Motion-Powered Phone Charging Case (May 2016)

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***Abstract*—Presented in this report is a motion-powered phone-charging case that converts kinetic energy into electrical energy. This harnessed energy can then be used to charge a phone or any other type of mobile device. The case will implement electromagnetic induction that will be used to charge device.**

I. Introduction

Mobile devices today have become a popular commodity in today's technology-driven world. While they are used in everyday life for many tasks, their limited battery life detracts from their versatility. Consumers constantly have to be cognizant of their battery life, or they risk their battery depleting

Consumers have attempted to mitigate this widespread problem by carrying external battery packs. These packs also require their own charge to be full, which only adds another device to take care of for the consumer. While these solutions may correct the issue in the short-term, it is not feasible to expect consumers to have an extra charger on their person at all times.

With this idea in mind, we propose a motion-powered phone-charging case that constantly charges the consumer's phone as they walk or exercise. By integrating the charging aspect into a widely used commodity such as a phone case, we eliminate the need for an external battery, and reduce consumer involvement in charging the phone. This quality-of-life improvement would enhance the user's satisfaction with their devices, while also addressing a critical problem in the booming smartphone business.

A suitable solution for this situation would be to use electromagnetic induction. This method utilizes a magnet and a solenoid coil. By repeatedly passing the magnet through the coil, an induced current comes about. Electromagnetic induction is commonly used in motion-powered flashlights and electrical generators. Overall, this approach suits the project directive quite well, and can be scaled down to fit an object as small as a phone case.

In recent years, there have been adaptations of converting kinetic energy to charge phones. The most popular of these adaptions is Ampy[1], an external battery pack that is charged through motion from the consumer. The consumer carries Ampy around in their pocket or strapped to their arm in order to get maximal benefit. While this approach seems convenient, it does not remove the issue of having the consumer carry around an external device in order to ensure that their battery life is suitable.

Another example, AmpWare CrankCase[2], is a case that allows the user to charge their phone through an integrated crank. The user can rotate the crank as much as they wish, and the phone will receive charge by using the converted mechanical energy. This product addresses the issue of external devices that Ampy had, and adds a sense of novelty to the product. However, cranking for phone charge still requires heavy involvement of the user in the charging process; arguably more so than carrying an external battery pack.

Both of the products above have their own respective strengths in terms of improving the consumer's quality of life. The product we propose integrates both of these ideas into a singular product: uninvolved motion-based charge with the ease of merely putting on a case once without further maintenance.

In the following sections, the design of the motion-powered phone-charging case will be presented. Each step will be supported with simulations to verify that the schematics are feasible. With the data extrapolated from these simulations, the final product can be assembled using the necessary hardware materials, such as circuitry and 3D-printing. Finally, testing its usage from various users will show the results of the completed product.

II. Components and Implementation

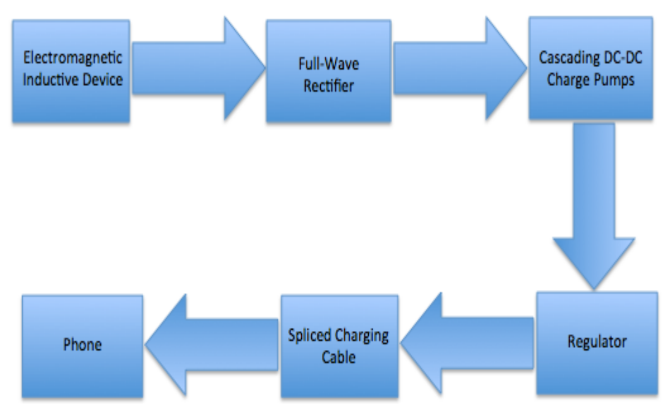

Fig. 1. Flow chart of the components for the phone-charging case implementation

A. Electromagnetic Inductive Device

The electromagnetic inductor (EMI) works by moving a rare-earth cylindrical magnet through a solenoid with multiple turns. This action produces a current and voltage moving through the coil, which will serve as the basis for the charge of the phone.

