CHAPTER 6: OSCILLATORS & ELECTRONIC SOUND

Learn By Doing®

Your electronic stereo and radio are powered by electricity and play music, so how does electricity make sound? In this chapter you will find out. You will also learn about oscillator circuits, and build some simple ones using snap circuits.

Oscillators are used in all radios, TVs, and electronic communications equipment to set the transmitter or receiver frequency. Different types of oscillators are used as timing references in computers and almost all complex electronic products. It would be hard to count how many oscillator circuits are in your home since there are different types and they can be hard to identify.

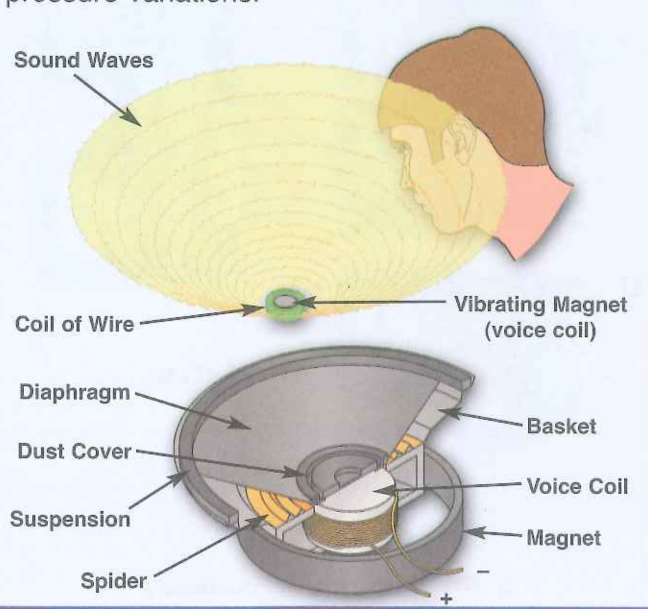
Oscillators can be among the most difficult electronic circuits to design, due to the tight requirements placed on them by today's communications technology. They usually don't use a lot of components, but the way they are arranged is complex and often difficult to analyze. But they are fun to learn about.

6-1 Electronic Sound

Introducing New Parts

Snap circuits includes a speaker:

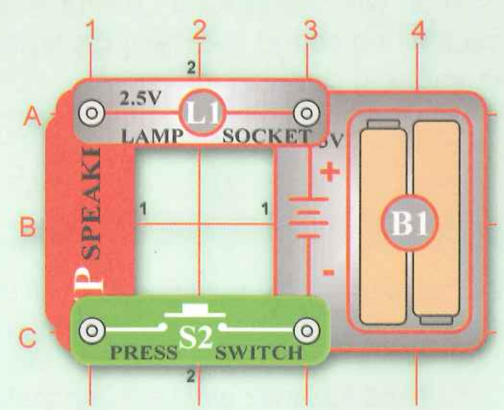
A **speaker** converts electricity into sound. It does this by using the energy of a changing electrical signal to create mechanical vibrations (using a coil and magnet similar to that in the motor). These vibrations create variations in air pressure, called sound waves, which travel across the room. You "hear" sound when your ears feel these air pressure variations.

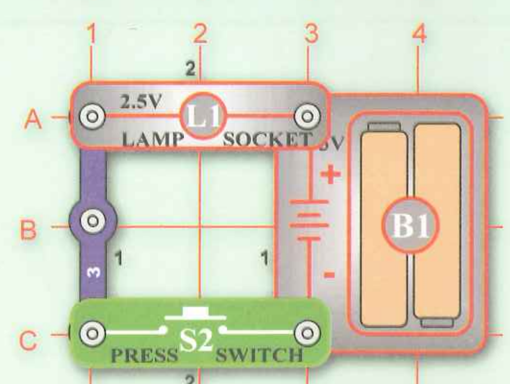


A speaker can only create sound from a CHANGING electrical signal, for unchanging electrical signals it acts like an 8Ω resistor. (An unchanging signal does not cause the magnet in the speaker to move, so no sound waves are created).

