

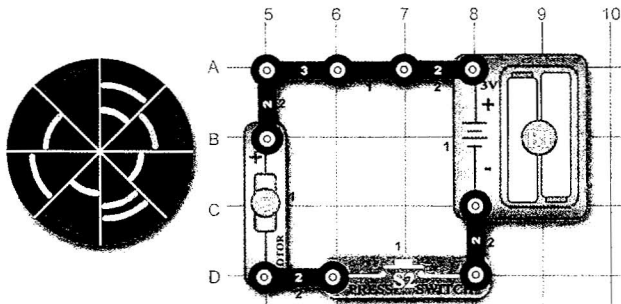
8-1 AC

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.

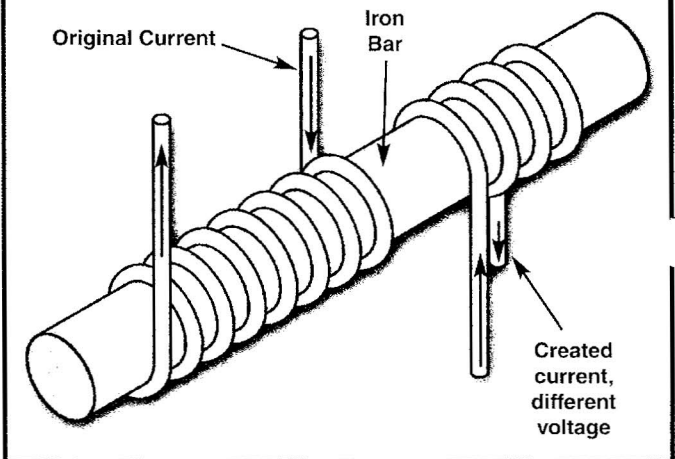
Do you know why it does this? The reason is because the lights are blinking 60 times a second and the changing speed of the motor is acting like a strobe light to catch the motion at certain speeds. To prove this, go into a dark room and try the same test with a flashlight. The light from a flashlight 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

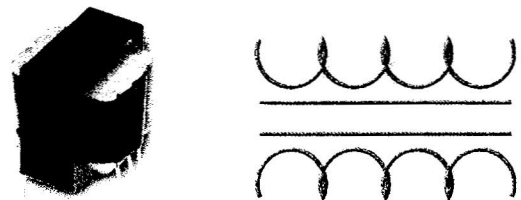
In a motor, electricity can make mechanical motion: an electric current flowing through a coil of wire can make a magnet rotate on a shaft. But what if the small magnet was instead a large, heavy, iron bar and was held in position? The current in the wire magnetizes the ordinary iron bar, and it becomes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

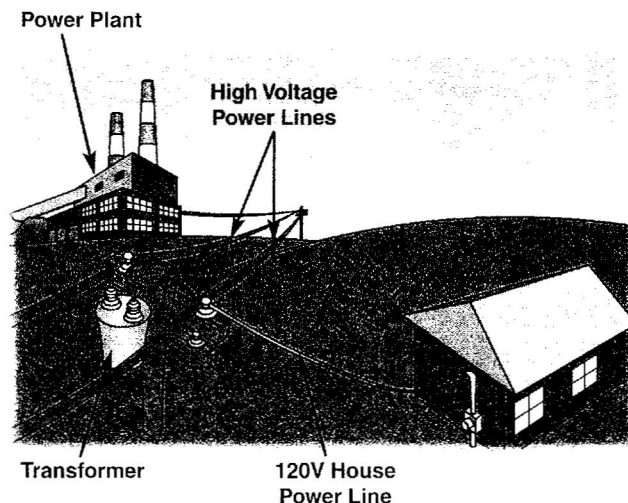


If the second coil in the transformer had twice as many loops of wire as the first, it would have twice the voltage but half the current as the first. The reason is that power is not lost across a

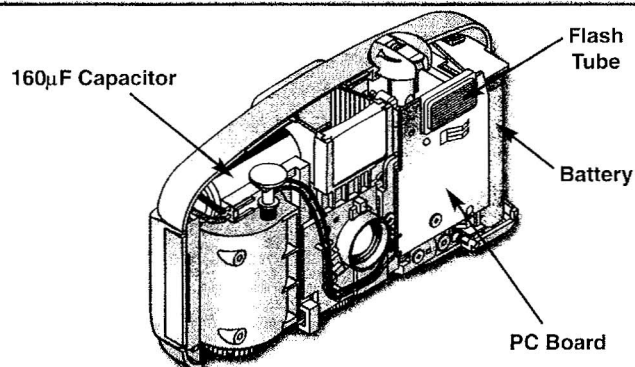
transformer, and $\text{Power} = \text{Voltage} \times \text{Current}$. A transformer can use a small voltage to create a very large voltage by using a many-loop coil with a few-loop coil.

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 $160\mu\text{F}$) 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.

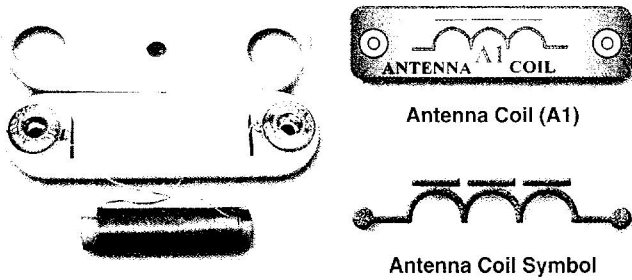
Transformers use electromagnetic fields through iron bars to "bridge" a gap between circuits. If the iron bars through the two coils were close but not connected to each other, their electromagnetic fields would be reduced but would still affect each other.

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:



Antenna Coil (A1)

Antenna Coil Symbol

The antenna you will use is a $25\mu\text{H}$ coil wrapped around an iron bar, which increases the inductance to $300\mu\text{H}$. 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:

$$R_{\text{inductor}} = 6.28 \times \text{Frequency} \times \text{Inductance}$$

For example, your $300\mu\text{H}$ antenna will have a resistance of only 1.884Ω at 1000Hz , but a resistance of $1,884\Omega$ at $1000,000\text{Hz}$ (1MHz).

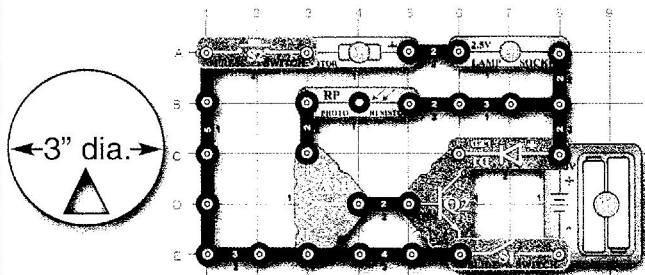
8-4 RADIO

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.

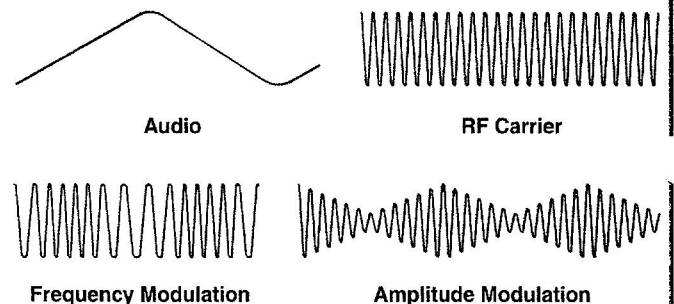
Experiments

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:



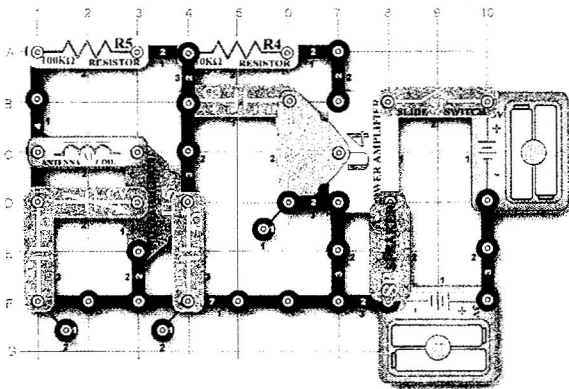
AM radio was developed before FM radio, because the transmitter and receiver circuits are not as complex. FM's greater complexity means it is better protected from interference (such as storms). FM also has wider channel bands (25kHz vs. 7kHz for AM), which gives it better music quality. AM radio uses a carrier frequency range of 500 to 1600kHz while FM radio uses 88 to 108MHz.

There are many different radio signals floating around, but we only want to listen to one. Think of this as being in a large, crowded room and trying to talk to someone on the other side. Connecting the antenna to a capacitor in sort of an antenna-capacitor oscillator solves this. Together, these two components "filter" out a small range of frequency that you listen to.

8-5 Radio Circuits

Experiments

Consider this AM radio receiver circuit (which is project 242 and is pictured on the front cover of your "Experiments 102-305" manual):



Adjusting the variable capacitor changes the range of frequency that you are listening to. The high frequency IC amplifies and decodes the modulation into the original signal (voice or music). This is amplified by the power amplifier IC. Varying the adjustable resistor makes the sound louder or softer.

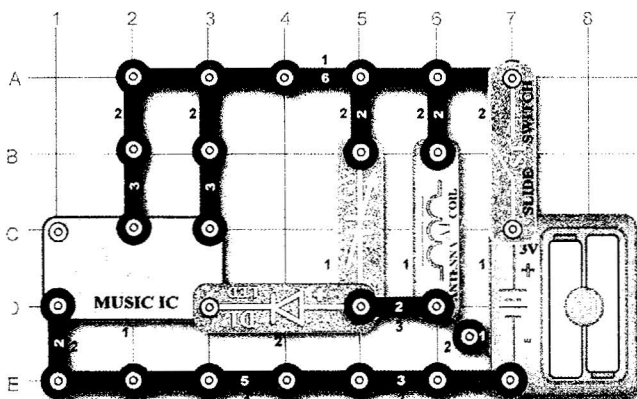
This simple radio has the same types of circuits as AM radios sold in stores, but does not have as much filtering and amplification circuitry. Take a look inside an old AM radio in your house; you'll see a lot more components. The tuning dial on all AM and FM radios is a variable capacitor just like yours.

Snap Circuits® project 288 shows another AM receiver circuit, but using a 2-transistor amplifier instead of the power amplifier IC. This circuit has similar performance and appears to be more

complex than the circuit with the IC, but there is actually a lot more circuitry hidden in the IC. Snap Circuits® project 289 is similar to project 242 but without loudness control.

Experiments

Consider this AM radio transmitter circuit (which is project 213):



Place the circuit next to an AM radio in your home. Tune the radio so no stations are heard. Turn on the switch. You should hear the song on your radio. Adjust the variable capacitor for the loudest signal.

This circuit uses the antenna to transmit electromagnetic energy to your AM radio. The antenna-capacitor combination tunes the transmit frequency. The music IC provides the amplitude modulation.

Notice that this circuit transmits across a wide part of the AM radio band, not just one station. This circuit has just two components tuning the transmit frequency; a commercial AM radio station will have a complex filtering circuit doing this.

Snap Circuits® projects 122, 145-150, 214, and 255 are variations of this basic AM transmitter circuit, using the alarm IC, space war IC, or the photoresistor. These circuits also show how to use this circuit as an alarm.

Snap Circuits® project 198 (in most manuals) is similar but transmits your voice to a radio. It also shows how variations in air pressure (caused by your talking) can make an electrical signal in a speaker – like a microphone, and opposite to how a speaker is normally used. Replace the speaker with the microphone in this circuit (+ side to Q2) and compare the performance.

Quick Quiz



1. List all the products in your home that use some form of radio or remote control.

Summary

Summary of Chapter 8:

1. An electrical current that is changing is called an alternating current (AC). An electrical signal that is constant and unchanging is called a direct current (DC).
2. The electricity in homes is AC power, with a voltage of 120V and a frequency of 60Hz.
3. Transformers allow one circuit to create a current in another using magnetic fields. This can change the voltage without wasting power.
4. Inductance is a measure of one coil of wire's ability to create a current in another, and is expressed in Henrys. Inductance can be increased by adding more loops of wire or by placing an iron bar inside the coil.
5. Radio uses electromagnetic waves to send information through the air. The coils used for transmitting and receiving these signals are called antennas.
6. Coils are inductors, which have lower resistance at lower frequencies but higher resistance at higher frequencies. Inductors and capacitors are often combined in radios to filter out a range of frequencies.
7. Modulation uses one signal to modify another.
8. In AM radio, a music/voice signal amplitude-modulates the transmit carrier frequency. In FM radio, frequency modulation is used instead.

Quiz

Chapter 8 Practice Problems

1. Why can't DC currents transfer energy across transformers?
 - A. DC currents have no magnetic properties.
 - B. DC currents don't have enough power to overcome the resistance of transformers.
 - C. Transformers block the transfer of energy from both AC and DC currents.
 - D. They are not digital circuits.
2. The following are true about transformers except:
 - A. They allow circuits to be isolated from each other.
 - B. They allow electricity to be efficiently transported over great distances.
 - C. They allow a small voltage to create a large voltage.
 - D. The coils used can never have the same number of loops.
3. The following are true about radio except:
 - A. Frequency modulation circuits are simpler than amplitude modulation circuits.
 - B. The FCC regulates radio transmission frequencies.
 - C. FM has better music quality than AM.
 - D. For DC currents, antennas act like ordinary wires.
4. At low frequencies, the Snap Circuits® antenna acts like a _____.
 - A. 10KΩ resistor
 - B. 0.1μF capacitor
 - C. 3-snap wire
 - D. whistle chip

Answers: 1. A, 2. D, 3. A, 4. C