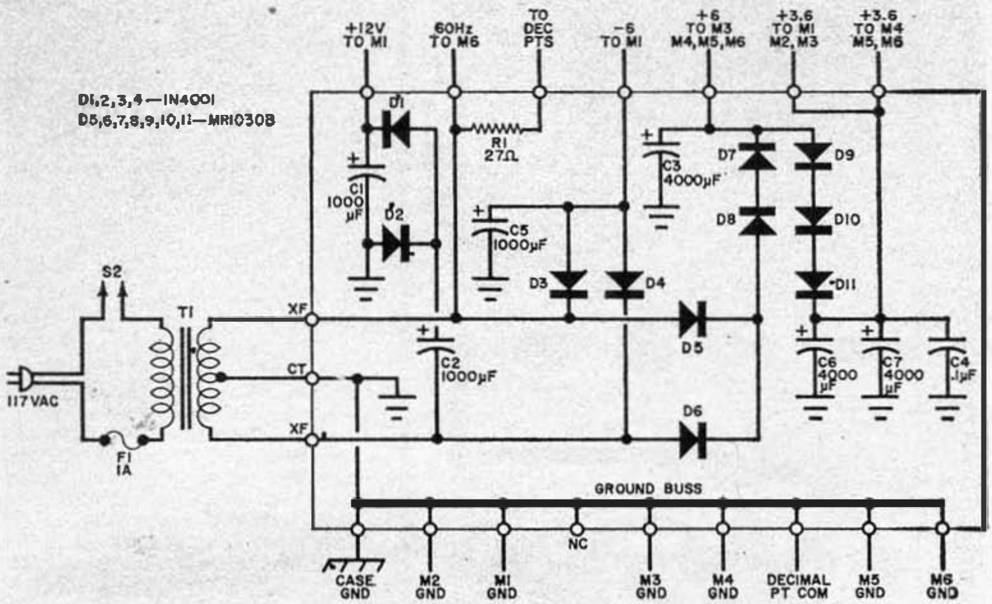

Fig. 13. Note the eight connections to the ground buss. This is done to reduce stray coupling between the various modules. Each module ground should be run on a short, heavy lead.

PARTS LIST
POWER SUPPLY MODULE

C1, C2, C5—1000-µF, 25-volt electrolytic capacitor
C3, C6, C7—4000-µF, 6-volt electrolytic capacitor
C4—0.1-µF, 10-volt disc ceramic capacitor
D1-D4—1-ampere, 50-PIV silicon diode, 1N4001 or equivalent
D5-D11—3-ampere average, 24-ampere peak, 50-PIV silicon rectifier (Motorola MR1030B, do not substitute)
F1—1-ampere fuse
R1—27-ohm, ¼-watt carbon resistor
T1—12.6-volt center-tapped, 2-ampere filament transformer
Misc.—PC mouting spacers and hardware, PC terminals (USECO 1310B, optional, 19, not provided in kit), line cord with strain relief, fuse-holder and mounting hardware, solder.
Note:—The following are available from Southwest Technical Products, Box 16297, San Antonio, Texas 78216: etched and drilled fiberglass circuit board, #M-7b, $3.50; complete kit of all parts required, #M-7, $19.10 plus postage, 3 lb.

HOW IT WORKS
GATE MODULE

The Gate module contains three circuits: the gate generator, the 10-second measure command generator, and the 0-1 counter and overflow latch with indicators. The first two circuits, together with scalers C and D in the Scaler module, provide the time base, while the last circuit extends the range of the counter by half a digit and provides an indication to call attention to the fact that the input signal has exceeded the full counter capacity.

The gate generator accepts the 60-Hz powerline reference from the power supply module, filters and clamps it, and then applies it to a hex-inverter squaring circuit, *IC1*. Positive feedback, via *C2*, provides additional edge steepening, to provide the 100-nanosecond rise and fall times required by the next stage.