Experiments

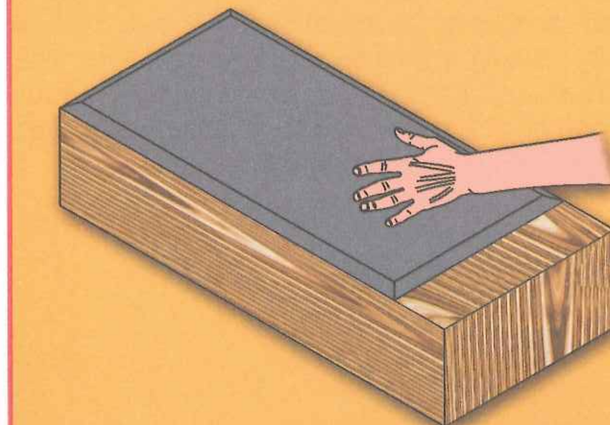
For example, compare these two mini-circuits:



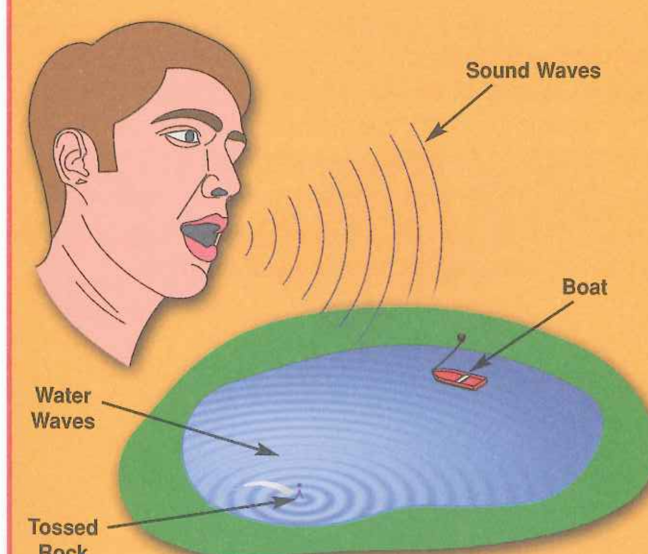


When you press or release the press switch, you hear static from the speaker. When you hold the press switch down, the speaker is silent and the lamp is not as bright as the circuit without it.

What is Sound? **Sound** is a variation in air pressure created by a mechanical vibration. For a demonstration of this, lay one of your stereo speakers on the floor, place your hand on it, and turn up the volume. You should feel the speaker vibrate. Now place a piece of paper on the speaker; if the volume is loud enough, you will see the paper vibrate.



You can compare sound waves from your voice to waves in a pond. When you speak the movements in your mouth create sound waves just as tossing a rock into the pond creates water waves. Sound waves travel through air as water waves travel across the pond. If someone is nearby then their ears will feel the pressure variations caused by your sound waves just as a small boat at the other side of the pond will feel the water waves. When you say a word you create a sound wave with energy at various frequencies, just as tossing a handful of various-sized rocks into the pond will create a complicated water wave pattern.



Nearly all sound waves have their energy spread unevenly across a range of frequencies.

What is Music? *Music* is when sounds occur in an orderly and controlled manner forming a pattern with their energy concentrated at specific frequencies, usually pleasant to listen to. *Noise* is when the sounds occur in an irregular manner with their energy spread across a wide range of frequencies, usually annoying to hear (static on a radio is a good example). Notice how some people refer to music that they don't like as noise.

Another way to think of this is that the ear tries to estimate the next sounds it will hear. Music with a beat, a rhythm, and familiar instruments can be thought of as very predictable, so we find it pleasant to listen to. Notice also that we always prefer familiar songs to music that we are hearing for the first time. Sudden, loud, unpredictable sounds (such as gunfire, a glass breaking, or an alarm clock) are very unnerving and unpleasant. Most electronic speech processing systems being developed use some form of speech prediction filters.

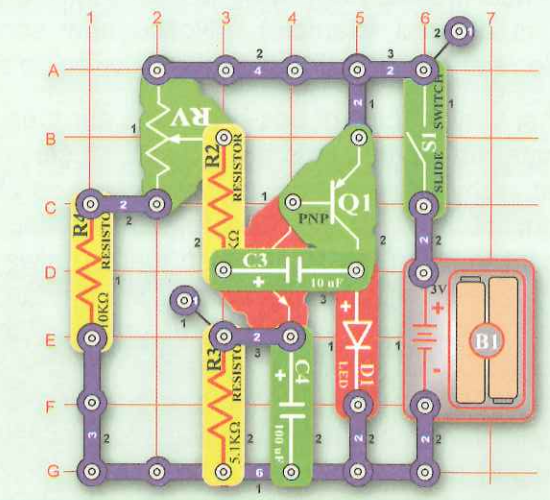
The musical world's equivalent to frequency is *pitch*. The higher the frequency, the higher the pitch of the sound. Frequencies above 3000 Hz can be considered to provide *treble* tone. Frequencies about 300 Hz and below provide *bass* tone. *Loudness* (the musical term) or *amplitude* (the electronics term) is increased by simply sending more electrical power to the speaker.

Alexander Graham Bell used a microphone and a speaker to make the first telephone in 1876. Although many parts of it have been replaced by new technology, the basic design of his electromechanical system was so good that it is still used today.

6-2 Oscillators

Experiments

Consider this circuit (which is project 259):



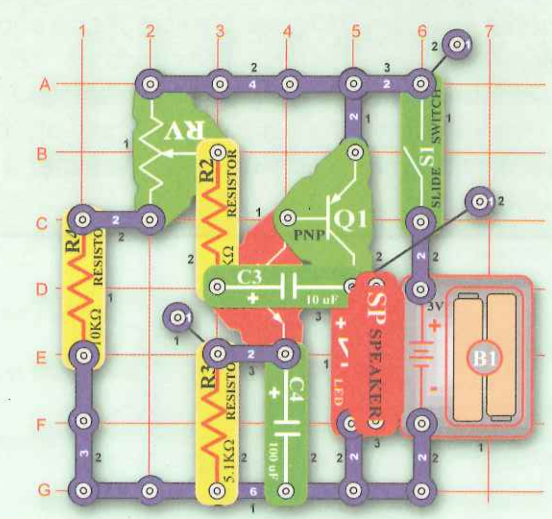
In this circuit the red LED will be flashing, the flash rate is controlled by the adjustable resistor. Although the LED might appear to be solid at the highest setting of the adjustable resistor, it is actually flashing at a faster rate than your eyes can see. Here the LED flash rate can be adjusted from less than once a second up to 30 times a second. This flash rate is called the frequency.

This type of circuit is called an **oscillator** circuit, it uses **feedback** to set and control the frequency. The basic circuit uses the NPN transistor to control the current to the red LED. However, the 10μF capacitor FEEDS part of the output signal BACK to the input. The result is that the NPN transistor will turn the current to the LED on and off in a repeating cycle. The flash rate is controlled by the resistor and capacitors in the circuit, such as the adjustable resistor.

Why do your eyes see only a solid light when the LED is flashing at a fast rate? The reason is that your eyes cannot adjust fast enough. They continue to see what they have just seen. That is the basis for the entire movie and television industries.

In a movie theater, film frames are flashed on the screen at a fast rate (usually 24 per second). A timing mechanism makes a light bulb flash just as the center of a frame is passing in front of it. Your eyes see this fast series of flashes as a continuous movie.

