A Delayed-Trigger Accessory for Oscilloscopes

A low-cost way of adding a laboratory-grade facility to inexpensive general-purpose oscilloscopes

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Laboratory-grade oscilloscopes often include a delayed triggering capability that allows you to "hold off" the sweep until a specified time (which you select) after a trigger signal occurs. With this feature, instead of being limited to the trigger points available in a circuit, you can trigger at any time you choose. If your oscilloscope doesn't have built-in delayed triggering, you can add to it the circuit to be described to upgrade it at very low cost.

To use our delayed-trigger accessory, you need an oscilloscope that has an external trigger input or two channels, a signal to examine, and a signal on which to trigger. Delayed triggering is generated by an ICM7250 programmable timer integrated circuit. Width of the timer's output pulses, and thus the delay time, is fully adjustable from 10 microseconds to 300 milliseconds.

The Programmable Timer

This project uses a 7250 programmable timer integrated circuit whose outputs are optimized for decimal counting. By wiring selected outputs in an AND configuration, you can choose any pulse width from 1 to 99 times the width of the main timebase oscillator pulses. Our delayed trigger accessory takes advantage of this feature to provide several user-selectable delay ranges.

Figure 1 illustrates how the delayed trigger accessory can be used to extend the capabilities of an oscilloscope. Figure 1(A) shows an oscilloscope display of a square-wave pulse followed by a decaying, oscillating waveform. The sweep is triggered near the top of the main pulse. But what if you want to examine the oscillations more closely? Trying to trigger at a lower voltage will cause multiple traces, as in Figure 1(B).

Figure 1(C) shows how, with delayed trigger, you can have the oscilloscope's sweep begin at any point you select. The trigger is delayed so that the oscilloscope sweep begins at the point of interest in the waveform. Then the timebase can be expanded, as in Fig. 1(D), for more detailed observation.

You can also use delayed triggering to focus on a particular pulse in a stream of data. In this case the delay would be timed from a trigger signal—perhaps a "write" pulse—that occurs at a specific time before the pulse stream.

About the circuit

Shown in Fig. 2 is the schematic diagram, minus power supply, of the delayed trigger circuit. The circuit consists of three basic parts: comparator *IC1*, which senses the trigger voltage; flip-flop *IC2*, which triggers a timer; and programmable timer *IC3*, which outputs the delay pulse.

Action begins when a signal is connected to one input of LM311 comparator *IC1*, whose trip level is set by potentiometer *R1*. This trip level is adjustable from −15 to +15 volts. When the input at pin 2 of *IC1* goes higher than the input at pin 3, the output at pin 7 goes high. Switch *S1* transposes the two comparator inputs, permitting triggering on either

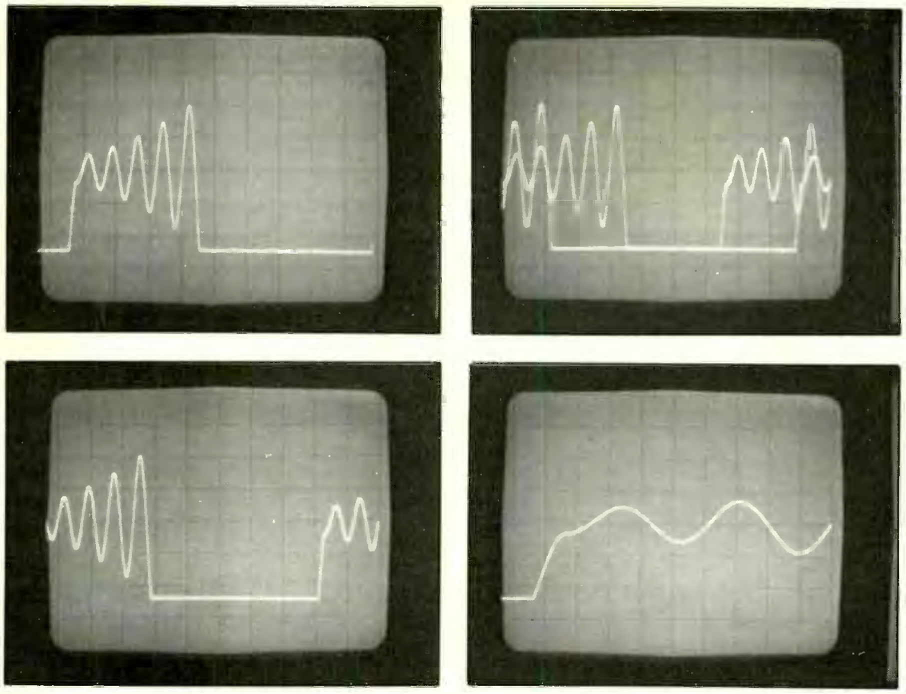


Fig. 1. Waveform (A) is triggered near the top of the main pulse. Lowering the trigger voltage results in the multiple traces shown in (B). Because the trigger signal is delayed in (C), the oscilloscope sweep begins at point of interest on waveform. For closer examination, timebase can now be expanded as shown in (D).

the rising or falling edge of the input signal.

