The logic probe and the oscilloscope

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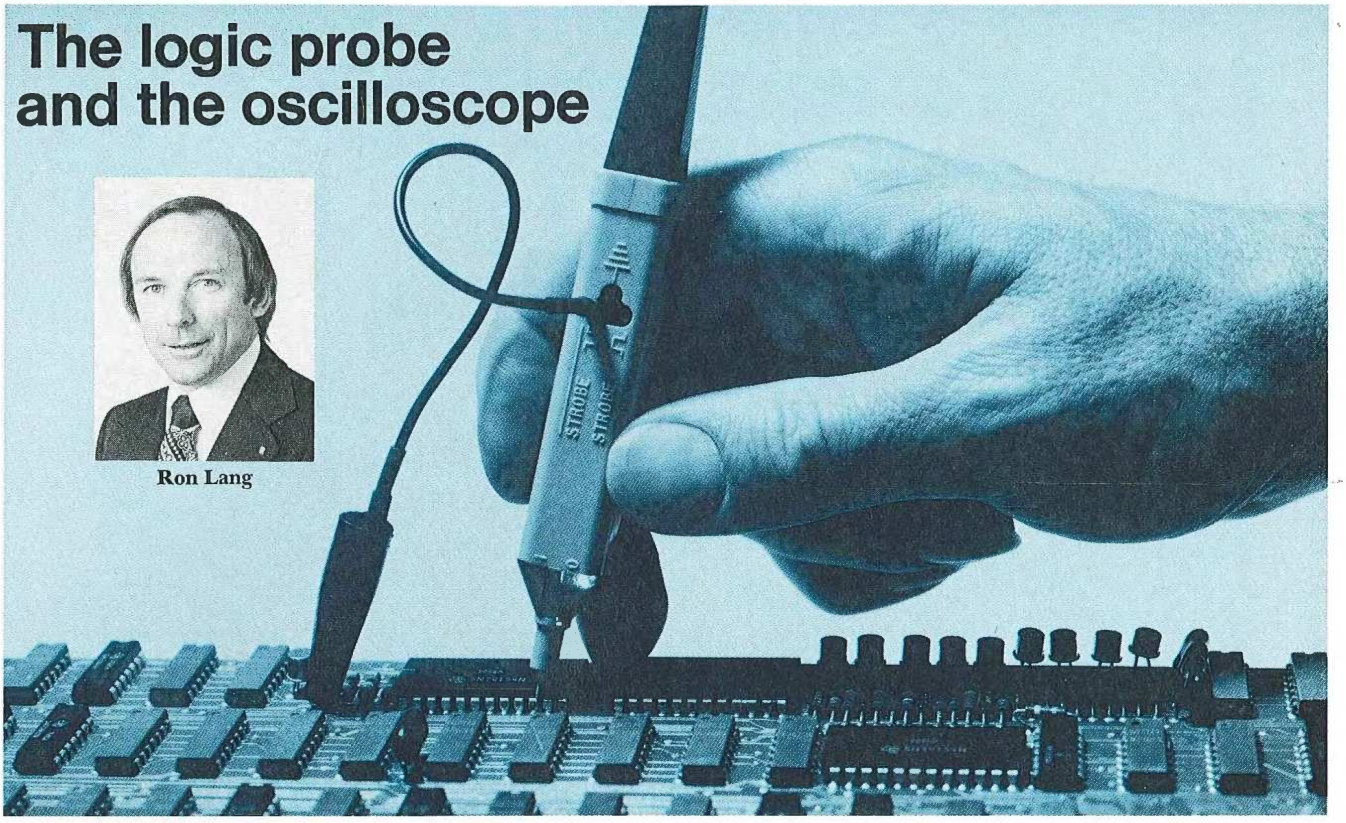

When the logic probe first appeared on the measurement horizon, it was touted by some as a low-cost replacement for the oscilloscope in troubleshooting and servicing digital logic circuitry. Time has, indeed, proven the logic probe to be a valuable tool in working with digital logic: not as a replacement for the oscilloscope but rather as a valuable adjunct.

