



SMARTPHONE-POWERED LAPTOP

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1. Executive Summary

In today's world you will notice the majority of people have a cell phone. This is because Smartphones are widely accepted as a necessity in today's society. Smartphones are the modern technological multi-tool; they provide security, entertainment, social interaction, and almost infinitely other things. In the United States, children are getting Smartphones as early as age 6. This fact speaks volumes about how accessible phones are in today's Society. Unfortunately with the advancement in technology has also come with an increase in price. Smartphones are costing anywhere from seven hundred to a thousand dollars each. In our modern market, this is very similar with today's prices of laptops. To some, this price comparison makes sense; we do a lot of similar work on our smart phones as we do our laptops today. This includes things such as checking email, browsing the web, watching videos, and even playing games. Even from a hardware level these devices have a similar setup. Both devices include a central processing unit (CPU), a graphics processing unit (gpu), a high resolution screen, a battery, a camera, and storage. Showing how similar both devices are and how commonly we use them for the same tasks makes you wonder, why do we have to buy both? Why not have devices that can serve as both a laptop and a smartphone? Not only would this save the consumer hundreds of dollars on average but it could also make laptop style computer more accessible to those who cannot afford both. Laptops are a common learning tool in today's schools and with most students and children already having these smart devices, making it even that much more crucial that laptops are affordable and accessible to students. Our project makes this Possible because were not using a fully functional machine, the goal of our project is to use a non-functional computer and apply functionality to it with the help of a microcontroller unit, Bluetooth module, and Wi-Fi module housed on a printed circuit board will give our product the same functionality as a normal functional computer. However the main component required to demonstrate the design is an Android device. The entire design is dependent on the smartphone since the laptop will only display the contents of the smartphone. In conclusion our product offers the use of a computer through an Android smart phone.

2. Project Description

In today's world many people are paying \$1000 for Smartphones that can handle everything from web browsing to video games, multitasking and much more. If we pay so much for these devices why pay more for another device that can perform all the same tasks? Using a smartphone to power laptops will be advancement in technology and it will also save hundreds of dollars in manufacturing these laptops extremely affordable. This disruptive technological innovation will create unique experience between phone and computer use while also making it seamless. Laptops will now be able to instantly switch between wifi and cellular connections, making them more mobile, user-friendly and versatile than ever before. Smartphone powered laptops will need no internal hardware other than a battery and a small PCB, making way for unmatched, mind blowing battery life for the new technology.

2.1 Existing Products

Innovation is the stepping stone for a more reliable and affordable product. There is no need to reinvent the wheel, instead, make it better. Since there is only a limited amount of smartphone powered laptops on the market, there is a lot of room for improvement. In the next sections are multiple products/designs that are in the consumer market or will be in the consumer market.

2.1.1 Razer Project Linda

There is a concept for an experimental project by a major company in the pc gaming realm known as Razer. Their experimental concept is called project linda. Project linda has a few drawbacks and interesting differences from our project. One of the most notable differences is that the phone does not go inside the laptop, but has a docking station just under the keyboard, which allows it to be used not only as a touchpad, but also as a second screen. Another difference is that Project Linda offers additional on board storage of about 200 gigabytes. From a consumer standpoint, this additional feature seems to take away from the grand idea of a smart phone powered laptop. One of the major attraction points is that everything you do from your laptop is also readily available to you on your phone from anywhere. This is easily done and handled in today's modern world with cloud storage. Adding physical storage to the laptop frame would just create something additional you have to rely on to get your material, with modern phones reaching 1 terabyte of space and the affordable use of cloud storage, there is no real need for additional storage space.

A negative aspect of project linda is that it only works with one phone, the Razer phone. This means that in addition to buying the laptop you would have to buy and change to this Phone, adding to the cost, making this just as expensive if not more expensive than today's windows laptops. Our project works with any android phone, meaning that a large majority of today's smartphone users would be able to purchase our product and use it with their existing phone. Additionally in the future you wouldn't be able to upgrade your phone without purchasing another laptop, whereas with our product you could continue upgrading to the latest android phone and have no compatibility issues with our product. From a software developers perspective, the second screen design also poses to be a problem. This is because each individual app developer would have to create custom support for a second

usable screen on their app, but with such a niche product for phone that has less than .01% of the market, where is the incentive? These poor design decisions overall make this concept not viable for today's consumers and not enticing enough for today's developers.

Figure 2.1.1 - Razer Laptop



2.1.2 Kickstarter Project Superbook

The next two products that even closely resemble our smart phone powered laptops are also not readily available to the consumer as they are startup projects listed on kickstarter sites like indiegogo.com. The first one to be discussed is Called superbook. Like ours it is compatible with almost any android device. One of the key feature differences between their product and ours is that their product is not completely wireless. You have to connect the phone to the laptop via the charging cable, which made them have to have multiple charging cables options to connect from the laptop since there are multiple cable standards in the android smartphone market. From an aesthetic standpoint this looks nothing but terrible to always have a cable coming from the laptop connected to you phone. It becomes very awkward being that laptops are known to be mobile, but you now have your smartphone permanently dangling from a cable to your laptop. Their best approach to a solution for this dilemma is to sell you a clamp that will hold phone next to your screen, which has no utility because you cannot use your phone screen while using the superbook. So you just have your blank screen phone attached next to your laptop screen for seemingly no reason.

Our smartphone powered laptop has a much more efficient and aesthetically pleasing approach to this issue. We made all the connections from the phone to our laptop completely wireless, this includes wireless charging. Firstly, this makes the connection

process much simpler and pleasing to the consumer. Second, we store the phone inside the laptop by having the user simply slide the phone into a compressed foam slot on the side of the computer. This makes it usable by phones of all shapes and sizes and keeps the true mobility of the laptop by making your phone a physical part of the laptop.

2.1.3 IndieGoGo Project Xfinitum

The third and final product that can be even somewhat compared to our product is called Xfinitum. This project was featured on indiegogo but was advertised as a multiple use laptop that could be used with all sort of devices. Xfinitum not only can connect to phones wirelessly but can also display any other device via it's hdmi in cable. While this Xfinitum can connect with multiple devices, it not only lacks a specific purpose but also in general does a poorer job of connecting to the phones compared to the other devices so far including our own project. This is because all of the previously mentioned projects connect to the laptop by displaying a modified, laptop friendly version of android that makes it just as usable as windows from a laptop. The Xfinitum simply just mirrors the image from the screen of the smartphone to the laptop screen. This extremely limits what you can do this Xfinitum laptop because you would still need to use the phone to control what is displayed on the screen.

Figure 2.1.3 - Indiegogo Project



2.1.4 Samsung Side Sync

Samsung provides software that lets the user install directly to his/her laptop. This software opens a window of the phone screen. From there, the user can simply drag and drop files into the laptop, make phone calls, or send text messages. While this design is not actually a smartphone powered laptop, it shows the necessity and ease of having one's phone synced to his/her laptop. In our case, the phone and laptop are one, which makes it easier for the

user to transfer any type of file from his/her phone directly through to the laptop without any delay or platform blocking the interaction between the phone and the laptop.

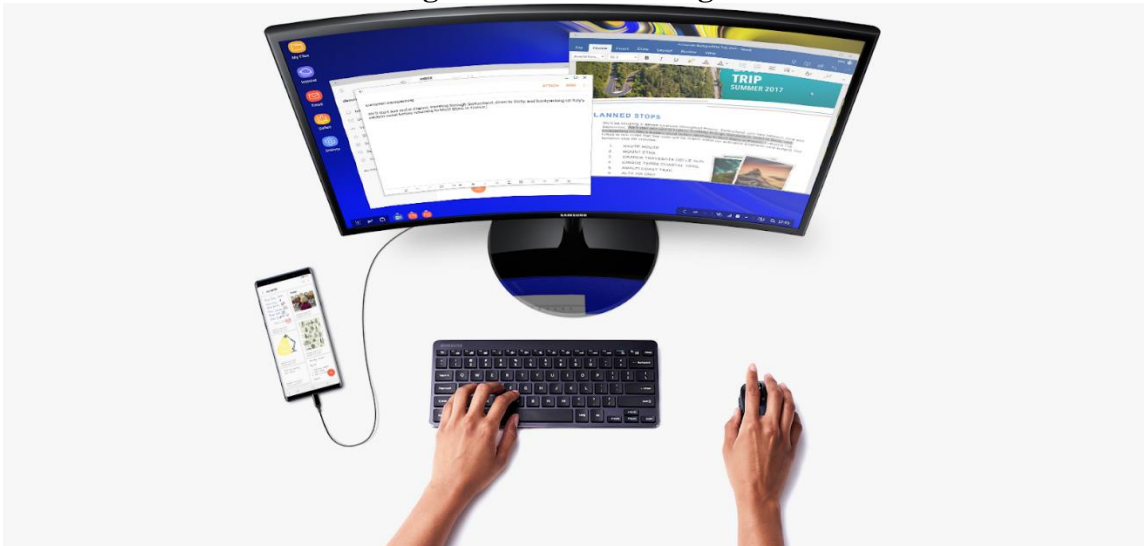
Figure 2.1.4 - SideSync



2.1.5 Samsung Dex

Samsung made something very similar to what we are trying to produce from a software perspective. They developed a physical device that you plug your phone into and it converts the look of the operating system to that of a Windows experience. How it physically works is that you plug your phone into the device and it sends out the Windows-like display via an HDMI cord to an external screen of your choice. It also has USB ports to connect the accessories of your choosing, things like a keyboard, mouse, etc. This device has its disadvantages because it is not mobile-friendly and they do not produce any laptop-like mobile form. Because of this, in order to use this device on the go, you would have to bring the device and all the accessories with you, not to mention you would need an HDMI-friendly display readily available at your location. From an internal hardware perspective, it is almost identical to our device. This is because the Android smartphone connects to Samsung's PCB and sends out a new visual signal to the display and sends the data from the keyboard and mouse to the phone. The only major difference between this hardware setup and our own is that all of our connections are wireless (accessories, display, and charging) using the Qi, Bluetooth Low Energy, and Wi-Fi Direct standards respectively. Another advantage of our device is that we can use almost any Android phone to power our laptops, but Samsung Dex hardware can only use Samsung phones. Samsung Dex has a large list of supported apps that work with it, including most Microsoft apps, Skype, Adobe Acrobat Reader, and multiple major Android games. Overall, we believe this is the best-made hardware that could be somewhat compared to our project; we also believe this is due to Samsung being a major powerful manufacturer in the Android market.

Figure 2.1.5 – Samsung Dex



2.2 Accessories

The amount of accessories we could possibly have available will completely depend on how many stretch goals we complete with our implementation phase of senior design 2. One of the most critical will be the external usb port stretch goals, which would allow us to design as sell accessories that connect externally to our smartphone powered laptop. There are other potential accessories too like a laptop case or other accessories that are gaming related.

