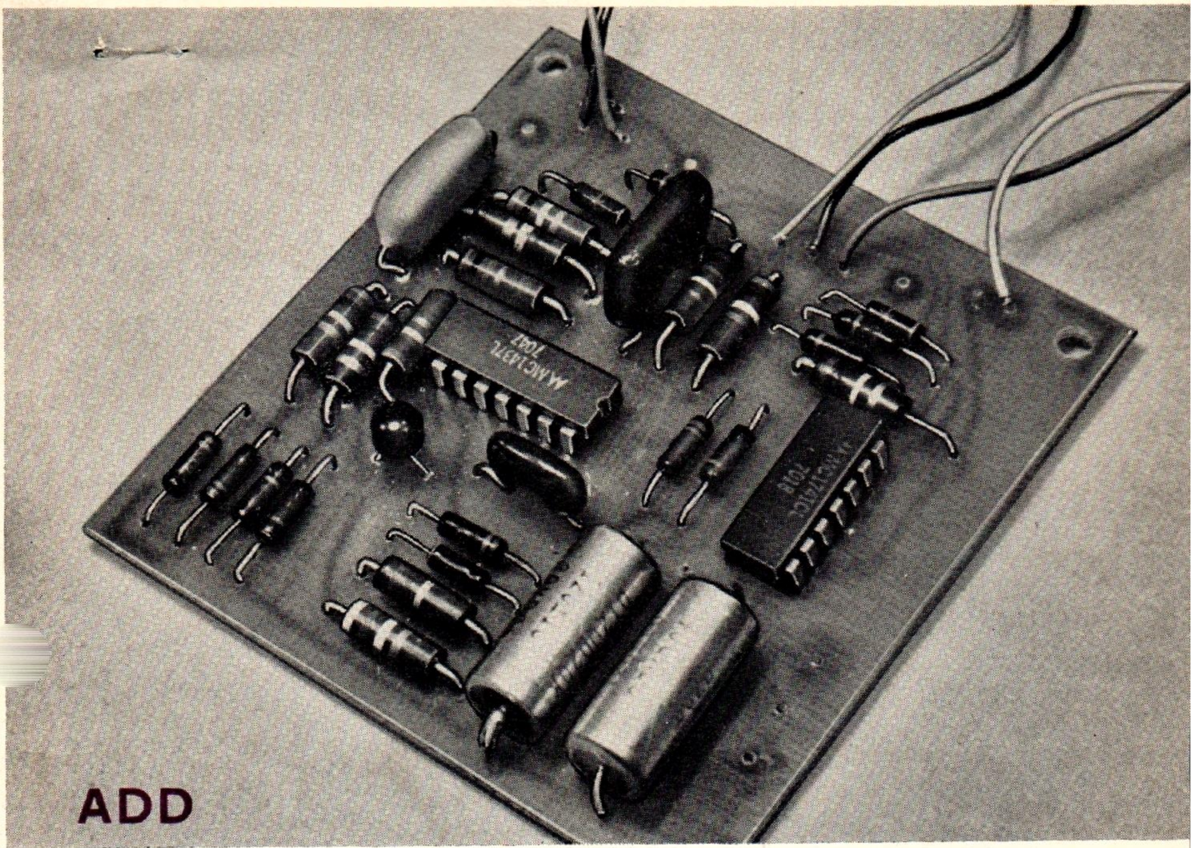


# ADD TRIGGERED SWEEP TO YOUR SCOPE

## NEW LIFE, NEW USES FOR INEXPENSIVE SCOPES

**BY HARRY GARLAND AND ROGER MELEN**

ONE OF THE BEST features of expensive oscilloscopes is that they usually have a built-in triggered sweep. Without a triggered sweep—using only the conventional free-running time base found in lower-priced scopes—it is very frustrating to try to get some waveforms to stand still. Built-in triggering also eliminates erratic multi-triggering; and, due to the extremely good linearity found in triggered sweep circuits, accurate time and/or frequency measurements may be made along the horizontal axis. Once a signal is displayed on the scope, it can easily be expanded horizontally without loosing sync.

