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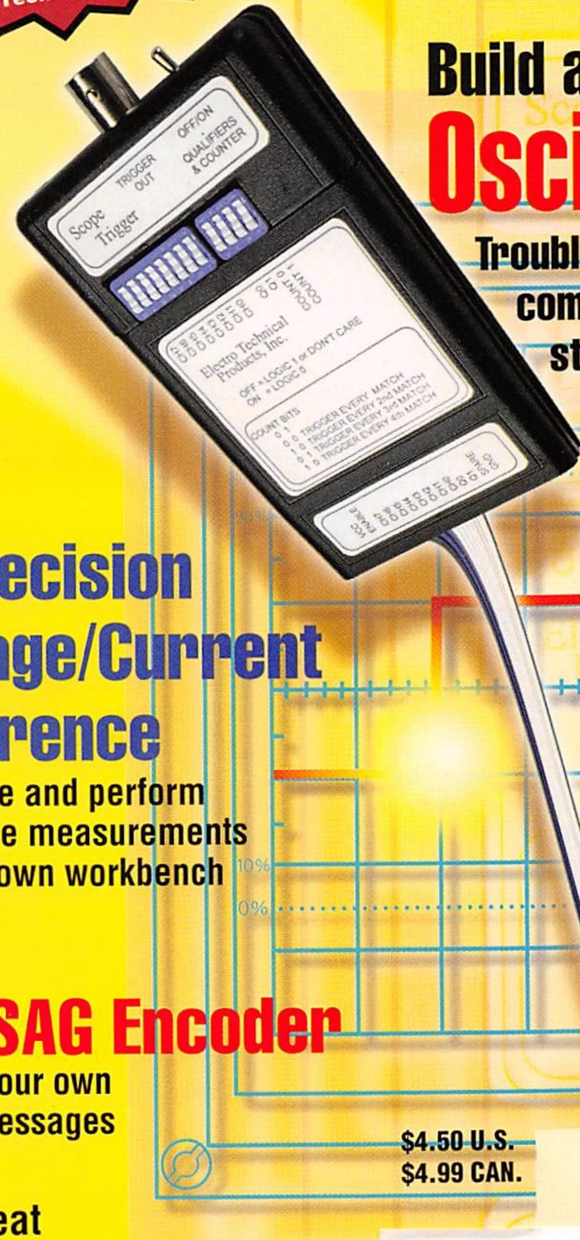
Troubleshoot and debug even the most complex digital circuits with a standard scope and this accessory



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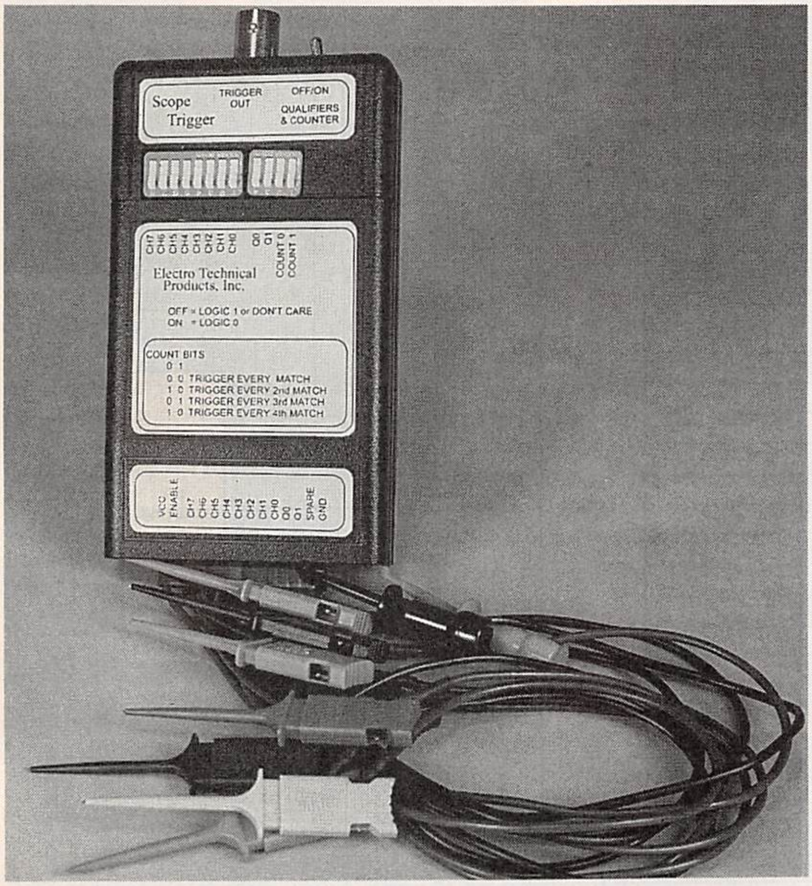
Build a Multichannel Oscilloscope Trigger

