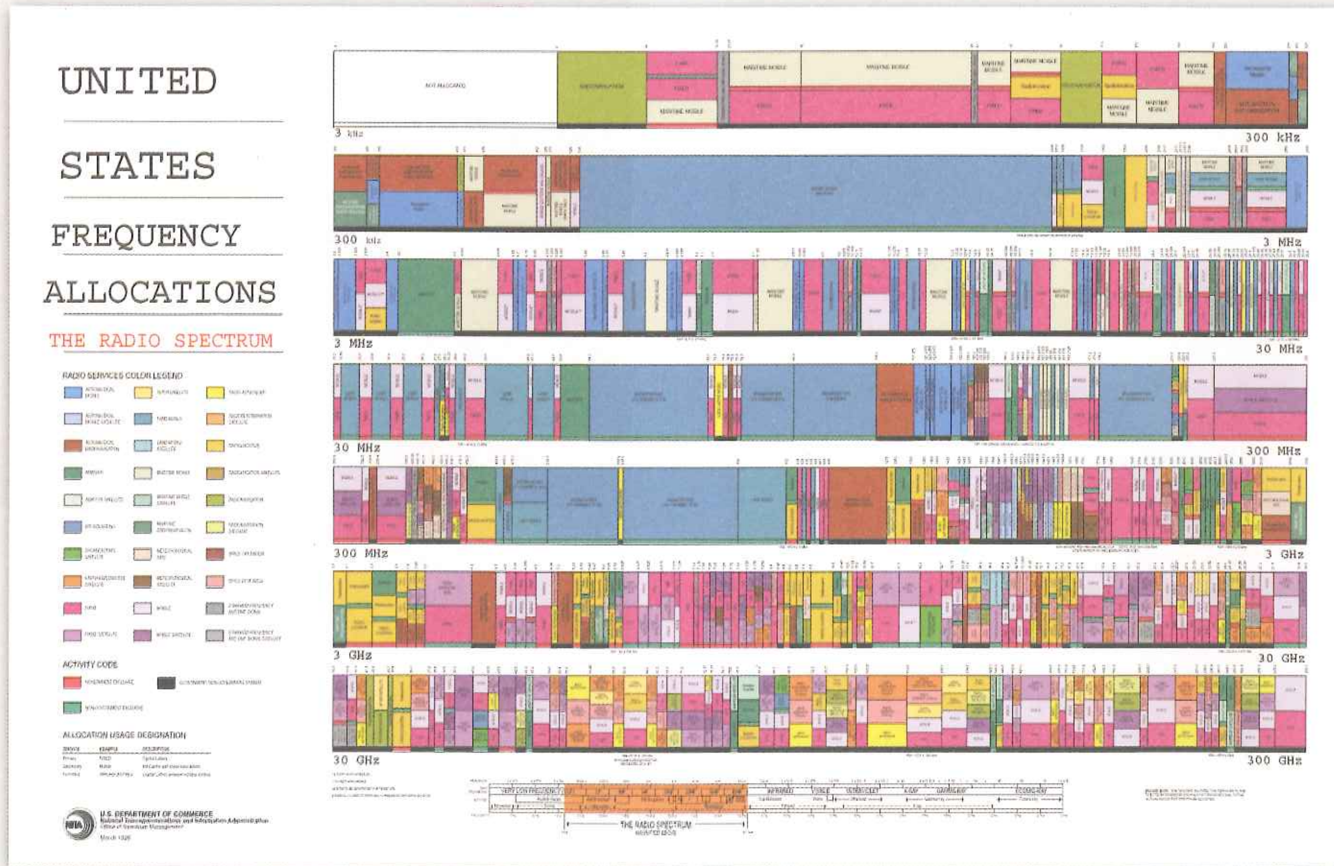
CHAPTER 8: ELECTROMAGNETISM & RADIO

Learn By Doing®

What would life be like without radio and television? Only a hundred years ago the fastest way to send a message between America and Europe or Asia was a fast ship. Now we get live television coverage of news and sports events from anywhere in the world.