The cylindrical magnet will be 1 inch tall with a 3/8th inch diameter. The solenoid will be wrapped around the case of the EMI device. This EMI casing will be a 3.5 inch long PVC pipe with an inner diameter 0.5 inches. The diameter of the solenoid is also 0.5 inch in diameter. This difference in diameters will give the magnet space to move through it. A spool of wire will be used as our solenoid with 75 turns in order to generate enough current. With simulations, the number of turns will be adjustable to the specifications.

B. Full-Wave Rectifier

The rectifier serves to change the current from AC to DC, and will also change the signal to a semi-constant value. It does this by the set of four diodes in conjunction with a capacitor. The diodes make the current flow in one direction and the capacitor will make the signal semi-constant. The specifications of the rectifier will be based off of results obtained from simulations. For preliminary purposes, the resistor will be a 10 kOhm value, while the capacitor will be a 0.1 microfarad capacitance

C. Cascading DC-DC Charge Pumps

Originally, the idea was to use a transformer to step up the voltage. However, this would not work during the trials run, as the device was able to step down the voltage by a factor of 10, but would not step up by a factor of 10. Because of this, other options had to be pursued in order to get the desired voltage.

In this situation, DC-DC charge pumps were the best alternative to get the minimum 5V out of the device, as it takes in a certain voltage and outputs a higher one. We used a pump to go from 1V to 3.3V[3], and another one subsequently after which takes in 3.3V and outputs a regulated 5V[4].

D. Regulator

The regulator is meant to keep the voltage within a specified range so that it sufficiently charges the phone. Originally, this was going to be a separate component in the circuitry. However, the DC pumps have an internal regulator before the output. This took care of one of the concerns in the overall device, and made the circuitry simpler as well.

E. Spliced Wire Cable

This component will be what directly connects the phone to the case. Inside the cable were four color-coded wires that each serve a different purpose in the charging method. The red and black wires were power and ground, the main parts that we use in the cable. The white and green wires were for data transfer which were not part of the objective of this project[5].

F. Phone Case

The case is the final component of the layout that aggregates all of the other components into one cohesive unit. The case will have a spliced phone charge at the base so that it can connect to the phone. This connection is the critical component that unifies the two technologies and allows them to work together.

III. Integration

The integration of all of these components is what will be able to charge an electronic phone. While the first design may be a bit bulky or aesthetically lacking, multiple iterations can be done in order to perfect the device. In addition, the components will be connected through a printed circuit board (PCB) in order to make the circuitry compact.

Starting with the EMI, the user's normal everyday movement will continuously move the neodymium magnet in and out of the solenoid. The current induced from this process will be connected to a full-wave rectifier to make sure the alternating current becomes direct current.

After the full-wave rectifier, the waveforms are all positive. The values coming out from the rectifier will then go through the two DC-DC charge pumps. As stated in before, the charge pumps raise the voltage to the desired 5V that will be fed into the spliced wire for the phone.

Using a spliced phone cable connected to the end of the charge pumps, the case will hold it in place so that the motion can feed into the phone.

With this design, the user sees the product as just another phone case to place onto their device, but will save them the time of charging the phone when it is low on battery at night.

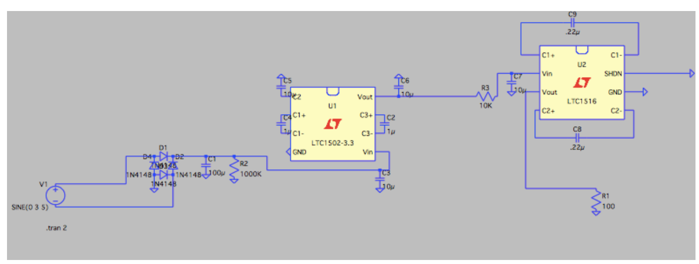

Fig. 2. Schematic of the overall phone case design

IV. Simulations

Before testing any component of the project with hardware, it was necessary to find theoretical results that could be compared against the experimental results. These theoretical results would be obtained through various formulas and circuit simulation software such as LTSpice.

Once the overall schematic was complete, the simulations in LTSpice would be brought over to Eagle, in which the PCB schematic would be made. The specifications on this were very important in order to make sure that the board was printed properly during the first trial. The following images are simulations of these steps.

