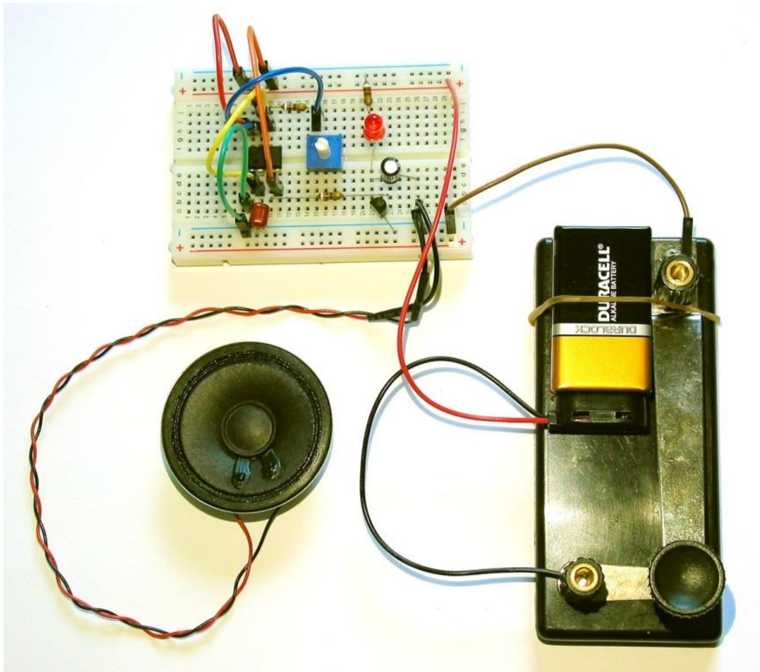
555 Morse Code Practice Oscillator Kit *(draft 1.1)*



This kit was designed to be assembled in about 30 minutes and accomplish the following learning goals:

1. Learn to associate schematic symbols with actual electronic components;
2. Provide a little experience soldering electronic components without consuming too much time;
3. Have fun by assembling a working Morse code practice oscillator you can keep!

Parts List

Quantity	Description
1	Morse Code Key
1	8 Ohm speaker w/leads
1	400-tie point breadboard
1	Jumper wire set
1	1M Ohm Potentiometer (the “knob”)
4	910 Ohm resistors
1	0.47 µF capacitor (marked “474”)
1	NPN transistor (BC337, 2N2222A, 2N3904, or equivalent[1])
1	Red LED
1	9 Volt battery clip
1	9 Volt battery
1	Kit Document w/assembly instructions and theory of operation
*	You may have extra components to use for other projects!

[1] Transistors may have similar electrical specifications, but their case style and lead arrangement may vary significantly. BE CAREFUL to use the proper pinout information for the transistor you are using otherwise you will destroy it.

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Assembly Instructions

The kit will be constructed in the following steps:

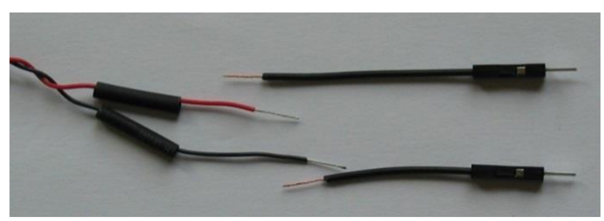
1. Solder jumper wires to speaker leads; (🡐 this step can be done at any time during assembly)
2. Pre-form resistors for use later;
3. Place 555 integrated circuit (IC) and jumper wires on the breadboard;
4. Place pre-formed resistors;
5. Place capacitors;
6. Place potentiometer ("POT");
7. Place LED and transistor;
8. Connect speaker and key, and battery;
9. Final inspection and battery connection. ***(🡐 DO NOT hook up the battery until completed!)***
10. ENJOY! (or troubleshoot if needed)

It is important that you have your assembled kit inspected by your instructor if you are unsure of anything. Some of the components in this kit can be permanently damaged by improper assembly, or unintentional contact between components.

