# THINK TANK

By John J. Yacono

## Supercharging a 555

Few will dispute that the 555 timer is one of the most popular IC's on the market today. It really boggles the mind to try to imagine all the ways it can be used. Despite all the cookbooks written in its honor, there are a few functions of the 555 that are seldom explained in any depth. Oddly one of those functions (namely, voltage-controled oscillator operation) is built into the chip—it even has a pin dedicated to that purpose—but it usually gets swept under the rug early in the text. To set things right, we'll explore voltage-controled oscillator (or VCO) operation in this article.

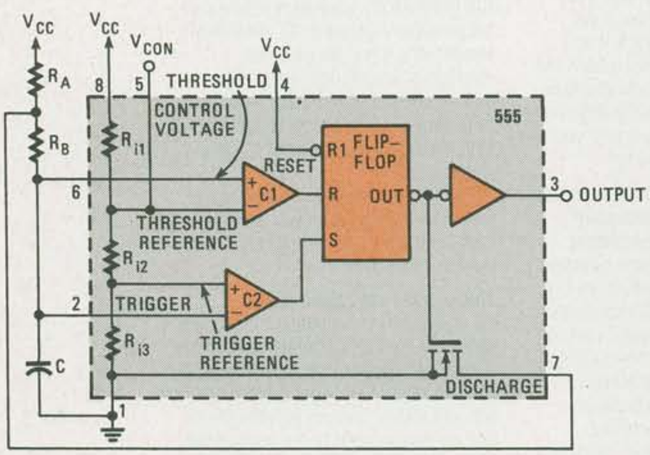


*Fig. 1. Shown here are the basic building blocks of the 555 timer IC accompanied by a few external timing components.*

But, first let me digress a little and give a simple explanation of how the 555 functions as an oscillator. A 555 connected as an astable oscillator is shown in Fig. 1. For now just ignore the control-voltage terminal (pin 5). When power is first applied to the circuit, capacitor C starts to charge via $R_A$ and $R_B$. The chip's output (at pin 3) is initially high. The 555's internal FET can be ignored at this time because it's turned off. So the capacitor's charging rate is determined only by $R_A$, $R_B$, C, and $V_{CC}$.

The chip's internal resistors ($R_{i1}$–$R_{i3}$) divide the supply voltage, $V_{CC}$, into $\frac{1}{3}V_{CC}$ and $\frac{2}{3}V_{CC}$. Those voltages are called the "trigger" and "threshold" reference voltages, respectively. The voltage across (or stored in) capacitor C is monitored by comparators C1 and C2 via the threshold and trigger inputs. Comparator C1 compares the capacitor voltage to the threshold voltage and C2 compares the capacitor voltage to the trigger voltage. When the capacitor voltage reaches the threshold-reference voltage, comparator C1 momentarily goes high, toggling the flip-flop. The flip-flop output causes the output terminal (pin 3) to go low and the internal FET to discharge the capacitor via $R_B$. The rate of discharge is thus determined by $R_B$, capacitor C, and $V_{CC}$.

When the capacitor voltage drops to the trigger-voltage level, it triggers comparator C2, which toggles the flip-flop. The FET then turns off, the output goes high, and the capacitor begins to charge again. That completes one cycle.

There are a few interesting facts about this method of oscillation. For example, the timing is independent of the power-supply voltage. That's because even though the charge rate will increase if you raise the supply voltage, the threshold-reference voltage would also increase, so it takes the capacitor just as long to reach the higher threshold-voltage level at the higher charging rate. Furthermore, although the capacitor dissipates that higher voltage slower, the trigger voltage is also higher, so the capacitor doesn't have to discharge as low.

