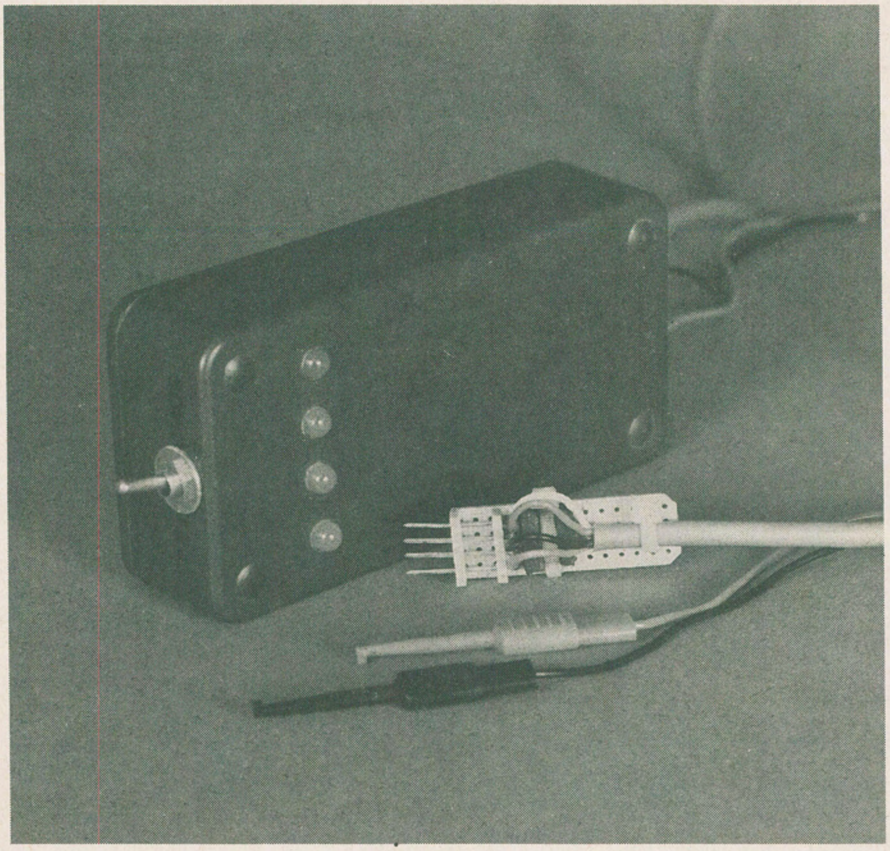


Build the ×4 Logic Probe

Our hand-held four-channel probe can indicate whether each of four test points is high, low, toggling, or open!

BY MARC SPIWAK AND JOHN YACONO

Let's face it: the more test instruments you have on your workbench, the quicker (in general) each job will get done. You may not need every instrument for every job, but you'll always find yourself in need of that one thing you don't have. And, while special-purpose instruments are often the only thing that can be used for a particular job, general-purpose instruments can come in handy for a wide variety of tasks. That's why we've developed the *×4 Logic Probe*, a 4-channel logic indicator.

The ×4 Logic Probe is built around four dual-color LED's, each of which can indicate one of four conditions: high, low, pulsing, or high impedance (or unconnected). The way in which they do that is simple. To begin with, each LED case actually contains two LED's: a red one and a green one. They are biased opposite each other, so the LED appears green when current flows in one direction, and red in the other. And the unusual thing is that when you apply an AC signal or square wave, an orange-like color is generated...to be somewhat more accurate, it looks like a half-ripe tomato. The amount of red or green depends on the duty cycle of the signal.

So there we have our four conditions. A ripe tomato (red) can be a high, a green one can be a low, a half-ripe (orange-like) indicates a changing signal, and, of course, an unlit one indicates no connection. The only difference between the prototype and the version presented here is that in the prototype red was used to indicate a low (and green for a high). That's because the original plans for the unit involved monitoring certain points in a circuit for a low, and red is easier to see. But you can set up yours however you like.

Another detail on the prototype are the four probe tips, which are designed to monitor four IC pins at once. We'll discuss the details concerning the probe tips in a little while, but keep in mind that you can use whatever you like, such as micro clips, alligator clips, a DIP clip, bare wires, etc. Also remember that, while the prototype contains four LED's, the circuit is easily expandable so you can build a unit with as many as you like.

TTL vs. CMOS. Before we discuss the design of the circuit, a little exploration into TTL and CMOS logic levels is in order. It'll help explain how the ×4 Logic Probe deals with both types of devices.

