Build an

Audible Logic Probe

Two-tone device "beeps" for high and low logic levels, and "warbles" for pulse trains

by Robert G. Krieger

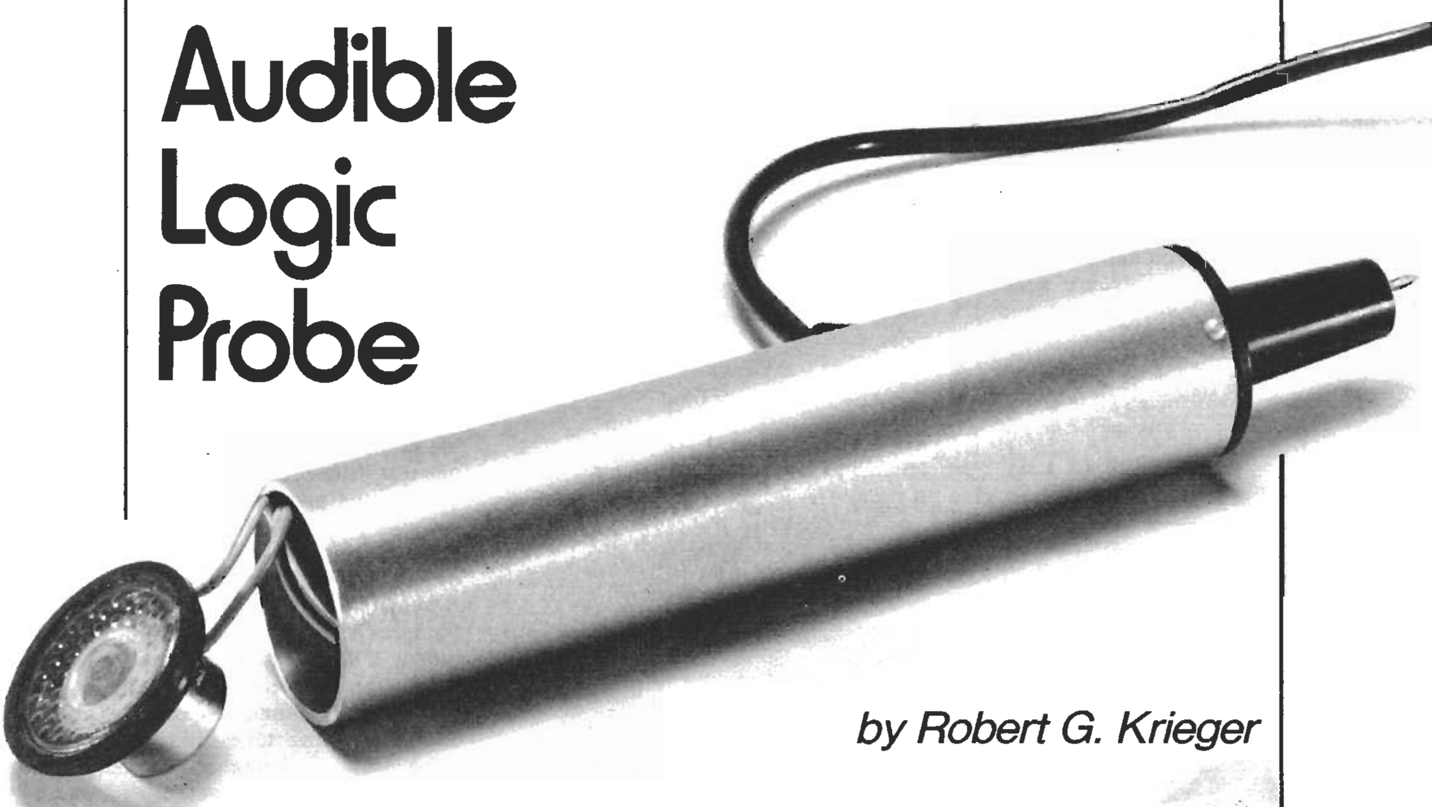
A HAND-HELD probe to indicate the status of a logic circuit is very useful in troubleshooting modern electronic equipment. Most digital probes use LEDs to indicate visually a logic state. This requires that the user watch the point being tested and the LED indicator simultaneously. This eye-shifting procedure can result in inadvertent probe slips which damage equipment.

The logic probe described here overcomes this problem by employing an audible indication—a high-frequency tone when its tip senses a high signal, a low-frequency tone when the signal is low, and a warbling tone (high-low-high . . .) when encountering a pulse train. The audible probe can be used with either TTL or MOS devices. Operating power, from 4 to 15 volts, is derived from the circuit being tested. Current demand is 10 mA from a 5-volt system and 35 mA from 15 volts. The input stage is protected against overload.

Circuit Operation. As shown in Fig. 1, two comparators (elements of a four-comparator chip) are used to sense the high and low input levels. A voltage divider (*R4, R5,* and *R6*) sets the reference levels.

When the input voltage from the probe tip at pin 5 of *IC1A* becomes greater than the reference voltage applied at pin 4, the output of this comparator (pin 2) goes high. This, in turn, forward-biases *D2* and the timing resistance of *R7* and *R9* causes astable oscillator *IC2* to produce a tone at approximately 3.5 kHz. This tone is the logic-high signal.

At low-level detector *IC1B*, when the



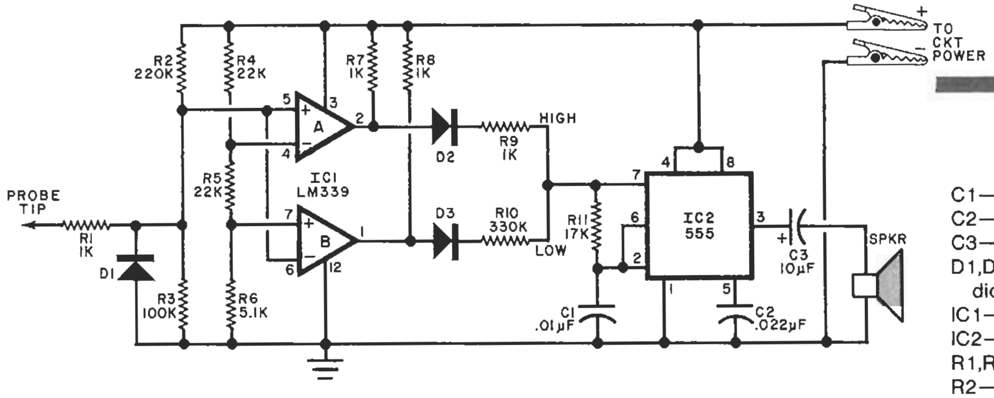


Fig. 1. One comparator detects logic high while the other detects logic low inputs. This causes the audio oscillator to change tone contingent on which comparator is operating.

voltage at pin 6 is lower than the reference at pin 7, the output at pin 1 goes high. This, in turn, forward-biases *D3* to place *R8* and *R10* in the *IC2* timing circuit. Since this combination has a greater resistance than *R7* and *R9*, the oscillator delivers an output tone at about 300 Hz. This becomes the logic-low signal.

Divider network *R2* and *R3* maintain a resting state of about one volt on the input line so that when the probe is not connected to a signal source, neither comparator will trigger, and no tone will be generated.

If you wish to use LED logic indicators, simply eliminate *D2, D3, IC2* and their associated components. Retain *R7* and *R8*, however, and connect a LED between each comparator output and ground (anode to the comparator).

Input Levels. TTL low level is usually specified as 0.8 volt and the high level at 2 volts. MOS levels are generally specified as 1.5 volts for zero and 3.5 volts for the high level. Therefore, some compromise was made in the design of the probe. The levels selected by the *R4, R5,* and *R6* network are 0.6 volt for logic low and 2.5 volts for logic high. If you wish to change levels, the network values will have to be recalculated. With 15-volt systems, the probe senses logic low as about 2 volts and below, and logic high as 8 volts and higher. Diode *D1* ensures that only positive-going signals are presented to the comparator inputs. The output of tone generator *IC2* is coupled via *C3* to a small (it must be capable of fitting into the aluminum tube that holds the complete probe) dynamic microphone or earphone element.

Construction. Although any type of construction may be used, a 1-inch diameter, 5½-inch long thin-walled aluminum tube was used in the prototype. In this case, the pc board shown in Fig. 2 can be used for the circuit.

The tip is formed from a sharpened nail passed through a tapered piece of wood to form a cone that can be press-fit into one end of the tube. A circular piece of perf board can be used to seal the transducer end. The power cable (two leads) is brought out of the tube via a small grommetted hole an inch or so up from the transducer end.

Since the operating dc voltage and ground lie on each side of the pc board, electrical tape insulation can be used to prevent accidental shorts. The transducer leads are kept short and soldered to their pads on the pc board.

After testing the assembled circuit insert it into the tube, transducer end first—passing the power leads out of the grometted hole first. The wood tip is press-fit into place. Ends of the color-coded power leads are terminated with suitable alligator clips.

Operation. Since power for the audible probe is derived from the circuit under test, connect the ground clip to circuit ground and the positive clip to the circuit's positive bus. With the probe tip isolated from a signal, no sound should be heard from the transducer.

When the probe tip is connected to the circuit positive bus, a high-pitched (about 3500 Hz) tone will be heard, and when connected to circuit ground, a low (about 300 Hz) tone should be heard. In use, a warbling tone indicates that a pulse train is being monitored. The probe will sense such activity to about 10 kHz.

It is possible to use a switch that connects the audio output back to the probe tip, so that the probe can also be used as a signal injector. ◊

PARTS LIST

- C1—0.01-μF small disc capacitor
- C2—0.022-μF small disc capacitor
- C3—10-μF tantalum capacitor
- D1,D2,D3—Germanium signal diode (Radio Shack 276-1123 or similar)
- IC1—LM339 quad comparator
- IC2—555 timer
- R1,R7,R8,R9—1000-ohm, ¼-watt resistor
- R2—220,000-ohm, ¼-watt resistor
- R3—100,000-ohm, ¼-watt resistor
- R4,R5—22,000-ohm ¼-watt resistor
- R6—5100-ohm, ¼-watt resistor
- R10—330,000-ohm, ¼-watt resistor
- R11—17,000-ohm, ¼-watt resistor
- SPKR—Medium- or low-impedance earphone or microphone element
- Misc.—Suitable thin-walled 1" by 5½" aluminum tube, wood block for tip, sharpened nail, small piece of perf board, glue, power twin-lead, alligator clips.

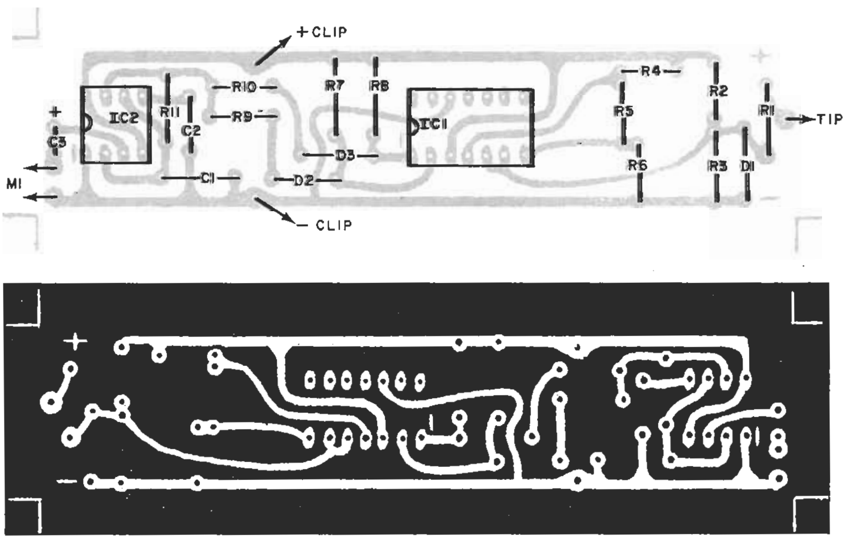


Fig. 2. Actual-size foil pattern and component installation for printed-circuit board of suitable size for placing the probe in a tube.

h-l logic tester

This is a TTL logic probe which, instead of the usual LED to indicate the logic states, uses a seven-segment Minitron or LED display to indicate 'H' for a high or '1' state and 'L' for a low or '0' state. The circuit also detects when the probe input is open-circuit and the readout is suppressed, thus indicating that contact with the desired test point has not been made. This avoids the false readings that may occur with some types of probe when the input is not connected.

The circuit makes use of a 7447 decoder driver. The input circuitry to this IC is designed so that when the input to the probe is high a '1' is applied to the 'C' or 4 input of the IC. When the input to the probe is low a '1' is applied to the 'A', 'B' and 'D' or 1, 2 and 8 inputs of the IC. This results in the display of the number 4 and the symbol ⊐ respectively in accordance with the truth table for the 7447. However, the connections from the outputs of the IC to the segments of the display are rearranged so that the display is actually H and L. When the input to the probe is open-circuit all four inputs to the 7447 are high (A = B = C = D = 1, i.e. '15') and the display is completely suppressed.

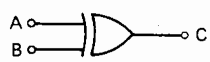
The input circuitry operates as follows: N_1 and N_2 are exclusive-OR gates. When a '0' is applied to the probe input both inputs of N_1 are '0' so the output is also '0'. One input of N_2 is held at '0' via R_1 and the other is held at '1', by R_2, so the output is '1'. This output is connected to the A, B and D inputs of the 7447. When the probe input is '1' one input of N_1 is '0' and the other is '1', so the output is '1'. This output is connected to the C input of the 7447. Both inputs of N_2 are '1', so the output is '0'. When the probe input is open-circuit the input of N_1 is not connected to ground floats at just above the '1' threshold level, so the output is '1'. The forward voltage drop of D_1 and D_2 prevents this from holding the input of N_2 high, so the input is held low by R_1. The other input is, of course, held high so the output is '1'.

1

7447 output	pin No.	connected to display segment
a	13	not connected
b	12	c,g
c	11	e
d	10	d
e	9	not connected
f	15	b
g	14	f

Truth Table for exclusive-OR gate

A	B	C
0	0	0
0	1	1
1	0	1
1	1	0



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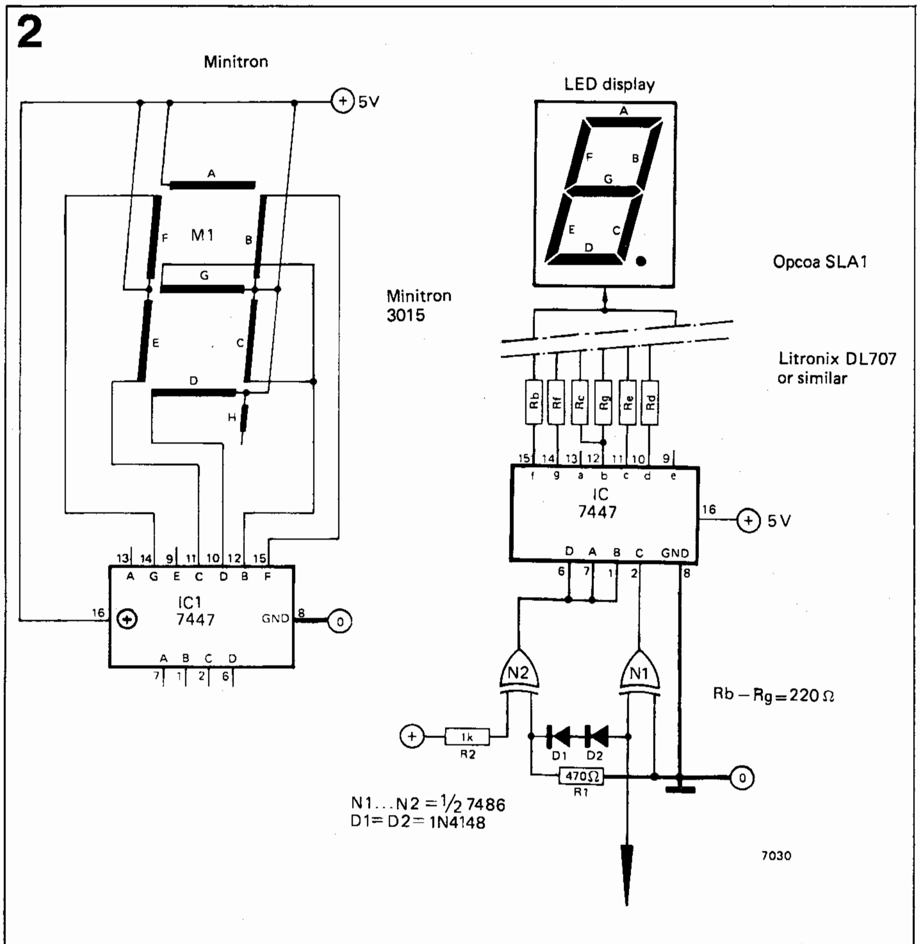
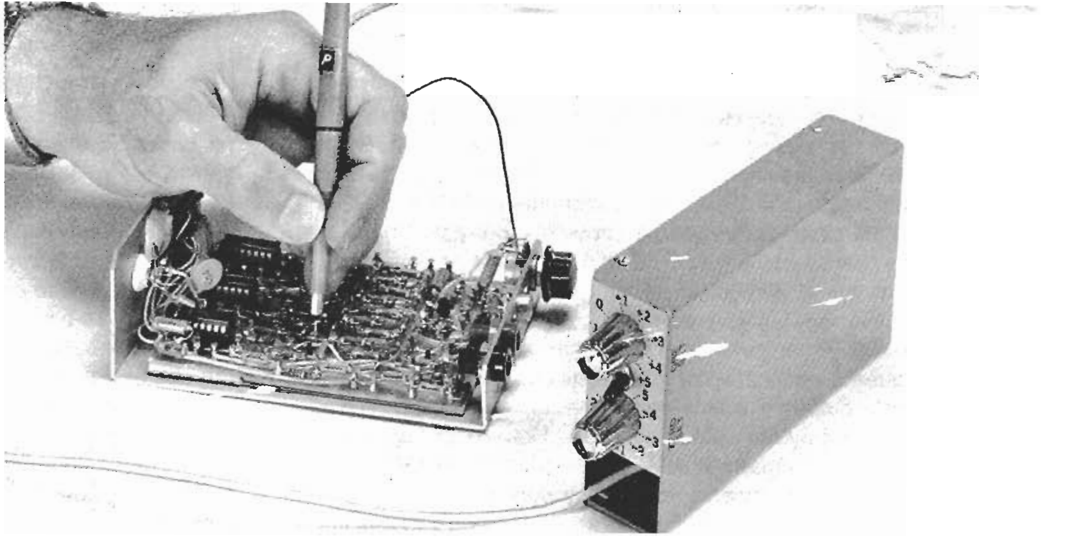


Figure 1. Connections from outputs of 7447 to display segments.

Figure 2. Complete Circuit of the H-L tester, showing the alternative connections for Minitron and LED display.

BUILD A "UNIVERSAL" DIGITAL PROBE



…tually any digital logic fam… at speeds to 10 MHz.

BY JAMES P. TIERNEY

MANY different designs for digital logic test probes have appeared in the past few years. Most tend to favor a specific logic family, with TTL getting the most attention. Few, if any, are capable of checking ECL and MOS devices and circuits. The logic probe described here is designed for testing virtually all the logic families currently in use, including RTL, DTL, TTL, ECL, and MOS devices and circuits.

The universal logic probe, while larger than "ordinary" testers, is also completely self-contained. It has its own built-in battery power supply to simplify test hookups. (Most popular test probes derive their power from the circuit under test.)

An important factor to be considered in logic probe design is frequency response. Most testers will not respond to high frequencies. Thus extremely short duration pulses are lost and, in some cases, cause signal degradation in the circuit being tested. The universal probe solves this problem by being able to respond to frequencies in excess of 10 MHz. Furthermore, it will check for a logic 1 or logic 0 within 5 mV of a set value.

About the Circuit. The tester is made up of two parts: a small case containing all of the electronics (including two controls that permit you to preset the logic levels) and a probe assembly with attached cable. The probe itself contains a 7-segment LED display. The ground lead is attached to the body of the probe for easy connection to the circuit being tested.

The heart of the circuit is dual differential comparator integrated circuit *IC1* in Fig. 1. The *IC1B* half checks for a logic 1. Its pin-8 output is held low until the input on pin 5 from the probe is 5 mV (or greater) above the voltage applied to pin 6. The latter is determined by the setting of *R5* and ranges from −1 V to +5.25 V dc. When the input is greater than the voltage on pin 6, the output of the comparator sends *Q1* into conduction to cause a 1 to be displayed.

