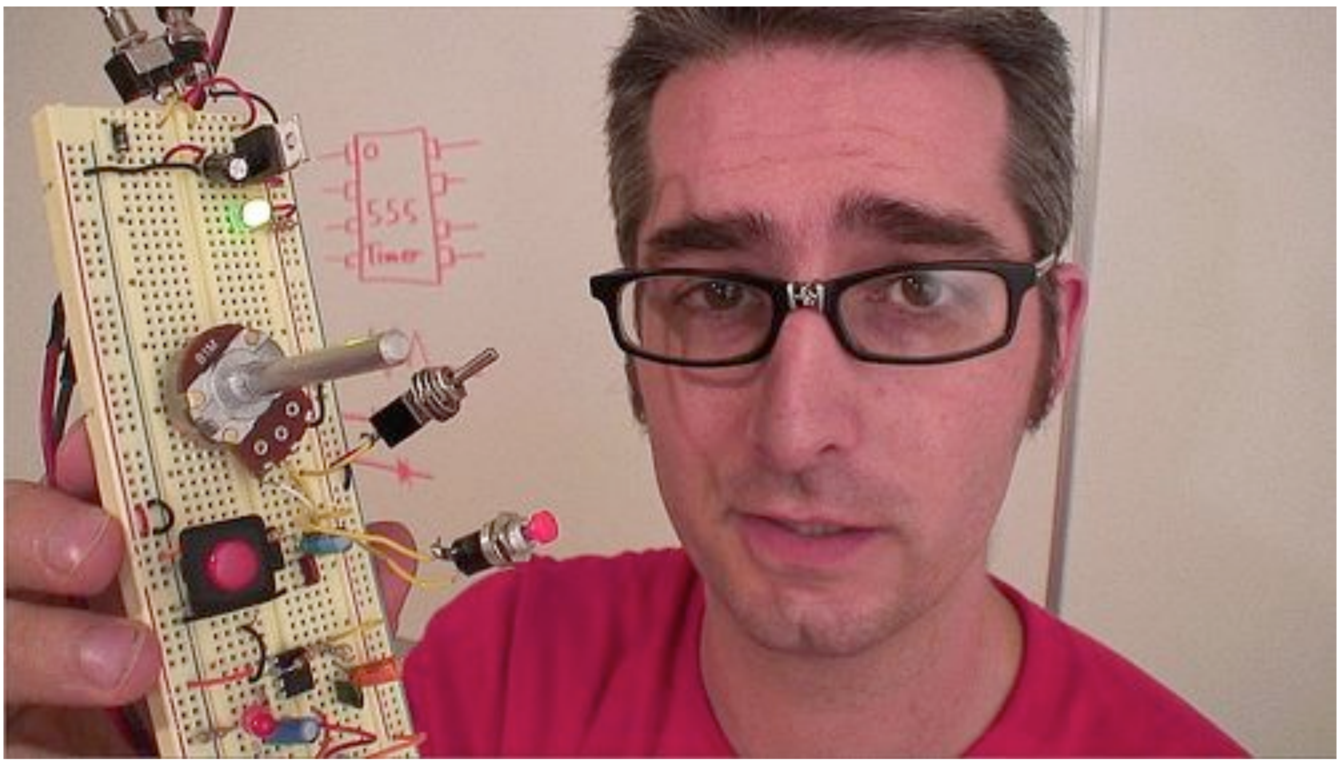
Weekend Projects Make: technology on your time

Introduction to Breadboard Electronics



Breadboarding is a great way to get started in electronics. You don't need to solder and you can put things in and take things out really easily.

Before you get started on the electronics for the game timer below, make sure to go over to the Sparkfun tutorial on setting up power to your breadboard at http://www.sparkfun.com/commerce/present.php?p=BEE-1-PowerSupply.

Then order up your parts from mouser, digikey, or jameco and you're all set to start playing with a breadboard! Take picture of your breadboard creations and upload them to the Make: flickr pool at http://flickr.com/groups/make/pool.

The Biggest Little Chip

AN INTRODUCTION TO THE VERSATILE 555 TIMER.

By Charles Platt

Back in 1970, when barely half a dozen corporate seedlings had taken root in the fertile ground of Silicon Valley, a company named Signetics bought an idea from an engineer named Hans Camenzind. It wasn't a breakthrough concept, just 23 transistors and a bunch of resistors that would function as a programmable timer. The timer would be versatile, stable, and simple, but these virtues paled in comparison with its primary selling point. Using the emerging technology of integrated circuits, Signetics could reproduce the whole thing on a silicon chip.

