

BUILD A

Low-Cost Counting Unit

YOU CAN ASSEMBLE TRUE DIGITAL READOUT
AT \$12 PER DECADE

BY DON LANCASTER

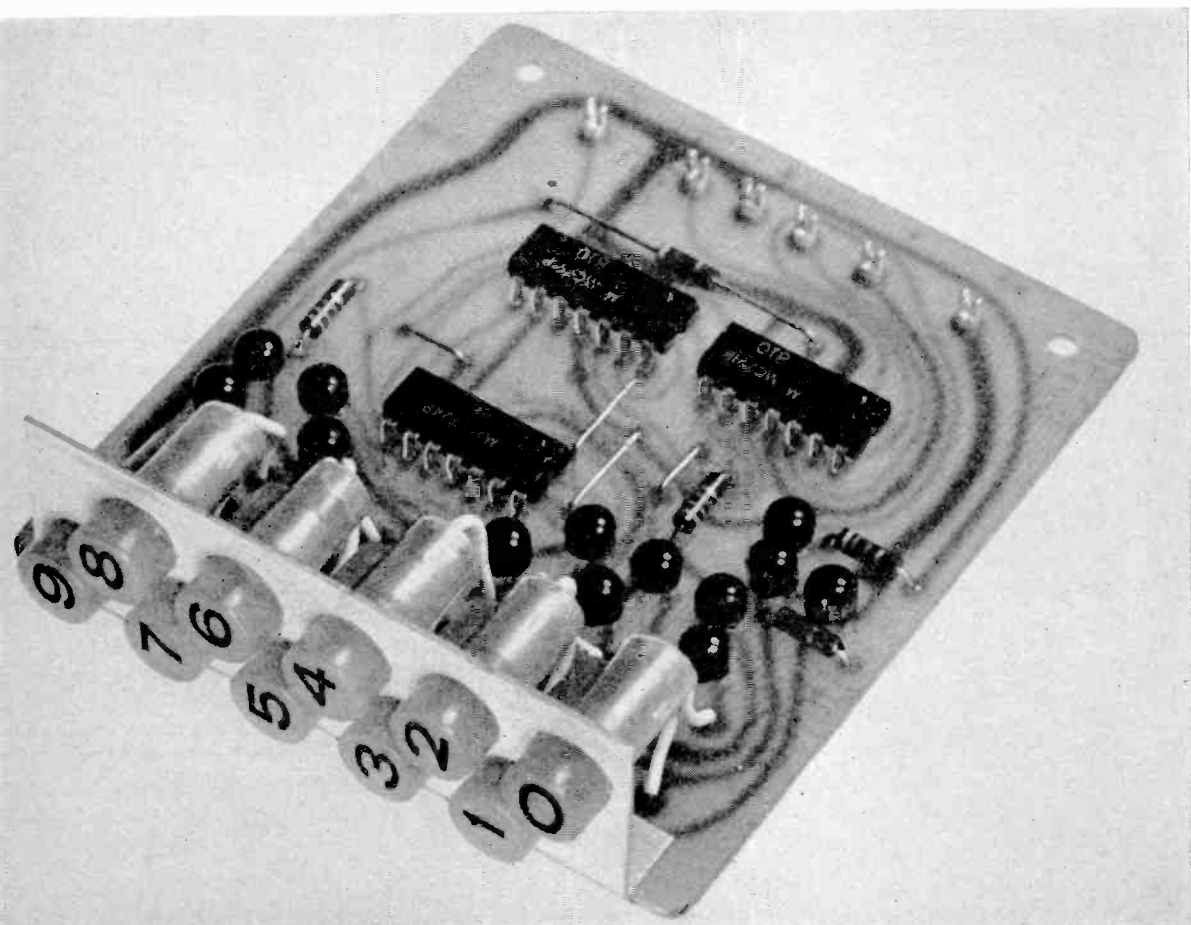
DIRECT, unambiguous numerical readout at low cost—the dream of most electronics experimenters, technicians, and engineers—is now made possible by inexpensive integrated circuits and a few seldom-used circuit tricks. For just \$12 per decade *total* cost, you can have a complete, resettable decimal counter with a bright staggered-line 0 to 9 incandescent readout, good from one count per day to 10 MHz.

