Imperial College London

EE2-PRJ E2 Project - Final Report

Mobile Wireless Charge Sharing Technology and Associated App Platform

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ABSTRACT

As wireless charging continues to expand into the mobile applications market, this project aims to bring a new look at the current utilisation of the technology. The project aims to create an environment in which users can and are incentivised to share charge between mobile devices. The project envisions the implementation of this as a wireless power transmitter/receiver circuit integrated with the mobile device which is controlled by an app that manages geo-matching and share requests between users, giving customers the opportunity to charge their phones wherever another mobile device is available.

The report details the processes undertaken since the previous interim report and conclusions reached as such. (Some sections refer back to information detailed in the interim report, which has not been repeated for conciseness purposes.) Primary work in this time period consisted of: building of the switching circuit and interfacing with the microcontroller unit, testing of full circuit efficiency and phone current supply, design and software implementation of the companion app and design of the 3D printed case in which the circuit and phone would be placed.

The process resulted in a working prototype, however various setbacks did appear. The major obstacles were the difficulties of working with small components designed for mobile devices with limited technical equipment, problems with getting the phone to recognise OTG mode and pressures to limit app functionality due to required intricate backend server design.

Overall however, a circuit was built which displays the crucial properties of the envisioned design, including switching transmitter receiver circuits and serial communication. Overall acceptable efficiency levels in the upper 60% range were achieved from the circuit. A companion app was designed and built that provides a demonstration of the working procedure of our charge sharing ecosystem.

Possible future work remains extensive. As wireless charging technology becomes more advanced the product can be made smaller lighter and more efficient, with eventual plans for it to become entirely integrated within mobile devices.

Keywords: *Wireless Power, Qi Standard, Charging, USB OTG*

1. INTRODUCTION, CONTEXT AND BACKGROUND

The modern world is dominated by mobile computing technology. Many depend heavily on such devices and services for both daily and professional tasks, such as finding the best route to take, finding a local restaurant, translating foreign languages or simply checking the temperature. Such technology has developed immensely within a very short amount of time to have become a ubiquitous part of today's society.

Battery and charging solutions, however, have progressed very slowly in comparison to technology developed to run on such power sources. The majority of mobile devices in the market provide users with underwhelming performances in terms of time of usage unplugged, and with limited access to power supplies on the go, many identify shortage of portable power sources as a major hindrance to fully enjoying the benefits of the modern mobile technology.

Market research has previously been carried out to confirm the proportion of the market that identify themselves as being affected by such problems. Out of 210 people surveyed, 75.4% identified regular issues with their mobile device's battery life, and over half responded positively when asked if they were willing to share their mobile power reserves with others.

Thus, it has been proposed that such technology that would enable users to wirelessly share the power reserves of their mobile devices be developed. The proposed technology will utilise wireless charging technology and a location-based online social platform to let users identify others in vicinity who are willing to share their power source, and transmit or receive the device's battery reserve.

The Qi[1] wireless charging standard has the potential to provide a versatile solution for mobile device users. What we propose to develop is a technology which can both receive and transmit power wirelessly. This will enable device to device wireless power transfer; providing users with the ability to share charge and in effect gain access to a substantial number of power sources.

The project being proposed has the capability of solving the problem of low battery levels by creating a physical device through which mobile phones can be charged by other mobile phones. This solution creates

[1] QI – Pronounced CHEE

freedom for our modern society by reducing the burden of worrying about phone battery levels and charging sources.

2. Improving Context

The benefit of the product - which we decided to name 'WiSP' (short for wireless sharing of power) - to its users is to serve as a means to effortlessly let multiple mobile devices 'share' power, especially in the event of having a mobile device run out of battery, allowing for on-the-go charging when wireless ports are not available.

It was asserted that a wireless charging technology was required to allow this, since even though wireless power transfer is often deemed very inefficient compared to wired transfer, the convenience of having no cables outweighs the efficiency for the purpose of this proposal and creates major attraction and benefit for the users.

FIGURE 1: PRODUCT LOGO DESIGN

The Wireless Power Consortium's Qi low-power wireless charging standard was chosen as the most appropriate form of medium of power transfer for the product, to allow as much versatility and compatibility as possible. This is made clear as the Qi standard is already clearly outlined, defined and implemented by a wide range of consumer electronics products already in the market.

The product also needs to be a portable solution for either frequent use on a daily basis, or occasionally in emergencies, depending on the consumer's' usage pattern of mobile devices. This confines the product to be a lightweight, portable device that is able to accommodate the Qi compliant coils and circuitry.

For this device to be a more convenient source of power than portable batteries, or having to resort to wall chargers, it would be perfect for users to be able to communicate with each other in order to utilise unused power reserves of mobile devices that other people carry around on a day to day basis. The ideal way to connect various users of the product would be through an online mobile medium which uses geolocation in order to locate the closest users.

Many people may not be willing to share charge with people they don't know without an incentive. This application could have a virtual currency to exchange in order to encourage users to share their power reserves.

3. Project Management & Planning

To transform the ideas on paper into a working reality the group has employed various strategies to organise itself. Initially, methods of communication were put in place between members including: social media messaging groups, shared file drives such as Google drive and GitHub, and a consistent meeting schedule to maintain up to date information and progress among all members. Meetings were held on a weekly basis on Thursday.

All material pertaining to the project that is stored on computers is also subsequently saved on Google Drive and One Drive folders which are accessible by every member of the group. The folders online are particularly useful and come into play around the time when the group is writing the report. Each member writes sections of the report regarding their activities in the project and edits the main draft online so that time can be saved compiling the report together at the very end of the deadline.

Minutes of each of the group meetings were taken by a new member each week; making note of proceedings and future plans of action, (provided in appendix 1). Roles were not assigned to group members however strengths were identified in the initial sessions giving good indication where specific human resources (particular group members) should be applied most.

Members of the group with technical backgrounds working with Arduinos, website design, circuitry etc. were assigned tasks relevant to their background. They would meet together in the EE labs once a week, usually on Tuesdays, to develop their part of the project and then report back to the group on the weekly meeting every Thursday.

The group continuously keeps track of outlying tasks and updates a Gantt chart to determine dependencies and time allocation of tasks to help plan logistics. (Provided in appendix 2).

At the start of the term a week by week plan was drawn up displaying the to-do list of the project and what week each task was expected to be completed. This kept the project going at a steady pace and the momentum stayed strong throughout the entire term. Having this structure ensured the group would never fall behind the required pace and also indicated to them where attention should be directed and spent accordingly.

4. Design Specification & Rationale

The requirements for the design of the product have been specified as follows. Several choices for design concepts have been formalised accordingly, for which the decision is discussed later in section 4.2.

4.1 HARDWARE

The purpose of our device is to allow multiple mobile devices to effortlessly "share" power whilst on-the-go. It was decided that wireless charging technology was required to allow this as it is more convenient than having cables to connect up the phones.

The device must receive power wirelessly from a Qi standard power source in order to charge a mobile phone. In addition it must be able to use the mobile phone's battery reserve in order to wirelessly transmit power to another device with a Qi standard power receiver. Power should not be drawn from the mobile device when not being used to charge another device.

Both the transmitter and receiver circuits will work from the same coil so the device must be able to switch between the two modes, the "off" state is receiving (so the phone can be charged when completely out of power) and the "on" state (active) is transmitting. The transmitter/receiver must comply with WPC Qi low-power standard. (Transmitter rated DV 5V 2.0-2.1A power supply. Receiver output is DC 5V 1.0A.)

The product needs to be convenient for everyday use. In order to achieve this the device must be kept lightweight and portable the device must weigh no more than 50g, be less than 5mm thick and its dimensions must be compatible to fit in a case for current mobile phones. By having the device within a phone-case it is not something the user needs to remember to take with them and is always there when needed, this makes it a lot more convenient than portable batteries or wall chargers.

4.2 SOFTWARE

The device should work alongside a mobile application which will provide a multi-user online platform for users of the device. It must operate on major mobile operating systems such as iOS and Android. The app should allow users to share/receive a device's power with other users in exchange for a virtual currency exclusive to the platform (as an incentive to share their power reserves). It must also provide the user with information about the amount of power being received or transmitted. It will need to connect users and allow them to communicate. Using the geolocation information from the phone, it must locate other users in the surrounding area and send/receive requests to share charge.

The phone must be able communicate with a microcontroller via a serial connection to switch the power sharing mode of the device. Therefore, a microcontroller which has a serial interface must be chosen with software capable of interpreting the input and switching the mode accordingly.

5. Concept Designs

Over the course of the project three different designs were considered. The first two of these were detailed in the interim report and are summarised below. The 3rd additional design is the one reverted to during prototyping and the rationale behind this is explained in the following sections:

DESIGN 1

This design envisioned an integrated transmitter receiver circuit on a single board that could be switched externally through a control signal by that would in turn set in place a set of circuit connection changes to switch the function of the module. This would constitute a highly compact design in that it would be formed of a single PCB which would be manufactured by the group. However, upon investigation into the workings of such modules it was found that such an implementation would surpass the knowledge level of the group and would require advanced soldering and manufacturing techniques for the extremely small controller circuit components that would have to be used.

DESIGN 2

The second design consisted of a separate transmitter and receiver circuit operating off a single coil. The two circuits would be switched with the use of a digital signal controlled power multiplexer, the TPS2115A. This system meant that the coils also had to be switched using these switches, which caused problems in implementation that will be detailed in later sections.

DESIGN 3

To ensure the design could be implemented the team decided to revert to using a double coil system. Rationale behind this is explained in concept selection and concept development sections. In this way the power switches were not needed on the coil side of the circuit and a switching mechanism on the USB connector side could simply be implemented. The design would use two digital signals to turn on one switch whilst keeping the other in high impedance output mode. Two switches are needed due to the opposite current flow from the phones positive power rail during charging and discharging.

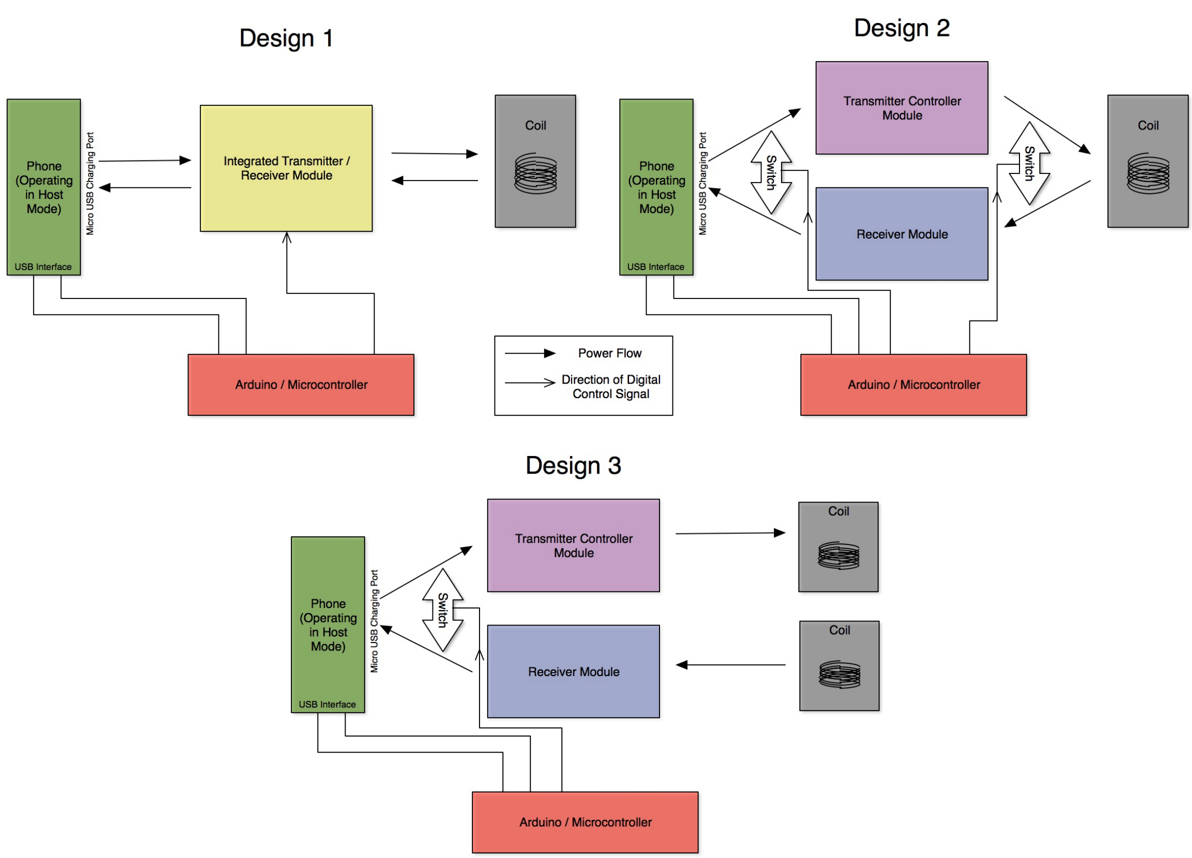


FIGURE 2: CONCEPT DESIGNS BLOCK DIAGRAMS (LARGER VERSIONS PROVIDED IN APPENDIX 3)

6. Concept Selection

We used a concept selection matrix in order to decide which concept design better fulfils the specified criteria. For selection of the concept design, the initial design was used as a baseline. As can be seen in Figure 3, based on the updated design criteria, the Dual Coil Separate Control Circuit scores better than the other two designs. Although both the single and dual coil designs with separate control circuit had better ease of implementation and interfacing with Arduino, the dual coil was found to be more reliable, due to the fact that more expertise was available with dealing with similar circuits, and steadier power transfer could not be achieved for the same reason as mentioned previously. These were both deciding factors in our concept selection which lead to the Dual Coil being chosen as our final design.