Resistor *R4* provides hysteresis to give the comparator "snap-action" response, which is important for quick response to slowly varying inputs. Diodes *D1* and *D2* protect *IC1* against damage from inputs that are greater in magnitude than the supply voltages.

When pin 7 of *IC1* goes high, it clocks D-type flip-flop *IC2*, causing the Q output of *IC2* at pin 13 to go high. Capacitor *C3* then charges through resistor *R6*, resetting the flip-flop. The result is a 5-microsecond duration pulse that triggers *IC3* and prevents this timer from retriggering until the next time *IC2* is clocked. (Only half of *IC2* is used in this project. Inputs to the unused flip-flop on the chip are tied to ground to assure stable operation.)

Timer *IC3* is configured to operate in a monostable, or one-shot, mode. The pinout for the *IC3* 7250 programmable timer is shown in Figure 3. The IC's output, a single low-going pulse, connects to TRIGGER OUT.

TRIGGER OUT also connects to the trigger input (external or channel 2) on the oscilloscope with which this project is used. When TRIGGER OUT goes high, the oscilloscope sweep is triggered; so the width of the output pulse equals the delay time for the oscilloscope sweep. In addition, the timer resets and waits for another trigger pulse.

Width of the divide-by-1 output pulse at pin 1 of *IC3* equals the RC time constant of the components at pin 13. In this circuit, the RC timing components are *R7*, *R8* and *C4* or *C5*. When *IC3* is triggered with *C4* selected and potentiometer *R7* set for minimum resistance, the width of the pulse at pin 1 is 10 microseconds (10 microseconds is the product of *R8* times *C4*, which is 10,000 ohms times 0.001 microfarad.)

Four of the eight programmable outputs of *IC3* are used in this application. Each output divides the timebase-oscillator frequency by a specified amount, permitting programming of different pulse widths. Wiring together two or more outputs has the effect of ANDing the individual outputs so that an output goes high only when all connected outputs are high, and the output pulse width is the sum of all of the connected outputs.

Different pulse widths are selected by *S2*, *S3* and *R7*. The Table details the outputs that are available for each position setting for *S2*.

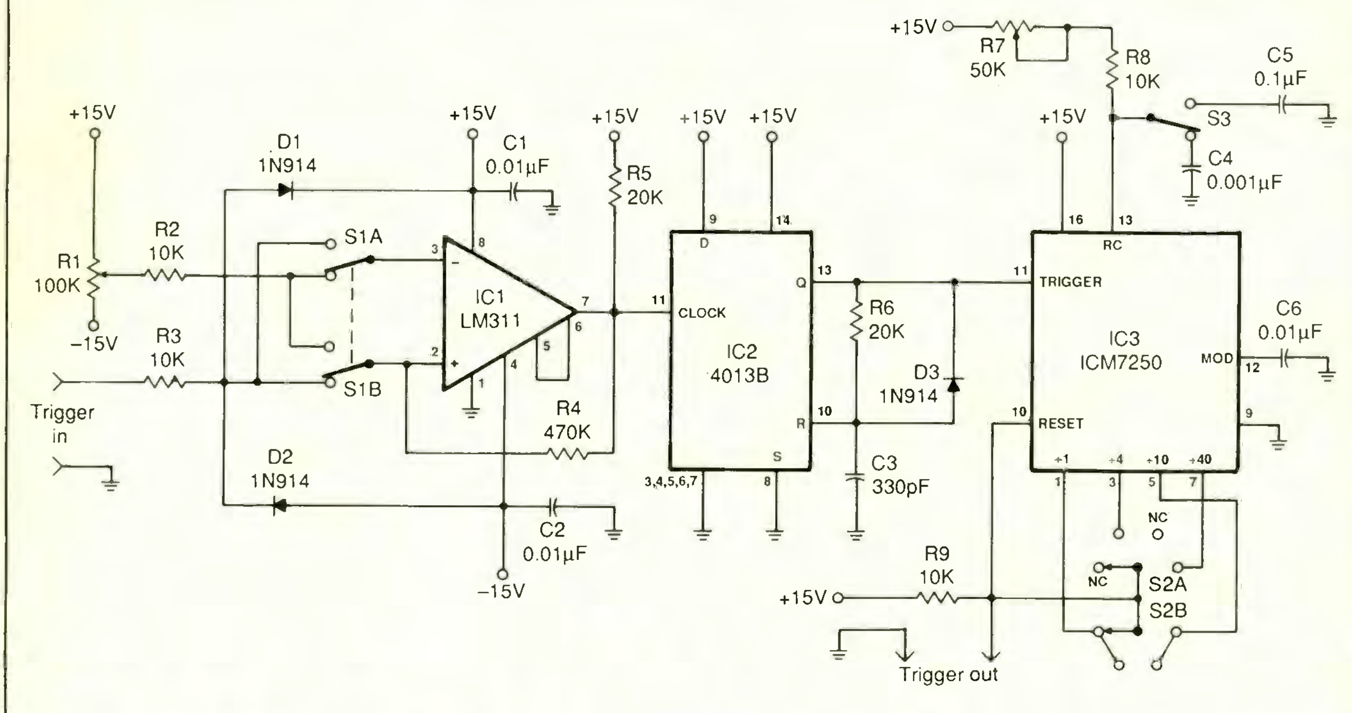
Switch *S2* is a double-pole six-position switch (only four positions are used) that is used to select different *IC3* outputs. With *S1* set to position 1, TRIGGER OUT connects to pin 1, the divide-by-1 output, and the output pulse goes low for 10 microseconds. In position 2 of *S2*, the divide-by-1 and divide-by-4 outputs are wired together to give a pulse width of 50 microseconds (10 plus 40 microseconds). Position 3 (divide-by-10) gives a pulse width of 100 microseconds, and position 4 gives 500 microseconds (divide-by 40 and divide-by-10).