2.2.1 USB to HDMI Converter Cable

A usb to hdmi converter would be the most important and probably most used accessory that needs to be available for our product. This would allow the consumer to take what they are displaying from their smartphone powered laptop and display it anywhere that accepts hdmi

2.2.2 Wireless Charger

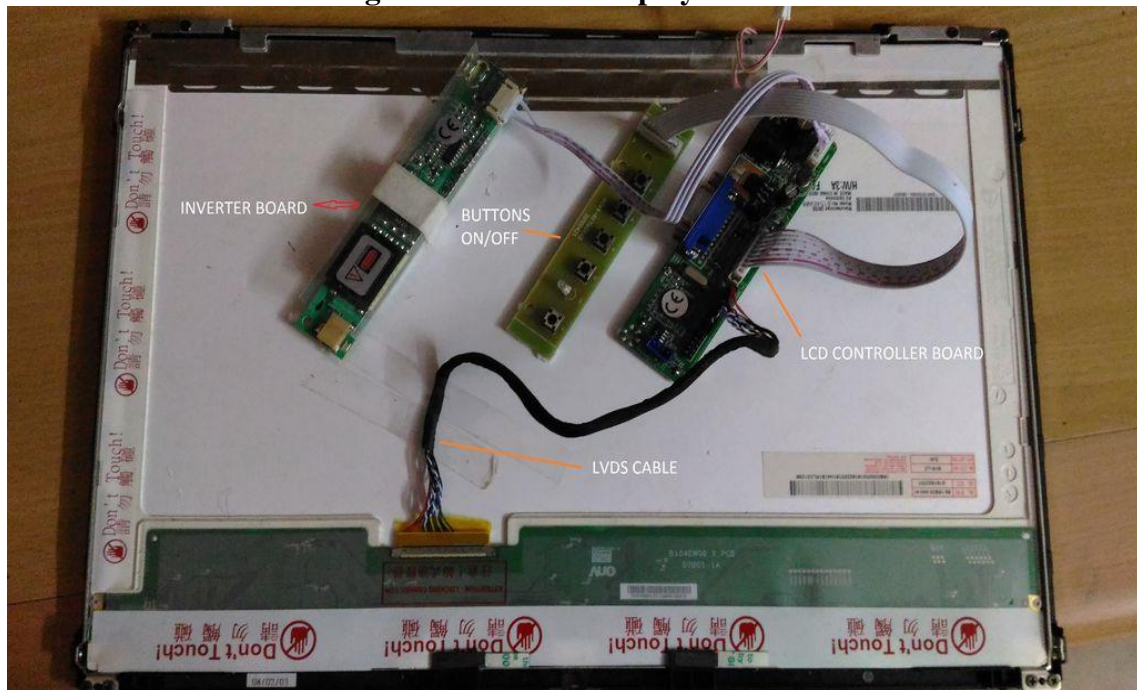
Wireless charging is becoming more prevalent in today's technology; however wireless charging is not a new idea. In fact, wireless charging has been around since the 1800s and the first phone with wireless charging was released in 2015. Wireless charging circuits provide the user with easy access to charge his/her phone with no extra cost and no cables/adapters. This is essential in modern day technology, because a large number of devices are transitioning from wired to wireless and provides a new market for customers and developers.

2.3 Requirement Specifications

We will need to design a battery, a PCB for power management, implement wifi, bluetooth, and a complete overlay for the operating system. Also, our PCB will connect to a standard laptop screen (30 pin CCFL screen). To establish this connection, we need an lvds cable, an lcd controller, and an inverter board. The lvds cable will connect directly between the laptop screen and the LCD controller. The inverter bridges the connection between the

PCB power and the power to the LCD controller. The purpose of the inverter is to convert the battery's DC power to AC that is required by the backlight of the LCD displays. The LCD controller will have a media connection tool for us to connect to via wifi (vga or hdmi). In this case, Wi-Fi is a better choice than Bluetooth due to the amount of power needed to transmit from the phone to the LCD. While Wifi is more costly, it is the best solution for the phone to communicate to the LCD.

Figure 2.3a - LCD Display w/Cables



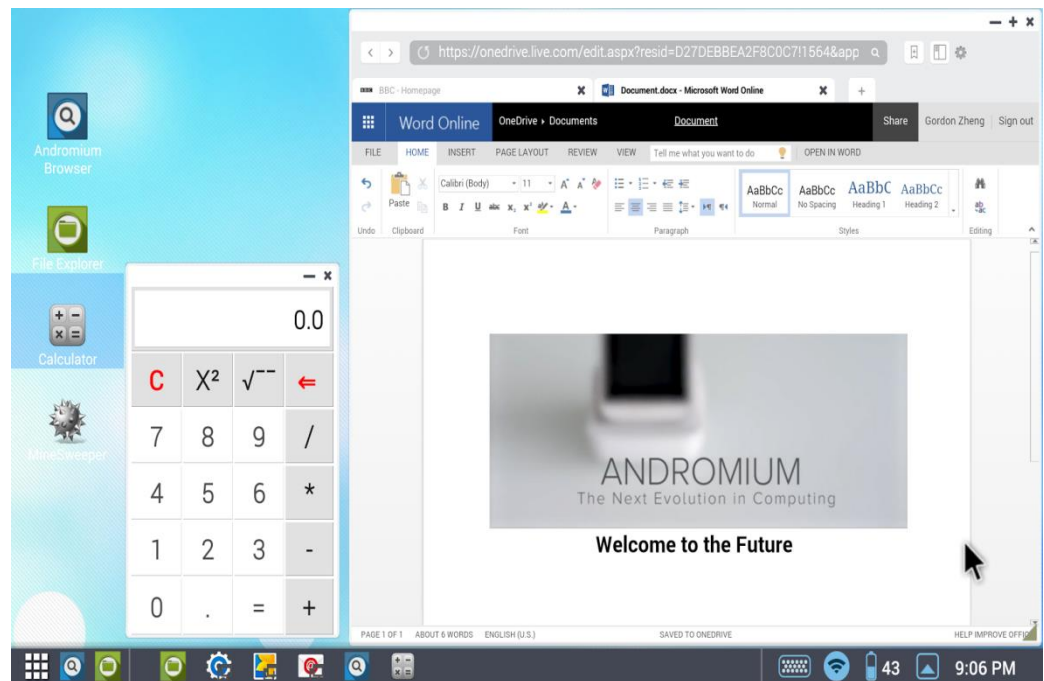
Moreover the battery design, we are completely scrapping almost all of the laptop's essential parts, to make it extra space for the size of the battery. With ample battery space, it can have a much long lasting battery life than most laptops that are currently available in the market. In order to implement this, we would need to design the battery/charge controller so that the controller can communicate between the battery power level and the laptop adapter.

Our track pad and keyboard will be connected via bluetooth. Bluetooth is optimal for track pad and keyboard connection, because it is actually important for low powered devices at close range, and supports a secure protocol. In order to implement Bluetooth, the PCB must supply the appropriate power to the track pad and keyboard. The Bluetooth module will communicate with the MCU, and the MCU will transmit data to and from the track pad and keyboard. Once the user is connected via Bluetooth, they will instantly be able to communicate with the laptop. To implement our design, we will make all the functional connections with a development board and the appropriate add ons for wifi and bluetooth found on sparkfun.com. This will give us the advantage for our final design given that sparkfun gives us the full eagle schematics for all the parts we use from their site. This will make unifying them into one schematic easier on us as computer engineers and easier for

our electrical engineers being that we will have all the power specifications readily available for them.

The Operating system overlay simply needs to add mouse support (via touchpad or bluetooth), add closing and minimization option to the corner of individual apps, and lets app windows be dragged for multitasking. All system notifications that are normally on the top of a phone will now be displayed in the bottom right corner, similar to that of a windows powered device. The bottom left corner that typically displays the windows button (on a pc) will have a button to display all app available on the device.

Figure 2.3b - Laptop Display of Phone



2.4 Design Aesthetics

For our initial design of the laptop we are using a big ugly decade old laptop shell called the Asus g50v. This laptop was well over an inch thick and only supported a screen with a 1366 by 768 resolution. This specific shell does not meet the standards we designated for our design aesthetics, but was selected for other purposes. The first being that the ridiculous large size of the laptop allowed ample space for our many initially large computer hardware parts like an arduino mega. Another reason is that this was an old laptop that one of our group members owned and was willing to donate to our group for use. This allowed us to have an initial testing laptop shell at no additional cost which helped our overall budget costs. For our final design in the senior design 2 showcase, we plan on using a modern, sleek ultra-book that is just big enough to slide an android phone inside.

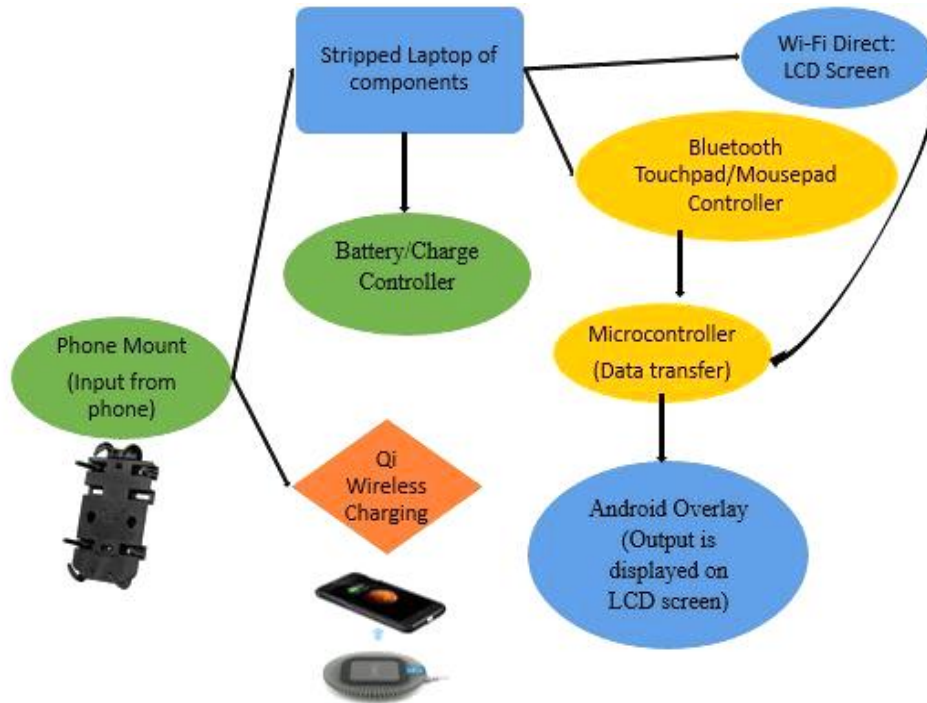
2.4.1 Project operation

- Download Custom Android Software
- Accept all permissions
- Slide in your smartphone into the pocket on the side of laptop