	Integrated Tx-Rx Circuit (Single Coil)	Separate control circuit (Single Coil)	Separate Control Circuit (Dual Coil)
Steadiness of power transfer	s	-	+
Power Rating	s	s	s
Weight of product	s	s	-
Thicknes of product	s	s	s
Fits standart Smartphone dimensions	s	s	s
Switching efficency	s	-	s
Reliability	s	s	+
Ease of Implemenation	s	+	+
Interfacing to Arduino	s	+	+
Total Negatives	0	2	1
Total Positives	0	2	4
Total	0	0	3

FIGURE 3: CONCEPT SELECTION MATRIX

7. Concept Development

7.1 Hardware

7.1.1 Updated Circuit

The circuit was initially implemented with the switches on the phone side of the transmitter and receiver circuits. This set up was successfully constructed, and input from the Arduino to the switches would ensure that the transmitter and receiver circuits could be switched on and off simultaneously with nearly no immediately visible efficiency loss. However, when the switches were implemented on the coil side, problems were encountered with the particular switch models. The power multiplexers used were uni-directional, and hence had reverse current blocking. The alternating currents in the coils obviously caused problems when put through this setup. Various different orientations were tested but all gave less than satisfactory results. It was concluded that the existing two way current flow in the coils was the cause of the problem, and for this reason bi-directional load switches were initially investigated, however these appeared to mostly be designed for mobile applications and thus only came in flip chip packages, which were not suited to our available manufacturing/soldering equipment. For this reason the dual coil solution was brought forward. In fact, this method did not add much volume to the overall product due to the lightweight small build of the receiver coil as compared to the transmitter coil, which was originally planned to be used. Also it was observed that the switch drawn in the ground connections in our previous design was irrelevant and was therefore scrapped. The updated circuit is provided in figure 4.

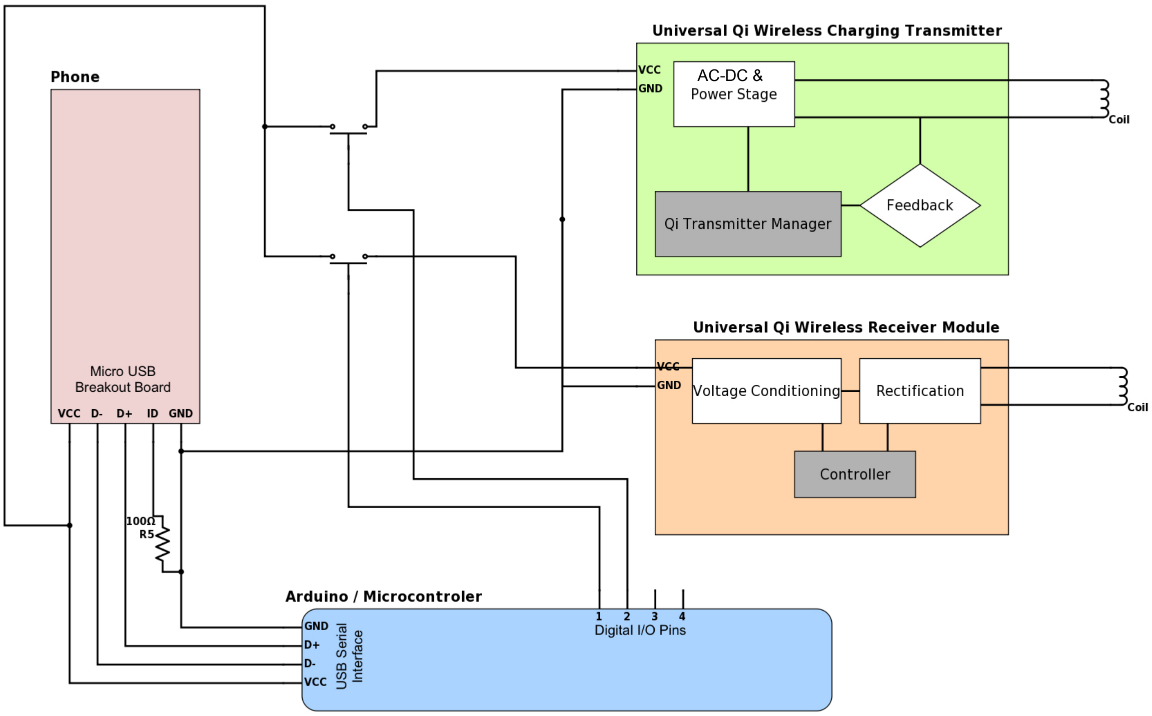


FIGURE 4: FULL CIRCUIT DIAGRAM (LARGER VERSION PROVIDED IN APPENDIX 4)

7.1.2 UPDATED EFFICIENCY DATA

Following the measurements of the isolated circuits in the interim report, it was decided that updates were needed for measurements of the final circuit including the mobile phone and the switching circuit. The tests were completed using two power meters, original coils on transmitter and receiver and the phone as a transmitting circuit to also test maximum current output and voltage levels from the phone. The test phone was a Samsung Galaxy J5 (2016 model). Raw data is provided in the appendix, whilst plots of data are provided below.

The plot shown in figure 5 describes the effects on efficiency of varying the load on the receiver. From the data provided in appendix, it can be noted that for a wide range of load values the phone is able to provide around 700 mA of current at around 4V, a result better that our previously predicted 500mA. This means that the phone has no trouble charging another phone, which roughly pulls a current in this range. At very high loads efficiency drops significantly as does it at small loads. The interesting behaviour around 700mA of input current where the current appears to drop was deemed a result of the internal current regulation of the USB port, causing a sudden and sharp decrease in efficiency. It is also notable that there exists an ideal operating range, which mostly lies around the 9-17Ω, in the mid-section of the plot.

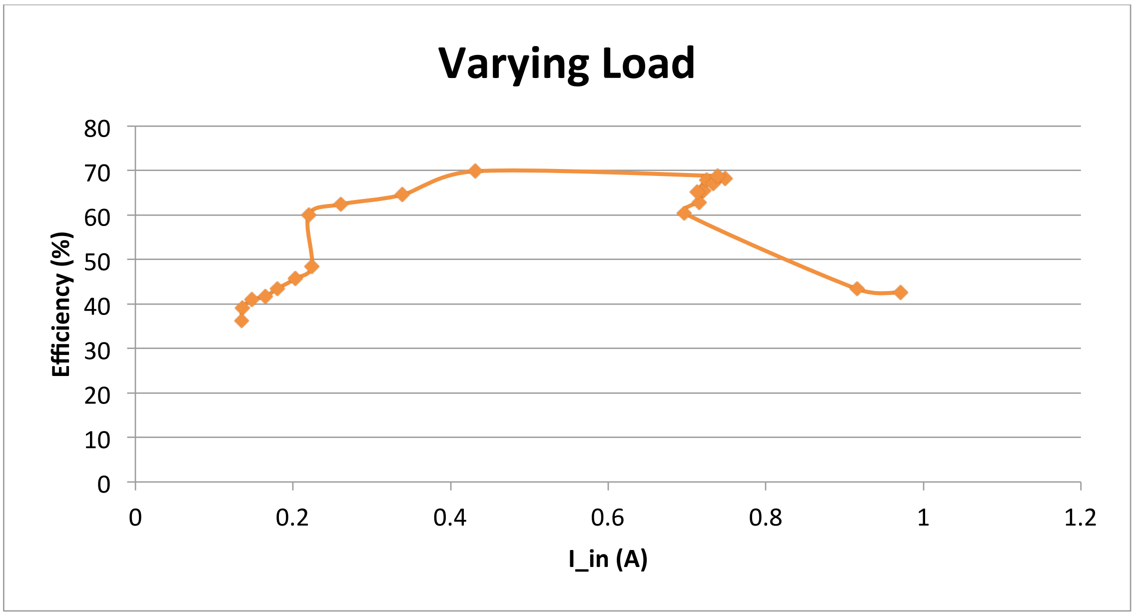


FIGURE 5: EFFICIENCY OBSERVED AT DIFFERENT LOADS

We further tested for efficiency against separation distance, shown in figure 6. Tests were made with the same setup as above and a 10.4Ω load. We see that we have good efficiency until around 3mm after which it starts to fall off, realistically this means that we must keep the back cover thickness of our 3D printed case to a minimum, and must place coils directly beneath this to ensure minimal charging distance.

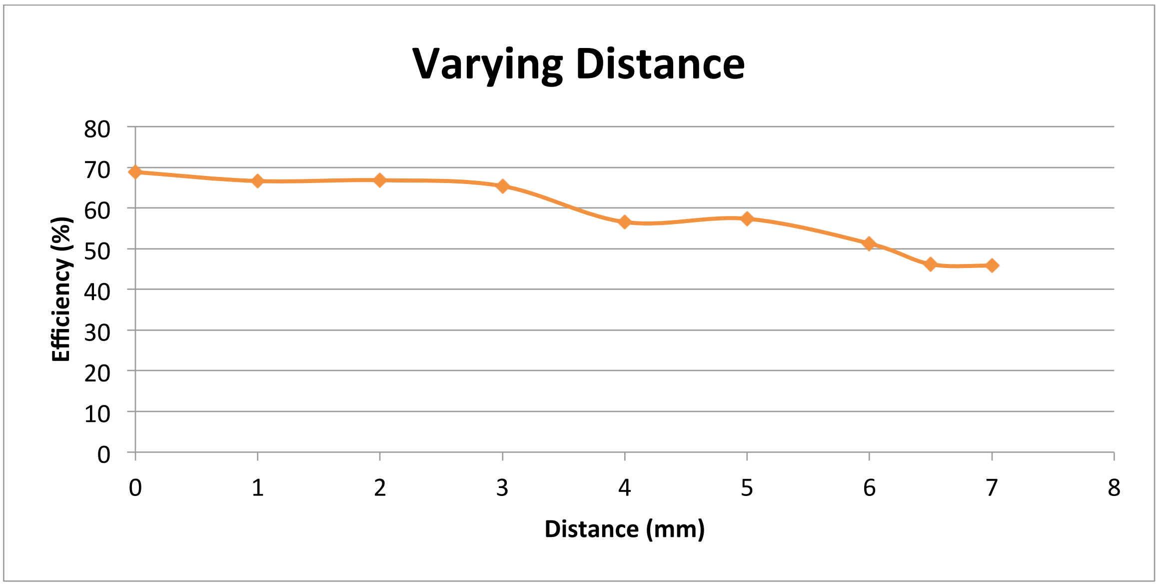


FIGURE 6: EFFICIENCY OBSERVED AT DIFFERENT SEPARATION DISTANCES

Overall we see that adding the switches has not had a significant impact on the efficiency of the circuit. This is expanded on in the next section.

