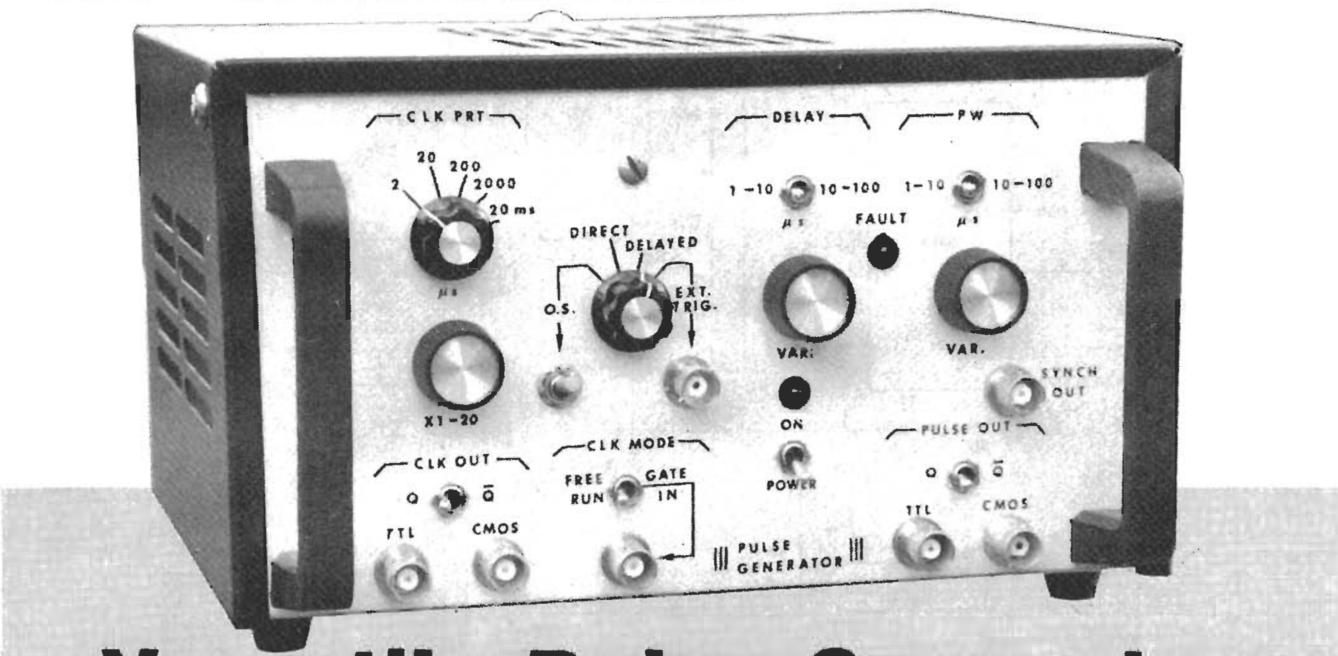

Versatile Pulse Generator

This full-featured pulse generator is so easy to build that you have no excuse for not adding it to your workbench!

JOSEPH GIANELLI

PULSE GENERATORS ARE NOTORIOUSLY absent from many hobby-electronics test benches. That's not because hobbyists have no use for them. On the contrary: A pulse generator can be invaluable for testing, troubleshooting and experimenting with digital equipment. Unfortunately, commercial pulse generators are expensive.

We'll show you how to build a pulse generator that's not expensive; it should cost under $80 if you use all new parts. If you have some of the parts on hand, especially the switches and cabinet, you'll be able to build it for much less. The generator features a free-running, square-wave clock output that may be gated, and it also features a pulse output that may be derived directly from the clock circuit, from an external trigger, or from an internal delay generator. In addition, there is a one-shot output that delivers one pulse of the selected width for each depression of a front-panel switch. The polarity of all outputs is selectable by the user.