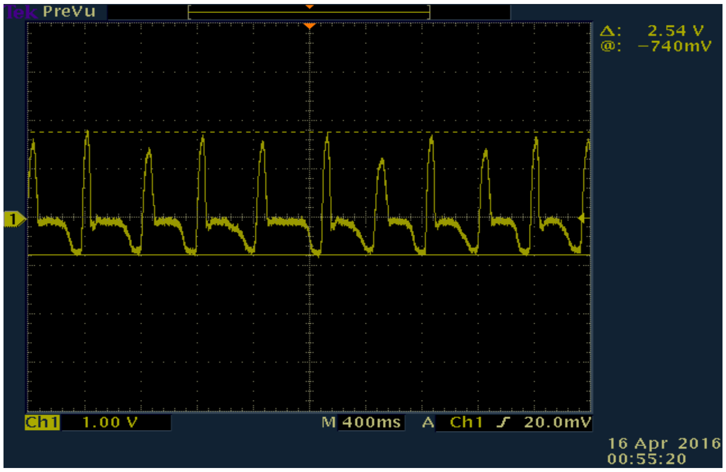

Fig. 3. Waveform of the EMI's signal before rectification.

The above waveform is a simulation of the electromagnetic inductive device being put to use. As shown in Figure 2, the peak to peak voltage being reached by solely moving the magnet through the solenoid is about 2.5V. While this is a good starting voltage, it shows that the set up needs some type of device to amplify the signal. Before that, however, the signal must be rectified in order to keep all signals above 0 and to limit the range of the voltage.

The rectification is inherently taken care of by the charge pumps, which made the simulations of the data much easier to map.

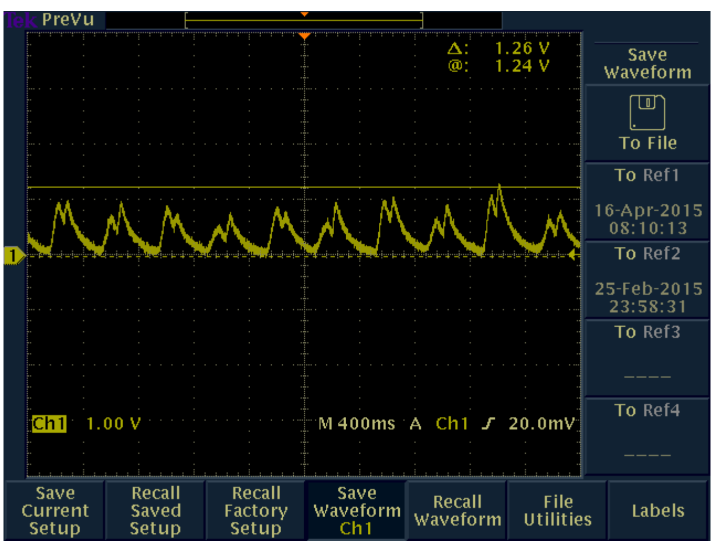

Fig. 4. Waveform of the EMI's signal after rectification.

After the signal goes through the full-wave rectifier, the voltage peak lowers to about 1.25V, as seen in Figure 3. In the final set up, a DC-DC converter pump was used to bring the voltage up to 3.3V, and then a cascading one is used to bring that signal up to 5V. This is the desired voltage for the device, and will allow for charging in the device from everyday movement

Label	Wattage (W)
EMI - .5 Hz	3.481E-07
EMI - 1 Hz	6.40E-07
EMI - 5 Hz	3.39E-06
Estimated Charger Output - 5 Hz	25E-06

Fig. 5. Power output of the device based on different shaking frequencies.

V. Discussion

The original intent of the product was to make it so that the user could charge their phone while normally walking.

Unfortunately, the schematic from LTSpice did not properly match the design created in Eagle. This led to a faulty connection between one of the charge pump's outputs to ground, which caused a short circuit. We attempted to remedy the situation by severing this connection with an X-Acto knife, however the connection needed too much precision to cut without affecting other connections.

