Low-priced logic probe indicates levels with tones

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Changes in sound tones are detected more readily than changes in light levels. Taking advantage of this fact, a penlite-size sound probe for troubleshooting digital circuits has been designed to provide an alternative to the conventional LED-type probe. The probe also checks continuity and is handy for testing cables and connectors. It is powered by two AA batteries mounted in the hand-held case, requires no on/off switch, and can be assembled easily from ordinary components.

The circuit emits these indications of logic levels:

- A low-pitched "boop" for a low TTL-logic level (0.8 volt or less).
- A high-pitched "beep" for a high TTL-logic level (3.0 V or more).
- No tone for an open or high-impedance connection.

It works like this: Transistors Q_4 and Q_5 (Fig. 1) form a relaxation oscillator whose frequency is roughly proportional to the charging current I. If logic LO is applied to the probe, Q_1 conducts and charges C through the 220-kilohm resistor. The resulting current I_L causes Q_4–Q_5 to oscillate at a low frequency, producing the "boop" sound. Logic HI will turn on Q_2 and Q_3, causing I_H to flow through the 15 - kΩ resistor. Since I_H is larger than I_L, Q_4–Q_5 oscillates faster, producing the "beep" sound. A dead-band effect occurs if the probe tip is left open or if the applied voltage falls between the maximum value of V_{LO} and the minimum value of V_{HI} (i.e., between 0.8 V and 3.0 V for the circuit shown); all transistors remain off, and battery drain is almost zero.

The charging resistors can be adjusted to vary the pitch of the tones. The logic probe in Fig. 1 has f_{LO} = 60 Hz and f_{HI} = 2,000 Hz.

To modify the probe for logic families other than TTL, the voltage of battery B_1 must be changed. This voltage should be $[V_{LO}(\text{max}) + V_{HI}(\text{min})]/2$, but, of course, batteries come in standard sizes, so values of V_{HI}(min) and V_{LO}(max) are adjusted by use of diodes as shown in Fig. 2. For example, if B_1 were a 2-V battery (instead of 1.5-V), V_{LO}(max) could be lowered back to 0.8 V by connecting one diode in series with the base of Q_1. (A diode would have to be removed from the base circuit of Q_2 to leave V_{HI}(min) unchanged.)

The logic probe in Fig. 1 uses silicon transistor types 2N4401 (npn) and 2N4403 (pnp), but any transistors with a high gain and low leakage will serve.

Although a miniature speaker may be used for the output device, a small magnetic earphone works nicely and has enough volume to be heard across a room. ☐

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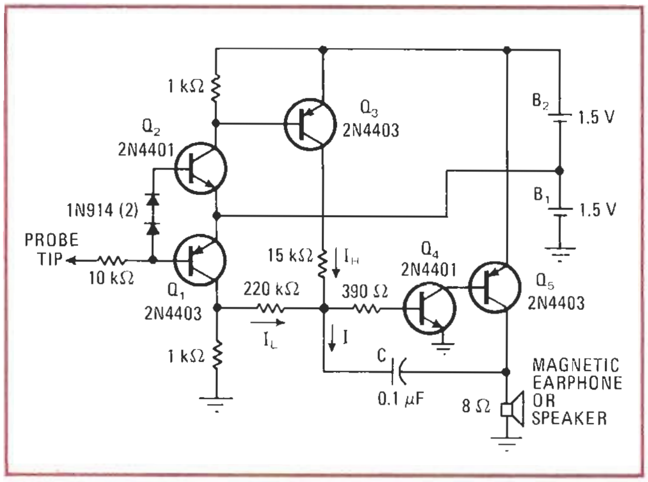
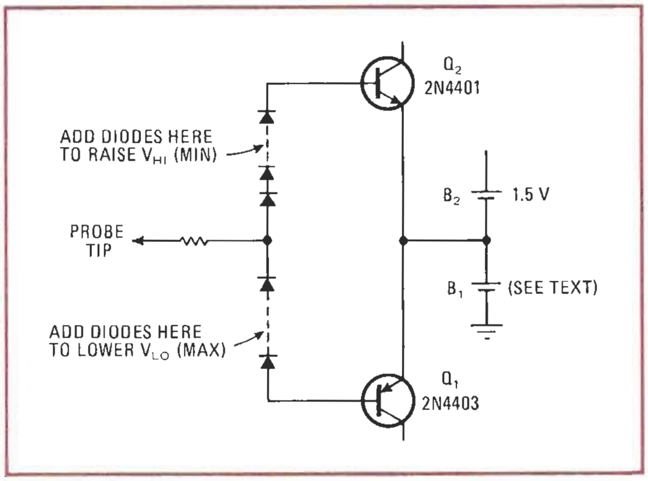


1. Sounds logical. Handheld probe "boops" when tip touches TTL pin at logic LO, and "beeps" when tip touches a HI pin. Tones are generated by Q_4–Q_5 relaxation oscillator, with C charged through 220 kΩ if LO voltage is applied, or through 15 kΩ if HI voltage is applied. Voltages between V_{LO}(max) and V_{HI}(min) produce no output.



2. Setting the gap. Circuit of Fig. 1 can be modified by addition of diodes to change the maximum voltage for "boop" tone, V_{LO}(max), and/or the minimum voltage for "beep" tone, V_{HI}(min). Any silicon diodes can be used; the voltage drop is about 0.5 volt per diode at the low diode currents.

and changes in beta are reflected in the value of V_{out} (β is inversely proportional to $V_{out} - V_{BE}$). If the value of R_B is chosen to give a V_{out} of approximately 10 V, changes in V_{BE} can be neglected. Thus

$$\beta = (R_B/R_C)(V_{CC} - V_{set})/V_{out}$$

The useful range of operation of the circuit of Fig. 1 is limited by the input common-mode range of the op amp. For a op amp operating with a ±15-V power supply, the differential gain becomes smaller when the common-mode voltage exceeds approximately 8 V. With a 40J op amp, common-mode voltage as high as 12 V can be tolerated. In the circuit of Fig. 1, the maximum permissible value of V_{CE} can be extended to 27 V by referencing the emitter to the negative side of the amplifier power supply rather than the common ground. In this case, $V_{CE} = V_{set} + 15$ V. This modification also allows larger values of R_B for a given base current and increases the system sensitivity to changes in beta. It cannot be used in power transistors when V_{CE} may be several hundred volts and a base drive of several hundred milliamperes may be required—far in excess of the current-handling capabilities of most op amps.

The circuit in Fig. 2 shows how the original circuit may be modified to maintain constant power in such cases. Instead of the direct connection of V_{CE} to the noninverting input of the operational amplifier, a fraction, γV_{CE}, of this potential is tapped from a voltage divider chain to ground. The impedance level of this chain is kept high to minimize the current drain from the current flowing through R_C. A current amplifier is used in the base-drive circuit. In Fig. 2, an emitter follower is shown; the base current is given by the relationship $I_B = (V_{out} - V_{BE1} - V_{BE2}) \times A_I/R_B$, where A_I is the current gain of the emitter follower and V_{BE1} and V_{BE2} are the base-emitter-junction voltages of the transistor under test and the current amplifier, respectively. Thus changes in beta are reflected in changes of V_{out}, as in the original circuit. □