As you may know, TTL chips typically operate with 5-volt supplies, and their logic-level voltages are rigidly defined (0 to 0.8 volts is a low and 2 to 5 volts is a high). CMOS circuits, on the other hand, can be run at various voltages, so their logic levels are determined by percentages of the supply voltage (0 to 30% is a low and 70 to 100% is a high).

When we set out to design the probe we wanted it to be able to test both families of logic (and "tri-state CMOS," which we'll discuss later), as well as voltages not associated with IC's. To test CMOS circuits, the probe would have to be connected to the power supply for the D.U.T (device under test) so it can determine what voltages are valid highs and lows; as you'll see, it does that with a voltage-divider network that provides voltages at 30 and 70%. That being true, the probe might as well be powered from the supply for the D.U.T., and as long as the probe contains all CMOS chips (as it must to test CMOS devices) that's fine.

However, a problem arises when we want to test TTL logic. The probe's CMOS gates will operate fine at the 5 volts from the D.U.T.'s power supply but, if they were set up only for CMOS, they would assume that valid lows range from 0 to 1.5 volts (30% of 5 volts) and valid highs

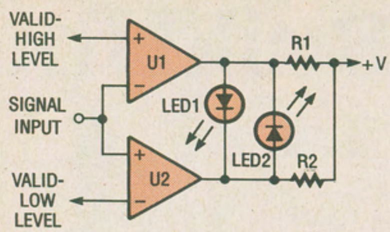


Fig. 1. The ×4 Logic Probe is based on this strangely symmetric circuit. In the actual circuit, LED1 and LED2 are replaced by a single dual-color LED.

run from 3.5 (70% of 5 volts) to 5 volts. If the probe was allowed to operate that way, a lazy pin on a chip—one not going low enough—might not be detected. Also, acceptable logic highs between 2 and 3.5 volts could not be detected, leading you to suspect that a good chip is bad.

One obvious, but very inelegant, solution is to reduce the 5-volt supply to a value such that 2 volts is a high (70%) and 0.8 is a low (30%). That can actually be done by operating the probe at 3 volts, but its ground must be 0.1 volts lower than that of the D.U.T. To produce such an offset would require the use of a negative or switching power supply, programmable regulators, a two-pole three-throw switch, and a menagerie of support components. As you'll see, our design went a different route.

Under the Hood. The best way to go was to use gates that could be "programmed" to go high or low at specific voltage levels. A voltage comparator is the perfect gate for such operation. For the less familiar, a comparator output is high when its non-inverting input is at a higher potential than its inverting input. It's low when the reverse is true.

Take a look at the circuit in Fig. 1. The non-inverting input (+) of U1 is tied to the lowest acceptable voltage representing a high. The inverting input (−) of U2 is tied to the highest voltage that can represent a low. Their remaining inputs are tied together to receive the input logic. If the input level is higher than the voltage at the non-inverting input of U1, U1's output goes low; remember, if the inverting input is higher than the non-inverting input, a comparator's output goes low.

Simultaneously, U2's output is idle at a high output. That means current will flow through R2 and light LED2, which is now forward biased. If the input signal is lower than the voltage at the inverting input of U2, U2 goes low and U1 is high. That lights LED1. If the voltage at the input is in the intermediate range (which can be achieved with a little extra circuitry that overcomes the internal biasing of the comparators) both LED's will be off.