By adjusting potentiometer *R7*, you can increase the width of the outputs by up to six times. The delay available at each position overlaps the range provided by the previous position, so any delay from 10 microseconds to 3 milliseconds is available.

For longer delays, *S3* is used to deselect *C4* and select *C5*. This causes the pulse width of the timebase oscillator, and thus the delay times, to increase by a factor of 100. The result is full pulse width, or delay time, adjustability from 10 microseconds to 300 milliseconds.

The bipolar power supply for the delayed-trigger accessory is shown schematically in Figure 5. This supply uses a 25-volt center-tapped transformer to generate the +15 volts and −15 volts required by the circuitry in the accessory.

Transformer *T1* steps down the 117-volt ac line potential to 25.2 volts and bridge rectifier *RECT1*



PARTS LIST

Semiconductors
D1,D2,D3—1N914 or similar silicon diode
IC1—LM311 comparator
IC2—4013B CMOS D-type flip-flop
IC3—ICM7250 programmable timer (ICM7240 can be substituted; see text)
IC4—78L15 + 15-volt regulator
IC5—79L15 − 15-volt regulator
RECT1—50-volt, 1-ampere bridge rectifier
Capacitors (25 WV minimum)
C1,C2,C6—0.01-μF ceramic
C3—330-pF ceramic
C4—0.001-μF timing
C5—0.1-μF timing
C7,C8—100-μF electrolytic
C9,C10,C11,C12—0.1-μF ceramic
C13,C14—10-μF electrolytic
Resistors (¼-watt, 10% tolerance)
R2,R3,R8,R9—10,000 ohms
R4—470,000 ohms
R5,R6—20,000 ohms
R1—100,000-ohm, linear-taper, panel-mount potentiometer
R7—50,000-ohm, linear-tape, panel-mount potentiometer
Miscellaneous
F1—0.5-ampere slow-blow fuse
S1—Dpdt toggle or slide switch
S2—2-pole, 6-position rotary switch
S3—Spdt toggle or slide switch
S4—Dpst toggle or slide switch
T1—25.2-volt, 450-mA center-tapped power transformer
Printed-circuit board or perforated board with holes on 0.1-inch centers and suitable soldering or Wire Wrap hardware; sockets for IC1, IC2 and IC3; suitable enclosure; pointer-type control knobs (3); fuse holder; ac line cord with plug; rubber grommet; labeling kit and clear acrylic spray (see text); ½-inch spacers; machine hardware; hookup wire; solder; etc.

Fig. 2. Complete basic schematic diagram of delayed-trigger accessory minus its + 15- and − 15-volt ac power supply.

changes the stepped-down ac voltage to pulsating dc. Because transformer ratings are given as rms voltage (0.7 × peak voltage), peak output from *T1* is actually about 36 volts, which is sufficient to enable using *T1* to generate potentials that can be converted to both + 15 and − 15 volts. Using *T1*'s center tap as a reference, *IC4* regulates the + 15-volt, *IC5* the − 15-volt supply rails.

Construction

Component values for this project are not critical. However, because the combination of *R7*, *R8* and *C4* or *C5* sets the delay time, components that are stable in value are recommended here. If available, use 1-percent precision resistors and temperature-stable capacitors, such as the Y5P series.