The time it takes for the capacitor to charge from $\frac{1}{3}V_{CC}$ to $\frac{2}{3}V_{CC}$—the length of time that the output remains high—can be calculated using:

$$t_h = 0.693(R_A + R_B)C$$

The time it takes for the capacitor to discharge from $\frac{2}{3}V_{CC}$ to $\frac{1}{3}V_{CC}$—the length of time that the output is low—is given by:

$$t_l = 0.693(R_B)C$$

Now let's throw a monkey wrench into the works by applying a voltage ($V_{CON}$) to the control-voltage terminal (pin 5). That pin is connected directly the threshold-reference input of C1, and it allows you to program in your own threshold-reference voltage. The control voltage also indirectly sets the trigger-reference voltage, which is always equal to half the threshold-reference voltage (take a close look at the resistor divider network inside the chip to see why that's true). However, altering the trigger-reference voltage does not affect the discharge time ($t_l$) of the capacitor for the same reason a different supply voltage doesn't affect it (go back a couple of paragraphs if you forgot why). It does change the charging time ($t_h$), however, which can be computed using the following formula:

$$t_h = (R_A + R_B)C(-0.693 + \ln[1 + 1/(1 - V_{CON}/V_{CC})])$$

There are a few neat

tricks that you can do by controlling the 555 in that way: The first is that by changing the control voltage, you can perform pulse-width modulation. You can also modulate the frequency and simultaneously modulate the duty cycle. (Unfortunately, you can't change the frequency without changing the duty cycle with this method.) Further, by swinging the control voltage up and down, you can even sweep a range of frequencies.

Now let's take a look at what some of you clever readers have done with 555's on their own. The first circuit is valuable if you use 555's a lot.

**A TEST FIXTURE**

When I was building a 40,00-volt induction coil, a 555 oscillator timer used in the electronic-interrupter circuit kept burning up. Because of the current levels involved and the destruction of other components that occurred when the 555 would burn out, I could not use a logic probe as they are usually powered by the circuit under test.

That being the case, I built a 555 oscillator/timer tester (see Fig. 2). I placed it in a plastic enclosure and mounted the SPST slide switch, LED1, and the 8-pin IC socket on the cover. To test the 555 in question, you place the IC in the socket and throw the switch. If the LED blinks fully on and off, the IC is okay. If the LED blinks dimly then turns fully on, the 555 is beginning to fail because it's having trouble turning off. If the LED just glows brightly, the IC is completely bad.

The operation of the circuit is very simple. When power is applied to the 555, it should go through normal oscillations, so it's output should turn completely high and low, turning the LED fully on and off, respectively. Anything else will cause the LED to glow dimly during one part of the cycle. The unit is a simple, easy-to-use circuit that can be an important tool for the workbench.

*—Kent Ponton, Manteno, IL*

*Way to go, I like the circuit. Although it is unlikely, it is possible that the 555 being tested is so shot that the LED doesn't glow at all. Of course that could also be caused by a lack of power to the test fixture, so an LED power-on indicator*

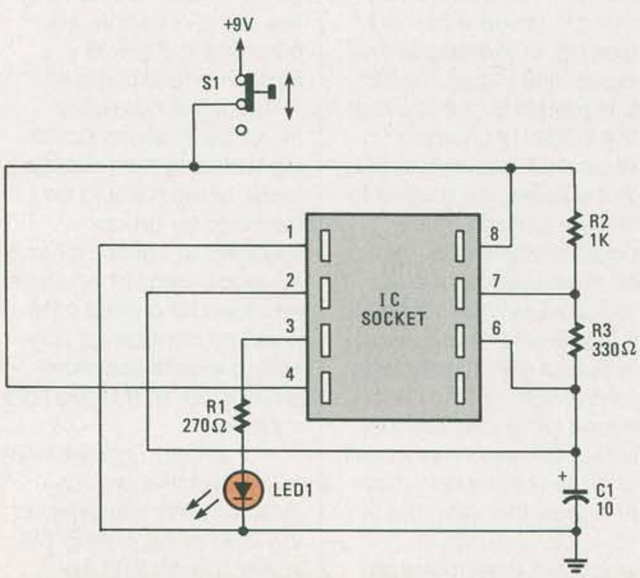


*Fig. 2. This test fixture for 555's is a great time saver. Just pop in the suspect IC and watch the LED indicator.*

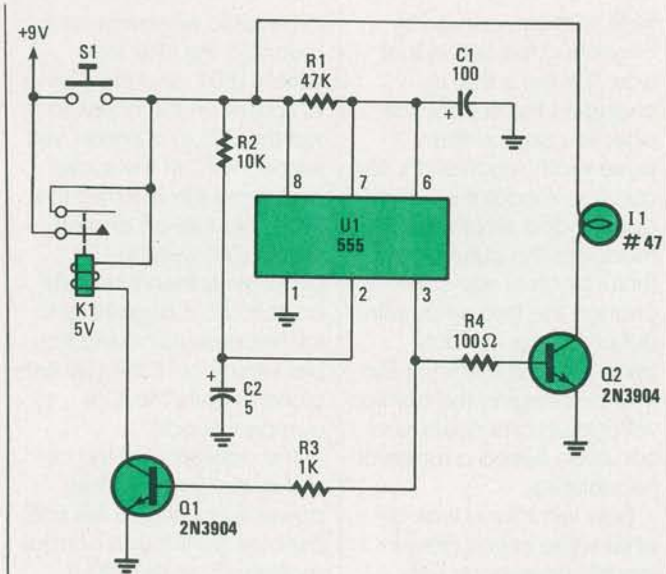


*Fig. 3. If you've banged one of your big toes on the dresser enough times to form it into a ping-pong ball shape, then this circuit can at least save your other big toe from the same fate.*

*would be a nice but simple feature to add.*

## A TIMED NIGHT LIGHT

I needed a wall-mounted, battery-powered night light to illuminate certain areas in my home. I only needed the light to be on for a brief period of time and since I wanted to use battery power, the current drain had to be kept to the bare minimum. That meant the circuit should draw no current until triggered.

Of course the first thing to come to mind was a 555 wired in a one-shot mode (see Fig. 3). Pressing S1 energizes the circuit. The 555 is triggered by the low that the initially uncharged capacitor C2 presents to pin 2. The capacitor is wired to charge through R2 because the timer will not turn off if the voltage at pin 2 remains low. When the 555 is triggered in that fashion, its output (pin 3) goes high for a length of time determined by R1 and C1. That biases Q2, which turns on I1, and also biases Q1, which energizes the relay. The relay keeps the circuit energized after the pushbutton, S1, is released until the one-shot times-out, at which point the circuit shuts down.

Standard components are used throughout the circuit. Although the transistors are shown as 2N3904's, any NPN switching transistors will do. I used a Gordos 5-volt reed relay for K1. I housed the circuit in an 8-ounce opaque dish-shaped food container by mounting the circuit, a 9-volt battery, and I1 on the inside of the snap-on lid. Switch S1 was mounted so that it protruded through the dish portion of the container. The entire assembly was mounted to the wall through a hole in the lid.

The circuit has many more applications including switching high-voltage loads. Lamp I1 could be replaced by an optoisolator to control 117-volt AC loads. Relay K1 could be replaced by a small multipole unit capable of controlling several separate devices. For all that, do I get a book?

—*J. dePrisco, Hazleton, PA*

*You certainly do. For those readers interested in the idea of controlling 117-volt AC power with optoisolators, look back at last month's* Think Tank *column.*

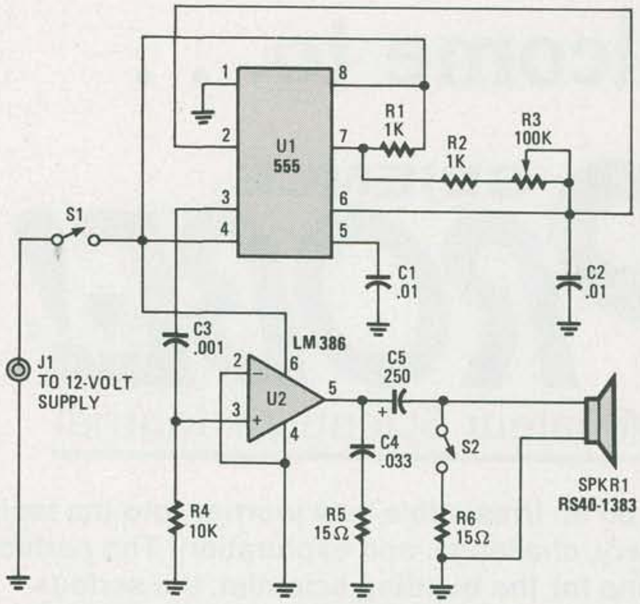


*Fig. 4. This is a perfect circuit for the ultrasonic experimenter. However, be cautious and kind when using it; it can cause great pain to pets with sensitive hearing.*

