Simple Logic Probe uses LEDs for readout

Easily built at low cost, this simple unit is ideal for troubleshooting in modern digital circuits using ICs. It uses a TTL device and two light-emitting diodes (LEDs), and is housed entirely within a transparent probe case. Build it to gain valuable experience!

by JAMIESON ROWE

Familiar test aids like the multimeter or VTVM are not much help for troubleshooting in or debugging digital circuitry, due to the on-off nature of digital signals. Until recently, this meant that one had almost no choice but to use an oscilloscope, and generally quite an elaborate one at that.

Happily the progress of digital technology has evolved a new type of test device, one appropriate to itself: the logic probe. Something like a pen-sized digital version of the old signal tracer, this new device provides a quick and convenient indication of the digital state-of-affairs at any point in the circuit.

Small wonder, then, that the logic probe is already widely used among those involved in either development or maintenance of digital equipment, and in fact is fast becoming as ubiquitous and indispensable as the slide rule.

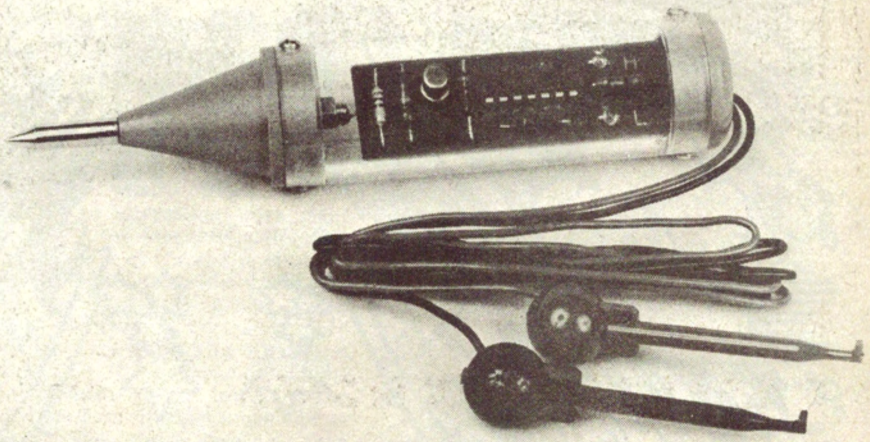
Commercially available logic probes tend to be rather elaborate devices, generally designed to perform such functions as detecting ultra-fast and narrow pulses, and indicating a wide variety of possible circuit malfunctions. Accordingly the price tends to be rather high, and this together with the fact that a somewhat simpler probe is still quite adequate for many situations has resulted in a spate of designs for simpler and cheaper probes.

The logic probe described in this article falls into the latter category; its main claim to fame is that it achieves what must surely be some sort of "ultimate" in terms of simplicity and low cost, using currently available components. It uses only one IC, a transistor, three resistors and two LEDs. An additional resistor and zener diode may be fitted if desired, to allow the probe to cope with a greater range of input voltage levels.

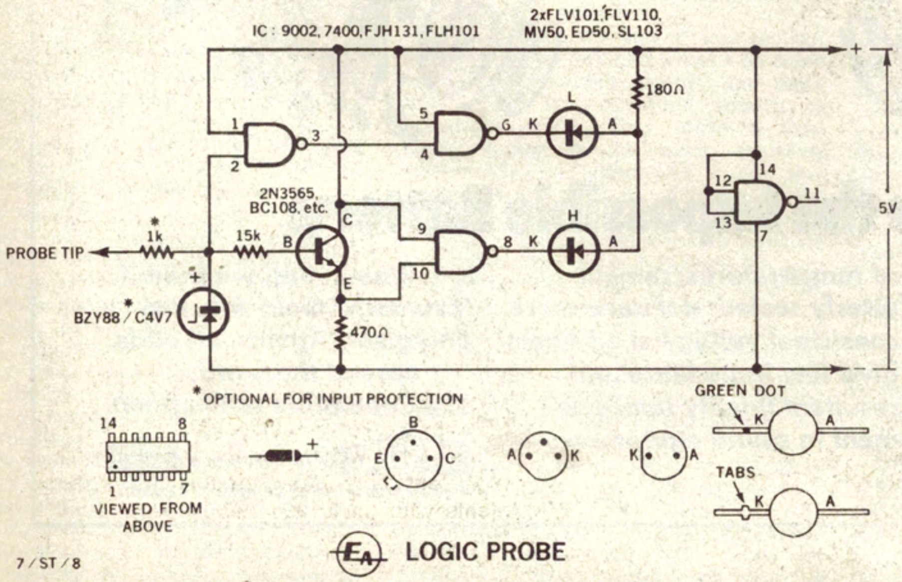
Yet despite its simplicity, the probe gives a clear and unambiguous indication of either circuit high voltage level (H), low voltage level (L), or an open circuit. It will also indicate if pulses are present, allow an estimate to be made of their duty cycle, and in the case of low-speed circuits also allow estimation of repetition rate.

