Production logic tester checks a variety of ICs

by T.K. Tawfiq
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A complete stand-alone IC logic tester, which is ideal for small production lines, can be built at low cost by making use of Hewlett-Packard's model 10529A logic comparator. This production IC tester performs full functional testing of a logic circuit, yet is compact enough to fit on a small metal plate.

The performances of two identical circuits—that of the device being tested, and that of a reference device—are compared. All possible binary combinations are applied to the inputs of both devices, and the states of their outputs compared. A defective IC will light the display on the logic comparator.

The figure shows the schematic for the tester, and the photograph depicts an assembled tester (excluding the main body of the logic comparator). Three decade counters are connected in series; their outputs, which are designated A through M, are brought out to a row of jacks. The clock signal is applied to a BNC-type connector before it is gated to the counter chain.

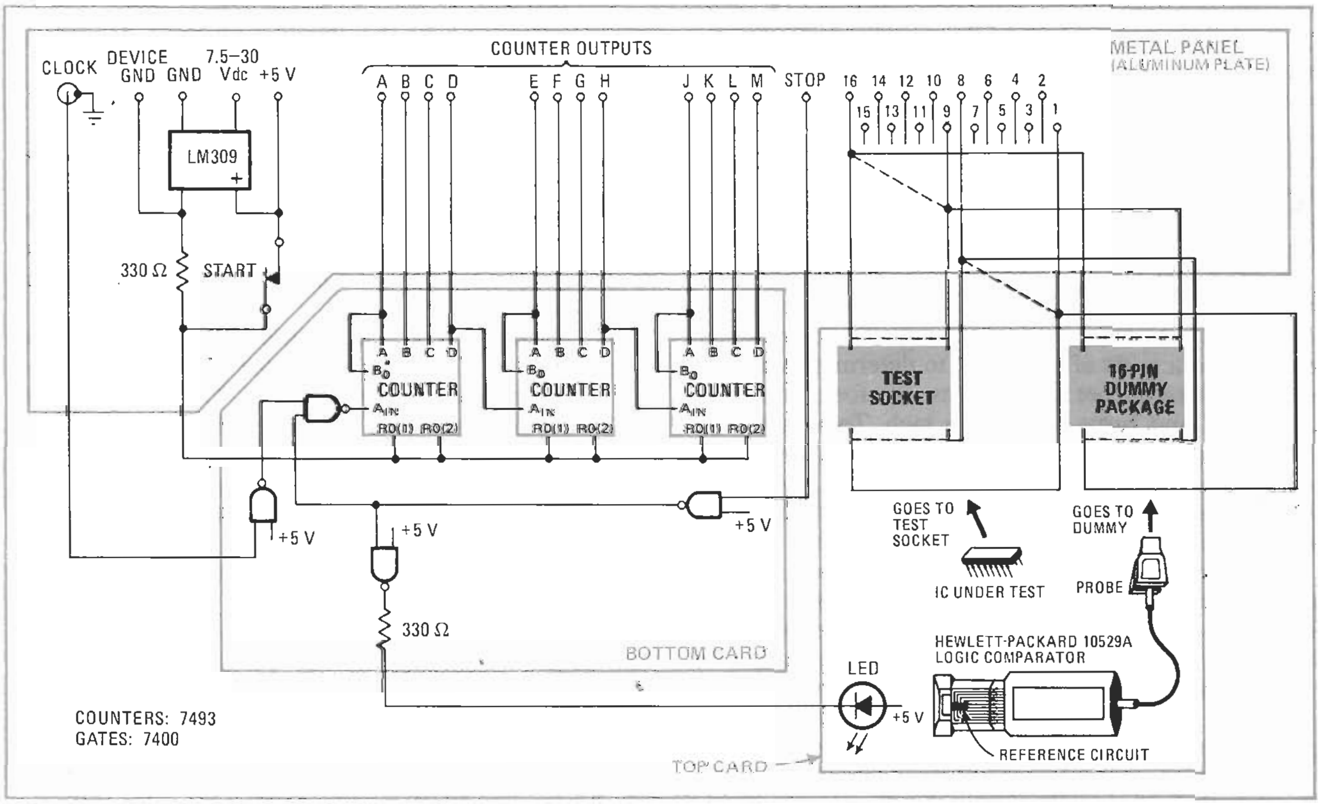
To fix the duration of a test, a patch cord is run from the STOP jack to the counter output jack following the last-used counter output. This output goes high at the end of the test cycle, preventing the clock from reaching the counter input. When the test ends, the light-emitting diode on the top card turns on. The START push button manually clears the counters for a new test cycle.

The power-supply terminals labeled 7.5—30 volts dc and GND are for the counters, while the ones labeled 5 V and DEVICE GND are for the package being tested. Here, a 22-pin socket serves as the socket for the device to be checked, and a 16-pin dummy package receives the probe of the logic comparator.

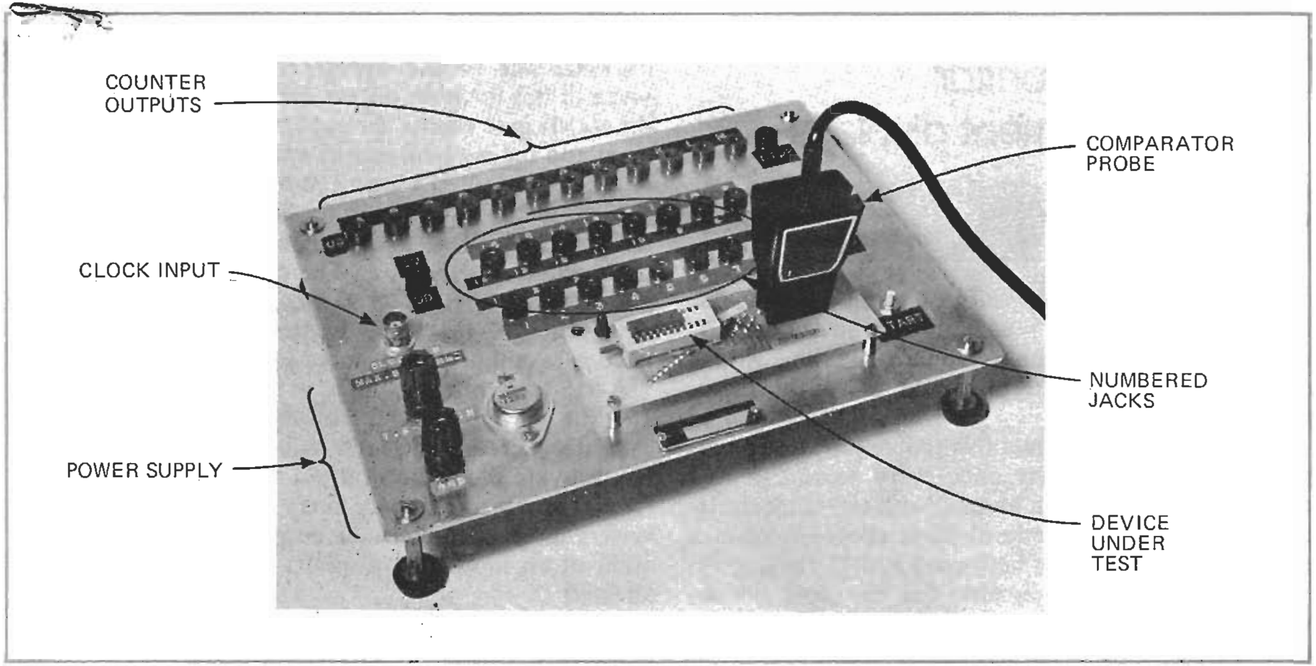
The pins of the dummy package are connected in parallel to the pins of the IC test socket. These same pin connections are also brought out to two rows of jacks and numbered to correspond with the two sets of socket pins. Patch cords can be used to connect the pin jacks to the appropriate supply terminals and counter outputs.

To test a device, begin by inserting a reference circuit into the logic comparator and plugging the comparator's probe into the dummy package. Next connect the dc power supply to the tester's supply terminals, and then run patch cords from the 5-V and DEVICE GND jacks to the appropriate numbered jacks of the IC to be tested. The on-indicating LED in the logic-comparator's display will now light.

Using a data sheet as a guide, connect patch cords be-



Functional checkout. Compact IC tester makes a complete functional check of many different logic circuits. The performance of the device under test is compared with that of a reference circuit. Series-connected decade counters provide the necessary binary inputs for the test device. A defective unit will light the display on the logic comparator. The assembled tester occupies a small metal panel (see photo).



tween the counter output jacks and the numbered jacks to the inputs of the IC to be tested. Run another lead from the STOP jack to the jack following the last-used counter output. The clock signal generator can now be hooked up to the CLOCK jack. (The maximum clock amplitude should not exceed 5 V, nor the maximum clock frequency 10 megahertz.)

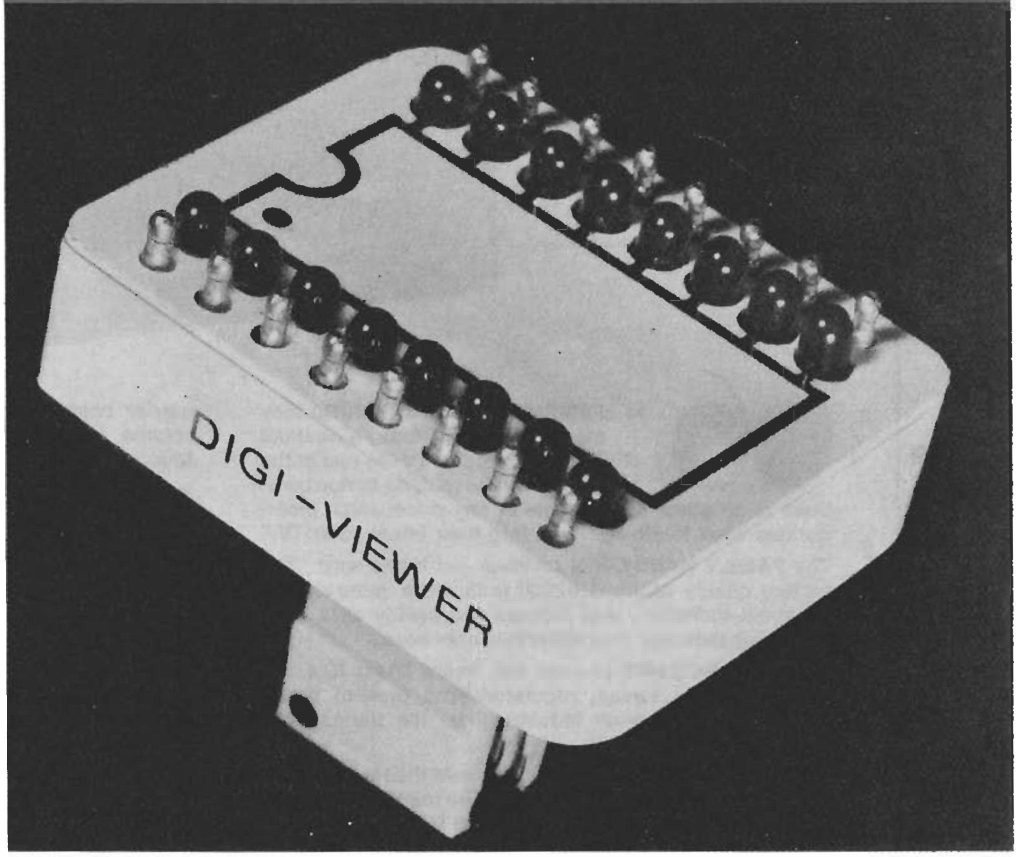
After inserting the test device, depress the START button and observe the LED display on the logic comparator. If any LED position in this display lights, the test device is defective. At the end of the test cycle, the LED on the top card lights.