- Open the laptop
- Laptop is ready to use
- Whenever you're done you can just remove the smartphone

2.5 Block Diagram

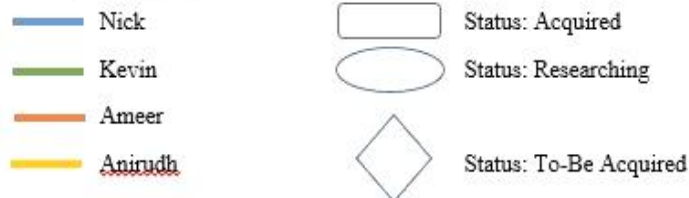
Figure 2.5 – Block Diagram: Hardware & Software



Other Task(s):



Block Diagram: Legend



The block diagram is shown above and is an important part of the project because we can use this diagram to see how the design should flow when all of the components are working in unison. The block diagram starts with an input, inserting the Android phone into the designated section of the laptop, and producing an output, which is a user interface displayed on the LCD screen of the laptop. Once the Android phone is inserted into the laptop, then the phone is connected to the Bluetooth/Wi-Fi module to send data. Also, the Android phone will be placed on top of a wireless Qi charging pad and wirelessly charge the Android phone. Once the Android phone is connected to the Bluetooth/Wi-Fi module, the Wi-Fi Direct will display the Android phone's content to the LCD screen. The mouse pad and touchpad will be connected via Bluetooth from the Android phone to the Bluetooth/Wi-Fi module. The data will be sent to the microcontroller, ATmega2560, and the data will be sent from the microcontroller to their designated areas to the printed circuit board components. Essentially we split up the hardware and software design aspects of the design between the electrical and computer engineering disciplines. So, the electrical engineering disciplines will handle the hardware component aspect of the design, which includes power delivery, voltage regulation, and the design of the overall printed circuit board to house all of the components. The software aspect of the design will be handled by the computer engineering disciplines, which will incorporate the programming of the Bluetooth that is the embedded systems aspect, and the programming of the Wi-Fi Direct which will display the Android phone's contents onto the LCD screen of the laptop. There will also be an Android Overlay displayed on the LCD screen of the laptop that will look similar to a Windows OS so the user will have easy access to navigate the user interface. This user interface can incorporate various features like battery percentage of the laptop, battery percentage of the Android phone, date and time displays, and more features like the Windows OS displays.

2.6 Stretch goals

There are quite a few stretch goals we have in mind for this project. Some are more realistic than others due to time and financial constraints. One of the important qualities of the stretch goals that all of ours have in common is that they increase the usability of the our product. Some of the goals listed will be features that our competitors projects had while others were things we thought be useful additions to a unique phone laptop combination scenario. Even though stretch goals are designed to be something you attempt with extra time or funding, we think that our stretch goals collectively might be worth more value to our project than others, thus we are putting a massive effort into implementing as many of our stretch goals as possible into our smartphone powered laptop.

2.6.1 Webcam

A webcam would be a great addition to our smartphone powered laptop. This is due to its multiple possible uses. In today's world it is very common to video chat with friends and family. This is so accessible to our modern society simply because even the cheapest phones having a front facing camera. Also this poses a slight issue for our project because we planned on all phone functionality being available from the smartphone. If a potential contact of the user tried to make a video call, there would simply be no way to see the user, rendering the video call functionality useless. An second useful and possible use of the camera accessory would be for security purposes. Many modern smartphones use the front facing camera for general facial recognition, which allows the user to simply unlock the phone using just their face and makes it more secure than a password anyone could use to unlock the device. We would like to implement this with a camera on the laptop, making

the project more secure for daily use. The laptop shell we are using for our project design already has a 720p high resolution camera wired and built in above the screen on the laptop. In order to implement this camera into our project we will have to identify the camera's connection type and establish a method of connection to our pcb. We would that make that pcb connection available to our smartphone, and make sure to have the android operating system then identifies the camera as a camera accessory. We can then set this camera as default when the connection to the laptop is established. This would allow seamless functionality of the video calling between both the smartphone and our laptop.

2.6.2 Microphone

Another truly beneficial feature for both the laptop design as a whole and a crucial feature in order for the webcam stretch goal to work is a microphone. This additional would allow us to both fully implement the video chat feature and general phone calls. This could also add the speech to text functionality, increasing the functionality of the laptop in many diverse ways. Even though there was a microphone built into the laptop shell we are using for our design, it was connected to chipset that was built into the motherboard. To implement a microphone into our design we will have to either identify the current microphones connection type and make our custom firmware on our pcb to connect in to the phone, or we could purchase a microphone that easily connects to our Arduino and use the code that comes with it to make the connections. Once that connection is made we would need to make sure the android operating identifies this peripheral as a microphone. Just as discussed with the possibility of added security with the webcam, having a microphone would create another opportunity to make our smartphone powered laptop more secure. Many android powered smartphones also support voice verification unlock features, making it a great possible security addition.

2.6.3 Speakers

Adding speakers to our project makes for a great possible stretch goal, given all the possibilities it would allow. This defining feature would make our project a multimedia powerhouse. Our current plan for audio for the laptop is to use the existing speakers on our android powered smartphone. They are down firing speakers located on the bottom of the smartphone. Because of the way our smartphone slides into the laptop, we will be able to leave the existing speakers facing outwards. This will allow them to provide a mediocre sound for the laptop, where general sound is required for video watching, music playing ,etc. This is why we created the stretch goal of adding speakers to the laptop. This will allow us to add premium sound to the laptop without any additional strain on the battery of the laptop due to the new speakers being powered by the laptop battery. There are possible complications here as speakers take a lot of power and we will have to test how much of a negative effect this has on the general battery life of our design.

2.6.4 LED Status Indicator Lights

Led status indicator lights are currently our lowest priority stretch goal. This is because their difficulty and time consumption level rivals that off all our other stretch goals, while the indicator light would yield the smallest benefit to the user of our laptop. Regardless, indicator lights could provide potential benefits to our users. These lights could show the

charging status of your phone (whether it is full or not), and a battery level light for the laptop's own battery. We could do this multiple ways, one being changing the color of the led to indicate full, half full, low status with colors such as green, orange, red. We could additionally have multiple lights designated to show each batteries charge (one light for low battery, four lights for full battery). We also feel the placement of these indicators is crucial for their usefulness. If we locate the lights that could be seen both when the laptop is closed and open, it would be the most useful for the user. If a suitable location could not be found for this we could simply install two sets of status indicator light that perform the same task, but are somewhere ideally seen in both open and closed form.

Figure 2.6.4 – Battery Indicator



2.6.5 Physical Storage

An additional feature we are currently looking into is the ability to keep physical storage space for data in the smartphone powered laptop. As previously mentioned in the project comparison section of our senior design paper, we are conflicted and are not all convinced as a group that this feature would be a true benefit to the consumer. While having extra physical storage space sounds nice in concept, one of the major features of the smartphone powered laptop is the seamless integration between your phone and the laptop. Our goal for the laptop is for it to truly feel like it is just an extension of your phone and that everything you create on the laptop is then immediately accessible from anywhere on your smartphone. Having physical storage on the laptop creates an issue here because anything stored locally on the laptop will not be accessible from your phone. Essentially creating the same issue people have with today's computers. We truly believe the most viable option is to use one of today's highly available and free cloud services. This allows you to not only store large amount of data elsewhere, but simultaneously keeps it accessible anywhere you need it to be. Regardless many have argued it is still an extra feature and is something that it wouldn't hurt to showcase. We find this to be an attractive stretch goal due to its ease of completion. This could be very simply added to our hardware design by adding another usb connection port to our pcb and purchasing a usb drive of a certain size to connect to the pcb for the additional storage. The only part of this design we would have to investigate

further would be how to connect the usb storage device to phones. This could potentially pose an issue for us being that all of our connections and being done wirelessly. We will have to meter our use of the bluetooth connection and see how many other wireless connections we can afford to send simultaneously via this route.

2.6.6 External USB Port

Adding a external usb port to our smartphone powered laptop could add a lot of financial potential to our senior design project. This is because having an extra port that is easily accessible to the user would allow limitless possibilities for accessories. If this product was ever redesigned for consumer we could then also design and sell accessories as an extra source of revenue for the product. To implement this into our project we would simply have to add another usb connection to our pcb design and use soldering to connect it to one of the existing usb ports already built into our asus gaming laptop shell. We would also need to verify how many usb connections the android operation can support simultaneously, as we will already have the touchpad and keyboard connected, along with other potential stretch goals. Once we have verified this and that we haven't reached maximum bandwidth on our bluetooth connection, we will be able to confirm that this is a viable stretch goal.

2.6.7 Smartphone Fan

A fan installed in the laptop to cool the android smartphone powering it is one of our more realistic stretch goals for the project. This is because from a design perspective we simply just have to purchase a fan that will fit into our laptop shell design and supply power to it. Even with how simple and easy this stretch goal appears to be, we found it to be a worthy idea due to the potential issues that might arise from the heat generated by the android phone. If too much heat is produced during intensive and prolonged use of our smartphone powered laptop, it could potentially cause the smartphone to overheat and freeze up the operating system. This would render our project useless and require the user to remove the phone, restart it manually, and reinstall it into the slot on the laptop. Much of our projects usability would be gone if this case and would cause alot of frustration for the consumer. As we continue to make more and more progress on our project, we will continue to monitor the temperature of the smartphone through the many sensors preinstalled the on the device. This will help us determine whether this stretch goal is truly critical for our project or not.

Figure 2.6.7 – Laptop Cooling Fan



2.6.8 Touch Screen Interface

A touch screen interface without a doubt would be the most difficult stretch goal to implement into our product. We believe the benefits of this stretch goals are so huge, that it is still worth mentioning regardless of its likelihood of being added to our smartphone powered laptop. The reason a touch screen interface would be so critical and useful to our project is because it would break down the last barrier between our smartphone and our laptop, treating both screens identically as a touch screen. This is especially helpful because not all apps and software are design or optimized to work with the modified version of the android operating system, meaning that some will not work very well with a keyboard and mouse. This is because when the software is not optimized for laptop form it will default to its smartphone form (which is meant to be used as a touchscreen), thus making it difficult to navigate. If we added the touchscreen interface, this could potentially eliminate all those issues by treating your laptop screen just are you would your phone screen. Not only would this make for less and more simple software optimization but any future apps would instantly work on our smartphone powered laptops. There would no longer be a need to wait for software patches or updates to use new apps and games. Additionally if we ever optimized the design to ultrabook form, this would allow us to essentially transform and smartphone not only into a laptop, but also a tablet. I believe this would open many doorways for new multimedia uses of our laptop. To highlight the difficulties of implementing this stretch goal into our smartphone powered laptop, I will start with the need to completely replace the screen in our current design. Even with the already high level of difficulty brought by finding a new screen that has touch screen capabilities that will physically fit into our design, it brings a whole new set of issues given that we would have to completely redesign our connection from our pcb to our display. We believe this to be well outside of our time and financial budget allotted for the scope of our whole senior design project.