In any triggered sweep system, the sweep does not start until the reference signal (usually the signal to be displayed on the vertical axis), reaches some predetermined level. Once triggered into operation, the sweep becomes immune to any other input signal for the duration of that trace. After retracing, the sweep is once again triggered and the process is repeated. Since the horizontal sweep is then very linear, the trace can be calibrated in microseconds, milliseconds, or seconds per division, enabling time and frequency measurements to be made during the display period. Nonperiodic wave-

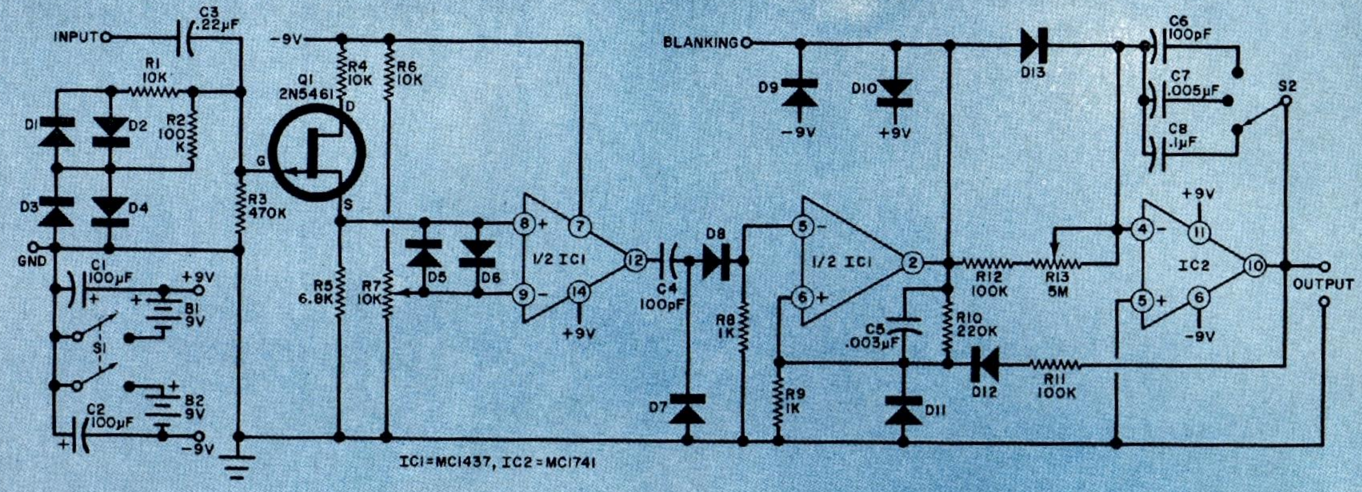
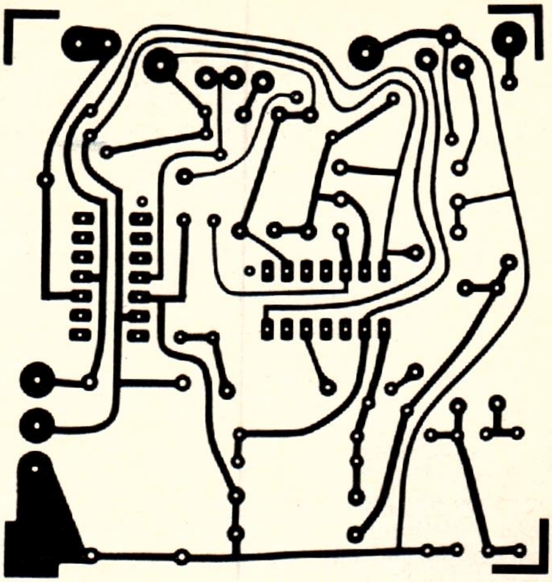



Fig. 1. High input impedance for sweep generator is obtained by use of the field effect transistor in the first stage. The two halves of IC1 are shapers and amplifiers while IC2 acts as an integrator.