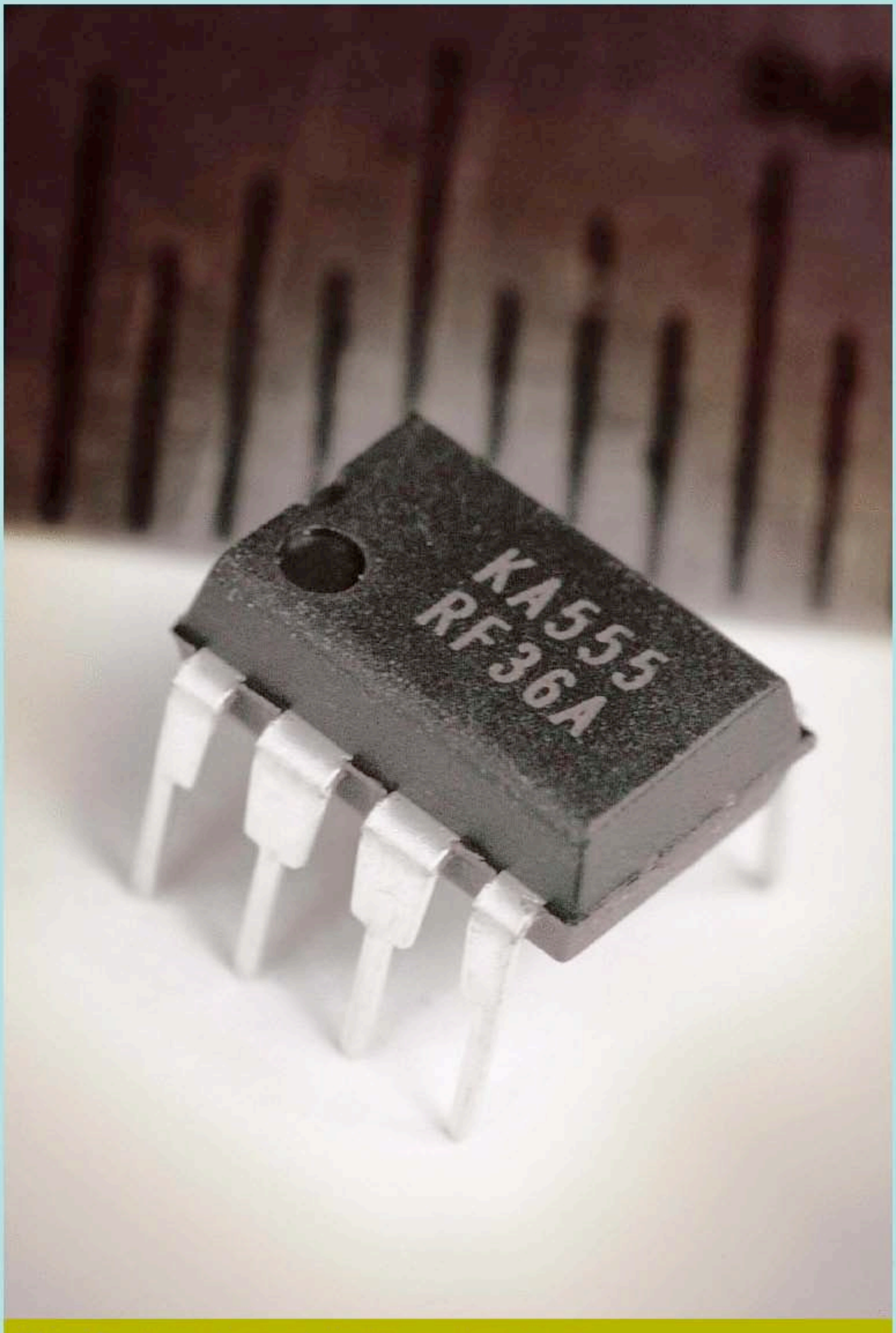
This entailed some handiwork. Camenzind spent weeks using a drafting table and a specially mounted X-Acto knife to scribe his circuit into a large plastic sheet. Signetics then reduced this image photographically, etched it into tiny wafers, and embedded each wafer in a half-inch rectangle of black plastic with the product number printed on top. Thus, the 555 timer was born.