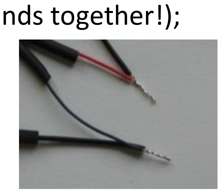
"Don't panic" if you find that you have extra parts! We have included some additional components that can be used for other projects. One of the neat things about breadboards is that you can wire up different circuits to try out other project ideas!

1. **Check your kit:** Ensure the kit contains all of the parts listed above. To keep the parts from getting damaged or lost, please return them to the bag until ready to use.

2. **Solder speaker wires to jumpers. (NOTE: If the soldering station is not available, this step may be skipped until later.)** Locate the speaker and *one* jumper wire (and piece of heat shrink tubing if included):



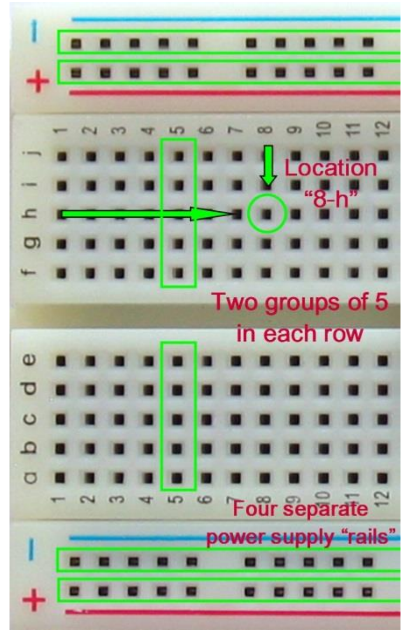
   a. Find a ventilated area for soldering in and put on a pair of safety glasses;
   b. Cut the jumper wire (and heat-shrink tubing if included) in half;
   c. Strip the ends of both the speaker wires and the cut jumper wire about ¼" and twist the strands together (if you are using heat-shrink tubing, put it on ***before*** twisting the ends together!);

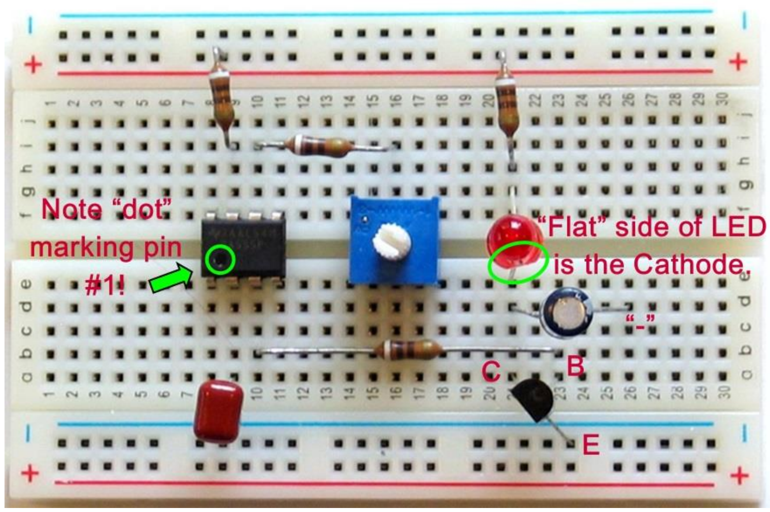


   d. Solder the connections (avoid breathing the fumes);
   e. Use a heat gun to shrink the tubing (or wrap with a small piece of electrical tape) around the connection for protection.

3. **Understand the breadboard's layout:** Breadboards are wonderful tools for quickly constructing electronic circuits. Because connections are made with jumper wires on top as well as underneath the breadboard, it is important to understand which "holes" (i.e. contacts) inside the breadboard connect to each other and which do not.

   The breadboard included in this kit is labeled with letters, numbers, colored lines, and "+" and "-" symbols. The center "groove" is the proper width for small "DIP chips" – <u>**D**</u>ual <u>**I**</u>nline **P**ackage integrated circuits – to "straddle." As shown in the picture on the right, there are internal connections for column contacts **a-e** and **f-j** in each row **1-30** and the red and blue power "rails" – *<u>all</u>* the holes along the red and blue lines on each side. ***<u>All of these groups of contacts are separate from each other as highlighted on the picture below.</u>*** (Having separate "power rail" rows on each side of the board can be handy if you need more than one supply voltage.)