The 0 part of the circuit operates in the opposite manner. The input on pin 13 must be more negative than the preset voltage on pin 12, determined

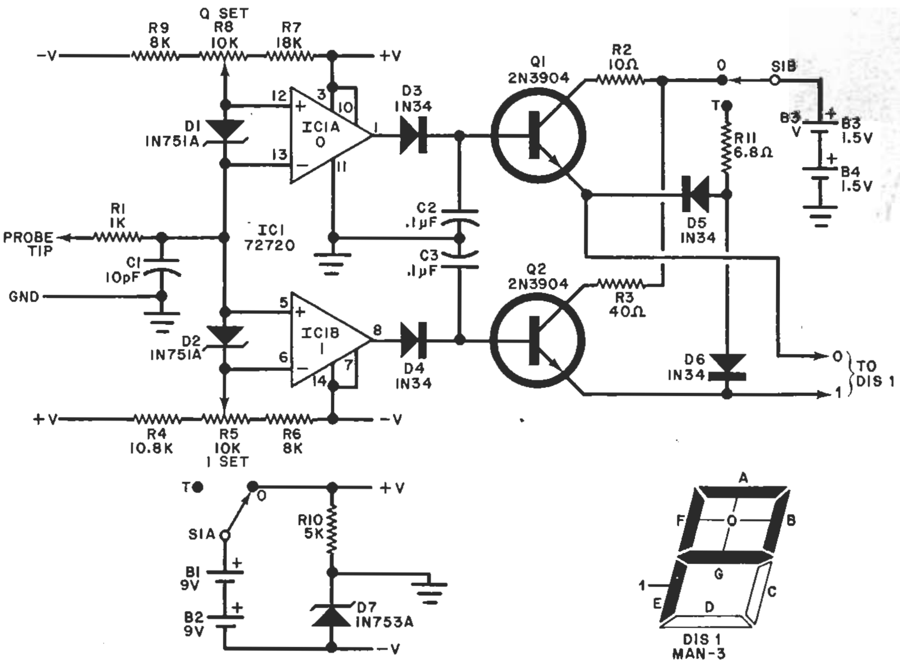


Fig. 1. Dual comparators sense the voltage at probe tip.

PARTS LIST

B1,B2—9-volt battery
B3,B4—1.5-volt battery (AA cell)
C1—10-pF, 10-volt capacitor
C2,C3—0.1-µF, 10-volt capacitor
D1,D2—1N751A zener diode
D3 to D6—1N34 diode (or similar)
D7—1N753A zener diode
DIS1—Seven-segment LED display (Monsanto MAN-3 or similar)
IC1—72720 dual differential comparator
Q1,Q2—2N3904 transistor (or similar)
The following resistors are ¼ watt:
R1—1000 ohms
R2—10 ohms
R3—40 ohms
R4—10,800 ohms
R6,R9—8000 ohms
R7—18,000 ohms
R10—5000 ohms
R11—6.8 ohms
R5,R8—10,000 ohm miniature potentiometer
Misc.—Length of three-conductor shielded cable, plastic felt-tipped pen, cement, needle tip, knobs (2), press-on type, battery connectors, chassis, mounting hardware, etc.

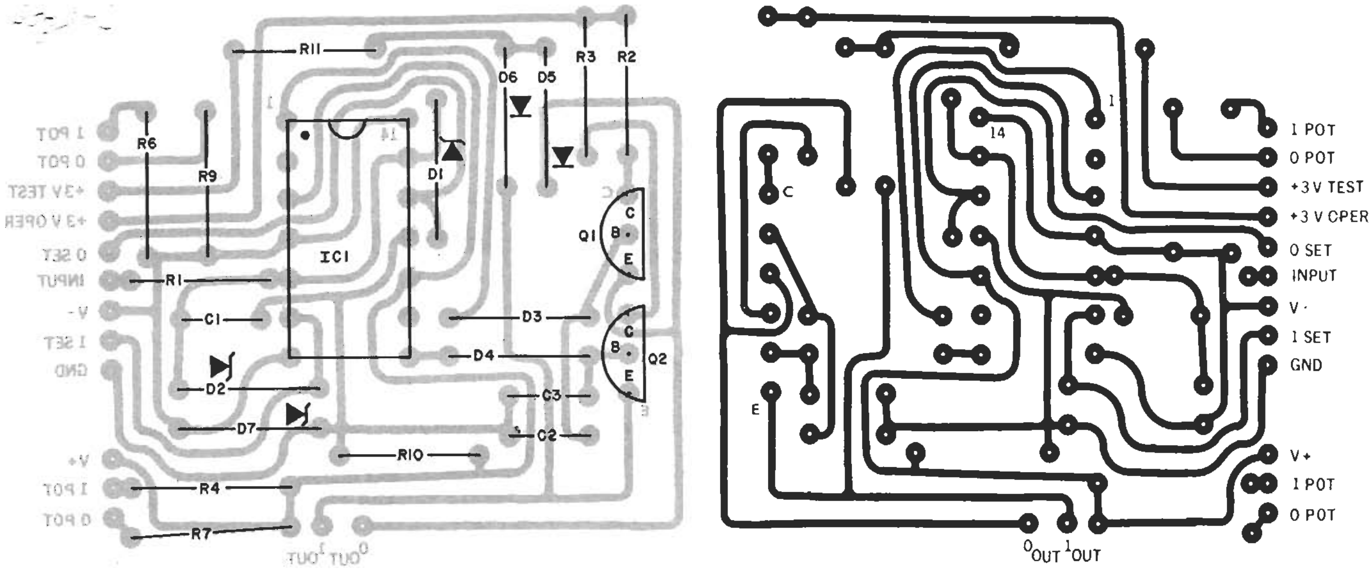


Fig. 2 Foil pattern (right) and component installation.

by the setting of *R8*. The range here is from −2 V to +3 V dc. When this section of the comparator turns on, *Q1* saturates, and the 0 portion of the display is illuminated.

Diodes *D3* and *D4*, in conjunction with capacitors *C2* and *C3*, ensure that, once the indicator is activated, it will remain on long enough to be seen, even with reasonably high pulse repetition frequencies. Resistors *R2, R3,* and *R11* provide current limiting for the display. Diodes *D5* and *D6* form a gate that allows testing the indicator before operation. Diodes *D1* and *D2* protect the IC inputs. Resistor *R10*, with *D7*, converts the 18 V from batteries *B1* and *B2* to −6 V and +12 V for the IC. Batteries *B3* and *B4* provide the higher current required for the seven-segment display.

Construction. The tester can be assembled on a printed circuit board using the actual-size etching and drilling guide shown in Fig. 2. However, if care is exercised, the circuit could be assembled on perforated board using point-to-point wiring.

Mount the board and batteries in an enclosure approximately 1½" by 3" by 5½" as shown in Fig. 3. Note that part of the box is used to store the probe and cable when not in use. The two potentiometers and switch are mounted on one end of the chassis with appropriate identifications made with press-on type.

The probe can be made from a used plastic felt-tipped pen case as shown in Fig. 5. Using a three-conductor shielded flexible cable, identify the leads as 0, 1, and tip. Make the tip lead long enough to go through the end of the plastic case. Cut an opening on the side of the case slightly smaller than the LED display. Feed the 0 and 1 leads through this hole. On the display, interconnect segment leads A, B, F, and G. Solder the 0 lead to this combination. Solder the 1 lead to the E segment. Connect the display common to the coax shield. Feed the shield lead through a small hole below the readout and wrap it around the plastic case. Feed the tip lead through the front opening on the case. Seat the display in place and cement it securely. Fabricate a needle tip and solder it to the probe tip lead. Cement this in place.

When assembly is complete, connect a voltmeter between the rotor of potentiometer *R5* and ground. Rotate this potentiometer between its two extremes and mark the 1-volt calibration points on the front panel at the rotor of *R5*. Do the same for *R8*. Don't forget to indicate the polarity. Also make sure that the rotor of *R8* is always more negative than the rotor of *R5*.

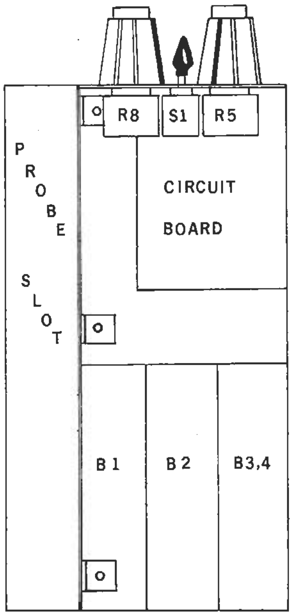
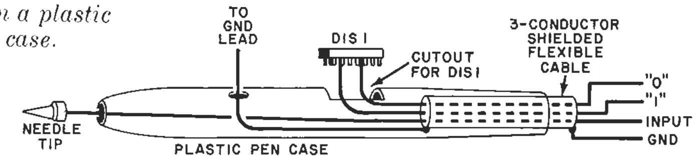


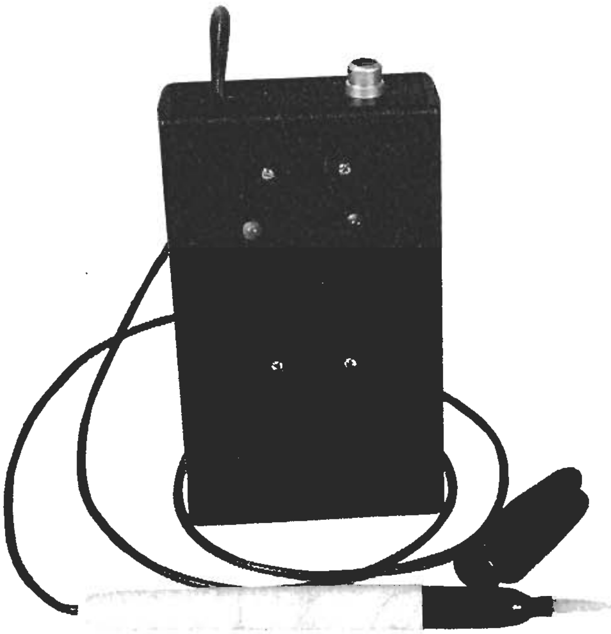
Fig. 3 Layout of chassis as used in prototype.

Fig. 4. The probe can be fabricated from a plastic felt-tipped pen case.



Operation. To check a logic circuit, determine the high and low voltages for the 1's and 0's of the circuit being tested. Set the two potentiometers accordingly. Attach the probe ground to the circuit ground. Place *S1* in the test position (T). The display should indicate both a 0 and a 1 (which looks like the letter P). Place *S1* in the operate position and touch the probe tip to the circuit being tested. A logic 0 or a logic 1 should be properly displayed; or, if the circuit is transitioning between 0 and 1, both sections of the display will light. If the display remains blank, the test point is operating somewhere between 1 and 0, which means something is wrong. ◈

INFRARED LOGIC PROBE



Here's a device to help you troubleshoot infrared emitters. You can't buy it anywhere—you have to build it yourself!

ALEXANDER D. FIRMANI

IF YOU HAVE EVER TRIED to test an infrared LED with a fluorescent phosphor card, you'll be happy to know that there's a better way. This project, called the infrared logic probe, combines an infrared photodiode sensing circuit and a logic-probe pulse detecting circuit. The device is handy for checking just about any infrared emitting source.

The infrared logic probe consists of two sections: a probe and a PC board containing the electronics. The probe is packaged in a felt-tip pen case. The electronics are packaged in a plastic case and connected to the probe through a thin coaxial cable. The circuit will detect 0.3-milliwatt continuous levels and pulses as narrow as 40 microseconds at a frequency of 7.1 kilohertz. The probe's tip is small enough to fit in a slotted optical switch and other hard-to-reach optical sensing devices. Sensitivity to ambient light is not a problem, but the probe can be sensitive to sunlight or incandescent light that is rich in infrared. The photodiode is packaged in a visible-light rejecting case with a peak spectral response of 925 nanometers and a usable range of 725 to 1150 nanometers.

Circuit description

The schematic for the IR logic probe is shown in Fig. 1. Infrared light detected by photodiode D2 is amplified by IC1-a, half of an LM392N op-amp. Resistors R1 and R2 set the voltage gain of IC1-a. The value of R2 can be changed to decrease the sensitivity of the circuit if your application demands it. Connector J1 provides an output to an oscilloscope for the display of the amplified photodiode signal. This is handy when checking the pulsed emitters found in most remote controls.

Voltage comparator IC1-b squares up signals from IC1-a to digital logic levels for IC2-a. Resistors R4 and R5 set the reference voltage at the non-inverting input to one half of the supply voltage, and R6 provides hysteresis to prevent oscillations. Resistor R8 pulls up the comparator's output for a near rail-to-rail voltage swing for IC2-a. LED1 and current-limiting resistor R7 indicate the presence of steady-state infrared and also function with pulsed emitters, if the duty cycle is appropriate.

Monostable multivibrator IC2-a conditions pulse trains with any period shorter than the time constant of R9 and C1 into a low-frequency waveform with a very high duty cycle. Monostable IC2-b triggers on the waveform from IC2-a. This provides pulses for LED2 that are constant in frequency and duty cycle, regardless of the high input frequency to IC2-a. Any frequency input to IC2-a with a period longer than the time constant of R9 and C1 creates IC2-b output pulses with the same width as before at the input frequency. Resistor R10 and C2 set the output pulse width for IC2-b.

Tricolor LED2 (a dual red/green device) functions as a pilot lamp and indicator for pulsed infrared sources. LED2 will always glow red and pulse amber (red + green) when infrared pulses are detected. Transistor Q1 is an emitter-follower buffer that allows IC2-b to drive the green diode. Resistors R11 and R12 limit current for LED2.

The power source for the circuit is a 9-volt battery. Diode D1 protects the circuit from accidental voltage reversals when you install the battery. Power supply noise is decoupled by C3 and C4. Alkaline batteries will provide many hours of operation, because the circuit has low-power integrated circuits

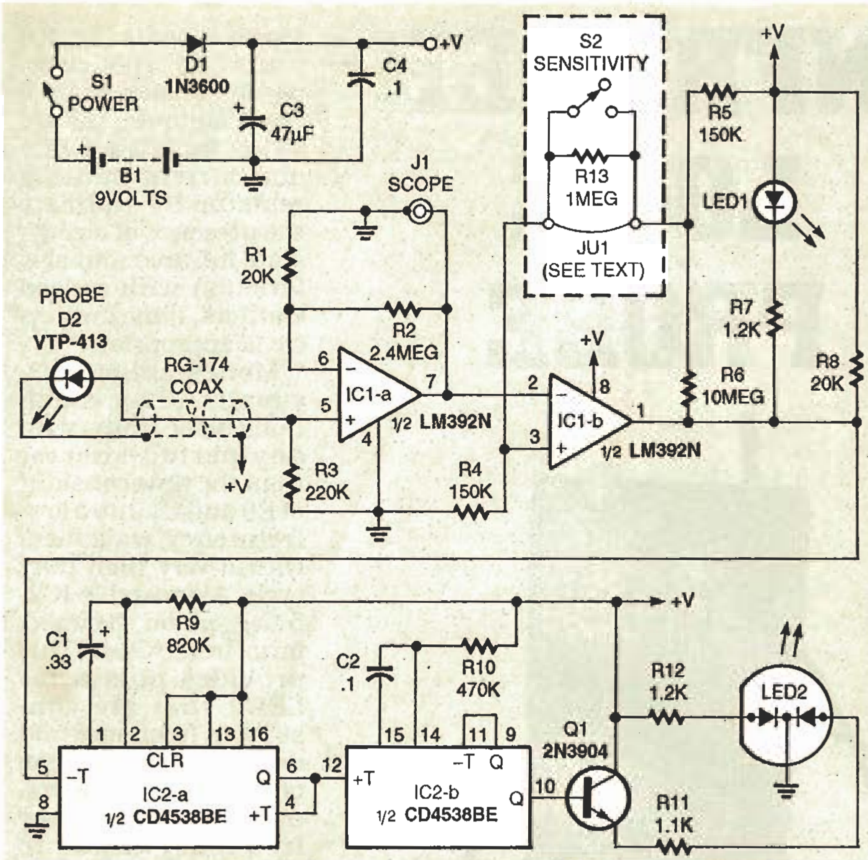


FIG. 1—SCHEMATIC FOR THE IR LOGIC PROBE. Infrared light detected by photodiode D2 is amplified by IC1-a, half of an LM392N op-amp.

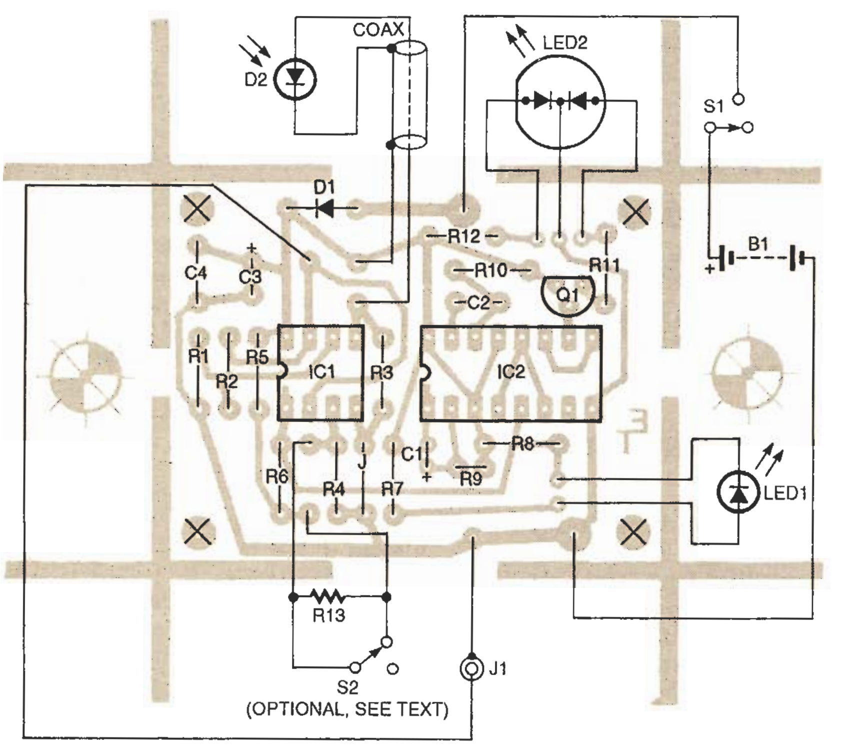


FIG. 2—PARTS-PLACEMENT DIAGRAM. Sockets for mounting the integrated circuits are recommended.

and high-efficiency LEDs.

Switch S2 (and R13) is optional. The probe will operate properly with a wire jumper in place of S2 for most emitters (remote controls) found on consumer electronic equipment. For certain devices such as slotted optical switches, CD laser diodes, and reflective sensors, more sensitivity might be desirable. If you plan to use the probe for LEDS that operate below 0.5 milliwatts, install S2 and R13—if not, you can install a wire jumper on the board instead of the switch.

Construction

The circuit can be built on a PC board or point-to-point wired. You can make your own PC board from the foil pattern provided here, but point-to-point wiring is practical because of the low component count. The photograph and parts placement diagram within this article will help. Sockets for the ICS are recommended. Figure 2 is the parts-placement diagram.

If you are using the same case as the prototype (see the Parts List), place the unpopulated PC board on the bottom half of the enclosure, centered and positioned about 5/16-inch from the battery compartment wall. Mark the four mounting holes and then drill them for 2-56 hardware.

Mount the components on the board, taking care not to make any solder bridges or poor connections. Note that R9 must be mounted vertically. Again, if you are using the recommended case, cut the leads on the LEDs to approximately 5/8-inch, and solder them to the board straight up. (If you are using a case with a different height, cut the LED leads to a length so that they will just extend through holes drilled in the top of the case after the board is mounted in the case.) Next solder 6-inch lengths of No. 24 wire for the switch/switches (remember that S2 is optional), jack J1, and the negative lead of the battery snap, to the points indicated in Fig. 2. Do not connect the switches and jack now. Mount the board to the bottom of the case with short 2-56 machine screws and nuts.

Drill two holes in the en-

PARTS LIST

All resistors are ⅛ watt, 5%.
R1, R8—20,000 ohms
R2—2.4 megohms
R3—220,000 ohms
R4, R5—150,000 ohms
R6—10 megohms
R7, R12—1200 ohms
R9—820,000 ohms
R10—470,000 ohms
R11—1100 ohms
R13—1 megohm (optional, see text)

Capacitors
C1—0.33 µF, 50 volts, electrolytic
C2—0.1 µF, 50 volts, Mylar
C3—47 µF, 16 volts, electrolytic
C4—0.1 µF, 25 volts, ceramic disk

Semiconductors
IC1—LM392N dual op-amp/comparator National Semiconductor
IC2—CD4538BE dual monostable multivibrator
Q1—2N3904 NPN transistor
D1—1N3600 or NTE-519 silicon diode
D2—Vactec VTP-413 photodiode (Allied Electronics)
LED1—High-efficiency yellow LED
LED2—Tricolor LED (Digi-Key P391 or equivalent)

Other components
S1—SPST slide switch
S2—SPST slide switch (optional, see text)
J1—Chassis mount phono jack
B1—9-volt alkaline or lithium battery

Miscellaneous: One 8-pin low profile IC socket, one 16-pin low-profile IC socket, 4 feet of RG-174 coaxial cable, 9-volt battery connector, Pac Tec HM-9VB or Radio Shack 270-293 plastic project case, 2-56 hardware, clear casting resin and catalyst or clear RTV silicone sealer, 5-minute epoxy, Sanford *Sharpie* fine-point permanent marker pen (use a dried up one if you have one), small piece of 1⁄10-inch thick clear Plexiglas, denatured alcohol, black paint, foam rubber, No. 24 hook up wire, solder.

closure's removable end plate: one ⅛-inch hole for the probe's cable and one ¼-inch hole for phono jack J1. Install J1 in the end plate and place the plate into the enclosure. Solder the wires to the jack, observing polarity and taking care not to melt the plastic end plate.

