Interfacing 555 Timers

A hands-on look at real-world use of this ubiquitous and very versatile IC timer chip

By Joseph J. Carr

The 555 timer chip ranks as perhaps the all-time most popular device in the IC arena—with good reason. Its immense popularity derives from the fact that the 555 is inexpensive, well-behaved and is so utterly useful in an almost limitless variety of applications. Since a lot has been written over the years about the 555, we will not begin at the beginning here. We will assume that you either already know the basics or where to look for them. Instead, we will concentrate in this article on interfacing between the 555 device and the "outside world."

Definitions

Shown in Fig. 1 are the package and pinout details for the popular eight-pin mini-DIP version of the 555 timer. In reviewing pin function definitions and their uses, keep in mind that "high" means a potential that is greater than 2(V+)/3 and "low" means either a grounded condition, where V = 0 (as in the case of the RESET pin) or a potential that is less than (V+)/3 (as in the case of the TRIGGER pin).

Pin function definitions for the 555 timer are as follows:

- **GROUND** (pin 1) serves as the common reference point for all signals and voltages in the 555 circuit, both internal and external to the chip.
- **TRIGGER** (pin 2) is normally held at a potential greater than 2(V+)/3. In this state, 555 OUTPUT pin 3 is low. If the TRIGGER pin is brought low to a potential that is less than (V+)/3, OUTPUT pin 3 abruptly switches to the high state. The output remains high as long as pin 2 is low, but the output does not necessarily revert back to low immediately after pin 2 is brought high once again.

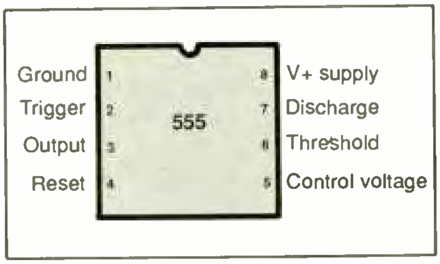

Fig. 1. Package configuration and pinout details for the 555 timer.

- **OUTPUT** (pin 3) is capable of either sinking or sourcing current up to 200 milliamperes, which is in contrast to other IC devices in which the outputs either sink or source current, but not do both. Whether the 555 output operates as a sink or a source depends on the configuration of the external load. Figure 2 illustrates both types of operation.

The arrangement shown in Fig. 2(A), in which external load R_L is connected between the 555 output and V+, allows current to flow in the load only when pin 3 is low. In this condition, the external load is grounded through pin 1 and small internal source resistance R_{S1}. In this arrangement, the 555 output is a current sink.

The circuit shown in Fig. 2(B) is for the case where the load is connected between pin 3 of the 555 and ground. When the output is low, the load current is zero. However, when the output is high, the load is connected to V+ through small internal resistance R_{S2} and pin 8. Here, the output is a current source.

- **RESET** (pin 4), when low, immediately switches the output of the 555 at pin 3 to a low state. In normal opera-

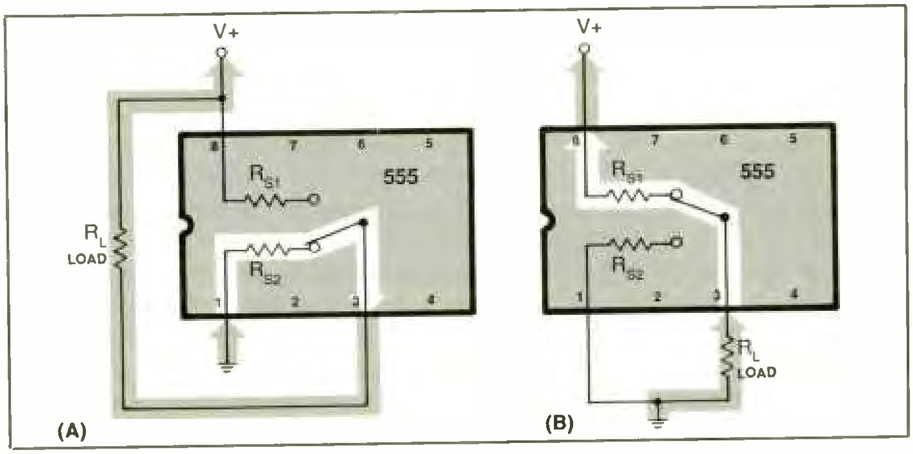

Fig. 2. Examples of a 555 used as (A) an output current sink and (B) an output current source.