Trigger an oscilloscope sweep on a combination of input signals!

THOMAS PETERICK



If you have ever experimented with your PC's hardware, you have probably figured out that a two-channel oscilloscope isn't exactly the best tool for debugging or troubleshooting computers. Generally, when digging around in any computer-based circuit, you want to look at the resulting output of several input signals. A two-channel scope doesn't provide that capability. With the Multichannel Oscilloscope Trigger presented here, you can examine one or two signals with a triggering circuit based upon as many as ten other inputs. Such a capability can be very handy when you want to be sure that data is written to the correct I/O address or the correct bit is set when a memory operation takes place.

The Multichannel Oscilloscope Trigger can assist in providing faithful and reliable information when probing digital circuits. The scope trigger is a ten-bit comparator with a built-in counter feature. It generates an output pulse when the inputs match the value set into the selector switches or on some multiple of matches. The counter feature allows the scope trigger to provide an output pulse on every second, third or fourth count. The output pulse can be fed into the trigger of a standard oscilloscope causing the scope to trigger only when the digital signals present at the monitored inputs match the switch settings on the trigger unit.

Circuit Description. The schematic for the scope trigger is shown in Fig. 1. It consists of two integrated circuits, three resistor packs, and some support circuitry. The monitoring portion of the circuit is built around IC1, a 74AC520 eight-bit comparator. It compares the inputs that are connected to pins 5–12 of J1 to the switch settings on S2. Pin 13 of J1 is an enable control that must be at a low logic level (or grounded) for IC1 to operate.

When the inputs match the switch settings, a negative-going pulse appears on pin 19 of IC1 and is passed on to IC2, a GAL16V8 Programmable Logic Array (PLA). The programming for IC2 is set so that it acts as both a 2-bit comparator and a counter. Inside IC2, the inputs from pins 3 and 4 of J1 are compared to S1-c and S1-d. If the inputs match the switches and there is a negative pulse from IC1, the logic inside IC2 decodes a data match and outputs that condition on pin 17. In other words, S1-c and S1-d act like a ninth and tenth comparator bit, extending the range of IC1.

The count process is also controlled by IC2. If both S1-a and S1-b are on, every match is passed out of IC2 on pin 19. If S1-b is turned off and S1-a is turned on, every other match is passed out of pin 19 of IC2. The full set of combinations for S1-a and S1-b is shown in Table 1. The counter feature gives the Multichannel Oscilloscope Trigger greater flexibility for whatever type of triggering is needed.

Resistor packs R1, R2, and diode D1 provide some isolation from the circuit under test as well as protection for the scope trigger, in case the Multichannel Oscilloscope Trigger is not hooked up properly to a circuit. Resistor pack R3 acts as a set of pull-up resistors for S1 as well as for the inputs on J1. That is done in order to have a valid signal on the inputs in case not all of the inputs are needed. Capacitors C1 and C2 are for power decoupling.

The final output to the oscilloscope trigger is selected by S3. If the output from IC1 is to be used directly by the oscilloscope, the final trigger can have up to eight trigger

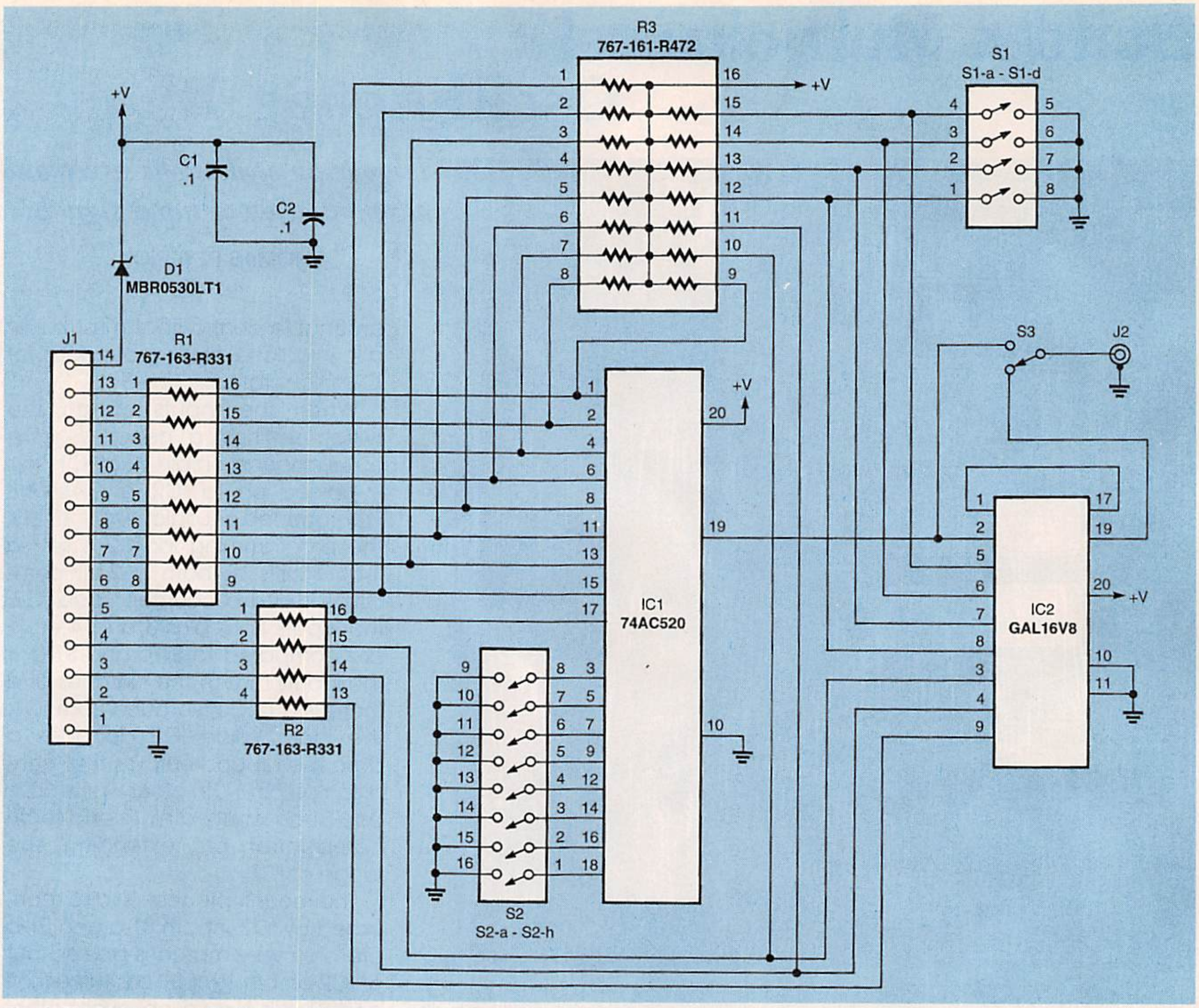


Fig. 1. The Multichannel Oscilloscope Trigger is a simple device that lets you use your oscilloscope to examine complex circuits. You can trigger your oscilloscope on a combination of either eight or ten logic inputs. You can also set the output to trigger on every trigger occurrence up to every fourth trigger occurrence.

inputs at a speed up to 100 MHz. By using the output from IC2, the trigger output can be more sophisticated in operation. However, the speed of the trigger will drop to about 50 MHz.

Building the Multichannel Oscilloscope Trigger. The Multichannel Oscilloscope Trigger uses several surface-mount (SMT) components. Anyone with knowledge of soldering should be able to build the unit without difficulty. If you do not have any experience with surface-mount technology, this project is a good first exposure to the methods used in working with SMTs. The sidebar on soldering SMT components should be reviewed before starting construction.

The programmable logic array,

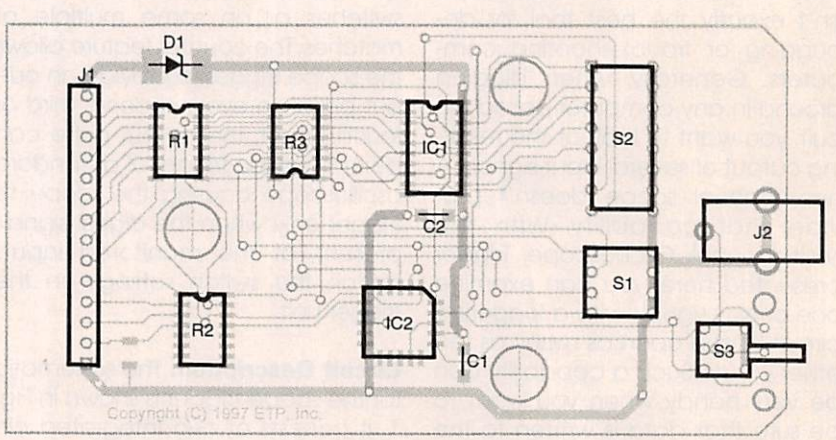
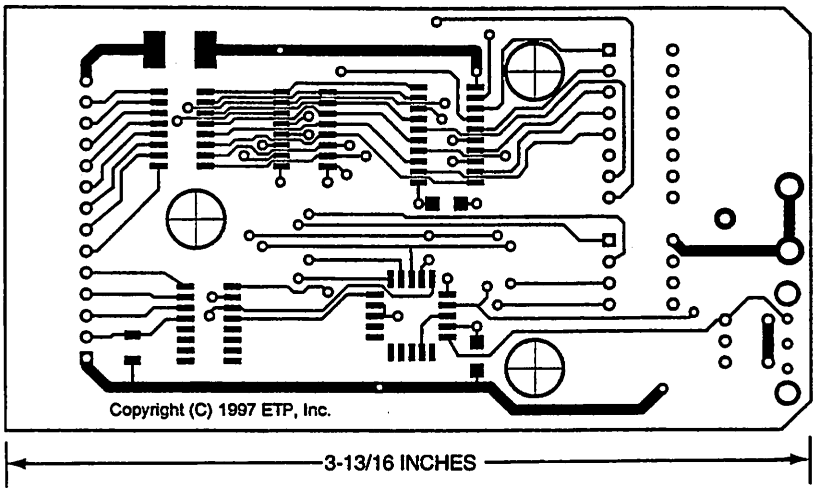
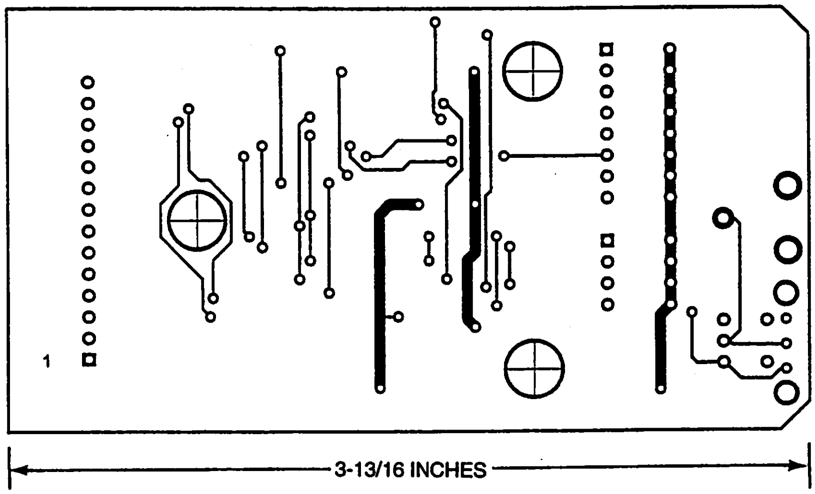


Fig. 2. The Multichannel Oscilloscope Trigger is based on surface-mount components. This project is a good introduction if you've never worked with SMT components before.