7.1.3 Switch Efficiency

The switches are designed for power applications, and as shown in the previous section we expect their impact on efficiency to be minimal. Data sheet values for drain source on state resistance give a typical value of 84mΩ. From I^2R and assuming 700mA current, we can compute an on state power loss of around 0.041

Watts. This is obviously negligible. Furthermore switching losses can also be ignored due to the switches being used in either on or off state for long periods of time as opposed to a fast switching circuit where these would constitute significant efficiency losses.

7.1.4 USB OTG Considerations and USB-C

Micro-USB was introduced to the project as the primary means of interfacing with the phone, as it is the most commonly used standard. Almost all of the required components can be found with a micro-USB port. However, Standard Micro-USB uses a master/slave architecture; a host acts as the master device for the entire bus, and a USB device acts as a slave. A detailed in the interim report, with USB OTG, mobile phones are able to act as host. In order to implement our design, the mobile phone must act as a host to supply power to the Arduino and transmitter, however it must also be able to be charged by the receiver circuit. This mode of operation is available and can be implemented by placing a resistor between the ID pin and ground of the micro-USB port.

This mode was first tested with store bought USB OTG and simultaneous charging cables. A few models were tested, however the phone didn't seem to recognize the cables. Upon completing background research it was found that the internal resistance value can differ from manufacturer to manufacturer and that Samsung phones were expected to recognise a value of around 40kΩ rather than the standard 100kΩ. We tested the circuit with a value of 39kΩ by utilising a purpose bought USB connector component which had all pins accessible. This test provided successful results in that the phone was able to charge, however host mode appeared slightly problematic and would sometimes not be recognised by phone for this reason for future models a more reliable mode of configuring host/slave mode must be developed.

Upon various considerations of the micro USB standard, it was decided that an investigation and possibly preliminary testing of the applicability of the USB-C standard would serve as a valuable addition to the project. With the new standard USB-C, mobile phones can take roles depending on which role is detected on the other end and bi-directional power transfer is possible due to the increased number of bus lines. In addition, most smart phones on the market which have a USB-C port allow the user to choose the role of the device. (i.e. charging, powering another device, file transfer etc.). Future work would be figuring out the pin setting of the USB-C and modifying the existing application to control and synchronise the mode of USB-C with the switching circuit. This system would allow a simple software change to switch between charging and discharging mode. Furthermore USB-C has the potential of supplying higher currents and therefore can manage greater power output. Based on these benefits we decided to conduct some exploratory tests in the first

7.1.5 PCB Design

In order to make a highly integrated prototype for purpose of demonstration, the group made a PCB board for the switching circuit. The PCB was designed using 'Circuitmaker' software. The board consists of the two power multiplexers and three resistors, two the 400Ω current sense resistors for the power multiplexers and the other the USB ID pin resistor. Surface mount resistors were used so that soldering within the lab would be possible and so that resistor values could easily be interchanged with other values available in the lab. The board has dimensions of 18x23x1.6mm. It takes one day to fabricate express PCB and the cost for 3 boards was £61.13. The full schematic diagram and PCB layout are provided in appendix 6.

7.1.6 The Qi Standard

To further understand the inner workings of the Qi system and the relevance it may have to our design, an investigation was conducted into the technical implementation of the standard. Qi is a wireless power transfer standard developed by Wireless Power Consortium. The technology is mainly implemented in low power applications, most notably charging mobile devices wirelessly, which is now a feature that can readily be found in a wide range of consumer mobile electronics in the market.

A Qi system is largely comprised of two parts; electromagnetic interface, and information interface. Electromagnetic interface is where the actual wireless power transfer is achieved through electromagnetic induction. It could also be seen as a "loosely coupled transformer (pg. 2, Wireless Power Consortium)," in which the primary and secondary coils belong to power transmitter and receiver devices respectively. Information interface is where the power transfer is controlled and the transmitter and receiver modules communicate to form control feedback.

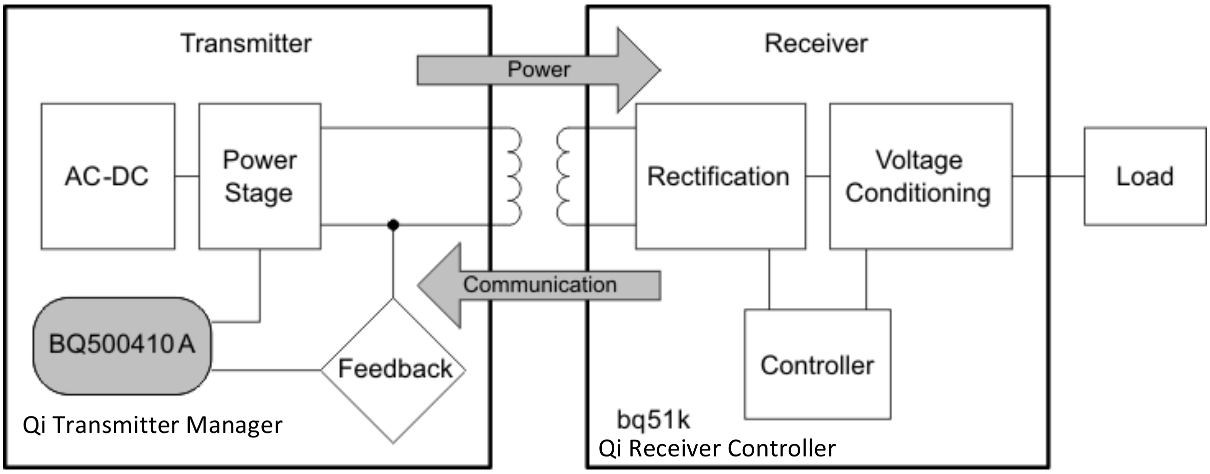


FIGURE 7: FUNCTIONAL DIAGRAM OF TI BQ500410A QI TRANSMITTER AND BQ51K RECEIVER COMPONENTS. (TAKEN FROM PG. 1, TEXAS INSTRUMENTS INCORPORATED)

At the power conversion stage in the transmitter, a DC voltage input is converted to AC signal of controlled frequency, using a power inverter. Reference design examples from the WPC Qi system specifications include half or full bridge inverters. This is then fed into the resonant series RLC circuit, comprised of mainly the primary coil and a serial resonance capacitor. The WPC Qi system specifications also states the need for a multiplexer to choose from an array of primary coils to match the power ratings of receiver module.

In the analogue part of the power pick-up stage (or receiver unit), the secondary coil is coupled with a series resonance capacitor and a parallel resonance capacitor to form a dual resonant circuit. The parallel resonance capacitor here serves for detection of the primary coil. The signal picked up from the dual resonant circuit is then rectified with a bridge rectifier and a parallel capacitor.

Communication between the transmitter and the receiver is necessary for control of the circuits for transmitter's detection of receiver and vice versa, identifying the power rating of the receiver, feedback for control error and other 'unusual' events. The communication, mediated through the inductive or resonant coupling of the coils, is feedback only from the receiver to transmitter unit, except for the transmitter's standby signal to enable approaching standby receiver unit. When the receiver control switches a resistor (parallel to rectifier) or capacitor (parallel to dual resonant circuit) dedicated for modulation, load reflection occurs on the primary coil, and thus modulating a bi-phase encoded binary signal into the magnetic coupling. By measuring the difference in primary coil current or voltage induced by the load reflection, the transmitter control can demodulate the signal.

7.1.7 CHOICE OF MICROCONTROLLER

Choosing the microcontroller was an integral part of the project. It was a decision that required the group to take into account several factors.

7.1.7.1 SIZE

The microcontroller was required to fit inside the 3D printed case. The case is designed to attach to the back of the mobile device as an add-on component for the user to purchase. Therefore the microcontroller's size is desired to be as small as possible so that the user does not experience any discomfort with a large add-on component. Smaller, sleeker options were considered so that it could effortlessly attach to the PCB.

Initially the idea was to purchase the microcontroller chip ATMega328, which is attached to Arduino development boards. The ATMega328 must be programmed using an external programmer. This required a deviation from the prepared Arduino code. Furthermore direct USB serial communication was not an included feature on this and many other microcontroller models considered and would require external USB interface circuitry, usually in the form of an add on board or chip, which significantly increased the size of the microcontroller circuit to the level that it was no longer smaller than a regular development board.

Therefore the option to directly purchase a microcontroller was ruled out and the group would now consider development boards.

7.1.7.2 Programming Feasibility

When considering various development boards that were available the group decided that it would be time-efficient and their skills more effective if a board that was compatible with the Arduino programming language was chosen. Numerous boards matched the criteria such as the following:

1. Redbear development board products
2. LightBlue Bean
3. Arduino development boards e.g. Arduino Nano, Micro

All the products stated were compatible with the Arduino programming language so at this point the group could have chosen any of them. However no one in the group was familiar with the Redbear boards or the LightBlue Bean and whether any additional products or components would be required to be purchased alongside them such as programmers, add-on boards etc.

That is why the Arduino development board range was looked at more closely. A few more factors had to be considered first.

7.1.7.3 Price

When considering which board to purchase price was obviously a factor to which the group heeded much attention. Being as cost effective as possible was a dominant mentality during this project.

When searching for a cheap solution the team found that the source of the supplier was the dominant factor effecting price. Both Arduino Nano and Arduino Micro are similar prices when bought directly from the Arduino website – approximately £20 each.

Therefore due to its slim size, programming feasibility and the group's familiarity with the Arduino community and libraries; the Arduino Nano was chosen as the development board of choice.

7.1.7.4 Serial Communication

Serial communication is the means through which embedded electronic components such as microcontrollers, processors and sensors communicate and transfer data between one another.

It is given the name serial communication because bits are transmitted from the components serially i.e. one by one over the communication channel or data bus. This is in contrast to parallel communication which transmits bits in parallel over a link with several channel paths.

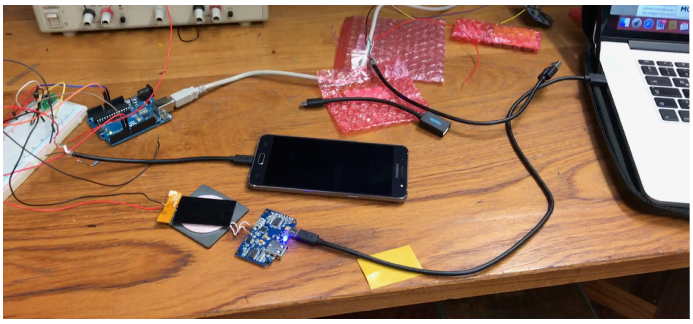
Serial communication is used quite commonly, especially when synchronisation difficulties arise and bits cannot be transmitted in parallel. In small microcontrollers and development boards, serial transfer is used due to the lack of space to put several links on the components to have parallel transfer.

Serial transfer works with the Arduino boards through the RX/TX pins present on the board and it also works through the USB cable. The Arduino IDE has a built in serial monitor through which information can be transmitted to and from the Arduino. In order for this to work the settings for the port through which the Arduino is connected to the computer via USB must be input in the IDE's settings. This is usually done automatically once the board has been plugged in. Sometimes if this does not work immediately then it is an indicator that perhaps the Arduino drivers need to be updated.

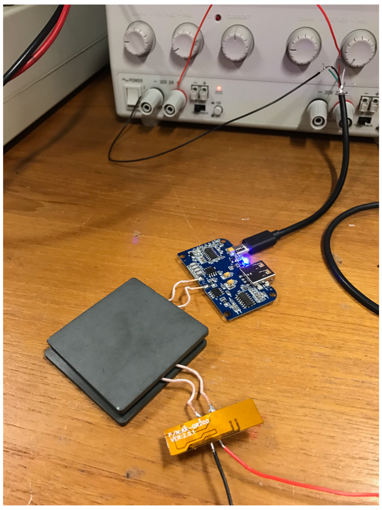
USB is a universal method of serial transfer. Its acronym stands for "Universal Serial Bus". It works with nearly all devices. Inside the USB is four wires – black, red, green and white. Black is ground, red is the 5V rail, green is the data- wire and white is the data+ wire. A micro USB also contains another wire/pin which is called the ID pin/OTG wire – 'On The Go'. This feature is particularly useful to the groups' project. This wire determines whether the USB is connected to a host or slave and is used in situations determining whether the device plugged in and should be charged or share charge.

The presence of a 100kΩ pull up resistor on the USB OTG pin determines that it is in host mode where it is sharing charge with another device. If the ID pin is floating, then the device is in receiving mode.

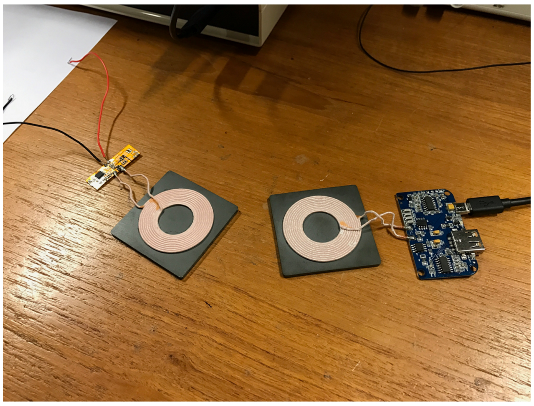
7.1.8 Constructed Prototype and Test Circuit



Wireless Transfer Circuit integrated with phone and serial connection to Arduino from computer



Coupled Wireless Coils



Qi Compliant Transmitter & Receiver Circuits

Switching Circuit with Arduino in Background

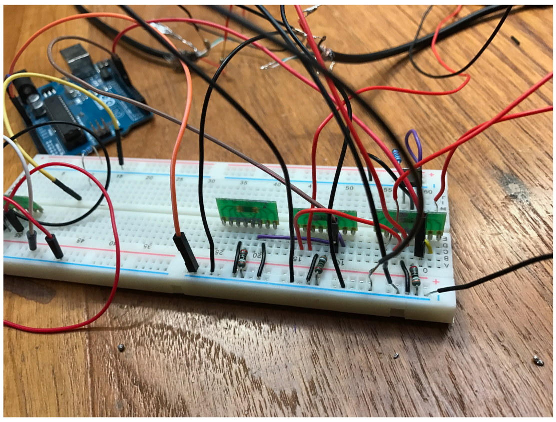


FIGURE 8: CONSTRUCTED PROROTYPE

The prototype was constructed using breakout boards to be able to test the power multiplexers on the breadboard. We also had to strip USB cables to be able to make connections to the rest of the circuit and to connect to the transmitter and receiver modules. The can be seen in the diagram above with its various components. In its current form it constitutes a large volume, however once implemented with our custom PCB and smaller microcontroller it will consume significantly less space.

7.2 3D printed Phone Case Design

The deployment of our technology will require suitable housing, with the aim to provide a robust packaging whilst maintaining optimal performance. The 'Samsung Galaxy J5' mobile phone was chosen as host device, which lead to the development of a 3D printed structure tailored to the phone's dimensions to house our technology in a case. The current prototype model is shown in figure 9, and was developed using ‘SketchUp’ software.

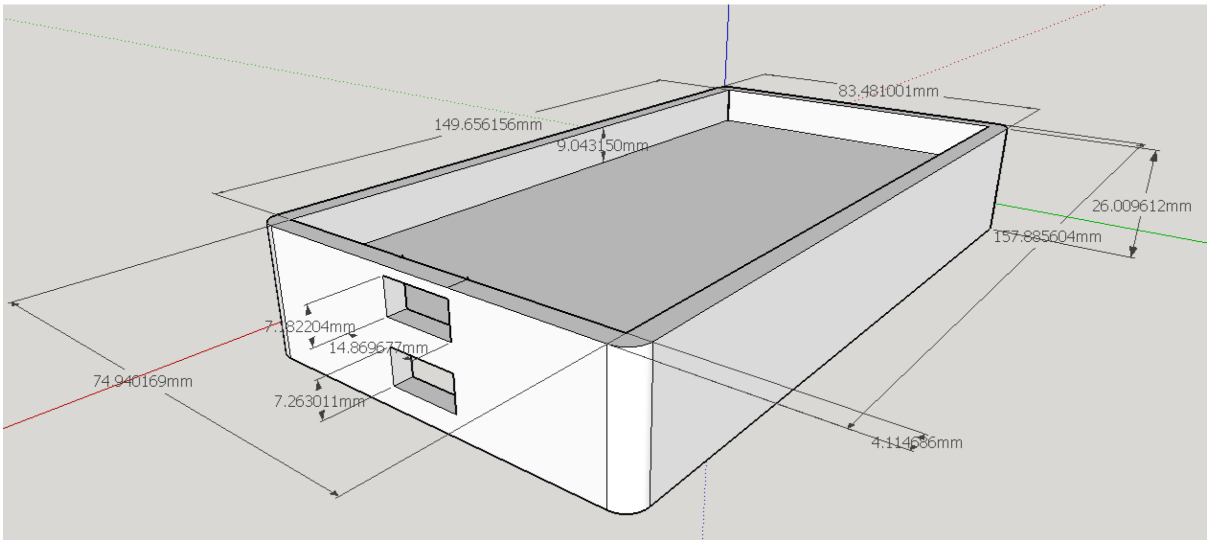


FIGURE 9: IMAGE OF PROTOTYPE 3D MODEL. CASE HAS DIMENSIONS 15.8X8.35X2.8CM

The main phone case is split into two sections: the upper section for the phone and lower one for the components with a thin partition between them. There is also a cover to be fitted underneath to hold the components. The phone itself has dimensions 14.5x7x0.7cm, so the dimensions of the inner compartment were chosen to just exceed this: 14.9x7.5x0.9cm. This was done to give an appropriate fit for the phone and may be adjusted in future prototypes.

The lower section, figure 10, has dimensions of 14.9x7.5x1.7cm. This has been chosen to accommodate the volume which the components will take up. In this current prototype, the way components are connected to the phone is via a USB Micro B cable which will be fed through the gap left to the under section. From here the phone can be connected to our technology by connecting the USB breakout board directly to the phone’s charger port. There is also a bottom cover for the lower section, which is set at a width of 2mm as a compromise between robustness and keeping the separation distance between the coils minimum. NB, separation in practise will be 4mm between the coils as there will be two covers in total from both phone cases, which has been shown to be an appropriate distance from experiments, figure 6.

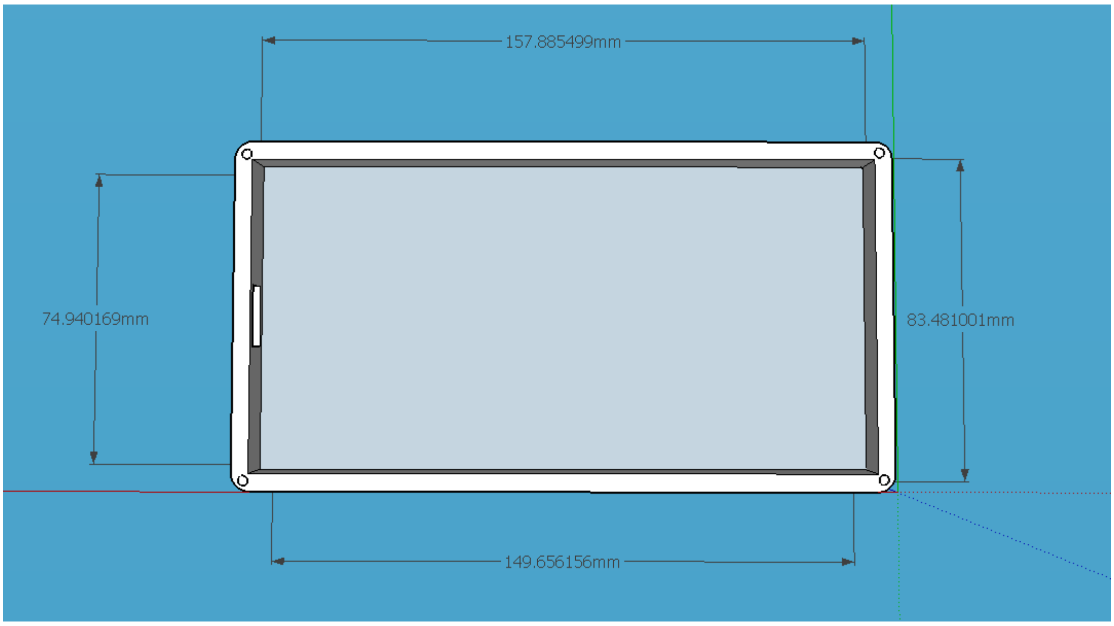


FIGURE 10: LOWER SECTION OF THE CASE TO HOUSE THE COMPONENTS

The manufacturing process of this model will involve 3D printing of the phone case and the bottom cover. Once the components are placed within the lower section, a bottom cover will then be fitted with screws to contain and protect the electronics. Certain elements of the model have been included to aid in the practical construction of the case. Pilot holes for the screws have been inserted at the four corners of the phone case with a diameter of 2.4mm. An additional square trench has been cut around the holes in the cover to accommodate the screw heads such that they are flush with the cover and do not stick out, as shown in figure 11.

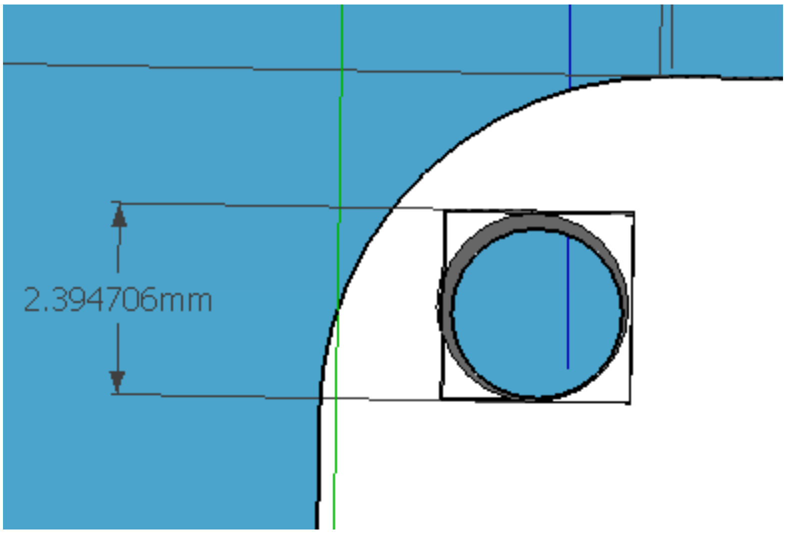


FIGURE 11: PILOT HOLE FOR SCREWING THE COVER TO THE CASE

Various design features make considerations for the potential user. The phone case itself has been adjusted in size to fit the phone comfortably. Access to key features of the phone such as volume buttons and charger port have been made available. The corners of the case have been bevelled to give a more aesthetically pleasing look.

In future prototypes of the model it is anticipated there will be several advancements. Further improvements to the volume that the components take up will allow the case to be scaled down. In the model's current state the electronics are exposed and easy to access as this makes experimentation easier. The case also blocks the camera which is not ideal. Therefore, once the characteristics of the technology have been established through tests ran with the phone, the case will be modified further for consumer use.

7.3 SOFTWARE

7.3.1 APP USER INTERFACE AND SOFTWARE DESIGN

The app design can be considered in two sections. The primary objective was to design an easily accessible user interface, followed by the second task of implementing this using available Android SDK tools. Rationale for focusing on Android, as explained in the Interim report, was that it is open-source and easier to utilise for our needs.

7.3.1.1 USER INTERFACE CONSIDERATIONS

The user interface for the app was designed to be as user friendly, with most of the main commands easily accessible from the home page. We considered two implementations, each with its benefits, before deciding on a final implementation. Each are explained below:

APP MANAGED REQUEST SYSTEM WITH LOCATION DATA SHARED UPON MATCHING

This interface foresaw that there would be a single request button on the home screen, and upon the user's pressing of this button, the app's servers would compute an optimal match and upon matching, share the location information of the sharing device to the requesting app. The benefits to this design were that the sharer could open themselves to requests without the need for having to share location data with all app users unless they accepted a request. This however proved to be a problem for the charge consuming side as the user had no input as to the location at which they wanted to charge their phone. We decided that this constituted a more significant problem and for this reason formulated the following concept design.

User Selected Charge Location

This system, which was finally implemented, would constitute a home page with a map, displaying the location of the user, alongside the locations of other users that had opened themselves up to charge requests. The user would then be able to select which charge point they wished to request from.

The procedure following this is that a request is sent to the user and the charge sharer and that user has the option to accept/decline that request. If they accept, this is relayed to the requester and then the status screen appears where they can control/stop the charge process. The app communicates with the serial port to control the switching processes of the wireless charge sharing circuit. Furthermore the status screen displays information such as power transferred etc. The draft user interface design can be seen in figure 12.

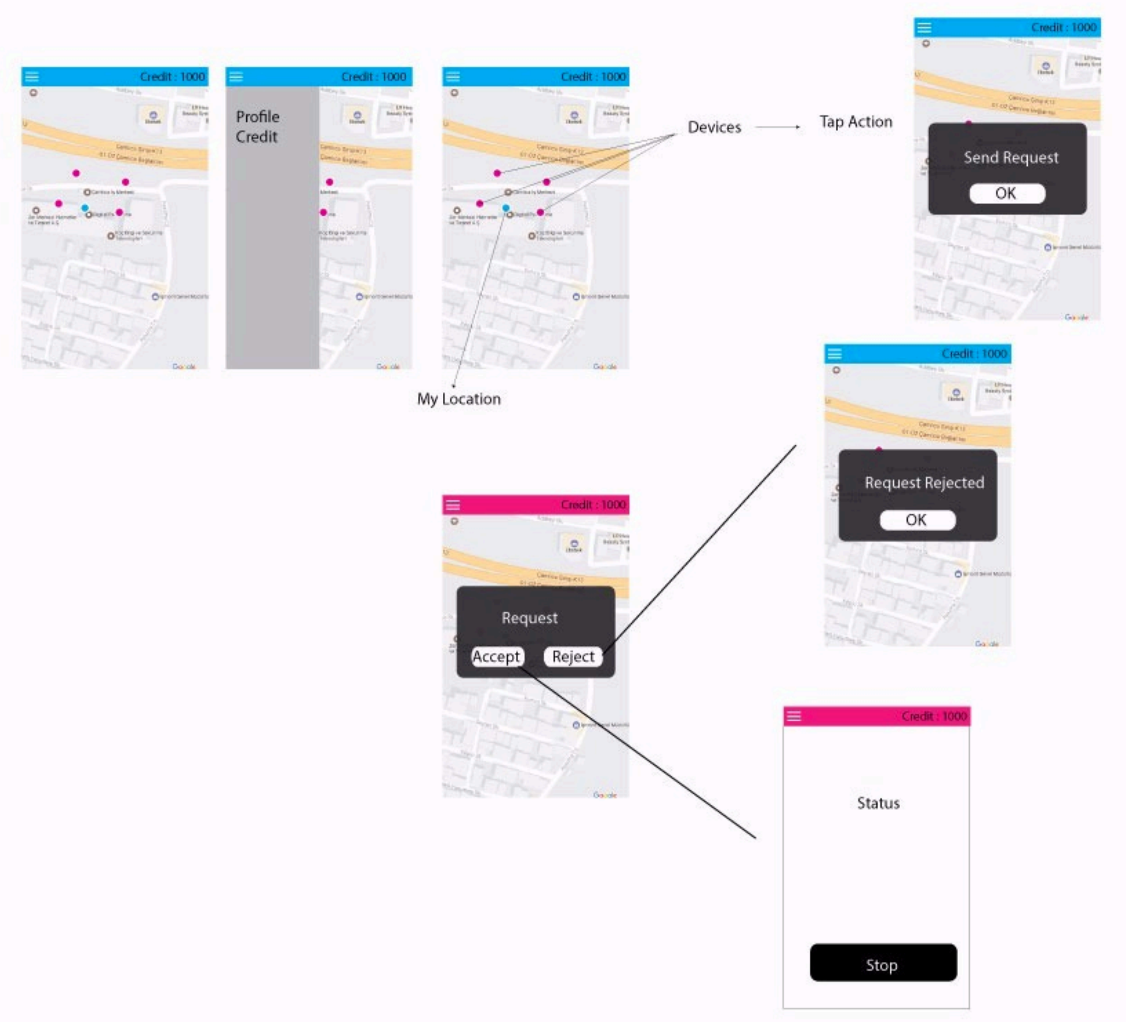


FIGURE 12: USER INTERFACE DRAFT DESIGN

When creating these screens within our app we decided to utilize a fairly clean, uncluttered design. Our lack of prior experience in app design was a limitation in this process, however with the available resources we managed to come up with a design which follows the same design lines as most android apps, with the homepage containing an integrated Google map, upon which user location and charge point are displayed and could be interacted with as described above. There exists a side menu where information such as signed in user name and available credit are displayed, along with space for possible features that may be added in the future. The settings menu is accessible by clicking on the three dots on the top right of the screen.

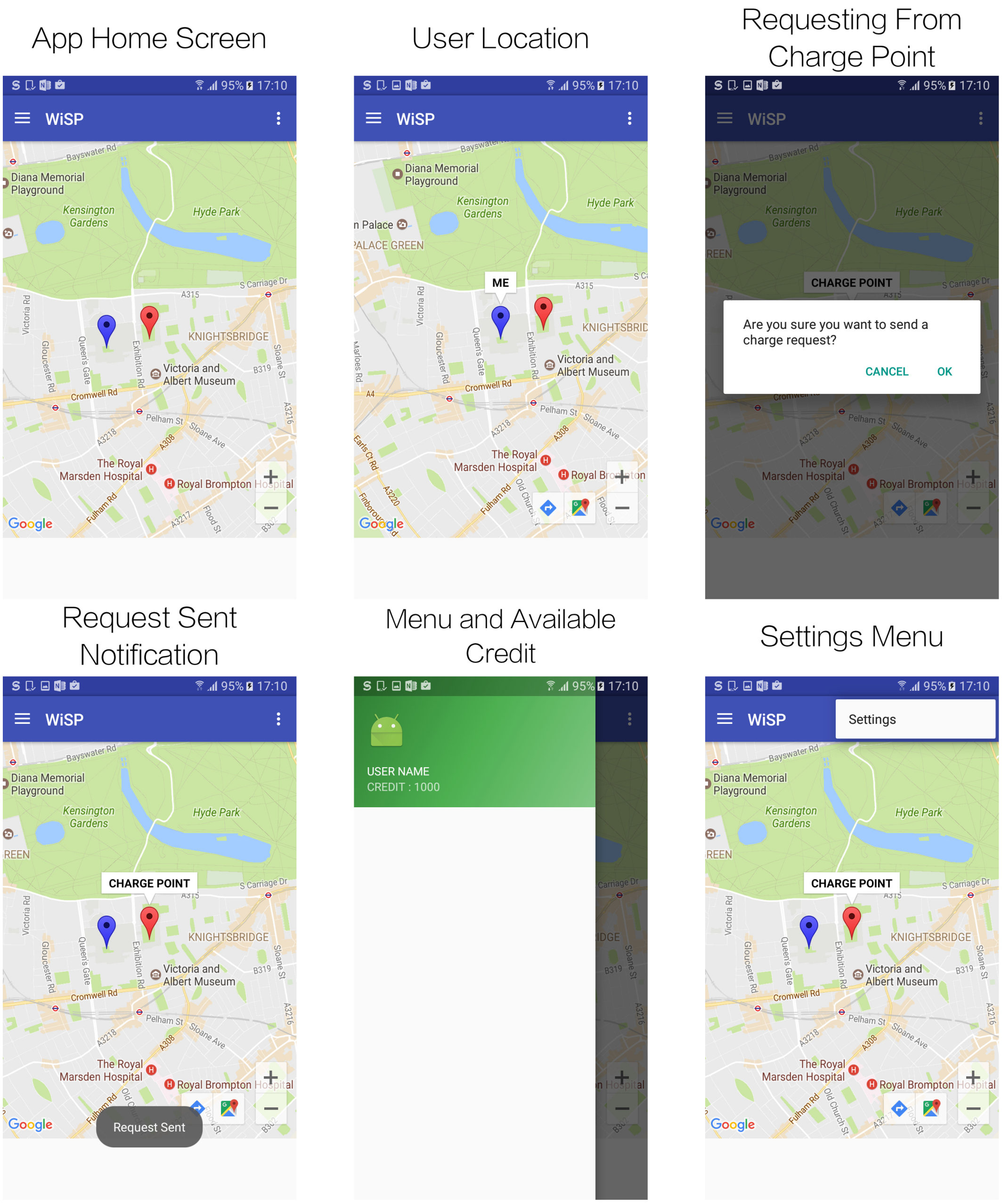


FIGURE 13: USER INTERFACE SCREENSHOTS

7.3.1.2 Software Implementation

The app was designed using the model-view-controller method. This design method consists of a model, the core of the application, which manages all processing of data etc., the view which is the part of the application visible to the user, including menus, map interface etc. and the controller which enables communication between the two.

Our file structure for the app is centred around our main file “MainActivity.java” (provided in appendix) which essentially describes background program behaviour. The file consists of a set of void functions describing the actions to be taken if it is indicated to the model that any of the menus, option screens etc. are pressed. It describes the selectable options on these screens.

Followed by these is the main void function “onMap Ready” that describes the user interactions with the map interface. Here member functions provided for Google maps integration into applications are utilised.

One obstacle we encountered in this section is that to implement our final design of matching phones with real phones in the immediate area we would require a back end web server to store locations of phones and manage app requests. As this solution was costly and unnecessarily intricate for a demo that matches two phones we decided instead to implement a demonstrative app in which the request appears to be sent to and appears at the other phone, where the normal programme procedures continue. The version of the main file currently includes the working of the app until this section. The following functions, including serial write to the port using Arduino compatible libraries, and displaying of charge data will be implemented in the following week, and demonstrated at the project presentation.

Beyond this our file structure includes a set of .xml files which define user interfaces such as headers, text, icons etc. from which we can edit the various pages of the app.

*App design, drafting and programming was completed in conjunction with (Erbas, 2017).

7.3.2 Arduino Code and Serial Read Functionality

Our current implementation involves the phone communicating with a microcontroller which then sends commands to the switch to alter the mode of the system. As discussed before, this process requires a serial interface to the controller, and hence why the Arduino Nano was chosen. In the Arduino language it is possible to search for inputs from the serial connection using the 'Serial.available()' function. The following code is then only executed if there is an input, ensuring that the current state of the system doesn't change without request. Then, the 'Serial.read()' function is used to determine from the input which mode the phone wishes the circuit to be in, assuming the mode is represented by either a 0 or a 1. The rest of the code's logic is then simply sending a high signal to the output pin which is connected to the corresponding switch pin. (Code provided in appendix).

7.4 Updated Cost Analysis

Even though the total cost per unit has increased, it is worth noting that the PCB manufacturing cost plays a large role in this since it was ordered through the one day expedited service line, adding expense that may have been avoided if more time was given. Furthermore, cost per unit will likely be reduced by a significant amount at a larger scale in a mass production environment. Economies of scale states that the more units manufactured, the lower the cost per unit becomes, and especially so assuming proprietary transmitter/receiver circuits and USB interface microcontroller units are built.

Final Product Components/Service	Mfr.Part No.	Quantity	Unit Price/£	Total Price/£
Texas Instruments Power Mux Autoswitching	TPS2115APW	2	1.362	2.724
Adafruit Industries LLC Wireless Charging Receiver	1901	1	11.97	11.97
Adafruit Industries LLC Wireless Charging Transmitter	2162	1	22.15	22.15
Arduino Nano		1	26.82	26.82
PCB Printing Service (Distributed cost of 3)		1	20.38	20.38
3D Printing Service (Estimated)		1	5.21	5.21
SparkFun USB MicroB Plug Breakout	BOB-10031	1	3.24	3.24
Total Cost				92.494

Prototyping Equipment	Mfr.Part No.	Quantity	Unit Price/£	Total Price/£
Capital Advanced IC Adapter	33108	6	4.176	25.056
Adafruit Industries Wire Bundle	153	1	6.29	6.29
Arduino Microcontroller Board	A000066	1	21.66	21.66
Total Cost				53.006

FIGURE 14: COST ANALYISIS

8. Discussion

8.1 Product Design Compromises

One of the priorities of this project is to create a customer friendly product that is convenient, affordable and functions to the highest standards.

There is a trade-off that occurs here. Trying to create the optimal product in term of quality sometimes leads to areas where the design takes a hit. In other cases the quality of the technology within the product needs to be reduced in order to create a slicker design.

One of the problems the group encountered was that they wanted a fully functional development board present within the phone case in order to have the most accessible and simple technology so that they could program it easily and it would work without complications (see section about microcontroller choice).

In order to achieve this the group had to purchase a development board rather than a microcontroller chip. The problem here is that the development board, which increases the ease of prototyping and debugging of the technical design, leads to a design trade-off since it is larger and will take up more space inside the phone case. This will lead to a bulkier phone case, which will be unaesthetically pleasing to the end user. Another issue is the increased cost of using a development board rather than a microcontroller.

If the phone case is a large oblong attached to the back of their phone then it may be uncomfortable to carry and attach as an add-on component. This is a major problem that the team had to tackle. Therefore, in order to compensate for the increased size of the phone case they decided to make the case more aesthetically pleasing by creating it with a curvature so that it would fit and slide gently into the users hand rather than be an awkwardly placed box.

8.2 Challenges

8.2.1 Hardware

One of the problems encountered during the final stage of prototyping was the difficulty in working with components designed for mobile phones. Having used components designed for laboratory and experimental work, unfamiliarity with the size of industrially used components posed a major problem, especially with their size and durability. Moreover, the equipment available was also designed for use with experimental components, such as the soldering irons available in the electronics laboratory. This delayed the prototyping process, and more time had to be reallocated to this stage than previously predicted. For example, for testing purposes, a break board had to be used for power switches, due to the connections on them being too small and close to each other. This proved more difficult than originally projected due to inexperience with the soldering technique necessary for these components.

Another issue that delayed the project was the fact that flip chip components could not be used. While researching suitable components, it came to the group's attention that most available components were available only in flip chip packages, which cannot be manually connected and require specialized equipment which was unavailable at the time. The reason for this was that many of the components desired were designed for the mobile phone industry in which size is prioritized. Some other components, such as a breakout board for micro-USB connectors had to be ordered separately from abroad. All the issues mentioned above caused delay in the project, and in some cases called for reconsideration of the original approach to the development and modification of the design concept to fit with the available equipment and components.

8.3 Future Work

Various difficulties arose whenever the group explored ways of making this device into a realistic product which users will find convenient and have the incentive to use.

The device will require a software platform which will connect users together. When this is complete a user-friendly mechanism will be needed to contact one user to another in order to meet to exchange charge. The charging process will be strenuous time-wise and this may discourage individuals from sharing their charge. It will be vital that the project is optimised in the time domain so that charge can be shared as quickly as possible with no hassle. The group aims to make it as near to the charging time as it would take from being connected to a laptop or computer. It is also for this reason that the group introduced the credit system to incentivize sharing.

Another factor to consider is the proximity of which the devices need to be in order to share charge; about 1 cm of each other in order to work, so essentially they need to be placed together. This isn't ideal, as people may have to pass their phone over to another user in order to charge it. Future plans could involve looking for an alternative to the Qi technology, which works at greater distances and utilises higher transfer frequencies. Although some longer distance wireless charging systems do exist, the technology would not be feasible for a portable device as they take up far too much space. For this project the requirement of keeping the device small for convenience outweighs the aspect of distance over which we can charge, but could be considered in the future as a feature to improve.

Apart from increasing the charging distance, the usability could also be improved by increase the power efficiency. When customers considering purchasing this product, one of the most important feature they would look into is the power efficiency. If the system has low power efficiency, the whole idea would be pointless, as most of the power would be wasted. At the moment, the prototype has an efficiency around the 60-70% range. By looking for better transmitting and receiving modules, a system with 70% or even greater efficiency could be achieved. Better user experience will be achieved when mobile phone retains more power after giving a set amount of charge.

In order to make the product highly integrated so that it can even be placed internally as a component in mobile phones and laptops, a PCB which contains every component should be built. In addition, currently the prototype is still using Arduino development boards which occupy a large amount of space. Changing it to a single microcontroller and soldering it to the PCB board for product design would significantly reduce the total size. The prototype is still using one transmitting and one receiving coil for the purpose of stability, it is able to be improved by integrating two coils into one as mentioned in the interim report. In this way, whilst having a stable charging and discharging system, the size of the product can be reduced even further.

If the project gets invested on in the future, products would be tested on many other mobile phones with different USB standard to improve the feasibility between all kinds of mobile phones. We also plan to program an application for IOS, as it is a huge market. In the end, the goal is to to build a global ecosystem, which allows all electronic devices to be interactive with each other.

For the device and app to be effective and widely used among the public, it would require a baseline number of users on the network through which it is hosted. A large quantity of users would be required to exist in order for users requiring charge to search through their GPS for other users in the close proximity willing to share charge. Ensuring a cost efficient device is quintessential to this need; the cheaper the product, the more people will purchase and use it. The most similar device currently on the market at the moment is a portable charger, which is relatively cheap, so this piece of equipment will need to be used as a price marker and the product should aim to cost around about the price of an average portable charger. Overall aiming to keep the cost of our device down is important as users need to think the added convenience is worth the cost.

9. CONCLUSION

As the 2nd year scope of the project comes to a close the working prototype represents only a small portion of what must be achieved to truly implement the product on the market. Over the past few months a working prototype was developed, that demonstrates the technical feasibility of the proposed concept. The major points of success could be stated as the retained efficiency, which essentially almost matches the standard expected from the Qi system.

The process brought about many design considerations along with many areas for improvement. These include integration of components on a single PCB, and designing of a proprietary circuit to handle bi directional power transfer.

As such future work remains extensive and there remain many obstacles to transforming our circuit into a widely used product. For this to become a reality the product must become much smaller, and realistically would have to come readily integrated in mobile devices. Furthermore use in conjunction with higher power devices such as laptops would increase the potential of the product.

Nevertheless the project has been a meaningful exploration into an area that represents a user market of extremely high growth and potential. For this reason insights reached provide a meaningful overview of obstacles and opportunities to realising a successful product for this market.

REFERENCES

Erbas, A. (2017, March 7). Adroid App Design.

Wireless Power Consortium. How it works; Wireless Power Technology. (2010). https://www.wirelesspowerconsortium.com/data/downloadables/1/3/7/4/how-it-works-20100420.pdf

Wireless Power Consortium. The Qi Wireless Power Transfer System - Power Class 0 Specification; Version 1.2.2 - Parts 1 and 2: Interface Definitions. (2015).

Wireless Power Consortium. The Qi Wireless Power Transfer System - Power Class 0 Specification; Version 1.2.2 - Parts 4: Reference Designs. (2015).

Texas Instruments Incorporated. BQ500410A Free Positioning, Qi-Compliant Wireless Power Transmitter Manager. (2015). http://www.ti.com/product/BQ500410A/datasheet

USB On-The-Go. https://en.wikipedia.org/wiki/USB_On-The-Go

Appendix

Appendix 1 – Meeting Minutes

09/02/17

Attendance:

Eren Kopuz
Jerome Hallett
Keidi Kapllani
Hang Zhou
Jee Yong Park
Molly Ainscough
Suraj Tirupati

Progress from last meeting:

- Interim report complete
- MOSFET Switch components arrived

Minutes:

- Switches need to be tested
- Arduino UNO is going to be used to prototype switches
- Website needs to be started - Keidi is in charge of website design

16/02/17

Attendance:

Eren Kopuz
Jerome Hallett
Keidi Kapllani
Hang Zhou
Jee Yong Park
Molly Ainscough
Suraj Tirupati

Progress from last meeting:

- Website has been started and template has been chosen.
- MOSFET Switches are functioning with Arduino code and are able to switch between transmitter and receiver power circuits

Minutes:

- Smaller Microcontroller is required to prototype the project component
- 3D case and PCB need to be designed
- Jerome is in charge of designig and printing 3D case
- Eric is in charge of designing PCB board
- Content needs to be written for the website - Molly is in charge of that

23/02/17

Attendance:

Eren Kopuz
Jerome Hallett
Keidi Kapllani
Hang Zhou
Jee Yong Park
Molly Ainscough
Suraj Tirupati

Progress from last meeting:

- Website content has been uploaded by Molly
- Jerome has created a basic model of the 3D case and requires dimension measurements of all components
- Eric has started designing the PCB but needs to consider aspects of the project such as microcontroller size and whether one or two coils are being used

Minutes:

- It was decided that 1 coil would be used however polarity complications arose whenever switching the MOSFET switches onto the same coil so two coils are going to be used to prototype.
- The group wanted to use a microcontroller chip instead of a pre-made development board so the PCB and 3D case would be smaller. This is not possible however due to complications such as programming a microcontroller chip directly. An Arduino Nano is going to be used.
- Dimensions of the Arduino Nano are required for next week alongside dimensions of the PCB for the 3D case.

02/03/17

Attendance:

Eren Kopuz
Jerome Hallett
Keidi Kapllani
Hang Zhou
Jee Yong Park
Molly Ainscough
Suraj Tirupati

Progress from last meeting:

Arduino Nano measurements are confirmed and have been given to Eric who has designed and reported back with the dimensions of the PCB for Jerome.

Website is still under progress but should be completed by next week by Molly and Keidi.

The switches are working with two coils and are responding well to the Arduino code and user serial input.

Minutes:

Arduino Nano has arrived

Jerome has noted dimensions off the PCB and will return the following week with a 3D model designed.

The PCB is going to be printed next week by Eric.

The report needs to be thought about and written - Suraj and Jee Yong are in charge of brainstorming points to talk about for the report.

App needs to be programmed - specifics were brainstormed by the team and noted down. Information was relayed to 3rd party app developer to create the basic structure.

09/03/17

Attendance:

Eren Kopuz
Jerome Hallett
Keidi Kapllani
Hang Zhou
Jee Yong Park
Molly Ainscough
Suraj Tirupati

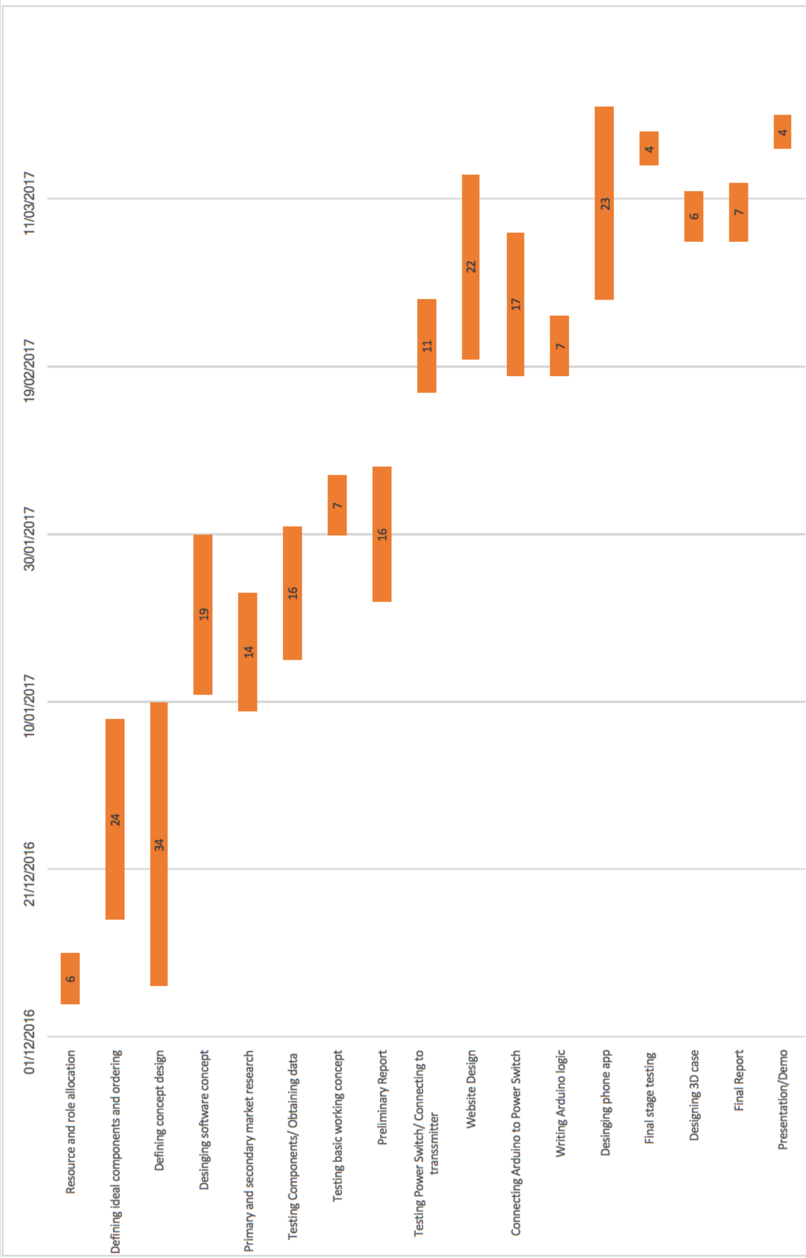
Progress from last meeting:

- Information about app has been relayed and the app structure has been started by the 3rd party.
- 3D case design is complete and needs to be 3D printed in the EEE robotics labs.
- PCB has been printed by Eric.
- The website is nearly complete - final touches are being added.

Minutes:

- Basic structure of report has been drawn up and created by Suraj and Jee Yong.
- Each member has been designated sections of the report to write - each section being relevant to the work they did this term.
- Logo for website has been designed by Keidi.
- Gantt Chart has been updated to accommodate events taking place prior to the final report.

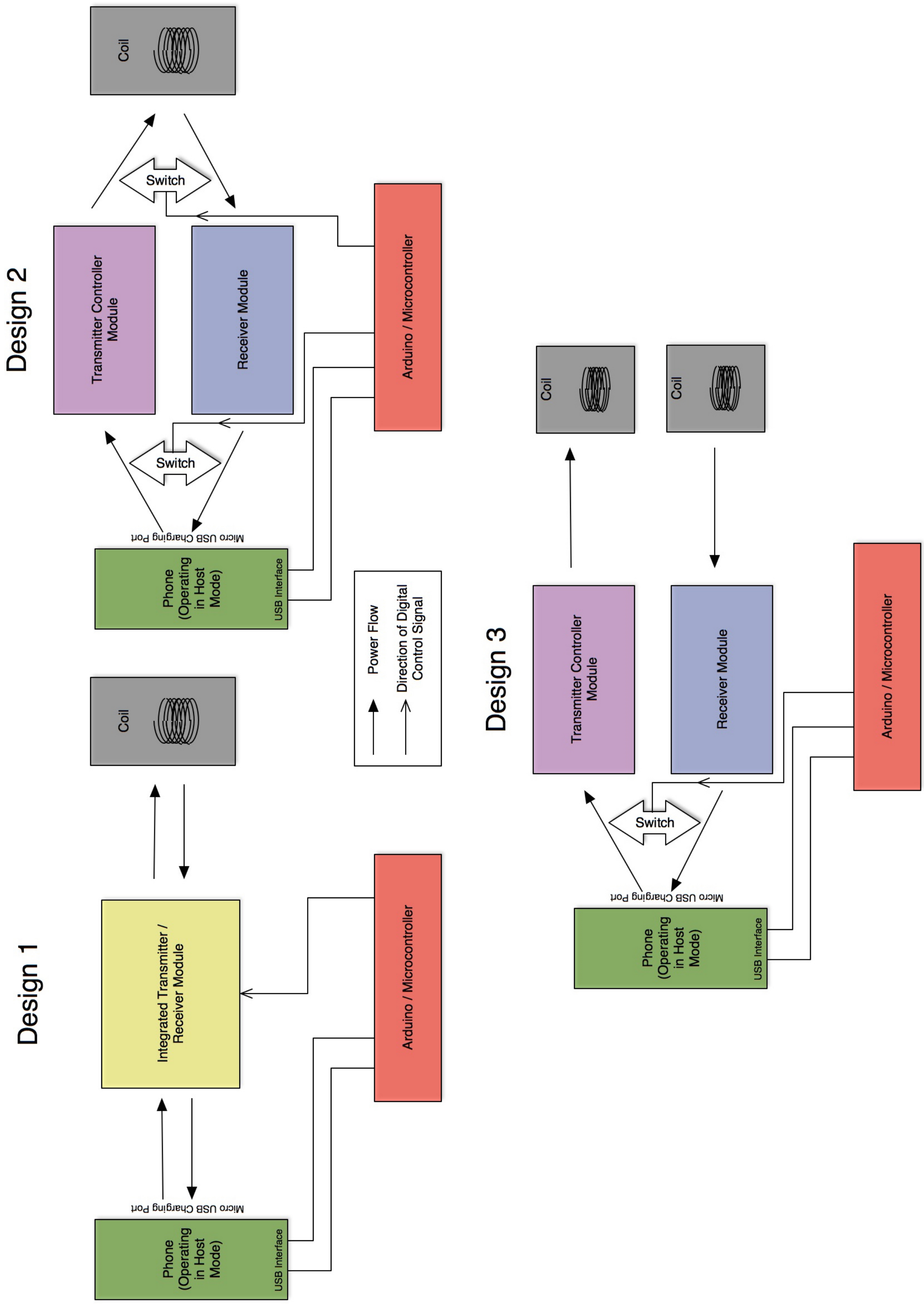
Appendix 2 - Gantt Chart



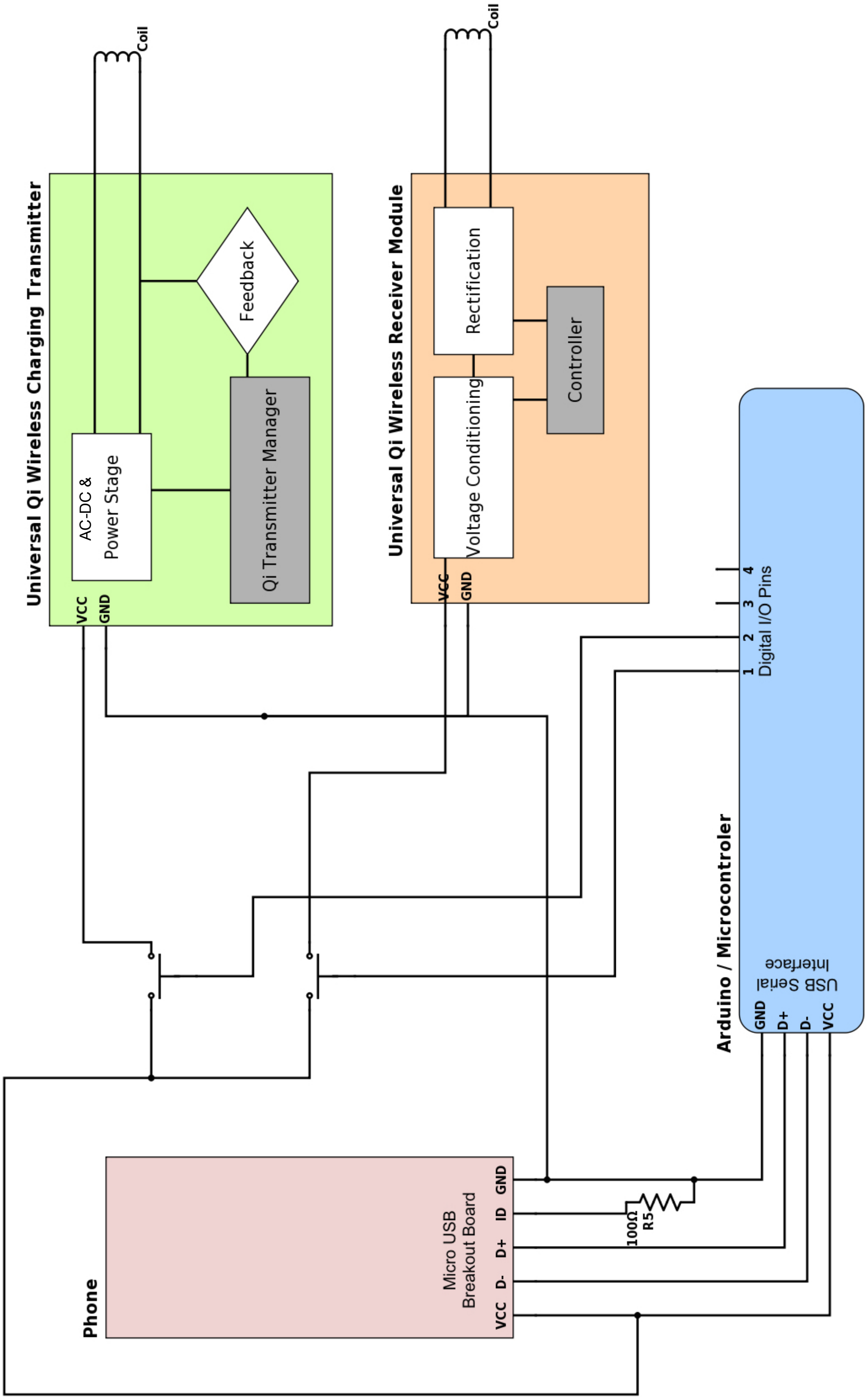
Wireless Charge Sharing

START DATE	END DATE	DESCRIPTION	DURATION (days)
12/5/16	12/11/16	Resource and role allocation	6
12/15/16	1/9/17	Defining ideal components and ordering	24
12/7/16	1/11/17	Defining concept design	34
1/11/17	1/30/17	Desinging software concept	19
1/9/17	1/23/17	Primary and secondary market research	14
1/15/17	2/1/17	Testing Components/ Obtaining data	16
1/30/17	2/7/17	Testing basic working concept	7
1/22/17	2/8/17	Preliminary Report	16
2/16/17	2/27/17	Testing Power Switch/ Connecting to transmitter	11
2/20/17	3/12/17	Website Design	22
2/18/17	3/5/17	Connecting Arduino to Power Switch	17
2/18/17	2/25/17	Writing Arduino logic	7
2/27/17	3/20/17	Desinging phone app	23
3/15/17	3/19/17	Final stage testing	4
3/6/17	3/12/17	Designing 3D case	6
3/6/17	3/13/17	Final Report	7
3/17/17	3/21/17	Presentation/Demo	4