If you cannot obtain a 7250 programmable timer, you can substitute the ICM7240, which is nearly identical to the 7250 but has binary-coded outputs. For this project, the only difference between the two is in the delay ranges. With the 7250 the outputs selected at positions 3 and 4 of *S2* are divide-by-10 and divide-by-50. With the 7240 these will be divide-by-16 and divide-by-80. These

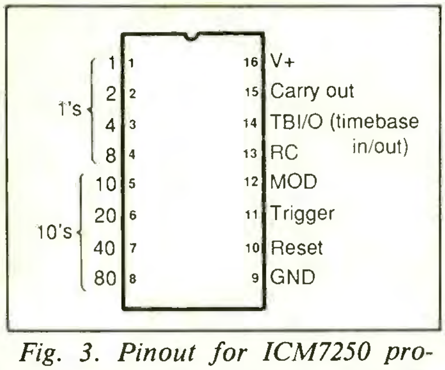


Fig. 3. Pinout for ICM7250 programmable timer integrated circuit.

will give slightly different, but still usable, delay ranges on the accessory.

You can fabricate a printed-circuit board on which to mount and wire the components, using the actual-size etching-and-drilling guide shown in Figure 6. Alternatively, if you prefer not to make a pc board, you can use perforated board with holes on 0.1-inch centers and suitable soldering or Wire Wrap hardware. Whichever method of wiring you choose, use sockets for the DIP integrated circuits.

Referring to Fig. 7, insert and solder the IC sockets—*not* the ICs themselves—into place. Set aside the ICs themselves for installation after initial checks have been made on the fully wired circuit. Follow up wiring the board with the capacitors, diodes and resistors, making sure to observe proper polarity for the electrolytic capacitors and the diodes. Then solder into place a bare wire at JUMPER, which can be either a cut-off resistor or capacitor lead or a length of stripped solid hookup wire. Install and solder into place regulators *IC5* and *IC6* in their respective locations, referring back to Fig. 4 for pinout details.

When you've finished wiring the circuit-board assembly, remove ¼ inch of insulation from 18 8-inch lengths of hookup wire. Plug one end of these wires into all unoccupied holes on the circuit-board assembly, except those labeled T1 and T1 C.T., and solder into place.

Next prepare the enclosure by drilling appropriate-size holes in the front panel to accommodate the four switches, two potentiometers and four jacks (see lead photo for details). Drill a hole through the enclosure's back panel to provide entry for the power cord and install the fuse block. Then drill the holes for mounting the circuit board and transformer in the case. Use a dry-transfer lettering kit or tape labeler to identify the front panel controls and jack. If you dry-transfer lettering to the panel spray on two or three *light* coats of clear acrylic to protect the lettering. Wait until each successive coat dries before spraying on the next.

When the acrylic spray has completely dried, mount the various controls and jacks on the front panel. Make sure the potentiometers and rotary switch are properly oriented so that their knob pointers are positioned properly for the panel markings.

Mount the fuse holder and power transformer in their respective locations inside the enclosure. Twist together the fine wires in both conductors at the end of the cord and sparingly tin with solder. Route the cord through the rubber grommet and into the enclosure and tie a knot in it inside the case about 4 inches from the end. The knot serves as a strain relief.

Solder one line cord conductor to one of the fuse holder lugs and the other to one toggle lug on *S4*. Then connect and solder a short wire between the free lug of the fuse holder and the other toggle lug of *S4*. Determine which of the power transformer's leads are to the primary (117-volt) winding and connect and solder these to the stationary-contact lugs of *S4A* and *S4B*.

Plug *T1*'s secondary and center-tap leads into the holes labeled T1

Delay Outputs Available

Switch S2 Position	IC3 Output(s) Selected	Delay (C4 Selected) in Microseconds (μs) Minimum	Delay (C4 Selected) in Microseconds (μs) Maximum	Delay (C5 Selected) in Milliseconds (ms) Minimum	Delay (C5 Selected) in Milliseconds (ms) Maximum
1	1	10	60	1	6
2	1 and 3	50	300	5	30
3	5	100	600	10	60
4	5 and 7	500	3,000	50	300

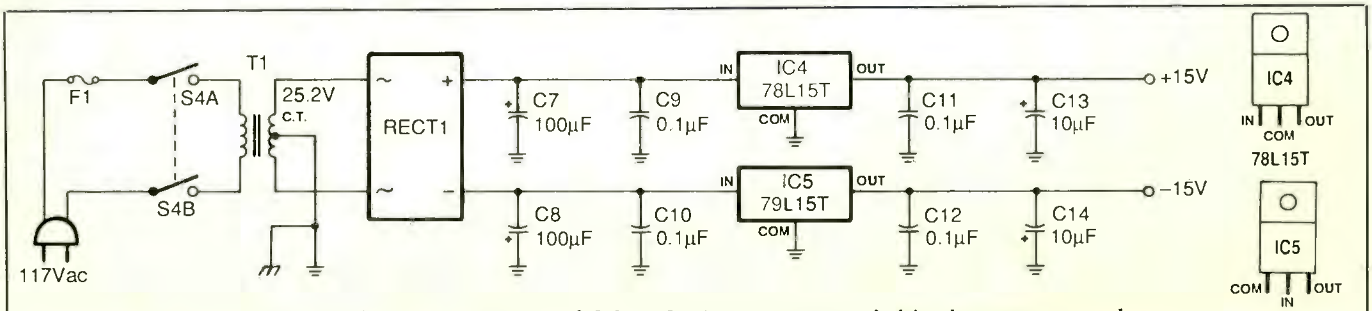


Fig. 4. Schematic diagram of delayed-trigger accessory's bipolar power supply.