3. Research and Part Selection

In section 3, we will talk about the research we have conducted to identify what we will need in order to build this project and have the cellphone-powered laptop operating correctly and efficiently. From battery selection to the microcontroller selection and to software research.

3.1 Battery

Since the laptop is a major component of our project, we will need a battery to power the laptop when the laptop is not plugged into the AC adapter to the outlet on the wall. A battery is detrimental to this project because without a battery, the laptop will not operate at all outside of the AC adapter being plugged into the laptop and the outlet on the wall. Without a battery in the design, the entire project will not work. In the sections below, we will explain the different battery types, like lithium ion and lithium polymer batteries.

3.1.1 Battery Types

When it comes down to choosing the right battery for our laptop, we had many choices to choose from. The choices of batteries are Lithium-Ion (Li-ion), Nickel Cadmium (NiCad), Nickel Metal Hydride (NiMH), Lithium Manganese Oxide (LiMn₂O₄), Lithium Nickel Manganese Cobalt Oxide (NMC), Lithium Iron Phosphate (LiFePO₄), Lithium Nickel Cobalt Aluminum Oxide (LiNiCoAlO₂), and Lithium Titanate (Li₄Ti₅O₁₂). Nowadays, Lithium-Ion is the prime choice for modern laptops due to its performance and lightweight material. But, before making a final decision we must first compare the different batteries and their characteristics as shown by the table 3.1.1a.

For Lithium-Ion batteries, there are several advantages to having this type of battery in our design because of its high energy density, rate of self-discharging, doesn't require priming, and there are different kinds of Lithium-Ion batteries that can be applied toward a specific application. The rate of self-discharge increases as temperature increases, so decreasing the storage temperature of the batteries can dramatically reduce the self-discharge rate. Furthermore, Lithium-Ion batteries have a higher energy density than NiCad and NiMH so this allows any electronic equipment to operate at much longer times.

NiCad was invented by Waldemar Jungner in 1899 and was an improvement to the battery, prior to NiCad, which was using lead acid. The materials for NiCad are very expensive compared to other versions of the rechargeable battery. In the 1980's, NiCad was very popular due to major improvements of the battery involving a 60% increase in storage capacity. This battery can suffer from the memory effect, just like the NiHM battery.

NiHM research was first started in 1967, but was short lived due to heavy stability issues and energy efficiency issues. But, today NiHM is more robust compared to the NiCad battery because of its 40% increase in higher specific energy. Although, NiCad has higher specific energy, the NiHM battery falls short because of the complex charging algorithm for the battery cells to recharge. Companies today like Panasonic, Energizer, Duracell, and

Rayovac have focused more on rechargeable batteries as well, mainly focusing on the NiHM type.

Table 3.1.1a – Battery Type Comparison

	Capacity (mAh)	Nominal Voltage (V)	Average Price (\$)	Self-Discharge rate (% per month)	Other
NiHM	2,700	1.50	6.50	13.9	Suffers from Memory Effect
NiCad	900	1.20	6.00	15-20	Suffers from Memory Effect
Li-Ion	3,000	3.60	3.95-8.00	2-3	Highest Energy Charge Density
Li-Polymer	2,500	3.70	100.00	2-3	Thinnest/ Lightest Design
LCO	1500	3.60	5.50	2-3	Quick Charge & Discharge
Li-Manganese Oxide	1350	3.70	200.00	7	Never charge battery
Li-NMC	1500	3.70	300.00	7	Used in Electric Vehicles
Li-Iron Phosphate	700	3.30	26.00	1-2	Lasts longer than 10 years
Li-NCA	2250	3.60	7.00	2-3	Largest Capacity
LTO	560	2.40	86.00	1-2	Safest battery

Self-discharging can pose as a major issue with batteries because the more you charge your batteries the more the batteries will lose their charge over time. This can cause a phenomenon known as the “memory effect” where rechargeable batteries lose their charge over time, so the battery “remembers” a smaller storage capacity. Unlike the NiCad and NiHM batteries, Lithium Ion batteries do not experience this “memory effect” at all, thus making Lithium Ion a prime choice of battery selection. Although, NiCad and NiHM batteries are a lot more cheap than Li-ion batteries. Also, using a Lithium Ion battery requires the battery to have a protection circuit to make sure the battery stays at a safe current.

The better choice out of all three basic battery types would be the Lithium Ion battery because the Nickel Cadmium and Nickel-Metal Hydride batteries suffer heavily from the “memory effect” and are just too obsolete. Also, Lithium-Ion’s energy density is much higher than that of NiCad and NiHM batteries, making Lithium-Ion the prime candidate for a rechargeable battery.

Now that we’ve chosen the Lithium-Ion type of battery to use, now there are many types of Lithium-Ion batteries to choose from. Once again, there are different trade-offs when it comes to these different choices of Lithium batteries. The first type of Lithium battery is just the regular Lithium-Ion batteries, as shown below. They are bigger in size and heavier in weight, but Lithium-Ion does have higher energy densities. Lithium-Ion is also a lot cheaper in price, and has a low self-discharge rate. The self-discharge rate for a Lithium-Ion battery is about 5%. Moreover, Lithium-Ion batteries do suffer from aging, even when the battery is not actually being used. Another more important characteristic of Lithium-Ion type batteries is that it does not require priming. Priming is basically a form of battery cycling to improve the rated capacity of the battery because some batteries, when coming freshly made from the factory, aren’t prepared to fully dish out the rated amount of capacity that they are listed for. Alternatively to the Lithium-Ion battery is the Lithium-Polymer battery. This battery is the slim and sleek version of the Lithium-Ion battery, but it is flat out more expensive. Utilizing this type of battery can greatly reduce the overall size of the laptop, but does have some trade-offs as well. For example, the Lithium Polymer battery is a lot more slim compared to the Lithium-Ion battery, but the Lithium-Polymer battery has less energy density than the Lithium-Ion battery. Also, the Lithium-Polymer has a much lighter weight and sleeker design, but somewhat decent battery life compared to the Lithium-Ion battery. But overall, choosing between these two Lithium batteries is a no-brainer because we are choosing the Lithium-Ion battery again. It is a lot cheaper, more energy density, lower self-discharging rate compared to the Lithium Polymer battery.

The next Li-Ion battery is Lithium Cobalt Oxide and it is a common type of Lithium-Ion battery, hence the Cobalt being bonded with the two Oxides making an ion. Just like the Lithium-Ion battery, LCO has a high specific energy, or high energy density. This type of battery is usually used for high performance electronics, like cell phones and digital cameras. Although LCO has very high performance, it has a relatively short life span due to its low thermal stability and limited specific power. LCO can also charge very quickly in lower temperatures, but should not be charged with a current higher than its rated current. This can be achieved with the protection circuit limiting the current to not exceed the LCO’s current rating. Due to LCO’s high performance and quick charging capabilities, the price can run pretty expensive for these rechargeable batteries. A key tradeoff of the LCO battery is that if the battery is fully charged then it has a chance to induce thermal runaway. Thermal runaway is when the current exceeds the capacity of the battery, therefore creating too much internal heat which exceeds the expulsion of the heat leading to the destruction of the battery.

Lithium Manganese Oxide was first published in 1983 and then later in 1996 the battery was commercialized for consumers. A main characteristic about Lithium Manganese Oxide is that the structure of the architecture improved the ion flow on the electrode. This

structural shape, called a spinel shape, results in a much smaller internal resistance which can improve the current stability and control of the Lithium Ion battery. This spinel architecture also improves the thermal stability which means that the battery is efficient even at higher operating temperatures. Along with having a lower internal resistance, this can equate to faster charging times and high-current discharging. This type of lithium ion battery can output high amounts of current while operating at moderate heat temperatures. The applications for this type of lithium ion battery include power tools, electric vehicles and other high powered devices. It is more commonly used in medical equipment. So, this type of lithium ion battery will not be used in our design.

Much like the Lithium Manganese Oxide battery, Lithium Nickel Manganese Cobalt Oxide is just a cathode combination with Nickel and Cobalt metals. Li-NMC can be used in two ways, one as an energy cell and the other as a power cell. An advanced feature of Ni-NMC is that there are many combinations of Li-NMC to suit either a larger capacity and deliver a smaller amount of current or have a smaller capacity and deliver a higher amount of current. Nickel itself is known for its high specific energy and bad stability and Manganese is known for its spinel structure to effectively reduce the internal resistance. But, combining the two metals brings both of the benefits of each metal together and makes a stronger ion. Li-NMC is typically used for electric bikes, power tools and other electric power trains.

Lithium Iron Phosphate was introduced as a cathode material in 1996. Like Lithium Manganese ion, Lithium Iron Phosphate has low internal resistance. Meaning that the same attributes from the Lithium Manganese Oxide ion apply to the Lithium Iron Phosphate ion. But, along with have a low internal resistance, the battery life cycle is a lot longer than the Lithium Manganese ion. Also, Lithium Iron Phosphate provides a high-current rating along with tolerating being held at high voltages for long periods of time. Moreover, this lithium ion battery can tolerate higher charge conditions, unlike many other Lithium-Ion batteries. A major disadvantage with the Lithium Iron Phosphate battery is that it has a lower nominal voltage of only 3.2 V per cell, which reduces its specific energy (capacity). Lithium Iron Phosphate has a much higher self-discharge than most other Lithium Ion batteries, which can cause battery life problems if battery storage temperatures and operating temperatures and charging cycles aren't performed properly. The types of applications for Lithium Iron Phosphate are mainly used in electric vehicles, so we will not be using this battery in our design.

Lithium Nickel Cobalt Aluminum Oxide was introduced in 1999 for very specific applications. Li-NCA has a high amount of specific energy, and a long battery cycle. Li-NCA also has decent specific power. Although Li-NCA offers these great attributes there are other major concerns relating to the high costs and safety concerns. But, the added aluminum does increase the stability a bit. But, we will not be using this type of Lithium Ion battery in our design.

Lithium Titanate has been around since the 1980s, this Lithium Ion type also has the same spinel structure as the Lithium Manganese ion described earlier. Along with the same characteristics as a Lithium ion that has a spinel structure, LTD has a low nominal voltage, about 2.4 V, and it can deliver about 10 times its normal capacity in current. This Lithium

Ion battery is among the safest Lithium Ion batteries in the market, but the cost of the rechargeable battery is very expensive. We will not be using this type of battery in our design.