To speed up the testing process, patch-cord connection charts can be prepared for various logic ICs. □

BUILD DIGIVIEWER II

Simultaneously checks up to 16 pins of any digital IC

BY DON LANCASTER



SOONER or later if you are working with digital IC's you're going to have to check the states of the signals at the various pins. You can view the waveforms on a scope, check the voltages with a meter, or use a standard logic probe. With either of these procedures, however, you can only check one pin at a time.

Now, with the Digiviewer II (costing less than $19), you can simultaneously check all 14 or 16 pins of an in-circuit DIP package. The IC can be CMOS, TTL, DTL, RTL or other positive-supply digital logic. All you do is "glomp" the Digiviewer on the IC and LED readouts will indicate the state (0 or 1) at each pin. Masks can be inserted in the face of the Digiviewer to show the internal arrangement of common IC's so that there is no need to refer to a data book.

The Digiviewer also allows a solderless, snap-on connection to IC pins for measurements, monitoring, or "force-feeding" functions such as a reset. The glomper clip has gold-plated contacts that cannot short between pins, and a sliding clamp firmly locks the Digiviewer to the IC being tested.

The fixture locates the positive power supply automatically and the ground point is obtained either by plugging the Digiviewer's ground lead into the proper test pin or by using a ground extender to the system ground. The top half of the Digiviewer can be used alone as a permanent 16-place state monitor to be built into any circuit.

The logic decision point of the Digiviewer is 1.3 volts. Input signals above this level cause the associated LED's to light. Signals below 1.3 V indicate a logic 0, a ground, no connection, or an unterminated tri-state or open collector output.

While the Digiviewer works best on a visual rate with static clockings of the digital circuit, at higher speeds, the duty cycle of a particular pin will show up as a variable brightness. For instance, the Q and $\bar{Q}$ pins of a binary dividing flip-flop will cause the LED to glow at half brightness.

The input impedance of the Digiviewer is 100,000 ohms at 1.2 volts and it will operate over any supply voltage from +4 to +10 volts. For higher supplies, voltage-dropping resistors can be used.

Circuit Operation. As shown in Fig. 1, each of the 16 pins of the glomper

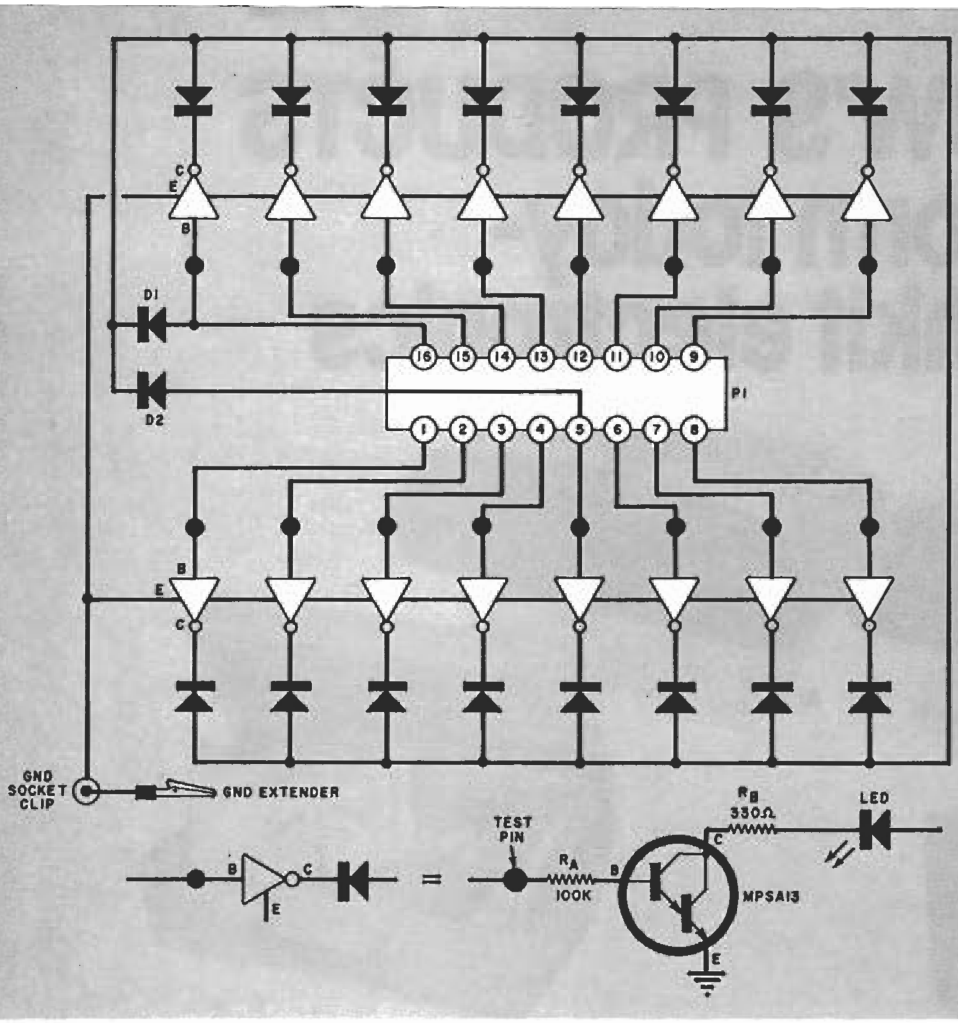


Fig. 1. Circuit consists of 17 identical high-input-resistance Darlington LED drivers. Power is derived from pin 5 or pins 14/16, common positive pins.

PARTS LIST

D1, D2 — 1-ampere silicon rectifier diode
LED1-LED16 — 0.2-in. diameter LED
P1 — Glomper clip (Guest International)
Q1-Q16 — MPSA13 or MPSA14 npn Darlington transistor (minimum gain 5000, do not substitute)
R_A(16) — 100,000-ohm, ¼-watt resistor
R_B(16) — 330-ohm, ¼-watt resistor
Misc. — Test pins (Molex 0.093" diameter by 0.6" high, 17 required); heavy wire for board interconnections; flexible insulated wire; test socket (Molex 02-09-1118); heat-shrinkable tubing; insulated alligator clip; etc.
Note: The following are available from Southwest Technical Products, 219 W. Rhapsody, San Antonio, TX 78216: etched and drilled pc boards at $3.25; complete kit of parts (#VU-2) at $19.50; mask sets (specify RTL, 7400TTL, 4000CMOS, or blank) at $2.50.

clip (*P1*) is connected to a Darlington transistor npn amplifier through a 100,000-ohm resistor. The output of each transistor goes through a current-limiting resistor and then through an LED indicator to the positive line. All 16 emitters are connected to the common ground. Diodes *D1* and *D2* are connected to pin 5 and pins 14/16 to handle the positive power supply. On a 14-pin DIP IC, pin 16 becomes pin 14 and the two right-hand LED's should be ignored. Only the most positive pin contributes to the Digiviewer power; the other diode is back biased and does not load the input. To test an IC that does not have pin 5 or pin 14/16 as the supply, another diode is needed (or 14 more diodes can be added—one for each pin).

Construction. Two printed circuit boards, stacked, are recommended for the Digiviewer. One is used to hold the glomper clip and the rest of the electronics is mounted on the second.

Assemble the top board (Fig. 2A and B) first. Attach the resistors first. In mounting the transistors, arrange their leads so that the transistor bodies are as close as possible to the pc board. The emitter terminal of each transistor goes on the inside, so half of the transistor "flats" point one

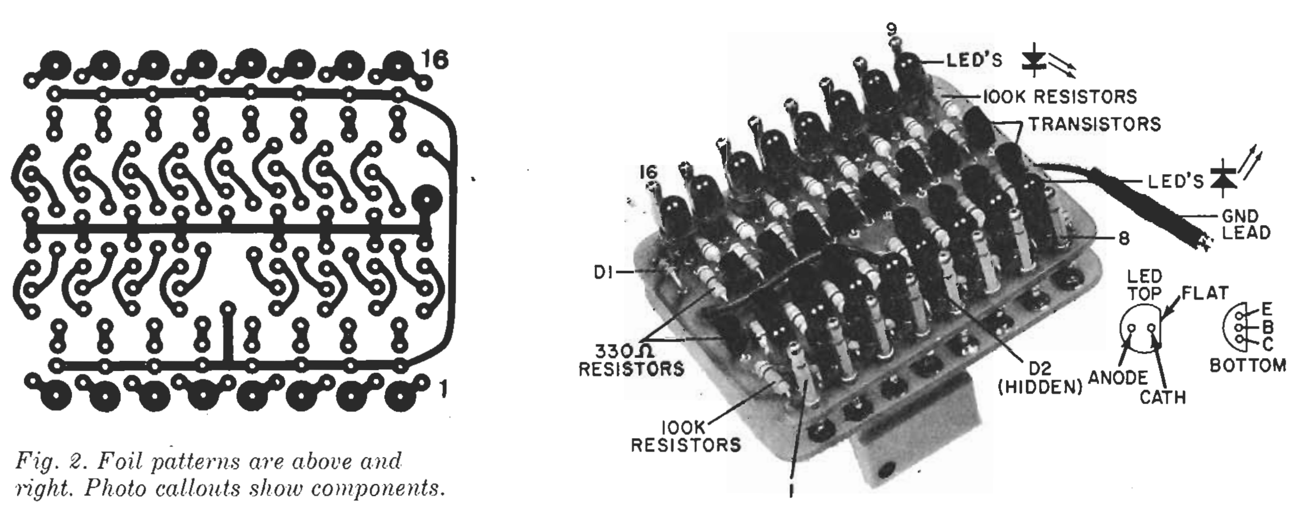


Fig. 2. Foil patterns are above and right. Photo callouts show components.

way and the other half the other way. This insures that all the emitter terminals are connected to the common grounds. Attach the diodes last.

Now temporarily insert and solder tack a test pin in each of the four corners. These pins and a flat surface are used to set the height of the LED's, which are uniformly spaced 0.2 in. off the pc board.

Note that an LED has a critical polarity. The cathode or resistor end has a slight flat on the plastic base. If the leads are of different lengths, the longer lead is usually the anode. One LED at a time is slipped into place and the pc board is then turned upside down (on the flat surface) to stand on the four corner test pins. Each LED pin is brought out vertically and tacked in place. Be sure the tops of the LED's just touch the flat surface and that the units are vertical.

The remainder of the test pins are then inserted on the same side as the LED's. Make sure that the pins are vertical and firmly seated before soldering them in place. Be careful not to let solder flow into the small hole at the bottom of each pin.

Complete assembly of the top board by adding an insulated (black) flexible ground lead, feeding it through a hole drilled above *D2*.

To test the board, use a 5-volt dc power supply and connect the loose end of the ground lead to the power supply negative. Connect the positive supply (5 volts) to the 14/16 test pin and note that the associated LED comes on. Make a connection between pin 5 (+5 volts) and each of the other pins and note that each associated LED comes on. To make a threshold check, leave the 5-volt supply on and use another, variable dc supply to check each input. The LED's should be off at about 1.1 V and fully lit at 1.5 V.

The foil pattern for the lower pc is shown in Fig. 2C. The outside dimensions of this board should be exactly the same as those of the upper board. Note that there is a slot in the board spanning pins 1 through 8.

Pins 9 through 16 of the glomper clip mount in the indicated holes, with the glomper on the nonfoil side of the board. (In the finished project, the foil sides of the board are facing each other.) Pins 1 through 8 of the clip pass through the slot in the board so that the arm of the clip can swing through a slight arc when the clip is mounted on an IC. The arm of the clip is the thinner side.