Basically it has been designed for troubleshooting in modern TTL and DTL circuitry, but if the zener diode input protection is fitted, it may be used to test in circuits using higher voltage levels, such as MOS logic and older discrete bipolar logic.

The probe may be used with circuits having either supply polarity grounded, and with circuits having any logic convention, as its indication is purely in terms of voltage high (H = more positive level) and voltage low (L = more negative level).



Above is a view of the completed probe, fitted with input overload protection. The complete circuit is at lower left.



Power supply requirement of the probe itself is 5V DC, at between 10mA (idle current) and 35mA. This may be taken from the circuit under test in the case of TTL and DTL circuitry, simply by clipping a pair of leads from the probe to the circuit power bus lines. With higher voltage circuits a suitable source of 5V will have to be provided, with its negative polarity tied to the most negative circuit supply line.

The basic logic circuit of the probe is not original. I have taken it from a similar unit described in the August 1972 issue of the US amateur radio magazine "QST", by E. H. Rogers, KOGKB, and apparently developed at the Metrology Section of the National Bureau of Standards, in Boulder, Colorado.

The probe described by Rogers uses small incandescent lamps, and a hex inverter IC with two inverter elements paralleled to drive each lamp. I have replaced the incandescent lamps with LEDs, which are not only more efficient but considerably more reliable. The use of the LEDs has also allowed me to avoid the necessity of paralleling TTL elements (a technique frowned upon by the makers), due to the lack of inrush current. Instead of a hex inverter device I have been able to use a quad NAND gate, which may be either a 7400, a 9002, or an FJH131.

Although different from the original probe in these respects, the new probe uses the original logic configuration. Although I tried a number of other possibilities, I came back to the original Rogers logic because it seems to be the simplest and most reliable way of achieving the desired result. In fact it is most ingenious in the way it uses only a handful of elements to indicate not only the H and L states, but also open circuits.

The "low" (L) indicator LED is driven by two cascaded gate elements, each connected as an inverter. When the probe tip is pulled down to the low level by a "low" in the circuit under test, the output of the first inverter is driven high, and in turn the output of the second inverter goes low. This pulls the LED cathode down, allowing the LED to draw approximately 20mA of current via the 180 ohm limiting resistor.

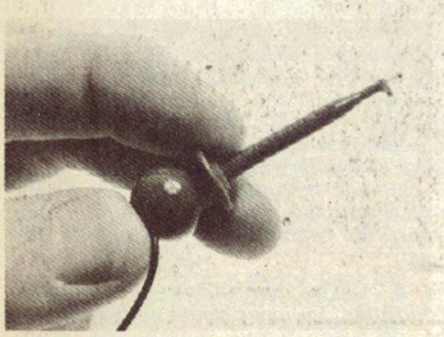
The "high" (H) indicator LED is driven by a single gate, again connected as an inverting element. However in this case the input of the inverter is not connected directly to the probe tip, but rather to the output of a simple emitter follower stage used as an input buffer.

It is actually the emitter follower which prevents the H indicator LED from operating in the event of the probe tip being connected to a point which is open circuit. Without the follower, the H indicator LED would glow for both high levels and open circuits, because a TTL gate input is inherently "high" until pulled low. The 470 ohm emitter resistor of the emitter follower effectively pulls the H inverter gate input down to "low" in the event of an open circuit, yet the follower still allows the gate input to be taken high by an H input.

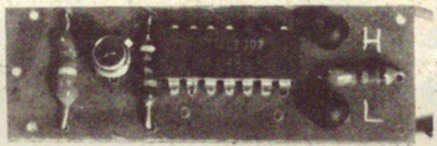
Note that the base current taken by the follower is quite small, so that in the open-circuit input condition insufficient current is drawn from the input of the first "low" inverter gate to lower its potential significantly.

By keeping both LEDs extinguished for the open-circuit input condition, the emitter follower thus allows the probe to indicate this condition unambiguously.

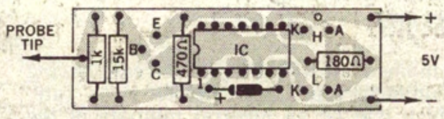
In the basic form thus described the probe is completely practical, and suitable for all TTL and DTL logic circuits operating from a nominal 5V supply. However the base-



A close-up of an X100W Mini-Hook, as used with the probe.



