Inductive Charging Case

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1. Introduction

1.1 Objective

As USB type C is becoming more common in phones, many companies are removing the headphone jack on phones [1]. This creates a big problem for those who want to transfer data or listen to music while charging their phone. This problem increases as phones become more powerful and their battery life do not grow at the same rate. It is very common to run out of battery at the end of the day after having used your phone during the whole day.
Our idea to solve this problem is to develop a rechargeable wireless battery that can give your phone an extra amount of power without taking up the only jack the phone has. We will implement a Qi transmitter circuit into a case along with the rechargeable battery. Power will flow from the battery to the transmitter circuit and will be received by the circuit integrated in our phone.

1.2 Background

Nowadays there are some phone cases that allow you to charge your phone without plugging it into the socket [2]. Our device is different because we are going to use a system that transmits the power wirelessly. In the already existing cases, the rechargeable battery is directly connected to the charging port. These cases partially solve our problem as you do not need the phone to be connected to the wall, but we want to completely solve it by charging the phone wirelessly so we can use the port for other purposes.

1.3 High level requirements

- The system has to be able to fully charge the mobile device.
- No more than 0.1 V shift in the DC-DC circuit because voltage stability is crucial.
- The system efficiency has to be greater than 70%.

2. Design

Our design is composed of, mainly, three general blocks. First, a DC current is taken from the Lithium Ion Polymer battery and sent to the voltage regulator. This will keep our voltage at a constant rate and increase it to a voltage suitable to our circuit. Next, power is distributed to the various components of the circuit. The microcontroller will send and receive data from the phone using Qi, which transmits data along with power. Furthermore, the microcontroller will denote what frequency the DC-AC converter will operate at. Finally, an AC current is sent to the transmitting coil, which in turn induces a magnetic field. That magnetic field is used to inductively charge Qi enabled devices. Our software application will pull data from the phone in order to analyze charging efficiencies along with other useful user end data.