Next use the drill guide in Fig. 3 to mark and drill the holes in the enclosure's top. (The drill guide matches the PC board layout, so it can be used for any case.) Remember, S2 is optional, so don't drill holes for mounting it if you're not using it. The rectangular holes for the switches can be made by drilling a pilot hole in the center and carefully cutting away the plastic with a sharp hobby knife. Mount the switches and solder the wires to them. Figure 4 shows the inside of the completed unit.

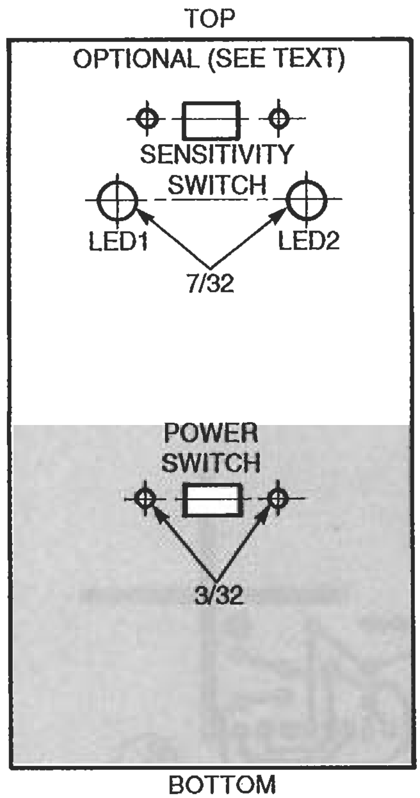


FIG. 3—DRILL GUIDE. S2 is optional, so don't drill holes for mounting it if you're not using it.

The IR probe

The prototype's photodiode probe case was made from a fine-point (not extra-fine point) Sanford *Sharpie* felt-tip marker pen. Figure 5 shows a cutaway view of the probe. To disassemble the pen, first pull out the writing tip with pliers. Grasp the pen's upper portion (the part that is the same color as the ink) and the pen's gray barrel. Then pull the pen apart with a twisting, bending motion. Wear rubber gloves to improve your grip on the pen. Discard the ink cartridge and wash the pen's interior with denatured alcohol to remove any remaining ink. Denatured alcohol will also remove the embossed lettering on the outside of the pen's barrel.

To make the "light pipe" that conducts light into the probe's interior, cut a small piece of 1⁄10-inch thick clear Plexiglas, ⅛-inch wide and 1¼-inches long.

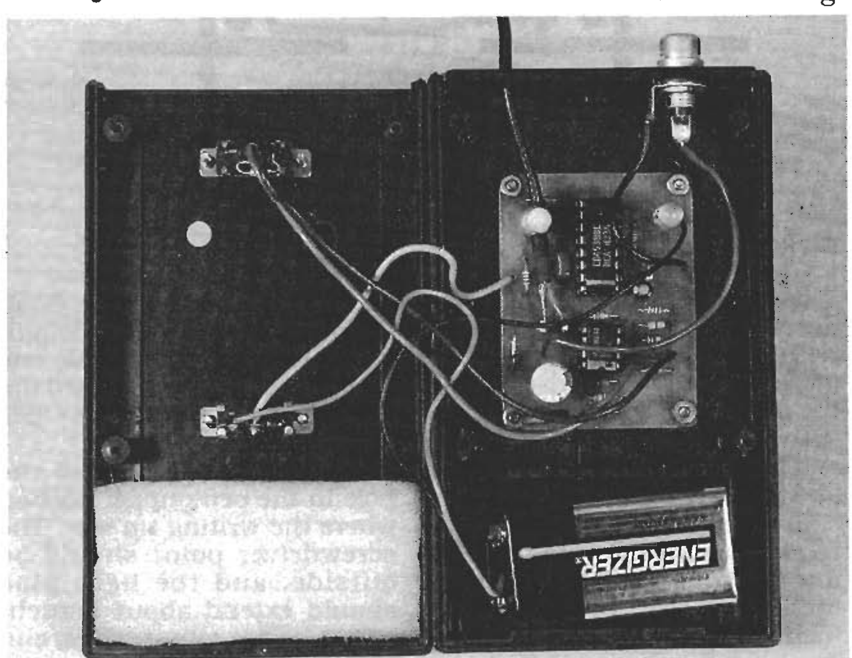


FIG. 4—THE INSIDE OF THE COMPLETED UNIT. You can use the same case (see the Parts List) or any other that will accept the board and a 9-volt battery.

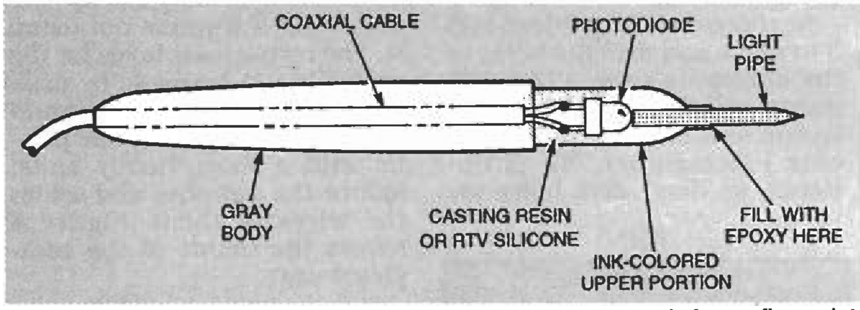


FIG. 5—CUTAWAY VIEW OF THE PROBE. The probe case was made from a fine-point felt-tip marker pen.

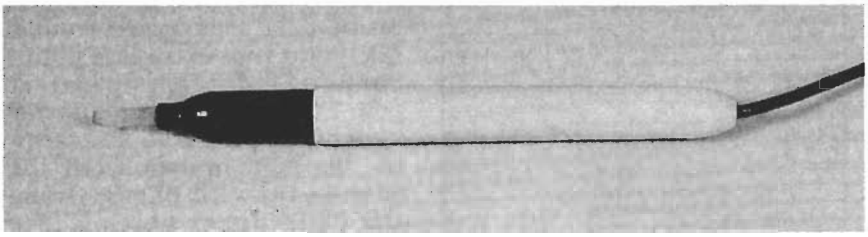
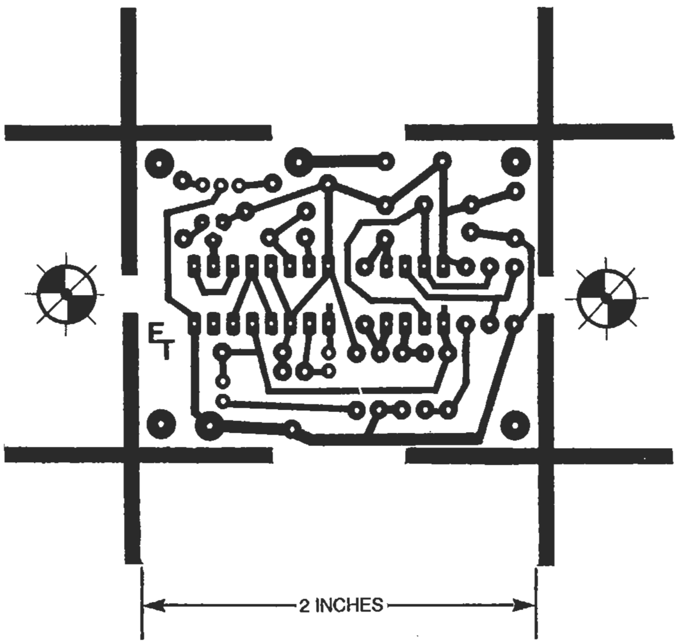


FIG. 6—THE COMPLETED PROBE. Use the pen's original cap to protect the light pipe from breakage.



IR PROBE FOIL PATTERN.

This can be accomplished by deeply scribing the sheet on both sides and clamping the piece to be cut off in a vise. Snap the piece off and cut it to length with diagonal cutters. File one end to a screwdriver-shaped tip, and then dress also clean up the

To make the "light pipe" that conducts light into the probe's interior, cut a small piece of 1⁄10-inch thick clear Plexiglas, 1⁄8-inch wide and 1¼-inches long. This can be accomplished by deeply scribing the sheet on both sides and clamping the piece to be cut off in a vise. Snap the piece off and cut it to length with diagonal cutters. File one end to a screwdriver-shaped tip, and then dress up the sides with the file.

Tap the light pipe into the hole in the pen's upper portion where the writing tip was. The screwdriver point should be outside, and the light pipe should extend about ½-inch. Mix some five-minute epoxy and seal the gaps where the rectangular light pipe enters the round hole in the pen's upper portion.

Prepare one end of the probe's coaxial cable by stripping about an inch of the jacket off and separating the braid with an awl. Place a length of heat-shrink tubing over the cut jacket for a neat appearance. Drill a hole in the end of the marker's gray barrel large enough to admit the coaxial cable.

The photodiode's leads must be bent to extend from the center of the device. Mark the photodiode's cathode lead (it's the shorter lead), and then cut both leads down to a ¼-inch length from the back of the device. Solder the leads of the coaxial cable to the leads of the photodiode; use the cable's braid for the cathode and the center conductor for the anode. Make sure the leads cannot short together!

Mix about an ounce of clear casting resin (available at an art supply store) according to the directions on the package. (Alternatively, you can use clear RTV silicone sealant.) Place the probe's upper portion in a vise with the open end facing upwards. Insert the photodiode in the open end, and push it down until its lens touches the light pipe. Pour the resin (or RTV silicone) in the open end and completely fill the void, encapsulating the diode in the marker's upper body. The coaxial cable should be positioned in the center of the upper body while the resin hardens overnight.

When the resin (or RTV silicone) has cured, apply black paint to the resin around the cable. This prevents infrared light from entering through the probe's gray barrel. When the paint dries, slide the barrel over the cable, and push the two sections of the probe together. Sand the light pipe with 400-grit sandpaper to finish the surface. Use the pen's original cap to protect the light pipe from breakage when it is not in use. Figure 6 shows the completed probe.

Final assembly & testing

Pass the free end of the probe's coaxial cable through the hole in the enclosure, and

Continued on page 87

Logic tester has unambiguous display

by S. Jayasimha Prasad and M. R. Muralidharan
India Institute of Technology, Madras, India

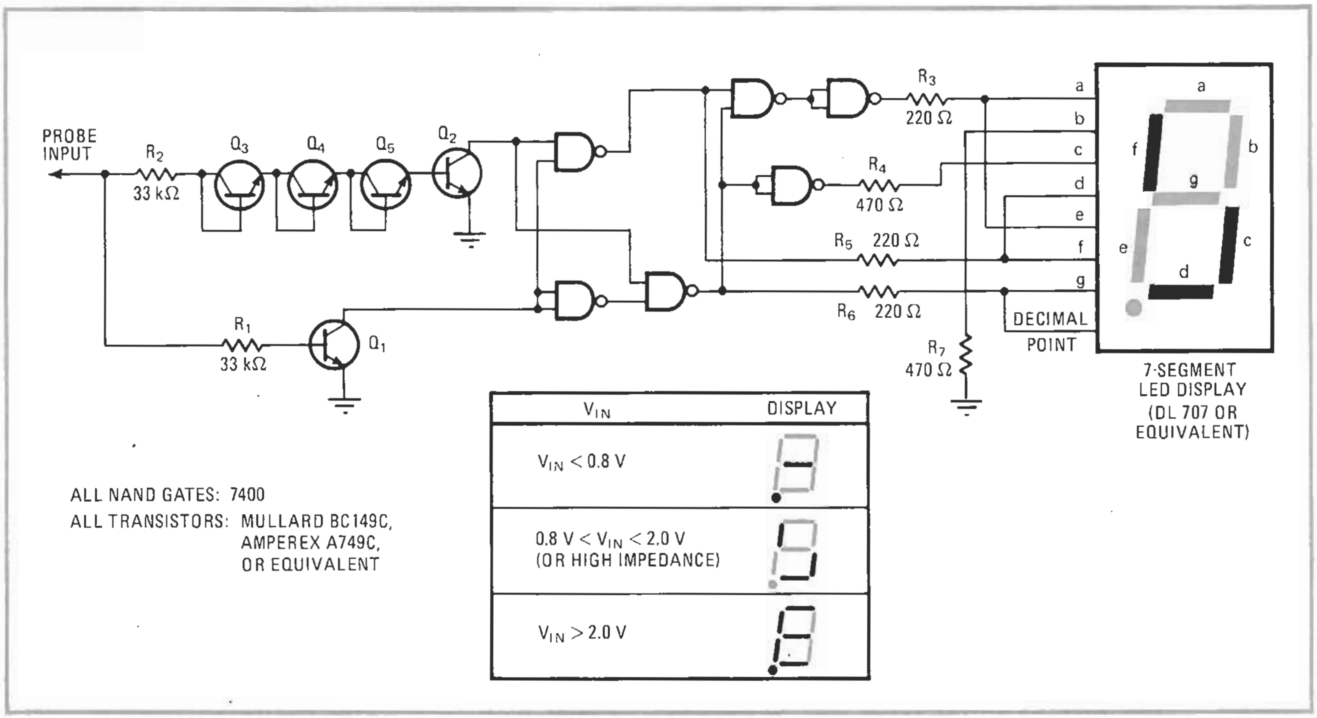
It usually takes a little time to interpret the display of most logic probes. But this tester flashes a totally unambiguous 0 or 1 or ? on its seven-segment display, the question mark indicating any voltage level not within the logic thresholds.

The circuit, built around transistor-transistor logic NAND gates, is shown in the figure. The output character display is controlled by the logic of input transistors Q_1 and Q_2. If an input of less than 0.8 v is encountered, both transistors are off and the display is gated to indicate a 0. For an input greater than 2.0 v, both transistors are on, and the display indicates a 1.

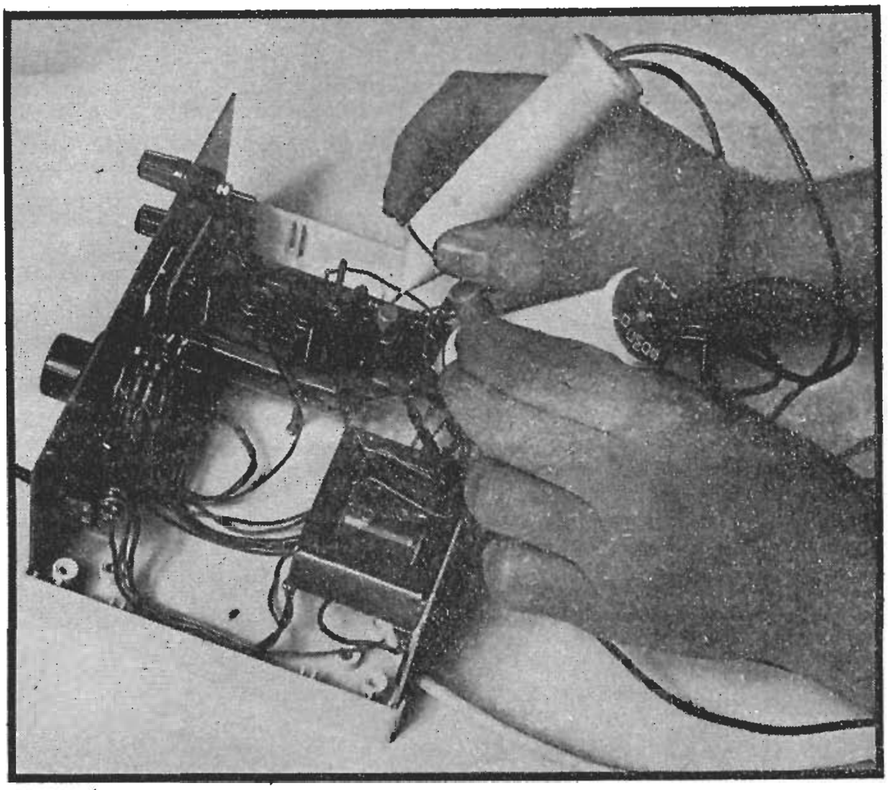
For an input that lies between 0.8 v and 2.0 v, Q_1 is on while Q_2 is off, and the NAND gating causes a question mark to be indicated on the display. A high impedance at the input registers a similar output.

The logic thresholds, being set by the voltage drops of the transistors, can be tailored to suit other needs. Transistors Q_3-Q_5, which determine the logic-1 threshold, may be replaced with an appropriate number of diodes, and diodes may even be added in the base circuit of Q_1 to raise the logic-0 threshold.

Resistors R_1 and R_2 limit the input current, and R_3-R_7 limit the currents to the display, which may be any low-power seven-segment light-emitting-diode unit. □



Unquestionably logical. TTL tester displays 0 for low level, 1 for high level, and ? for an open circuit or illogical level, as shown in table. Thresholds are set by transistors in the input circuit and may be changed to suit particular needs.



etiproject 120

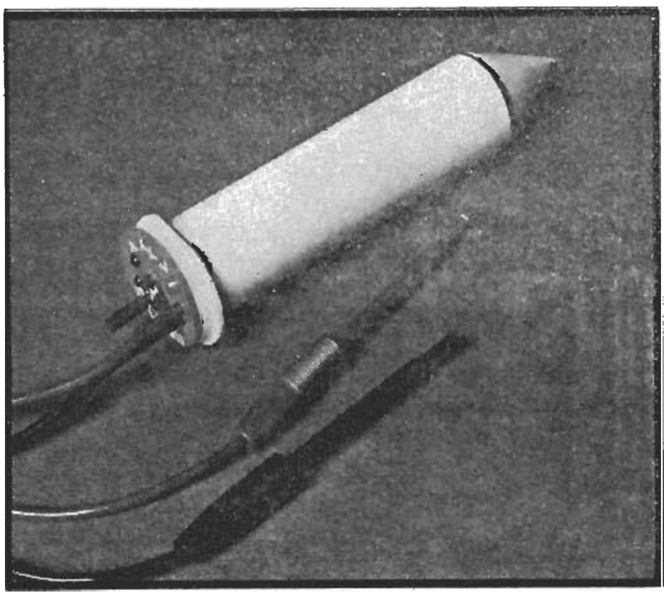
LOGIC PROBE

A basic tool for digital servicing.

THE SERVICING of digital equipment is greatly simplified by the use of a logic pulser and logic probe, for these two instruments enable one to follow circuit operation stage by stage.

THE PROBE

The probe must be capable of detecting pulses as short as 50 nanoseconds (for TTL operation) and make them visible. It was found that readily available linear ICs were not suitable as they are too slow and required dual supply voltages. Neither could CMOS be used as it also is too slow, for testing TTL gates, and its threshold voltages are not consistent. Further, TTL could not be used as it cannot withstand the voltages used with CMOS logic. This virtually means that the only devices that are suitable are discrete transistors.



The logic probe we built in a solder tube.

HOW IT WORKS

The probe consists of two independent voltage level detectors which, via pulse stretching monostables, drive light-emitting diodes to give a visual indication of the logic state being monitored. Transistors Q1 and Q4 form the low level or '0' detector, transistors Q5 and Q6 the high level or '1' detector whilst the remaining components form the pulse stretching monostables and visual indicators.

The high level detector works as follows. If the input level is below about 2.5 volts (1.3 volts above the level set on R17 by transistor Q5) transistor Q6 will be cut-off. When the input level rises above 2.5 volts, transistor Q6 will turn on, as will Q7, causing LED 2 to light – indicating a '1'. The transition at the collector of Q7 will, at the same time, be passed to Q8 turning it off. The current which was flowing through Q8 will now flow via R22 in to the base of Q7 holding it on even though Q6 may by now have stopped conducting. After fifty milliseconds the charge on C2 will leak away via R19, 20 allowing Q8 to conduct. When Q8 conducts it robs the current from the base of Q7 turning it and the LED off. However should the voltage at the tip of the probe still be present Q6 will still be turned on holding on in turn Q7 and the LED.

Resistors R11, 12, 13 and 14 set the operating conditions of Q5 such that the threshold voltage is optimized for either TTL or CMOS. As CMOS logic works on supply voltages ranging from five to fifteen volts, transistor Q5 has been arranged to track the supply so that the correct threshold is maintained at all times.

The low level detector works in exactly the same fashion except that it is inverted in order to detect pulses which approach within 0.45 volts of the negative line (TTL only). Each PNP transistor and each NPN transistor have been replaced with their complements. In this case Q4 sets the thresholds and the circuit operates exactly as stated for the high detector. Note that the diodes have also been reversed.