## ULTRASONIC-FREQUENCY GENERATOR

I have been an electronics hobbyist most of my life and I find your magazine to be a valuable source of information for designing and building circuits. I had a lot of fun with this circuit and thought your readers might enjoy it also. It's an ultrasonic-frequency generator built around a 555 oscillator/timer IC (see Fig. 4). The 555 functions as a simple oscillator. It's operating frequency is determined by the values of R1–R3 and C2. Resistor R3 can be used to vary the frequency from 3 to 100 kHz.

The output of the oscillator (pin 3) is fed to U2, an LM386 low-voltage audio-power amplifier, which is used to drive a piezo transducer.

—*Mack Hays, Birmingham, AL*

*Real nice. I hope Radio Shack continues to carry that transducer. It could form the basis of a lot of interesting projects.*

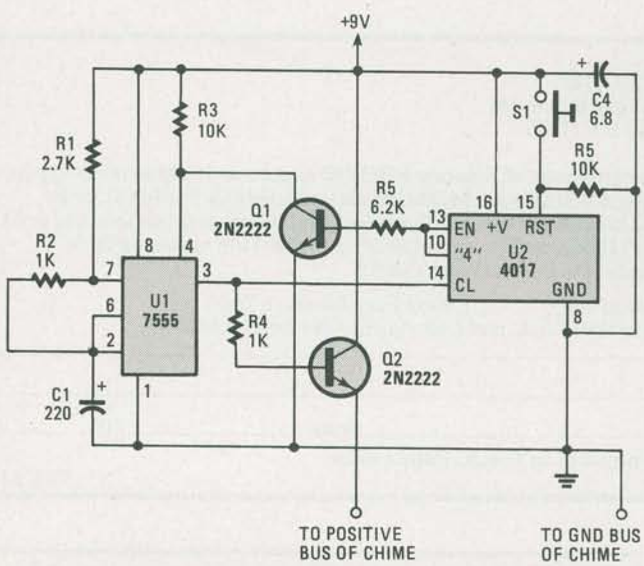


*Fig. 5. This add-on to a circuit that appeared in this magazine awhile ago uses the 4017 decade counter in a manner described in this column back in May 1991.*

## WHOOPING IT UP

In August of 1987, on page 94, *Think Tank* carried an interesting door-annunciator circuit that emits a nice and compelling "Whoop!," but I thought it should sound-off four "Whoops!" before quitting. So, I came up with an addition to that fantastic circuit (see Fig. 5).

If S1 is depressed, the 7555 (a special relative of the 555, although a regular 555 should do) clocks a 4017 decade counter/divider. It also turns on Q2 for a period of time determined by R2 and C1. That transistor should be used to apply power to the annunciator circuit (which means the old annunciator circuit will no longer need C1 or S1). After U1 goes through four cycles, pin 10 of U2 goes high and transistor Q1 conducts, bringing the reset input (pin 4) of U1 low, which shuts-down the whole circuit.

—*Sid Buck, Key Largo, FL*

*I'm glad you like the column; and don't worry, there's plenty more where this came from. Those of you that are interested in knowing precisely how the 4017 is used in this circuit should check out the discussion that appeared in the* Think Tank *column in the May 1991 issue of this magazine.*

Well friends, as the sun slowly sinks into the west, we come to the end of another month. Happy trails to you and until we meet again, please send your comments, requests, and fruitful efforts to *Think Tank*, **Popular Electronics**, 500-B Bi-County Blvd., Farmingdale, NY 11735. ■