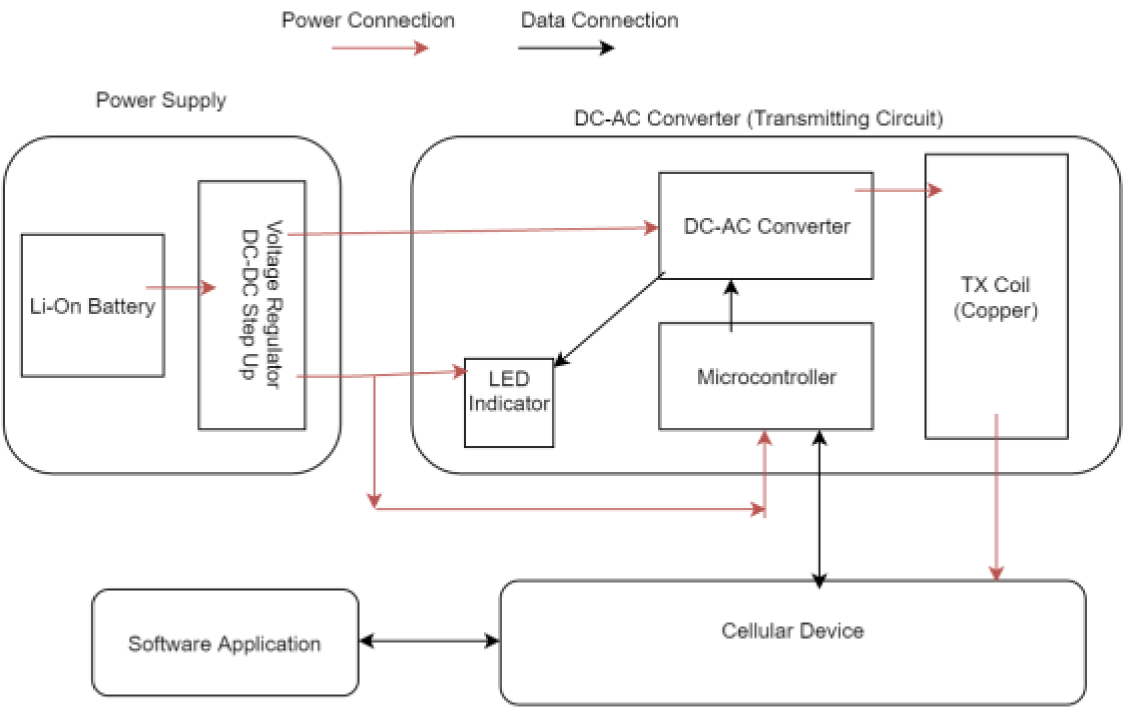

Figure 1. General block diagram

2.1 Power supply

2.1.1 Li-On Battery

The battery will be a rechargeable lithium ion polymer battery. The main way of charging the battery is through a Micro USB cable. It is also possible to add a receiving circuit to our case in order to charge the battery through inductive charging.

2.1.2 Voltage Regulator

The voltage regulator is going to step up the voltage from the battery. In addition, the DC-DC converter will help us maintain a constant input voltage in the transmitter circuit. We are going to design a Boost Converter as our voltage regulator. A boost converter is necessary as the battery voltage could switch between minimums and maximums. Rather than making a dual converter, it is simpler to just boost the voltage to a level above the battery's maximum or below its minimum. In this case, we will go above the maximum voltage of the battery.

2.2 Transmitting circuit

2.2.1 LED Indicator

The LED will indicate various modes within the circuit. It will indicate when the battery is charging, when the battery is connected to the circuit, and finally, when the phone is being charged.

2.2.2 Microcontroller

The microcontroller will have two main functions. First of all, it will send and receive data from the cellular device's receiving controller about the charging process. After it receives this information, it will process it and turn it into a control signal. That control signal will be sent to the DC-AC converter to adjust the frequency of the current that is eventually sent to the transmitting coil.

2.2.3 DC-AC Converter

This module will transform the DC current from the power supply into an AC current. It will receive signal from the microcontroller in order to change the frequency of the current. We do this in order to maintain resonance between the transmitting and receiving coil when charging the device. This DC-AC converter is atypical since it is constantly switching frequencies in order to match the receiving circuit rather than staying at a constant frequency.

2.2.4 TX Coil

The transmitting coil will turn the AC current into a magnetic field, which will be used to induce a current in the receiving coil located in the phone.

2.3 Software application

Since our idea is to allow the user to receive power from the phone case wirelessly, there must be an interface where the user can control how much power to receive, and view power statistics on the phone. We plan to develop an application where the user can turn on/off charging, control how much power to send, and various other functions such as viewing the speed of transfer, and efficiency. The application will also communicate with the circuit; when to turn on/off the charging. For safety concerns, the application will also warn the user if there is a risk of overpowering or any danger. The Qi data protocol allows limited data transmission between the charger and phone, thus we plan to use that to communicate between the phone and the circuit.