Seeing that the PCB did not allow the phone to charge properly, a new EMI was created to see if it could get more voltage. After creating a 6-layer solenoid with 200 turns per layer, simulations on the voltage output were run. With this component, the oscilloscope showed a peak-to-peak sine wave of 13V.

After connecting this output to the rectifier, it was found that while shaking the device, the voltage would increase steadily and would plateau in the 5V range. This was the target voltage for the charger in the first place, and acted as a suitable substitute for the idea.

In the final design, a proto board with the layout necessary for rectification was used in place of the PCB. The output from this would connect to the spliced charger cable, which would feed into the phone. The 3D-printed phone case fit all the size expectations that the device required.

With this new design, the user will have to shake the case back and forth in order to generate charge, rather than walk. This was a suitable compromise in the idea, as shaking is a simple movement, and still combines the best aspects of Ampy and AmpWare Crankcase in order to make a better product overall.

It was discovered that the phone required 5V to register that it was charging, but there was no amperage requirement for this. Seeing as the power calculated was in the microwatt range, we can deduce that very little current was being generated, but the voltage was enough to be registered by the phone.

The case was successfully demonstrated and showed the fundamental intent of the device, and allows for avenues to expand upon it.

VI. Future Development

While the original aim of the project was different from the result, it still leads quite well into optimizations that can be made for the future.

One aspect of the project that could be worked on would be the size of the case. The size directly depends on how thick the EMI device is. By shrinking this component, the case could easily fit in to a user's pocket, and would not be any larger than current OtterBox cases.

In addition, the charging method for the case should be pivoted toward walking instead of shaking in order to better align with the original goal. Given more time, we would correct the errors found on the PCB and print it again so that the charger could work with normal motion.

Getting more compressible, non-magnetic springs could help with moving the neodymium magnet through the solenoid, since the phone will mainly stay in the same orientation as the user is walking.

Another weakness that we did not account for was the noise that the solenoid makes as the magnet hits the phone case walls. In future adaptations, we would dampen the impact of the magnet on the walls of the case with, rubber stoppers, cotton balls, or the aforementioned springs.

Finally, we would of course try to increase the power output of the device, as it currently charges at slow base rate of 25E-6 watts. Manipulating the layers on the EMI, as well as optimizing the connections in the schematic could be done in order to achieve this. While the product might not charge as fast as conventional chargers, it is still a goal to make it so the charge can mitigate a significant deal of the phone's battery discharge.

Overall, the design goals of the project were met and it will be possible to expand and improve upon it in the future.

VII. References

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[5]"How to Charge a Smartphone With a Broken Charging Port or Faulty Charging Cable", *Download3k.com*, 2016. [Online]. Available: http://www.download3k.com/articles/How-to-Charge-a-Smartphone-With-a-Broken-Charging-Port-or-Faulty-Charging-Cable-01225. [Accessed: 09- May- 2016].

VIII. Member Biography

Anthonie Best is a junior at Johns Hopkins, studying Computer Science and Computer Engineering. He is from Phoenix, Arizona. He is an avid anime/manga enthusiast and likes to participate in various engineering competitions.

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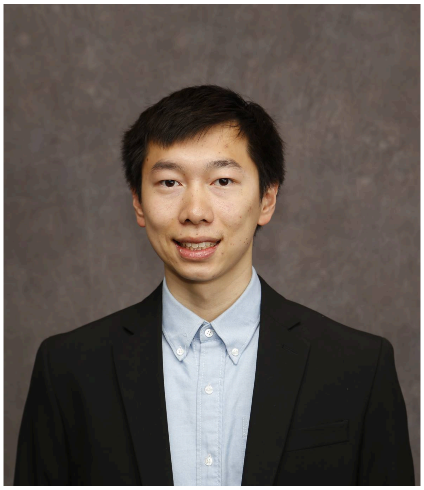

Jeffrey Sham is a junior at Johns Hopkins, studying Computer Science and Computer Engineering. He is from Ellicott City, MD. On campus, he is part of the talented dance group, Hopkins Breakers, and enjoys enhancing his dancing skills whenever he’s not working on schoolwork.