Figure 3.1.1b – Battery Pack Selection



3.1.2 Battery Selection - ASUS Standard Battery Pack

The ASUS laptop battery pack consists of Lithium Ion batteries which typically have a lifespan of three hundred to five hundred charging cycles. After about three hundred charge cycles, the Lithium Ion batteries would have lost about twenty percent of their total charge. Even with moderate use, the ASUS battery pack will deliver about eighty percent of its total capacity even after three hundred charge cycles. A major characteristic of Lithium Ion batteries is that the temperature can affect the total capacity of the battery pack. In just six months, the ASUS battery pack will only lose about five percent of its total capacity, which averages to around one hundred and fifty charge cycles. The ASUS battery pack discharge rate is also affected directly by the system's power management settings. For example, depending on whether or not the settings are set for optimal performance, the battery will drain a lot faster which will require more charging of the battery pack.

We chose this battery pack because not only does it contain a very high power Lithium battery, but because the original laptop we are using already contained that battery pack. This will save us money on buying a new laptop battery pack and buying a new protection circuit, or battery management system. Laptop battery packs come with the charge controller already integrated and protection circuit already integrated.

More specifically, the battery pack we chose to utilize has the Samsung ICR-18650-24E lithium ion battery cells. There are six cells in total, with 3 cells each in parallel respectively. The battery cells are soldered with nickel plating on the positive leads, in series, and connected to a printed circuit board that is home to a "smart" protection circuit. This battery pack is rated with an 11.1 V and 4800 mAh. We are choosing the original battery that was in the laptop, which is the ASUS A30-M50 model Lithium-Ion battery pack. Shown in Table 3.3, the ASUS A32-M50 is rated at 11.1 V with a 4800 mAh current rating. The ASUS A32-M50 battery pack is also a 6-cell-battery pack, and the number of cells determine the capacity of the entire battery. So the more battery cells there are in the battery pack, then the greater the battery capacity will be. The more battery cells also

translates to the life of the battery, meaning that the more cells there are the longer the battery life will be. The ASUS A32-M50 has a Battery Protection Analog Front-End, battery management system which is explained in section 3.4. The voltage rating on the ASUS A32-M50 battery pack is rated for 11.1 V, and the voltage can translate to how much power the battery is capable of outputting. So, the higher the rated voltage, the more power can be drawn from the battery pack at one time. Usually a laptop is rated for voltage and watt-hours or milli-ampere-hours. The ASUS A32-M50 is rated for 4800 mAh. This means that 4800 mAh translates into 4.8 Ah, which is how long the battery will last. So, the higher the mAh the longer the battery will last while operating. For example, a battery that is rated at 400 mAh has half the battery life of an 800 mAh battery. Although this is theoretical, we don't take into account the different types of applications and each of their runs times which can alter the battery life significantly. To get the watt-hour, Wh (Watt-hour), rating we use formula 1.1 as shown below. We will use the rated 11.1 V and the rated 4800 mAh, converted to 4.8 Ah, to get 53.28 Wh. Watt hours signify the amount of power or electrical power that the battery pack can supply for one entire hour. As shown in Table 3.2.1, the different battery pack suggestions and how we selected the battery pack.

Table 3.1.2 – Battery Pack Comparison

Name	Rated Voltage	Rated Current	Manufacturer/ Seller	Price
A32-M50 Li-Ion	11.1 V	4800 mAh	ASUS/ASUS	\$19.99
A41-X550A Li-Ion	14.4 V	2200 mAh	ASUS/Ebay	\$19.99
COM12190A Li-Ion	11.1 V	5200 mAh	ASUS/Batteries + Bulbs	\$129.99

Choosing between these three battery packs was almost a no-brainer because the original laptop that we are using as the design frame came with an ASUS standard factory lithium ion battery pack. So, if the battery pack is compatible with our design then we will choose this battery pack over another indefinitely. The A41 model has a much higher voltage rating, so the power draw can be a lot greater but the current rating is less than half of the A32 and COM model. Which means that the A41 model, although it is relatively a cheaper option, the battery life of the A41 is ultimately half that of the other two models. Furthermore, the COM model has a very high current rating so the battery life is optimal in this situation but the price is astronomically high compared to the A32 model, which has the same voltage rating as the COM model. So, ultimately the A32-M50 battery pack will be the prime choice in this situation. Although the ASUS G50V model already came with the A32-M50 model battery pack, the original battery pack is very old and worn out to the point where the original battery pack cannot sustain the amount of power we require to maintain the laptops power consumption. So, we are going to buy another A32-M50 battery

pack so that the compatibility will stay with the other components of the laptop, like the AC adapter and the DC power socket.

$$(Rated\ Ah) * (Rated\ voltage) = Rated\ Wattage\ (units: Watt - hour) \quad (1.1)$$

3.2 Protection Circuit Module (PCM)

A protection circuit module is vital to the life of a battery pack because it protects the circuit from operating at an unsafe current/voltage level which can cause a short circuit. The PCM is just a stand-alone circuit that solely protects the battery pack from a short circuit. The PCM also does not shut off the battery pack nor turns on the battery pack. It also does not have any “smart” technology integrated into the circuit, so the PCM cannot steer a motor nor can’t it calculate certain voltages or any potential battery statuses. Although the PCM is very basic, it still serves its purpose of protecting the battery pack from a catastrophic event and it is relatively cheap to buy in the market.

3.3.1 Battery Management System (BMS)

A battery management system would be a much needed addition to the longevity of a battery pack because it is important to adding “smart” technology to a battery so it can monitor different kinds of voltage levels, like how much each battery cell contains a certain amount of voltage. By definition a battery management system is an electronic system that manages rechargeable battery cells. The BMS can serve as a type of protection for the battery pack such as protecting the battery from operating outside its safe operating area, reports different types of data regarding voltage/capacity, monitors the battery’s current state, and can even calculate non-primary data.

Moreover, a BMS is a lot more advanced than a Protection Circuit Module because it can actually halt the process of charging from the AC adapter to the DC battery pack to prevent from overcharging the batteries and can switch off the battery pack.

The different types of calculations that the BMS can calculate are things like the SOC, state of charge, or the SOH, the state of health. A BMS also has a stand-by mode to prevent extra power consumption from the battery pack, increasing its efficiency. The BMS also has the capabilities to steer a motor or chargers, other consuming units as well, and can try to optimize the behavior of a system.

Table 3.3.1 – PCM vs. BMS Comparison

Traits	PCM	BMS
Protects components from short circuiting	✓	✓
Calculates different voltages		✓
Stop charging process		✓
Switch off the battery		✓
Price	\$	\$\$\$
Steer motor		✓
Check battery status		✓

The choice between the PCM and BMS is dependent upon the application that is being used. We chose the protection circuit that is integrated in the ASUS battery pack.

Figure 3.3.2 – Battery Pack Printed Circuit Board



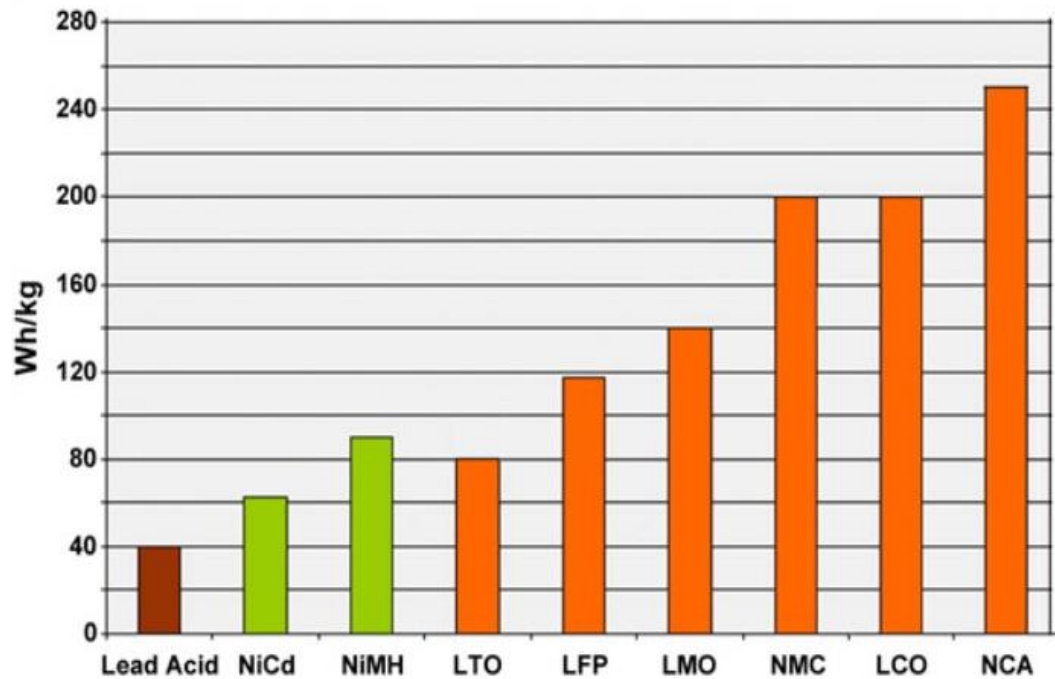
3.3.2 Battery Management System Selection

The Battery Management System that we chose was the bq29330 from Texas Instruments, also this BMS was already soldered onto the printed circuit board that the chosen battery pack came with. This is a factory standard battery management system that was placed in the battery pack circuit board to protect the battery pack from short circuiting and protection and control. Also, the battery management system is formally called the Lithium-Ion/Lithium-Polymer Battery Protection AFE. Choosing this battery management system not only makes the battery pack “smart” it also controls the power distribution and charging of the battery pack to protect the cells from an overload of current. It also provides individual cell voltages and battery voltage to battery management host. As shown in Table 3.5.1, the comparisons between multiple battery management systems and how we selected this battery management system.

Table 3.3.2 – Battery Management System Comparison

Name	Manufacturer	Price	Key Features
bq29330	Texas Instruments	N/A	-Comes attached to chosen battery pack already on PCB -Multi-cell Li-Ion supports
bq2409	Texas Instruments	\$1.26	-Operate either USB port or AC Adapter port -System load can be placed in parallel
bq76PL536A-Q1	Texas Instruments	\$11.01	-3 to 6 series Cell Li-Ion support -High Accuracy Analog to Digital Converter

Figure 3.3.2b – Battery Type Comparison



The table represents all of the batteries to choose from in our design. As you can see, most of the Lithium Ion batteries surpass the Nickel and Lead Acid batteries in terms of capacity. Most laptops have NiMH battery packs, but the battery pack we are using in our design will be the standard ASUS battery pack that originally came with the laptop that we are using as the shell for our project.

3.4 Microcontroller

A microcontroller is very similar to a standalone computer which makes it a very powerful device that is able to execute a series of preprogrammed tasks along with communicating with multiple hardware devices like Bluetooth modules, Wifi modules, HID (Human Interface Device) etc. In today's technological world microcontrollers are the perfect tool for machines that require some sort of intelligent automation. There are many different types of microcontroller families; these are some of the most commonly used microcontroller families 8051, PIC, and AVR microcontrollers.