One special feature of our generator is the inclusion of a fault-detection circuit that lights a front-panel indicator whenever the delay or pulse width is greater than the selected clock rate; output will also be disabled. Reducing either the pulse width or the delay time will extinguish the indicator and restore output.

Our generator is built entirely from CMOS circuits, so power requirements are extremely modest. In fact, battery operation is entirely feasible. A nine-volt alkaline battery should provide about 150 hours of operation. Complete specifications for the pulse generator are given in Table 1.

Circuit description

Referring to Fig. 1, IC1 is a multivibrator used in the astable mode. Its oscillating frequency is determined by resistors R1 and R2, and one of capacitors C1–C5, as selected by the CLOCK RATE or CLK PRT (*P*ulse *R*epetition *T*ime) switch S3. With CLK MODE switch S1 in the FREE RUN position, output will appear continuously at jacks J4 and J5; however, with S1 in the GATED position, output will be inhibited whenever pin 5 of IC1 is brought low. To restore output, a gate signal with a voltage exceeding ½ V_{CC} should be applied; for the present circuit, a seven-volt gate signal will suffice.

Sync-generator IC5-a, half of a 4098 dual monostable multivibrator, is also triggered by IC1's Q output. When S2 is in the DIRECT position, the sync-generator's output is fed directly to pulse-width generator IC3-b. The width of the pulse generated by IC3-b is determined by resistors R5 and R6 in combination with C10 or C11, as selected by the PW switch S6. The width of the pulse may vary from approximately 1 μS to 100 μS. Note that IC1 determines the repetition rate of the pulse generator; IC3-b determines the width of those pulses.

When S2 is in the DELAYED position, the sync generator drives IC5-b, the delay generator, which in turn drives IC3-b. The delay generator uses the same resistor and capacitor values as the pulse generator, so the delay may also vary from approximately 1 μS to 100 μS.

When S2 is in the EXT. TRIGGER position, the clock and delay generators are disconnected from the pulse generator circuit. In that mode, a pulse of the selected width is generated on the leading edge of each pulse applied to J6, TRIGGER INPUT. As with the clock-gating signal, the trigger pulse should have an amplitude exceeding ½ V_{CC}, again seven volts. The sync generator is driven by clock generator IC1, so the sync pulses appearing at J1 will not be synchronized to the external trigger.

When S2 is in the ONE-SHOT position, the clock and delay generators are again disconnected from the pulse-generator circuit. In that mode, a pulse of the se-

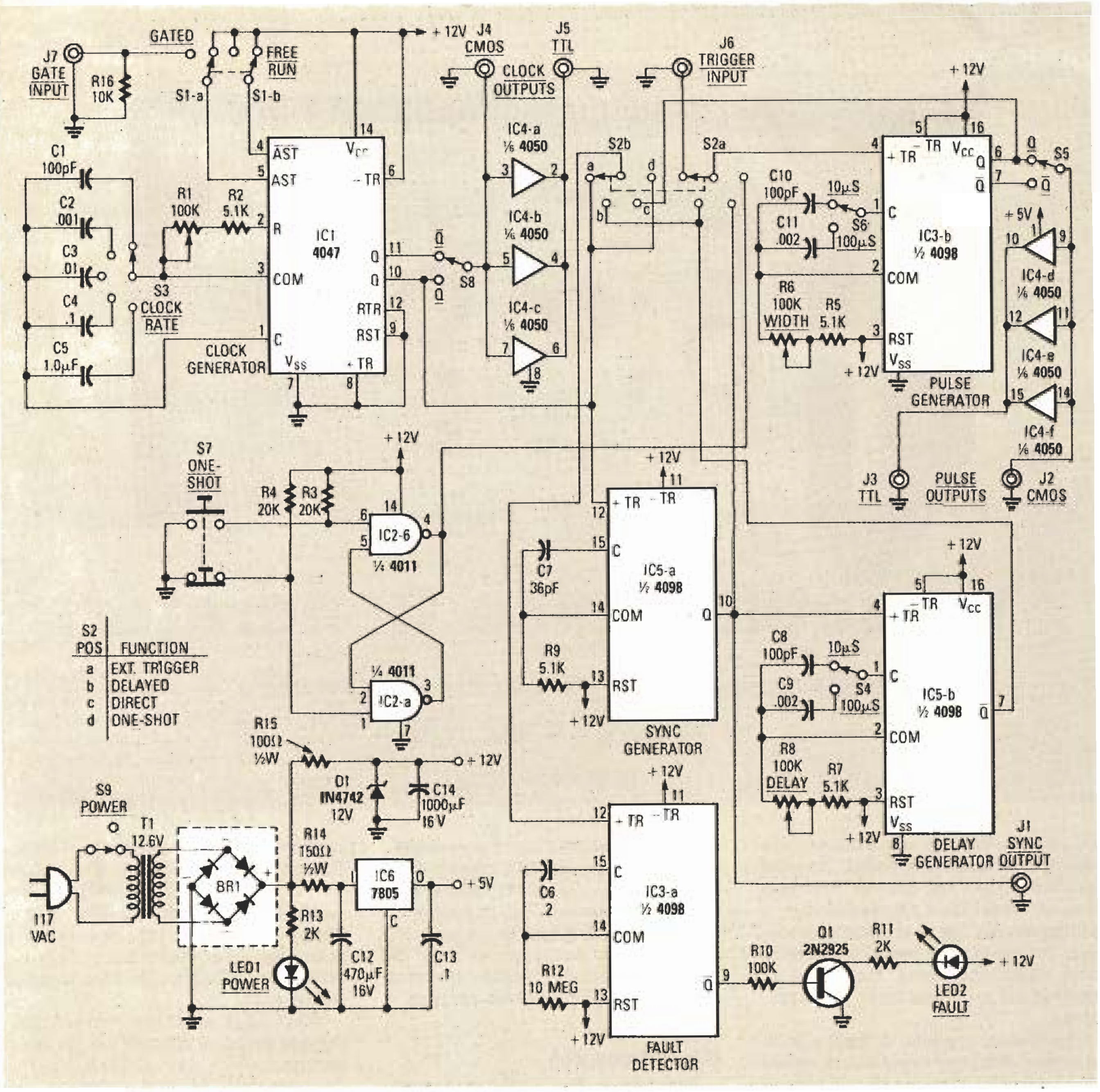

FIG. 1—SCHEMATIC DIAGRAM of the pulse generator. All CMOS components are used, making this a very-low-power device.

lected width is generated each time ONE-SHOT switch S7, is depressed. Sync pulses are not synchronized to the one-shot output.

The clock output from IC1 and the pulse output from IC3-b are each fed through three 4050 non-inverting buffers wired in parallel. Doing that allows the pulse generator to drive six TTL loads. Separate jacks were used for the CMOS and TTL outputs in lieu of a switch in order to avoid accidentally overdriving TTL IC's with a high voltage. If you don't need to drive TTL circuits, IC4 may be eliminated, as well as the components associated with the five-volt power supply (R14, C12, C13 and IC6). On the other hand, if you work solely with five-volt circuits (TTL or CMOS), the twelve-volt power supply (R15, D1 and C14) could be eliminated, and the entire circuit powered from the five-volt supply.

Switch S2-b connects FAULT detector IC3-a to the output signal selected by S2-a. IC3-a operates in the re-triggerable mode so that, as long as it is receiving trigger pulses, its $\overline{Q}$ output will remain low, which will keep Q1, and hence LED2, turned off.

When S2 is in either the EXT. TRIGGER or the ONE-SHOT mode, IC3-a's TRIGGER input is connected to the Q output of the clock generator, IC1, so the fault detector will remain off. When S2 is in the DELAYED mode, the fault detector's input is connected to the output of the delay generator, IC5-b, and when S2 is in the DIRECT mode, the fault detector's input is connected to the output of the pulse generator, IC3-b. In either case, fault detector LED2 will remain off as long as the delay time, or the pulse width, respectively, does not exceed the clock period.

Two NAND gates in IC2 are set up as a latch to debounce switch S7, and provide dependable triggering in the one-shot mode.

Construction

The pulse generator may be built in any convenient manner, but a printed-circuit

TABLE 1—SPECIFICATIONS

One Shot	1 TO 100 μs duration
Pulse Output	1 TO 100 μs duration (Q and $\overline{Q}$)
Pulse Delay	1 TO 100 μs duration
Ext. Trigger	Active on rising edge
Sync. Output	12 volts, 1 μs
Clock Output	2 μs to 400 ms squarewave (Q and $\overline{Q}$)
Gated Clock	variable burst
Outputs	TTL (5 Volt) AND CMOS (12 Volt)
Fault LED	Lights when pulse delay or width greater than pulse repetition rate.

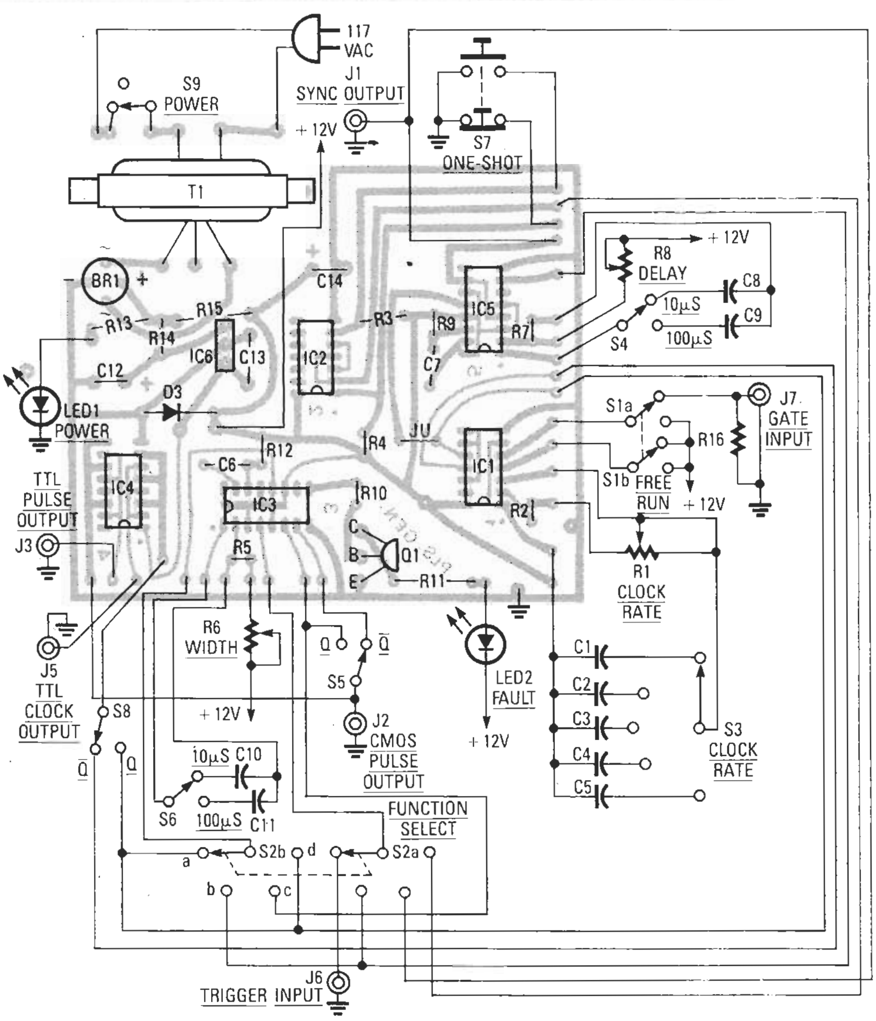

FIG. 2—COMPONENT-PLACEMENT DIAGRAM of the pulse generator. The lines going to +12 volts and ground actually go to a small terminal strip mounted on the front panel. Note that there is one jumper, to avoid using a double sided board.

board simplifies things considerably. Full-size PC artwork is shown in the "PC Service" section of this magazine; alternatively, you may purchase a pre-etched and drilled board; see the Parts List for information.

Whether you buy a PC board or make your own, inspect it carefully before mounting any components. If there are any shorted traces, *carefully* scrape between them with a sharp hobby knife.

When the board is up to snuff, you can start mounting components using the component-placement guide shown in Fig. 2. Mount components in a progression starting with those having the lowest profile: First mount the jumper, then add the resistors and diodes, then the IC sockets, and so on. After each group of a certain height has been inserted, turn the board over, making sure that the components remain flush, bend their leads slightly, then solder and clip those leads. After all components have been mounted, check the board carefully for solder bridges between adjacent pads and traces. Fix any problems that you find, but don't insert the IC's in their sockets yet. There's more wiring to do.

Now connect all the front-panel switches, potentiometers and BNC jacks to the PC board, as shown in Fig. 2, with short lengths of insulated wire. Note that timing capacitors C1–C5 and C8–C11 mount directly to their associated switches, not on the PC board. The timing capacitors should be mica, metal polyester, or other high-quality types. Resistor R16 similarly mounts on front panel jack J6.

PARTS LIST

All resistors ¼-watt, 5% unless otherwise noted
R1, R6, R8—100,000 ohms, linear potentiometer
R2, R5, R7, R9—5100 ohms
R3, R4—20,000 ohms
R10—100,000 ohms
R11, R13—2000 ohms
R12—10 megohms
R14—150 ohms, ½-watt
R15—100 ohms, ½-watt
R16—10,000 ohms
Capacitors
C1, C8, C10—100 pF, mica
C2—0.001, metalized polyester
C3—0.01 μF, metalized polyester
C4, C13—0.1 μF, metalized polyester
C5—1.0 μF, metalized polyester
C6—0.2 μF, metalized polyester
C7—36 pF, mica
C9, C11—0.002, metalized polyester
C12—470 μF, 16 volts, electrolytic, radial leads
C14—1000 μF, 16 volts, electrolytic, radial leads
Semiconductors
IC1—4047 multivibrator
IC2—4011 quad two-input NAND gate
IC3, IC5—4098 dual multivibrator
IC4—4050 noninverting hex buffer and TTL driver
IC6—7805 5 volt regulator
Q1—2N2925
BR1—bridge rectifier 50 volts, 1.5 amps
D1—IN4742 12V Zener
LED1, LED2—standard red LED
Other components
J1–J7—BNC female connectors
S1—DPDT, miniature toggle
S2—2 pole, 4 position miniature rotary
S3—1 pole, 5 position miniature rotary
S4–S6, S8—SPDT, miniature toggle
S7—SPDT, miniature momentary
S9—SPST, miniature toggle
T1—Transformer 12.6 volts, 0.12 amps, Radio Shack #273-1360

Note: An etched and drilled PC board is available from E²VSI, P.O. Box 72100, Roselle, IL 60172 for $ 11.95 postpaid.

Check over your wiring, and if everything looks OK, apply 117 volts AC power to the pulse generator, and turn on switch S9. With a voltmeter verify that the power-supply voltages are correct, and that +12 volts appears at pin 14 of IC1, and pin 16 of IC2, IC3 and IC5. Also make sure that +5 volts are present at pin 14 of IC4. If everything checks out, remove power and insert the IC's.

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PULSE GENERATOR

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Connect an oscilloscope to either the TTL or the CMOS clock output, set S1 to FREE RUN, and verify that R1 and S3 vary the clock speed as expected. Toggling switch S8 should invert the output. Next connect the scope to one of the pulse outputs. With S2 in the DIRECT position, R6 and S6 should vary the width of the pulses, and S5 their polarity. R1 and S3 vary their repetition rate, of course.

With S2 in the EXT. TRIGGER position, each low-to-high transition on jack J6 should cause a pulse of the selected width and polarity to appear at jacks J2 and J3. Similarly, with S2 in the ONE-SHOT position, each time S7 is depressed a pulse of the selected width and polarity should appear at those jacks.

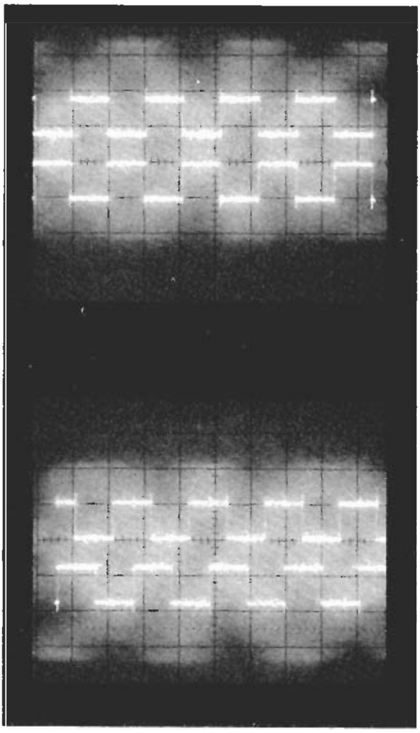


FIG. 3—THE TOP TRACE of each oscilloscope photograph shows the pulse output, while the bottom trace shows the clock output. The pulse output in *a* is direct, while that shown in *b* is delayed by about 7 microseconds.

You'll need a dual-channel scope to test the delay function. Place S2 in the DELAYED position. Connect one channel to a clock output and one channel to a pulse output. If your scope has a separate SYNC input, connect it to the pulse generator's SYNC OUTPUT jack, J1. Now by varying S4 and R8, you should be able to vary the length of time (from 1 µS to 100 µS) that the pulse train lags behind the clock output. Figure 3 shows two oscilloscope photographs, one showing zero delay, and the other showing a delay of about seven µs.

When everything checks out, mount the PC board to the chassis with short standoffs, tighten all hardware, and screw the cabinet together.

Practical applications

Our pulse generator may be used to troubleshoot or test already-existing equipment; it may be used to aid the design of new equipment, and it may also be used for experimental and educational purposes.

For example, the pulse generator could be used to troubleshoot a high-speed clocked-logic system that seemed to be missing pulses and giving erroneous outputs. You could disconnect the system clock from the piece of equipment under test, and then substitute the pulse generator's clock output. Then, by running that device at a slower rate—perhaps one pulse at a time—you would find it easier to trace a signal through the system. That sort of procedure won't always work; NMOS microprocessors, for example, often cannot be run below about 250 kHz. But you can usually slow things down enough to be able to see what's going on better than at the full clock rate.

You can use the pulse generator to experiment with shift registers and counters. Wire up your circuit on a solderless breadboard and single-step through all logic states.

For example, suppose you have a circuit built around a 4018 presettable dividy-by-n counter. That IC has five "jam" inputs and five (complemented) data outputs. The outputs may be recycled, in various combinations, to the IC's DATA input, allowing division of the input clock by any ratio between two and ten. The only hitch is that division by an odd ratio (three, five, seven or nine) requires use of an external AND gate.