Appendix 3 – Concept Designs Block Diagrams



Appendix 4 – Full Circuit Diagram



Appendix 5 – Efficiency Test Raw Data

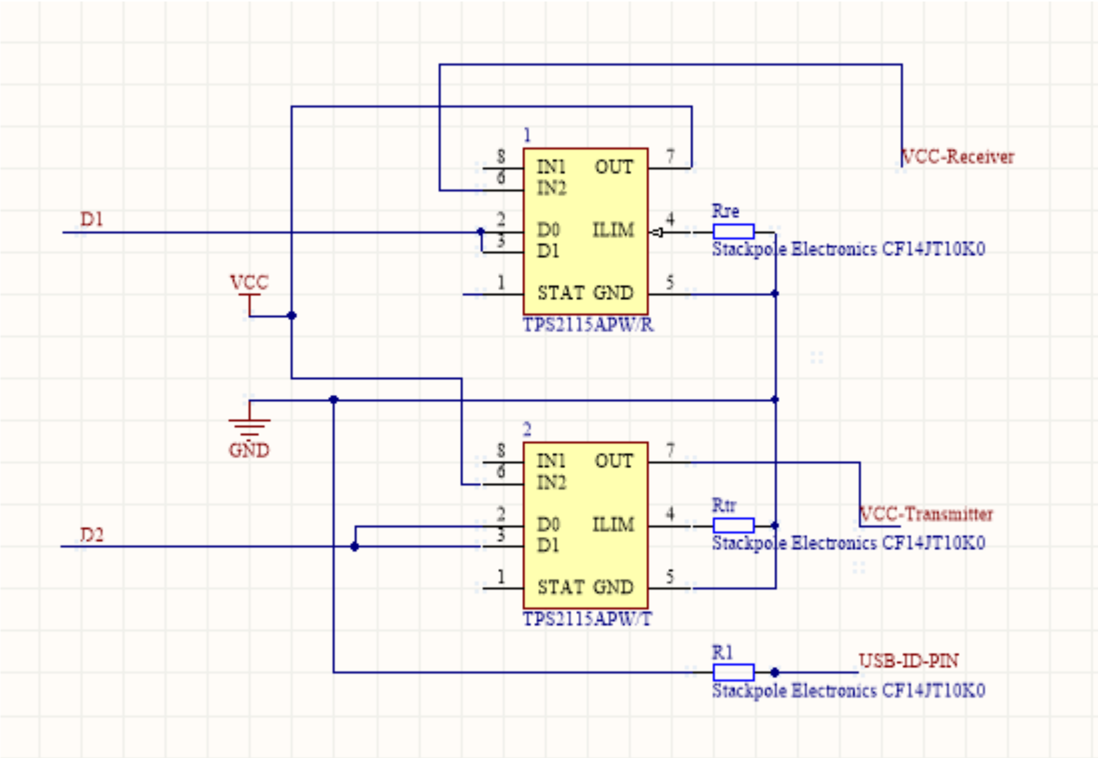
Varying Load

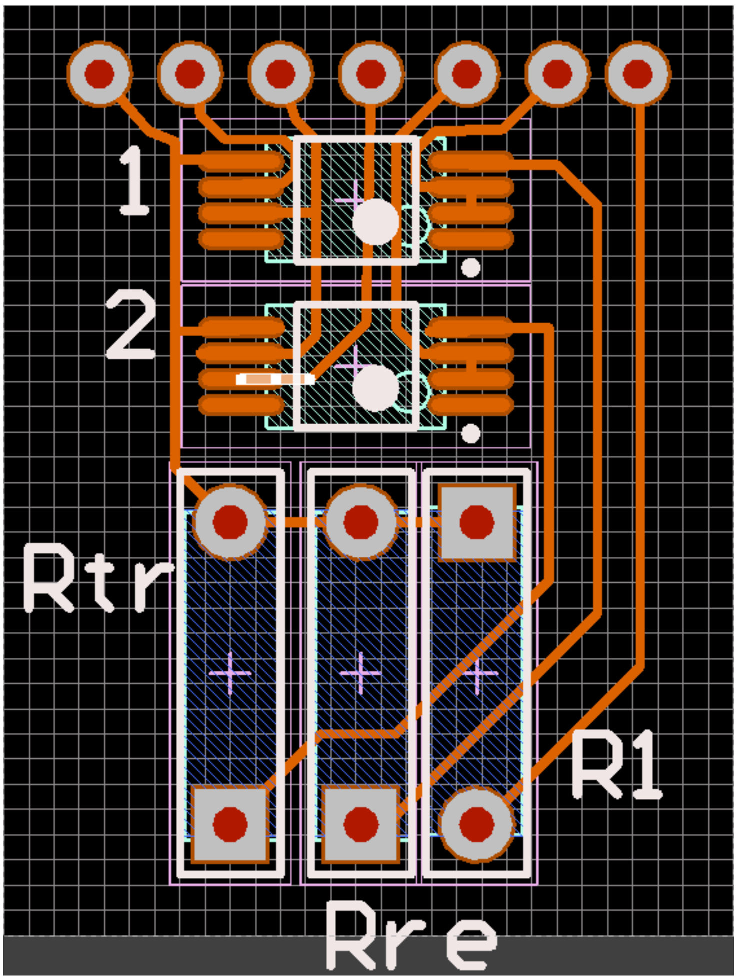
V_in (V)	I_in (A)	V_out (V)	I_out (A)	Efficiency (%)
3.8	0.971	2.3	0.684	42.63645726
4.1	0.916	2.8	0.582	43.39120247
4.1	0.697	3.1	0.557	60.42271757
4.1	0.715	3.5	0.527	62.92000682
4	0.721	3.7	0.51	65.42995839
4.1	0.713	3.9	0.488	65.10450518
4	0.725	4.2	0.469	67.92413793
4	0.733	4.3	0.457	67.02251023
4	0.749	4.7	0.435	68.24098798
4	0.739	4.6	0.442	68.78213802
4.4	0.431	4.8	0.276	69.8586796
4.5	0.339	4.9	0.201	64.56243854
4.6	0.261	4.9	0.153	62.44377811
4.6	0.22	4.9	0.124	60.03952569
4.6	0.224	4.9	0.102	48.50543478
4.7	0.203	4.9	0.089	45.70799707
4.7	0.18	4.9	0.075	43.43971631
4.7	0.165	4.9	0.066	41.70212766
4.7	0.148	5	0.057	40.97182289
4.7	0.136	5	0.05	39.11138924
4.7	0.135	5	0.046	36.24901497

Varying Distance

V_in (V)	I_in (I)	V_out (V)	I_out (I)	Distance (mm)	Efficiency (%)
4	0.739	4.6	0.442	0	68.78213802
4	0.799	4.7	0.453	1	66.61764706
3.9	0.817	4.7	0.453	2	66.82045005
3.9	0.835	4.7	0.453	3	65.38000921
3.9	0.852	4.4	0.427	4	56.54267485
3.8	0.933	4.6	0.442	5	57.34754894
3.8	0.916	4.3	0.415	6	51.26695013
3.8	0.93	4.1	0.398	6.5	46.17430673
3.8	0.942	4.1	0.4	7	45.81517488

Appendix 6 – PCB Schematic and Layout





APPENDIX 7 – ANDROID APP CODE – "MAINACTIVITY.JAVA"

File - /Users/Eren/Downloads/SharePower-master/app/src/main/java/com/ae/sharepower/MainActivity.java

```java
package com.ae.sharepower;
/*
*
*
*
*
* Valid from: Sat Mar 11 16:40:18 GMT 2017 until: Mon Mar 04 16:40:18 GMT 2047
Certificate fingerprints:
     MD5:  2B:F4:AA:7D:7C:3F:98:EC:4F:04:9B:5B:B1:9B:50:CA
     SHA1: A3:53:56:C7:D0:AE:AA:3B:26:5D:4B:2E:44:BD:39:A9:8A:55:31:0C
     Signature algorithm name: SHA1withRSA
     Version: 1
*
*
*
*
*
* */

import android.content.DialogInterface;
import android.content.pm.PackageManager;
import android.os.Bundle;
import android.support.v4.app.ActivityCompat;
import android.support.v7.app.AlertDialog;
import android.support.design.widget.NavigationView;
import android.support.v4.view.GravityCompat;
import android.support.v4.widget.DrawerLayout;
import android.support.v7.app.ActionBarDrawerToggle;
import android.support.v7.app.AppCompatActivity;
import android.support.v7.widget.Toolbar;
import android.util.Log;
import android.view.Menu;
import android.view.MenuItem;
import android.widget.Toast;

import com.google.android.gms.maps.CameraUpdateFactory;
import com.google.android.gms.maps.GoogleMap;
import com.google.android.gms.maps.MapView;
import com.google.android.gms.maps.OnMapReadyCallback;
import com.google.android.gms.maps.model.BitmapDescriptorFactory;
import com.google.android.gms.maps.model.CameraPosition;
import com.google.android.gms.maps.model.LatLng;
import com.google.android.gms.maps.model.Marker;
import com.google.android.gms.maps.model.MarkerOptions;

public class MainActivity extends AppCompatActivity
        implements NavigationView.OnNavigationItemSelectedListener, OnMapReadyCallback {

    MapView mapView;

    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_main);
        Toolbar toolbar = (Toolbar) findViewById(R.id.toolbar);
        setSupportActionBar(toolbar);


        DrawerLayout drawer = (DrawerLayout) findViewById(R.id.
```

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```java
drawer_layout);
        ActionBarDrawerToggle toggle = new ActionBarDrawerToggle(
                this, drawer, toolbar, R.string.navigation_drawer_open, R.string.navigation_drawer_close);
        drawer.setDrawerListener(toggle);
        toggle.syncState();

        NavigationView navigationView = (NavigationView) findViewById(R.id.nav_view);
        navigationView.setNavigationItemSelectedListener(this);

        mapView = (MapView) findViewById(R.id.map);
        mapView.onCreate(savedInstanceState);
        mapView.getMapAsync(this);

    }


    @Override
    protected void onResume(){
       super.onResume();
        mapView.onResume();
    }

    @Override
    protected void onPause(){
        super.onPause();
        mapView.onPause();
    }

    @Override
    protected void onSaveInstanceState(Bundle outState){
        super.onSaveInstanceState(outState);
        mapView.onSaveInstanceState(outState);
    }

    @Override
    public void onBackPressed() {
        DrawerLayout drawer = (DrawerLayout) findViewById(R.id.drawer_layout);
        if (drawer.isDrawerOpen(GravityCompat.START)) {
            drawer.closeDrawer(GravityCompat.START);
        } else {
            super.onBackPressed();
        }
    }

    @Override
    public boolean onCreateOptionsMenu(Menu menu) {
        // Inflate the menu; this adds items to the action bar if it is present.
        getMenuInflater().inflate(R.menu.main, menu);
        return true;
    }

    @Override
    public boolean onOptionsItemSelected(MenuItem item) {
        // Handle action bar item clicks here. The action bar will
        // automatically handle clicks on the Home/Up button, so long
        // as you specify a parent activity in AndroidManifest.xml.
        int id = item.getItemId();
```

```java

        //noinspection SimplifiableIfStatement
        if (id == R.id.action_settings) {
            return true;
        }

        return super.onOptionsItemSelected(item);
    }

    @SuppressWarnings("StatementWithEmptyBody")
    @Override
    public boolean onNavigationItemSelected(MenuItem item) {
        // Handle navigation view item clicks here.
        int id = item.getItemId();

//          if (id == R.id.nav_camera) {
//              // Handle the camera action
//          } else if (id == R.id.nav_gallery) {
//
//          } else if (id == R.id.nav_slideshow) {
//
//          } else if (id == R.id.nav_manage) {
//
//          } else if (id == R.id.nav_share) {
//
//          } else if (id == R.id.nav_send) {
//
//          }

        DrawerLayout drawer = (DrawerLayout) findViewById(R.id.drawer_layout);
        drawer.closeDrawer(GravityCompat.START);
        return true;
    }

    @Override
    public void onMapReady(GoogleMap googleMap) {

        googleMap.setMapType(GoogleMap.MAP_TYPE_NORMAL);
        googleMap.getUiSettings().setZoomControlsEnabled(true);

        LatLng NYC = new LatLng(51.498304, -0.177333);
        googleMap.addMarker(
                new MarkerOptions().position(NYC).title("ME")).setIcon(
                BitmapDescriptorFactory
                        .defaultMarker(BitmapDescriptorFactory.HUE_BLUE));


        LatLng istanbul = new LatLng(51.498879, -0.172818);
        googleMap.addMarker(
                new MarkerOptions().position(istanbul)
                        .title("CHARGE POINT"))
                .setIcon(
                        BitmapDescriptorFactory
                                .defaultMarker(BitmapDescriptorFactory.HUE_RED));

        Log.e("DEBUG","--************---************--");

```

```java

        googleMap.moveCamera(CameraUpdateFactory.newLatLngZoom(istanbul,14));

        googleMap.setOnMarkerClickListener(new GoogleMap.OnMarkerClickListener() {
            @Override
            public boolean onMarkerClick(Marker marker) {

                if (!marker.getTitle().equals("ME")) {

                    new AlertDialog.Builder(MainActivity.this)
                            .setMessage("Are you sure you want to send a charge request?")
                            .setPositiveButton(android.R.string.yes, new DialogInterface.OnClickListener() {
                                public void onClick(DialogInterface dialog, int which) {
                                    Toast.makeText(getBaseContext(), "Request Sent", Toast.LENGTH_LONG).show();
                                }
                            })
                            .setNegativeButton(android.R.string.no, new DialogInterface.OnClickListener() {
                                public void onClick(DialogInterface dialog, int which) {
                                    // do nothing
                                }
                            })
                            .setIcon(android.R.drawable.ic_dialog_alert)
                            .show();
                }

                return false;
            }
        });



    }



}

```

Appendix 8 – Arduino Code

```
const int MODE_SWITCH = 5;
const int D0 = 6;
const int D1 = 7;
 boolean sw ;

void setup() {
Serial.begin(9600);
pinMode(MODE_SWITCH, INPUT);
pinMode(D0 , OUTPUT);
pinMode(D1 , OUTPUT);
}

void loop() {

 int SVal;
if (Serial.available()){
SVal = Serial.read()-48;
Serial.println(SVal);
  if (SVal > 0){
    sw = true;
  }
  else{
    sw = false;
  }
 Serial.println(sw);
}

//If input is on, set the D0 on
if (sw){
 digitalWrite(D0 , HIGH);

 digitalWrite(D1 , LOW);
}
  else {
  digitalWrite(D0 , LOW);
  digitalWrite(D1 , HIGH);
}
Serial.println(digitalRead(D0));
}
```