4. **Place components:** Using the picture above as a guide, place the following components on the breadboard. It is very important to place parts such that their leads do not touch each other. This can result in incorrect operation, or worse destroyed parts, once power is applied. Using needlenose pliers to "form" leads so parts fit better on the breadboard can help avoid this problem.

   > **NOTE!** Many electronic parts, including ***<u>all</u>*** semiconductors, are polarity sensitive and may be destroyed if connected incorrectly! (e.g. "+" and "-" reversed) Refer to the included diagrams and pictures for correct connections.

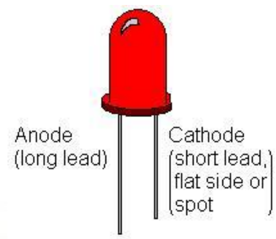
   a. 555 integrated circuit (note the "dot" indicating pin 1); **[locations 8, 9, 10, 11-e/f]**
   b. Four (4) 910 **Ω** resistors (white-brown-brown-gold bands); **[locations + → 9-I, 10-I → 16-I, + / 21-H, 10-b / 23-b]**

c. 1M **Ω** potentiometer (the part with the "knob" and three wires; a blue one is pictured); **[locations 15, 16, 17-f]**

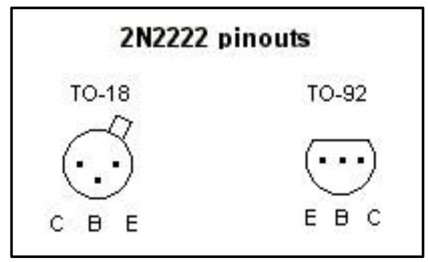
d. 0.47 µF capacitor; **[locations 9-a → "-"]**

e. 10 µF electrolytic capacitor (note the "-" stripe on the side indicating the negative lead); **[locations 21-d → 26-d]**

f. NPN transistor (NOTE!!! Some transistors have different pinouts; if you connect it wrong, it may be destroyed. Look at the part number of the transistor you have and verify it against the pinout diagram provided.) **[locations 21-a (C), 23-a (B), "-" (E)]**



g. LED (the diagram on the right shows the correct lead orientation; the anode is "+" and the cathode is "-"); **[locations 21-e, 21-g (anode)]**



5. **Place the jumper wires:** Although some of the circuit connections are already completed by virtue of the pin connections underneath the breadboard, the rest will need to be made using the colored jumper wires included with the kit. (Gently peel the individual leads apart from each other if they are not already separated.) Make the following connections:

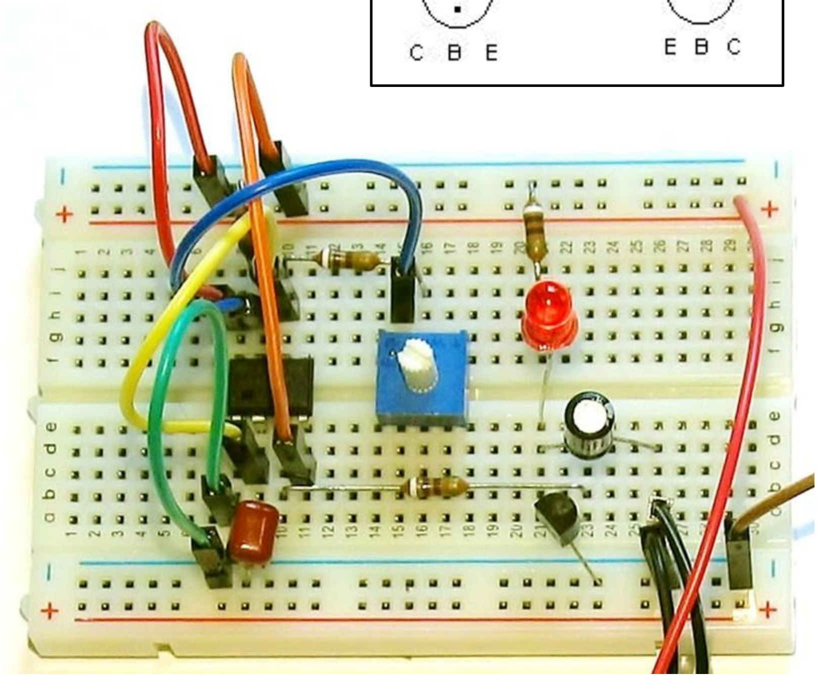
    a. **+ → 8-h**

    b. **+ → 11-c**

    c. **- → 8-a**

    d. **9-c → 10-h**

    e. **9-h → 15-h**



6. **Connect the speaker:** Use the jumper pins you soldered to the speaker wires in step 2 above to connect the speaker to locations **26-a** and **"-"** (you can see them in the picture above in the lower right corner underneath the red battery lead).

7. **Connect the battery clip and key:**

    a. Connect the red lead of the battery clip to the "top red" row;

    b. Connect the black lead of the battery clip to one of the screw posts on the key;

    c. Use a jumper to connect from the other screw post on the key to the "bottom blue" row on the breadboard.

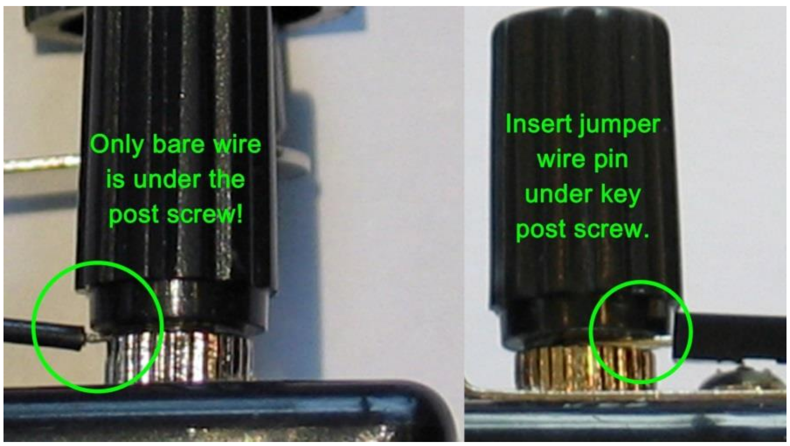
d. **DO NOT** connect the 9 Volt battery until you have double-checked your work!

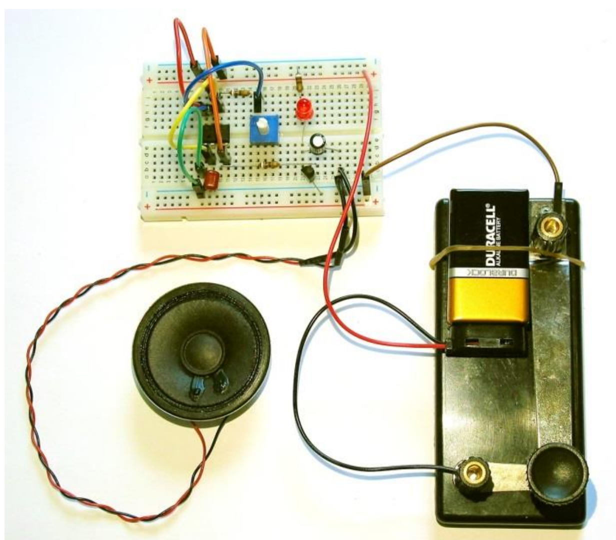
8. **DOUBLE-CHECK YOUR WORK:** With wires and parts running all over, even good breadboard layouts need to be double-checked for proper connections before you apply power to them. It is very easy to be "off" by a row or column which can result in a circuit that doesn't work, or worse, destroyed parts.

> ***It is <u>always</u> a good idea to ask for help if you are not sure your circuit is connected correctly!***

9. **Connect the battery and test!** Try tapping the key a few times. If you hear a tone in the speaker and see the LED light when you tap, you have completed your circuit successfully! GOOD JOB! Adjusting the potentiometer will change the frequency of the tone. Check out how the very lowest frequency tones make the LED blink!