Above is the board wired for the basic probe circuit, shown actual size. Below is the wiring diagram for the full version.



PARTS LIST

- *1 Printed board, code 72/10, 0.7 x 2.25in.*
- *1 Probe case, 3in, with transparent barrel (Jabel type PH3T).*
- *1 Quad 2-input TTL gate IC, 7400 or similar.*
- *1 2N3565, BC108, or similar.*
- *2 Light-emitting diodes (see text).*
- *2 Test clips (E-Z-Hook type X-100W), one black, one red.*
- *1 180 ohm ¼ watt resistor.*
- *1 470 ohm ¼ watt resistor.*
- *1 15k ¼ watt resistor.*
- *1 1k ¼ watt resistor (optional)*
- *1 BZY88/C4V7 or similar 4.7V/400mW zener (optional).*

emitter junction of the input transistor of the first "low" inverter gate would be damaged if the probe input were connected to a voltage higher than about 5.6V with respect to the negative supply line.

To enable the probe to be used for checking operation in circuits using higher voltage levels, it is therefore necessary to protect it from damage. This is simply achieved by the addition of a clipper circuit using a series 1k resistor and a low cost 4.7V/400mW zener diode.

The complete probe circuit is mounted on a very small printed wiring board — it measures only 0.7 x 2.25in (18.5 x 156mm). The pattern for the board is coded 72/10. Sample boards for the prototype probes were kindly supplied at short notice by RCS Radio Pty Ltd, but other manufacturers have been sent the pattern also, and should be able to supply boards shortly.

The IC used in the probe is a standard low cost TTL quad NAND gate. Suitable devices which may be used are the 7400, the 9002 (Fairchild), the FJH131 (Philips Elcoma), and the FLH101 (Siemens). These are all pin-for-pin equivalents.

As with the IC there are many possible low cost LEDs which may be used. In fact you can use almost any type of visible-output LED which will fit into the board physically. Suitable types are the FLV101 and FLV110 (Fairchild), MV50 (Monsanto, from Hawker Siddeley Electronics), ED50 (European Electronic Products, from General Electronic Services), SL103 (Plessey Imported Components) and 5082-4403 (Hewlett-Packard).

The transistor used in the emitter follower may be any general-purpose NPN silicon type with a beta of around 100 or more. The usual choice would be a 2N3565 or a BC108, etc, but almost any NPN silicon device could be pressed into service.

The resistors used should preferably be quarter-watt types as these will fit more conveniently into the spaces available on the wiring board. However the more readily available half-watt types may be used if the smaller resistors are found hard to obtain.

The wiring board of the probe fits snugly inside a probe case made of transparent acrylic. The probe case is a new addition to the well known "Jabel" range, distributed by Watkin Wynne Pty Ltd, and has in fact been designed by this firm especially for the project. Designated the PH3T, it is very similar in appearance to the other Jabel probes apart from the clear barrel. Watkin Wynne very kindly made samples of the new probe case available to us at short notice for use in the prototypes.

It is desirable to fit the power supply leads of the probe with some sort of quick-connect clips so that they may be easily and rapidly hooked onto the 5V supply lines of the circuit being tested, and then just as easily removed when testing is completed. While casting around for suitable clips for the prototype units, our attention was drawn to the "E-Z-Hook" range of clips, made by Tektest Incorporated in the USA. The Australian agents for these products are General Electronic Services Pty Ltd, of 114 Alexander Street, Crows Nest 2065.

We finally settled on the type X100W Mini-Hook from the E-Z-Hook range, and these are visible in the photographs. They are available in red and black for polarity marking, and feature a very small spring-loaded hook connector which provides a very convenient and effective means of connecting to small component leads.

When you have completed the probe, using it is simplicity itself. The first step is to clip the two power supply leads to the 5V supply lines of the circuit to be tested, making sure that correct polarity is observed. Then it is simply a matter of touching the probe tip to each point of interest in the circuit, and observing which of the two LEDs glows — if either.

If the H LED glows, the point concerned is at the high level, while if the L LED glows the point is at the low level — or conceivably it could be shorted to the negative line. If niether LED glows, the point is open circuit.

If pulses are present, both LEDs will tend to glow, either alternately in the case of long slow pulses, or with apparent continuity in the case of short pulses with a high repetition rate. In the latter case the relative brightness ratio of the two LEDs will allow a reasonable estimate to be made of the pulse duty cycle or "mark-space" ratio.