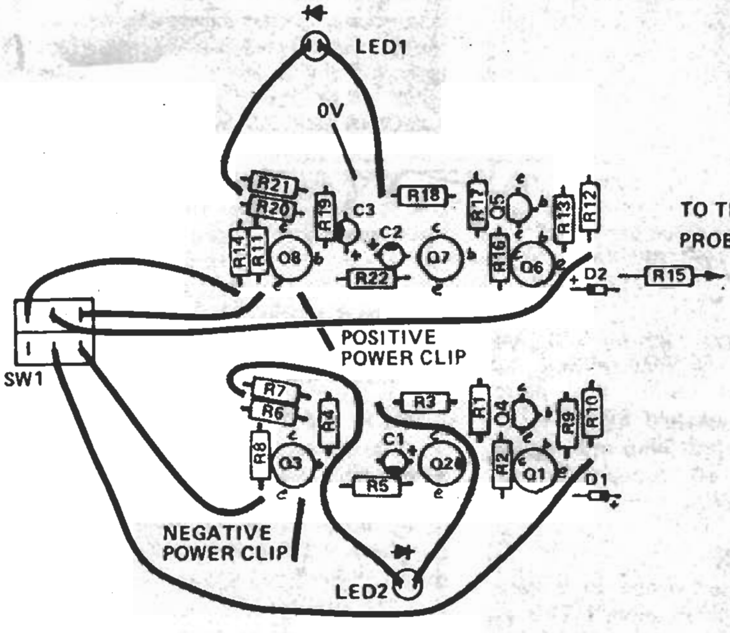


Fig. 3. Component overlays for the two comparators showing interconnection wiring.

PARTS LIST – ETI 120

R3,18	Resistor	680	¼ W	5%
R4,15,19	"	1 k	"	"
R10,13	"	1 k8	"	"
R1,9,12,17	"	2 k7	"	"
R5,14,22	"	3 k3	"	"
R2,16	"	8 k2	"	"
R7,21	"	10 k	"	"
R8,11	"	27 k	"	"
R6,20	"	100 k	"	"
C1,2	Capacitor	0.47 µF	25 V tantalum	
C3	"	10.0 µF	25 V "	
D1,2	Diode	IN914 or similar		
Q1,7,8	Transistor	BC177		
Q2,3,6	"	BC107		
Q4	"	BC179		
Q5	"	BC109		
SW1	Switch	Two pole, two position miniature toggle		

PC boards 2 off ETI 120
Probe case (see text)
LED 1, 2 Light emitting diodes TIL209 or similar
2 Alligator clips or Ezy-hooks

CHARACTERISTICS

PULSER – ETI 121

- Will source, or sink, up to 500 mA.
- Operates on supply voltages from 5 to 15.
- Suitable for both TTL and CMOS.
- Power supply drain less than 15 mA under worst case conditions.
- Press for '1' release for '0'. High impedance at other times (>1 M).
- Will drive capacitive loads up to 1000 pF.
- Protected against accidental reversal of supply leads.
- Duration of pulse 500 nanoseconds.

PROBE – ETI 120

- Pulses as narrow as 50 nanoseconds will be detected.
- Stretches narrow pulses to 50 milliseconds for ease of detection.
- Operates on supply of 5 to 15 volts.
- Suitable for TTL or CMOS.
- True '1' and '0' level detectors. Neither LED is alight if the circuit is faulty or the probe is not making contact.
- Current drawn from the circuit is less than 20 microamps.
- Current drawn from power supply (one LED alight) 12 mA on 5 volts, 35 mA on 15 volts.

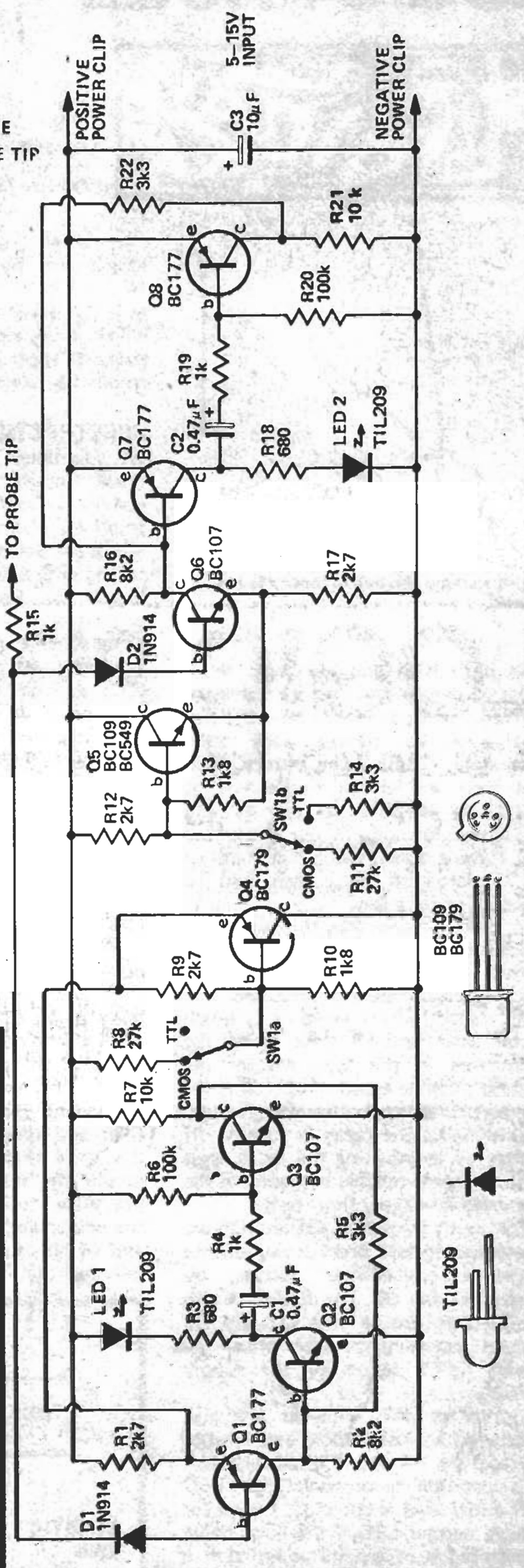


Fig. 1. Circuit diagram of the logic probe

LOGIC PROBE

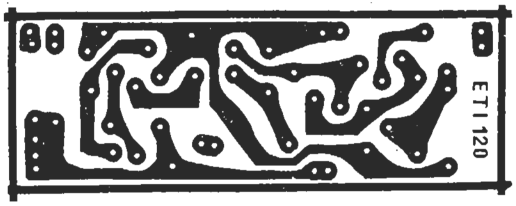


Fig. 2. Printed circuit board for the logic probe (2 required). Full size 23 x 66 mm.

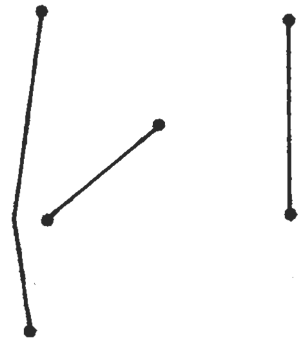


Fig. 4. Linking required between the two boards.

As both high and low logic states must be detected, a discrete transistor voltage-comparator circuit was designed to detect each state separately. These comparators must not load the circuit under test as CMOS is sensitive to current and capacitive loading. In our prototype the current drawn was a maximum of 19.7 microamps for a high, and 10 microamps for a low.

In both comparators the transistors associated with the pulse detector are turned on by an input level that exceeds the comparator threshold.

As transistor turn-on time is much faster than turn-off time, using the transistors in this way ensures the highest possible speed of operation for the particular types of transistors used. Additionally, the delay in turning off assists by lengthening the pulse, thus ensuring more reliable triggering of the monostable on very short pulses.

The input transistors Q1 and Q6 are protected against breakdown, due to excessive base-emitter voltage, by diodes D1 and D2. The diodes are also required to ensure that Q1 and Q6 remain conducting even when the probe tip is taken to the supply voltage.

Transistors Q3 and Q8 are also protected against reverse base-emitter voltages by R4 and R19 respectively.

In operation the probe will light LED 1 if a low level is detected, LED 2 for a high, neither LED if the point being monitored is at ground potential or a poor contact is made with the tip, and both LEDs will light if there is a pulse train present.

A single pulse input will be lengthened, by the monostables, to 50 milliseconds with the pulse polarity being indicated by the LED which is illuminated. Thus even single pulses as short as 50 nanoseconds may readily be detected.

CONSTRUCTION

We assembled our probe in a case made from a solder tube. This is commonly available from component shops for about 35p (containing Ersin Multicore Solder). Any probe case or tubing with a diameter of 23mm and a length at least 90mm (excluding nozzle) will do. The solder tube has a detachable plastic end-cap which supports SW1 and the LEDs. SW1 is used to hold a small name-plate in position as shown in Fig. 6. Two LEDs are mounted into the end plate, together with SW1, and after soldering leads to the LEDs they should be passed through the holes in the plate, and the plastic end-piece, and secured in position with a drop of epoxy cement. Another hole is drilled in the stopper through which is passed the two supply-voltage leads.

A removeable nozzle has to be made and for this we used a polyester resin filler (Isopon or any of the car body repair fillers is ideal). First saw of the original nozzle and line the inside of the tube with grease or cow gum. This stops the filler making a permanent joint. Then mix some filler and spread it for about 25mm down the inside of the tube. Roughly mould the nozzle shape around the polythene tubing which comes with the solder and bed this firmly in the end of the tube. After a couple of minutes the nozzle can be whittled into shape. After hardening remove the nozzle and clean up the inside face (saw off the rough moulding). Remove the polythene tubing and in the hole R15 and the probe tip can be fixed with more filler. Use a darning needle or one of the needles made for sewing up knitting as the tip. Do not leave more than 15mm protruding or the needle is likely to break. Finally the nozzle can be filed and sanded to give a neat appearance.

The electronics are built on two printed circuit boards. The two boards are identical and care should be taken to use the correct overlay for each board as different transistors are used and some components are reversed on the two boards. Note particularly diodes D1 and D2 and capacitors C1 and C2. Also note how the two boards are linked together and that the supply rails are reversed. No difficulty should be experienced if the printed-circuit boards and the component overlay as specified are used.

Connect the leads from the stopper assembly to the boards. Position the boards together, copper side to copper side, with a piece of insulating material between them. Make sure that the board assembly will fit into the tube without bending the sides. Cut a piece of cardboard or plastic 75 x 85mm, roll it into a tube and fit in the probe body. Now fit the board assembly into the tube – it may be necessary to dress the sides of the boards with a file to obtain a neat fit.

The tip may now be connected and both ends screwed into position. Finally, alligator or, better still, Ezy-hooks clips should be fitted to the supply leads.

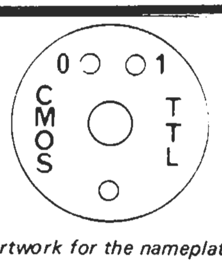


Fig. 5. Artwork for the nameplate on the probe.

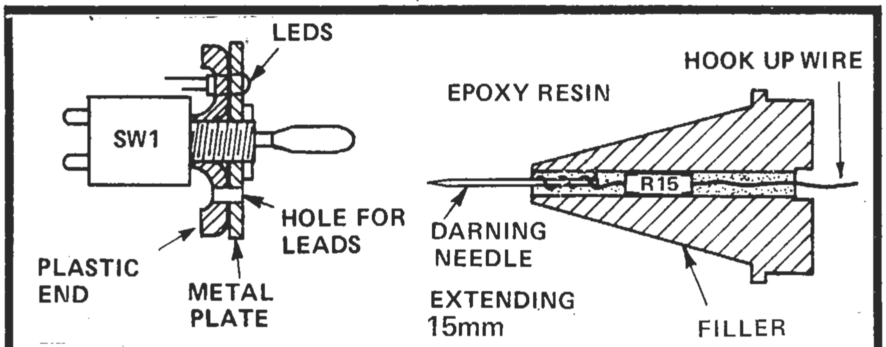


Fig. 6. How the probe ends are constructed.

etiproject 121

LOGIC PULSER

Companion instrument to the logic probe.

ALTHOUGH the logic probe used alone is a very valuable piece of digital test equipment, it is limited by the fact that it can only observe the logic states that occur naturally within the piece of digital equipment under test.

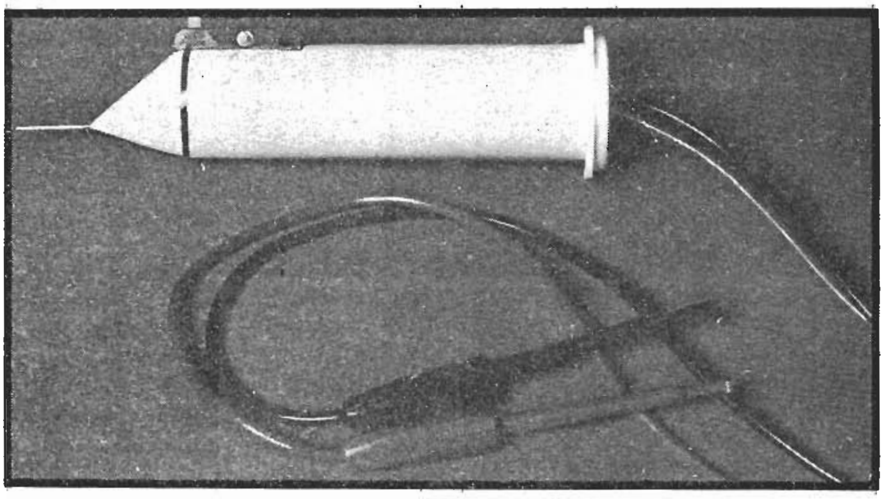
The logic pulser is a further valuable tool that is used in conjunction with the logic probe. It's function is to override the naturally occurring state at the particular circuit node under test. That is, if the circuit node is normally at the '1' state, the pulser will drive that node to a '0' for a very short period when the microswitch is pressed. If the circuit node is normally at a '0', the probe will drive it to a '1' for a very short period when the microswitch is released. Thus it puts a short pulse into the circuit node regardless of it's normal state when SW1 is pressed and released.

A fairly powerful pulse is required to override the normal logic state of a circuit node and care must be taken to ensure that the devices either driving, or being driven from that node are not damaged. This is achieved by making the pulse of very short duration. In our probe the pulse width is 500 nanoseconds. Thus although the pulse is of high current the energy released is insufficient to damage normal logic devices.

The probe must be suitable for driving either TTL or CMOS that is, it must operate from a supply ranging from 5 to 15 volts, it must be capable of operating into loads having a capacitance as high as 1000 picofarads and must supply a current pulse of around half an amp. All these conditions are fulfilled in the ETI 121 Pulser and the prototype has been tested by causing it to generate several hundred thousand half amp pulses without any problems. The probe is quite capable of pulling two (in parallel) high-power TTL 'zeros' to a '1' level and this is the most severe condition it has to meet.

At the same time as providing high level pulses, the pulser should not draw too much supply current as some CMOS supplies may not have much additional capability. Under worst-case conditions the ETI Pulser drew a maximum of 10 mA.

The probe is capable of overriding a normal logic state but is not capable of overriding a point that is connected to ground or to a supply rail. Thus by pulsing a node and at the same time looking at that point with the logic probe it is possible to tell if that point



A basic tool for digital servicing.

is shorted to either rail.

The logic pulser combined with the logic probe is thus capable of performing stimulus — and — response testing of both TTL and CMOS logic and of determining the exact nature of a fault at a particular circuit node.

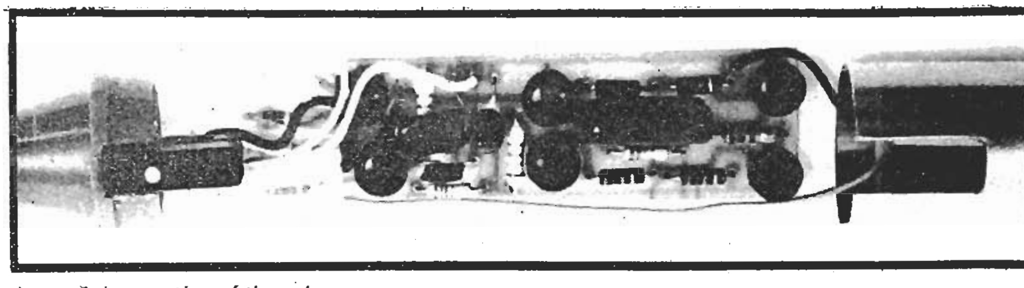
CONSTRUCTION

Construction is greatly simplified if the printed circuit board of Fig. 2, is used. This should have the components assembled to it in accordance with the component overlay. Note particularly the polarity of C1, and the connections of the microswitch such that the normally-closed terminal of the switch is connected to the base of transistor Q1. Also make sure that a red lead is connected to the positive rail of the board, and a black lead to the negative rail, to facilitate later connection.

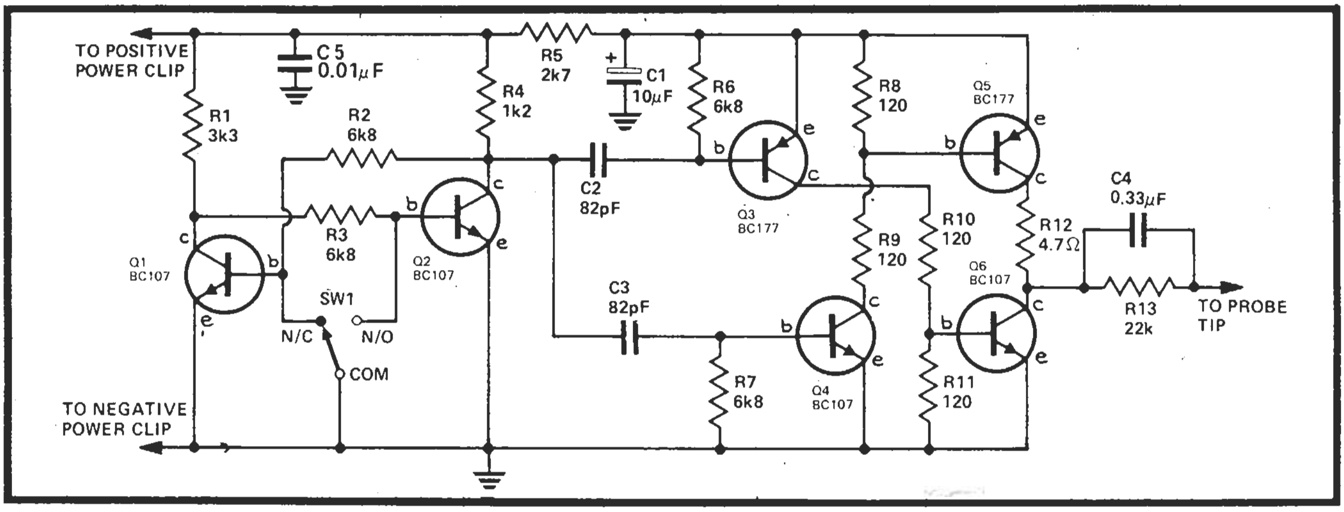
We used the same probe case for the pulser as for the logic probe. The probe tip again uses a darning needle and the microswitch SW1 is mounted into the plastic filler tip as follows. First check switch to determine what the contact arrangement is. Attach colour coded wires to the switch, to aid later identification. If you use a solder tube as a case you have to saw off the nozzle and cut a slot for the microswitch. Keep the switch as far forward as possible to give more room for the pcb. Line the tube end with grease so that the filler will not stick. Wire or tape the switch into position and fill the end of the tube with filler. Make sure there is a hole, for fixing the probe tip by inserting the polythene tubing which comes with the solder. Roughly mould a nozzle. After a couple of minutes this can be carved with a knife. Then remove the polythene tubing and insert the needle. Fix this into the correct position using more filler. When the filler is hard the nozzle can be removed for filing and sanding into shape.

Connect the probe tip and microswitch leads to the board and, after insulating the inside of the case with cardboard or plastic as previously described, insert the board into the case. Pass the supply leads through the plastic end piece and then fit both end pieces and secure them in position. Finally attach Ezy-hooks or crocodile clips to the supply leads.

Keep the supply leads as short as is reasonably possible as excessively long leads will degrade the performance of the pulser.



Internal construction of the pulser.



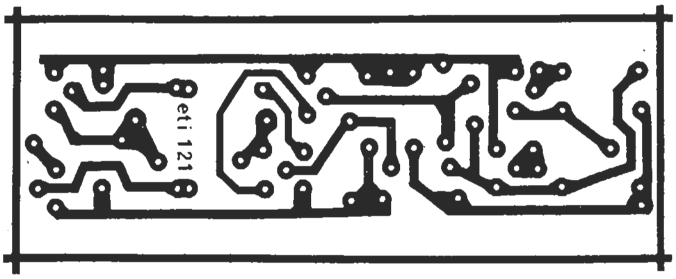


Fig. 2. Printed circuit board for the pulser. Full size 23 x 65mm, or 23 x 85mm. If this board is made to 23 x 85mm (same scale as shown here) it will not fit into a solder tube case. In this case the board should be reduced to 65mm in length (as shown below). To save confusion when ordering the board ask for ETI121–85 or ETI121–65.