While the telegraph and telephone allowed instant communication at great distances, these required wires. The development of radio made instant communication possible without wires. Initially the equipment required was expensive, so the first main use was in large ships at sea.

Today the air around us is full of radio transmissions for things such as music, television, cellular phones, aircraft navigation, communication with probes in outer space, radio-controlled toys, and thousands of other uses. The Federal Communications Commission (FCC) makes sure that all of these uses operate on different frequencies so that they don't interfere with each other.



In this chapter you will learn how antennas are used to send radio signals through the air, how modulation is used to encode the information being sent, and about transformers. You will also use snap circuits to build radio circuits.

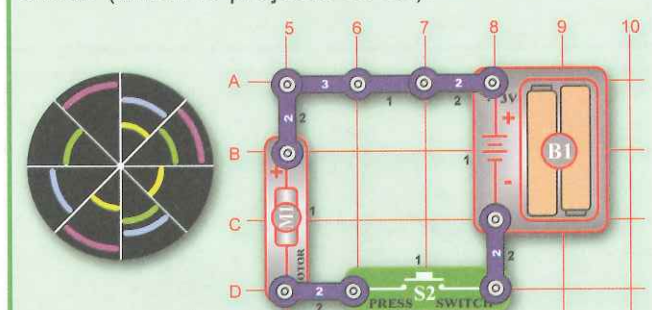
8-1 AC

The electricity supplied to your home and school by your local electric company is not a constant voltage like that from a battery. It averages about 120V but is constantly changing, due to the design of the generators that produce it. This is not a problem, since all equipment that uses it accounts for this change. Its frequency is 60 Hz.

An electrical signal that is changing is called an **alternating current**, or **AC**. Because of this, the power from the electric company is also called AC power. An electrical signal that is constant and unchanging is called a **direct current**, or **DC**. The power from a battery is also called DC power.

Experiments

For a demonstration of this, consider this simple circuit (which is projects 55-56):



Make a paper disc with lines on it like the one shown here (a sample for cutout is on page 46 of project manual #1). Tape it to the fan blade and place it on the motor. Place this circuit under a white fluorescent light in your home or school (don't use an ordinary incandescent lamp). As the speed changes you will notice the white lines first seem to move in one direction then they start moving in another direction.

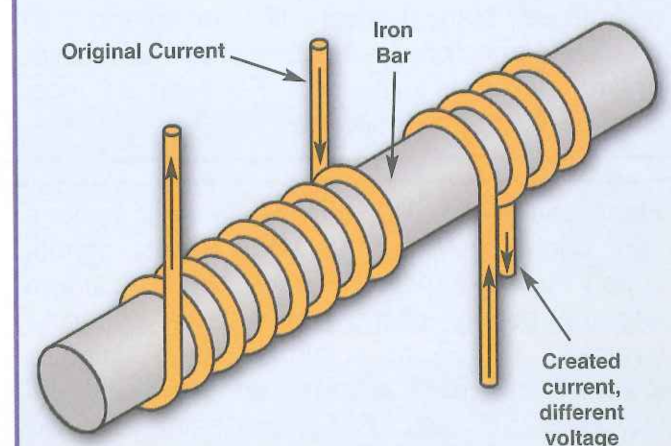
Do you know why it does this? The reason is because the lights are blinking 60 times a second and the changing speed of the motor is acting like a strobe light to catch the motion at certain speeds. To prove this, go into a dark room and try the same test with a flashlight. The light from a flashlight is constant, so you won't see this effect and will always see the lines move in the same direction.

The fluorescent lights are blinking because they use the AC power from the electric company. A flashlight uses DC power from batteries. Note: some new fluorescent lights use an electronic ballast and they also produce a constant light.

8-2 Transformers

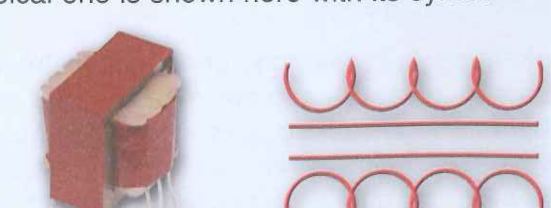
In a motor, electricity can make mechanical motion: an electric current flowing through a coil of wire can make a magnet rotate on a shaft. But what if the small magnet was instead a large, heavy, iron bar and was held in position? The current in the wire magnetizes the ordinary iron bar, and it becomes an **electronic magnet**. The iron bar stores electrical energy as magnetic energy.