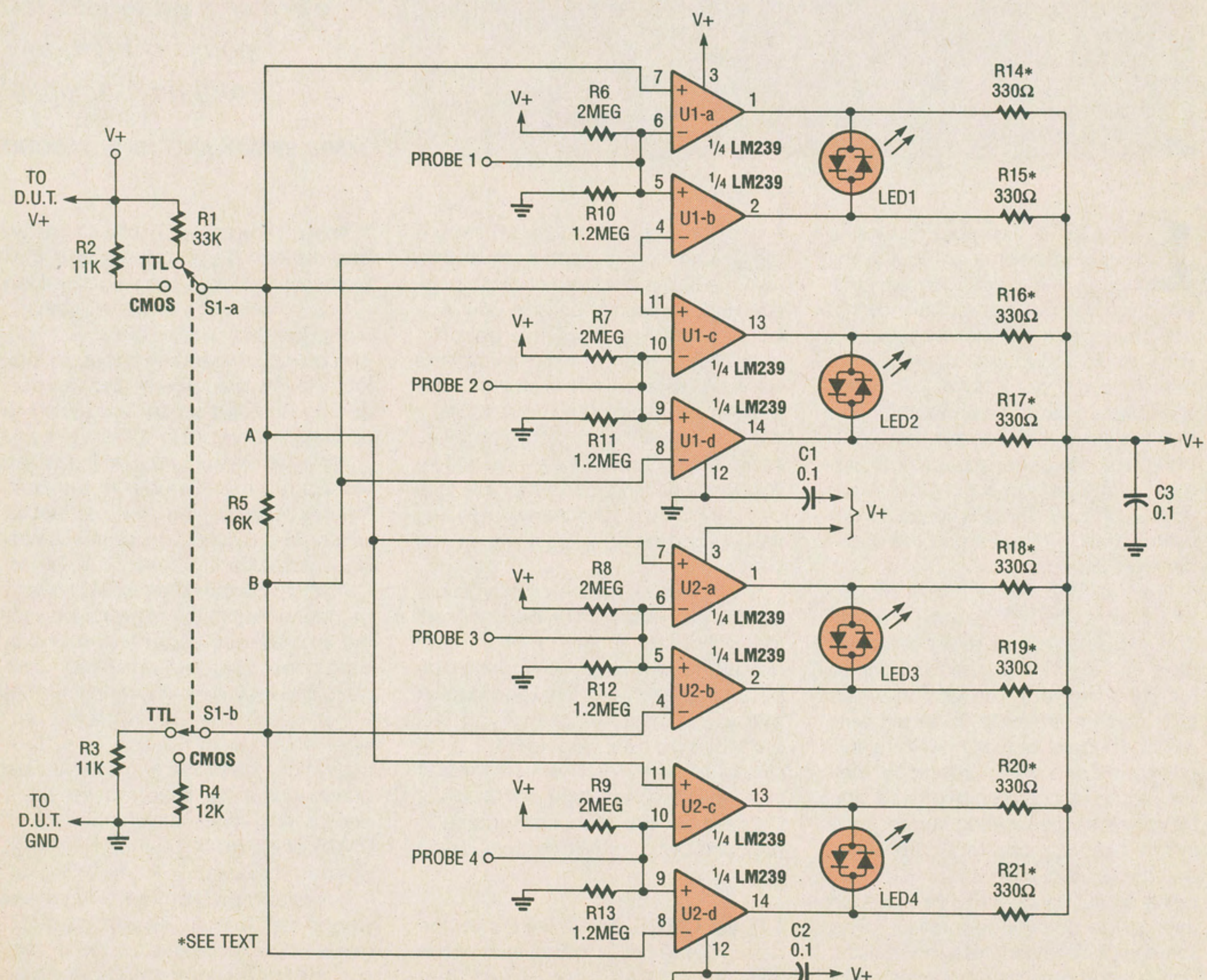


Fig. 2. The resistor networks (R1/R2 and R3/R4, respectively) to the left program the comparators with the proper voltage levels.

Now, if LED1 and LED2 are replaced by dual-colored LED's, and the circuit is multiplied by four, we come up with the circuit you see in Fig. 2.

Resistors R1–R4 "program" the comparators for the right high and low voltage levels. Switch S1 allows the user to select a resistor network that sets either TTL- or CMOS-compatible voltage levels. Resistors R6–R13 bias the probe inputs to prevent the probe from indicating a high for open circuits. When a probe tip is on an open IC pin, the corresponding LED will be off.

That's an important feature for three reasons: it allows you to detect failing pins or chips without power, it can keep you from incorrectly suspecting a chip because you misalligned the probe, and it will allow you to test tri-state chips. Tri-state chips have three logic levels (states): high, low, and high impedance. When testing such IC's, an off LED tells you its corresponding pin is in a high-impedance state. What all that means is that a single dual-colored LED will tell you if a pin is high, low, alternating, or even high-impedance/malfunctioning.

One thing should be mentioned about the alternating indication: Many computer circuits send out pulses that are too brief to light an LED or too brief for you to see them. Such test points may appear continuously high or low because of their lopsided duty cycle. It is assumed that the probe will not be used on such overwhelmingly fast circuits without other test equipment to check for such possibilities.

However, for "hobbyist-speed" circuits, the probe shines in this capacity. It will emit the half-ripe tomato color for duty cycles close to 50%. Its easy to see alterations in current for duty cycles from 30 to 70% even at respectable frequencies, although the color varies. During the initial testing of the dual-color LED's, it was a lot of fun adjusting the duty cycle of an input signal to modulate the LED's color from red to orange to yellow to green.