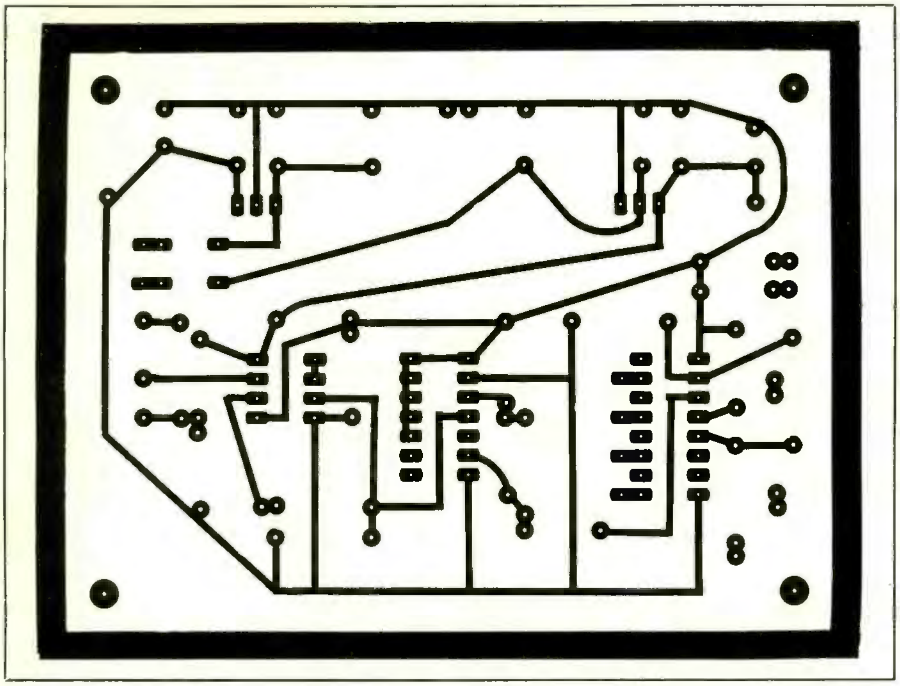


Fig. 5. Actual-size etching-and-drilling guide to use for fabricating printed-circuit board.

and T1 C.T. in Fig. 6 and solder into place. Then mount the circuit-board assembly inside the enclosure with ½-inch spacers and ¾-inch machine screws, lockwashers and nuts. Use electrical tape or heat-shrinkable tubing to cover all exposed 117-volt ac line-potential wiring on *S4* and the fuse holder.

Referring to Figs. 6 and 7, wire the free ends of the wires on the circuit-board assembly to the various controls, switches and input and output jacks into the circuit. Remove ¼ inch of insulation from both ends of an appropriate length of hookup wire and connect and solder this from the TRIGGER INPUT to the TRIGGER OUTPUT ground jacks.

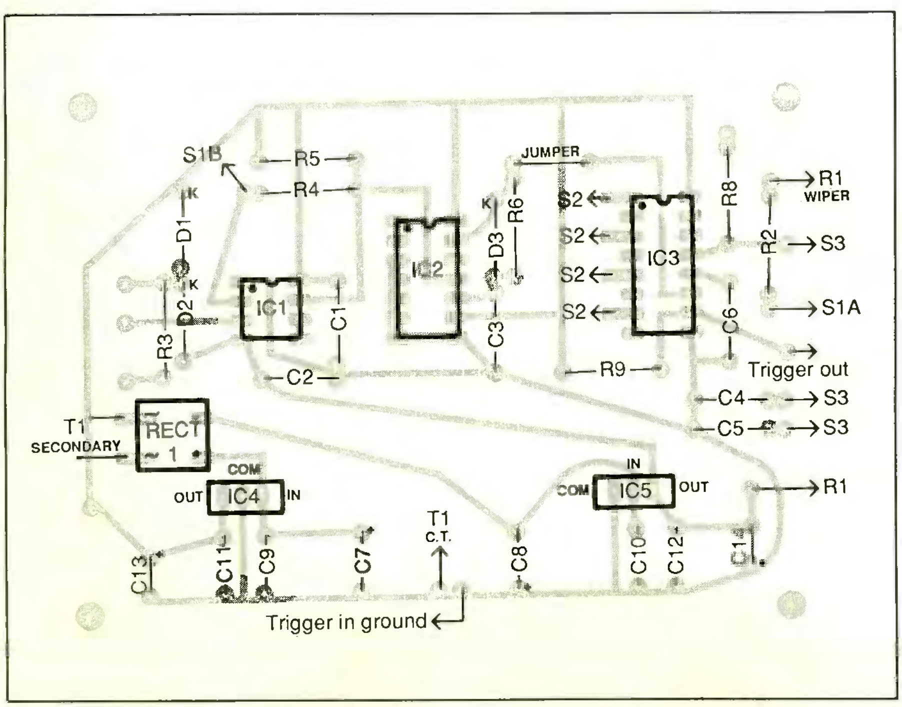


Fig. 6. Wiring guide for pc board. Use this as component-placement guide if you wire circuit on perforated board.