tion, it is common practice to connect pin 4 to V+ to prevent false resets from noise impulses.

• **CONTROL VOLTAGE** (pin 5) normally rests at a potential of 2(V+)/3 due to an internal resistive voltage divider. Applying an external voltage to this pin, or connecting a resistor to ground, changes the duty cycle of the output signal. If not used, pin 5 should be decoupled to ground through a 0.01- to 0.1-microfarad capacitor.

• **THRESHOLD** (pin 6) monitors the voltage across the capacitor in the external RC timing network. If pin 6 is at a potential of less than 2(V+)/3, the output (at pin 3) is high. Alternatively, when the voltage on pin 6 is less than 2(V+)/3, the output is low.

• **DISCHARGE** (pin 7) is connected to the collector of an internal npn transistor. The emitter of this transistor is connected to the ground (pin 1) of the 555. When the 555 times out, the transistor turns on and can discharge the external timing capacitor.

• **V+ POWER SUPPLY** (pin 8) connects to the positive rail of the power supply that drives the 555 timer chip (and usually any other circuitry). Good practice dictates that a 0.1- to 1.0-microfarad decoupling capacitor be used between pin 8 and ground.

Monostable Operation

The monostable multivibrator (MMV), also called a one-shot multivibrator, produces a single output pulse of fixed duration when triggered by an input pulse, as illustrated in Fig. 3(A). The output of the one-shot snaps high following the trigger pulse and remains in this condition for a predetermined duration. When this time expires the one-shot is "timed-out" and, so, snaps low again.

The output of the one-shot remains low indefinitely, unless another trigger pulse is applied to it. The 555 timer can be operated as a monostable multivibrator with suitable connection of the external circuit, as in Fig. 3(B). It is this monostable multivibrator configuration of the 555 that we will use as the basis for our discussions here.

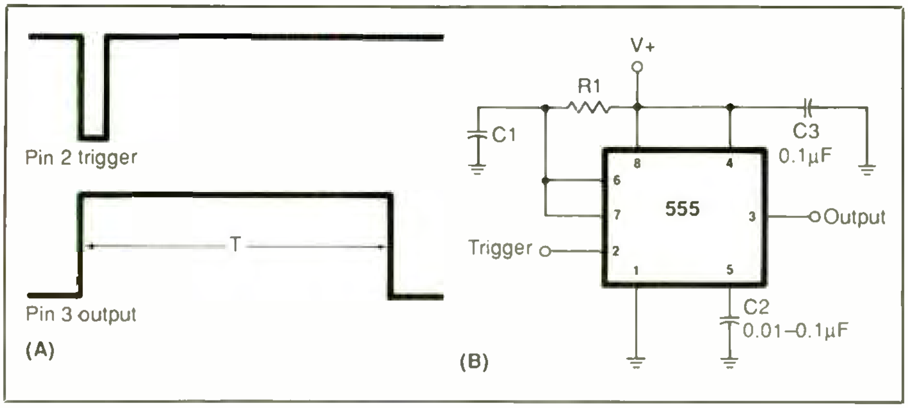

Fig. 3. Timing diagram (A) of a one-shot multivibrator built around the 555 timer and (B) details for assembling a 555 a one-shot multivibrator.

Input Triggering

The 555 MMV circuit triggers by bringing pin 2 from a positive voltage down to a potential of less than (V+)/3. Triggering can be accomplished by applying a pulse from an external signal source or through other means.