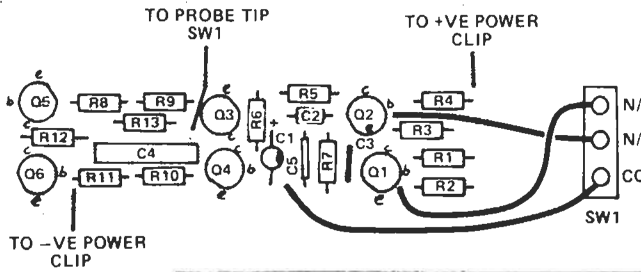


Fig. 3. Component overlay for the pulser.

HOW IT WORKS

The pulser is activated whenever microswitch SW1 is pressed. This switch controls the state of a flip-flop formed by transistors Q1 and Q2. The flip-flop is necessary to prevent contact bounce of the microswitch from having effect.

The output transistors of the probe, Q5 and Q6, which in turn are controlled by Q3 and Q4 are both normally off. However when the microswitch is pressed Q2 turns off and the rising voltage on its collector is coupled, via C3, to the base of Q4 turning it on. This in turn, turns on Q5 pulling the output to the positive rail. This generates a '1' pulse if the point under test was at a '0' level. Resistor R12 provides a current limit of around 500 milliamps. Due to the small value of C3 the pulse output is only about 500 nanoseconds long, short enough so that there is insufficient energy to damage the device under test.

When the switch is released Q2 turns on and the negative-going edge is coupled to Q3 by C2 turning it on. This turns on Q6 causing the output to be pulled to the negative rail. This gives a '0' pulse which, like the '1' pulse, is only 500 nanoseconds long.

The output from the probe is taken via the paralleled combination of R13 and C4 where C4 carries the current and R13 discharges C4 between pulses. This network protects the probe against the condition where the probe is inadvertantly connected to a voltage which is above or below the logic supply rails.

Resistor R5 isolates the high current pulse from the power supply, capacitor C1 providing the actual current needed.

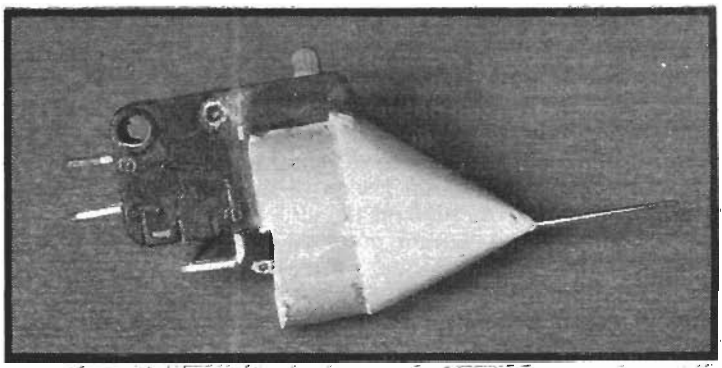


Fig 4. The tip of the logic pulser, made from a darning needle, a microswitch, and a small quantity of car body filler.

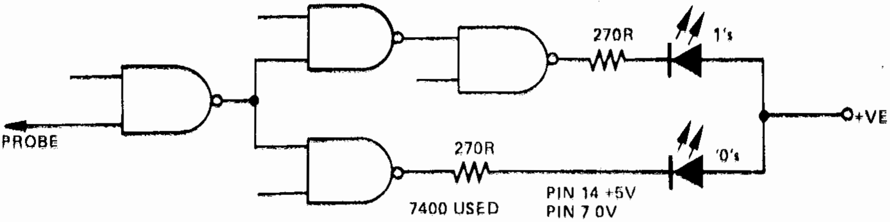
SPECIFICATION
See page 33.

PARTS LIST

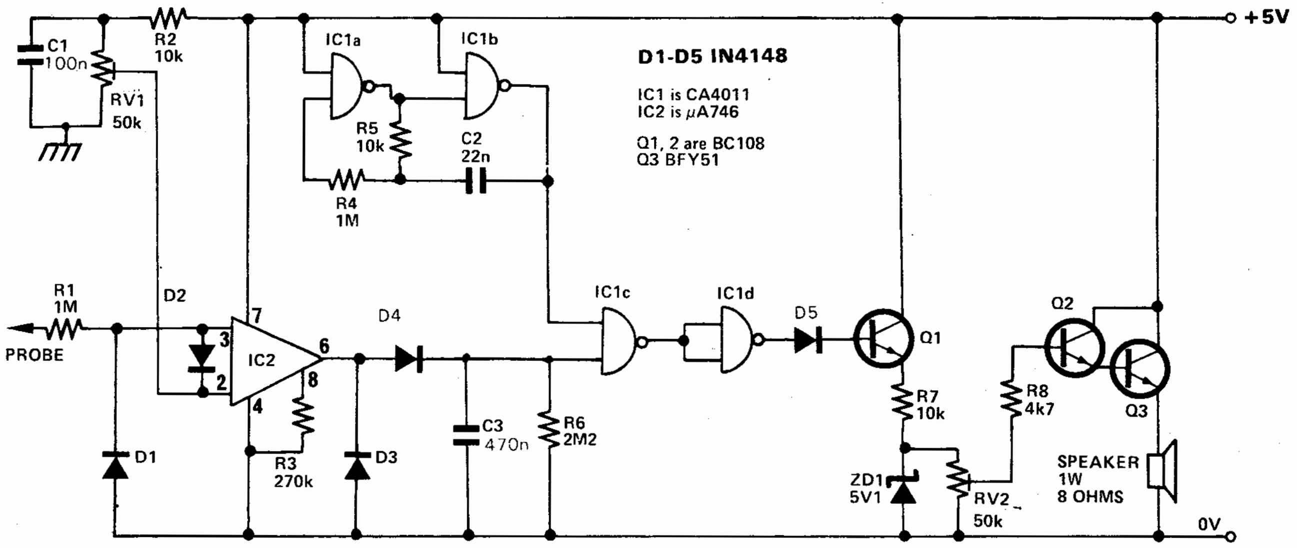
R12	Resistor	4.7 ohm	¼W	5%
R,8,9,10,11	"	120 ohm	¼W	5%
R4	"	1k2	¼W	5%
R5	"	2k7	¼W	5%
R1	"	3k3	¼W	5%
R2,3,6,7	"	6k8	¼W	5%
R13	"	22 k	¼W	5%
C2,3	Capacitor	82 pF	ceramic	
C5	"	0.01 μF	polyester	
C4	"	0.33 μF	polyester	
C1	"	10 μF	25 V tantalum	
Q1,2,4,6	Transistor	BC107 or similar		
Q3,5	"	BC177 or similar		

1 micro switch
2 crocodile clips, Ezy-hooks or Doram probes
PC board ETI 121
probe case (see text).
polyester filler (from a car accessories shop).

LOGIC PROBE WHICH DISPLAYS 1's & 0's



The logic probe automatically goes to logic 1 when not in use and uses the power supply of the circuit under test.



AUDIBLE LOGIC STATE INDICATOR

The indicator will work with either TTL or CMOS circuits. A useful feature is that the unit can be powered by the same supply as the one supplying the circuit under test. Logic state 1 at the probe will produce an audible tone on the loudspeaker. A switching signal at the probe also activates the loudspeaker.

RV1 sets the threshold level at which IC2 will switch on. This is normally set at maximum (wiper at the R2 end). RV2 sets the volume of the audible tone, and can be adjusted as required.

IC2 can be substituted by the equivalent LM748, but R3 must be removed first.

A SIMPLE LOGIC PROBE

Few parts combined to provide a versatile logic state indicator.

BY ROBERT LEFFERTS

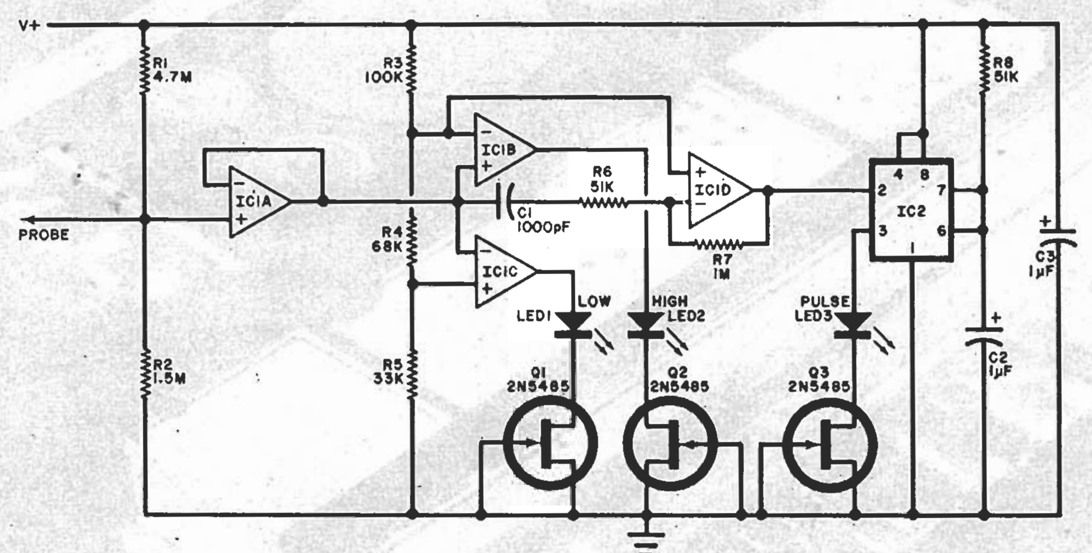
THIS circuit was inspired by R.M. Stitt's "Build a Direct Reading Logic Probe" in the Steptember 1975 issue of POPULAR ELECTRONICS. Although the seven-segment display technique used in that article was intriguing, I found that it could lead to some problems. For example, if a signal is oscillating between about 0.5 and 3 volts, at a frequency of, say, 100 Hz, the signal would appear to be low, high and a pulse—all at the same time! Either the digit "8" would be displayed or, if the monostable overrode the high and low displays, a "P" would appear. However, there would be no relative indication of duty cycle.

The probe presented here not only solves this problem, but is also useful with CMOS logic levels, as well as 555 and other timer outputs. It will operate on supply voltages ranging from 5 to 15 volts and draws less than 12 mA. Its op amp input circuit has high input impedance and low capacitance.

Further, three LED's display high, low and pulse levels and the approximate duty cycle (indicated by relative brightness). The possible states displayed range from all three LED's lit (a square wave with about a 50% duty cycle and high and low levels above and below V/2 and V/7, respectively) to only the PULSE LED glowing. This indicates a train of narrow, positive- or negative-going pulses riding on a level somewhere between the lower and upper switching thresholds, or some other oscillation with amplitudes between these two levels.

Voltage follower *IC1A*, one fourth of an LM324 quad op amp, isolates the probe from the rest of the circuit and passes the input signal to the low (*IC1C*) and high (*IC1B*) comparators, with thresholds of V/7 and V/2 furnished by the resistor string *R3-R5*. The input signal also drives *IC1D*, an ac amplifier with a gain of 20. This amplifier triggers *IC2*, a 555 one-shot with a pulse width of about 0.05 second. The state-indicating LED's are current limited by FET's *Q1, Q2,* and *Q3*.

Construction of the probe is a matter of taste, but most probably you'll want to assemble it in a cigar tube or a length of PVC tubing. Either pc or perforated board techniques can be used. LED size and color is left to the individual. Choose a distinctive color combination—possibly red for LOW, green for HIGH, and yellow for PULSE. After a few days of use, you'll probably agree that a versatile logic probe is very handy to have around. ◈



PARTS LIST

C1, C2—1-µF, 25-volt tantalum capacitor
C3—1000-pF disc capacitor
IC1—LM324 quad op amp
IC2—555 timer
LED1-LED3—20-mA light emitting diodes
Q1-Q3—2N5485, HEP F0021 field effect transistors
R1—4.7-megohm, ¼-W, 5% resistor
R2—1.5-megohm, ¼-W, 5% resistor
R3—100,000-ohm, ¼-W, 5% resistor
R4—68,000-ohm, ¼-W, 5% resistor
R5—33,000-ohm, ¼-W, 5% resistor
R6—51,000-ohm, ¼-W, 10% resistor
R7—1-megohm, ¼-W, 10% resistor
R8—51,000-ohm, ¼-W, 10% resistor
Misc.—Probe tip, case, pc or perforated board, solder, hookup wire, etc.

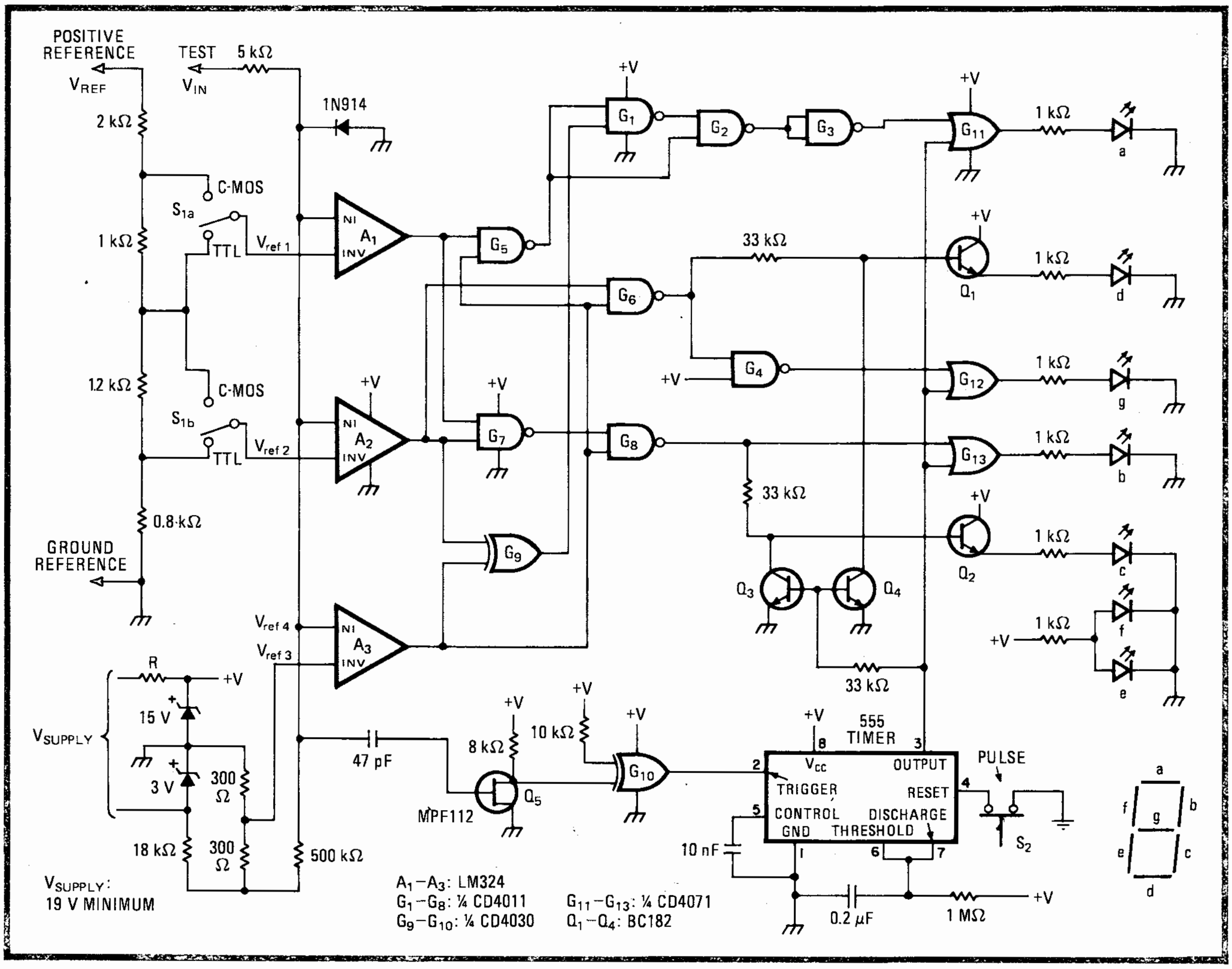
Dynamic logic probe displays five states

by Mihai Antonescu
Federal Institute of Technology, Lausanne, Switzerland

Providing the convenience of the logic probe proposed by Prasad and Muralidharan[1], which utilizes a seven-segment display readout rather than discrete LEDs or lamps, this five-state detector also senses the presence of pulses and differentiates between the logic 0 and open-circuit conditions. Furthermore, provision has been made to bias the probe via its external-reference inputs, permitting it to check logic levels in circuits built with either TTL or complimentary-MOS devices.

As shown in the figure, the test signal, V_{in}, is compared with reference voltages V_{ref1} to V_{ref4} at comparators A_1 to A_3. Voltages V_{ref1} to V_{ref2} are derived from the supply that powers the circuit under test, with V_{ref3} (developed from the probe's power source) and V_{ref4} at approximately 0.05 volt and 0.1 V below ground, respectively. Switches S_{1a} and S_{1b} at the voltage divider are used to set the required logic-level references at A_1 and A_2 in order to check either TTL or C-MOS circuits.

Gates G_1–G_{13}, comprising the combinational-logic detector, determine V_{in}'s relation to V_{ref1}–V_{ref4} and activate the appropriate segments of the display (see table). A_1 and A_2 are used to check for the logic 1, 0, and guard-band conditions. A_3 is used to detect the no-connection, or open-circuit, condition, which can be differentiated from the logic 0 state because V_{ref4} is maintained at 0.1 V below ground. Note that the logic 0 state for TTL will typically be 0.4 V and is hardly ever below 0.2 V, whereas the logic 0 state for C-MOS will be typically 0.01 V.



All-state. Logic probe having seven-segment display detects logic 1 and guard-band conditions, can differentiate between logic 0 state and open circuit, and senses a pulse train. Unit can check logic levels in circuits built with the two most popular families, C-MOS and TTL.

RESPONSE OF FIVE-STATE LOGIC PROBE

Test voltage		Display	Comparator			Display segments						
C-MOS*	TTL	Letter	A_1	A_2	A_3	a	b	c	d	g	e	f
$V_{in} < 40\%$	$V_{in} < 0.8$	L	L	L	H				on		on permanently	on permanently
$40\% < V_{in} < 60\%$	$0.8 < V_{in} < 2$	F	L	H	H	on				on		
$V_{in} > 60\%$	$V_{in} > 2$	H	H	H	H		on	on		on		
NC	NC	O	L	L	L	on	on	on	on			
pulse	pulse	P	–	–	–	on	on			on		

*% of V_{ref}

Switch S_2 must be depressed to catch any expected input pulses having a width down to 15 nanoseconds. This action resets the 555 one-shot, enabling it to override the displayed symbol with the letter P when the pulse arrives. If a train of pulses having a repetition rate greater than about 0.2 seconds (the time constant of the 555) is detected, the P will be displayed indefinitely. With faster one-shots, pulses of 5 ns can be snared.

The probe can be powered by any dc source having a minimum voltage of 19 V. Resistor R should be selected to pass about 30 mA to the probe circuit. □

References

1. S. Jayasimha Prasad and M. R. Muralidharan, "Logic tester has unambiguous display," *Electronics*, March 3, 1977, p. 117.

Tone Probe for Testing Digital IC's

BUILD

This easy-to-build test instrument costs less than $16 and emits an audible tone to denote low and high logic-levels

LARRY FORT

HAVE YOU EVER COMPLETED A DIGITAL circuit project only to find that something is wrong? It's no problem if you have an oscilloscope, particularly one with a triggered sweep, but if your scope isn't too good, troubleshooting digital circuits will be difficult.

What if all you have is a voltmeter? They're fine for low-speed circuits where a signal stays at a given level long enough for the meter to react and settle at a reading, but fast pulses and high repetition rates make meters almost useless.

A logic probe then, is almost indispensable if you're building projects that use digital circuits, because you must be able to tell whether inputs and outputs are high, low or floating. Many probes are available today, but most of them use some kind of visual indication to tell the signal level. If your hands are steady and you have your wits about you, it's possible to look away from what you're probing to determine the signal level, then immediately return your attention to the probe and start again at the next lead. If not, you're in trouble unless you have a *tone probe.*

The tone probe described here uses sound to tell the status of the signal being probed. That means you can probe difficult points rapidly and know each signal level without any distractions. It has the added advantage of detecting intermittent problems just by the sound "pattern" changes that occur as you manipulate other components of the circuit.

There are really only three voltage levels of interest. A voltage level of less than 0.8 is considered *low* for almost all DTL and TTL families of digital IC's. Voltages greater than 2 volts are considered *high*, and any voltages between 0.8 volts and 2 volts are not guaranteed to be either high or low and can cause noise problems. The tone probe has an input circuit that senses the condition of the signal and produces either a low-pitched tone for low-level signals, or a high-pitched tone for high-level signals. Any signal between these two produces no tone.

An important consideration for all logic probes is that they must have a high input impedance so they will not load down the circuit under test. A low input-impedance can cause a good circuit to malfunction.

The tone probe is powered by the circuit-under-test rather than being self-powered, for two reasons: The supply voltage affects the switching points to some extent; and it is necessary to have a ground lead to all probes so the inconvenience of clipping one or more wires for B+ is insignificant.