It turned out to be the most successful chip in history, in both the number of units sold (tens of billions, and counting) and the longevity of its design (unchanged in almost 40 years). The 555 has been used everywhere from toys to spacecraft. It can make lights flash, activate alarm systems, put spaces between beeps, and create the beeps themselves. Today, you can buy a single chip online for about 25 cents.

For the introductory project described below, you can use the 555CN, Fairchild LM555CN or KA555, Texas Instruments NE555P, or STMicroelectronics NE555N. The brand makes no difference. Each manufacturer offers a Complimentary Metal-Oxide Semiconductor (CMOS) version, a dual version, and a surface-mount version in addition to the old-style chip that stands on eight metal legs spaced 1/10" apart. For various reasons, you should use the old-style version.

First I'll show how the 555 can make an LED flash on and off. Then I'll adapt it to generate a musical tone, and finally I'll chain three 555s together to create a gadget you can use to impose a time limit in nonvideo games such as checkers or Scrabble. At the end of a preset interval, the timer will make a groaning sound to tell a tardy competitor that his time's up and his turn is over.

Photography and illustrations by Charles Platt



555 CHIP: The ruler in the background is calibrated in sixteenths of an inch.

1. TURN A 555 CHIP INTO A NOISEMAKER

Figure 1 shows a 555 chip seen from above, with its pins identified. The circular mark stamped in its body is adjacent to Pin 1.

Figure 2 shows a basic light-flashing circuit using the astable mode of the 555, meaning that the output on Pin 3 flips to and fro between positive and negative for as long as the power is switched on. The cycle time is determined by a capacitor and two resistors. A capacitor has electrical storage capacity (hence its name), while resistors reduce the flow of electricity. If you put a resistor in sequence with a capacitor, the resistor slows the charge and discharge times of the capacitor, thus offering a simple way to use electricity to measure time.

When you close switch S1 in the circuit, current flows through R1 and R2 and gradually starts charging capacitor C1. IC1 (the 555 timer) monitors this process. When C1 acquires ⅔ of the positive voltage powering the circuit, the 555 reverses its output on Pin 3 from positive to negative and forces C1 to discharge itself through R2. When the charge on C1 diminishes from ⅔ to ⅓, the chip flips back to its original state, resets its output from negative to positive, and repeats the cycle.

Using a 0.1 microfarad (μF) capacitor for C1, a 120 kilohm (kΩ) resistor for R1, and a 1 megohm (MΩ) resistor for R2, the LED flashes about 5 times each second. (The other components in the circuit have no effect on timing: R3 protects the LED from excessive current, while C2 protects the 555 timer from random electronic noise.)

Suppose you use a 1μF capacitor instead of the 0.1μF capacitor as C1. Now each cycle lasts 10 times as long. Conversely, if you use a 0.01μF capacitor for C1, the cycles are 1/10 as long. You can also change the timing by adjusting the resistor values. The value of R1+R2 affects the "on" cycle, while R2 alone determines the "off" cycle.

With high resistance and a small capacitor, the 555 will cycle very fast indeed — easily fast enough for its pulses to make musical noises through a loudspeaker.

Figure 3 shows a modified version of the circuit. The LED and its series resistor have been replaced with a different resistor, capacitor C3, and L1, a 1" RadioShack miniature loudspeaker. (Note: You cannot drive a full-size loudspeaker with a 555 timer unless you add an amplifier.) Make sure you update the values of R1, R2, and C1, which have been changed to make the 555 run faster. Now when you connect power, you should hear a low-pitched drone.

555 CIRCUIT BEGINNING: This is how the LED-flasher circuit in Figure 2 should look, using components plugged into a breadboard.

