Electro-magnetic induction in wireless charging devices

Pasquale J. Graziosi '17, Hugh O. Thurman, III and Walter C. McDermott, III

Department of Physics and Astronomy, Hampden-Sydney College, Hampden-Sydney, VA 23943

INTRODUCTION

Just like how telephones went from wired to wireless, and computers went from desktops to laptops to smartphones, there are advances in charging technology as well. While we still use wired charging systems today, advances in wireless charging technology are being made. Qi charging is a charging system that incorporates electro-magnetic induction and resonant charging to transfer AC current from a normal wall socket to DC current within the devices battery. Electro-magnetic induction is a system in which two coils are placed very closely together. One coil is connected to a power source, which sends current through the coil, inducing a magnetic field. When the receiving coil is aligned, and placed very close to it, within about 4-7 millimeters from it, the magnetic field becomes induced in the receiving coil. Within the circuit board of the receiving coil, there is either a diode or a transformer that takes the induced magnetic field, and converts it into DC current, which is what the battery within a device runs off. Electro-magnetic resonance works in much of the same as induction, except it allows the receiving device to be only within a few centimeters of it as opposed to a few millimeters. As of right now, there are about 150 wireless devices that can accept, or can be retrofitted to accept, Qi charging technology. The only difference appears to be whether the battery can take the AC current and induced magnetic field and convert them into DC current.

The original intent for this research project was to build a wireless charger. However, after seeing the complications pile up after further testing, I ran out of time to try and build one myself. Although, constructing a wireless charger took a lot of time just to figure out how it works. My intent is to continue this research next semester.

In order to figure out the amount of turns in the pickup coil, as well as the magnetic field and current in either the pickup coil or charger, the following equations needed for this experiment included the use of Faraday's Law (Eq.1) and the Biot-Savart Law (Eq.2), as well as the variable substitutions used. The equations needed were the following:

Eq.1 $I_{coil} R_{coil} = (-N)/R_{charger} \quad \Delta Q/\Delta t$

$\Delta Q/\Delta t = \Delta B/\Delta t \; A$

Eq. 2 $B = (N\mu_0 I)/2R = \mu_o \; N/L \; I = \mu_o nI$
$n = N/L$

EXPERIMENTAL PROCEDURES

In order to figure out how Qi wireless charging works, I needed to acquire a Qi wireless charging device. Fortunately, Wal-Mart had a device made by Belkin, which contained Qi wireless charging technology. From there, I needed to crack open the charging platform. Holding the platform together was nothing more than a couple of extremely small screws and epoxy. Upon opening the platform, there was a coil epoxied on the back of a circuit board. The coil contained 10 turns and was essentially flat, for all intents and purposes of this experiment. After examining the circuit board and coil, it was determined that to take measurements from the charger coil, two leads would need to be soldered onto the circuit board. After the leads were soldered in place, a pickup coil of unknown turns was placed on the charger coil and measurements were taken using a standard multimeter, as well was current sensors and a magnetic field sensor on the Pasco interface system as seen in Figure 1.

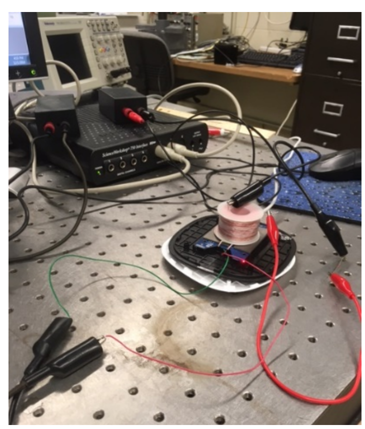
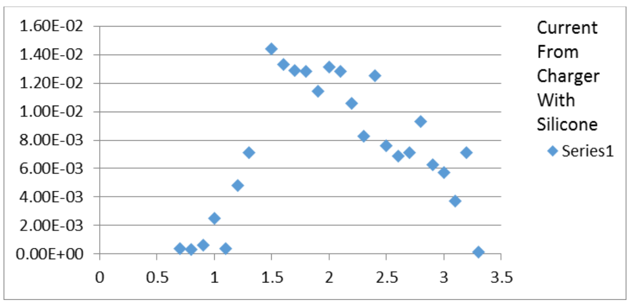