Slide pointer-type control knobs onto the shafts of *R1*, *R7* and *S2*. Rotate the knobs and note the maximum counterclockwise and clockwise positions of the pointer on the potentiometer knobs. Rotate the knob on the rotary switch and note where the pointer rests for each position (remember that only four positions are of interest if you are using a six-position switch). If necessary, reorient the pot or switch to obtain perfect indexing with the panel markings.

Checkout & Use

Before plugging the ICs into their respective sockets, power up the circuit and use a voltmeter set to read at least 20 volts dc to check for proper power routing. Connect the meter's common lead to circuit ground (either ground jack on the front panel, for example). Then touch the "hot" meter lead to pin 18 of the *IC1* socket, pins 8 and 14 of the *IC2* socket and pin 16 of the *IC3* socket. In all four cases, you should obtain a reading of approximately +15 volts. Touching the hot lead to pin 4 of the *IC1* socket should yield a reading of −5 volts.

Once your readings are correct, power down the project and wait a couple of minutes for the charges to bleed off the electrolytic capacitors in the power supply. Then install the ICs in their respective sockets, taking care to properly orient each and making sure that no pins overhang the sockets or fold under between ICs and sockets as you push the ICs into place. Handle *IC2* and *IC3* as you would any other MOS device.

To check operation of the delayed-trigger accessory, you need a test os-

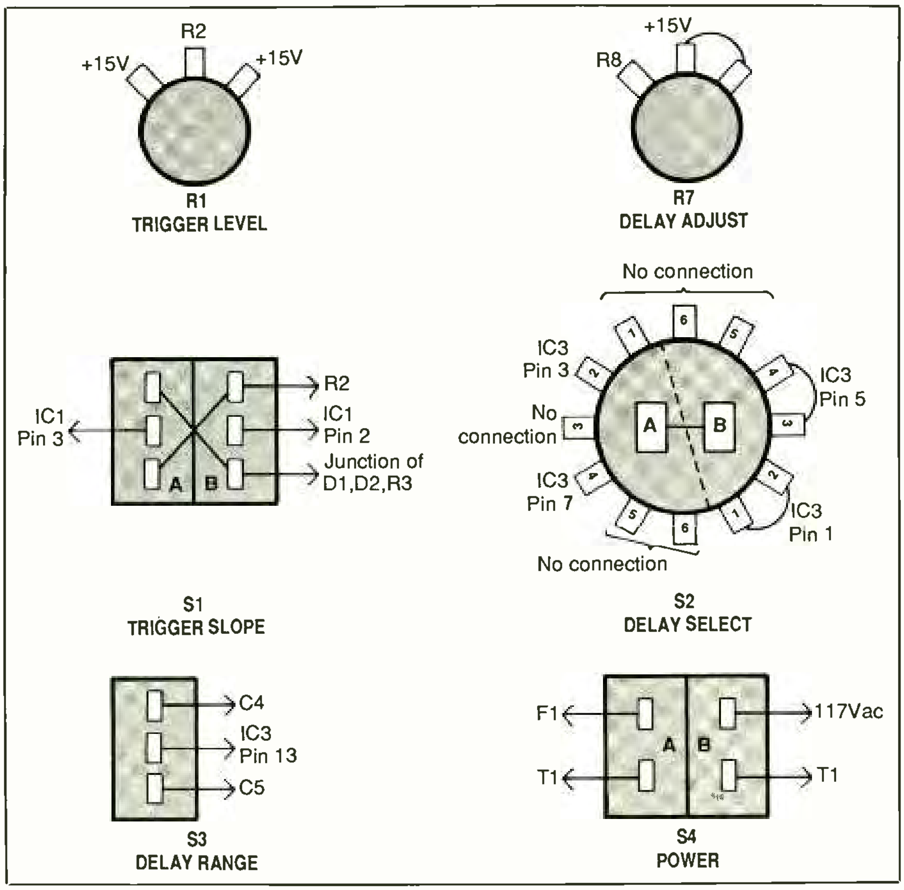
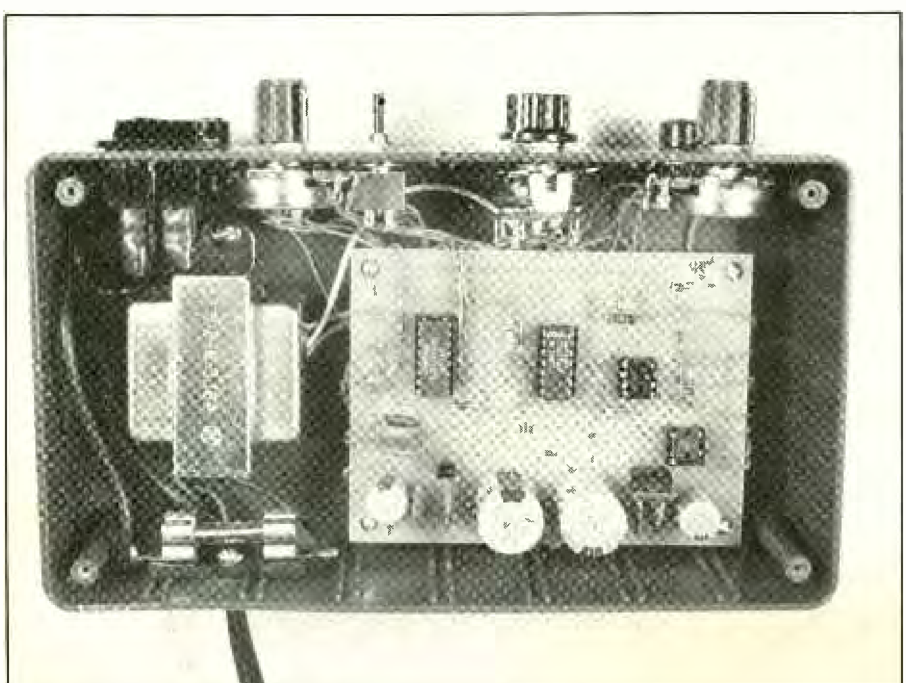