Each of the arm pins is connected to the pc foil through a short length of very flexible, thin, insulated wire. Be sure that these leads do not get covered with solder which will make them stiff. Be sure the clip arm moves freely.

The two pc boards are attached as shown in Fig. 3, with a spacing of ¼ in. Make up 16 short, heavy wire stubs just thick enough to slip through the holes in the bottom board. Insert the stubs in the holes and solder them in place on the foil side. Allow a small stub on the nonfoil side so that optional contact can be made to each pin.

Fit the boards together, soldering each stub into the hole of its associated test pin. Be sure not to loosen the test pin as you solder. Pass the insulated ground wire through the hole in the lower board and cut it so that it is about 6 or 8 inches long. Solder a push-on connector to the end and cover it with a length of heat-shrinkable tubing. Make up an extension ground lead, using a mating push-in connector and heat-shrinkable tubing at one end and an insulated alligator clip at the other.

The snap-on cover is fabricated of thin-walled (preferably white) plastic sheet. It can be made in two pieces (the top and a skirt) which are then cemented together after all drilling is complete.

The upper surface is $2\frac{1}{16}$ in. by $2\frac{7}{16}$ in., which is just large enough to fit over the LED's and test pins, with a little to spare. Sixteen $\frac{3}{16}$ in. holes should be drilled to mate with the LED's. Also drill 16 ⅛-in. holes to mate with the test pins. The outline of a 16-pin DIP should be drawn on the upper surface with a notch and dot code used to identify pin 1. The skirt, about ⅝" deep, is cemented to the upper cover. When the assembly is complete, the snap-on cover should seat firmly over the pc board assembly.

Use. Make up a series of masks for the most commonly used DIP IC's. Use indelible pencil or ink to draw the logic of the IC and identify the positive and ground pins. The masks should be held snugly against the LED's.

In fitting the glomper clip over an IC, be sure that pin 1 of the clip is on pin 1 of the IC. Connect the floating ground test lead to the circuit ground, or to the ground pin of the Digiviewer. Note that the supply voltage is present at the correct pin as indicated by an illuminated LED at that position.◆

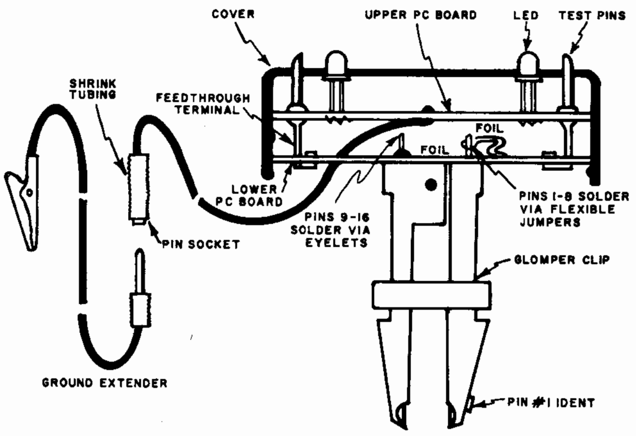
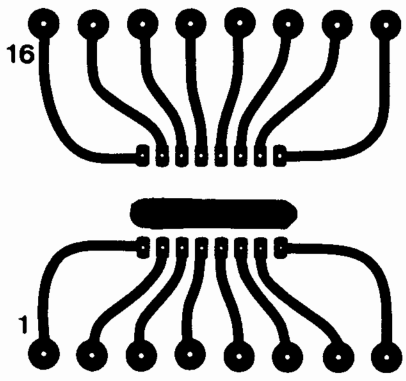


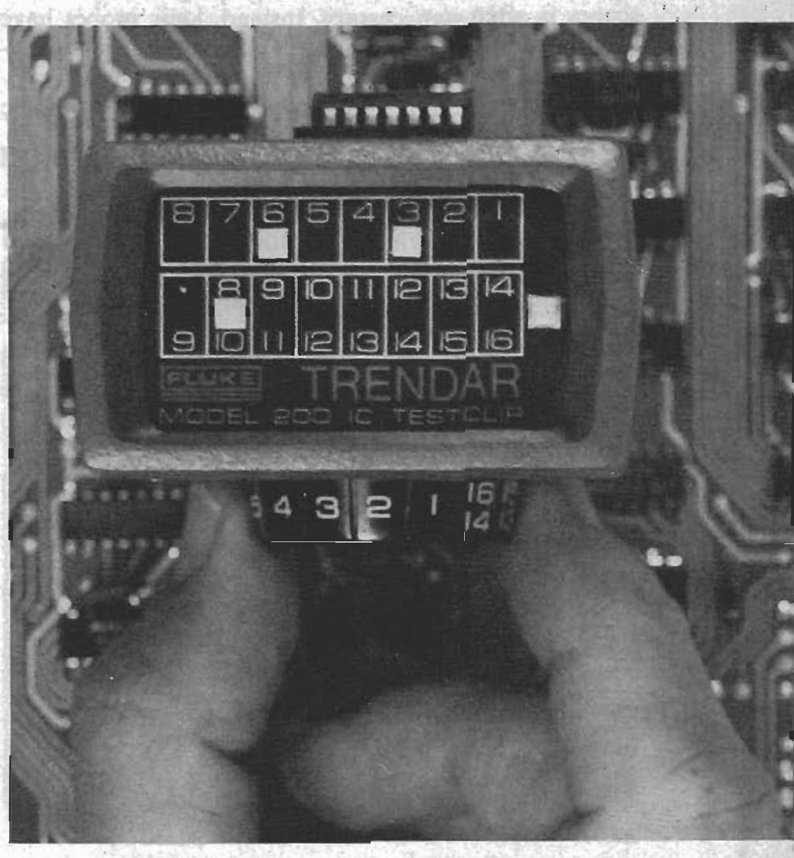
Fig. 3. Cross section of finished unit shows mechanical assembly.



Logic tester uses single trial procedure to troubleshoot digital IC boards

Combining the properties of a logic probe, a logic clip, and an IC comparator, this hand-held instrument promises significant cost reductions, both in factory use and in checking actual systems operating in the field

Donald P. Allen, *Trendar Automation Corp., Mountain View, Calif.*



☐ **About 10 million of the 500 million or so digital ICs produced this year will prove to be defective, and the** process of wave-soldering devices to digital logic boards will probably produce about 90 million solder defects. For some companies, the cost of isolating these faults represents 20% to 25% of their total board-production cost. At $1 per defect, the industry as a whole could pay out $100 million.

For equipment in the field, solder defects show up only rarely, and component-defect rates drop with time—the current crop of ICs may be expected to produce about 2.5 million failures, and an equal number may be expected from all ICs previously installed. However, the service cost per defect may be 10 to 100 times that on the production line—an industry total of $50 to $500 million.

Looking for the trouble

These high troubleshooting costs have spurred the evolution of several faultfinding aids, the most complex of which (Teradyne's "Trace" and General Radio's "Caps") are highly sophisticated programs for specialized computer-based test systems. The Fluke Trendar Testclip, however, represents a simpler breed of tool.

The Testclip allows a single test procedure to troubleshoot a digital IC board, either operating in an actual system or being run by a pattern from a logic tester. A combination logic probe, logic clip, and IC comparator, the instrument promises to reduce costs significantly both in the factory and in the field.

All troubleshooting is an exercise in comparing what one finds with what one expected to find. In the case of logic-fault detection, the latest tools merely speed up the original diagnostic methods—operating-mode analysis and oscilloscope-waveform observation—and have led to the first generalized procedures for fault-isolation of any logic.

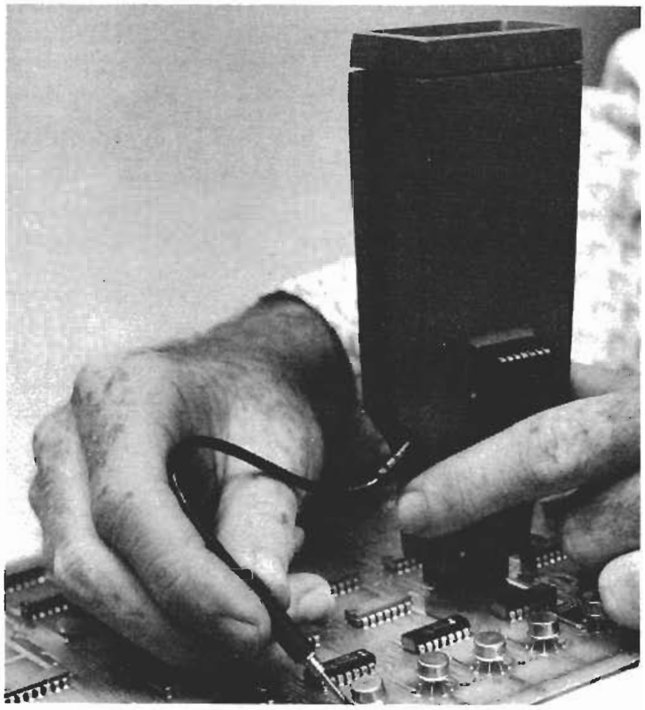
Operating-mode analysis applies when a system has enough operating modes and displays for faults to be diagnosed, at least down to the module level, by clever control sequencing and deductive reasoning on the part of the operator. It is occasionally possible to carry this method all the way to pinpointing the defective circuit stage itself—in fact, military maintenance technicians pride themselves on their ability to narrow the location of a fault down to two or three stages through display analysis only. More typically, however, the method is combined with scope waveform analysis and power-level checks.

The traditional troubleshooting technique is fast and costs little in the way of test equipment, especially if an experienced technician is at hand. But it has disadvantages.

It may be impractical to fully recreate the control combination or sequence that produces a fault that is not catastrophic. Or the human observer may miss a fault's fleeting appearance on a scope. The usefulness of logic-pattern analysis can be greatly extended by Hewlett-Packard's new 5000A logic analyzer [*Electronics*, April 26, pp. 139–140] which, however, is still like a scope in being unable to examine more than two circuit points at a time.

Since logic circuits operate between two nominal voltage levels, the continuous coverage provided by oscilloscopes is often unnecessary. Instead, logic probes have been introduced as a low-cost way to observe static levels and the presence or absence of toggling.

The dozen or more single-point probes now available can detect that large class of IC faults that manifest themselves as stuck pins and are caused by shorts to ground or collector-supply voltage or by open-circuit lead-bond failures. This single-point sleuthing works for perhaps 50% of IC faults—it will not pick up the defect in a counter that periodically miscounts or fails to reset, for example.



