Wireless Power by Resonant Induction

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For most people, the power cord is accepted as a necessary burden. However, with today's technology when information can be sent half way around the world virtually instantly and cell phones have become portable computers, it seems outlandish for our electronic devices to require direct connection to an outlet in order to be charged. Fortunately for us, physics agrees. There exist several techniques capable of eliminating this reliance upon physical contact; however, the world demands price efficiency and practicality as much, if not more, than it does convenience. Resonant inductive coupling provides a simple, price and power efficient solution to the innate problem of restraint associated with older methods of power transfer. This technology could also be used, in a more sophisticated manner than demonstrated in the following experiment, to transfer information wirelessly. However, the goal of the following project was to simply light an LED bulb wirelessly by harnessing a magnetic field and using it to create an electromotive force on a coil of wire. The materials necessary included a function generator, oscilloscope, magnet wire, two capacitors, an LED bulb, solder, and a soldering iron.

In the past, power has been carried to devices simply through a conductive wire from a source such as an outlet. The goal of wireless power is to cause this direct contact between the power provider and the power receiver to become obsolete. The crux of this task, in the case of inductive coupling, is to induce an electromotive force, *emf*, on an independent coil. This electromotive force provides the power necessary to light the bulb, thus achieving the goal of wireless power. In order to accomplish this goal, it is vital that a clear understanding of several general concepts of physics be present. The most prevalent concepts illustrated in this project include magnetic flux, Faraday's law, and resonance. Magnetic flux is defined by a surface integral that takes into account attributes such as magnetic field strength, number of turns in the wire, and the orientation of the normal of the surface to the magnetic field. Put in easily understandable terms, magnetic flux is the amount of magnetic field passing through a closed path. In order for a closed surface to experience flux, there must be a magnetic field present.

This magnetic field, as with any, is the result of the movement of electrons. In the case of this project, a function generator provided the necessary electron movement. The function generator sent a square wave alternating current with a frequency of 52.81kHz through a circular coil of magnet wire with radius 5.7cm thus inducing a magnetic field around the wire. The magnetic field created by the loop runs in a circular path around the wire, causing a net field running into the loop, around, and then back through the circular loop. This system works because of Faraday's law which is:

$$\oint_C \vec{E} \cdot d\vec{l} = -\frac{d\varphi_m}{dt}$$

Faraday's law states that an *emf* induced on a closed surface will be equal to the negative derivative of the magnetic flux through the surface. There are several methods by which a changing magnetic flux can be created. These techniques include changing the strength of the magnetic field over time, altering the area of the closed surface over time, and changing the number of turns. This project puts to use the method of creating a magnetic flux by sending a time-dependent square wave through the primary coil, thus creating a constantly changing magnetic field. Furthermore, Lenz's law states that the induced current will be in such a direction as to oppose the change in magnetic flux. While this law is vital in understanding directional properties of electromotive forces, it has little importance in the following experiment because alternating current has a constantly alternating direction. Also, as previously mentioned, efficiency is always a consideration concerning new technology and the applications thereof. Due to this necessity of a high percent energy yield, capacitors have been soldered onto each coil so as to cause the two separate coils to resonate at the same frequency. This technique eliminates much of the power loss caused by inherent differences in the composition of the primary and secondary coils. While the goal is simply to light a bulb, there is always motivation in the search for efficiency.

The mechanism used in this example to accomplish wireless power is fairly simple; assuming a reasonably strong understanding of physics is present. First, the function generator sends out a square wave at a certain frequency. The current runs through the outer, primary coil as well as the capacitor that has been soldered in parallel with the coil so as to act as a regulator. The current causes a magnetic field around the wires. More specifically, the field enters the coil from one side of the loop, exits the other side, then returns again through the first side. The goal of creating a change in magnetic flux of the inner coil is accomplished even though the area remains constant because of the varying magnitude of the field. According to Faraday's law, this change in magnetic flux induces an electromotive force on the secondary coil. This *emf* travels through the inner magnet wire loop as well as an identical capacitor also soldered in parallel to the coil. This is what allows the system to resonate and increase efficiency. The concept or resonance is fairly simple, for our system we wanted to make it such that as the inner capacitor was fully drained the outer capacitor would begin to drain into the inner. This would allow the system to be as efficient as possible. Due to the fact that capacitors do not fill and empty instantly it is important to know how long it takes for the capacitor to fill, then leave the current on until it is exactly full. The easiest way to know how much current has entered into the capacitor is to use a square wave which allows the current to be fully on for a set amount of time and then turns it on in the opposite direction for the same amount of time. We tried using a sinusoidal wave but the oscilloscope showed that the induced current was very unstable with no apparent pattern. When we switched to a square wave the oscilloscope showed that the induced current was sinusoidal. The reason this happens is because of the capacitors in the loop. When the current is at its peak it is filling the capacitor, then it switches to its negative peak and the capacitor drains into the loop, this constant filling and draining is what causes the current to be sinusoidal. This resonant effect increases the efficiency of the mechanism by a very noticeable amount. Finally, the current travels through the LED bulb that is connected to the ends of the inner coil and the light is powered.

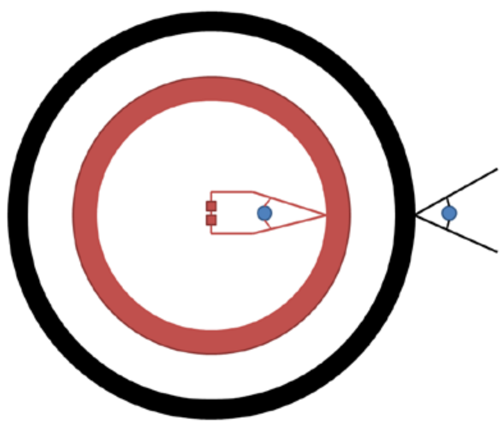
Construction and Diagram

Construction of the project began with determining the necessary materials. We knew we would need a function generator, some magnet wire, and some capacitors at the very least so according to the instructions from the instructable we ordered the capacitors, bought the magnet wire from RadioShack, and ordered the kit to make a function generator. Since the function generator is the most important part of the process we started by building that first. With what can most likely be attributed to novice soldering skills and limited understanding of circuits the function generator did not do its job.

Fully Assembled Function Generator

After finding out that the function generator didn't work we proceeded to build the coils. This was a simple process; just wind the big coil around a CD case and the small coil around a two by four then pull them off and make them circular. After doing that we sanded the ends of the wires and soldered the capacitors on. This is our final project.

Outer ring, Inner Ring, Capacitor (blue) and two LED's



Black is outer ring, red is inner ring, blue circles are capacitors and red squares are LED's

References

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