## PARTS LIST

*B1,B2—9-volt battery (or power supply)*
*C1,C2—100-µF electrolytic capacitor*
*C3—0.22-µF capacitor*
*C4,C6—100-pF capacitor*
*C5—0.003-µF capacitor*
*C7—0.005-µF capacitor*
*C8—0.1-µF capacitor*
*D1-D13—1N914 diode*
*IC1—Integrated circuit (Motorola MC1437)*
*IC2—Integrated circuit (Motorola MC1741)*
*Q1—2N5461 field effect transistor*
*R1,R4,R6—10,000-ohm, ½-watt resistor*
*R2,R11,R12—100,000-ohm, ½-watt resistor*
*R3—470,000-ohm, ½-watt resistor*
*R5—6800-ohm, ½-watt resistor*
*R7—10,000-ohm potentiometer*
*R8,R9—1000-ohm, ½-watt resistor*
*R10—220,000-ohm, ½-watt resistor*
*R13—5-megohm potentiometer*
*S1—Dpst slide or toggle switch*
*S2—Three-position, one-pole, rotary switch*
*Misc.—Battery holders and clips, chassis, knobs, and mounting hardware.*
*Note—The following are available from Photolume Corp., 118 E. 28th St., New York, NY 10016: etched and drilled PC board #SGB at $3.75; two integrated circuits #SGIC at $12.00; complete kit of parts including switch and knobs #SGK at $22.00. All prices postpaid; add insurance if desired. Residents of New York state, add 6% sales tax.*



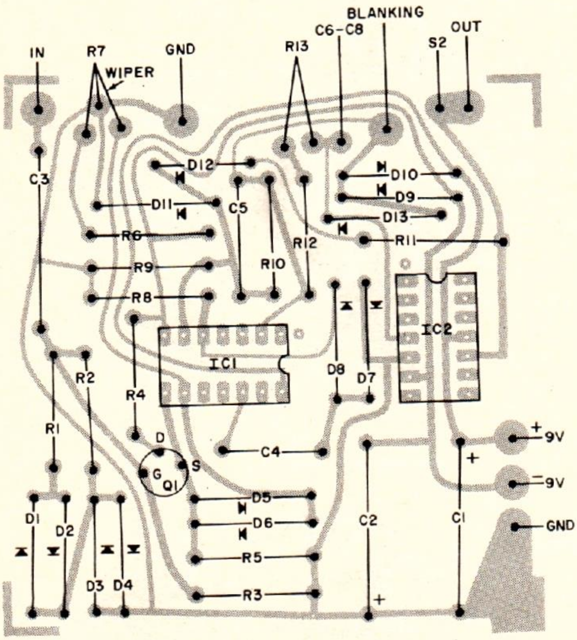



Fig. 2. The actual size foil pattern above can be used to make a printed circuit board, with the components mounted on it as shown at left. Control components S2 (with C6, C7, and C8), R7, and R13 are located off the circuit board.

forms, such as those found in many digital pulse circuits can be displayed properly only on a triggered sweep scope.

The triggered-sweep generator whose schematic is shown in Fig. 1 has a high input impedance, a 100-mV triggering sensitivity, three switch-selected sweep rates with provisions for vernier control, and a sweep linearity of better than 0.01%.

**Construction.** The circuit can be assembled on a printed circuit board such as that shown in Fig. 2. Be sure to observe the coding on the IC's and use a low-wattage soldering iron and fine solder for installing all components.

There are two ways of mounting the board. A small chassis can be used with three operating controls (sweep switch *S2*, sweep vernier *R13*, and sensitivity

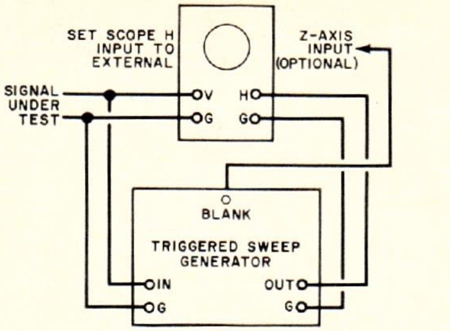
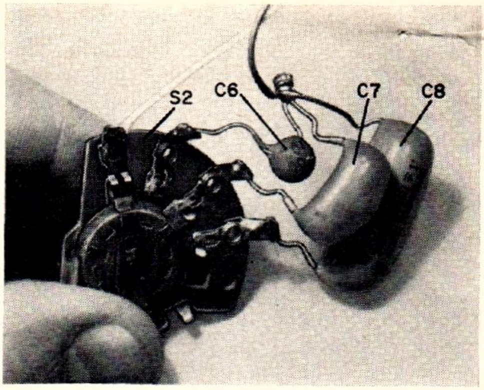



Fig. 3. When sweep generator is assembled outside of scope, make connections to scope as shown here.




Shown here is method of attaching capacitors C6, C7, and C8 to the sweep rate selector switch S2.

control *R7*) mounted on the front panel and with another switch used to turn the power on and off. A pair of 9-volt batteries can be used for power in this case. The sweep generator is connected to the scope as shown in Fig. 3.