Figure 4(A) is the schematic diagram of the circuit for a simple push-button-switch trigger circuit. Pull-up resistor *R2* is connected between pin 2 and V+. If normally-open push-button switch *S1* is open, the TRIGGER input is held at a potential very close to V+. But when *S1* is closed, pin 2 is brought to ground potential. Because pin 2 is now at a potential that is less than (V+)/3, the 555 MMV triggers. This circuit can be used for contact debouncing in digital circuits.

A circuit for inverting the trigger pulse applied to the 555 is shown in Fig. 4(B). Here, a common npn bipolar transistor, such as the 2N2222, is used in the common-emitter mode to invert the pulse. Again, a pull-up resistor is used to keep pin 2 at V+ when the transistor is turned off. However, when the positive-polarity trigger pulse is received at the base of *Q1*, the transistor saturates, which forces the collector (and pin 2 of the 555) to near ground potential.

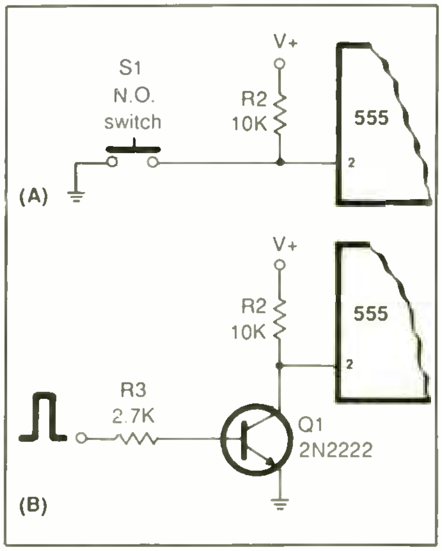

Fig. 4. Examples of (A) simple push-button switch triggering for the 555 timer and (B) transistor inverter that permits positive-going pulses to trigger the 555.

Shown in Fig. 5 are two ac-coupled versions of the trigger circuit. In both circuits, a pull-up resistor keeps pin 2 normally at V+. But when a pulse is applied to the input end of *C3*, a differentiated version of the pulse is created at the TRIGGER input of the 555. Diode *D1* clips the positive-going spike to 0.6 or 0.7 volts, passing only the negative going pulse to the 555. If the negative-going spike