3.4.1 8051 Microcontroller

The 8051 microcontroller was developed by Intel in the year 1981 and consists of an 8 bit processor meaning it can only process 8 bits of data per clock cycle. This family is one of the most popular families of microcontroller being used across the world. This microcontroller is referred to as "system on chip" since it consists of 128 bytes of RAM (Random Access Memory), 4 Kilobytes of ROM (Read Only Memory), 2 timers, 1 serial port, and 4 additional ports on a single chip, however the ROM can be exceeded up to 64 Kilobytes. This microcontroller has been utilized in a wide number of devices simply due to the ease of integration into project or device. This microcontroller focuses on four major

areas energy management, touch screen, automobiles and medical devices. In the figure below is an example of an 8051 microcontroller.

3.4.2 PIC Microcontroller

The PIC microcontroller stands for peripheral interface controller and was developed by General Instrument's microelectronics division. This microcontroller is fast and simpler to implement compared to the 8051 microcontroller family, furthermore this microcontroller offers everything the 8051 with the addition of ADC (Analog to Digital Converter) and DAC (Digital to Analog Converter). It also supports communication protocols for interacting with different devices like CAN, SPI, and, UART. This microcontroller is considered to be faster than the 8051 microcontroller because PIC used RISC (Reduced Instruction Set Computer) ISA (Instruction Set Architecture) whereas 8051 uses CISC (Complex Instruction Set Computer). In the figure below is an example of a PIC microcontroller.

3.4.3 ARM Processor

An ARM processor is also a family of CPU's that is based on RISC (reduced instruction set computer) and was developed by Advanced OISC Machines (ARM). ARM manufactures 32-bit and 64-bit multi-core processors. These RISC processors are designed to operate at high speeds which allows them to process million instructions per second (MIPS), this is achieved by removing any unnecessary instructions and optimizing pathways. These ARM processors are widely used in consumer electronic devices such as smart phones, tablets, and other multimedia devices. Due to their reduced instruction set architecture they don't require a large amount of transistors which leads to a smaller size integrated circuit. The small size, reduced difficulty, and low power expenditure makes them suitable for miniaturized devices.

3.4.4 AVR Microcontroller

This microcontroller was developed by Atmel Corporation in the year of 1996. It gets the name AVR by its developers Alf-Egil-Bogen and Vegard-Wollan this microcontroller is also comprised of RISC architecture. This microcontroller is also available in many categories such as TInyAVR which offers less memory, small size and is appropriate for simpler applications. The MegaAVR these type of microcontrollers are the most popular in the AVR family and offer a decent quality of memory upto 256 Kilobytes and a high number of integrated peripherals. Finally the last type is the XMega AVR which offers everything that the Mega offers but in a larger scale and is used for large and complex operations. The figure below is an example of an AVR microcontroller followed by a table comparing the three families of the microcontrollers.

Table 3.4.4 Technical Specifications

SPECS/MCU	8051 Microcontrollers	PIC Microcontrollers	AVR Microcontrollers
Bus Width	8 Bit	8/16/32 Bit	8/32 Bit
Communication Protocols	<ul style="list-style-type: none"> • UART • USART • SPI • I2C 	<ul style="list-style-type: none"> • PIC • UART • USART • LIN • CAN • Ethernet • SPI • I2S 	<ul style="list-style-type: none"> • USART • USART • SPI • I2C (special purpose support) • AVR • CAN • USB • Ethernet
Speed	12 Clock/ Instruction cycle	4 Clock/ Instruction cycle	1 Clock/ Instruction cycle
Memory	<ul style="list-style-type: none"> • ROM, • SRAM • Flash 	<ul style="list-style-type: none"> • SRAM • Flash 	<ul style="list-style-type: none"> • Flash • SRAM • EEPROM
ISA	CISC	Some features of RICS	RISC
Power Consumption	Average	Low	Low
Cost	Very Low	Average	Average
Manufactures	<ul style="list-style-type: none"> • NXP • Atmel • Silicon Labs 	Microchip	Atmel

From the technical specifications table shown above we have decided to choose a microcontroller from the AVR family of microcontrollers. The AVR microcontrollers are clearly faster than the 8051 and PIC because of their 1 clock per instruction cycle which means that each clock cycle one instruction is processed. The second reason being are the communication protocols which allows for a special purpose USB which is required for our project in connecting the laptop keyboard to the microcontroller. The third reason of pick an AVR microcontroller is that it has many low power modes and is very cheap; if we needed to order multiple AVR microcontrollers for testing purposes we can do so because it does not expand the budget of this project by a very large amount. In the following

sections the role of our microcontroller in the project is discussed along with a list of other microcontrollers that have the potential to carry out the tasks we require in our project.

3.4.5 Microcontroller Selection

The role of the microcontroller is split into two major tasks, first is to receive inputs from the keyboard and touchpad of the laptop then to use Bluetooth technology to send these inputs to the Android based phone connected to our smart phone powered laptop. The second task is to display the contents of the phone on the laptop LCD screen using WIFI – Direct technology. The laptop which we are using for our project has been customized in such a way that the only components remaining in the laptop are the connections to the touchpad, keyboard, and LCD screen. Keeping this in mind we have decided to choose from the following three microcontrollers, the ATmega 2560 ADK, MSP430, and Broadcom BCM2837 SoC. In the following sections, each of these microcontrollers will be technically evaluated to determine which option the best is given our groups budget, and the technical constraints of our design.

3.4.6 MSP430

Texas Instruments offers many microcontrollers including the popular MSP430 series of ultra low power mode MSP430's. These microcontrollers have a considerable amount of documentation available because of its popularity. These types of microcontrollers are also used for academic purposes at the University of Central Florida in the Embedded Systems course offered there for the computer and electrical engineers. All four members of our group are familiar with the programming basis of this microcontroller for various tasks. The specifications for the MSP430F4551PN are available in the table below.

As depicted in the technical specifications table above for the MSP430F4551PN the cost is within the budget of our project, it also consists of sufficient general purpose input and output pins required for this project with multiple ultra low power modes available. This microcontroller can be configured to run up to 8 MHZ if required although the flash memory is very insufficient for programming use because the key mapping software for the laptop keyboard will have to be re written along with the laptop touchpad. The provided clock speed in this microcontroller will execute the written program at a slower pace than the other microcontroller described in this section, below is a figure which shows the pin mapping for MSP430F4351PN.

3.4.7 Broadcom BCM2837 SoC

This microcontroller was the second choice for this project, and is used in various types of projects including education, home automation and for ones hobbies. This type of microcontroller is also used in commercial products like media players, vending machines, and wireless transceivers. This type of MCU is found on the Raspberry Pi 3 boards, it consists of an ARM cortex-A53 processor which is capable of running at 1.2 GHz. The architecture of this microcontroller is composed of a quad-core 64 bit with a level 2 cache memory of 512 KB. The technical specification for the BMC2837 is given in the table below.

As depicted in the technical specifications table above this microcontroller is very powerful compared to the MSP430f4351. This MCU is capable to use as a small computer on its own, it comprises of sufficient amount of GPIO pins required along with the core size and clock speed which will help the MCU to process the code very fast and produce outputs in very little time. But this MCU is way more powerful than what is required for this project, it does however have everything that is technically needed to develop a functional prototype for our project but most of the specifications will not be touched if this MCU is used which is a waste of money in our budget hence this is not the correct MCU for our project.

3.4.8 ATmega 2560 ADK

This microcontroller falls into the Arduino series, the Arduino development boards are the primary selection when it comes down to developing a functional prototype as a hobbyist. They are the first choice because of the open source implementation of different devices to the Arduino development boards. The Arduino community itself has so many different projects that are available on the internet that it makes it very easy to understand and implement different devices to this microcontroller. This particular microcontroller is the best fit for our project because of the USB interface to HID. This microcontroller has the MAX3421E USB host interface already embedded within it. This USB interface is necessary to connect the laptop keyboard to the microcontroller more information of the connection between the laptop keyboard and microcontroller will be discussed in a different section. The technical specs of all microcontroller discussed above are shown in the Table 3.4.8 below.

Table 3.4.8 Technical Specifications

Technical Specifications Table			
MCU/SPECS	MSP430F551PN	BCM2837	ATMega 2560
Clock Speed	8 MHz	1.2 GHz	16 MHz
Flash Memory	16 KB	512 KB L2 Cache	256 KB
RAM Memory	512x8	1 GB BLPDPR2	8 KB
Operating Voltage	1.8 V – 3.6 V	2.5 V – 6.0 V	5 V
Number of GPIO pins	48 Pins	40 Pins	54 Pins
Core Size	16 Bit	64 Bit	64 Bit
Connectivity	<ul style="list-style-type: none"> • SPI • UART • USART 	<ul style="list-style-type: none"> • Bluetooth • HDMI • USB • Ethernet • CSI and DSI 	<ul style="list-style-type: none"> • SPI • USB • USART • TWI
Manufacturer	Texas Instrument	Texas Instrument	AVR
Cost	\$ 7.12	\$ 35.99	\$ 25.9

3.4.9 Microcontroller Comparisons

Given the initial count of the 4 microcontrollers mentioned above only one was selected for our project. As research was done on different projects using different microcontrollers in a large quantity our project only requires one microcontroller. The reason we only need

one is because as mentioned in the above sections the sole purpose of the microcontroller is to establish an interconnection with the help of the Wi-Fi module to stream data from the android device to the LCD screen of the laptop and to use the Bluetooth module to send commands taken from the keyboard and touchpad to the android device. In this section the best microcontroller for our project will be selected on three merits which are clock frequency, general-purpose input/output, and memory size.

3.4.10 Memory Size

While researching memory size it was discovered that memory has three types, flash memory, electrically erasable programmable read only memory (EEPROM), and finally RAM. The flash memory is a non-volatile type of memory meaning that it keeps the data stored even after the microcontroller is turned off and then back on again. This is the memory where all the programs are stored, also the bigger the flash memory the more complicated the code can be. The electrically erasable programmable read only memory performs the same functions as the flash but is slower than the flash itself. This type of memory is specially used in the case of interrupt programming. Finally the third type of memory is RAM which stands for random access memory. The RAM is a volatile memory which means that once the microcontroller is turned off all of the data stored before that operation will be wiped out once it is turned back on again. Same as flash memory the bigger the RAM the more complicated programs can be executed on the microcontroller.

Looking at the technical specifications tables listed above in the microcontroller selection section it is clearly noticeable that the ATmega 2560 which has a flash memory of 256 KB and a RAM of 8KB is higher than the MSP430GF4168 and the MSP430F4551PN. The Broadcom BMC2867 is not considered because it is too powerful for the design of this project, yes it has higher specifications than any other microcontroller that was researched for this project but while designing this project as an Engineer the goal was to use parts that were economical in their price range and were as effective as any other part like the BCM2867.