What if another coil of wire from a different circuit was also wrapped around the iron bar? The magnetization of the iron bar would create a current in it. This is a **transformer**, which allows one circuit to create a current in another circuit using magnetic fields.



Important Note: Transformers only work with changing voltages (AC). Unchanging voltages (DC) have no magnetic properties and don't work with transformers. Many motors (like the one in snap circuits) have a mechanical design that allows them to use the DC voltage from batteries.

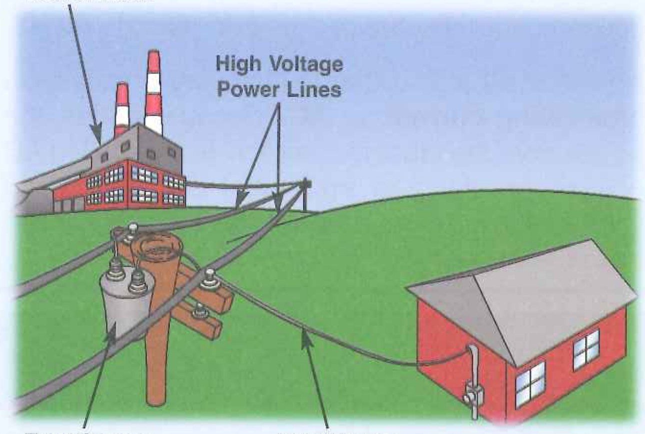
Think of a transformer as a magnetic bridge in electronics, since we use magnetism to cross an air gap that electricity cannot cross by itself. Snap circuits does not include a transformer, but a typical one is shown here with its symbol:



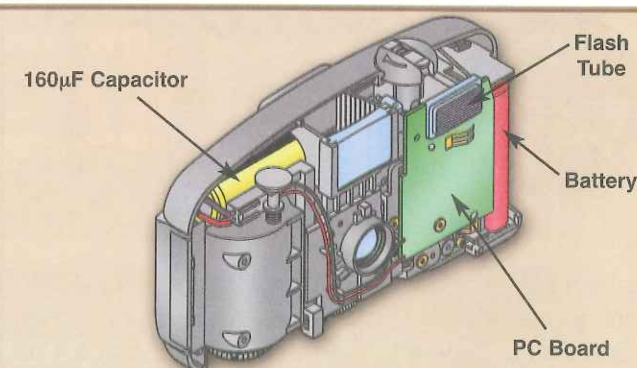
If the second coil in the transformer had twice as many loops of wire as the first, it would have twice the voltage but half the current as the first. The reason is that power is not lost across a transformer, and Power = Voltage x Current. A transformer can use a small voltage to create a very large voltage by using a many-loop coil with a few-loop coil.

Transformers are very important in electronics for two reasons. First, they allow circuits to be isolated from each other, since the connection between them is magnetic and not electrical. Second, they can change the voltage without wasting power (by using coils with more or less loops of wire).

When electric power companies transport electricity across great distances (like between power generating plants and cities), they use very high voltages and low currents since this reduces power loss in the wires. Large transformers convert this to 120V, which is supplied to homes and offices. Many products (like computers) then use small transformers to convert this to smaller or larger voltages as needed. For example, most circuits in computers use 5V.



Flash camera: A flash camera needs to make a very bright flash, but its small battery cannot supply this much power at once. So the camera lets the battery charge up a large capacitor (typically 160μF) to a high voltage using a transformer. It takes a few seconds to charge the capacitor (to about 300V); the flash tube will discharge this in an instant.



8-3 INDUCTANCE & ANTENNAS

Inductance is a measure of one coil's ability to create a current in another. It is expressed in **henrys** (H, named after Joseph Henry who developed electromagnetic induction) or microhenrys (μH, millionths of a henry). The more loops in a coil of wire, the more inductance it has. Placing an iron bar inside a coil of wire magnifies that coil's inductance.