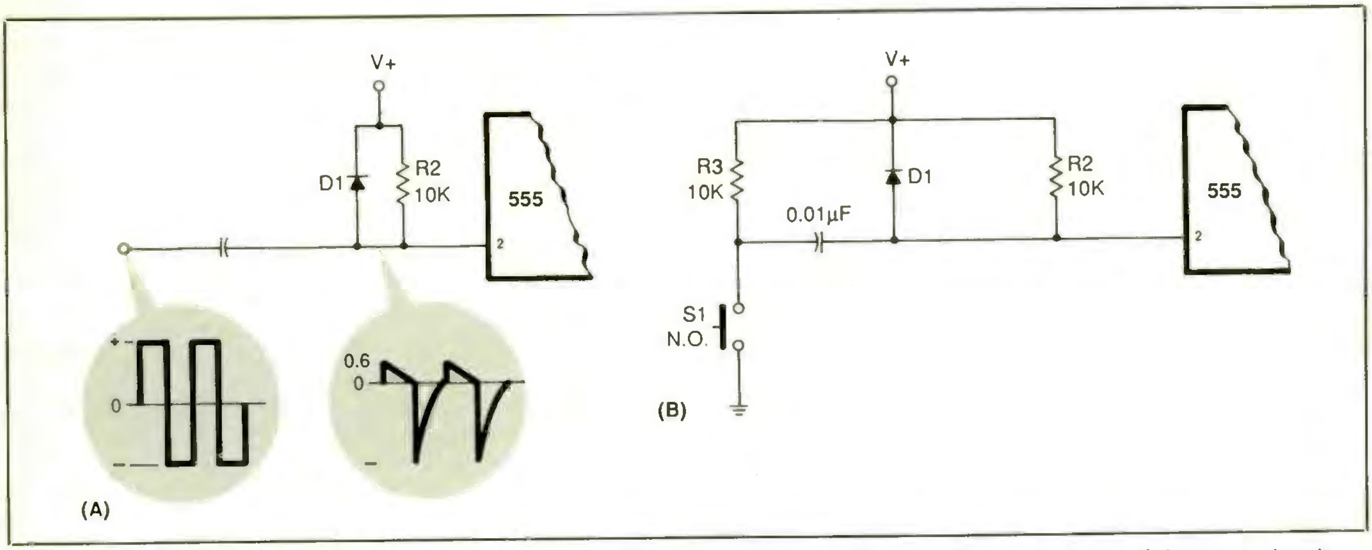

Fig. 5. Examples of (A) ac-coupled triggering of a 555 using pulses and (B) push-button version of the same circuit.

can counteract the positive bias provided by *R2* sufficiently to force the voltage lower than (V+)/3, the 555 will trigger. A pushbutton switch version of this same circuit is shown in Fig. 5(B).

A touchplate trigger circuit is shown in Fig. 6(A). Pull-up resistor *R2* has a very high value (22 megohms shown). The touchplate consists of a pair of closely spaced electrodes. As long as there is no external resistance between the two halves of the touchplate, the TRIGGER input of the 555 remains at V+. However, when a resistance is connected across the touchplate, the voltage (V1) drops to a very low value. If the average finger resistance is about 20,000 ohms, the voltage drops to: $V1 = [(V+ \times 20 \times 10^3)/(R2 + 20 \times 10^3)]$. Thus, when *R2* is 22 megohms, the voltage drops to 0.0009(V+). This is considerably less than the (V+/3) triggering criterion for the 555.

The same concept is used in the liquid-level detector circuit shown schematically in Fig. 6(B). Once again, a 22-megohm pull-up resistor is used to keep pin 2 at V+ in operation. When the level of the liquid rises sufficiently to short out the electrodes, however, the voltage on pin 2 (V1) drops to a very low level, forcing the 555 to trigger.

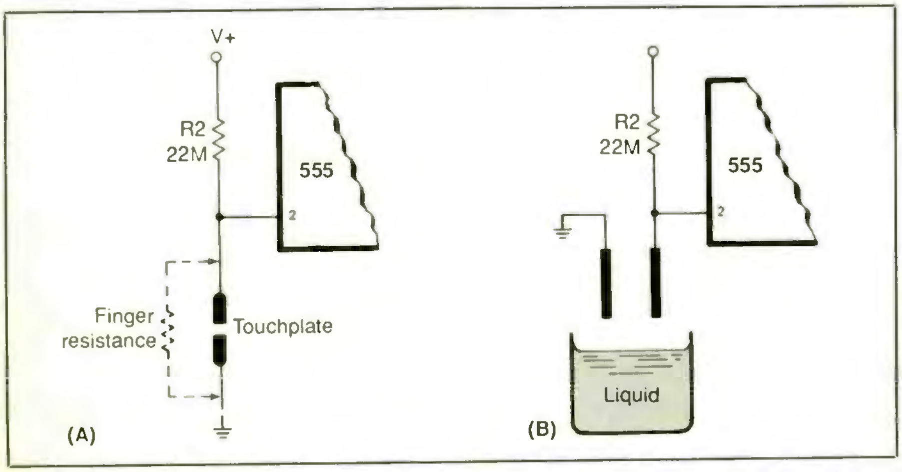

Fig. 6. Examples of (A) touch-plate sensor triggering of a 555 and (B) liquid-level alarm version of the same principle.

Output Circuits

As stated above, the output at pin 3 of the 555 can serve as either a current source or a current sink, depending on how you wire the circuit. The output can be made TTL-compatible by making V+ 5 volts dc. It can also be made CMOS-compatible by matching the 555 power supply potentials to the levels used in the particular CMOS circuit.

Figure 7 shows how light-emitting diodes can used as the load for the 555. Although LEDs are used here, almost any load that draws less than 200 milliamperes could be used instead. The usefulness of the 555 is demonstrated by these circuits. There are times when you might want a LED indication when the output of the 555 is low, other times when it is high. The 555 can accommodate either need without requiring an intervening open-collector inverter stage.

In Fig. 7(A), the LED, wired between pin 3 and ground, requires the 555 to act as a current source. When the output is low, there is no potential across the LED, no current flows, and the LED is off. When the

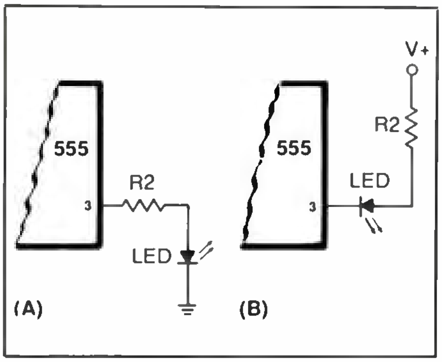

Fig. 7. Light-emitting diode load used with a 555 timer in (A) current-source and (B) current-sink modes.

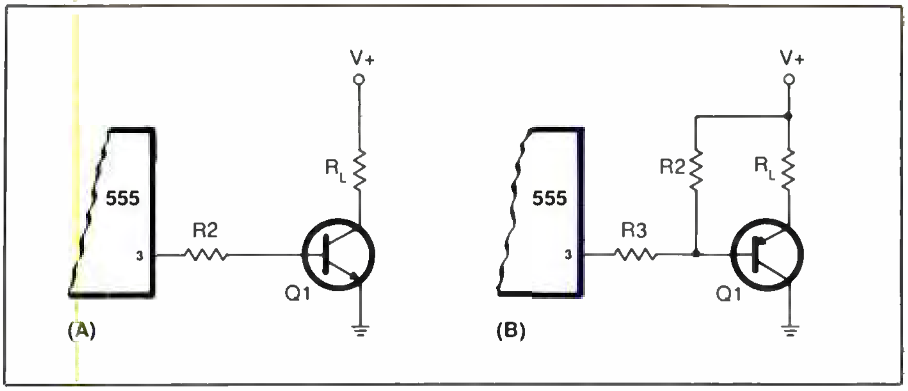

Fig. 8. Details of use of (A) npn and (B) pnp transistor switches to increase current-handling capability of a 555.

output is high, however, a potential appears at pin 3, current flows in the LED, and the LED turns on.

In Fig. 7(B) the opposite connection is shown. Here, the LED is wired between the OUTPUT terminal and V+, causing the output of the 555 to sink current. When the output is low, the cathode end of the LED is essentially grounded through a small resistance, so the LED is turned on. When the output is high, the potential at both ends of the LED is close to V+. Thus, with no differential voltage between cathode and anode, no current flows through the LED and the LED is off.

In both Fig. 7 examples, the resistor in series with the LED limits the current flowing in the LED. For most unmarked LEDs, maximum safe current is 15 mA (0.015 A). Therefore, you should set the value of *R2* to a value of (V+)/0.015 or greater.

When the current through the load exceeds the 200-milliampere output capacity of the 555, you can add an external transistor switch, as illustrated in Fig. 8, to handle the greater current. The output of the 555 is used to turn on and off the transistor. In Fig. 8(A), an npn transistor version is shown. When the output of the 555 in this circuit is low, no bias voltage is applied to the base-emitter junction of the transistor. This keeps the transistor in cutoff. But when the output of the 555 is high, the transistor is biased into saturation, causing it to turn on hard. The "cold" end of the load, connected to the collector of *Q1*, is thereby grounded and current flows. The value of the *Q1* base resistor is dependent upon the load current and the beta of the transistor. It can be found experimentally.

A pnp transistor is used in the same manner in Fig. 8(B). With the pnp transistor, the base must be less-positive than the emitter so that this circuit turns on when the output of the 555 is low. When the output is high, the emitter and base are at close to the same potential, so no action occurs.

Even greater currents can be accommodated if you use a relay as the load for the 555 output, as in Fig. 9. In addition, the relay makes it possible to use the 555 in a low-voltage dc circuit with other electronics to control a high voltage load circuit.

Select a relay with a coil rating of 18 volts dc or less (5, 6 and 12 volts are common). Match that voltage to the V+ used to power the 555. For example, if you are powering the 555 from a 12-volt dc source, select a 12-volt dc relay. Also, make sure that the rated coil current is less than 200 milliamperes. If you do not know the coil current rating, calculate it using the known or measured dc coil resistance (the most commonly listed relay specification) from the formula: $I_{coil} = (V+)/R_{coil}$.

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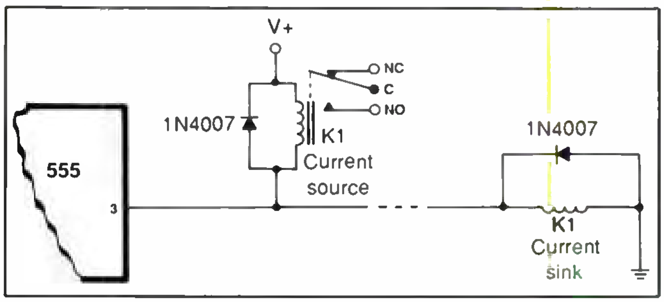

Fig. 9. Current-sink and -source details of a 555 used to drive relays.

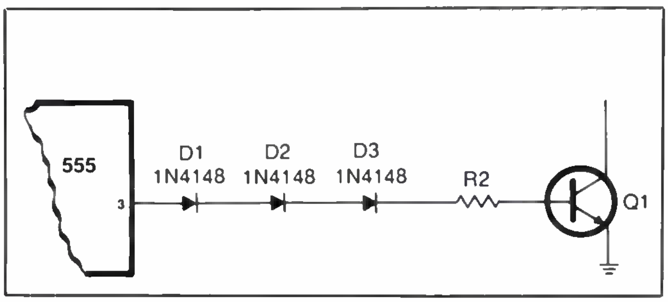

Fig. 10. Diodes can isolate the 555 output from transient pulses in the external load circuit.

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The two configurations shown in Fig. 9 are for current-source and current-sink operation, just as in the case for the LEDs above. Make sure that you use only one of these in a given circuit, of course.

Note in Fig. 9 that each relay coil is shunted with a 1N4007 rectifier diode. Diodes are used for spike suppression when the relay coil is de-energized. The back-emf generated when a relay coil deenergizes can be a high-voltage spike that can destroy the 555 and other components in a circuit. It has a reverse polarity with respect to V+. Thus, the diodes are normally reverse-biased, except when a large inductive spike from the relay is received. Keep firmly in mind that these diodes are *not* optional.

Shown in Fig. 10 is a method for solving a problem that is sometimes encountered with 555 relay drivers and certain other 555 circuits in which digital pulses or noise spikes appear. The spikes can get inside the 555 via its OUTPUT pin, where it forces the internal digital chip circuitry to reset. The diodes shown provide some crude isolation for the output of the 555.

If you have ever experienced seemingly unstable operation from a 555 timer, an unusual occurrence with this well-behaved chip, first determine whether the problem is external pulses coupled through pin 3. If so, the Fig. 10 circuit may well solve the problem.

In summing up, remember that the low-cost 555 provides a variety of functions at very low cost for it and any additional components needed to configure a circuit around it. In this article, we have examined a small number of different ways to interface the ubiquitous 555 timer to the external world, at both input and output ends. Now it is up to you to broaden your use base of this extremely versatile chip, through further study and experimentation. You will be glad you did. ME