3.4.11 General-Purpose Input/Output

A general-purpose input/output pin (GPIO) is a pin that can be used to transfer data or power. A GPIO can act as either an input or an output which can be specified at run time. For our project the GPIO is going to be used to connect the laptop touchpad to the MCU. The serial ports will be used to connect the Wi-Fi and Bluetooth modules to the MCU. As it can be seen in the technical specifications tables listed above in the microcontroller selection section the ATmega 2560 is a clear winner when compared against the MSP430FG4168 and the MSP430F4551PN. Also the greater the number of GPIO pins the more the design can be expanded by allowing more parts to connect to the MCU.

3.4.12 Clock Frequency

The clock frequency can be defined as the rate at which the microcontroller executes an instruction. Basically the faster the clock frequency is the faster the CPU can process the instructions to deliver the output. The clock frequency is an important factor to consider

since the user is relying on the Wi-Fi module so that the contents of the android device can be displayed on the LCD screen through the LCD controller board hence the microcontroller that was chosen was based on which one had the highest clock frequency. A higher clock frequency will allow the MCU to process the streamed data faster so that there is no delay for when the data is on the LCD screen. The ATmega2560 has a higher clock frequency when compared to the MSP430FG4168 and MSP430F4551PN this can be verified by looking at the technical specifications table listed above in the microcontroller selection section.

3.4.13 Microcontroller Choice: ATmega 2560 ADK

The development board which is ATmega 2560 ADK is a specially designed board that comes with an integrated USB host interface MAX3421E which uses SPI to communicate with the ATmega2560. This development board is retired however still purchasable online for our project. This MCU is the best choice for our project because it has a higher clock speed of 16 MHz than the MSP430 with 8MHz along with flash and general purpose input and output pins. Comparing this MCU to the Broadcom BCM2837 the BCM2387 come out on top for every technical specification also this MCU has a lot of extra and unnecessary features for the design of this project. The ATmega 2560 is capable of handling all tasks required for this project, below is figure-3.4.9.3 which shows the pin mapping.

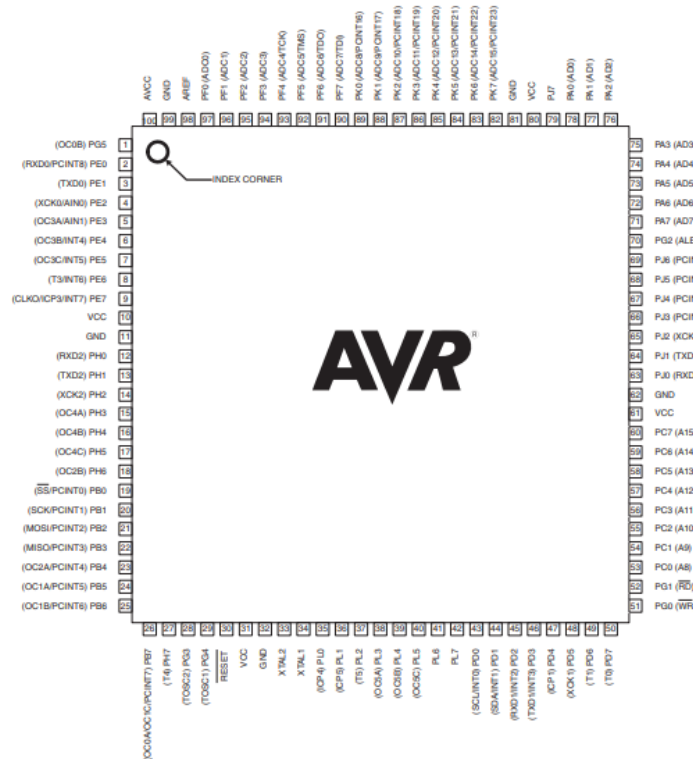


Figure 3.4.9.3 for ATmega 2560 pin mapping

3.5 Microcontroller Research for Design

When powering/designing the microcontroller, there are many hardware considerations that must not be overlooked. Considerations that must not be overlooked consist of decoupling and bypass capacitors, inductor in series, reset circuit, and oscillator circuit. Each consideration has a constraint associated with it.

According to “Learn about Electronics”, a bypass capacitor is, “capacitor that shorts AC signals to ground, so that any AC noise that may be present on a DC signal is removed, producing a much cleaner and pure DC signal.” [C3] So, a bypass capacitor basically acts as a way to filter out any noise or in other words AC signals. To expand on this subject, capacitors are known for their high resistance at low frequencies and low resistance at higher frequencies. So when DC signal is supplied to the microcontroller, there will be noise due to the temperature and noise due to the chip. At low frequencies, the current will take the path with the least resistance, which is the path directly into the chip. However, at higher frequencies, capacitors have lower resistance, which means the current will take the path with the capacitor straight to ground. This creates a filter for noise or AC signals, therefore reducing the amount of the noise the chips sees.

Another consideration to implement are decoupling capacitors. In this case, a supply is used to power multiple regulators, which means the power supply is supplying voltage to multiple devices. When current from any of the device changes, this creates a voltage drop at the power supply. A change in voltage can affect the overall operation of the circuit, by creating voltage spikes. In order to solve this problem, a capacitor can be used a power reservoir, that supplies voltage to the device when there is a voltage drop.

While bypass and decoupling capacitors provide proper voltage levels and ultimately resists noise in the circuit, there are also problems that can arise with current. Just like voltage spikes, current can also be affected by spikes. This is why an inductor is needed. Inductors current cannot change instantaneously, which means an inductor can resist the change in current spikes at the supply, basically smoothing out the signal. Overall, capacitors and inductors provide stability at voltage sources. The capacitor and inductor values is discussed in the “Part Selection” section of the document.

Another design requirement is to build a reset circuit. Reset circuits provide the user with a way to properly hard reset the circuit without any software programming. While a reset isn’t necessarily needed, a reset switch also provides our team with the ability to reset the circuit without having to unplug the battery. The Atmel Atmega2560 reset pin is active low this means the circuit will go into reset when the pin is at ground. Therefore, the pin must be pulled up to Vcc or 5 volts, when the switch is not active.

The last design requirement for the microcontroller is to implement an external oscillator. There are two types of oscillators, resonator and crystal. In our case, a crystal oscillator is chosen because they provide more accurate oscillation with very minimal error over a long

period of time. The only big difference between oscillators from different companies with the same frequency stability and tolerance are operating temperature and ESR. The table 3.5 below shows these differences.

Table 3.5 Comparison Table

Features	Abracon LLC	ECS Inc.
Frequency Stability	±50ppm	±50ppm
Frequency Tolerance	±20ppm	±30ppm
ESR	40 ohm	50 ohm
Operating Temperature	-20°C ~ 70°C	-10°C ~ 70°C
Price	\$0.32	\$0.38

The Abracon oscillator is chosen because it is cheaper, has better frequency tolerance, ESR, and operating temperature.

3.6 Keyboard and Touchpad to MCU

One of the key features of our project is that the user should be able to use the keyboard and touchpad on the laptop for navigation and selection on the android phone. The current laptop being used by our group has a 24 pin ribbon cable which means that the keyboard controller is directly attached to the motherboard. As mentioned in above section that our laptop will just consist of the connections for the keyboard, touchpad, and LCD screen everything else has been scraped out. There were two options to establish a connection between the keyboard and MCU. The first option was to research about keyboard controllers and how to solder a USB connection onto the controller. Unfortunately all members partaking in this project have very little or no knowledge about soldering different connections together so this was not the best option, however research is still ongoing to find the keyboard controller and solder a USB connection to it. Meanwhile the second option of purchasing a mini USB keyboard is being utilized. To make a successful connection between the MCU and keyboard first the 857 miniature keyboard which is microcontroller friendly with PS/2 and USB connection and will have to be replaced with the original keyboard on the laptop. A full replacement procedure will have to be performed where the existing laptop keyboard will be removed and the miniaturized keyboard will take its place. Then the next step is to slide the USB wire underneath the keyboard and then finally connect it to the USB interface in the MCU. Below is a picture of the 875 miniature keyboard.



Figure 3.6.1- Miniature Keyboard

The touchpad for our project is also going to be connected in the same way as the keyboard. A microcontroller friendly touchpad will be purchased and replace the original touchpad on the laptop. The capacitive track/touchpad was selected simply because of its friendly connection to the MCU. This touchpad has a PS/2 cable so a PS/2 breakout adapter cable will be used to make the connection on the MCU. This device is very essential for our project because it can perform both as a trackpad and touchpad. Programming wise this touchpad has to function in two ways. One it has to work like a regular laptop touchpad the other is that it also has to work as a swipe screen. For example while using our smart phone powered laptop the user decides to click on the apps button and then use the touchpad as a swipe screen to swap between different pages to select the desired application. In order to do so it has to be programmed to work like a touchpad and as a swipe screen. Below is a picture of the capacitive Trackpad/Touchpad. While the capacitive touchpad is a great feature for our Smartphone Powered Laptop it is known to be option B. Option A is the touchpad used directly from the Asus G50V, which is also microcontroller friendly due to the protocol that was established when the touchpad was made. This protocol is called PS2 and makes implementing a touchpad easy direct.



Figure 3.6.2 of Capacitive Trackpad/Touchpad

3.7 Wireless Communication

The smart phone powered laptop requires a means of communication to allow the contents of the smart phone to be displayed on the laptops LCD screen. The following sections will discuss each type of communication technology that was considered, it will also discuss the advantages and disadvantages of each technology and detailed explanation of how each technology operates. The technologies that will be discussed are the popular Wi-Fi module ESP8266 and the ZigBee wireless technology.

3.7.1 ‘Why use wireless technology?’

The main goal when designing the smart phone powered system is that it must be adaptable and easy to use. When researching on wireless technologies two options were considered: one was wireless, and the other was having a hardwire connection between the android device and MCU. The reason behind avoiding hardwire connection is that it would leave too many wires to deal with and also the fact that the PCB along with the wires will have to fit where the motherboard lies in the laptop, in this case opting to choose the hardwire connection would be a huge mistake since it can also lead to some confusion because of the large number of wires that will be required so rather the wireless option was chosen. The wireless technology is required for our project because one of the main goals is to show the contents of the android device on the LCD screen of our smart phone powered laptop. This task can be achieved by providing the MCU with Wi-Fi capability to construct a websocket. A detailed description of websocket technology will be provided in the software design section. In the following sections two wireless technologies will be covered which are the ZigBee Technology and Wi-Fi technology. Only one technology will be selected to be implemented in the design of the smartphone powered laptop.

3.7.2 ZigBee Technology

ZigBee is a low energy consumption WAN technology. It is a form of wireless communication technology that is suitable for short distance and low power consumption.