How it works

Figure 1 shows the schematic diagram. Resistors R1 and R2 form a voltage divider that supplies about 1.5 V to resistors R3 and R4. Resistor R3 supplies some base drive to Q1, causing it to conduct. Transistor Q1's collector will be near ground and D1 is reverse-biased, thus no current flows through D1 to IC1.

Transistor Q1 is the low-level input detector. When the circuit-under-test forces the voltage at the junction of resistors R1 and R2 below approximately .5 V, Q1 stops conducting. Its collector rises toward +5 V through R7. This action forward-biases D1 and supplies current to IC1. IC1 is the popular 555 one-shot. It is connected to run in the astable mode. When R7 and D1 supply current to IC1 pin 7, IC1 oscillates at a low frequency.

Transistor Q2 is the high-level detector. Resistors R5 and R6 form a voltage divider that provides approximately 1.6

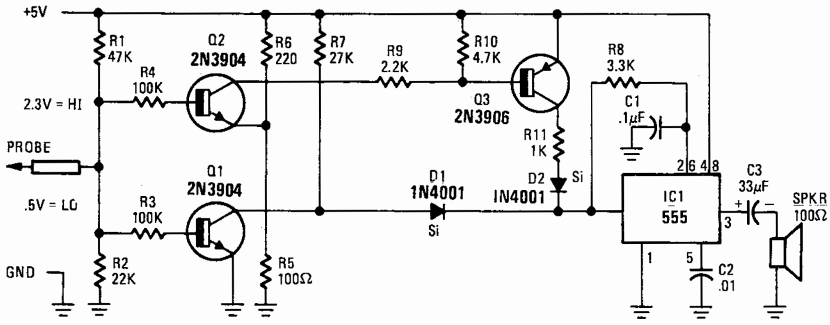
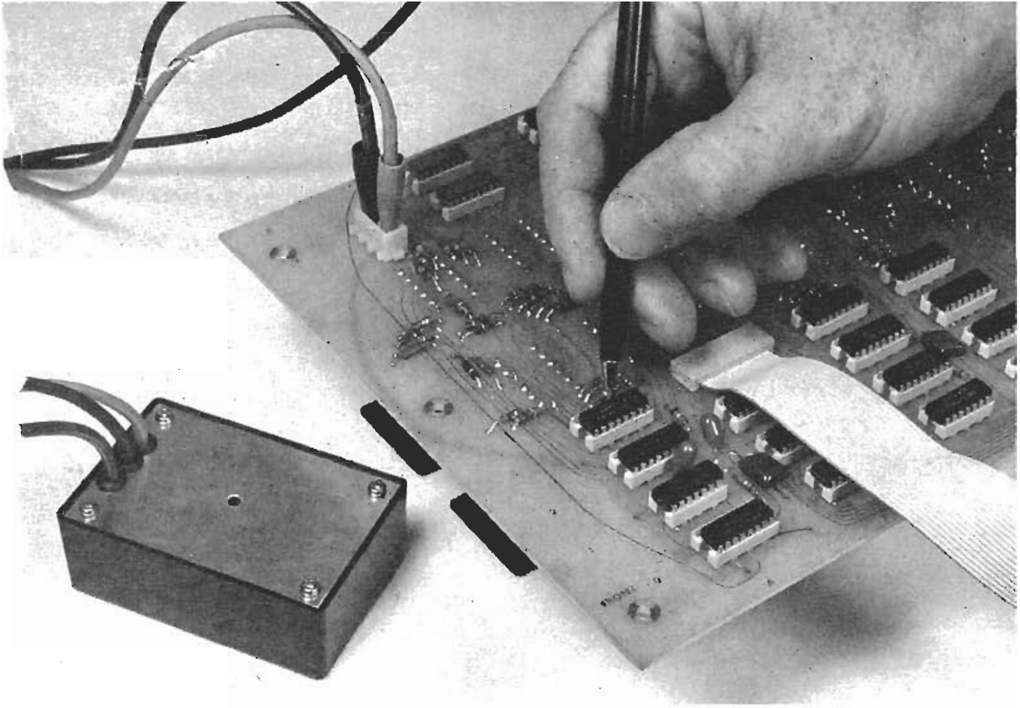


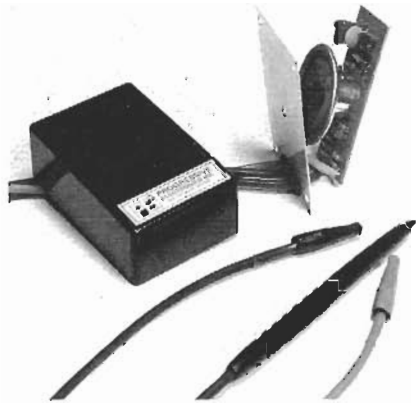
FIG. 1—THE TONE PROBE uses a 555 IC and three transistors.

PARTS LIST

All resistors are 1/4-watt, 10%.
R1—47,000 ohms
R2—22,000 ohms
R3,R4—100,000 ohmms
R5—100 ohms
R6—220 ohms
R7—27,000 ohms
R8—3300 ohms
R9—2200 ohms
R10—4700 ohms
R11—1000 ohms
C1—0.1 µF
C2—.01 µF
C3—33 µF
Q1,Q2—2N3904
Q3—2N3906
D1,D2—1N4001
IC1—555 timer
Misc.—5-volt power supply, 1 1/2-inch speaker (100-ohm), probe, circuit board or perforated board, 3 × 2 × 1-inch box.

The following items are available from Progressive Electronics, Inc., 432 South Extension, Mesa, AZ 85202. A pre-cut and pre-drilled printed-circuit board—$2.50. A complete kit of parts, including case—$15.75.





TONE PROBE shown removed from its case. Cover fits against speaker, holding assembly in place.

V for the emitter of Q2. With the probe low or floating, the base-emitter junction of Q2 is reverse-biased and no collector current flows. If the circuit-under-test changes state and goes high, Q2 begins to conduct at about 2.3 V.

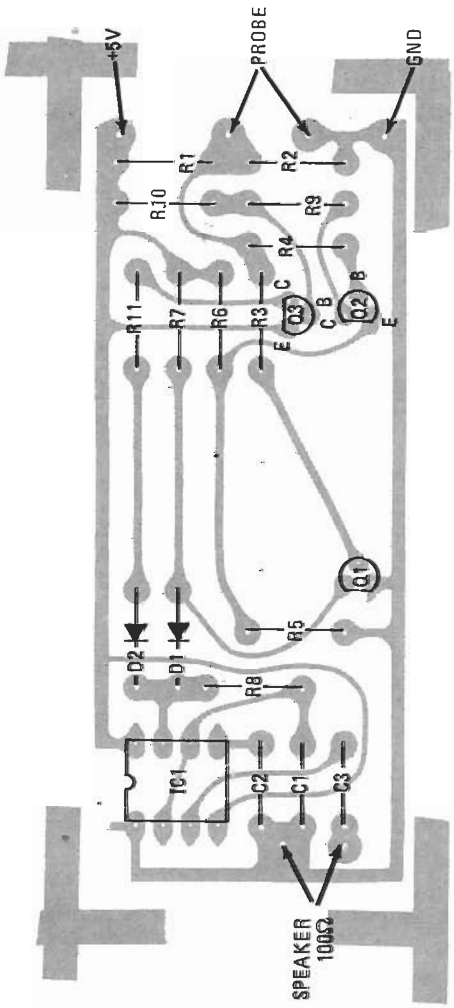


FIG. 2—PRINTED-CIRCUIT foil pattern. The board measures 6 × 2$^3/_8$ in. (15.2 × 6.0 cm.)

With Q2 conducting, R9 supplies base drive to Q3, causing it to conduct. The input signal causes Q1 to return to a conducting state and removes from IC1 the drive that causes it to oscillate at a low frequency. Transistor Q3 now supplies this drive current through R11 and D2. Resistor R11, being much smaller than R7, sends more current to IC1 and it oscillates at a much higher rate, producing a high-pitched tone.

Construction

The probe layout is not critical and may be built on perforated board or on a printed-circuit board made from the layout (Fig. 2) supplied.

All components, including the speaker, mount on the printed circuit board.

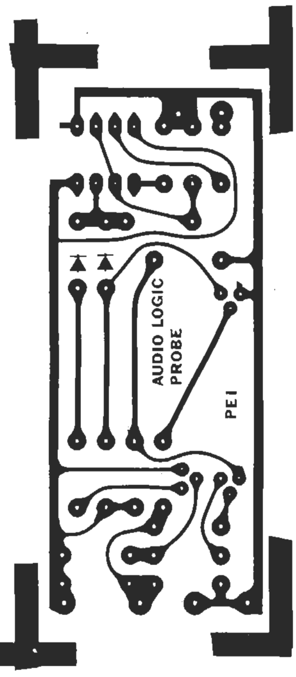


FIG. 3—COMPONENT PLACEMENT diagram.

A small amount of epoxy glue or silicon rubber sealant secures the rear of the speaker magnet to the component side of the board. When installed in the case, the cover is compression fit to the speaker.

The three leads have a knot just inside the cover of the box to act as a strain relief. The probe can be either a commercially available replacement probe or it can be made from a ball-point pen.

Checkout

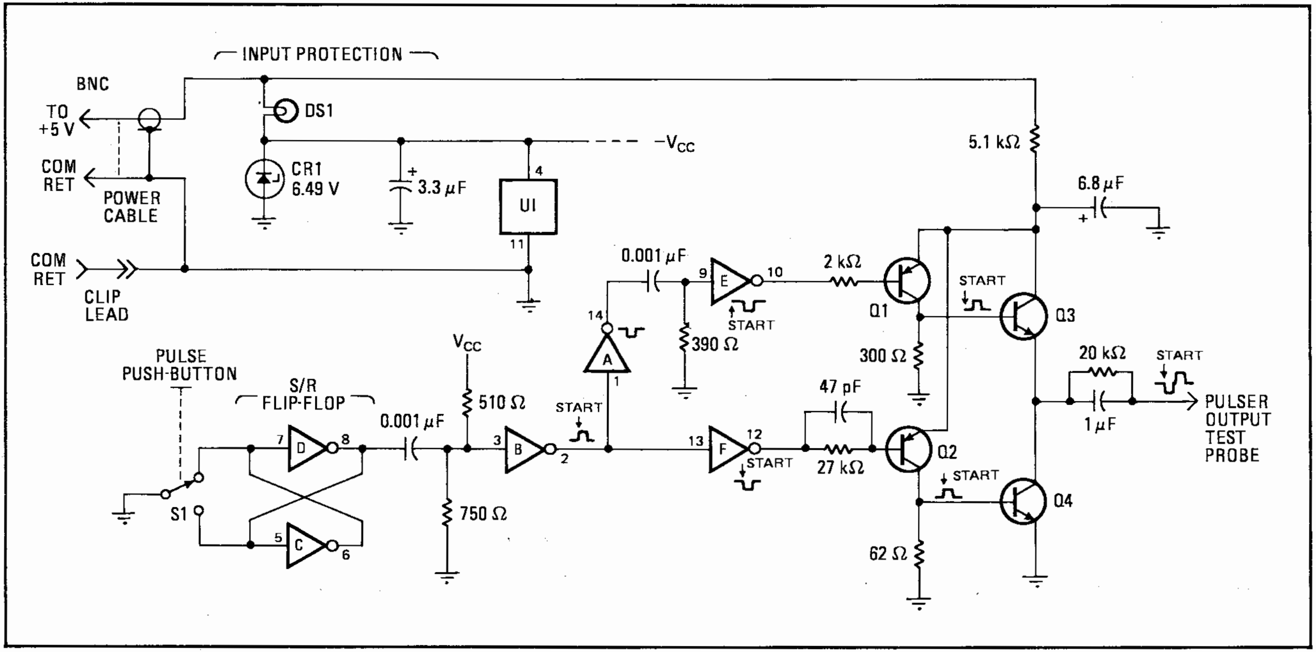
To check the tone probe, a 5-volt supply is needed as well as a 1,000-ohm potentiometer. Connect the supply to the + and – leads of the probe. Connect the outside terminals of the pot across the power supply and rotate the pot so the center terminal is at ground (–). Connect the probe to the center terminal on the pot and check for a low-frequency tone. Turn the pot, increasing the voltage until the tone just quits. Measure this voltage. It should be between 0.4 and 0.6 V. Increase the voltage further until a high-pitched tone just starts. Measure this voltage. It should be between 1.7 and 2.0 V.

If your probe triggers within these limits it is functioning correctly. If it does not test correct, check for proper value resistors in R1, R2, R5 and R6.

If the probe does not make any sound, check IC1, Q1 and Q3. Also make sure D1 and D2 are connected in the right direction.

Using the probe

After attaching the tone probe to a power source, touch the probe to each of the leads of the integrated circuit being checked. A high-pitched tone will be heard if there is a high-level signal (2 volts); a low-pitched tone will be heard if there is a low-level signal (0.8 volt). No tone will be heard if the signal is between these two voltages. To check the tone probe, touch the end of the probe to the B+ source—a high-pitched tone should be heard. **R-E**

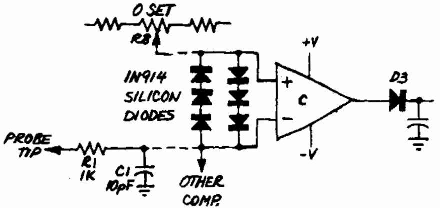


6. Up and down. Logic pulsers like HP's 10526T use complementary circuitry to drive high-state lines low and low-state lines high.

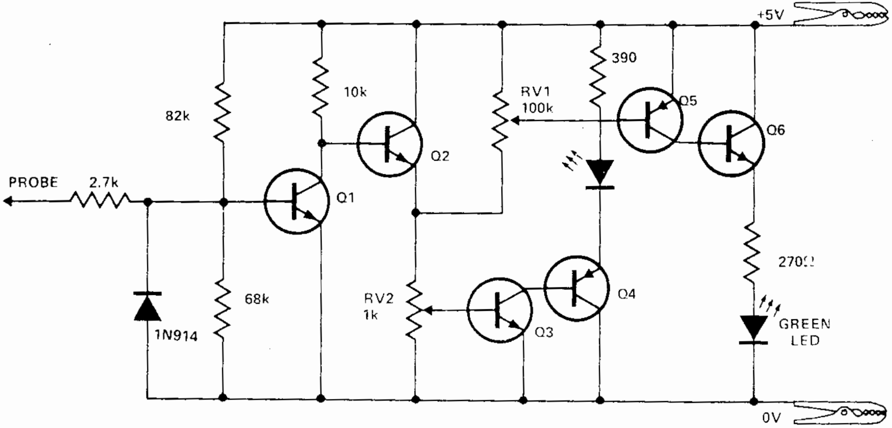
Letters

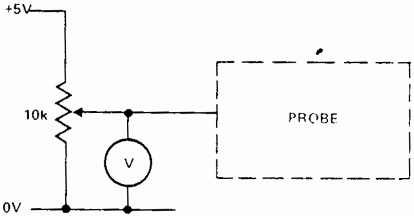
USING DIODES WITH LOGIC PROBE

In "Build a Universal Logic Probe" (February 1975), it is doubtful that the probe will perform well at frequencies near 10 MHz. The diodes used to protect the inputs of the comparator IC are the bad guys. The capacitance of a typical zener diode is many times that of a typical switching diode. With the 1000-ohm value of *R1* and approximately 560-pF capacitance of *D1* and *D2*, there will be very little 10-MHz square-wave signal amplitude available at the comparator's inputs.



Far better results can be obtained if the zener diodes are each replaced with two or three switching diodes connected across the comparator's inputs as shown in my schematic.—*W.E. Parker, Columbus, Ohio*





CIRCUIT TO ADJUST THRESHOLDS

LOGIC PROBE

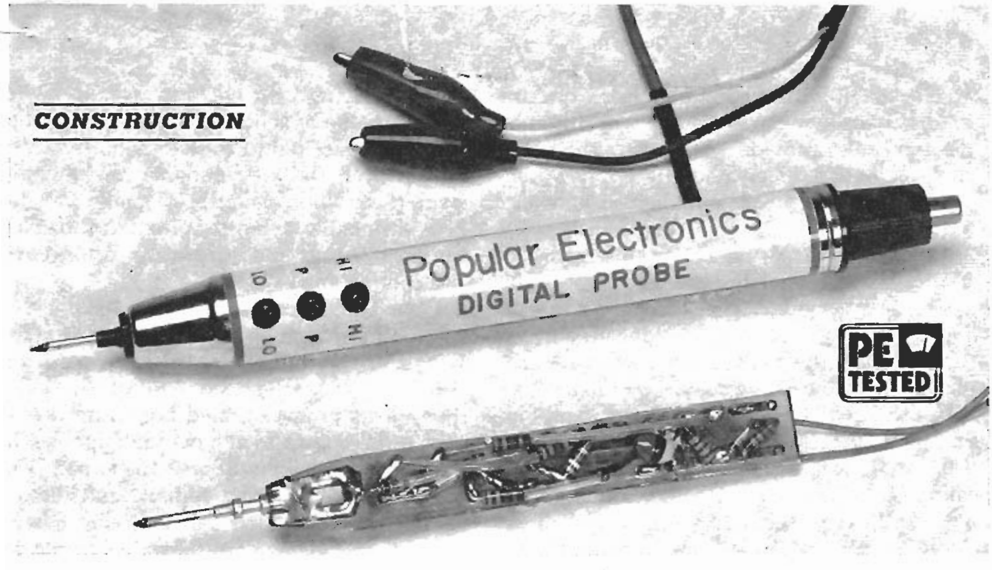
Transistors Q1 and Q2 form a simple voltage buffer, providing the probe with a reasonable input impedance.

Q3 and Q4 form a level detecting circuit as the voltage across the base-emitter junction of the Q3 rises above 0.6V the transistor turns on thus turning on Q4 and lighting the red (high) LED.

Q5 and Q6 perform the same function but for the green (low) LED.

Q1, Q4, Q5 are all pnp general purpose silicon transistors (BC178 etc). Q2, Q3, Q6 all pnp general purpose silicon transistors (BC108 etc). The threshold Low ⩽0.8V, the threshold High ⩾2.4V.

CONSTRUCTION



IC DIGITAL LOGIC MEMORY PROBE

INDICATES LOGIC STATE OF CIRCUIT AND DETECTS PULSES AS SHORT AS 50 NS

BY RICHARD P. MAY

ONE of the more vexing problems facing today's experimenter is finding a way to check the 5-volt logic devices that dominate the hobby construction scene. Lacking a high-speed triggered-sweep oscilloscope, the experimenter is left defenseless in coping with the frequent 50-ns pulses that are more than long enough to trigger IC logic devices. To cope with the problem without a scope, however, you can build the digital logic memory probe described here. It is designed to indicate the logic state of a circuit, providing detection capabilities for pulse durations as short as 50 ns.

The circuitry of the probe is housed in a penlight tube and derives its power from the 5-volt line and signal ground of the circuit under test. The indicator system consists of three light-emitting diodes (LED's) mounted in-line at the end of the probe tube. The top LED lights up for a logic 1, while the bottom LED illuminates for a logic 0 (2.4 or more volts and less than 0.8 volts, respectively). The center LED comes on to indicate a positive- or negative-going transition as short in duration as 50 ns and remains on for 200 ms without regard to the time duration of the pulse being observed. This stretching feature provides ample time to observe a short-duration pulse that would otherwise not be seen on the 1 and 0 LED's.

To expand the stretching feature, a switch on the probe can be used to activate a memory mode that causes the stretch LED to remain on permanently after a positive or negative pulse occurs. The memory mode can aid in establishing the presence of unwanted pulses (such as noise). To reset the memory, the switch is simply returned to the stretch mode.

The memory mode can also be used to detect a power failure that might cause a sequence scrambling in the system under test. To accomplish this, the power input leads of the probe are connected to the 5-volt supply line and the switch is set to the memory mode. If the power should fail and self-restore, it will leave the stretch LED illuminated, indicating that a power interruption has occurred.

Construction. To keep the project as compact as possible so that its simple circuit (see Fig. 1) will fit into the penlight body, printed circuit construction is highly recommended. An actual-size etching and drilling guide is shown in Fig. 2. Also shown are two component placement guides, since the components mount on both sides of the board.

Before you begin assembly, remove from *IC1* (7404) pins 5, 6, 8, 9, 12, and 13 and from *IC2* (9601) pins 5, 8, 9, 10, and 12. This will permit maximum utilization of the available board space. Then mount and solder in place all components as shown.

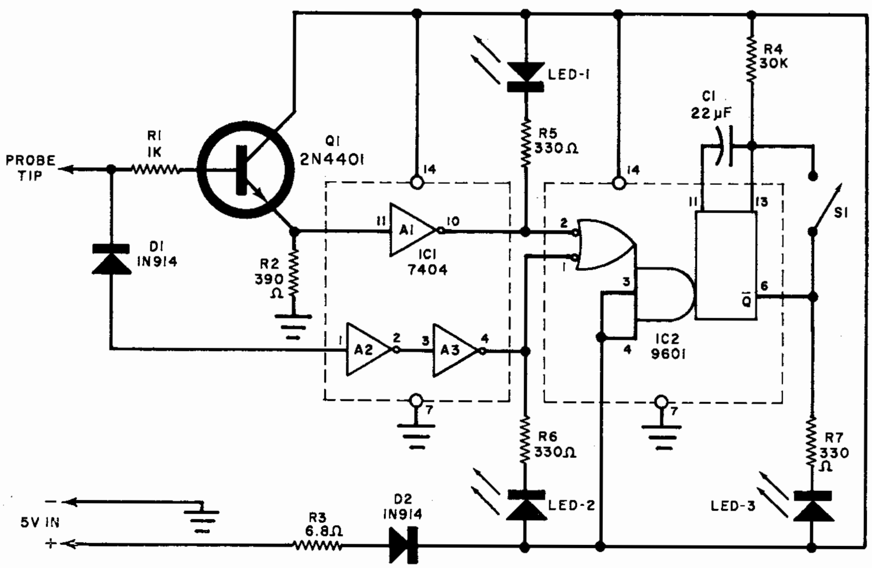
Mount the probe tip in the board's end slot as follows: First, place the tip in the slot and secure it with a couple of turns of bare solid hookup wire, passing the wire through the four holes provided. Heat sink the cathode end of *D1*. Then liberally apply solder along both sides of the tip where it joins the foil pattern.

Prepare the ends of two 5-in. lengths of stranded hookup wire. Solder these wires to the holes shown. Then prepare one end of the coaxial cable and solder the inner conductor to the + hole on the board and the shield to the − hole.

Carefully spot on the body of the penlight flashlight the three holes for the LED's, using the board assembly to guide you. The exit hole for the coaxial cable does not require critical location so long as it is clear of the board and does not interfere with switch operation. Label the LED holes LO, P, and HI from tip end toward the switch end of the body. Then fit small rubber grommets into the tip and cable exit holes.

Slip over the free ends of the memory switch wires ½-in. lengths of small-diameter, heat-shrinkable tubing. Solder the leads to the switch lugs and shrink the tubing over the connections.

Over the free end of the coaxial cable, slip a 4-in. length of shrinkable tubing. Push it all the way down toward the board and shrink it. Pass the free end of the cable through its grommet-lined hole from the inside of the body and slip over it another 4-in. length of shrinkable tubing. Strip away 5 in. of outer insulation and remove and discard 4⅝ in. of the braided shield. Being careful to avoid heat damage to the cable's inner insulation, pre-tin the braid on one side with



PARTS LIST

C1—22-µF, 10-volt tantalum capacitor
D1,D2—1N914 diode
IC1—7404 integrated circuit
IC2—9601 integrated circuit
LED1-LED3—Light-emitting diode (Monsanto MV-5022)
Q1—2N4401 transistor
R1—1000-ohm, ¼-watt resistor
R2—390-ohm, ¼-watt resistor
R3—6.8-ohm, ¼-watt resistor
R4—30,000-ohm, ¼-watt resistor
R5-R7—330-ohm, ¼-watt resistor
S1—Part of penlight flashlight
Misc.—Printed circuit board, probe tip, penlight flashlight body, insulating spaghetti, 4"-long X ½"-diameter heat-shrinkable tubing, small-diameter heat-shrinkable tubing, 3' length small-diameter coaxial cable, one black-booted miniature alligator clip, one red-booted miniature alligator clip, stranded and solid hookup wire, solder, etc.

Note: The following items are available from Phill-Curt Electronics, 4440 Elm Rd., Gurnee, IL 60031: Etched and drilled board No. DPB101 ($3.00); kit of all parts, including drilled body, No. DPK101 ($17.50).

Fig. 1. Circuit diagram of the digital probe, which uses two IC's.

solder. Strip ⅜ in. of insulation from a 5-in. length of stranded hookup wire and pre-tin the exposed wires. Then carefully tack-solder the wire to the shield stub. Slip the tubing down over the connection, overlapping it by ½ in., and shrink it.

Strip away ¼ in. of insulation from the free ends of the inner conductor of the coax and the stranded wire. Solder a red-booted miniature alligator clip to the inner conductor and a black-booted clip to the stranded wire.

Next, make a ½-in. slit, lengthwise, in one end of a 4-in. length of ½-in.-diameter shrinkable tubing. Slip the tubing over the board, slotted end toward the tip located on the foil side of the board. Locate and mark the positions of the LED lenses. Remove the tubing and punch or drill ⅛-in. holes in the marked locations. (Note: This tubing will *not* be shrunk during final assembly.)

To assemble the probe, slip the tubing into the probe body and line up the two sets of holes. Slide the board assembly, probe end first, into the body and push it home, orienting the LED lenses under their respective holes. Gently pull on the coaxial cable to take up the slack. Then screw on the switch cap.

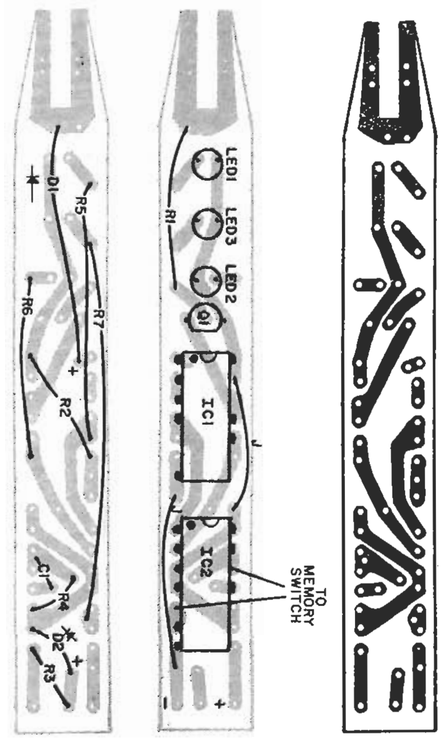


Fig. 2. Foil pattern (right) and component layouts for both board sides.

Testing The Probe. Observing polarity, connect the alligator clips to a variable dc source. With *S1* set to the stretch mode, slowly advance from 0 to 5 volts. At 2.8 volts, the memory (P) LED should flash on then off as the potential is increased through 4.1 volts. This condition can be used to check for low voltages.

With the supply set to 5 volts, touch the probe tip to the common lead. The LO LED should light while the P LED comes on for 200 ms. When the common is removed from the probe tip, the LO LED should extinguish and the P LED should again light for 200 ms.

When +5 volts is applied to the probe tip, the same thing should be observed on the 1 LED. To check for memory action, place *S1* in the memory mode and touch the probe tip to either common or +5 volts. LED P should come on and remain on until *S1* is returned to the stretch mode. ◈

HOW IT WORKS

The memory probe (Fig. 1) is powered by the circuit under test. Diode *D2* protects the probe should the wrong hookup be made to the power line. The combination of *D1* and *R1* provides over-voltage protection. Diode *D1* buffers *IC1* from excessively high inputs and insures a high input impedance (better than 75,000 ohms with a high input).

Transistor *Q1* provides a high input impedance and serves as a buffer for the input of A1 in *IC1*. When the probe tip is not terminated, pin 11 of *IC1* is low and pin 1 goes high. Inverting through A3 and double inverting through A1 and A2. *LED1* and *LED2* extinguish. With a low input (0.8 volt or less), pin 1 of A1 goes low. Then by double inversion through A1 and A2. *LED2* turns on. All the while, *Q1* is cut off and *LED1* remains extinguished. A high input causes *LED2* to turn off and sends *Q1* into conduction, resulting in *LED1* turning on.

The on time of *IC2* (a triggerable one-shot multivibrator) is determined by the time constant of *C1* and *R4*, which is 200 ms with the component values specified. The IC is triggered by a negative-going transition at pin 1 or pin 2. Any level change at the probe tip will cause this condition, triggering *IC2* and turning on *LED3* for 200 ms.

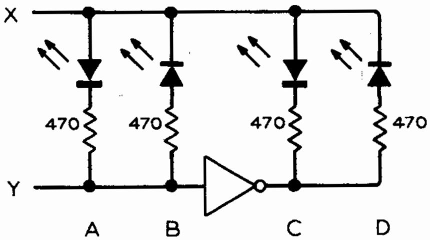
To prevent *IC2* from timing out after being triggered, memory switch *S1* must be closed. When pin 6 of *IC2* goes low at the moment of triggering, the signal is applied to the junction of *C1* and *R4*. This prevents *C1* from charging, and *IC2* remains in the triggered state. Opening *S1* permits normal timing to resume.

Out of Tune

In "Build a Direct-Reading Logic Probe" (September 1975), in the Parts List, *DIS1* should be a common-anode unit, not common-cathode.

Binary state indicator

A simple circuit for displaying the four possible states on two binary lines uses four l.e.ds and one inverter which may be a spare gate or transistor. When x = y, A and B will have both sides at the same level and will therefore be off. Because y is inverted, C and D will have both sides at different levels, so one l.e.d. will be turned on. When x is opposed to y the reverse situation occurs.



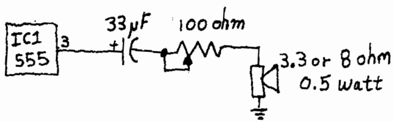
David Straker,
Dwyran,
Gwynedd.

MORE ON THE LOGIC PROBE

I built Larry Fort's probe for testing logic circuits ("Tone Probe for Testing Digital IC's", March 1977 issue) and would like to anticipate some letters you may get on the specified 100-ohm speaker. Use any speaker. I used an unmarked 4- or 8-ohm speaker, a 100-ohm resistor and a 25-µF capacitor. If you want to get fussy, replace R1, R2 and R6 and R5 with 100K and 500-ohm pots adjusted for optimum performance. They'll run about 70K to 80K and 350 to 400 ohms. However, I built mine with the values specified and only a speaker change. Everything worked fine.

L. G.
Pompano Beach, FL

Larry Fort's digital probe can be modified to include a volume control as shown



in the schematic. As a high school physics teacher, articles on building digital equipment are most appreciated. Keep it up!

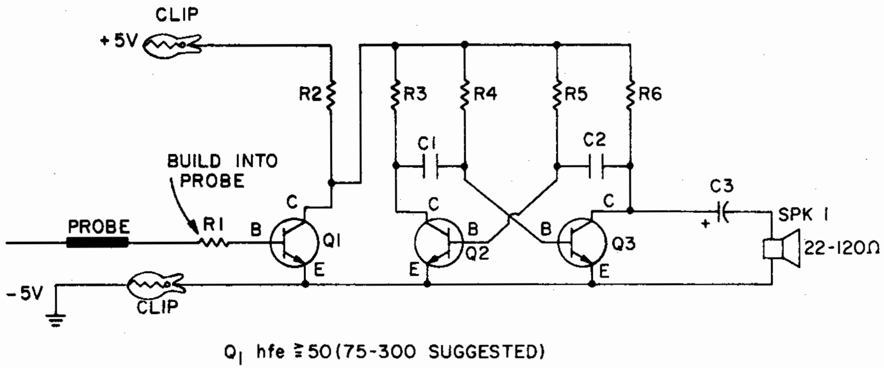
PHILIP REHBERGER
Oshkosh, WI

45 Audible Logic Probe

NEW 1976

☐ One problem when servicing modern IC circuits is that everything is packed in so tight, and IC terminals are so close together, if your test probe slips a fraction of an inch (or centimeter) it's ZAP!, another component bites the dust; and trouble is, solid state breakdowns usually take out a whole string of components.

Logic probes used to trace digital circuits often lead the list in devices that ZAP ICs because you've got to



PARTS LIST FOR AUDIBLE LOGIC PROBE

Resistors ½- or ¼-watt, 10%
R1—27,000-ohms
R2—1,000-ohms
R3—10,000-ohms
R4, R5—100,000-ohms
R6—3,300-ohms
Capacitors rated 10-VDC or higher
C1, C2—0.10-uF ceramic disc
C3—1 to 2.7-uF
Q1, Q2, Q3—NPN transistor, Radio Shack 276-2009
SPK-1—See text
Misc.—Clips

keep one eye on the probe indicator lamp and the other eye on the tip of the test probe. But all that's a thing of the past with this Audible Logic Probe because you can keep both eyes and your full attention on the tip of the test probe, and a tone indicates a logic low.

Normally, Q1 is cut off (no base input), and there is a small, insignificant voltage drop across R2 so multivibrator Q2-Q3 receives operating voltage and produces an output in the speaker of approximately 700 Hz (at low but comfortable volume). When the probe is touched to a logic low (0) Q1 is still cut off so sound output indicates a low. When the probe is touched to a logic high (1) Q1 is driven to saturation and the full supply voltage is dropped across R2, so the multivibrator and its output is cut off, indicating a logic high.

Alligator or crocodile clips are used to connect to the TTL equipment's + and – 5-volt terminals. Resistor R1 should be built directly into the test probe to provide good isolation between the TTL equipment and your test lead circuit. Speaker SPK-1

TTL level tester identifies logic levels by audible tone

by John M. Jamieson
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When checking a large number of test points for static TTL levels, turning one's attention from a probe to an oscilloscope or voltmeter is inconvenient and time-consuming at best, and disastrous if the probe should slip off the pin to contact a nearby high-voltage bus. This circuit was designed to simplify such checking.

The circuit produces one of two tones in an earphone or loudspeaker: low-pitched when the probe is in contact with a pin at less than 0.8 volt, and higher-pitched when the voltage is between 2.0 and 5.0 V. If the voltage is between 0.8 and 2.0 V, or if the test point is an open circuit, no tone is produced. The circuit uses a single quad operational amplifier such as the National Semiconductor LM324; two amplifiers serve as comparators and the other two generate the tones.

As shown in the diagram, the comparators test the voltage on the probe for one of the two TTL levels. Pin 3, the non-inverting input of one comparator, is held at 0.8 V by a 100-kilohm resistor R in series with two forward-biased diodes. When the probe is on an open circuit, the inverting input of the same comparator (pin 2) is held at about 1.5 V by a voltage divider R_2-R_3. Because the inverting input is at a higher level than the non-inverting input, the output (pin 1) of this comparator is near ground; but if a voltage less than 0.8 V is applied to the probe, the output goes to about 5 V.

Likewise, pin 13, the inverting input of the other comparator, is held at 2.0 V by another voltage divider, R_4-R_5. Here again, when the probe is on an open circuit, the inverting input is higher and the output (pin 14) is near ground; but if a voltage higher than 2.0 V is applied, the output goes to about 5 V.

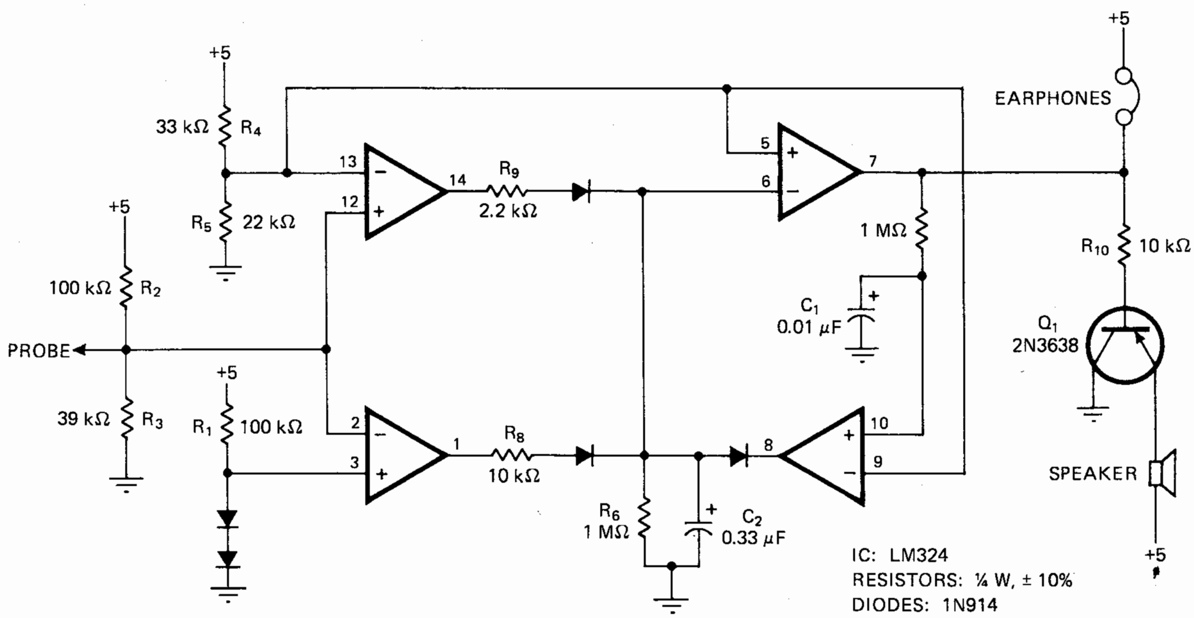
When both pins 1 and 14 are near ground, pin 6 is also near ground, held there by the 1-megohm resistor, R_6; pin 7, the output of the tone generator, is near the supply voltage, 5 V. From this the 0.01-microfarad capacitor, C_1, is charged through resistor R_7.

When pin 1 rises to its higher level, the 0.33-μF capacitor, C_2, charges through the 10-kilohm resistor, R_8. Likewise, when pin 14 is high, C_2 charges, more quickly this time, through the 2.2-kilohm resistor, R_9. Either way, when it exceeds the 2.0-V level on pin 5, the output of the tone generator drops to ground, and C_1 discharges. Eventually its level drops below that same 2.0 V, also on pin 9, dropping the output of the fourth amplifier, pin 8, to ground. That discharges C_2 and the cycle begins again.

Thus the signal on pin 7 is a square wave, the frequency of which is determined by the rate at which C_2 charges—through either R_8 or R_9. At either frequency, the square wave is approximately symmetrical, because C_1 both charges and discharges at all times through R_7.

The output on pin 7 is sufficient to drive most earphones. Additional loading affects the absolute values of the two frequencies, but not their relative values. If the earphones are unsatisfactory for any reason, the 10-kilohm resistor R_{10} and a pnp emitter follower Q_1 can drive a small loudspeaker. □

Engineer's Notebook is a regular feature in Electronics. We invite readers to submit original design shortcuts, calculation aids, measurement and test techniques, and other ideas for saving engineering time or cost. We'll pay $50 for each item published.



Beep-beep, boop-boop. Checking for static TTL levels is simplified when the voltage level is indicated by one of two audible tones in an earphone or loudspeaker. This circuit does the trick with only one quad op amp for level-comparing and tone-generating.

Versatile logic probe displays four modes

by Gordon W. Martin
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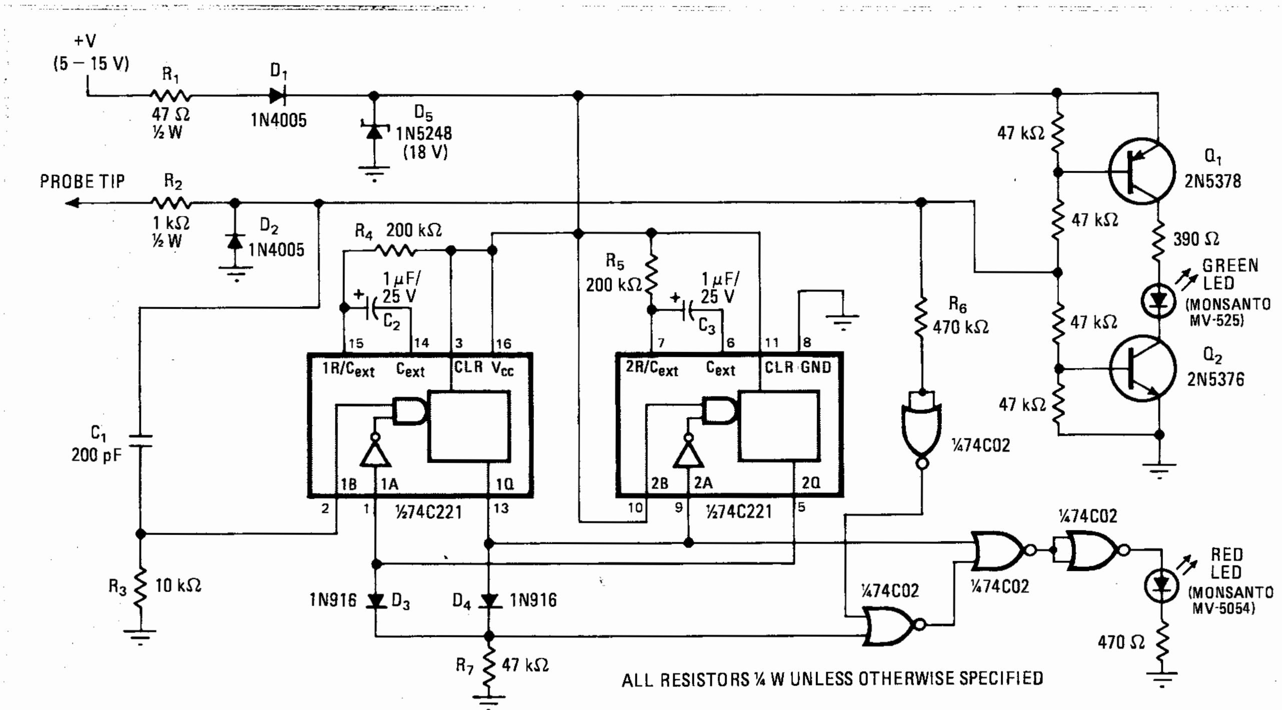
In addition to indicating static states—high and low logic levels as well as open-circuited nodes—an inexpensive logic probe can be built to indicate a pulse train by flashing. Packaged in a pen-type flashlight or similar enclosure, the probe performs as well as commercial models at a fraction of their cost, and it is compatible with both complementary-metal-oxide-semiconductor and transistor-transistor-logic voltage levels.