The province of the logic probe is fast failure detection, that of the oscilloscope in-depth analysis — a perfect complement. With the logic probe the user can often quickly locate a circuit fault or failure. The oscilloscope is then brought into play to analyze the character of the fault or failure.

Although designed primarily for fast checking and troubleshooting of existing digital circuits on location by service personnel, the logic probe is also a time-saver for designers of circuits being breadboarded.

A digital logic probe's sole function is to indicate the state of the logic: high, low, or faulty, i.e., open or in the indeterminate range. There are many logic probes that do this. They use incandescent lamps or light emitting diodes as indicators. Some probes have a one-light readout using a bright and a dim indication; others have two, three, or four light systems; and at least one uses four LEDs as the readout.

There is also a variety of options to choose from. In some cases, these options are attached to the probe externally. Included are storage or memory, fast response or slow response, strobe input, and accessory packages.

The TEKTRONIX P6401 TTL Logic Probe combines all the features needed to verify any logic condition in one small, lightweight package. Two lights, red and green, are located in the nose of the probe. There they can be easily viewed without moving your eye from the point under test. The red light indicates logic 1 (2.15 to 5 V dc) and the green light logic 0 (0 to 0.7 V dc) in the following manner:

Logic State	Indication
Steady high state	Steady red light
Steady low state	Steady green light
Pulse trains (normal switching)	Blinking red and green lights at full intensity
Abnormal state (between high & low)	No lights
Open circuit (greater than 10 kΩ)	No lights
Excessive input voltage (greater than 6 volts)	Both red & green lights lit
Alternating between high state and indeterminate state	Blinking red light
Alternating between low state and indeterminate state	Blinking green light
Single pulse (+)	Green, red, then green
Single pulse (−)	Red, green, then red.

The P6401 has a fast response time and recognizes pulse widths as short as 10 ns. The circuitry controlling the indica-

tor lights has a built-in stretch feature. Once a light is turned on, the circuitry holds it on for 100 ms; once extinguished, it won't allow it to turn on again for 100 ms. In the observation of rapid pulse trains, this gives time to turn the light on and time to let the eye recognize that the light has come on and turned off. If the signal repetition rate is below 5 Hz, the blinking of the lights will follow the signal repetition rate. When the point being observed exceeds about 6 V dc, both red and green lights will glow steadily. This lets the operator know that an over-voltage condition exists in the circuitry being checked. Built-in protection for the probe input permits momentary overloads up to ±150 V dc or rms without damage to the probe. At high-input voltages, an easily resettable fuse in the input will open and prevent circuit damage. Probe input impedance is high in all states (7.5 kΩ paralleled by 6 pf) so as not to disturb the circuit under test.

The length of ground path returns is an often overlooked consideration in the use of logic probes. The P6401 has provision for plugging a short ground lead directly into the probe. This is the same ground as the negative, or black, power lead, but provides a considerably shorter path for the fast-signal acquisition encountered in TTL circuitry. This eliminates ringing and overshoot that could cause false light indications. Short ground leads should be used in all measurements.

Many features that are optional or even add-on modules on other logic probes are standard on the P6401 — for example, the "store" mode. This holds the light readout on until manually reset and is a valuable aid in single-pulse detection. As mentioned previously, pulse widths as short as 10 ns can be detected and indicated by the readout lights. Another feature, the "strobe" or gate mode, is employed when the coincidence of logic levels at two points needs to be confirmed.

The P6401 at work

Let's put the P6401 to work in actual circuits and see how it performs. Power is usually applied to the probe from the circuit under test through convenient clip leads attached to the probe. The red lead attaches to the +5 V dc bus and the black lead to the ground reference bus. Now simply touching the probe tip to the point under investigation will indicate the logic condition.