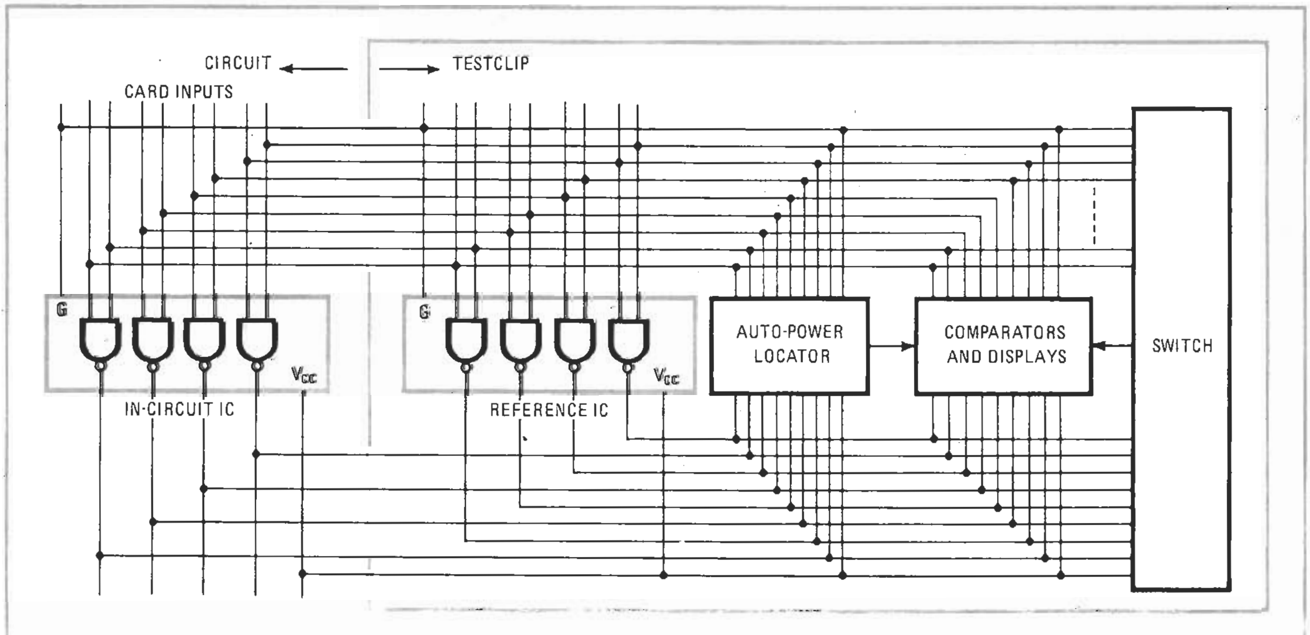
1. Three-in-one. Testclip clips onto board IC to be tested. There it can act as an IC-comparator, a logic clip, or a dial-up logic probe. When used as a comparator, the Testclip has plugged into it a reference IC known to be good. The logic probe extension, shown in use here, is used to examine nearby circuit nodes.

The logic clip was a natural outgrowth of the probe. It contains an array of LED lamps and slips onto a working dual in-line package to display the logic states of all of its pins at the same time. Most such clips require the system clock to be slowed down if they are to be able to differentiate between a steady logic 1 state and toggling at a high duty cycle. The Fluke Trendar Testclip and the Rohde and Schwarz Logiscope, in addition, contain stretching and blinking circuits to catch and stretch narrow pulses.

A short circuit, whether caused by a solder sliver on the board or a fault internal to the IC, may lock the behavior of a number of ICs connected to a common trace. Hewlett-Packard and Testline make various forms of single-pin and multiple-pin pulsers for use with either a scope or a clip that generate narrow high-current pulses of either polarity. The current delivered by these pulsers is sufficient to drive the node to the opposite logic state, but narrow enough to prevent excessive heating. If the states of the other input pins allow it, the good ICs will respond, preventing false changeouts. But not all ICs are amenable to this treatment—an eight-input NOR is an example.

Component substitution is an age-old cut and try method of troubleshooting. Since digital ICs are generally soldered on the boards, an adaptation of this technique is to operate a duplicate IC that's known to be good by paralleling its inputs with the IC in the circuit. The functional behavior can be checked through an exclusive-OR comparison of corresponding IC outputs.

The comparator will detect failures in total IC func-



2. Making the comparison. The in-circuit IC and the reference unit are compared by having their inputs paralleled by long pins on the reference IC socket. Short pins on the output leads prevent shorting of the outputs which go only to the comparator and display circuitry.

tion if proper input toggling signals are present. Sequential logic must be initialized by circuit action. Otherwise, a false reading might occur. Also certain ICs cannot tolerate the circuit load presented by an unbuffered comparator.

One of the first IC comparators was the HP 10529A which used reference ICs on small circuit boards plugged into a small case cabled to an IC clip. For production testing, the Trendar 2000 Test Station has this capability built in, with the added protection of buffer isolation of the clip.

Three on one

While each of these new tools removed or ameliorated some difficulties in troubleshooting logic circuits, many problems remained. For example, many fault types require the simultaneous use of several tools, yet people have only two hands. The result has been a trend toward inferential troubleshooting methods and a consequent increase in the time needed to diagnose a given fault.

To help reverse this trend, Fluke Trendar set itself the task of developing an instrument that would meet the following objectives:

- In a small hand-held package, incorporate the capabilities of a logic probe, a logic clip, and an IC comparator. (These three were chosen because they are the minimum complement of tools that will provide a universal troubleshooting procedure.)
- Try for hands-off testing because of the need for frequent manipulation of system or unit controls to exercise the board.
- Place the reference IC in the closest possible proximity to the IC under test and use high-impedance circuitry. This would eliminate false readings caused by excessive loading of the board under test and would also minimize vulnerability to overvoltage.
- Eliminate the need for power inputs, connectors, clips, and cables. Enable the instrument to power itself automatically from the board, despite wide variations in supply voltage.
- Find the simplest possible means for programing the reference IC—that is, telling the Testclip the difference between an input and an output.
- Handle bipolar logic families automatically with no adjustments or switching.
- Catch and display single narrow pulses or pulse streams to a high frequency.

The instrument that resulted is shown in Fig. 1. The case slips over the IC to be tested, and the reference IC is plugged into a conventional socket, which, in turn, is plugged into the case. The reference IC is paralleled with the board IC, each seeing the same input signals (Fig. 2).

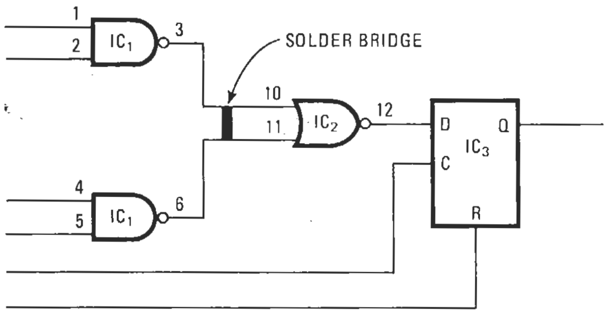
The outputs are compared by high-impedance comparators. Failures are displayed on an array of light-emitting diodes driven by the comparators. Logic states and toggling activity are displayed on a separate LED

Faultrack finds faults in both boards and ICs

The Faultrack procedure is a step-by-step backtracking of logic states that do not correspond with normal states. The non-correspondence is displayed in two ways to the operator: stuck states are observed by using the Testclip in its logic-probe mode, and truth-table faults are displayed in the IC-test mode. Both board faults and IC faults cause abnormal states that can be tracked by the Faultrack procedure. Here is an abbreviated version:

1. Verify that the active inputs of the failing IC stage are toggling by using the Testclip in its logic-probe mode. This is important with sequential logic to be sure initialization occurs. If some inputs are not toggling, the signal flow is probably being interrupted elsewhere. The instrument should be moved to the preceding IC or ICs. If all inputs that should be toggling are, move on to step 2.
2. Examine the failing output by using the logic-probe mode. If there is logic activity, go to step 3. If the output pin is stuck at a logic 1, go to step 4. If the output is stuck at a logic 0, go to step 5.
3. Check adjacent pins and parallel traces for a solder bridge. If there is none, replace the IC being tested.
4. Check for a short-circuit to V$_{CC}$. If there is no short-circuit, replace the IC being tested.
5. Check for a short-circuit to ground. If there is none, the failure could be in the IC being tested or in an input to an IC being driven by the IC under test. Depending upon the number of fan-out ICs, the fault usually can be located by trial changeout or by disconnecting the failing output of the IC being tested from its fanout and then retesting. A high-resolution ohmmeter can null a mechanical short without cutting traces or lifting pins.

The circuit shown in the figure, complete with failure, illustrates the application of the Faultrack procedure. Assume that the fault is a solder bridge across the inputs to the NOR gate, IC$_2$. Since the procedure can be started anywhere, assume the first check is of IC$_3$, the D flip-flop. All nodes (pins) are found to toggle when their logic states are checked. In-circuit IC comparison to a reference shows no faults in the state diagram. The next check is of IC$_2$. Its inputs and output toggle in spite of the input bridge. IC comparison would pass the IC. (Note that because of the short, the complete truth table of this IC is not being tested. For thoroughness, it must be done after the fault is found.) When IC$_1$ is checked, all nodes will be toggling, but failure indications will be obtained at pins 3 and 6. If the input rate is slowed and behavior of the pins' logic states examined, simultaneous transitions independent of input truth conditions will indicate the presence of the short. If the fault had been a stuck low condition at pin 11 of IC$_2$, then the logic-states check of IC$_2$ would have revealed the unchanging logic 0 state.



that can be connected to any pin by a rotary switch. The signals detected by an external probe can be displayed, as well.

How it works

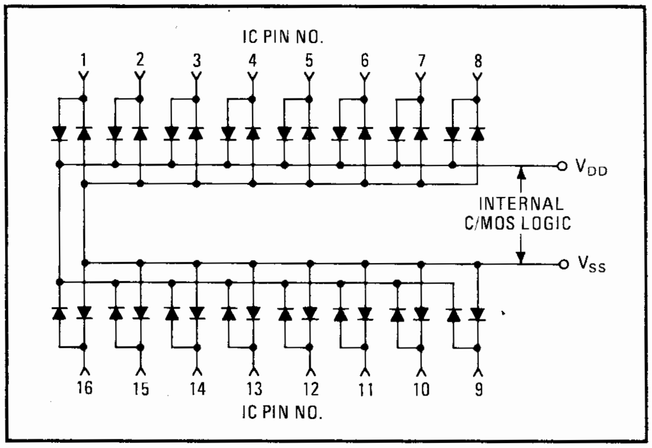
To present high-resistance, low-capacitance inputs to the device under test, the Testclip was built with complementary-MOS logic. Its circuitry will load inputs of the device being tested with a 50-kilohm pull-up resistance plus one input load of the reference device. Outputs are loaded by a 100-kilohm pull-up resistance. The C-MOS circuits draw negligible current from the board being tested.

The instrument automatically locates the most positive and most negative pins of the IC under test and draws its power from them. The circuitry that does this is illustrated in Fig. 3.

An important item to consider regarding the automatic power-locating circuitry is the minimum value of the drain supply voltage, V_{DD}, that the circuit will provide to the C-MOS circuits. This voltage must be at least 3.0 V for the device to work properly. When 5-V logic is being tested, the collector supply voltage, V_{CC}, at the IC under test can be expected to be at least 4.5 V (5 V minus 10%). As Fig. 3 shows, the automatic power-locating circuit puts two forward-biased diodes in the supply-voltage path; thus the V_{DD} supplied to the C-MOS circuitry is equal to $V_{CC} - 2V_F$, where V_F is the forward voltage drop across each diode. With a maximum V_F of 0.7 V for the diodes, V_{DD} has a worst-case value of 3.1 V, so all is well.

At first sight, C-MOS logic circuitry operating at a V_{DD} of 3.1 V might seem unsuitable for the functional testing of transistor-transistor logic operating at a V_{CC} of 4.5 V. The brief analysis that follows, however, shows that there's nothing wrong with this combination.

Two criteria must be satisfied if C-MOS comparators are to be suitable for testing TTL circuitry. First, the maximum voltage that the C-MOS comparators will recognize as a logic 0 ($V_{IL(max)}$) must be greater than or equal to the maximum voltage of a TTL output in the logic 0 state ($V_{OL(max)}$). Second, the minimum voltage that the C-MOS comparators will recognize as a logic 1 ($V_{IH(min)}$) must be less than or equal to the minimum voltage of a TTL output in the logic 1 state ($_{OH(min)}$).



3. Finding the power. Simple diode circuit performs the twofold function of automatically locating the most positive and most negative pins of the board IC and drawing power from them.

$V_{IL(max)}$ is given by 0.3 V_{DD} for a C-MOS input, and therefore, remembering that the comparators are raised above ground by the drop across one forward-biased diode:

$V_{IL(max)} = 0.3(V_{CC} - 2V_F) + V_F$.