A divide-by-three counter (*IC2*) uses a pair of flip-flops to reduce the 60-Hz input to a 20-Hz square wave. This circuit is twisted slightly from a "normal" divide-by-three circuit to save some PC board jumpers. The first flip-flop in *IC3* divides the 20-Hz time-base signal into 10 Hz (a 0.1-sec period) which is the reference required to run scalers C and D on the Scaler module. The second flip-flop converts the output of scaler C which has a 10-sec period into a 10-sec on and 10-sec off measure command as required for the 0-200-Hz range.

The 0-1 counter and overrange latch is made up of *IC4* driving transistors *Q1* through *Q3*, which supply power to the appropriate front-panel indicator lamps.

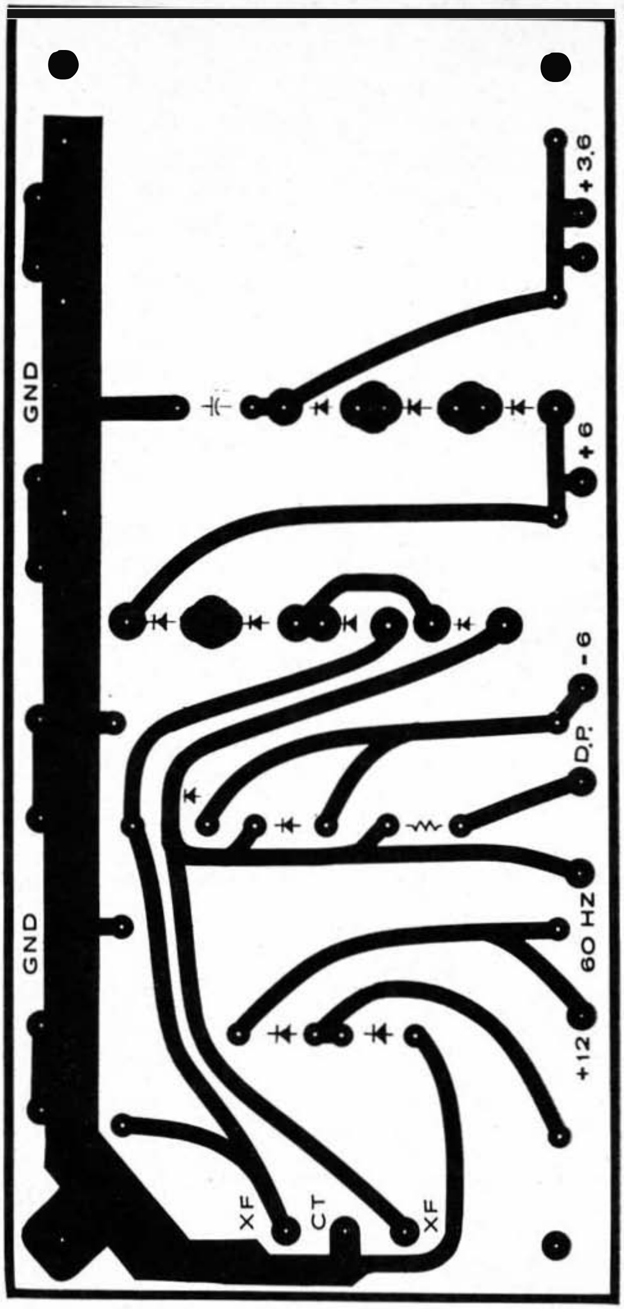

Fig. 14. Power supply foil pattern is the largest one in the instrument. It should be made on fiberglass to avoid heat damage from power diodes. To assist cooling, mount all diodes slightly off the board to allow cool air to circulate around them to dissipate the heat. Also, do not allow the diodes to touch the capacitors.

in Fig. 14. The power transformer (*T1*) and the fuse (*F1*) are mounted on the counter chassis. Use a G-10 fiberglass base for this circuit board so that it can withstand the heat generated by the power diodes. Drill holes as shown in Fig. 15.