You can cascade many of these decades together as you need for almost any digital display. Using these decimal counters, *ELECTRONIC EXPERIMENTER'S*

HANDBOOK will, in future issues, show how you can make a digital voltmeter, digital multimeter, and a universal frequency counter.

You'll be able to create an adding machine, a ballistic-velocity meter, or an event counter. And the list does not end there. Using this low-cost DCU, you can also make digital thermometers, electronic clocks, engine tachometers, direct-reading CE crystal (or other frequency) crystal checkers, photographic shutter checkers—and even a digital computer.

The basic decimal counter, whose schematic is shown in Fig. 1, uses three IC's,



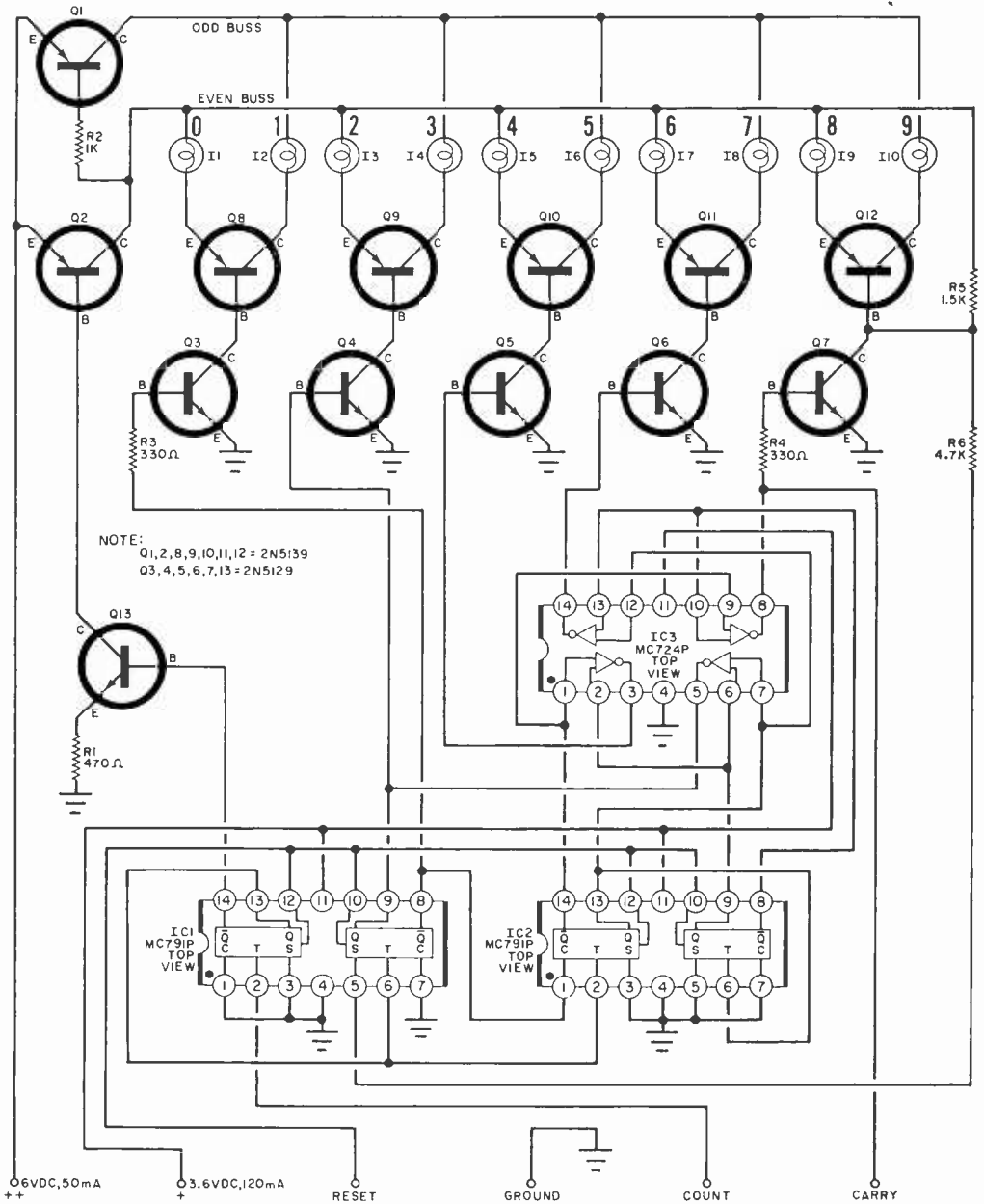


Fig. 1. In IC1 and IC2, the rectangles represent flip-flops while in IC3 and IC4, the triangles with circles represent multiple input gates. Logic symbols replace complicated circuitry.

six resistors, 13 transistors, and 10 incandescent bulbs. If desired, a complete decade kit is available (see Parts List).

Construction. An actual-size printed circuit board appears in Fig. 2, while Fig. 3 shows how the board is drilled, and also indicates the positions for in-

serting the four jumpers required. These jumpers are made from #24 solid wire and are added on the component side of the board.