Fig. 7. Wiring guide for switches and potentiometers.



Circuit-board assembly and power transformer mount on floor of enclosure, switches, controls and jacks on front panel.

cillator. Circuit operation is easiest to observe when the period of the test signal is slightly longer than the delay time. Thus, it is best to have available signals of several frequencies; 10 kHz, 1 kHz, 100 Hz, 10 Hz, and 1 Hz are recommended. You can use a square wave output from a bench signal generator for these.

If a bench generator isn't available, you can use a spare 7250 IC to build the simple oscillator shown in Figure 8. By using two timing resistors and connecting a jumper wire to different outputs as shown, all the required frequencies can be obtained.

To begin checkout, set *S3* to "μs" (*C4* selected), set *S2* to position 1 (pin 1 of *IC3* selected), and set *R7* to minimum resistance. The position of *S1* isn't important at this point.

Power up the project, connect a 10-kHz signal and ground reference to the TRIGGER IN jacks, and monitor pin 7 of *IC1* with your oscilloscope. Adjust *R1* until a rectangular waveform appears at pin 7. Then check pin 13 of *IC2* for a 5-microsecond positive-going pulse occurring each time pin 7 of *IC1* goes high.

Next, connect your scope to TRIGGER OUT on the project and check for a 10-kHz rectangular wave. Varying the setting of *R7* will cause the "low" portions of the waveform to vary from 10 microseconds to 60 microseconds in width, though the total period of the waveform will remain constant. The length of time the waveform is low in each cycle is the delay time generated by the circuit.

To see the delay in action, set up your scope to display the 10-kHz output of the test oscillator on channel 1. Leave the oscillator also connected to TRIGGER IN on the project. Then set the scope to trigger on channel 2 or external trigger. Connect TRIGGER OUT of the delayed-trigger accessory to the trigger source you've chosen on the scope. Shown in Fig. 9 is a drawing of the test setup.

Adjust the trigger level on the scope for a stable display. The sweep

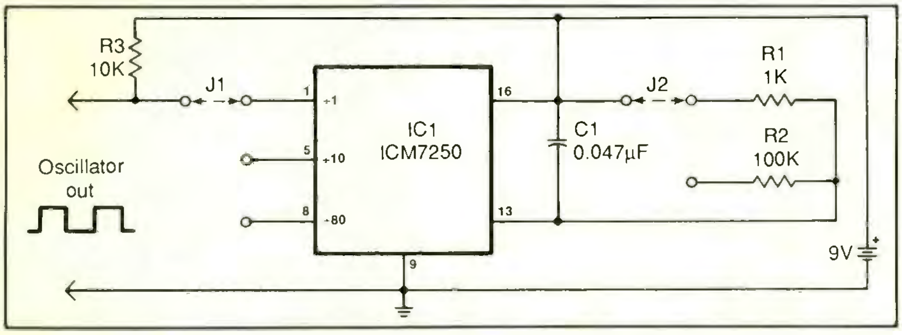


Fig. 8. A 7250 wired as shown here serves as a suitable test oscillator for checking out operation of project.

will begin 10 microseconds after the output of *IC1* goes high. Varying *R7* will increase the delay and cause the waveform to "shift left" on the display even farther. The trigger delay is easy to see when displaying a rectangular wave because the sweep can now be set to begin anywhere along the flat parts of the pulses, not just on their rising and falling edges.