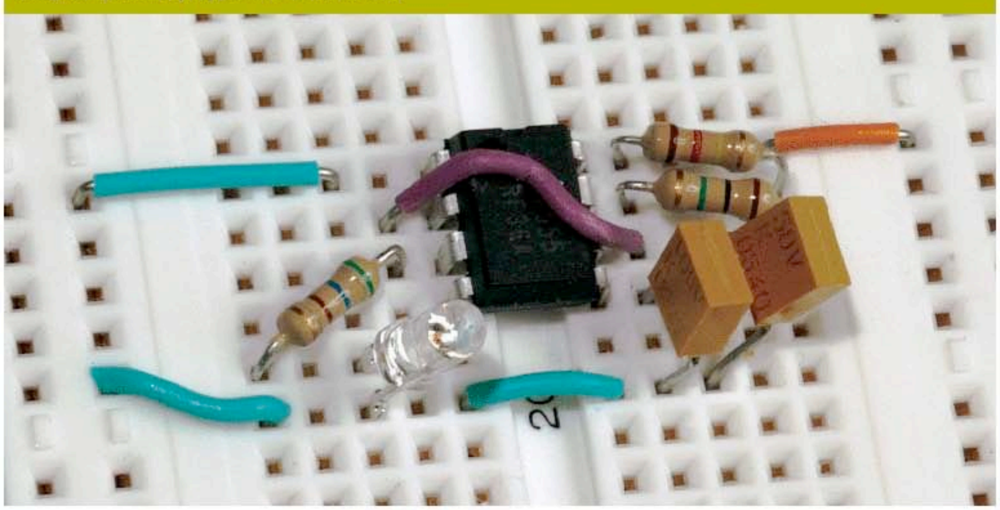
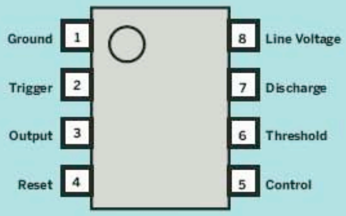
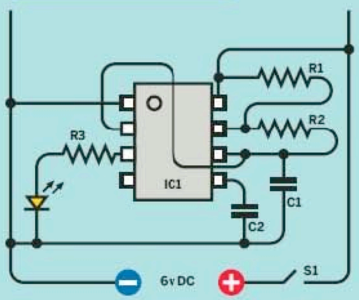


FIGURE 1



Pin functions on a 555 timer chip.

FIGURE 2



R1: 120kΩ
R2: 1MΩ
R3: 600Ω

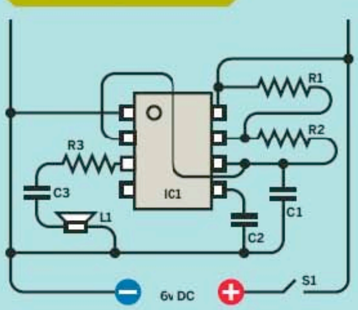
C1: 0.1µF
C2: 0.01µF

IC1: 555 Timer

D1: Any LED

S1: Power Switch

FIGURE 3



R1: 560kΩ
R2: 560kΩ
R3: 30Ω

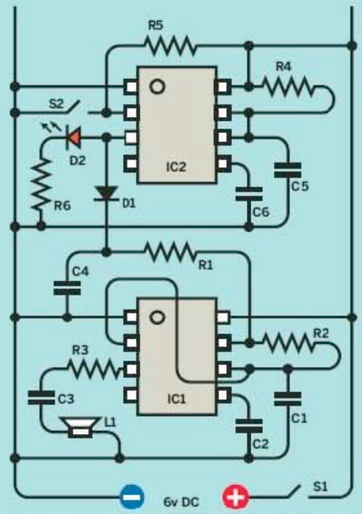
C1: 0.01µF
C2: Unchanged
C3: 2.2µF

IC1: Unchanged

L1: 1" Loudspeaker

S1: Unchanged

FIGURE 4



R1 through R3: Unchanged
R4: 1MΩ
R5: 10kΩ
R6: 600Ω

C1: 2.2µF
C2: Unchanged
C3: Unchanged
C4: 4.7µF
C5: 0.47µF
C6: 0.01µF

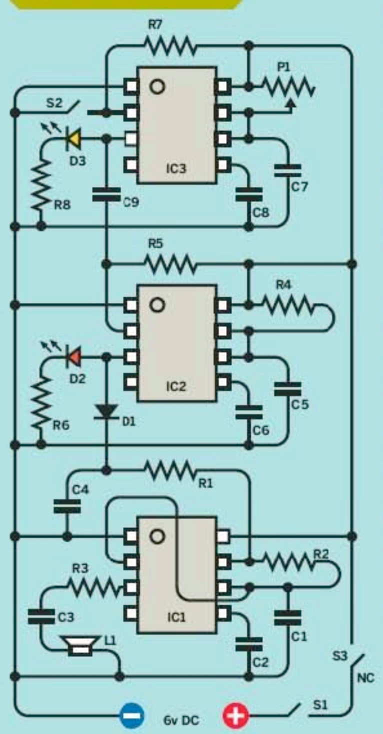
S1: Unchanged
S2: Single-pole momentary push-button, normally open.