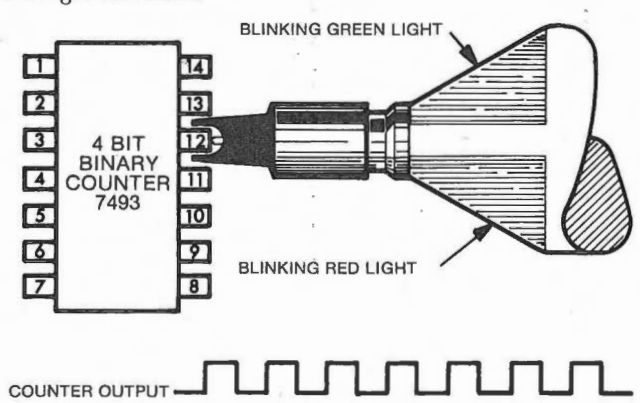

Fig. 1. P6401 measuring the output of a binary counter. The IC-lead adapter on the probe nose prevents slipping off the pin and causing circuit damage.

In Figure 1 the logic probe is being used to check the output of a binary counter. The red and green lights will blink on and off at a 5-Hz rate indicating that the logic level is transiting from logic 0 to logic 1 and back.

The IC Test Lead Adapter used in this application was designed especially for IC chip leads. It prevents the probe tip from slipping from the lead under test and causing faulty indications or disrupting circuit operation. It is also convenient for probing components mounted on circuit boards, such as resistors, capacitors and diodes.

Figure 2 shows the logic probe being used to verify the inputs and outputs of a positive NAND gate. When the two inputs are low, the output is high; when pin 8 is probed, the red light will come on. If the inputs, pins 9 and 10, are probed the green light will come on, indicating a low state.

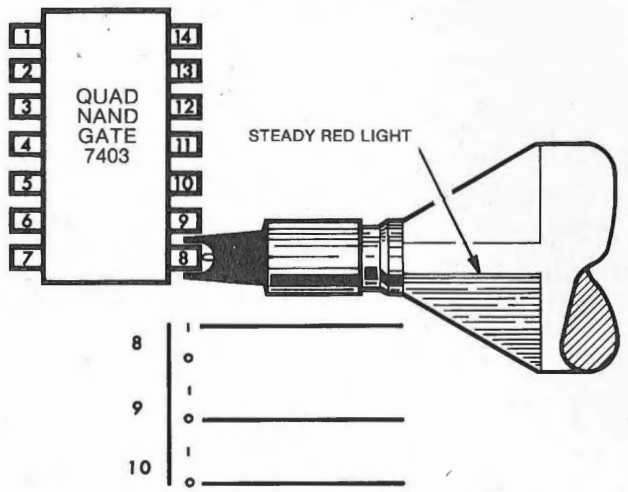

Fig. 2. The P6401 indicating the output of a NAND gate.

Often it is necessary to know if an event has happened. This may be a pulse that happens only once in several minutes. Here the "store" feature of the probe is used to capture a single pulse that may be as narrow as 10 ns. Switch the logic probe to the "store" mode with the switch located on the probe. It can now be attached to the test point to be monitored. (See Figure 3.) The green light comes on and stays on when pin 8 is probed; this is a logic 0. The red light turns on when the four inputs become positive, causing the output, pin 8, to go positive, a logic 1 state. The two lights will stay on even if the probe is removed from pin 8. To reset the probe, slide the "store" switch back. If the "store" mode is needed again, simply push the "store" switch forward. If desired, the probe may be attached to the circuitry and left unattended. When the event happens, the appropriate light will come on and remain on indefinitely for a record of the event.

Many times it is desired to detect the coincidence of two pulses. The P6401 has this capability as a standard function. To determine coincidence, the strobe input of the probe is connected to the strobe point that the event is to coincide with, such as a gate or strobe pulse. If the gate or strobe is a negative pulse, connect the strobe lead to the $\overline{\text{strobe}}$ (strobe not) input on the probe. With the probe tip, monitor the

point in question. (See Figure 4.) If the indication of the event is to be retained, the "store" mode may be used in combination with the strobe.

The probe recognition circuitry is gated off until the advent of the strobe pulse. Therefore, whatever transitions occur at the probe tip will not turn on a light. When the strobe does occur, the probe is gated on. An event at the probe tip will be indicated by the lights and retained if the "store" mode is used. If the event does not happen for at

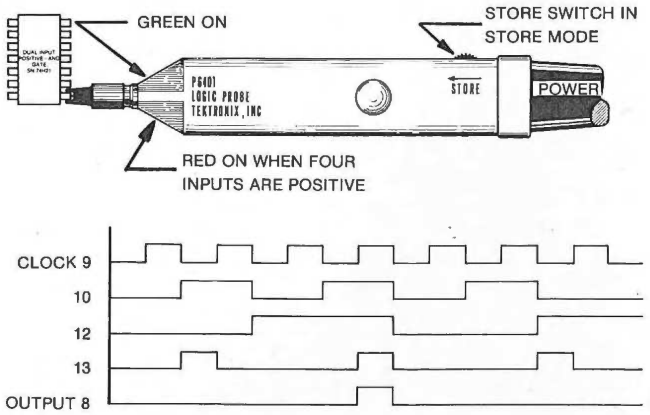

Fig. 3. The P6401 used in the "store" mode to indicate coincidence of four events. Pulses as narrow as 10 ns can be captured in the "store" mode.

least 2 ns after the strobe, the green light will come on first, and stay on if in "store" mode; then the red light will come on and stay on. Because of the short, 2-ns, period both green and red lights will appear to come on together.

If, as in the techniques shown, the desired event does not materialize, the problem can be traced to a faulty component such as an IC chip having the appropriate inputs but a wrong output. The faulty component can then be replaced and the circuit put back into correct operation, or an oscilloscope can be used to examine exact wave shapes and voltage levels for an in-depth analysis of the problem.

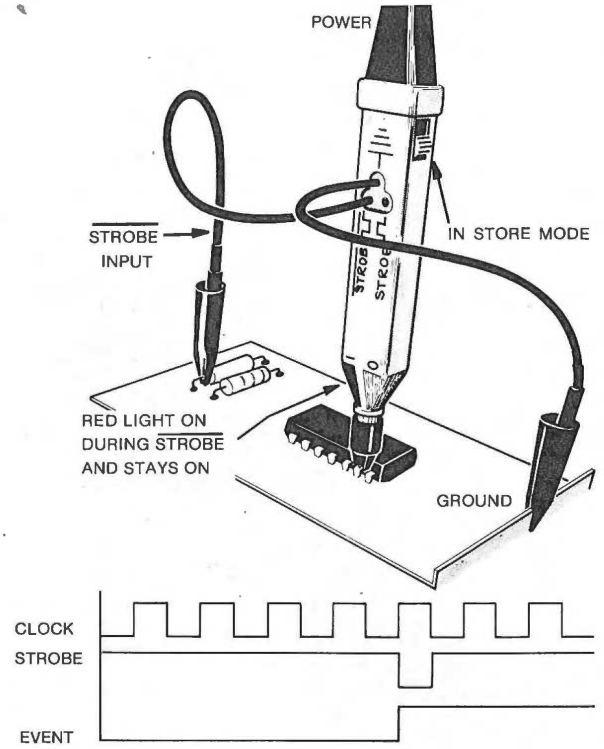

Fig. 4. The STROBE function is used to determine if an event occurs during a strobe, or gate, interval.

In summary, the P6401 Logic Probe is a lightweight, dynamic, decision-making tool that derives its power from the circuit under test to determine logic states. It can quickly find faults that can be corrected on the spot. Used alone or with an oscilloscope the logic probe is finding increasing use in designing and troubleshooting systems such as point-of-sale terminals, computers, inventory control systems, video tape record and playback systems, readout systems, or any other system using TTL logic, singularly, or in combination with any other logic family.