For V_{CC} = 5.0 V and V_F = 0.7 V, this works out to $V_{IL(max)} = 0.3(5.0 - 1.4) + 0.7 = 1.78$ V. Since $V_{OL(max)}$ = 0.4 V, the first criterion is satisfied with room to spare.

Turning to the second criterion, observe that the devices used for comparator inputs are selected to have a $V_{IH(min)}$ value of 0.47 V_{DD}. Plugging in the same values of V_{CC} and V_F, as were used before yields,

$V_{IH(min)} = 0.47(V_{CC} - 2V_F + V_F$

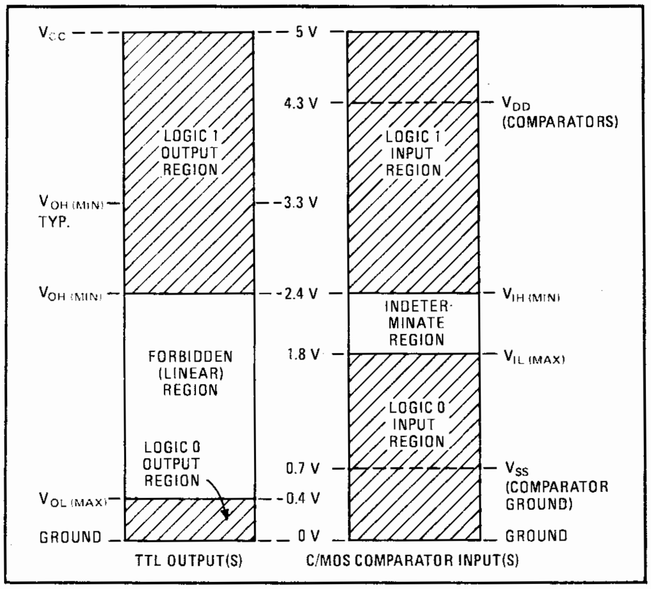
$= 0.47(5.0 - 1.4) + 0.7 = 2.392$ V.

Since $V_{OH(min)}$ is 2.4 V, the second criterion is met—just. Actually, the situation is not as critical as these numbers make it look because the 2.4-V figure is really a minimum, and a typical limit value for $V_{OH(min)}$ is usually listed as 3.2 to 3.4 V, depending upon the TTL device type.

The relationships between TTL output levels and the C-MOS comparator-input levels are presented graphically in Fig. 4. If the output of a TTL device falls into the forbidden (linear) region because of a parametric defect, this may not be detected. Such defects are rare, however, and, in the author's experience, are almost always accompanied by logic failures.

It's all done with pins

When operating as an IC comparator, the instrument must be provided with some means for distinguishing IC outputs from IC inputs. Corresponding input and power-supply pins on the reference IC and the IC under test must be connected in parallel so that both ICs receive the same excitation. Output pins, on the other hand, must be kept separate so comparators can see if the board IC behaves the way the reference IC does.



4. Compatibility. Though C-MOS comparators may operate at a V_{DD} of only 3.1 volts, their inputs are compatible with the outputs of TTL circuits operating at a V_{CC} of 4.5 volts.

What about testing C-MOS?

Can the Testclip, which uses C-MOS circuitry, also be used to test C-MOS devices in circuits? The answer is that it depends upon the individual circuit and device.

Obviously, the input characteristics of the Testclip are C-MOS-compatible. However, C-MOS output characteristics must be examined also. Unlike TTL, C-MOS logic is inherently subject to wide variations in transition time because of capacitive loading, as well as power-supply voltage. Also, as a family, current C-MOS products vary widely in transition time from one manufacturer to the next; differences as great as 4 to 1 have been measured for simple gate circuits under identical load conditions. Furthermore, since C-MOS manufacturers specify up to 50 C-MOS input loads for some devices, significant stray capacitance may exist on the printed-circuit board.

The outputs of a reference IC plugged into the Testclip drive one C-MOS input load with a 100-kilohm pull-up resistance. The outputs of the unit under test, however, may have to drive:

- One C-MOS load and 100 kilohms from the Testclip,
- An additional C-MOS input in parallel with 150 kilohms to V_{CC}, if the logic probe is dialed to that output,
- Plus up to 50 C-MOS input loads and an unknown amount of capacitance on the pc board.

This means there will be significant variations in transition time between the unit under test and the reference IC, which will be seen as noncomparable outputs by the comparison circuits in the Testclip.

Now, even with TTL circuits, some variation in transition time is to be expected, and the Testclip incorporates failure-blanking to ignore errors that persist for only a short time. For typical C-MOS circuits tested to date 200-nanosecond failure-blanking has proven adequate over power-supply levels from 5 V to 10 V. Thus, failure-blanking allows the Testclip to detect logic errors in TTL circuits operating up to a 2.5-MHz square-wave frequency, while compensating for typical C-MOS timing variations.

Sufficient failure-blanking is provided for the faster transition times of the most recent C-MOS devices. As C-MOS manufacturers continue to improve transition times and approach a common standard, C-MOS testing will become universally practical.

In earlier comparators, this identification of input and output pins has been done by means of a small, programing printed-circuit card for each IC. A special tool is used to break those board wires that would have resulted in shorted output pins. The Testclip uses a replaceable-pin IC socket in which the reference IC is mounted. The standard pins in the socket are long enough to short together the corresponding pins on the reference IC and the IC under test. To program the socket, the pins carrying IC outputs are replaced with short pins, which automatically break the connections with the unit under test and allow the Testclip to compare the output behavior of the board IC and the reference device.

When used as a logic probe, the Testclip has a pulse-stretching feature that can capture and display pulses as short as 100 nanoseconds. In this mode, the operator can observe the states of the various IC pins, one at a time, by dialing them up with the rotary switch on the body of the instrument and observing the logic-state LEDS.

When the reference IC is omitted, the instrument becomes a logic clip, indicating the logic states of each pin. However, in this mode, as with most logic clips, its principal use is for checking quasi-static states because the pulse-stretching feature does not operate on any pin except the one dialed up by the rotary switch. Nevertheless, an operator can use this mode to check out a counter or note the action of a gate. (A pulser can be used with the clip in this mode).

Toggling rates of greater than 1 megahertz cause continuous blinking at approximately five blinks per second; consequently single events can be observed and stuck pins distinguished from toggling pins. The plug-in probe extender enables the operator to examine the toggling behavior of any nearby pin while observing the failure indications on the board IC. Failure coincidence with another board event can thus be noted.

A failure is a noncorrespondence in logic states between corresponding output pins and is sensed any time it occurs. Failure-sensing is asynchronous. Once a fault is sensed, it is latched for 0.1 second so the human eye can detect it, and then it is automatically reset. If another failure occurs during the latch period, it extends the time of reset 0.1 seconds longer. Thus, a stuck fault will cause a continuous failure display, but a single fault is reset, opening the comparator to catch the next one.

The single test procedure

Improved diagnostic tools are all well and good, but to realize their full potential, they should be combined with improved troubleshooting procedures. One such new procedure, called Faultrack, is based on the fact that logic faults will leave a track of abnormal logic states in the system in which they occur (see "Faultrack finds fault with both boards ICs," p. 91). These improper states can be detected and traced back to their causes.

For this procedure to be valid, two conditions must be met: the logic board must be operating (on an extender in its normal unit or in a logic exerciser/tester), and all sequential logic must be either initialized automatically or of such a nature that initialization can be forced. The procedure itself is based upon the checking of two criteria: (1) are all the actively used nodes toggling? and (2) do the ICs behave the same as known-good ICs under the same inputs? If the answers are yes, the confidence level is extremely high that the ICs and the board are free of defects. If the answer is no, the fault can be tracked to a node where one of three causes will be found: a solder or trace defect, a defective IC driving the node, or a defective IC being driven by the node.

The Faultrack procedure applies to both simple and more complex circuits. In particular, it combines the ability to track stuck nodes with the ability to confirm the operating integrity of an IC and the board, even within logic feedback or in the presence of multiple faults. Technicians find the ability to confirm stage integrity quite valuable in zeroing in on faulty nodes. □

A LOW-COST 16-LED LOGIC MONITOR

BY TOM KRONENWETTER

Checks all signals on an IC simultaneously

USING single-LED logic probes is the most common way to check the logic operation of a digital IC. This is fine as long as all you want to know is whether a particular pin is high or low or is switching between these two states. But most logic circuits require that correct *timing* be maintained between a number of signals from the same IC. This is something that a single-LED probe cannot test.

The logic monitor described in this article allows *all* of the pins of an IC to be examined simultaneously, which means that timing can be observed. The monitor reads out via 16 LEDs, each connected via a high-input resistance driver to a pin of the IC. Interconnection between the monitor and the IC is through a length of ribbon cable terminated to a clip that clamps on to the IC.

The project can be constructed for 8-, 14- or 16-pin DIP packages. If desired, it can be expanded to handle 40-pin devices. The monitor is powered from the circuit under test. Operating characteristics are given in Table I.

Basic Circuit. As shown in Fig. 1, the basic circuit consists of a relatively high-input resistance (100,000 ohms) Darlington transistor driving a LED. Resistor *R2* ensures that when the input is logic 0 (low), the transistor will be cut off and the LED will remain dark. This circuit is duplicated for each required pin connection. Current-limiting resistor *R3* is common to all LEDs.

Construction. In constructing the logic monitor, a solderless breadboard (see photo) is used. In this breadboard, the five holes across each row are interconnected inside the plastic housing.

Start assembly in one corner of board. Skip two holes and install a LED in third and fourth holes with the LED cathode in hole 4 as shown in Fig. 2. Install the transistor in the second column with the collector lead in the same row as the LED cathode, the base lead in the fifth row hole and the emitter lead in the sixth row hole. The cathode of the LED is thus connected to the transistor collector internally.

Cut one lead of a pair of 100,000-ohm resistors to 0.7″ and the other lead to 0.3″. Each of these resistors will be mounted vertically. Insert the short lead of *R2* into the second hole past the LED, then bend the longer lead over and insert it into the hole adjacent to the LED. Thus *R2* is connected between the base and emitter of *Q1*. Insert the long lead of the remaining resistor into the hole above the base of *Q1* so that it connects to the base of *Q1*. The short upper lead of this resistor will be connected to the cable later on.

If you are making a 16-pin arrangement, follow the above assembly procedure seven more times to produce eight LEDs on one side. If you are making a 14-pin array, then only seven LEDs are needed.

To complete the assembly, start the component installation at the diagonally opposite corner (no hole spaces), and work up the other side. Resistor *R3* is installed in a hole near the last LED.

Cut 32 one-inch long jumpers from #22-gauge solid insulated wire and strip 0.3″ of insulation from each end. Sixteen of these jumpers are used to interconnect the 16 ground points to form a common bus. The remaining jumpers are used to couple the anodes of all the LEDs into a common bus. This bus is then connected is to *R3*.

At this time, each LED must be identified as to pin number. Make up some small stick-on labels, each identified in numerical sequence from 1 to 16, and affix one to the top of each transistor. The sequence should be 1 through 8 from top to bottom on the left side, and 9 through 16 from bottom to top on the right side.

The final step is wiring the 1.5-foot ribbon cable from the clamp-on connector to the breadboard. Lay the connector down with its color-coded side facing up. Using Fig. 3 as a guide, from the tip of the brown conductor at one edge of the cable, measure a diagonal 3-inches long to the blue conductor on the opposite side of the cable. Use masking tape to mark this diagonal. Cut the ribbon cable with scissors along the upper edge of the masking tape. Separate the leads to a length of about one-inch, then strip about 0.2″ of insulation from each lead. Tin each lead and form into small closed loops so that they will fit over the ends of the leads at the top of each *R1*.