The second approach is to mount the sweep generator directly in a scope, locating the printed circuit board in any suitable spot (away from heat if the scope uses vacuum tubes). A pair of silicon rectifier diodes and filter capacitors may be used to obtain the necessary dc operating voltages from the scope filament supply, or if the scope is all solid state, a look at the schematic will show where the suitable voltages can be picked off.

The input to the sweep generator may be derived from the existing scope input or from the scope sync leads. In the latter case, the high-input impedance FET stage may be omitted and the circuit shown in Fig. 4 used for the input. The 100,000-ohm potentiometer in this circuit is used as the sensitivity control. The blanking output may be connected to the scope blanking circuit if desired.

**Operation.** With the desired input signal connected (using an audio generator for testing), and the triggered sweep not turned on, only a vertical trace will be seen on the scope. Adjust the height to some convenient value. When the triggered sweep is turned on, a horizontal trace may appear. If it does, adjust both the sweep rate selector switch, *S2* and sweep vernier *R13* until the display shows some multiple stationary signals. If the trace does not appear, adjust the sensitivity control, *R7*, until it does. Lower the input level from the generator and keep adjusting the sensitivity control until the sweep triggers at some low level. Once the lowest trigger level is established, the sensitivity control may be left alone. The scope horizontal gain control determines sweep length.

With a steady signal now displayed, note that manipulation of the sweep vernier and sweep rate switch produces a stationary signal from a small part of a sine wave to any desired number of sine waves, without losing sync lock at any time. Also, with a single sine wave displayed, it is possible to adjust the audio frequency generator over a wide range of frequencies without losing sync lock.

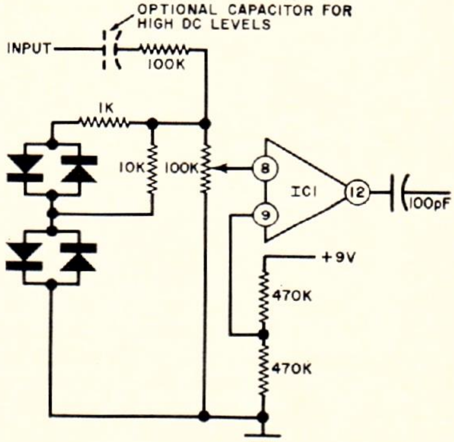



Fig. 4. If scope sync leads are used for sweep input, omit Q1 and use this circuit for first stage.

## THEORY OF CIRCUIT DESIGN

To avoid loading the input circuit (which is also applied to the scope), the first stage of the sweep generator uses a field effect transistor. Resistors *R1* and *R2* and diodes *D1* through *D4* provide automatic range selection. As the input voltage rises, the diodes conduct to shunt the input and reduce the signal applied to the FET. If high-level inputs are used constantly, a series resistor will reduce the loading effect.

The output of the FET source follower is coupled to the first op amp which is half of *IC1*. The sweep cycle begins when the signal to pin 8 exceeds the bias set by the threshold potentiometer *R7* at pin 9. The high-gain op amp amplifies the difference signal until its output is +9 volts. The positive output of the first op amp appears at the minus input of the second op amp, causing its output to swing to −9 volts. This level is held to −9 volts by the feedback action of *R10*. The next stage (*IC2*) is known as a Miller integrator and produces an ultra-linear ramp voltage when the negative signal is applied to pin 4. The speed of the sweep is determined by the value of the switch-selected feedback capacitor (*C6*, *C7*, or *C8*) and the value of *R13*.

When the sweep voltage ramp reaches its maximum value, the feedback signal through *R11* and *D12* causes the output of the second op amp to change from −9 to +9 volts. Diode *D13* is then forward biased and the selected feedback capacitor is rapidly discharged. During the discharge of the capacitor, the scope trace returns to the left side of the screen, where it remains until the trigger cycle starts again.

**Calibration.** If you want to calibrate sweep vernier R13 and sweep rate S2, an accurate source of frequencies must be available. To calibrate the horizontal graticule, apply a known frequency to the input and establish a steady trace. Adjust the scope horizontal shift to start the trace at some known mark on the left side of the horizontal graticule. Adjust the scope horizontal gain until the trace reaches another known mark on the right side of the screen. Determine the time period of the input frequency by using the equation $T = 1/f$, where T is the period and f is the frequency. For example, using a 100-kHz sine wave, each cycle is 10 microseconds long. Adjust R13 until one cycle occupies exactly one division on the scope graticule. Mark the knob position on R13 10 μs/div. Other points on either R13 or S2 can be found using the same technique. For example, 60 Hz is 16.66 milliseconds and 15,750 Hz (TV line frequency) is 63.6 microseconds. If desired, a series of fixed resistors and trimmer pots may be used for R13 (with a selector switch).