IC2, must be programmed before it is installed in the board. If you wish to program your own part, the programming data can be downloaded from the Gernsback FTP site (ftp://ftp.gernsback.com). The



Here's the foil pattern for the component side of the Multichannel Oscilloscope Trigger.



The solder side of the Multichannel Oscilloscope Trigger completes all of the connections needed to the other side of the board. If you're making your own board, don't forget to make the connections between the two sides of the board or the Multichannel Oscilloscope trigger won't work.

name of the file that contains the data is otrigger.dat.

If you are using the PC board from the kit given in the Parts List or you have etched your own board using the foil patterns included here, follow the parts-placement diagram in Fig. 2 for component location. Start by soldering the surface-mount components to the PC board. That approach will make it easy to position the soldering iron and solder the components to the PC board without some of the larger components getting in the way. After C1, C2, D1, R1–R3, IC1, and IC2 are in place, install the through-hole components. If you wish, you could add a jumper wire between pin 13 and pin 1 of J1. That will disable the pin 13 input on J1 and permanently enable IC1. A disadvantage to that modification is that it will not be possible to cascade several Multichannel Oscilloscope Trigger units together. However, it is not necessary to remember to ground the enable line when using a single unit. The enable input can also be used as an active-low qualifier input for the Trigger—the choice is entirely up to you.

Install sockets for S1 and S2. That will lift the switches off the PC board and project them through the top of the case. The trigger output jack, J2, has a large thermal mass, making it more difficult to solder to the PC board with a small iron. When soldering J2 onto the board, heat the two large pins more than the pads on the PC board. The joint will

AN SMT PRIMER

Soldering surface-mount components is no different from any other soldering task. The limited contact area that SMT components have just makes the same job more critical. Dirt or contamination that could be ignored on through-hole components cannot be tolerated on SMT components. Therefore, the first rule of SMT soldering is cleanliness. The least bit of contamination on the PC board or component can drastically change the amount of solderable surface area in a connection.

Use fresh components and PC boards to reduce the chances of contamination. The soldering iron should be tinned and shiny. If there is any flux crust or dark spots on the iron tip, wipe it off with a damp sponge and re-tin the tip. Always use fresh solder.

The second rule is that the equipment should match the job. You don't crack walnuts with a sledgehammer, nor should you solder SMT components with an oversized soldering iron. To do the job right, the soldering-iron tip should match the physical size of the SMT connections. A suggested tip size should be no bigger than 1/16 inch. It is also a good idea to purchase solder that is appropriate for soldering SMT components. A solder diameter between 0.015 and 0.031 inch is suitable for most SMT tasks.

The third rule is to watch the temperature of the soldering iron. All common electrical solders begin to melt at about 361° F. Applying an iron with a tip temperature over 800° F to the joint could damage the component or the board. If the tip is properly sized to the job, there is no need to heat a component lead and PC board contact to more than 600° F to solder components.

Now that we have the right tools for the job, let's examine how to hand-solder an SMT component to the board. For multi-leaded components, pick a corner lead on the PC board for the component to be soldered. Melt some solder onto that pad. Position the component on the board. Heat the component and wetted pad with the soldering iron. The solder will reflow and the component leg will sink into the solder. Inspect the component's alignment with its footprint. If the alignment is good, solder the diagonally opposite corner from the first connection so that the component cannot move. If the alignment is not correct, reheat the joint and move the component until the alignment is good. With two diagonal corners soldered in place, the other pins can be soldered. Those connections are done the same way you would solder any other connection—heat the component and pad with the soldering iron and apply solder to the component leg. The corner-tack method holds the component in good mechanical alignment.

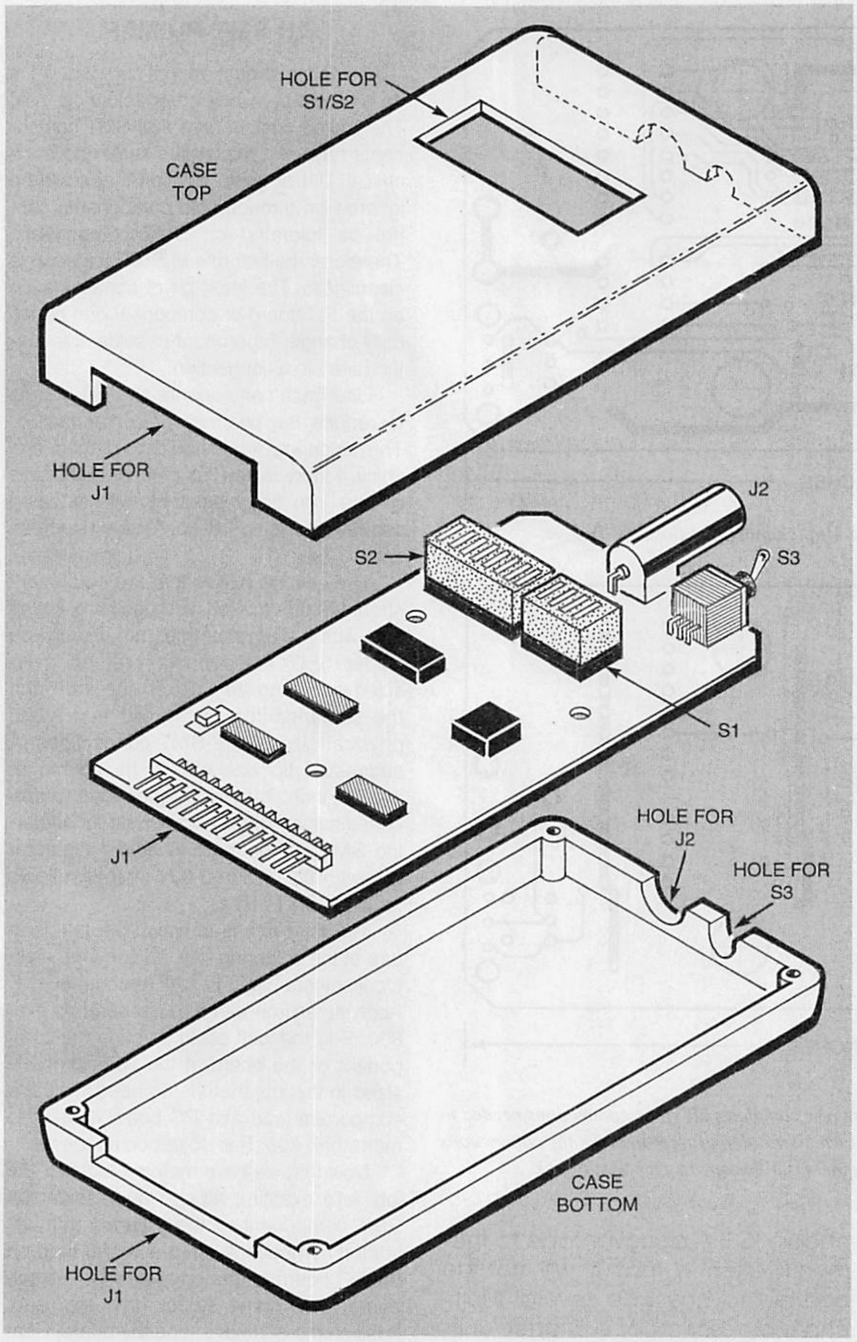


Fig. 3. The Multichannel Oscilloscope Trigger fits nicely into a small hand-held case. Several holes will need to be cut at specific locations in order for the controls to be accessible.

PARTS LIST FOR THE MULTICHANNEL OSCILLOSCOPE TRIGGER

SEMICONDUCTORS

IC1—74AC520SC 8-bit comparator, integrated circuit, surface-mount
IC2—GAL16V8 programmable logic array, integrated circuit, surface-mount
D1—MBR0530LT1 Schottky diode, surface-mount

RESISTORS

R1, R2—767-163-R330G resistor network, surface-mount
R3—767-161-R472G resistor network, surface-mount

ADDITIONAL PARTS AND MATERIALS

C1, C2—0.1-µF capacitor, ceramic surface-mount
J1—14-pin right-angle header (Digi-key A5308 or similar)
J2—BNC connector, right-angle PC-board-mount (AMP 414373-1 or similar)
S1—4-position DIP switch
S2—8-position DIP switch
S3—Single-pole double-throw switch, right-angle PC-board-mount (Digi-key EG1905 or similar)
IC sockets, case (Digi-key SRM6-B or similar), wire, test probe clips, hardware, etc.