Fig. 1

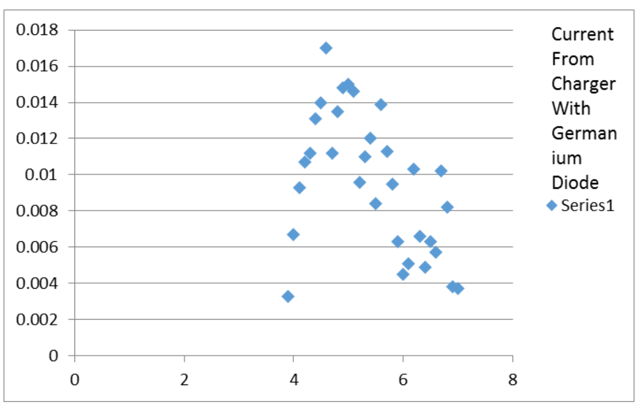
Initially, the measurements that were being taken were sporadic at best and inconclusive. There was a multimeter connected to the pickup coil, as well as a multimeter connected to the charger leads. Even Pasco was picking up sporadic measurement that could hardly be repeated. It became obvious that there was a sensor in the circuit board that told the charger to shut itself off and not produce current when it detected something that could potentially receive the current, but wasn't capable at that point in time. After wondering how to bypass this safety feature, the feature being that metal that is on it doesn't get hot from trying to receive the current, it was brought to my supervisor's attention, Dr. Thurman, and myself by Dr. McDermott that the pickup coil most likely needed a diode connected in series to it to convert the AC current that was being pushed through the charger coil into a DC current that would be used in a phone are tablet battery. After connecting both a germanium diode and a silicone diode, not only were the measurements taken with the multimeter and Pasco repeatable, but the data shown was also conclusive.

ANALYSIS

After connecting a germanium and silicone diode in series with the pickup coil, the following graphs were produced below:



Graph 1.



Graph 2.

The two graphs above both observe the current in the charger coil with the pickup coil connected in series with both the germanium and silicone diode. The difference between the two diodes is that the germanium diode has a voltage threshold of 0.3 volts while the silicone diode has a voltage threshold of 0.7 volts, which is why the silicone diode graph (Graph 1.) has a longer curve than the germanium diode. I took two points from the silicone graph and plugged their points in Eq.1. Using that equation, and the known resistance of the pickup coil, which was measured to 8 ohms, I could calculate the theoretical current running through the pickup coil, which came out to be 0.002153 amps. This theoretical value fell within the known range of 0.002-0.0036 amps that the pickup coil measured when connected to the multimeter during the experiment as well. This all but solidified the idea that the receiving coil in a battery needs a diode or a transformer in the circuitry of the battery to accept Qi charging.

CONCLUSION

After analyzing the date acquired, and calculating the theoretical value of the current running through the pickup coil to be 0.002153 amps, and then comparing it to the experimental value range of 0.002-0.0036 amps, it is very possible that the construction of a battery that can be wirelessly charged has a diode or a transformer, to convert the AC current into DC. My goal from here is to build my own Qi charging coil and test it on a Qi enabled battery, to see if I can increase the effectiveness of wireless charging.

REFERENCES

Faraday's Law." Faraday's Law. N.p., n.d. Web. 04 Dec. 2016. http://hyperphysics.phy-astr.gsu.edu/hbase/electric/farlaw.html

"Qi: Charging, Simplified." Benefits. N.p., n.d. Web. 04 Dec. 2016. https://www.wirelesspowerconsortium.com/about/benefits.html

@qi_charging. "List of Qi Compatible Smartphones, Tablets and Other Devices." Qi Wireless Charging. N.p., n.d. Web. 04 Dec. 2016. http://qi-wireless-charging.net/qi-enabled-phones/