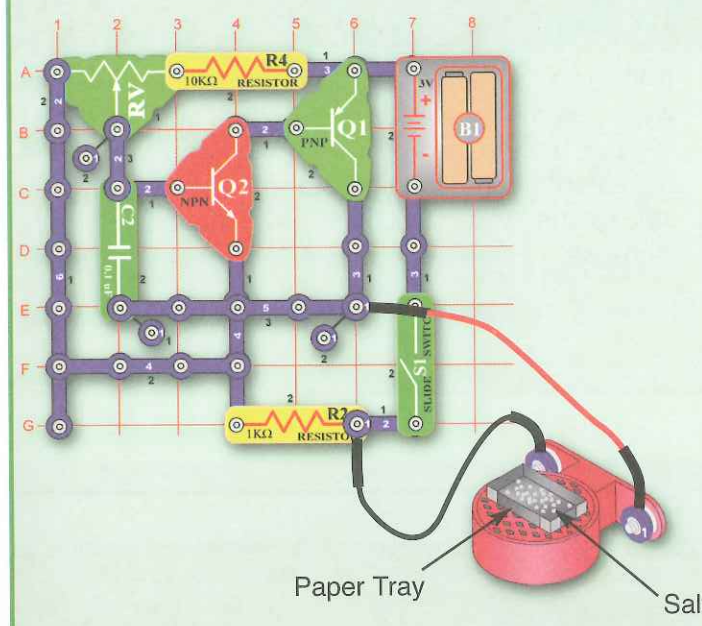
If the speaker is placed directly over the LED (use a 1-snap with it, as in project 260), then you can both hear and see the oscillator effects:



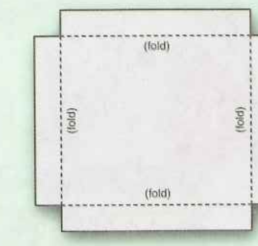
Frequency measures how fast something repeats. It is expressed in **Hertz** (Hz, named after Heinrich Hertz for his work in electromagnetism), **kilohertz** (kHz, 1,000 Hz), or **megahertz** (MHz, 1,000,000 Hz). The range of frequencies that can be heard by the human ear is approximately 16 to 16,000 Hz, and is referred to as the **audio** range.

Experiments

Consider this circuit (which is project 236):



This circuit can be used to demonstrate how a speaker creates sound using mechanical vibrations. Connect the speaker using the jumper wires and lay on a table. Using paper, scissors, and tape, make a small tray and lay on the speaker, as shown. Here is a sample cutout pattern:



Sprinkle some table salt in the tray and turn on the switch. The speaker uses vibrations to create sound waves; those vibrations will also move the salt around in the tray. Adjust the adjustable resistor to change the pitch (frequency) of the sound, and see how the salt moves.

6-3 The Whistle Chip

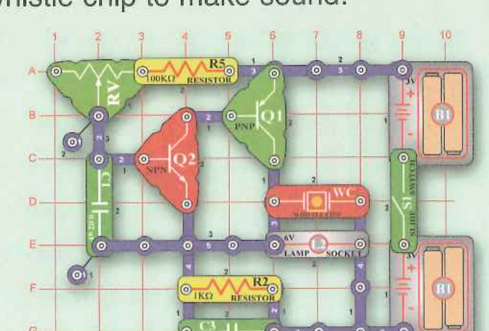
The whistle chip is like the 0.02μF capacitor, except that it also can make sound like a speaker does.

It contains two thin plates separated by a dielectric material, similar to a capacitor. When a voltage is applied across them they will stretch slightly in an effort to separate (like two magnets opposing each other), when the signal is removed they come back together. If the voltage is changing quickly, then the plates will vibrate. These vibrations create variations in air pressure that your ears feel, just like sound from a speaker.

Introducing New Parts

Experiments

Consider this circuit (which is project 199), it uses the whistle chip to make sound:



The frequency (pitch) of the sound is controlled by the resistors and capacitors in the circuit, increasing their values decrease the frequency. One way to change it is using the adjustable resistor. Another way is to place the 0.1μF capacitor on top of the 0.02μF, increasing the capacitance (project 200). You could also replace the 100kΩ resistor with the photoresistor to control the frequency using light.