> If your circuit does not appear to work correctly, DON'T PANIC. Skip to the Troubleshooting section and don't hesitate to ask for some help.





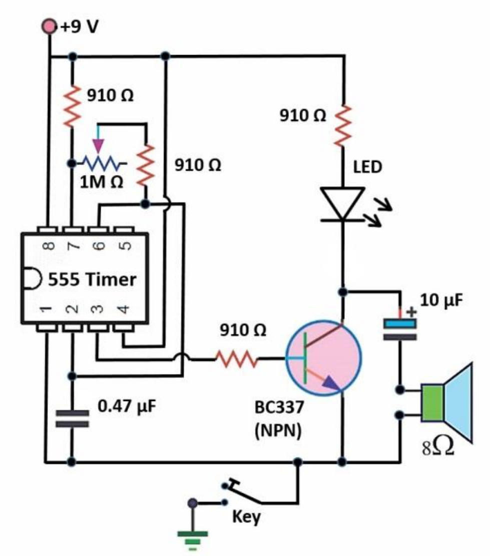
Troubleshooting

If your circuit does not work, there are a few basic steps you can take to identify the problem:

1. Disconnect your battery and verify its condition by trying it on another working circuit. (You can also use a Voltmeter or a battery tester if one is available.) LEAVE THE BATTERY DISCONNECTED FOR THE FOLLOWING STEPS!
2. Carefully review all your connections.
3. Carefully examine all wire connections to ensure that insulation on the wire is not creating a "disconnect" in the circuit by preventing a metal-to-metal connection. (This typically happens with the battery clip wire connection to the screw post on the key.)
4. If you have a multimeter with a semiconductor test feature, test the transistor junctions by putting the probes across the Base/Emitter and Base/Collector leads to ensure they conduct properly (ask for some help with this).
5. Use an Ohmmeter to test the speaker and jumper wires to ensure they are functional. (You can test the resistors too if you want, but they are rarely a problem – unless they are in the wrong places!)
6. Use an Ohmmeter to test the potentiometer. It should read 1M Ohm (that's "one million Ohms) across the "outer" leads and an amount that varies between 0 and 1M Ohm between the center and one of the outside leads as you turn the knob. (You can completely bypass the POT by connecting the blue jumper wire directly to the end of the 910 Ohm resistor that normally connects to the POT. This will set the output tone to the highest frequency.)
7. If all of the above steps fail, try "swapping" each component into a working kit to test them individually. (BE SURE TO DISCONNECT THE BATTERY BEFORE DOING THIS!) Test the semiconductor parts first (i.e. 555 chip, transistor, LED) as those are most-likely the problem. If those work, swap the other parts one at a time. If all of the parts work separately, but not together, there are other steps to try – ask for some help.

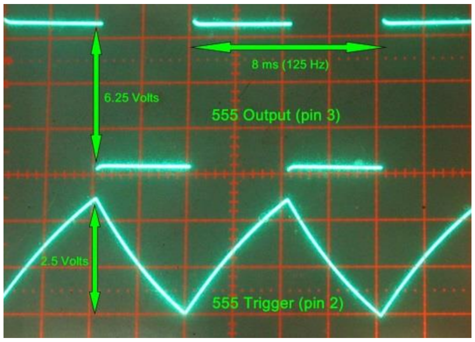
Theory of Operation

Use the circuit schematic to the right as a reference for this section.



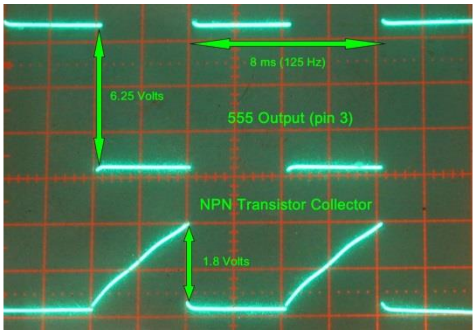
The 555 timer chip is capable of several "modes" of operation. In "astable" mode – which means "never stable" – the output never stays high or low. The capacitor connected to pin 6 (via pin 2) is charged and discharged through the resistors connected to pins 6 ("threshold") and 7 ("discharge"). Because pin 6 is also connected to pin 2 ("trigger"), it constantly retriggers itself resulting in a continuous stream of rectangular pulses (i.e. a "square wave") on pin 3 ("output") having a frequency that is determined by the "R" (resistor) and "C" (capacitor) values used.[2]

