NOTES

A simple inexpensive computer-controlled tone generator

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A simple circuit for a keyed tone generator is described. The total construction cost is less than \$5. Various adaptations and modifications of the circuit are discussed.

The tone generator described here can be used in a variety of applications. We use the unit as a ready signal in computer-controlled reaction time experiments.

THEORY OF OPERATION

A single CMOS integrated circuit (IC), one transistor, and six discrete components are used to construct an inexpensive, yet versatile, keyed tone generator. Sections A and B of the 4001 quad NOR gate IC shown in Figure 1 form an oscillator. Lancaster (1977) describes a similar circuit using two CMOS inverting buffers. In this circuit, the two inputs of the A and B sections of the 4001 are joined (jumped) so that the NOR gates act as inverting buffers. The other two sections of the IC are then available for gating and other functions.

The circuit works as follows: If the output of Section B is high, its input(s) will be low and thus resistor R1 will charge capacitor C1 in the positive direction. When C1 charges sufficiently to surpass the input

threshold of Section B, the output of this section goes low. The inputs of Section A also go low, and thus the output of this section goes high. Since the output of Section B is now low and its inputs are high, R1 charges C1 in the negative direction. When the charge on C1 drops below the threshold of the Section B inputs, the output of this section and the inputs of Section A go high, returning the circuit to its original state. The circuit continues to alternate between the two states as R1 charges C1 first in the positive and then in the negative direction.

The output of the oscillator is connected to one input of Section C of the 4001 IC, where it is gated by a signal from a computer or other source attached to the other input of this section. While the gating signal is low, the oscillator signal is applied to the base of the 2N2222 transistor through a 470-ohm current-limiting resistor. When the oscillator signal drives the base of this transistor high, it turns on. This completes the path from the power source through the primary of the audio output transformer to ground. This path is broken when the oscillator signal drives the base of the transistor low once again.

CONSTRUCTION AND OPERATION

Layout of the components (see Table 1) and wiring are not critical. The prototype was wire wrapped on a small piece of perfboard using a wire-wrap socket and individual wire-wrap posts to mount the components. It is important that Pins 12 and 13 of the IC be tied high, as shown in Figure 1, or grounded. Floating inputs may cause the gate to drift into its active state, thereby

Figure 1. Circuit diagram of the keyed tone generator. Total construction cost is less than \$5.

Table 1
Parts List for Tone Generator

Q	Item
1	CMOS IC (4001)
1	NPN transistor (2N2222)
1	Capacitor (.1 mylar)
2	Resistor (.25 W, 5.6K, 470 ohms)
1	Audio output transformer (15K primary, 8-ohm secondary)
1	Speaker (8 ohms)

Note—Q = quantity.

dramatically increasing the current drawn by the IC. This spare gate can be used as an inverting buffer with a PNP transistor (described below), or it can be used in a manner similar to that of Section C of the IC to gate on another signal. For example, if Pin 12 is connected to Pin 8 and Pin 13 is grounded, Pin 11 can drive the anode of an LED. The cathode of the diode must be grounded. This connection of the LED causes it to light at the same time the tone is heard from the speaker.

The circuit operates well at any voltage between 4.5 V and 15 V. It is important, however, that the gating voltage applied to Pin 8 of the IC be coordinated with the supply voltage. Thus if the power source supplies 12 V, the gating voltage must rise to nearly 12 V in order to turn the tone off. If the keying signal is at TTL levels (as it will be from many computer interfaces), the supply voltage must be 5 V and a 2.2K pull-up resistor must be connected between Pin 8 of the IC and the supply voltage. This pull-up resistor is also necessary if the circuit is to be keyed by a mechanical switch that grounds Pin 8. Supply voltage is unimportant in this instance. With a 12-V supply, the "tone-off" current is 1.5 mA and the "tone-on" current averages 10 mA. Both currents drop slightly as supply voltage is reduced.

For any supply voltage, the current requirements are small enough to make battery operation quite feasible.

The electrical characteristics of the audio output transformer and speaker are not critical. Components salvaged from a transistor radio will do nicely. Any general-purpose NPN switching transistor will work in the circuit as shown. It is also possible to use a PNP transistor such as a 2N2907, but it will be necessary to connect Pin 10 of the IC to Pins 12 and 13 and then connect the 470-ohm resistor from the base of the transistor to Pin 11. This uses Section D of the IC as an inverting buffer, to insure that the transistor remains off when the tone is not gated on. If a PNP transistor is used, its emitter must be connected to the supply voltage, and the free end of the audio transformer's primary must be grounded.

Other values for C1 and R1 may be chosen to achieve different tone frequencies. The indicated values produce an 800-Hz tone. The formula relating frequency to the values of R1 and C1 is indicated in Figure 1. R1 can be replaced with a potentiometer to achieve a continuously variable tone frequency capability. A 100K potentiometer can be inserted between the collector of the transistor and the primary of the audio transformer to control the volume of the tone. It is also possible to construct this circuit using a TTL IC (e.g., a 7402) rather than the CMOS IC specified. This will increase the current drawn by the circuit somewhat and will also restrict its application to 5-V logic systems.

REFERENCE

LANCASTER, D. *CMOS cookbook*. Indianapolis: Sams, 1977.

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