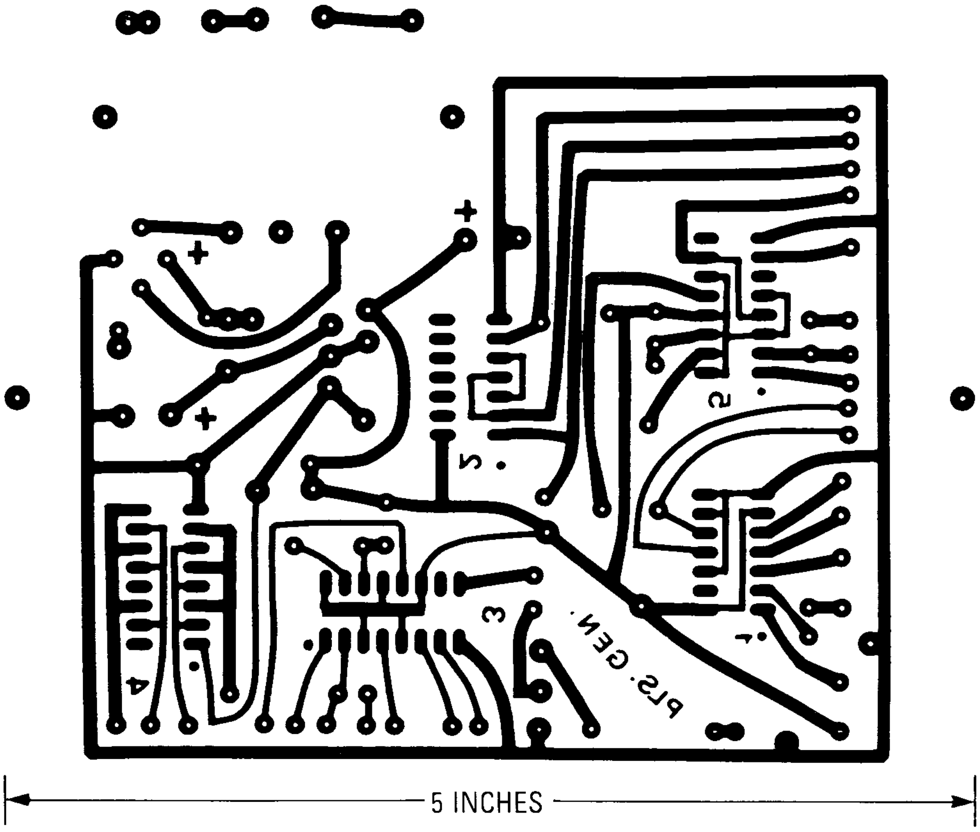
Anyway, suppose your design requires outputs that cycle from four to nine and then reset (i.e., start counting from four again). You have wired the circuit up, but there is a bug; the circuit counts from four to eight and then resets. Feeding the pulse generator's output to the 4018's clock input and monitoring the IC's outputs, you discover that you have forgotten to AND the $\overline{Q}_4$ and $\overline{Q}_5$ outputs.

To synchronize pulse output with an external clock, connect the clock to J6 and place S2 in the EXT. TRIGGER position. If you need one output pulse for a predetermined number of clock pulses, simply insert a divider IC between the clock source and J6. The 4059 is a programmable divide-by-N counter which can be used for that purpose. That IC can divide the frequency of the clock fed to it by any ratio between three and 15,999. If your work involves much of that sort of thing, there is room on the PC board to mount several extra IC's. You would then mount appropriate division-ratio selection switches on the front panel. **R-E** side with the pattern) because you'll contaminate the sensitized surface of the copper blank. After the oil has "dried" a bit—patting with a paper towel will help speed up the process—place the pattern front side down on the sensitized copper blank, and make the exposure. You'll probably have to use a longer exposure time than you are used to.

We can't tell you exactly how long an exposure time you will need because we don't know what kind of light source you use. As a starting point, figure that there's a 50 percent increase in exposure time over lithographic film. But you'll have to experiment to find the best method to use with your chemicals. And once you find it, stick with it. Don't forget the "three C's" of making PC boards—care, cleanliness, and consistency.

Finally, we would like to hear how you make out using our method. Write and tell us of your successes, and failures, and what techniques work best for you. Address your letters to:

Radio-Electronics
Department PCB
200 Park Avenue South
New York, NY 10003



USE THIS FOIL PATTERN to make the PC board for the versatile pulse generator.