Note: The following items are available from Electro Technical Products, Inc., PO Box 16658, West Palm Beach, FL 33416-6658, E-mail: etpinc@pb.seflin.org: Complete kit of parts including pre-programmed IC2, case, PC board, and case labels, $64.95; Assembled and tested unit, $84.95; 13-piece test clip set for use with J1, $29.95. Please add $3.00 for shipping and handling charges. FL residents add appropriate sales tax.

eventually get hot enough for the solder to flow. When installing J1, you could cut off pin 2. That pin is not used, and can be utilized as an orientation key. Filling the hole on the corresponding plug will reduce the risk of installing the input cable backwards.

Once all of the components have been soldered to the board, inspect each solder connection thoroughly. Use a magnifying glass or jewelers loupe, if possible. Look for all the indications of a good solder joint. They should be shiny and even, without either too much solder or too little solder. Joints that have peaks or points have too much solder. If there is too little solder, it will be difficult to tell if the connection is soldered. Solder bridges and excessive solder can be cleaned up by using solder wick to draw the excess solder away from the components.

Drill and cut appropriate holes in a suitable enclosure. Square holes will have to be cut for J1, S1, and S2. Round holes are needed for J2 and S3. Measure the locations of those components on the PC board to find the locations that need to be cut on the case. Additional holes will be needed in the back of the case for mounting the PC board. Screws, nuts, and spacers can be used. As an alternative, plastic tubes can be glued to the inside of the case and the PC board held in place with self-tapping screws. The general

(Continued on page 56)

MULTICHANNEL TRIGGER

(continued from page 36)

arrangement for fitting the PC board into the enclosure given in the Parts List is shown in Fig. 3. Using a different case will probably need a different arrangement. The only requirement is that the switches and jacks be readily accessible.

TABLE 1

Count 1 (S1-b)	Count 2 (S1-a)	Trigger Function
OFF	OFF	Every occurrence
OFF	ON	Every second occurrence
ON	OFF	Every third occurence
ON	ON	Every fourth occurence

Using the Multichannel Oscilloscope Trigger. To use the Multichannel Oscilloscope Trigger, locate a 5-volt source and ground connection on the circuit you will be testing. Attach the 5-volt source to pin 14 of J1, and connect pin 1 to ground. If you didn't permanently ground the enable input (pin 13), that pin should also be either grounded or connected to a signal that is low during the time that you want to trigger your oscilloscope.

As mentioned before, there are three ways to use the Multichannel Oscilloscope Trigger. The mode with the fastest speed is the eight-bit mode. Operation at speeds over 100 MHz is possible. To use that mode, set the qualifier and counter switch in S1 to the off position and set the S2 switches to the desired pattern of on and off states. The eight settings on S2 will be compared to the inputs on J1. A negative-going pulse will appear at J2 when a match is detected.

Probably the most common mode of operation will be the 10-bit mode. With that mode, you can typically decode a full byte of data on a computer's data bus during a read or write operation along with an enable signal. The 10-bit mode works the same as the eight-bit mode, except that it will only decode at rates up to 50 MHz. To use the 10-bit mode, the qualifier and counter switch in S1 must be on.

To use the Multichannel Oscilloscope Trigger in the counter mode, simply set the count switches as shown in Table 1. The counter mode lets the trigger output toggle on every second, third, or fourth occurrence of a match on the input pins.

If you want to use the trigger to qualify fewer than 8 or 10 inputs, simply set the S1 switches for the unused inputs to logic ones. The internal pull-up resistors on IC1 will automatically set the unused pins to the same state, making them valid. That will let the Multichannel Oscilloscope Trigger pulse its output based upon the other inputs.

To troubleshoot complex circuits, you might want to have several units available on your bench. Connecting the output of one device into the enable pin of another will let you see the state of some very complex signal combinations. Ω