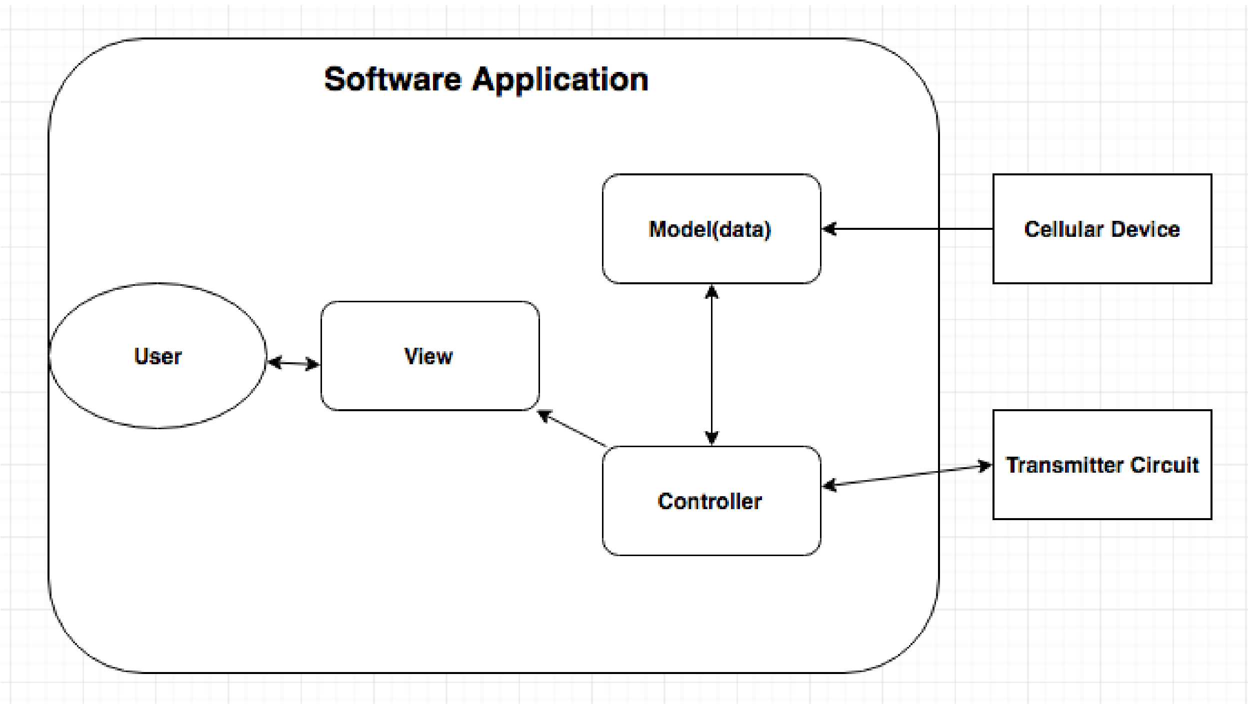

Figure 2. Software Application block diagram

2.4 Risk analysis

The riskiest block of this project is the DC-AC converter as it is very difficult to design and it is vital for the charger to work properly. This converter has to change the frequency of the AC current output in real time with the information that the microcontroller sends.
In addition, the design of the battery and its enclosure has to be extremely accurate to avoid overheating and short-circuits which may lead to explosions. We will test the battery separately to ensure safety at all times.

3. Ethics and safety

The greatest safety concern of our project is the battery. We have chosen a lithium-ion battery due to its high energy density. However, this characteristic can be a major drawback as the battery can be highly damaged or even destroyed if we do not design it properly [3]. It is extremely dangerous for a lithium battery to be punctured, so we have to design an enclosure around it in order to protect both the product and the user.
We are planning to test our batteries separately from other modules in order to prevent short-circuits and to test overheating issues as well. By testing batteries before attaching them to our circuit we can help to keep the lab environment safer.
Furthermore, lithium-ion batteries are difficult to recycle and can be dangerous to the environment if not disposed of properly. Another major concern is the production of the batteries. The mining of lithium contributes to the greenhouse effect, so we must maximize the usage of our battery to avoid endangering our environment as stated in #1 of the IEEE Code of Ethics [4]. Testing battery lifetime and stability will be a major component of our project.
In accordance with #8 and #10 of the IEEE Code of Ethics, we will work all together as a team and we will support our colleagues whenever it is necessary. We reject any form of discrimination. Racism does not belong here at Illinois.

4. References

[1] J. Chamary, "Why Apple Was Right To Remove The iPhone 7 Headphone Jack?," 2016. [Online]. Available: http://www.forbes.com/sites/jvchamary/2016/09/16/apple-iphone-headphone-jack/#574247633019.

[2] "Amazon," [Online]. Available: https://www.amazon.com/cell-phone-battery-charge-cases/b?ie=UTF8&node=7073958011.

[3] J. Horwitz, "Samsung finally explained what caused the Galaxy Note 7 explosions.," 2017. [Online]. Available: https://qz.com/892221/samsung-ssnlf-finally-explained-what-caused-the-galaxy-note-7-explosions/.

[4] IEEE, "IEEE Code of Ethics," [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html.