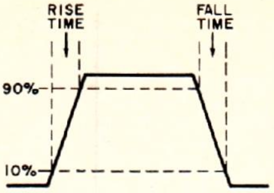
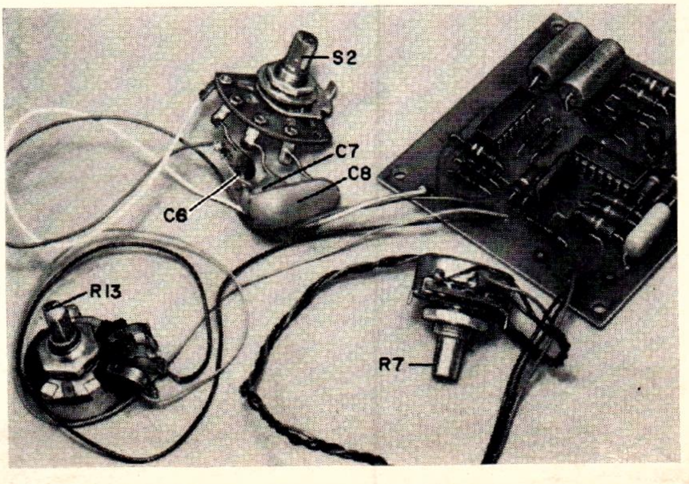
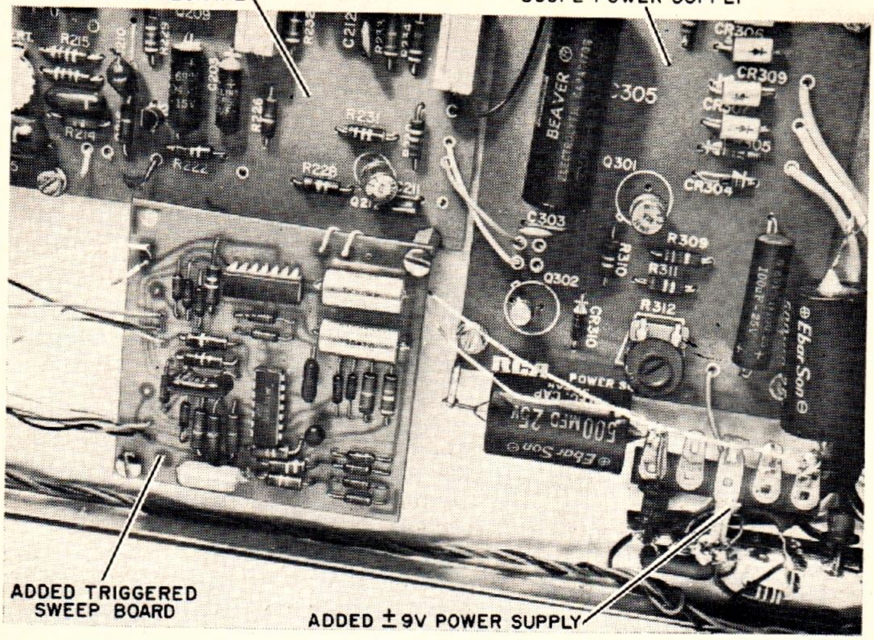



Fig. 5. To measure rise or fall time of an applied pulse, count time between 10% and 90% points.

Once calibration is complete, it is easy to determine the frequency of an applied waveform or to measure the rise or fall time of an applied pulse. In the latter case, note that measurement is made between the 10% and 90% points of the waveform (see Fig. 5). Adjust the triggered sweep for at least one complete pulse. The rise (or fall) time is calculated by determining how many divisions and parts of a division lie between the two

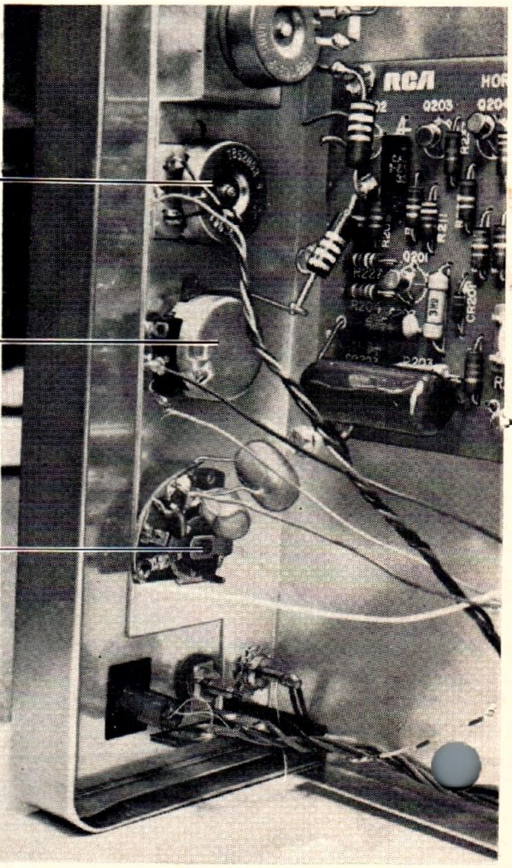



The sweep switch S2, with C6, C7, and C8, sensitivity control R7, and sweep vernier R13 are connected by wires of suitable length to appropriate points on PC board. Note that leads from R7 are twisted together.




This is a typical installation of triggered sweep generator in a scope. Location is not critical but it should be away from heat if the scope uses tubes. In the case illustrated here, a 9-volt power supply was added.

In the installation shown here, the "phase," "sync," and "sweep" controls on the front of the existing scope were removed and replaced by three controls for the sweep generator. Blanking output can be connected if desired.




measuring points and multiplying this number by the time scale of the controls.

Frequency is measured by determining the exact number of divisions (and parts of a division) in one cycle of a known waveform and then measuring the number of divisions occupied by an unknown waveform. The frequency is then found from the equation $f = 1/T$ where T is the number of divisions occupied by the unknown multiplied by the calibration factor determined with the known wave. ◈

BY RICHARD GOODPASTURE

# How to Add TRIGGERED SWEEP TO AN OSCILLOSCOPE

*Increase the performance capabilities of your scope by permitting expansion of waveforms.*

WORKING with an oscilloscope that uses recurrent sweep can be frustrating when it comes to getting the sync locked in—and keeping it there. The situation is particularly touchy when one is trying to observe fast pulses that have low repetition rates. A much more practical approach to the problem is to use triggered sweep, where the sweep is synchronized by the actual signal that is being observed.

If you have a scope that does not have built-in triggered sweep, there is no need to trade up to a new scope. Instead, you can adapt it for triggered-sweep observation of waveforms, using the circuit shown in the schematic. This add-on circuit can convert virtually any recurrent-sweep scope into a modern triggered-sweep instrument.

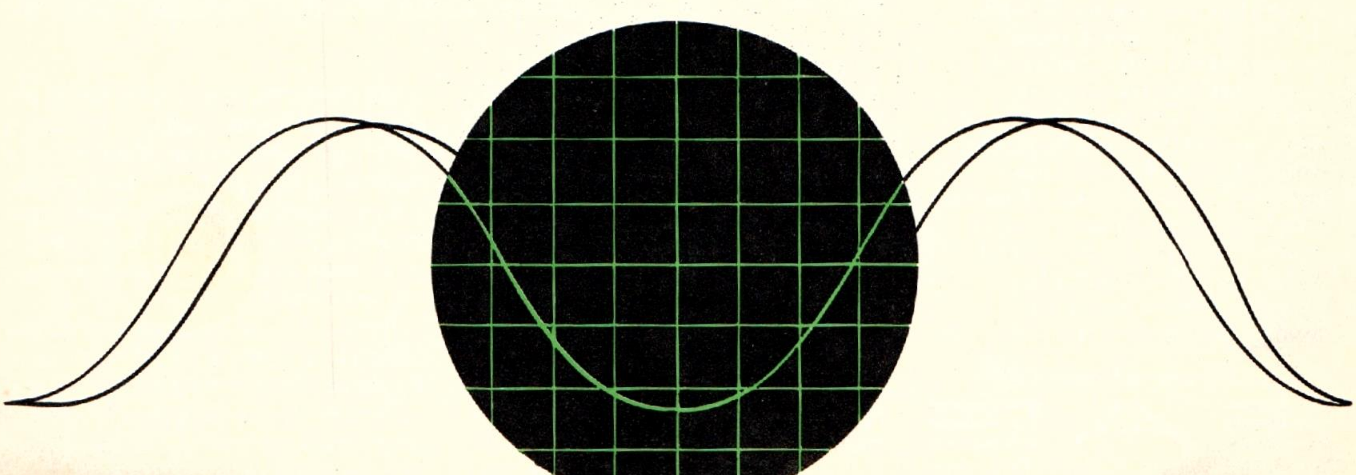
**About the Circuit.** Transistor *Q1* and resistors *R3*, *R4*, and *R5* make up a constant-current source for charging the sweep-range capacitor selected by switch *S1B*. Resistor *R1* determines the voltage to which the selected capacitor is to charge. The value of *R1* plus the charging current selected by *S1A* determine the sweep frequency. Resistor *R1* also determines the triggering sensitivity; and, with the 3300-ohm value specified, the sweep amplitude is 5 volts peak-to-peak. Omitting *R1* increases the sweep to 10 volts but decreases triggering sensitivity. (The value of *R1* can be changed without affecting the scope's sweep calibration.)

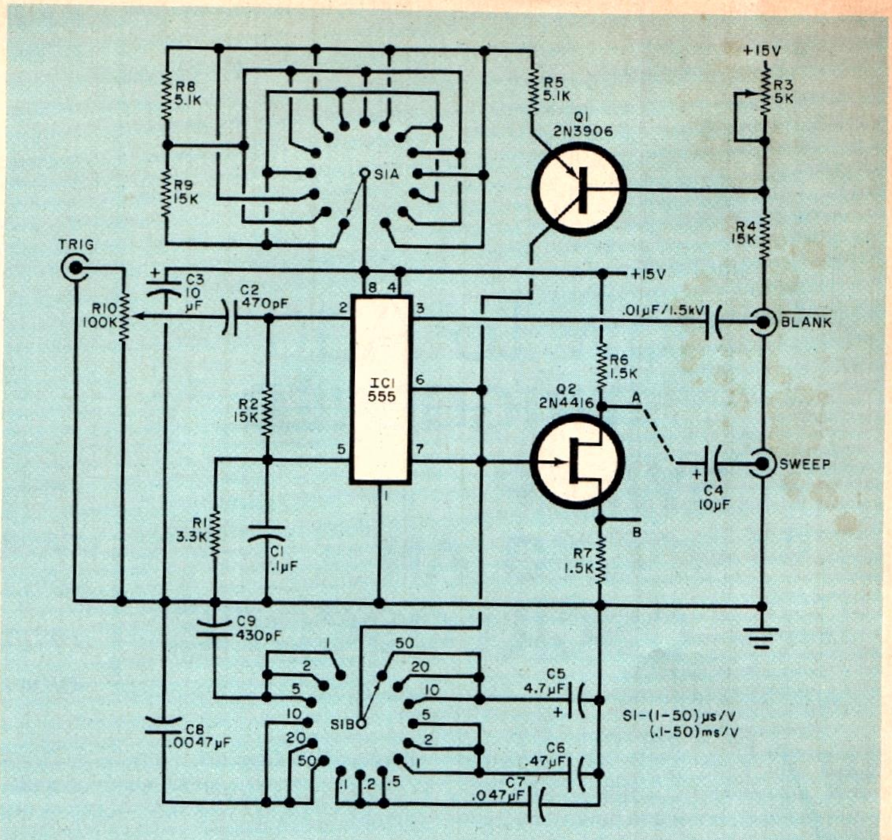
The unblanking pulse from pin 3 of *IC1* is coupled through an isolation capacitor with a typical value of 0.01 μF at 1.5 kV to the control grid of the CRT to intensify the trace during the sweep. Adjusting the scope's brightness control keeps beam intensity low while waiting for the next sweep.

The actual trigger signal can be taken from any point in the vertical amplifier channel where there is sufficient signal amplitude to trigger the sweep circuit.

The new triggered-sweep circuit is substituted for the existing sweep system that now drives the horizontal amplifier in your oscilloscope.

**Construction.** Just about any method of construction, from fabricating a printed circuit board to Wire Wrapping, can be used to assemble the circuit. Resistors *R8* and *R9* and capacitors *C5* through *C9* mount directly on switch *S1*.