By the way, if you want to add more LED's to the project, it's a simple matter of adding another LM239 for every two LED's added (two comparators from each quad IC are needed for each LED). Just connect the non-inverting and inverting inputs of the additional comparators to points A and B in Fig. 2 (non-inverting to A and inverting to B). It's also possible to build the unit with only two LED's and one LM239, but when four LED's can be incorporated into such a small package, it doesn't make much sense not to take full advantage of the circuit.

By the way, if LM239's are hard to come by, LM339's are a good substitute. Our first prototype unit used LM339's, which were replaced with LM239's because of their current-handling capability. If you consider that overkill, LM339's will work fine. Also, the resistor network, R14-R21, can be replaced by discrete 330-ohm, ¼-watt, 5% units if desired.

PARTS LIST FOR THE ×4 LOGIC PROBE

SEMICONDUCTORS

U1, U2—LM239 (or LM339, see text), integrated circuit
LED1–LED4—Dual-colored LED

RESISTORS

(All resistors are ¼-watt, 5% units unless otherwise specified.)
R1—33,000-ohm
R2, R3—11,000-ohm
R4—12,000-ohm
R5—16,000-ohm
R6–R9—2-megohm
R10–R13—1.2-megohm
R14–R21—330-ohm, 16-pin, DIP resistor network (Digi-key 761-1-R330 or similar), see text

ADDITIONAL PARTS AND MATERIAL

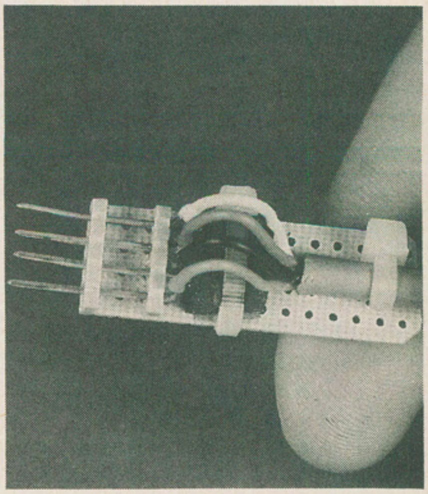
C1–C3—0.1-µF, polyester capacitor
S1—DPDT toggle switch
Micro-clips, 4-conductor wire, perfboard, IC sockets, wire-wrap wire, solder, hardware, etc.

Construction. The ×4 Logic Probe was built on a small piece of perfboard using wire-wrap techniques. Once the size of the cabinet was chosen, the components were first test-fitted on the board before any assembly began. Keep in mind the location of S1 when laying out your own unit to provide it with some clearance.

The only thing that complicated the otherwise simple job of wire-wrapping the circuit was the compactness we desired. That meant working in close quarters. If you don't need the unit to be as small as the prototype, or if you are using more than four LED's, use a bigger piece of perfboard and a larger cabinet to make your job easier. You might want to make a table-top version with a long cable for the "business end."

A piece of four-conductor wire was used to connect the unit to the special four-tip probe. The probe was assembled from scraps of perfboard and four probe-tips from a wire-wrap IC socket (see photos). Each pin slides through holes in two pieces of perfboard glued to a third piece. The wire from the cable keeps the pin from sliding out of the end, and a rubber block gives each pin a certain amount of give to ensure a secure seating on the test IC's pins.

If you like, you can avoid the probe entirely and put micro clips on the ends



Here is the probe tip, which was designed to make it quick and easy to check up to four IC pins at once.

of the test leads. That way, the unit might be a little more versatile. Micro clips were used for the power leads, but use anything that suits your needs.

Set-Up and Use. The probe needs only to be connected to the power supply of the D.U.T., and used like any other logic probe. However, some general testing rules are in order at this point.

When testing a suspect IC, if the V+ pin is high-impedance or low and gate outputs are low, the IC is not getting power. A foil trace, solder joint, or IC socket are likely suspects. If the ground pin is high impedance or high, the device has no ground, so again check the foil trace, solder joint, or IC socket. If the V+ pin is high, but all the chip's output pins are low, the gates are lacking internal power and the chip is probably shot. If all the outputs are high, but the ground is low, the gates aren't getting ground, and again the chip is shot.

Because the probe has four indicators, it is ideally suited to testing 2- and 3-input gates. You can monitor a gate's inputs and the resulting output simultaneously to make sure it's functioning properly. Because of features like that, you can expect a decrease in the time you spend testing IC's. ■