Flipping switch *S1* to its alternate position will turn the display "upside-down" as you change the trigger slope from the rising to falling edge or vice versa.

When you set *S2* to position 2, the delay increases by a factor of 5; instead of 10 to 60 microseconds, the delay will vary from 50 to 300 microseconds. Change the input signal to 1 kHz and expand your timebase on the scope for better observation of this delay. Again, varying *R7* will cause the waveform to shift as the delay is increased and decreased.

Use this same 1-kHz input to check position 3 of *S2*. Then use a 100-Hz signal to observe position 4. Refer to the table for the delay times available at each position. Then change *S2* back to position 1, select *C5* with *S3*, and observe delays ranging from 1 to 6 milliseconds—100 times as long as the original 10-microsecond delay.

Input a 10-Hz signal and check the delays at positions 2 and 3 of *S2*. Finally, a 1-Hz signal will allow you to observe the longest delays, at position 4 of *S2*. The final delay should be adjustable to about 300 milliseconds.

To use the accessory, do the following:

(1.) Select a trigger signal of equal or lower frequency than that of the signal to be observed.

(2.) Connect the signal to be observed to channel 1 of the oscilloscope.

(3.) Set the oscilloscope's trigger slope to + and trigger source to external or channel 2.

(4.) Connect the trigger signal to TRIGGER IN on the delayed-trigger accessory.

(5.) Connect TRIGGER OUT on the accessory to the trigger source input (external or channel 2) selected on the scope.

(6.) Adjust trigger slope and level on the delayed-trigger accessory for a stable display on the oscilloscope screen.

(7.) Adjust the delay range and delay time on the accessory to "tune in" the desired portion of the waveform.

(8.) Expand the timebase on the scope if desired to examine the signal more closely.

As you use the delayed trigger accessory, you'll almost certainly come to rely on it as much as laboratory users do with their very expensive scopes. In fact, you may even decide that you don't have to trade your old scope in for a newer-technology model if you had that in mind. ME

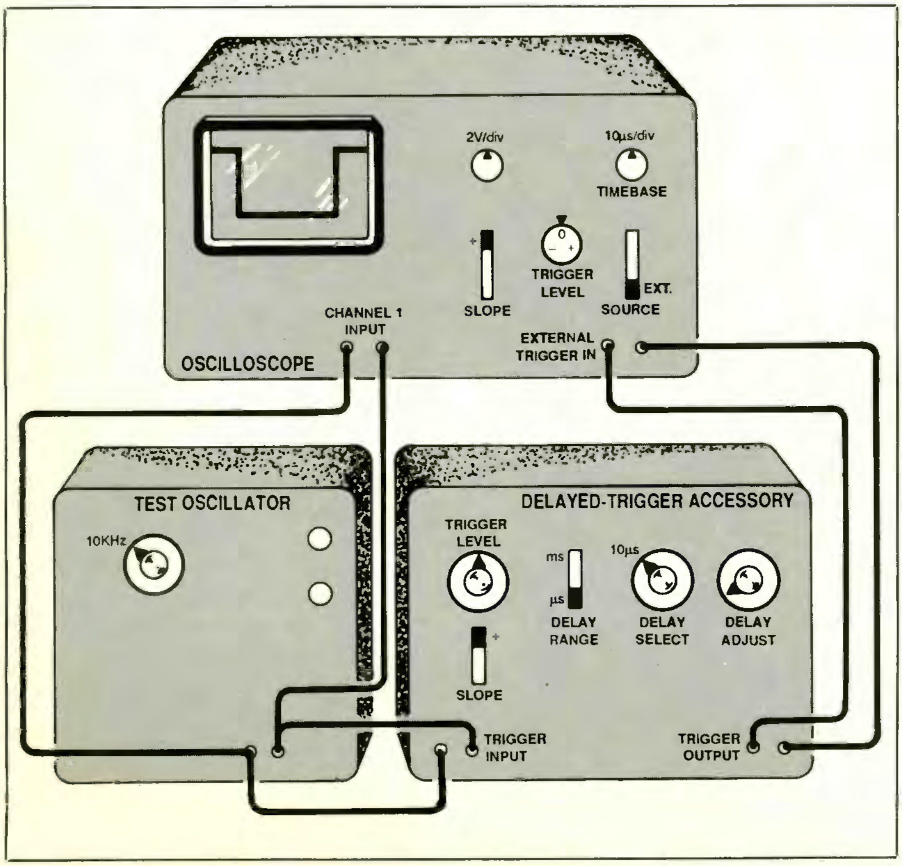


Fig. 9. Initial setup for testing delayed-trigger accessory.