*Constant-current source Q1 and timer IC1 combine to form a low-cost triggered sweep circuit.*

**PARTS LIST**

C1—0.1-µF, 50-volt ceramic capacitor
C2—470-pF ceramic capacitor
C3,C4—10-µF, 25-volt electrolytic
C5—4.7-µF, 16-volt tantalum capacitor
C6—0.47-µF, 16-volt tantalum capacitor
C7—0.047-µF, 50-volt polystyrene or Mylar capacitor
C8—0.0047-µF, 50-volt polystyrene or Mylar capacitor
C9—430-pF polystyrene, Mylar, or silver mica capacitor
IC1—555 or 1455 timer
Q1—2N3906 or similar pnp transistor
Q2—2N4416 or similar n-channel FET
The following are ¼-watt, 10% tolerance resistors:
R1—3300 ohms
R2,R4,R9—15,000 ohms
R5,R8—5100 ohms
R6,R7—1500 ohms
R3—5000-ohm trimmer potentiometer
R10—100,000-ohm potentiometer
S1—2-pole, 15-position nonshorting rotary switch
Misc.—Printed circuit board and socket (optional) for IC1; connectors (optional) for input and outputs; machine hardware; hook-up wire; solder; etc.

The 15 volts required to drive the triggered-sweep circuit can be obtained from the power supply in the scope.

**Calibration and Use.** Potentiometer *R3* must be adjusted to provide a voltage drop of 2.35 volts across *R5* when *S1* is set to the 1-µs/V position and the collector of *Q1* is grounded. A more accurate setting for *R3* can be had by using a signal whose frequency is accurately known once the sweep has been coupled to the scope.

The best place to inject the new sweep signal is via the scope's EXT HORIZ input, after first determining which polarity of the sweep output produces a left-to-right deflection on the CRT. If a negative voltage produces the appropriate deflection, couple the sweep output to jumper point A. On the other hand, if your scope requires a positive voltage, connect to point B.

The TRIG input requires a negative-going pulse of about 2.5 volts to trigger the circuit. The width of the pulse can be as short in duration as 100 ns if a greater amplitude pulse is available. Use potentiometer *R10* to adjust the trigger amplitude to obtain a stable waveform. ◇

# Oscilloscope triggered sweep: another job for IC timer

by Robert M. McDermott
*U.S. Army Korea Support Command, San Francisco, Calif.*

For less than $10, you can add a triggered sweep to upgrade the low-cost type of oscilloscope. The circuit, which essentially consists of an IC timer and an op amp, can be powered from the scope's supply and fits on a small pc board that can be placed inside the scope.

When an input signal from the scope's vertical amplifier rises above the circuit's trigger-level voltage setting, the op amp switches, causing its output to go from $+V_{CC}$ to $-V_{CC}$. This voltage change is coupled to the trigger input of the IC timer as a negative spike, which sets the flip-flop and cuts off the discharge transistor.

The switch-selected timing capacitor, C, now charges exponentially through timing resistance R until capacitor voltage reaches the level of control voltage existing at pin 5 of the timer. (Timing period is 0.4RC, and control voltage level is $0.33V_{CC}$.) The circuit's output frequency will be 2.5/RC and, in this case, can be varied from 1 hertz to 1 megahertz.

Once capacitor voltage is equal to the timer's control voltage level, the flip-flop resets and the output transistor discharges timing capacitor C. Pulses occurring before the flip-flop resets do not affect the circuit's output voltage. The flip-flop controls the discharge transistor and can only be reset by the timer's comparator, which is operated by the capacitor and control voltages.

Over-all cost can be reduced still further if the variable controls for trigger level and input sensitivity are replaced with fixed components. □

*Engineer's Notebook is a regular feature in Electronics. We invite readers to submit original design shortcuts, calculation aids, measurement and test techniques, and other ideas for saving engineering time or cost. We'll pay $50 for each item published.*

**Add-on triggered sweep.** IC timer holds down the cost of adding a triggered sweep to an economy oscilloscope. The circuit's input op amp triggers the timer, setting its flip-flop and cutting off its discharge transistor so that capacitor C can charge. When capacitor voltage reaches the timer's control voltage ($0.33V_{CC}$), the flip-flop resets and the transistor conducts, discharging the capacitor.