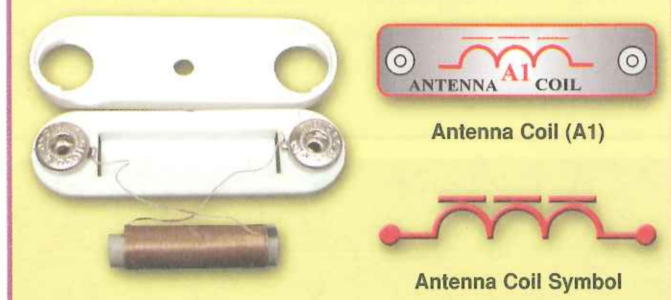
Transformers use electromagnetic fields through iron bars to "bridge" a gap between circuits. If the iron bars through the two coils were close but not connected to each other, their electromagnetic fields would be reduced but would still affect each other.

Coils can be designed with shapes and other characteristics that will maximize their electromagnetic fields for specific frequencies. If the original ("**transmitter**") coil and current through it were large, then the electromagnetic field from it could still be picked up by another ("**receiver**") coil and produce a small current even if the distance was many miles.

This is the concept of **radio**, which uses electromagnetic waves to send information through the air. The coils used for transmitting and receiving these signals are called **antennas**.

Introducing New Parts

Snap circuits includes an antenna:



The antenna you will use is a 25μH coil wrapped around an iron bar, which increases the inductance to 300μH. Although it has magnetic effects similar to those in the motor, those effects are tiny and may be ignored except at high frequencies (like in AM radio). At low frequencies the antenna acts like an ordinary wire.

Coils like the antenna are also called inductors. Their magnetic properties enable them to oppose changes in electrical current, and to store electrical energy as magnetism. This allows inductors to be made to **block high frequency signals while passing low frequency signals**. This is **opposite to how capacitors act** on high and low frequency signals, so inductors and capacitors are used together to make complex frequency filters.

An inductor has lower resistance at lower frequencies, but higher resistance at higher frequencies. The resistance of an inductor may be calculated from the frequency and inductor value:

Rinductor = 6.28 x Frequency x Inductance

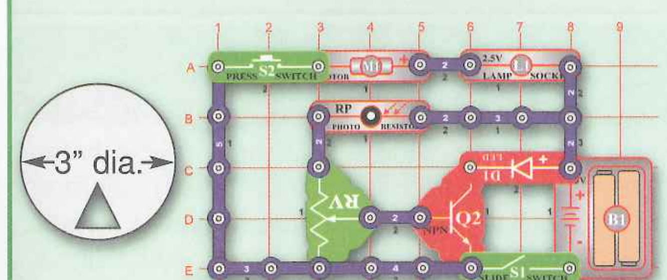
For example, your 300μH antenna will have a resistance of only 1.884Ω at 1000Hz, but a resistance of 1,884Ω at 1000,000Hz (1MHz).

8-4 RADIO

A wide range of schemes are used for encoding the radio signals with the information being sent. These are called modulation. Modulation uses one signal to modify another. You've probably heard of AM and FM radios. These stand for Amplitude Modulation and Frequency Modulation.

Experiments

For a simple demonstration using snap circuits, consider this circuit (which is project 258):



Using the fan outline as a guide cut a 3" circle out of a piece of paper. Then, cut a small triangle in it as shown. Tape the circle onto the fan and then place it onto the motor. Set the adjustable resistor to the center position and turn on the switches. The fan spins and the lamp lights. As the triangle opening moves over the photoresistor, more light strikes it. The brightness of the LED changes, or is modulated.

In AM radio transmitters, one signal (the "message") is used to modulate the amplitude of another (the "carrier"). In FM radio transmitters, one signal (the "message") is used to modulate the frequency of another (the "carrier"). The "message" will be talking or music, while the "carrier" will be an oscillator circuit tuned to the desired transmit frequency. Here is an example: