2015 Revs Up
Home Energy Management Systems (HEMS)

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Have you noticed the recent trend where manufacturers try to make every gadget and gizmo "smart"? Have you ever been interested in finding out just how much energy your TV, computer, coffee machine or any other appliance are using? In this project you will build an advanced network that does such monitoring for you. You will even translate the energy usage into dollar amount. You can also build some intelligence into the system and make it smart in your own way. For instance, you can set your dishwasher to wash the dishes only if its energy usage costs you $2. Or you can set your printer off whenever your computer is off. This is possible through what we technically call Embedded Systems. Once you learn about it, you can be creative and transform everything you are dealing with on a daily basis. You will build your own customized home energy monitoring and control system from scratch.

Tentative Schedule

Week of	Monday	Tuesday	Wednesday	Thursday
July 13 – July 16	Arduino Basics			
July 20 – July 23	Relay/ Current Sensor	A/C Dimmer	XBee: Follow Along	XBee: Continuation
July 27 – July 30	Develop Home Management Networks			
August 3 – August 6	Finish Networks/Poster			

Research Experience Vitalizing Science — University Program

2015 REVS UP: Basic Components

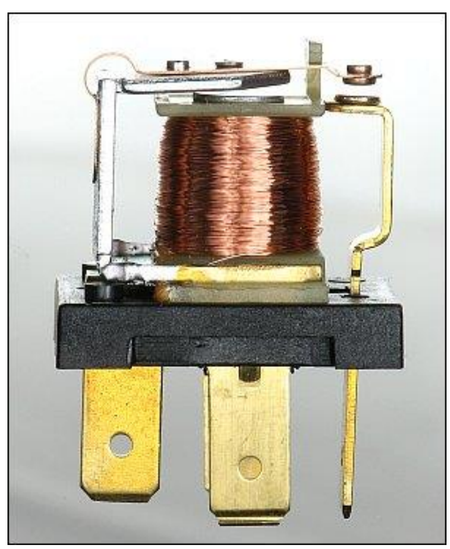
Department of Computer & Electrical Engineering & Computer Science

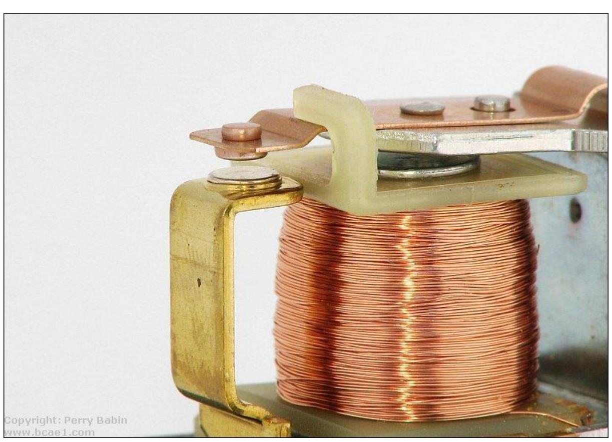
Lecture 1: Electromagnetic Relays

What is an Electromagnetic Relay?

A relay is an electromagnetic switch operated by a relatively small electric current that can turn on or off a much larger electric current. The heart of a relay is an electromagnet (a coil of wire wrapped around an iron yoke that becomes a temporary magnet when electricity flows through it). You can think of a relay as a kind of electric lever: switch it on with a tiny current and it switches on ("leverages") another appliance using a much bigger current. Why is that useful? As the name suggests, many sensors are incredibly sensitive pieces of electronic equipment and produce only small electric currents. But often we need them to drive bigger pieces of apparatus that use bigger currents. For example in your vehicle, the ignition switch cannot pass a significant amount of current without being damaged. You probably also know that the engine starter motor needs significant current to be able to start the engine. Since it would almost instantly destroy the ignition switch if you were to try to power the starter motor with the ignition switch itself, manufacturers use a relay (also known as a solenoid) as a buffer between the ignition switch and the starter motor. In this application, the relay/solenoid is used to allow a small current to control a larger current.

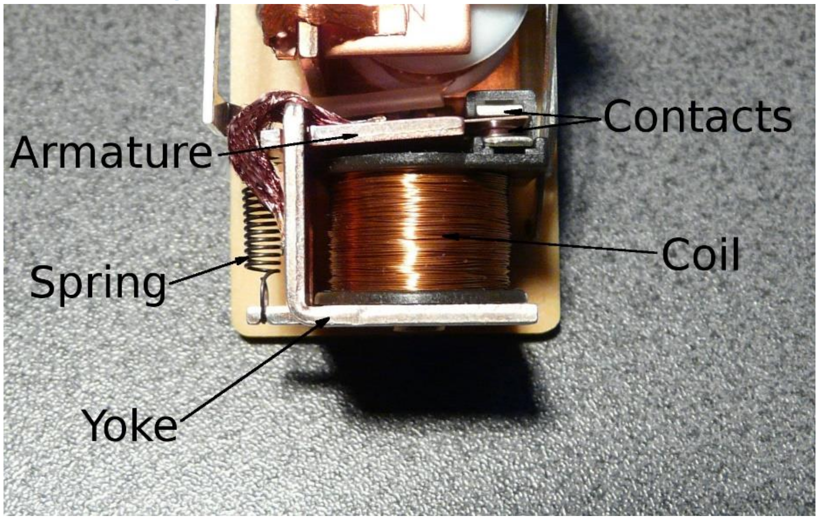
Right: car relay without the protective cap
Below: close up of a standard relay



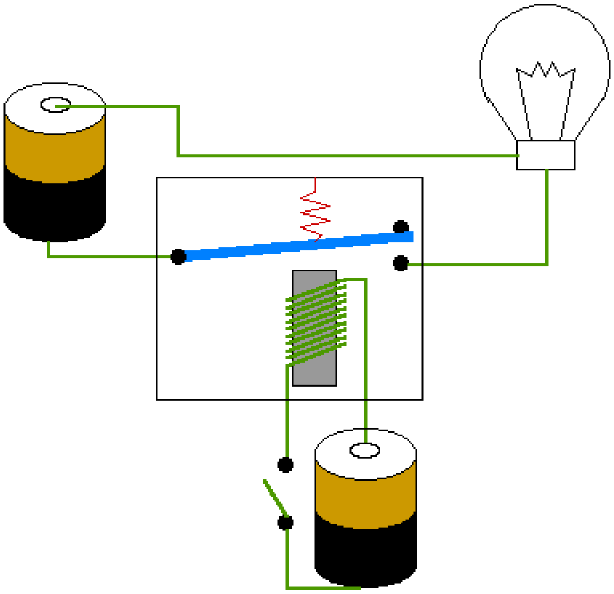


HOW DOES AN Electromagnetic Relay work?

Right: This exposed relay is very similar to the one we will be working with



The relay we will be using will have 5 basics parts; the electromagnet, a yoke, an armature, a spring, and electrical contacts. The electromagnet generates a magnetic field strong enough to pull the armature down when a small current is passed through it. This armature acts as a lever since a spring is attached to one end. When the electromagnet is not powered the spring keeps the armature up and disrupts current to flow through. When the electromagnet is powered, the contact point on the opposite end of the armature is pressed against the other contact point allowing current to flow through.



In this bottom left figure, you can see that a relay consists of two separate and completely independent circuits. The first is at the bottom and drives the electromagnet. In this circuit, a switch is controlling the power to the electromagnet. When the switch is on, the electromagnet is on, and it attracts the armature (blue). The armature is acting as a switch in the second circuit. When the electromagnet is energized, the armature completes the second circuit and the light is on. When the electromagnet is not energized, the spring pulls the armature away and the circuit is not complete. In that case, the light is dark.

Lecture 2: Hall-Effect Current Sensors

Introduction to the Hall Effect

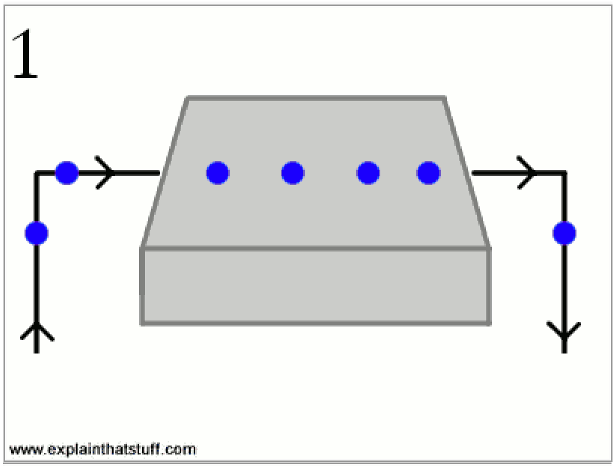
The Hall Effect was discovered by Dr. Edwin Hall in 1879 but has only been put to noticeable use in the last three decades. The first practical application was in the 1950s as a microwave power sensor. With the mass production of semiconductors, it became feasible to use the Hall Effect in high volume products. Today, Hall Effect Sensing Devices are now used in electric motors, loudspeakers, headphones and etc. If the parameter needed to be measured involves or can involve a magnetic field then a Hall Effect sensor is being used to measure it.

What is the Hall Effect?

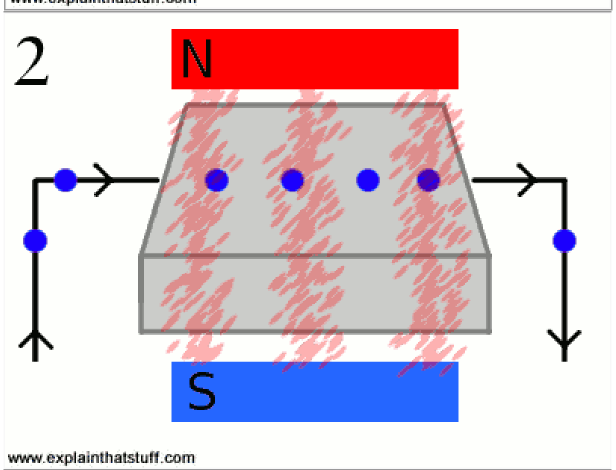
If we send a fluctuating electric current through a coil of copper wire and (although you can't see it happening) you'll produce a temporary magnetic field around the coil too. Put the coil near to a big, permanent magnet and the temporary magnetic field the coil produces will either attract or repel the magnetic field from the permanent magnet. If the coil is free to move, it will do so—either toward or away from the permanent magnet. In an electric motor, the coil is set up so it can spin around on the spot and turn a wheel; in loudspeakers and headphones, the coil is glued to a piece of paper, plastic, or fabric that moves back and forth to pump out sound.

How Does the Hall Effect Work?

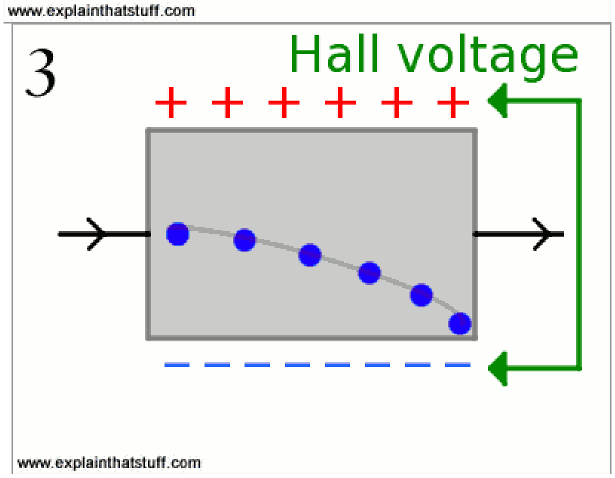
What if you place a piece of current-carrying wire in a magnetic field and the wire can't move? What we describe as electricity is generally a flow of charged particles (electrons) through materials. Broadly speaking, if you hook a slab of a conducting material up to a battery, electrons will march through the slab in a straight line. As moving electric charges, they'll also produce a magnetic field. If you place the slab between the poles of a permanent magnet, the electrons will deflect into a curved path as they move through the material because their own magnetic field will be interacting with the permanent magnet's field. That means one side of the material will see more electrons than the other, so a potential difference (voltage) will appear across the material at right angles to both the magnetic field from the permanent magnet and the flow of current. This is what physicists call the Hall Effect. The bigger the magnetic field, the more the electrons are deflected; the bigger the current, the more electrons there are to deflect. Either way, the bigger the potential difference (Known as the Hall voltage) will be. In other words, the Hall voltage is proportional in size to both the electric current and the magnetic field. All this makes more sense in the animation to the left.



1. When an electric current flows through a material, electrons (shown here as blue blobs) move through it in pretty much a straight line.



2. Put the material in a magnetic field and the electrons inside it are in the field too. A force acts on them (the Lorentz force) and makes them deviate from their straight-line path.

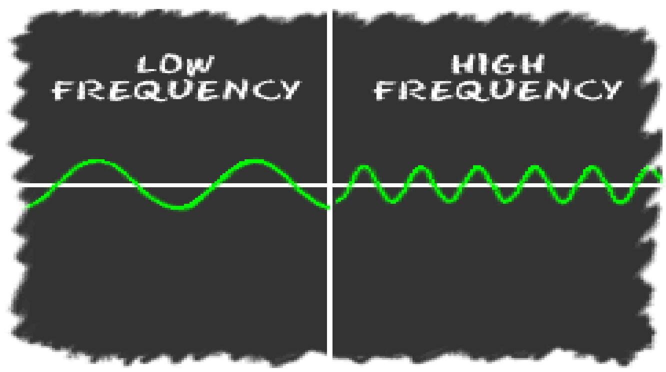


3. Now looking from above, the electrons in this example would bend as shown. With more electrons on the right side of the material than on the left, there would be a difference in potential (a voltage) between the two sides, as shown by the green arrowed line. The size of this voltage is directly proportional to the size of the electric current and the strength of the magnetic field.

Lecture 3: A/C Dimmer

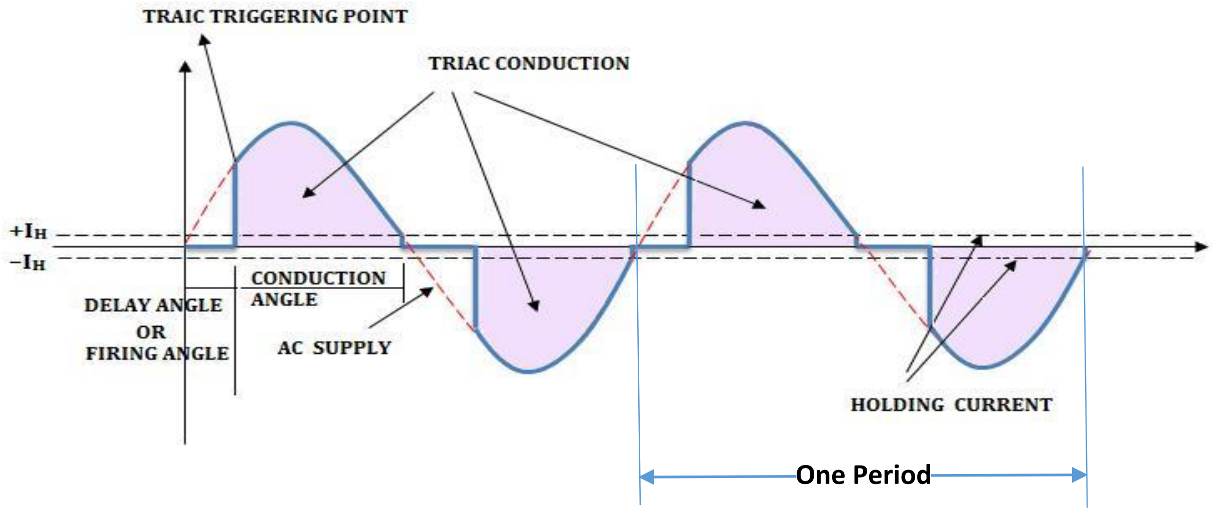
Intro to A/C

In alternating current, the charges move in one direction for a very short time, and then they reverse direction. This happens over and over again. Scientists describe the cycle of switching directions as the frequency. Frequency is measured in Hertz (Hz). Currents that cycle more often during a specific amount of time are said to have a higher frequency. AC power cycles 60 times per second in the US. This will prove usual in further later. Also, the standard voltage is the US for an outlet is 120V.



What is a Triac?

The TRIAC is an ideal device to use for AC switching applications because it can control the current flow over both halves of an alternating cycle. This means it can control a light fixture by itself. Be aware that the light fixture has to be an incandescent bulb or a halogen bulb. An LED bulb will not work as it does not act as a load like the incandescent or halogen. As seen in the image below, the triac chops the sinusoidal wave to reduce the amount of energy going into the light fixture. In basic terms, this can be thought of as a relay operating on and off. Once the triac is fired (turned on) it will let the sinusoidal wave through. The amount of energy the triac lets through depends on when the triac was fired. This timing is why we first we need to find out where we are in the sinusoidal wave.



What is a Zero-Crossing reference?

In alternating current, the zero-crossing is the instantaneous point at which there is no voltage present. In a sine wave or other simple waveforms, this normally occurs twice during each cycle. The triac uses the zero-crossing reference to determine its placement on the sinusoidal wave. Firing the triac after a number of microseconds delay starting from the zero crossing therefore gives a predictable level of dimming. This time interval is calculated by using the known frequency of 60 Hz. Since there is 2 zero-crossings per period we want to use the second one. This means we will use the frequency of 120Hz. Now we use the formula P = 1 / f to calculate the time it takes for one full wave. With P symbolizing a period and f symbolizing the frequency (120Hz) we get P = 8333uS. Now that we know one period we will have to divide by the number of steps we want. This will be the resolution to control the light fixture or the number of brightness steps we want to have. This can also be seen as how much precision you want over the light fixture. For example if we chose we want 128 steps then we simply divide 8333uS by 128. This will give us 65uS. We will use now use 65uS as a time interval of when to fire the triac.