Place the prepared end of the cable in the center of the breadboard, rainbow side up. Connect the second shortest lead (green) to the short lead of the *R1* for the first LED. This corresponds to pin 1 of the connector. The shortest lead (blue) is connected to the *R1* associated with the sixteenth LED. Using the cable color-code chart shown in Table II, connect the remainder of the ribbon-cable leads to their respective *R1*'s.

When all the connections are completed, fold the ribbon cable over on itself, slightly above the breadboard,

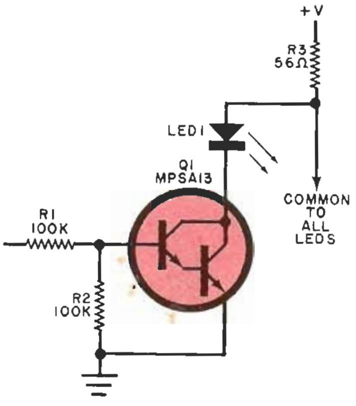


Fig. 1. Basic circuit consists of a Darlington transistor driving a LED.

TABLE I— OPERATING CHARACTERISTICS

Input impedance:	100,000 ohms
Logic threshold:	2.2 volts dc
Operating voltage range:	4 to 15 volts dc
Maximum current drain:	200 mA

TABLE II— CABLE COLOR CODE

Pin	Color
1	Green
2	Orange
3	Brown
4	White
5	Purple
6	Green
7	Orange
8	Brown
9	Red
10	Yellow
11	Blue
12	Gray
13	Black
14	Red
15	Yellow
16	Blue

PARTS LIST

LED1—Red LED (FLV-117 or similar, 16 required)
Q1—MPSA13 Darlington transistor (16 required)
R1,R2—100,000-ohm, ¼-watt resistor (32 required)
R3—56-ohm, ¼-watt resistor
Misc.—Solderless breadboard (AP Products Model 234), 16-pin clamp-on logic clip with cable (AP Products Model LC 160), small tie wrap, #22 AWG wire, labels.

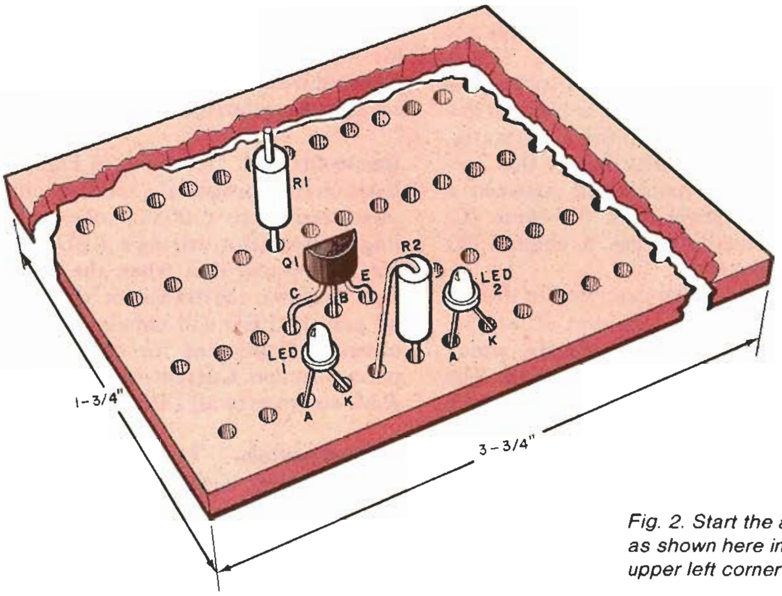


Fig. 2. Start the assembly as shown here in the upper left corner of board.

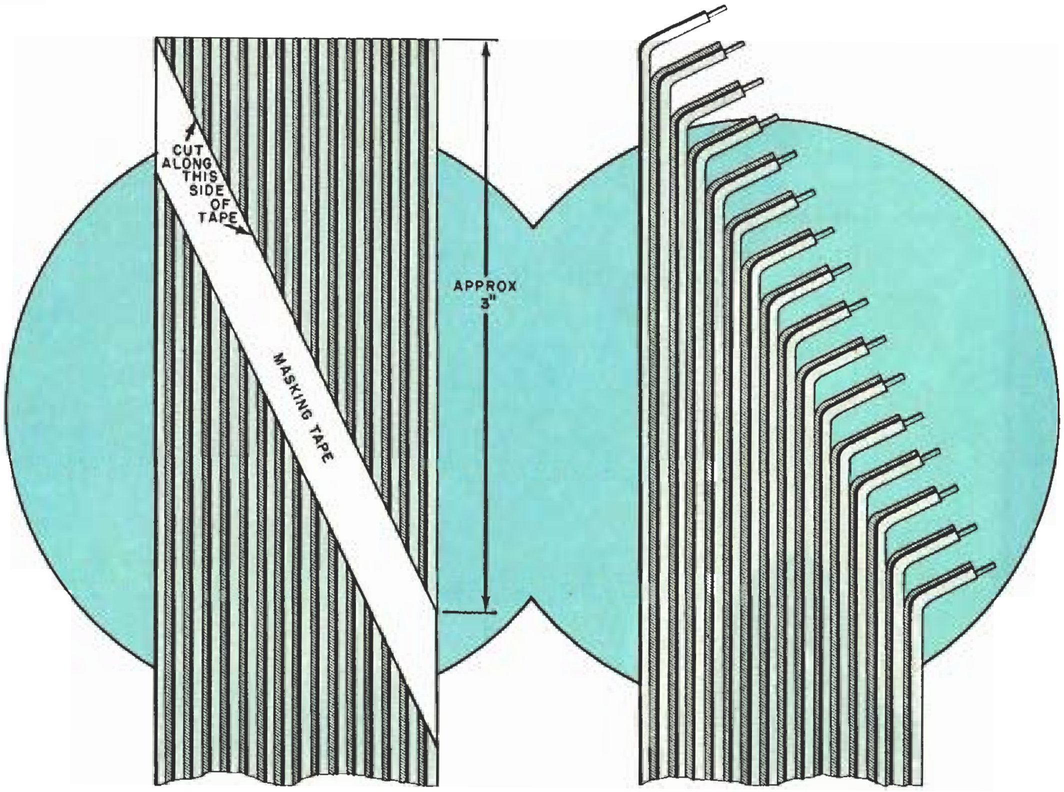


Fig. 3. The 16-lead ribbon cable is prepared as shown here with the leads cut diagonally so that they can be connected easily to circuits on the board.

and use a tie wrap to act as a strain relief for the cable.

Most 16-pin DIP packages use pin 16 as the dc source and pin 8 as ground. If you want to follow this convention, jumper input 16 (blue) to the common LED bus, and input 8 (brown) to the common ground bus. This means that the sixteenth LED will always glow and the eighth LED always remain dark.

Some digital IC's, the 7490 as an example, use pin 5 as the dc input and pin 10 as the ground. In this case, the circuit shown in Fig. 4A may be used. Here, two silicon diodes are used to pick off the dc voltage from either the pin-16 or pin-5 inputs for application to the common dc bus. A separate ground lead can be connected between the monitor common-ground bus and the ground of the circuit under test. It is also possible to keep each input isolated from either dc or ground, and use a separate lead connected between the monitor dc bus and the 5 volts of the circuit under test as shown in Fig. 4B. In this latter case, all the LEDs will be active. The human eye can distinguish flashing of the LEDs at rates up to about 15 Hz. Above that frequency the LEDs will appear to be constantly "on." ◇

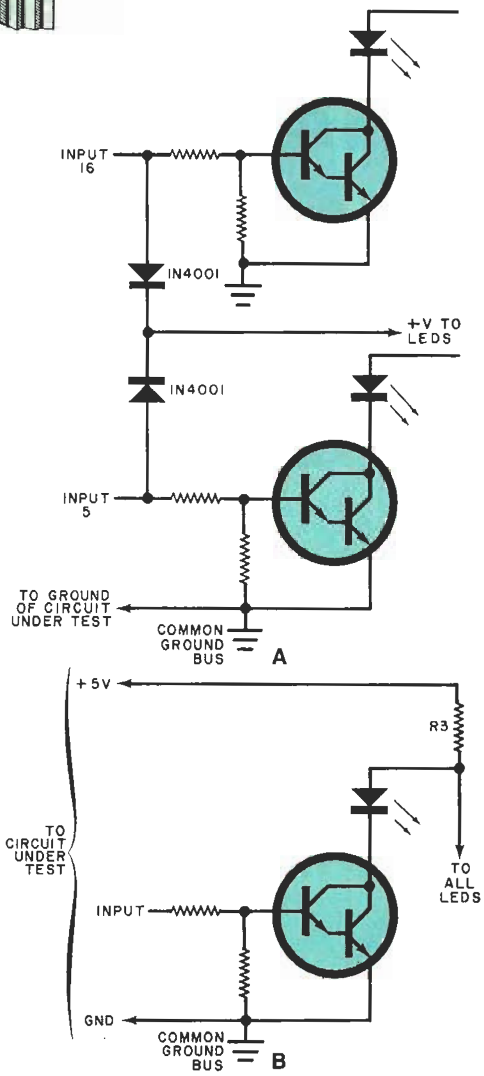


Fig. 4. If pin 5 of the IC to be tested is the dc input and pin 10 is ground, use the circuit at (A). To keep each input isolated from dc or ground, use the connections at (B).

Popular Electronics®
NOVEMBER 1978

A Basic Guide to Digital Logic Probes, Clips & Pulsers

BY CLAYTON HALLMARK

How to use low-cost digital test equipment

Hewlett-Packard Model 548A Logic Clip and 546A Logic Pulser.

TROUBLESHOOTING digital logic circuits can often be simplified by the use of low-cost testers especially designed for this purpose. These include logic probes, clips and pulsers. Every modern-day electronics experimenter, designer and service technician should know how to work with these important digital testers, as well as have an understanding of the sundry attributes.

Homebrew Testers. The most commonly used logic testers are the probe and pulser. Very basic versions of these, suitable for building in a test lead, ball-point pen, or spark-plug tester, are shown in Fig. 1.

The logic probe (Fig. 1A) is a state checker. It tells whether an input or output pin of an IC is "high" (logic 1) or "low" (logic 0). The clip lead attaches to the positive supply. The LED comes on when the probe is touched to a point at ground potential (low or logic 0) but remains off for a high state. You could also use a voltmeter, bearing in mind that for TTL, high is greater than 2.4 volts and low is less than 0.8 volt; but it is simpler to use a logic probe. It is also safer because it lets you keep your eye on the IC you are probing to avoid shorting adjacent pins and possibly damaging the IC.

It is generally convenient to trigger a logic circuit manually during troubleshooting, using a logic pulser. To use the one shown in Fig. 1B, clip one end of the capacitor to ground and touch the other end (prod) to the positive bus to charge the capacitor to the bus voltage. Then touch the prod to the input of a gate to be tested; the capacitor will discharge, creating a positive pulse. Now monitor the output of the gate with a logic probe.

The homebrew instruments just described are very crude, of course, but they do illustrate some fundamentals of the commercial instruments. For example, the simple LED state checker gives an unambiguous reading for only one state. The probe's LED lights for the low

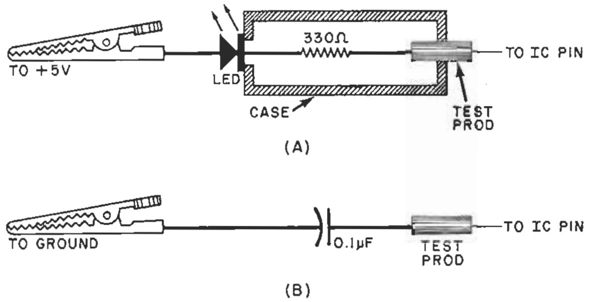


Fig. 1. How to construct your own logic probe (A) and pulser (B).

state and remains off for the high state. Unfortunately, it also remains off in the case of an open in the circuit or IC. A good commercial logic probe, in contrast, gives a positive indication of a low state or high state, as well as detecting bad levels (between high and low), single pulses, and pulse trains.