The picture on the right is a screen-capture of an oscilloscope display showing the output signal on pin 3 (upper trace) and what the signal on pin 2 is doing during each phase of the output (lower trace). This signal varies between about 1/3 and 2/3 of the supply voltage; that is, between about 3 and 6 Volts using a 9 Volt battery. As you can see, when pin 2 is brought low, it triggers a high output on pin 3.



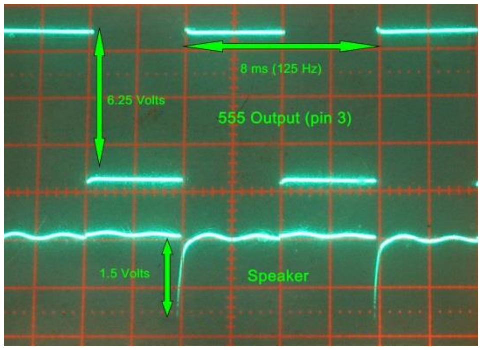
This square wave output (on pin 3) is used to bias the NPN transistor (BC337) to switch an LED on and off in step with the 555 output pin.

To create a sound, the speaker must use its cone to create air movement. The speaker cone is connected to a small coil of wire which can freely move back and forth over a permanent magnet inside the speaker. The magnetic field created by the current flowing through the coil of wire interacts with the permanent magnet to push or pull the speaker cone thus creating sound through air movement.



A small capacitor (10 µF) is attached to the collector pin on the NPN transistor. While the 555's output is low (pin 3's signal on the upper trace), the NPN transistor is "turned off." During this "down time," current flows through the resistor and LED to charge the capacitor until the output goes high. When pin 3 (upper trace) goes high, the NPN transistor is "turned on" allowing enough current to flow to cause the LED to illuminate.

[2] A vastly simplified excerpt from an excellent article by Tim Surtell on the Electronics in Meccano web site (http://www.eleinmec.com/article.asp?1).



Simultaneously, the stored charge in the capacitor is essentially "shorted" to ground causing a current to flow through the speaker's coil as described above to create sound.

This process repeats itself with the frequency determined by the resistor and capacitor values used for the 555 (pins 6, 7, and 2).[3]

The final oscilloscope capture shows the output of the 555 (upper trace) and the voltage on the speaker during the capacitor's quick discharge (lower trace). The speaker is essentially being "popped" each time the NPN transistor shunts the capacitor's charge to ground.

[3] Also, as the frequency increases, there is less time for the capacitor to charge resulting in a smaller current through the speaker resulting in a softer output; that is, the oscillator is louder at lower frequencies and softer at higher frequencies.

Creating a Telegraph Network

From 1838 well into the mid-1900's, telegraph stations were connected together for communicating over long-distances. By 1902 when the trans-Pacific link was completed, telegraph lines literally encircled the entire world! Messages received were transcribed onto "Telegrams" and delivered to recipients in-person much like registered mail and overnight letters are today.

You can connect your practice oscillator with others to create a telegraph network!

1. Disconnect the 9-Volt batteries of each kit before proceeding. ☺
2. Find a long pair of "telegraph" wires to use.
3. Connect one of the long "telegraph" wires to ***all*** of the key terminals with the breadboard jumper wire attached.
4. Connect the other "telegraph" wire to all of the key terminals with the black battery lead attached. (If you really want to be "authentic," skip using this wire entirely and simply attach all of the black battery leads to an earth ground instead! However, with only 9 Volt batteries, distance will likely be compromised.)
5. Reattach the 9-Volt batteries of each "telegraph station."
6. When any telegraph key is pressed, ALL oscillators should sound simultaneously!
7. Try sending messages to each other using Morse Code!

This document including the assembly instructions is available for download at:

http://tinyurl.com/555-Morse-Code-Oscillator-Kit