When mounting the components (as shown in Fig. 4), be sure to observe the polarities for all semiconductors—making doubly sure that the IC's are mounted as

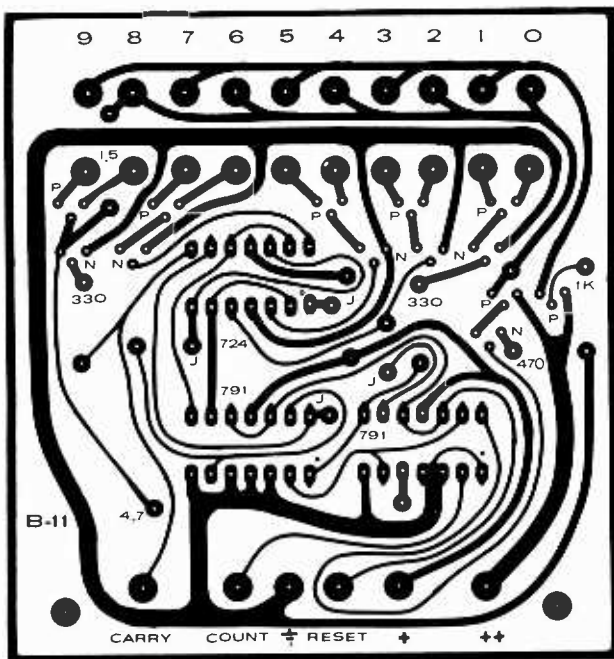


Fig. 2. Because of the complex wiring involved, it is almost mandatory that a printed circuit board, such as the one shown here actual size, be used. An etched and drilled board is available (see the Parts List).

PARTS LIST

11-110—6.3 Volt, 50-mA pilot lamp and lens assembly [Southwest Technical Products #0-6.3 or similar]*

IC1-IC2—MC791P Dual JK Flip Flop Integrated Circuit Motorola MRTL**

IC3—MC724P Quad Two Input Gate Integrated Circuit Motorola MRTL**

Q1, Q2, Q8, Q9, Q10, Q11, Q12—2N5139 PNP Transistor National Semiconductor***

Q3, Q4, Q5, Q6, Q7, Q13—2N5129 NPN Transistor National Semiconductor***

R1—470 ohm, 1/4 watt carbon resistor

R2—1000 ohm, 1/4 watt carbon resistor

R3, R4—330 ohm, 1/4 watt carbon resistor

R5—1.5K, 1/4 watt carbon resistor

R6—4.7K, 1/4 watt carbon resistor

MISC—Aluminum bracket (See Fig. 5); pop rivets (2); #24 solid wire jumpers (4); PC terminals (6); 3/16"-high instant transfer numerals, black; protective plastic spray; solder; etc.

*The following parts are available from Southwest Technical Products Corp. 219 West Rhapsody, San Antonio, Texas, 78216: Etched and drilled PC Board #148. \$3.00; Set of 10 lamps with plastic covers and spare bulb \$2.75; Complete kit of all parts, \$10.90, postpaid in U.S.A.

**Data sheet and distributor list available from Motorola Semiconductor, Box 955, Phoenix, Arizona, 85001. One distributor is Allied Electronics, 100 N. Western Avenue, Chicago, Illinois, 60680. IC1 and IC2 is stock #5E26-MC791P-MOT priced at \$2.35 each. IC3 is stock #5E26-MC724P-MOT at \$1.08.

***Data Sheet and distributor list available from National Semiconductor, 2950 San Ysidro Way, Santa Clara, California, 95051. The 2N5139 costs 22¢ each in single quantities; the 2N5129 costs 25¢ each in single quantities.

indicated. Use a low-wattage soldering iron and fine solder to make all connections.

The readout lamp display bracket is cut and bent out of 1/32" aluminum following the layout in Fig. 5. Two pop rivets secure the lamp bracket to the board. The indicator lamps press-fit into the holes in the bracket, through the front, and are secured by the wedging action of the plastic lens caps. Each bulb lead is

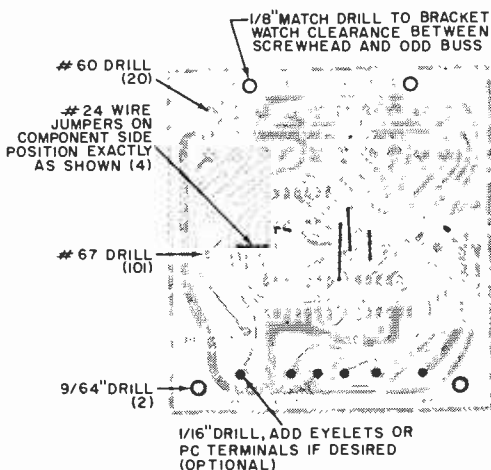


Fig. 3. Drilling details for the board. Don't forget to include the eight insulated wire jumpers.

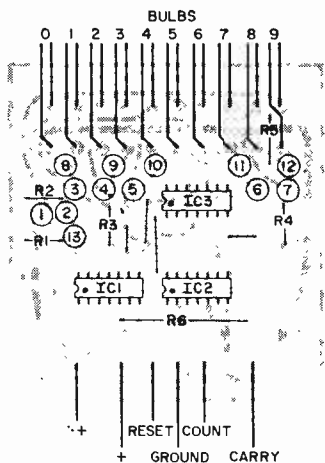
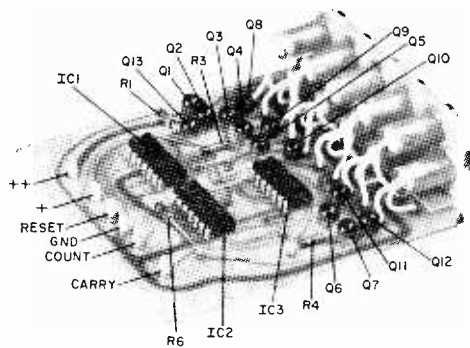
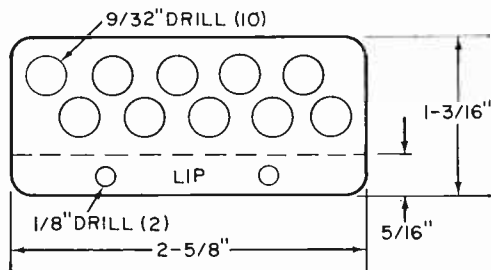


Fig. 4. Placement of the components on the board. Note that all IC's are notch- and dot-identified.



The PC board with all of the components installed.



1969 Winter Edition

soldered to its respective PC board terminal. Bulb marking (0 through 9) is done with $\frac{3}{16}$ " black instant transfer numerals, which are applied to the plastic lens cap, then coated with a clear acrylic spray.

Power Supply. There are three power supply connections to be made to the decimal counter. "+ +" requires 6.0 volts at 50 mA; "+" requires 3.6 volts at 120 mA (with less than 0.7-volt peak-to-peak ripple), while "GND" is the common supply return. The power supply shown in Fig. 6 will power up to six decimal counters.

In constructing the power supply, don't skimp on the value of $C2$ or the resultant a.c. ripple may be too great. All power supply leads must be of heavy-gauge wire.

Operation. There are three signal connections to be made to the decimal counter—"Count" input, "Reset" input, and "Carry" output. The "Count" input will advance the decade counter one count each time the input signal *abruptly drops* from +3 volts to ground. However, it is *important* that all input signals be properly conditioned to insure that they are noise-free and drop abruptly *once and only once* per count cycle. Failure to do this will result in erratic counting.

There are several ways to make a "bouncelless" input signal. If you want to use an s.p.d.t. push button, use the set-reset conditioning flip-flop in Fig. 7(a). If you want to use an s.p.s.t. "make" contact, use the monostable circuit in Fig. 7(b). This conditioning is mandatory for *any* mechanical contact.

Clean sine or square waves from 100 kHz to 10 MHz can be directly applied to the decimal counter "Count" input with-

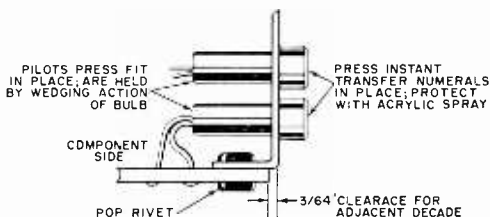


Fig. 5. Drilling details for the lamp bracket are shown at the left. The bracket is secured to the printed board and bulbs inserted as shown above.

HOW IT WORKS

Where most divide-by-ten circuits use a relatively complex, multi-transistor arrangement of decoder gates and readout drivers, the decimal counter described in this article first divides by *two*, and then by *five* to produce a *biquinary* counter. Such an arrangement is considerably simpler than the conventional decimal counter in that it requires three less transistors and seven less decoding gates to produce the same results.

The input pulse train is fed to a divide-by-two counter (part of *IC1*), a conventional flip-flop which changes state with each pulse input. One state of the input divided-by-two counter will indicate an odd number input while the other state will indicate an even number. The odd-even signal is processed by a section of *IC4* and used to switch transistors *Q1* and *Q2* so that on even numbers the "Even Bus" will be supplied with power, and on the odd numbers the "Odd Bus" is powered. The schematic of the complete decimal counter shows how the indicating bulbs are connected in pairs to the odd and even buses. Each pair of bulbs is connected to ground through a transistor switch (*Q3* through *Q7*) which is open when not energized, and closed when energized.

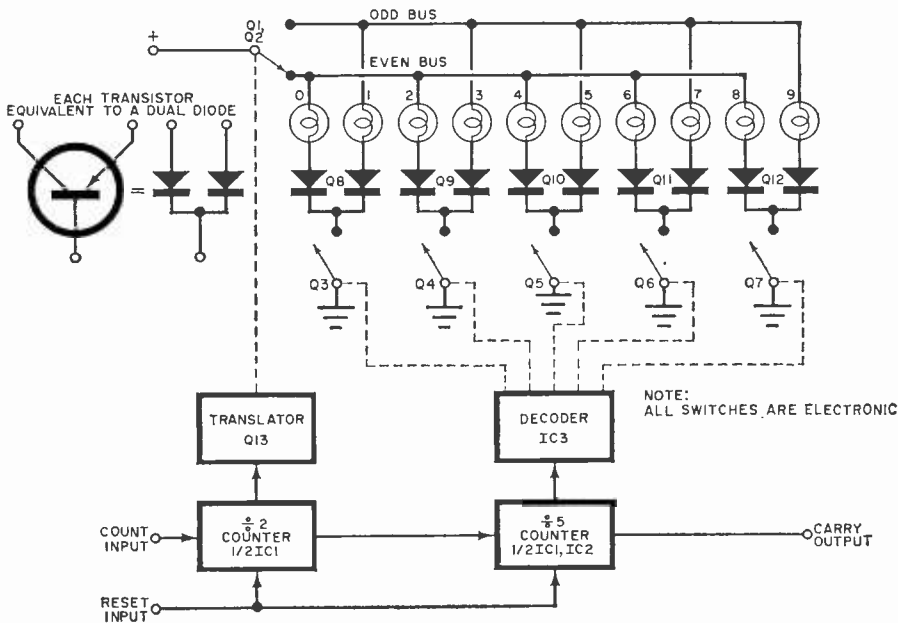
After division by two, the input pulses are fed to the divide-by-five counter, consisting of the remaining part of *IC1* and all of *IC2*. This counter decides whether the input signal is 0 or 1, 2 or 3, 4 or 5, 6 or 7, 8 or 9—and its selected output signals are processed by decoder *IC3* and the remainder of *IC4*. The output signal from the decoder will energize the appropriate transistor

switch, effectively closing it and allowing current to flow from the selected odd or even bus, through one bulb and through the transistor switch to ground, illuminating the pertinent bulb.

For example, assume the count has reached the number 7. The divide-by-two counter has determined that it is an odd number and has energized the odd bus. The divide-by-five counter decoder has determined that this pulse is either 6 or 7, and energized transistor *Q6*. Under those conditions, bulb 7 is the *only* bulb illuminated. Weak glow of the bulbs is prevented by the insertion of transistors *Q8* through *Q12* in the appropriate lines. Each transistor serves as a dual diode. Cycling of the counter is controlled by feeding a portion of the "8 or 9" signal back to *IC1* through *R6* (see Fig. 1).

On each tenth input pulse, the divide-by-ten characteristic of the decimal counter circuit causes it to cycle to 0 indication while simultaneously providing one output pulse which is used to start the count on another counter. Assume that two decimal counters are connected in cascade and the count is 9. The first decimal counter (indicating "one's") displays a 9, while the second decimal counter (indicating "ten's") displays a 0. When the count reaches 10, the "one's" counter cycles to its 0 indication, while the "ten's" counter receives one pulse to display a 1. The overall illuminated readout is then 10. Still another decimal counter can be connected to the "ten's" counter "Carry" output to provide a "hundred's" column, which will start indicating when the total count exceeds 99. And so on.

Although what appear to be six mechanical switches are shown here, actually they represent high-speed transistor switches that are driven by the electronic circuits shown connected to them by the six dashed lines.



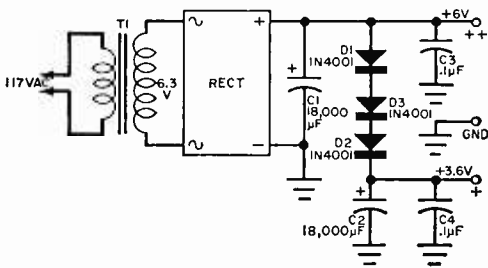


Fig. 6. This recommended power supply will handle up to three decimal counter modules simultaneously.

POWER SUPPLY PARTS LIST

- C1, C2*—18,000- μ F, 10-volt electrolytic capacitor (Sprague 183G010AC or similar)
C3, C4—0.1- μ F capacitor
D1, D2, D3—1N4001 diode
 RECT—1½-ampere full-wave bridge rectifier assembly (Motorola MDA942-1, or similar)
 T1—Filament transformer: primary, 117 volts a.c.; secondary, 6.3 volts a.c.; 1½ amperes (Allied Electronics 54 E 1419, or similar)

Fig. 7. Pin 8 of the μ L914 is identified by a dot. The MC789P is identified by a notch and dot code.

out conditioning. Slower signals must be squared up using either the hex inverter squaring circuit in Fig. 7(c), or the Schmitt trigger of Fig. 7(d). Either of the latter two circuits work well with 3 to 5 volts of peak-to-peak input signal. The Schmitt trigger can also be gated by holding its "Gate" input at ground when "Count" signals are to be passed, or at +3 volts or so when "Count" signals are *not* to be passed.

The decimal counter "Reset" input is normally grounded. It will automatically return the counter to its "0" condition any time this input is connected to a +3 volt source. The "Reset" push button need not be made "bounceless."

The "Carry" output is used when two counters are cascaded by directly connecting the "Carry" output of the first unit to the "Count" input of the second. The second counter will register "ten's," a third counter will register "hundred's," and so on. -30-