IC1: Unchanged
IC2: 555 Timer

D1: 1N4148 Signal diode
D2: Any LED

L1: Unchanged

FIGURE 5



R1 through R6: Unchanged
R7: 10kΩ
R8: 600Ω

P1: 2MΩ Potentiometer

C1 through C6: Unchanged
C7: 2.2µF
C8: 0.01µF
C9: 0.01µF

S1, S2: Unchanged
S3: Momentary pushbutton, normally closed (NC)

IC1, IC2: Unchanged
IC3: 555 Timer

D1, D2: Unchanged
D3: Any LED

L1: Unchanged

2. ADD A SECOND 555 TO TRIGGER THE NOISEMAKER FOR A FIXED INTERVAL

We have a noisemaker; now we need to trigger it for a fixed interval. This can be done with a second 555 wired in monostable mode, meaning that it emits only one pulse. Figure 4 shows it added to the circuit. S2 is a pushbutton, although you can improvise just by touching 2 wires together. When this happens, IC2 emits a single pulse lasting about 1 second. This illuminates D2, an LED, to provide visual confirmation. The pulse also goes through D1, a signal diode, and activates IC1, which makes a sound as before, except that C4 prolongs it and causes it to diminish in frequency, creating a groaning effect.

Make sure this version of the circuit works before you continue.

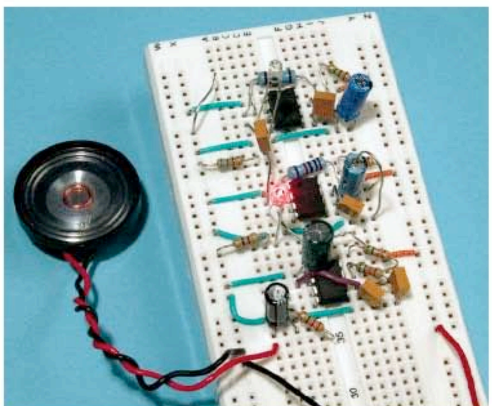
3. ADD A THIRD 555 TO TIME THE WAIT PERIOD

We have a noisemaker that can be triggered for a fixed interval; now we need to measure an interval of time before the sound occurs. A third 555 timer can impose this wait period, if we adjust it with higher-value resistors and a larger capacitor.

In Figure 5, C7 is charged through P1, a potentiometer (variable resistor). You can "tune" P1 to adjust the wait interval, and increase the value of C7 to make the interval even longer. At the end of the interval, the output on Pin 3 goes negative. This connects with the trigger pin of IC2 and tells it to emit its brief pulse, which tells IC1 to make its sound.

Note that S2 has been moved so that it controls IC3. When you use the circuit to impose a time limit during a game, hit S2 at the beginning of each person's turn.

So the circuit won't make its rude noise if a player does move within the allowed time, a cancel-reset button, S3, has been added. You hit this button when a player makes a move. The "NC" beside it tells you that it is a normally closed pushbutton. You still need the power switch, S1, to disconnect your power supply when the gadget is not in use.



555 CIRCUIT COMPLETE: The real-life version of the circuit in Figure 5. The top chip measures a time interval (using a fixed resistor that has been substituted for potentiometer P1). The red LED flashes at the same time that a sound is generated through a 1" loudspeaker (to the left of the chip).

WHAT NEXT?

You can substitute other components instead of the timing resistors to make the 555 behave in interesting ways. In Figure 3, if you use a thermistor or a photoresistor instead of R2, you can control the audio frequency with heat or light. A photoresistor and the 555 in monostable mode can function as a motion detector. Search makezine.com for "555". Also check out doctronics.co.uk/555.htm.

Hans Camenzind never imagined that his timer would become such a universal utility. He now thinks the internal design of the 555 isn't particularly elegant and should have been given a makeover decades ago. Elegance in design can be a big deal for engineers, but for end users, utility is usually more important. The 555 is simple, accurate, and robust, tolerating a wide range of power supplies and able to drive not only LEDs and loudspeakers but also relays and even small motors.

For 25 cents, that's more than enough.