To avoid stray coupling between modules through ground connections, it is very important that all module grounds be isolated from each other and at very low impedance. For this reason, a wide ground buss is provided on the power supply circuit board, with a separate terminal for connections to each of the other modules. A separate #16 (or other heavy-gauge) wire should be run from each module to the ground buss. All

HOW IT WORKS POWER SUPPLY

The power supply must provide more than an ampere of current at 3.6 volts d.c. and other lower current supplies at +6, −6, and +12 volts. It also provides a.c. to the decimal point lamp and the Gate module.

To obtain all these voltages from a single power transformer requires a few more diodes than would normally be needed with a multi-winding transformer.

The +12-volt supply is derived from a voltage doubler consisting of *D1*, *D2*, *C1*, and *C2*. The supply is actually about 17 volts at the output terminal; it is reduced to 12 volts by the decoupling network in the Comparator module. Similarly the full-wave rectifier made up of *D3*, *D4*, and *C5* provides about −9 volts, which is reduced to −6 volts in the Comparator.

A second full-wave rectifier (*D5* and *D6*) produces +6 volts with diodes *D7* and *D8* acting as a dynamic regulator. This supply is reduced by *D9*, *D10*, and *D11* to provide +3.6 volts for the integrated circuits. While the average current through diodes *D5* through *D11* is about one ampere, the peak current is much larger—high enough to damage ordinary silicon power diodes. That is why three-ampere silicon rectifiers are specified in the Parts List.

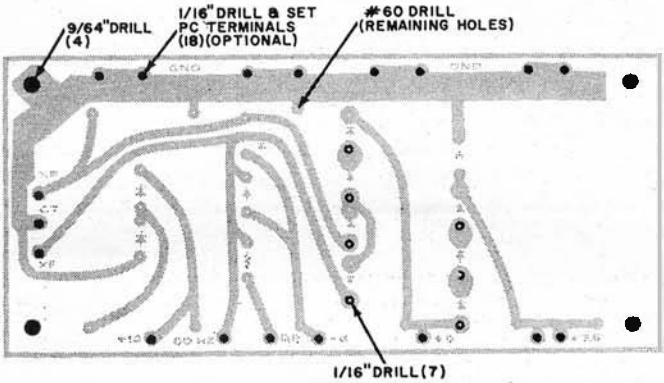

Fig. 15. There are no jumpers on the power supply board. After it is drilled, mount the components.

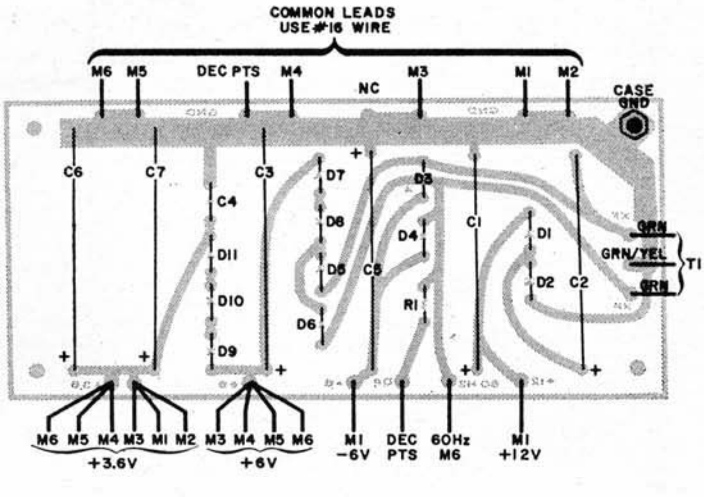

Fig. 16. Finish the power supply by mounting the components. Note that each module ground is made via an independent #16 gauge wire and one connection is made to counter case (upper right).

ground leads should be kept as short as possible.

Components are installed on the power supply board as shown in Fig. 16. Note that *C5* is upside down with respect to the polarity of the other capacitors. Note also that all diodes point in the same direction. Be sure that there is sufficient cooling space between the diodes and the electrolytic capacitors since the latter can be damaged by diode heat generation.

Connect the power supply module to the case through a single ground lead. Do not run any other ground leads to the chassis except the return for *J1*, the INPUT jack.

NOTE: Final assembly, alignment, and calibration will be given next month.