A pair of light-emitting diodes—red and green—indicates the various states in accordance with the truth table shown below. As evident from the schematic, the green LED glows only when the input is connected to a high impedance or open-circuited logic node; because neither situation affects the quiescent on state of Q_1 or Q_2, current flows through the LED. Application of a logic-1 or logic-0 level to the probe input turns off Q_1 or Q_2 respectively, and, in either event, the green LED goes off. The NOR gates turn on the red LED when a logic-1 input is applied through current-limiting resistor R_6. Note that the red LED will also glow when the 1Q output of the dual monostable multivibrator goes high. The monostable is employed solely for the fourth condition in the truth table—the dynamic input of a pulse train to the probe.

The 74C221 C-MOS dual monostable has both positive- and negative-transition-triggering inputs, either of which can be used to inhibit the other—the output Q remains low whenever input A is high or input B is low. Firing the monostable generates a positive pulse at Q that has its duration determined by an external RC time constant. A pulse-train input to the probe is ac-coupled and shaped through C_1 and R_3 to the positive-transition input of the first monostable, 1B. The 1Q output then goes high for $T = R_4 \times C_2 = 200$ kilohms $\times$ 1.0 microfarad = 200 milliseconds. Upon returning to the low state, the 1Q output triggers the second monostable through negative-transition input 2A, and its 2Q output goes high, inhibiting the first monostable through input 1A for an additional $T = R_5 \times C_3 = 200\ k\Omega \times 1.0\mu F$ = 200 ms. After this 400-ms period, the monostables are ready for triggering by the next positive transition at 1B, and hence the system exhibits a characteristic frequency of 2.5 hertz or $(400\ ms)^{-1}$, regardless of the input-pulse frequency. The 2.5-Hz signal at 1Q is coupled through the NOR gates to flash the red LED at this rate.

The OR gate consisting of D_3, D_4, and R_7 ensures positive indication of pulse-train inputs, irrespective of symmetry or duty cycle. Waveforms with very low or very high duty cycles, which could not otherwise be



Discriminating probe. A 74C221 dual monostable and a 74C02 quad NOR gate enable this logic probe to indicate pulse trains as well as static inputs. Housed in a pen-type case with clip leads for ground and supply connections, the unit simplifies digital troubleshooting.

RESPONSES OF LOGIC PROBE		
Input condition	Output indication	
	Red LED	Green LED
Open circuit (Hi-Z)	Off	On
Logic 0	Off	Off
Logic 1	On	Off
Pulse train	Flashes at 2.5 Hz	Off

distinguished from constant-dc levels, will therefore flash the red LED at the 2.5-Hz rate.

The probe input is protected from negative-polarity signals by R_2 and D_2. The unit, which will operate from any 5-V to 15-V source, is protected against overvoltage by D_5 and R_1 and against the wrong supply-voltage polarity by D_1. Logic-level thresholds are about 20% and 80% of the supply voltage, and the probe draws only about 10 milliamperes from a 5-V source. □

Build your own Logic Probe

A simple logic probe like the one described in this article can save hours of time when troubleshooting TTL logic circuits. This probe is built around a single IC and the source of power is derived from the circuit being tested

by DON LINGLE

THE SERVICE TECHNICIAN OR EXPERIMENTER who works with digital circuits can use this economical logic probe to determine the state of any point in a TTL circuit. By powering the probe with 5 volts from the circuit being tested and touching the tip of the probe to any point in the circuit, two Light Emitting Diodes (LED's) indicate the logic state. When a logic high is encountered, one LED lights; when a logic low is encountered, the other LED lights. If there is an open circuit, neither will light.

How it works

The heart of the logic probe is a CD4009 COSMOS hex inverter IC. The characteristic high input impedance of COSMOS gives the advantage of not loading the circuit being tested. In addition, the output current capability of the CD4009 can be increased by placing inverters in parallel, so it can drive the LED's directly without any other current amplification. The inverters in the logic probe circuit (See Fig. 1) are arranged to give complementary outputs if a logic low or high is encountered at the input and no output at all if the input is at an open circuit or other high impedance.

Since the output of the inverters is not specified at either a high or low level with a floating input, an input bias network produces lows at both input inverter pairs if the input is open or at less than 2 volts. Resistor R3 holds the input of inverter 3 low which makes the output of inverters 4 and 5 low and will not permit LED 2 to light. At the same time, R1 holds the inputs of inverters 1 and 2 high, so that their output is low and LED 1 will not light. If the probe input is touched to a logic low, the output of inverter 3 is held high by R3 and inverter 1 and 2 are brought low, which causes their outputs to go high and turns on LED 1.

All resistors ⅛ watt, 5%
R1—150,000 ohms
R2, R3—100,000 ohms
LED 1, LED 2—Monsanto MV 5020 or equal
IC—RCA CD4009 hex inverter
Misc.—marking pen, wire, alligator clips, safety pin, epoxy, cork, solder

Construction

For compact construction, mount the components on a printed-circuit board. The foil pattern is shown in Fig. 2. After etching, trim the board to ½ in. x 3 in. Solder the jumper wires where indicated and attach a 4-ft length of twisted pair lead to the +5 volt and ground connections of the board. The component layout is shown in Fig. 3. Tape the front section of the leads to the board for strain relief. Solder a sufficient length of wire to the input so that it can later be soldered to the probe tip. Use a large felt-tipped pen of sufficient size to contain the PC board for the probe housing. Pry the bottom off the marking pen cylinder with a screwdriver. Remove the packing inside and clean it out with solvent. Drill a .18 inch diameter hole in the bottom of the tube for the 5-volt leads and 2 holes .18 inch diameter and .18 inch apart in the front of the tube for the LED's.

After guiding the input lead wire through the probe tip, insert the circuit board into the tube by pushing it through the rear of the tube. Adjust

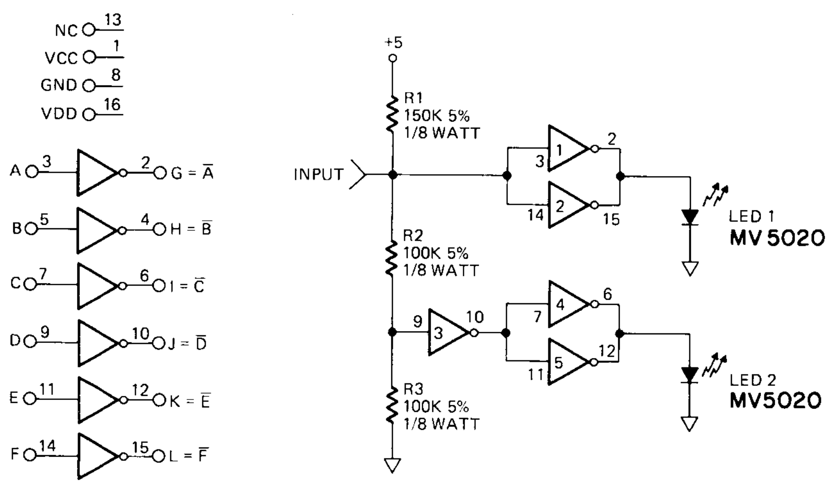
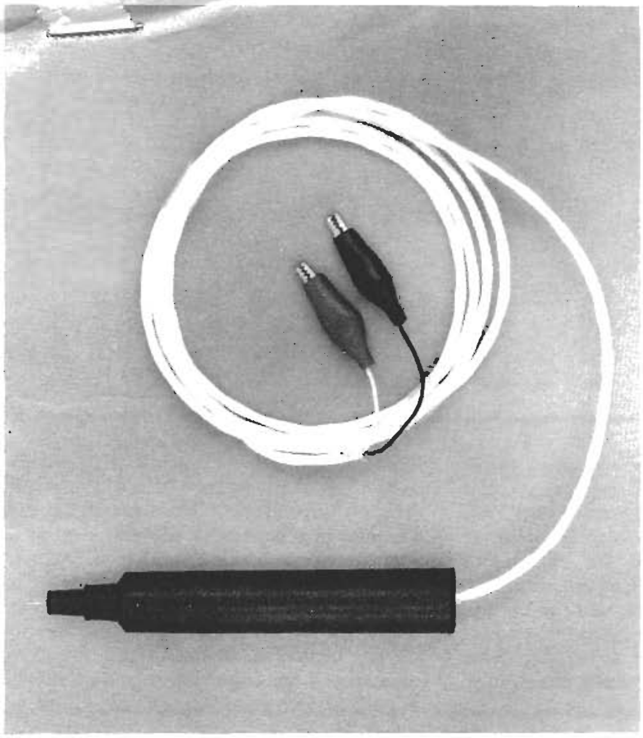


FIG. 1—LOGIC PROBE schematic using five of the six CD4009 inverters. The basing diagram of the CD4009 is also shown.



the board in the tube so the LED's fit through the holes drilled in the top of the case. Press the plastic down around the two LED's. This is a close enough fit to fix the board in position, but if you want to, secure the board with a dab or two of epoxy along the rear inside of the cylinder.

For the probe tip, snip a ¾" length off a safety pin. A heavy gauge straight pin could also be used. Solder the blunt end of the pin to the input lead coming from pin 3 of the CD4009. The pin can now be fixed in the tip of the probe with epoxy. Before you put the epoxy in, grease the inside of the probe tip so after the epoxy sets it will form a plug that can be pulled out of the probe tip if necessary. Use a cork to hold the pin so when the tube is placed horizontally the cork keeps the pin centered until the epoxy hardens. Drill a small hole in the rear cap of the cylinder. Fit the power leads through the hole and snap the cap back onto the end of the probe. Solder two alligator clips on the ends of the power leads and mark them so that the positive and negative leads cannot be confused.

Test the probe by hooking it up to a 5-volt supply and touching the probe tip alternately to the high and ground pins. LED 2 should light when you touch the positive pin; LED 1 should light when you touch the negative pin. If the probe is not contacting anything both LED's should remain off. **R-E**

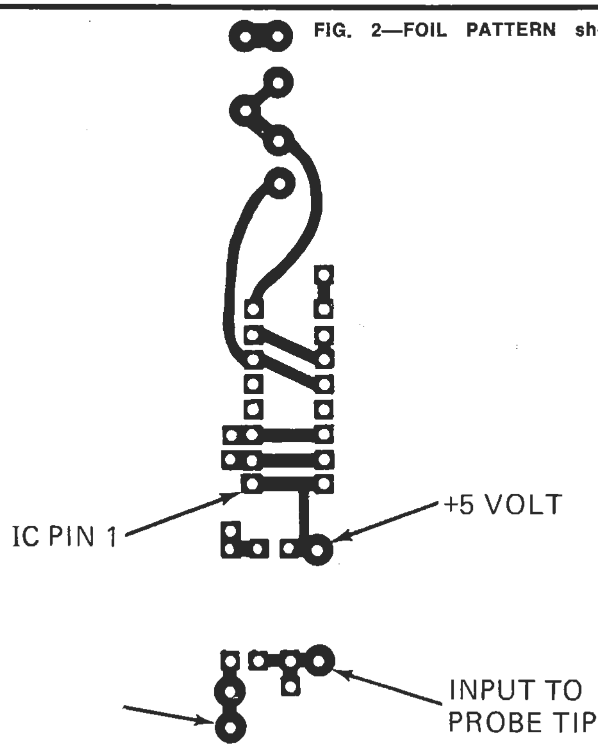


FIG. 2—FOIL PATTERN shown full-size.

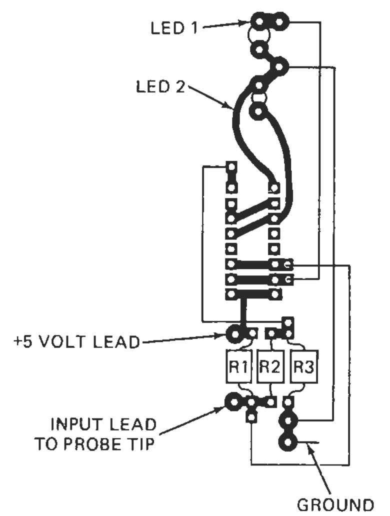


FIG. 3—COMPONENT LAYOUT shown from the component side of the PC board.

A SIMPLE LOGIC PROBE

Few parts combined to provide a versatile logic state indicator.

BY ROBERT LEFFERTS

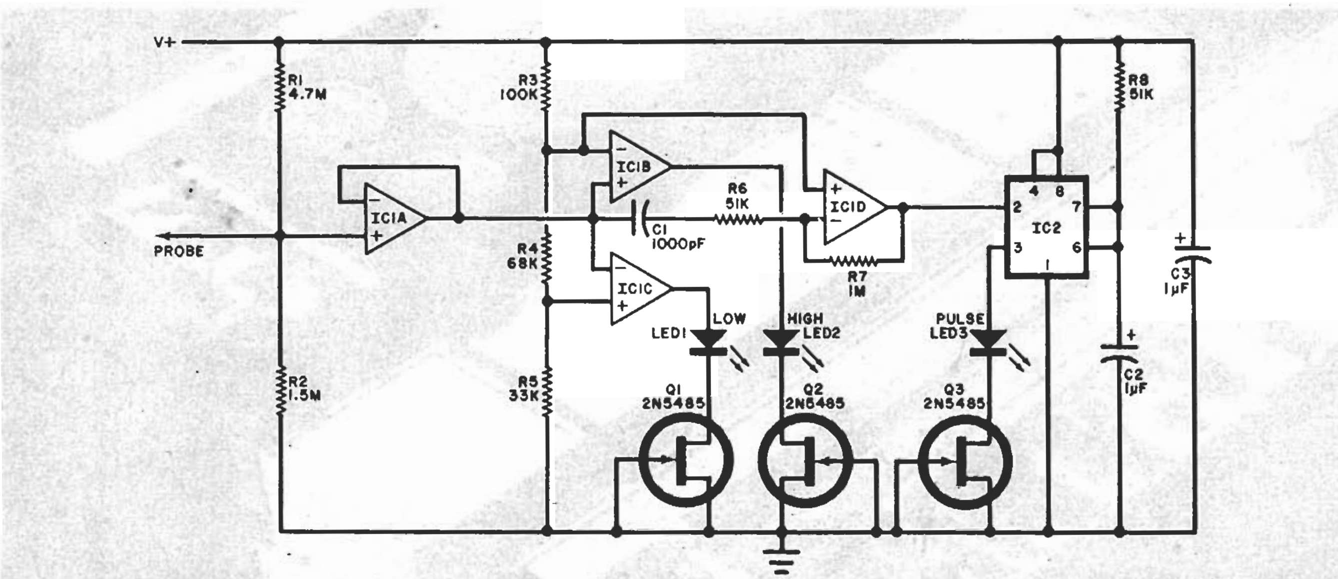
THIS circuit was inspired by R.M. Stitt's "Build a Direct Reading Logic Probe" in the Steptember 1975 issue of POPULAR ELECTRONICS. Although the seven-segment display technique used in that article was intriguing, I found that it could lead to some problems. For example, if a signal is oscillating between about 0.5 and 3 volts, at a frequency of, say, 100 Hz, the signal would appear to be low, high and a pulse—all at the same time! Either the digit "8" would be displayed or, if the monostable overrode the high and low displays, a "P" would appear. However, there would be no relative indication of duty cycle.

The probe presented here not only solves this problem, but is also useful with CMOS logic levels, as well as 555 and other timer outputs. It will operate on supply voltages ranging from 5 to 15 volts and draws less than 12 mA. Its op amp input circuit has high input impedance and low capacitance.

Further, three LED's display high, low and pulse levels and the approximate duty cycle (indicated by relative brightness). The possible states displayed range from all three LED's lit (a square wave with about a 50% duty cycle and high and low levels above and below V/2 and V/7, respectively) to only the PULSE LED glowing. This indicates a train of narrow, positive- or negative-going pulses riding on a level somewhere between the lower and upper switching thresholds, or some other oscillation with amplitudes between these two levels.

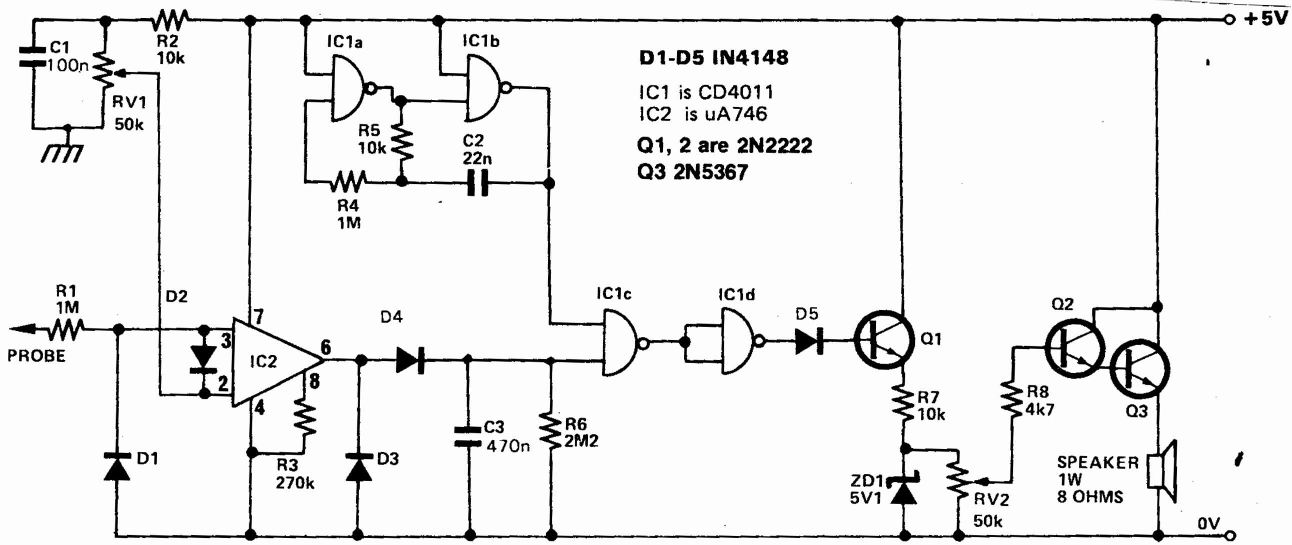
Voltage follower *IC1A,* one fourth of an LM324 quad op amp, isolates the probe from the rest of the circuit and passes the input signal to the low (*IC1C*) and high (*IC1B*) comparators, with thresholds of V/7 and V/2 furnished by the resistor string *R3-R5*. The input signal also drives *IC1D*, an ac amplifier with a gain of 20. This amplifier triggers *IC2*, a 555 one-shot with a pulse width of about 0.05 second. The state-indicating LED's are current limited by FET's *Q1, Q2,* and *Q3.*

Construction of the probe is a matter of taste, but most probably you'll want to assemble it in a cigar tube or a length of PVC tubing. Either pc or perforated board techniques can be used. LED size and color is left to the individual. Choose a distinctive color combination—possibly red for LOW, green for HIGH, and yellow for PULSE. After a few days of use, you'll probably agree that a versatile logic probe is very handy to have around. ◈



PARTS LIST

C1, C2—1-µF, 25-volt tantalum capacitor
C3—1000-pF disc capacitor
IC1—LM324 quad op amp
IC2—555 timer
LED1-LED3—20-mA light emitting diodes
Q1-Q3—2N5485, HEP F0021 field effect transistors
R1—4.7-megohm, ¼-W, 5% resistor
R2—1.5-megohm, ¼-W, 5% resistor
R3—100,000-ohm, ¼-W, 5% resistor
R4—68,000-ohm, ¼-W, 5% resistor
R5—33,000-ohm, ¼-W, 5% resistor
R6—51,000-ohm, ¼-W, 10% resistor
R7—1-megohm, ¼-W, 10% resistor
R8—51,000-ohm, ¼-W, 10% resistor
Misc.—Probe tip, case, pc or perforated board, solder, hookup wire, etc.



AUDIBLE LOGIC STATE INDICATOR

The indicator will work with either TTL or CMOS circuits. A useful feature is that the unit can be powered by the same supply as the one supplying the circuit under test. Logic state 1 at the probe will produce an audible tone on the loudspeaker. A switching signal at the probe also activates the loudspeaker.

RV1 sets the threshold level at which IC2 will switch on. This is normally set at maximum (wiper at the R2 end). RV2 sets the volume of the audible tone, and can be adjusted as required.

IC2 can be substituted by the equivalent LM741 but R3 must be removed first.