Logic Probes. A logic probe is much simpler to set up and use than a scope or meter. One simply connects the probe's clip leads to the power supply of the circuit being tested, touches the probe to the circuit point to be tested, and looks for an indication on the probe.

There are a host of different logic probe designs available. Continental Specialties and Kurz-Kasch probes have three indicators (LEDs for CSC and red, white, and blue lamps for Kurz-Kasch) to indicate highs, lows and pulses. AVR probes have two LEDs that indicate highs and lows and flash for pulses. Hewlett-Packard probes have a band of light all around the tip for omnidirectional viewing. The light is at full brilliance for highs, half brilliance for opens or poor levels, and off for lows. Production Devices probes indicate highs and lows with high- and low-frequency audio tones, and a new audio-visual model has LEDs as well.

When the power leads of a logic probe are connected to a circuit's power supply, circuitry inside the probe automatically programs the logic thresholds. For the TTL family, the circuitry sets logic thresholds at about 16% of the supply voltage for lows, and 48% for highs. Hence, a low indication occurs for potentials less than 0.8 volt, and a high indication occurs for potentials greater than 2.4 volts. There's a "no-man's" land between the thresholds (Fig. 2) where the absence of a light or tone indicates an open circuit or bad level.

Figure 2 shows how the HIGH and LOW LEDs indicate negative pulses from a high level or positive pulses from a low level. A probe can also indicate the duty cycle of pulses in a train (percent of time the logic level is high), since this determines the amount of time the LEDs are on (and thus their relative brightness).

Probes sometimes have a PULSE indicator. For continuous trains of pulses within the frequency limits of the probe, the PULSE LED blinks at a steady rate, typically of 3 or 10 Hz. For displaying short single-shot pulses, probes usually have a pulse-stretcher circuit that detects pulses of 200, 50, or even 5 ns, turning the PULSE LED on long enough to make a visible flash.

Probes sometimes even give a rough idea of pulse frequency. For square-wave pulses of 50% duty cycle, the CSC probe, for example, flashes its PULSE LED and turns on both HI and LO state LEDs if the frequency is below 100 kHz, or neither state LED if the frequency is above 100 kHz.

The ability of some probes to detect pulses as short as 5 ns and to handle frequencies of 50 or 100 MHz shames some very expensive oscilloscopes.

Buyer's Guide. In evaluating a probe, consider these capabilities:

Single Pulse. Look for an ability to catch short, intermittent single pulses and detect "glitches" (noise transients). The minimum detectable pulse width of probes varies widely. Some are capable of detecting pulses as narrow as 5 or 10 ns, something that is difficult to do with even a high-performance scope.

Memory. Some probes have a switch-selectable memory mode in which the leading edge of a pulse latches a flip-flop on to keep the PULSE LED lighted. This means you do not miss a short pulse because you blinked or turned your head when the LED flashed. It also means you can clip the probe in place and wait as long as necessary to trap a troublesome glitch. Or you can hang the probe on a backplane, make a change to the circuit under test, and come back to see if anything has happened. Best of all, a probe with memory costs a fraction as much as a memory scope.

Input Impedance. The input impedance of a probe must be high enough not to affect your measurements. For example, a low resistance into a Schottky gate will overload a low-power output in the low state.

Overload Protection. Most probes have input-overload protection that prevents damage even if the probe is plugged into a wall socket for 15 to 30 seconds.

Bad Levels. A probe should be able to detect bad levels between logic high and low. Ideally, it should be able to distinguish between highs, bad levels, and high impedance in three-state logic.

Multifamily Use. Some probes are compatible only with TTL and DTL. Others are compatible with TTL/DTL at one switch setting, and with CMOS and high-threshold families at another setting. Interestingly, the AVR probe requires no switch setting to go from one logic family to another.

When a logic probe is connected to the power supply of a circuit to be tested, circuitry inside the probe automatically sets the thresholds for high and low according to the supply voltage. For TTL, the thresholds for high and low are typically 48% and 16%, respectively, of the supply voltage. For other families they are typically 70% and 30%, although they may be 60% to 70% and 15% to 30%. Figure 3 shows how to connect a probe for various families. Always connect the positive (red) clip to the more positive power-supply terminal and the negative (black) clip to the more negative terminal.

(Continued on page 61)

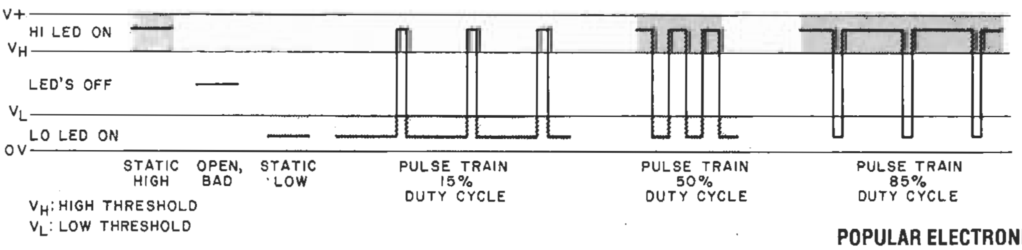


Fig. 2. Illustration shows the three light-indication possibilities of a logic probe under given circuit conditions.

(Continued from page 54)

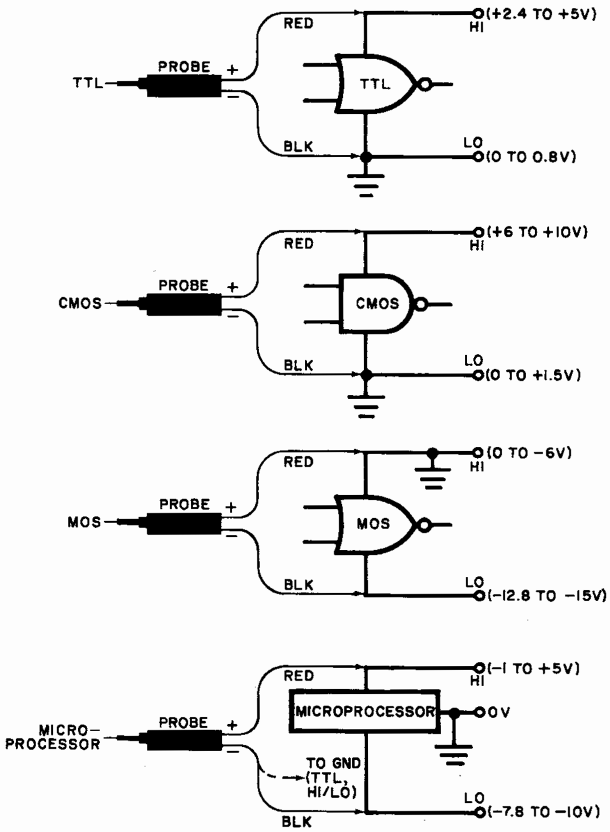


Fig. 3. Probe connections and tester thresholds for various logic families.

Sometimes the thresholds based on the supply voltage of the circuit under test may not be the ones needed. You can redefine the thresholds by connecting the probe's power clips to another power supply whose 70% and 30% points correspond to the desired thresholds, connecting the grounds of the two supplies together.

Logic Clip. A logic clip is another easy-to-use digital tester. Unlike the logic probe, it checks a number of points simultaneously. You just clamp it over an IC DIP package and two rows of LEDs instantly indicate the logic states of all pins. There are no controls to set—not even any power leads to connect. The clip's circuitry automatically locates the positive and ground supply pins, whichever way you connect the clip. You cannot connect it incorrectly. In contrast to these advantages, clips do have some relative shortcomings, as follows.

Logic clips cannot test many circuits that probes can, though they can give indications faster with static or slow-changing signal conditions (one simply can't monitor many fast-changing LEDs at the same time). Some clips are limited to 7 volts, while others can be used with ICs that have up to 15 or 18 volts between any two pins without suffering damage. Clips operate with positive-voltage logic families (TTL, RTL, DTL, CMOS, etc.), which means that they will not work with some MOS ICs and ICs with three supplies (such as −12 volts, ground, and +5 volts).

A logic clip has a single threshold, for logic high. It does not have a low threshold and, therefore, cannot indicate a bad

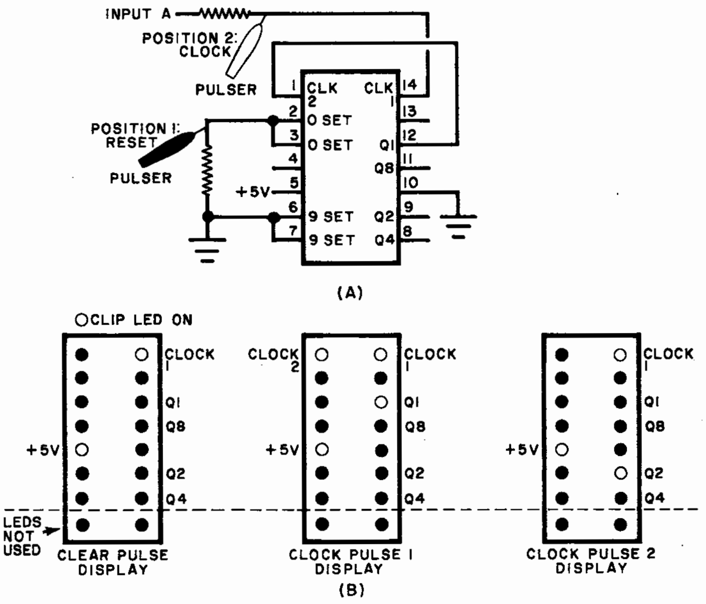
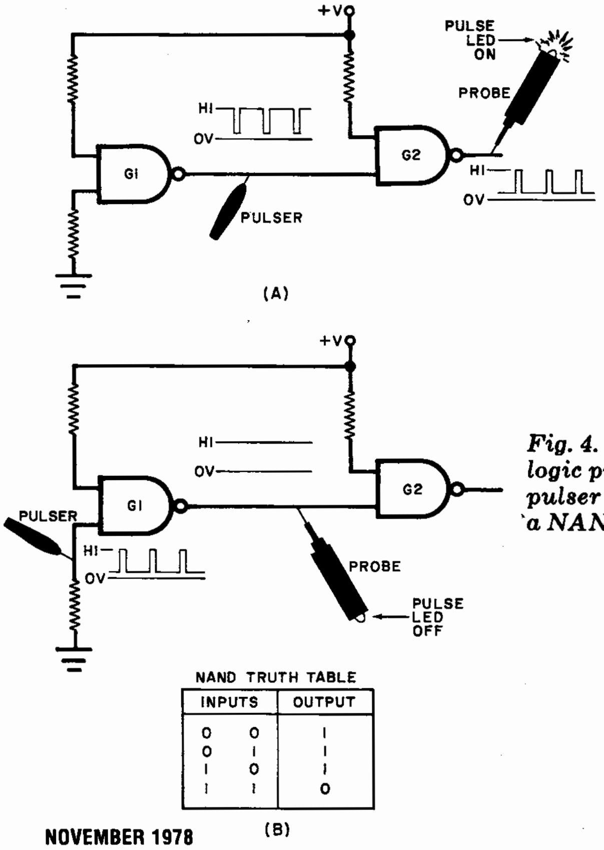


Fig. 5. Checking a 7490 decade counter with a logic clip and pulser. (A) Shows IC pins and pulser signal injection points. (B) Illustrates clip's expected display.



NAND TRUTH TABLE

INPUTS		OUTPUT
0	0	1
0	1	1
1	0	1
1	1	0

Fig. 4. Using a logic probe and a pulser to test a NAND gate.

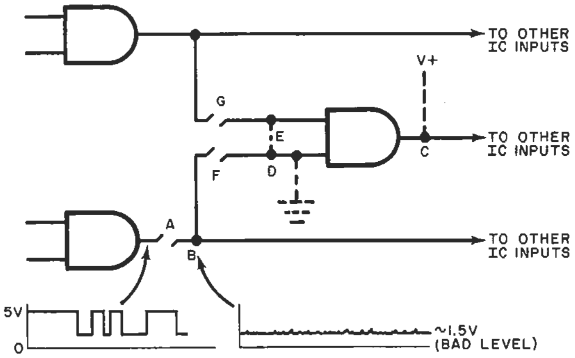


Fig. 6. Five steps to follow in isolating the most common faults in digital logic circuits.

level. The latter shows up as a high state on a clip. A clip also lacks pulse-stretching circuitry, so it cannot indicate narrow single-shot pulses. For viewing these or high-frequency pulses, you *will* need a probe.

Depending on the supply voltage and how many LEDs are on, a logic clip may draw 100 or 200 mA. This can tax some power supplies, especially if the clip is left in continuous operation.

The logic-high threshold of most clips is about 1.5 to 2 volts, which is compatible with TTL and DTL. In comparison, the costlier H-P Model 548A, has a threshold that is 34% to 46% of the supply voltage, and is also compatible with CMOS and other positive-voltage logic families.

A logic clip is usually used with a pulser to check sequential-logic ICs such as flip-flops, latches, counters, shift registers, and adders. A clip is sometimes useful for testing gates, too. For example, if the clip shows that the output pin of a 4-input NAND gate is constantly low and that the NAND gate's inputs are not all high, then as a look at a NAND truth table will reveal, the output must be shorted to ground.

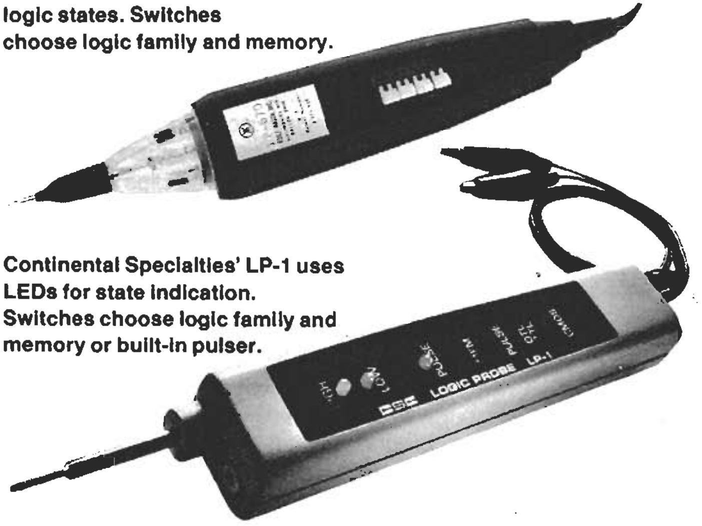
Logic Pulser. A commercial logic pulser is much more than a capacitor in a probe, as in our earlier home brew example. It is (or should be) a high-quality pulse generator with the versatility of a laboratory pulse generator minus the complicated controls. Just clip the pulser's leads to the power supply of the circuit under test, touch the pulser to the point to be stimulated, and press the PULSE button. All circuits connected to that point, outputs as well as inputs, are briefly driven to their opposite state. There is no need to unsolder any pins. Whether the test point is high or low, the pulser drives it to the opposite state each time you press the button. Holding down the button produces a series of pulses. The pulses should be bounceless, safe for the circuit under test, capable of overriding the state of any normal (unshorted) circuit node, and tailored to the logic family being tested.

Usually, the pulser is teamed with a probe for testing logic gates, and either a probe or clip for testing sequential circuits such as flip-flops and counters. To test a gate, the pulser drives the input while a probe monitors its transmitted pulses at the output. (A probe is required because a clip cannot monitor the pulser's narrow output pulses.)

Assume that the output of NAND gate *G1* in Fig. 4A is being held high, causing the output of *G2* to be low (refer to the NAND truth table). When its button is held down, the pulser overrides the high output state of *G1* and places a train of pulses on the input of *G2*. Accordingly, a train of narrow logic-high pulses appears at the output of *G2*. The PULSE LED of the probe flashes, indicating pulse activity and the LOW LED glows continuously to indicate a low that is going high. Although the output of *G2* is stuck at a low level, the gate is not defective since it does indeed transmit pulses from the pulser.

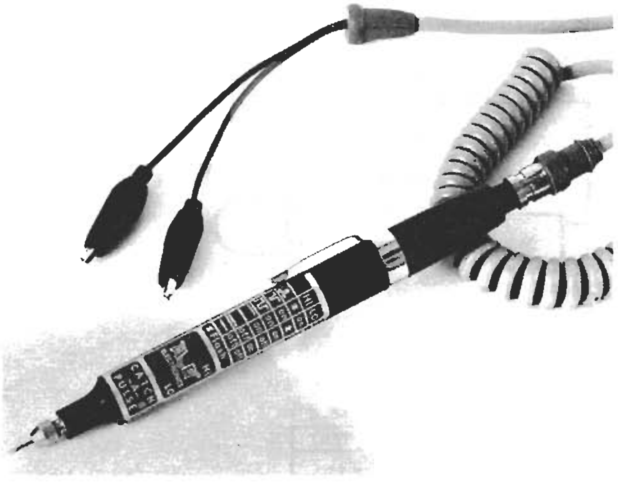
Next, assume that the probe and pulser are moved to the positions shown in Fig. 4B. The pulser now applies a series of high pulses to the input of *G1*. Note that the pulser automatically supplies pulses of the proper polarity with no intervention by the operator. If the PULSE LED of the probe does not respond, gate *G1* is defective and is the likely source of the stuck level at the output of *G2*.

Assume now that a 7490 decade counter sequential circuit is to be checked with a logic clip and pulser (Fig. 5). First, attach the 16-pin clip to the 14-pin IC (Fig. 5A) (the top or bottom two LEDs are not connected). Touch the pulser to the reset input and press the PULSE button once to inject a zero pulse into the IC and zero the outputs (Q1, Q2,



The Kurz-Kasch Model 670 probe has red, white, and blue lamps to indicate logic states. Switches choose logic family and memory.

Continental Specialties' LP-1 uses LEDs for state indication. Switches choose logic family and memory or built-in pulser.



In AVR's "Catch -A-Pulse," two LEDs indicate high and low states and flash for pulses.

Q4, Q8). The display should be as shown at the left in Fig. 5B. Next, move the pulser to the clock input and single-step the counter through its decade cycle (0 to 9 decimal, 0000 to 1001 binary). After the first clock pulse, the LED for *Q1* lights, indicating a count of 1. After the second clock pulse, the LED for *Q2* lights and the LED for *Q1* goes out, indicating a count of 2. Continuing this way, you can check the counter over its entire cycle of operation.

A probe is often all you need for testing sequential ICs. The circuit in which the IC is used can provide the pulses. For example, if there is a clock signal on a decade counter and the enabling inputs (usually reset lines) are enabled, the output should be counting. You can check this by monitoring the clock and enable inputs with a probe. If the probe indicates pulse activity on the outputs, you can assume that the IC is operating okay. When ICs fail, they usually do so completely and produce a circuit node stuck at a high, low, or bad level. Usually, it is not necessary to observe the timing relationships of the signals in a circuit under test, which would require an oscilloscope. An indication of pulse activity by a logic probe is normally sufficient evidence of proper operation.

Checking Logic Circuits. The most common defects found in digital circuits are shown in Fig. 6. The following five steps, performed in the sequence shown, will isolate the trouble quickly.

1. Narrow down the area of possible trouble by testing for bad nodes with a probe. A node is simply a circuit junction point common to two or more gates or other elements. A bad node may be stuck at logic high or low or somewhere in between. Service literature for the equipment under test, or a knowledge of the equipment, will usually suggest points to monitor with a probe.

2. Check for an open bond in the IC driving the failed node. An open output at A in Fig. 6 would cause the node at B to float to a bad level of 1.4 to 1.5 volts. Inputs connected to B would interpret this as a high level, but a logic probe would not be fooled! It would indicate a bad level. The IC driving the node should be replaced.

3. If the node is not at a bad level, then test for a short to V+ (point C) or ground (D). Inject a pulse at the suspect node while monitoring the same node with a probe. The pulser is powerful enough to override even a low-impedance TTL output, but it is not sufficiently powerful to cause a change of state on the V+ or ground bus. Therefore, the absence of a pulse indicates that the node is shorted to V+ if it is high or to ground if it is low.

In case of a short, examine the circuit board for solder bridges, shorted-together pins, etc. If this does not isolate the short, then it is equally likely to be an internal short in any of the ICs attached to the node. Try replacing the IC driving the node and then each of the other ICs until the problem disappears. (Sometimes there may be a shorted capacitor or resistor attached to the node.)

4. Check for a short between two nodes (E in Fig. 6). Pulse one failing node and observe each of the other failing nodes with a logic probe. If there is a short between the pulsed and probed nodes, the probe will detect the pulse. To verify the short, transpose the probe and pulser and check again. As a further check, you can remove the circuit board from the system and investigate the short with an ohmmeter. The most common short between nodes is a circuit-board short caused by a solder bridge, loose wire, or other visible defect. Only if the two shorted nodes are common to one IC can the failure be inside the IC. If the short is not visible, replace the IC.

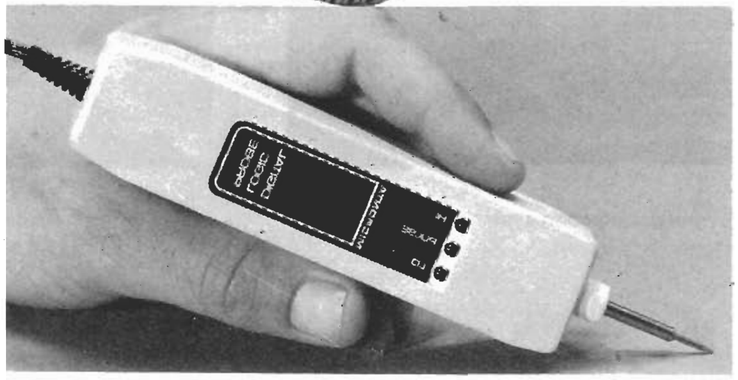
5. If you still have not isolated the problem, check for an open input bond (F in Fig. 6), a failure of the internal steering circuitry of the IC, or an open in the circuit outside the IC (G in Fig. 6).

With an open input bond (F), a signal appears at the input pin of the gate, but the gate responds as if a static high were applied. A failure of the steering circuitry will cause the output of an IC to be stuck high or low. In the case of a circuit open, inputs attached to the left side of the break will be driven normally, while inputs to the right will float to a bad level that looks like a static high.

In Conclusion. Logic probes, clips, and pulsers provide a digital answer to digital problems. Many of them cost less than you would pay for a multimeter. There are times, however (especially in complex computer circuitry), when a logic comparator is desirable because it can check out a host of logic levels simultaneously under dynamic conditions. But comparators are costly and require a large inventory of good ICs. ◇

Production Devices' Model 95 indicates highs and lows with audio tones.

CSC's 16-LED Logic Monitor clip displays states of all IC pins at once.



Micronta three-LED Digital Logic Probe