ZigBee supports high-level communication protocols used to create personal area networks with small low power digital radios for home automation, medical device data collection, and other low power bandwidth needs designed for projects on a small scale that require a wireless connection. ZigBee is restricted to WPAN (Wireless Personal Area Network) which ranges from 10 – 30 meters. The data transfer rate on the ZigBee is fairly slower than other Wi-Fi modules simply because of its low power consumption. The maximum speed in ZigBee networks is only 250kbps which is fairly low. To get into technical specifications the bit time which can be defined as the time taken to transmit one bit at a given data rate transfer is 4 microseconds for the ZigBee and only .00185 microseconds for Wi-Fi. Furthermore ZigBee technology is more useful when creating a personal mesh network which has no use in our project. Given the technical information discussed above ZigBee is not the optimal choice for our project.

3.7.3 Wi-Fi Technology

Wi-Fi technology uses radio waves (RF) to allow two different devices to communicate with each other. This technology in the modern world is used to connect internet routers to devices like computers, tablets, and smart-phones, it can also be used to connect two hardware components together. In our case the Wi-Fi technology will allow the communication between the Android device and the microcontroller. Wi-Fi is a local wireless network that runs of the 802.11 standard set by the institute of Electrical and Electronics Engineers (IEEE). Wi-Fi can utilize the global 2.4GHz and the 5GHz SHF ISM radio bands. However these Wi-Fi networks are extremely limited in range due to the transmissions of low power that allows the user to connect to a Wi-Fi network only within close proximity of the Wi-Fi router. Wi-Fi is very common in home networking applications and have to be secured with passwords for security purposes so that it cannot be accessed by a different user. Here are some advantages of using Wi-Fi networking.

- **Ease of Integration and Convenience:** This states that Wi-Fi networks allow the users to access resources from any location.
- **Mobility:** This states that users can access the internet outside their regular working environment.
- **Expandability:** This states that multiple users can access the Wi-Fi network using the same equipment.

However there are certain disadvantages to using Wi-Fi such as security problems, sometimes range is not sufficient enough to connect to a network, the speed of the network may vary from location to location. The biggest disadvantage of using a Wi-Fi network is that sometimes radio frequency and wireless networking signals experience a larger variety of interference whose effects are beyond the control of the network administrator.

In our design for the smartphone powered laptop the Wi-Fi technology will be integrated over the ZigBee technology in that ZigBee is very useful in the case where one wishes to implement a mesh network which allows different devices to communicate with each other over a personal area network. However, in our project we just simply need to microcontroller to establish a Wi-Fi connection, and once the Wi-Fi connection is established the Android device will also be connected to the same network in order to allow communication between the two. Using ZigBee technology for our project would

essentially be a waste because there are only two devices that are communicating with each other. Furthermore, when choosing a Wi-Fi module for our design, our options were found to be limited in that there existed only one module that would be highly compatible with an Arduino MCU. In the following section the technical specifications and a brief overview of said module will be discussed.

3.7.4 ESP8266 WI-FI Module

The ESP8266 is a popular Wi-Fi module that connects to the Arduino series MCU. A Wi-Fi module is a SOC (System on Chip) that is integrated with TCP/IP protocol stacks that allow communication between the MCU and the network that it will be connected to. The Wi-Fi module is being chosen over the ZigBee simply because the Bit time and the data transfer rate which allows up to 11Mbps to be transmitted. The ESP8266 fits in perfectly for our project because the one thing about Wi-Fi modules is that they can be used as stations that can receive and transmit data over an access point (Wi-Fi network). For our project the ESP8266 will act as a station where the android phone and Wi-Fi module will be connected to the same access point, the Wi-Fi module will act as a server receiving data from the client which is the android phone. Using that particular access point the android phone will transmit data to the Wi-Fi module with the help of websocket technology, the Wi-Fi module will then communicate with the MCU so that the data sent from the phone will be displayed on the LCD screen of our smart phone powered laptop. To display the data from the Wi-Fi module to the LCD screen the MCU will have an output cable HDMI or VGA which ever one that connects to the LCD controller board. The MCU will take the data from the Wi-Fi module and use the HDMI or VGA cable to display the data on the LCD screen. Below are figures: Figure 3.7.4.1 depicting the station mode and Figure 3.7.4.2 depicting access point mode for the ESP8266.



Figure 3.7.4.1 for Station Mode



Figure 3.7.4.2 for Access point mode

3.7.5 Bluetooth Technology

Bluetooth is a wireless short-range communications technology that is found in millions of products in everyday use. This technology is required for our project because the Bluetooth module is capable of sending commands to the android phone that are sent from the keyboard/Touchpad through the MCU. First the commands will be sent to the MCU, the MCU will then transfer that data to the Bluetooth module which will send the data to the android phone. Based on the current market and the progressing trend of the internet of things Bluetooth technology can be classified into two types' classic and low-energy Bluetooth. The classic Bluetooth has a high data rate transmission and is suitable for applications such as transmitting high quality music to a headset. Whereas the low-energy Bluetooth focuses on more simple information transmission hence the duration time of the low-energy Bluetooth is increased in comparison to classic Bluetooth. For this project the low-energy Bluetooth modules will be considered since the user of the smartphone powered laptop cannot be bound to power issues regarding the endurance time of the Bluetooth module. Several low-energy Bluetooth modules were researched for this project and only one was chosen of the merits of its protocols/standards, transmission distance, transmission rate, hardware interfaces, and frequency band.

3.7.6 Bluetooth Modules

The selected modules were researched HC-05 Bluetooth module, HC-06 RS232 TTL, BLE mini Bluetooth 4.0 low-energy module, Bluefruit EZ-link, and Bluefruit LE UART. In this section the selected modules will be discussed and then compared. Upon comparison the best choice for our project will be determined.

3.7.7 HC-05 Bluetooth Module

The HC-05 Bluetooth module is designed for transparent wireless serial connection using the SPP (Serial Port Protocol) which means connecting the Rx and Tx pins of the MCU and module together to establish a connection. This module allows two way functionality to any project it is applied to. It consists of two operating modes data mode and AT command mode. During data mode the Bluetooth module can send and receive data between two Bluetooth devices, while in AT command mode the default settings of the module can be customized. These two modes are altered between using the key pin on the Bluetooth module. The applications of this Bluetooth Module are wireless communication between two Bluetooth devices, data logging applications, consumer applications, wireless robots, and home automation. The technical specifications of this Bluetooth module are provided in Table below.

3.7.8 BM71 Bluetooth Module

The BM71 Bluetooth module is built embedded within microchip technology IS1871 low energy Integrated circuit (IC). The integrated circuit consists of an on board Bluetooth stack and a power management subsystem. It has two low power modes that are supported with wake up through general purpose input output pins or internal timer. This allows the Bluetooth module to independently maintain low power wireless connection in addition to offering low energy solutions for applications such as wearable devices, secure payment, health and fitness devices, and industrial data logger. This Bluetooth module uses the Bluetooth version 4.2 to enhance the throughput and security for applications related to internet of things also this module is capable of data transmission between Android and IOS devices. The technical specifications for this Bluetooth module are provided below in the following Table.

3.7.9 Bluefruit EZ-Link

This Bluetooth module also uses regular SPP (Serial Port Protocol) and is able to pair with a computer and Android Device however it is not able to communicate with an IOS device because they do not permit SPP pairing. Nevertheless this Bluetooth module can automatically detect and change the serial baud-rate which means that AT commands do not exist hence the option of customization does not exist since it supports all the common baud-rates. Also this module can be programmed directly using the Arduino Ide and does not require extra software or custom hardware.

3.7.10 Bluefruit LE UART

The Bluefruit LE UART is a very friendly module that is compatible with many microcontrollers. In our project it will be connected to the Arduino ATmega 2560 ADK. This is a multifunction Bluetooth module which is capable of communicating with other Bluetooth devices using the basic UART communication protocol which involves connecting the Rx and Tx pins from MCU to Bluetooth module. In addition this module offers software and hardware flow control that help prevent data loss during data transmission between two BLE devices. This Bluetooth module is one of many that offers

full control and customizability to the user through the use of AT commands. Similar to HC-05 Bluetooth module Bluefruit LE UART also consists of data mode for data transmission between an Android device and Bluetooth module. It also allows for manipulation of the GATT services and characteristics. GATT services are units in which the data is organized to be exposed to other devices, also at least one of the GATT services must be initiated to allow data transmission. GATT is shorthand for Generic Attribute profile which defines the way data is transferred back and forth between two low energy devices using concepts like services and characteristics. However once the Bluetooth module is connected to a device it will stop advertising itself to other low energy devices. The technical specifications are provided in the Table 3.7.9.1 below.

Table 3.7.9.1 Technical Specifications

Specifications				
SPECS/ Modules	Bluefruit LE UART	HC-05	BM71	Bluefruit EZ Link
Operating Voltage	5V	4 V – 6 V	1.9 V – 3.6 V	3.3 V – 10VDC
Communication Protocol	UART	USART, TTL	USART, UART, PWM	UART
Manufacturer	Aidafruit	Itead Studio	Microchip Technology	Aidafruit
Cost	\$ 17.50	\$ 2.30	\$ 4.18	\$ 22.50

3.8 Bluetooth Module Selection

As mentioned above in the Bluetooth technology section there were four Bluetooth modules selected for research Bluefruit LE UART, Bluefruit EZ-Link, HC-05, and BM71. Out of these four modules only one will be selected to fit the design of the smartphone powered laptop. Let's start with BM71 this module is part MCU with an embedded BLE module. This part is the most powerful part in the selection and is used or very complex applications, although it cannot be a part of the smartphone powered laptop design because if this part was to be used it will only be performing at its bare minimum. The extra features like 5 channel ADC (Analog to digital convertor), and the 18 general purpose input and output will never be touched. Although this Bluetooth module is very cheap compared to others listed it will never be used to its full potential. The second module that was crossed off the list was the Bluefruit EZ-Link. The reason this module cannot be used is because this part is discontinued by Aidafruit industries even though this module was the optimal choice for the design simply because of the automatic adaptation of baud rate. The baud rate is what signifies how fast all the bits are being transferred from one device to another hence this device is automatically adjusting the baud rate based on the device it is connected to was a huge factor in picking this part but it has been discontinued. The third choice HC-05 was omitted simply because there was not enough example material online on how to send keyboard and touchpad commands from this module to the Android device. Since all the above modules have been omitted the Bluefruit LE UART is the last one standing. The Bluefruit LE UART consists of an ARM Cortex M0 core which runs at

16MHz with a 256KB flash memory and 32KB SRAM. The transportation mode utilized is UART which has a baud rate of 9600 with hardware flow control. Again this device was chosen because of its popularity with the Arduino series MCU's along with online material that describes how to make a connection to the MCU and transmit or receive data. This Bluetooth module is one of the most important tool required to establish communication between the android phone and keyboard/ touchpad of the laptop. The Bluefruit LE UART will run on low power mode so it can access the UART/Data mode. Below in figure 3.8 is a picture of Bluefruit LE UART Module.

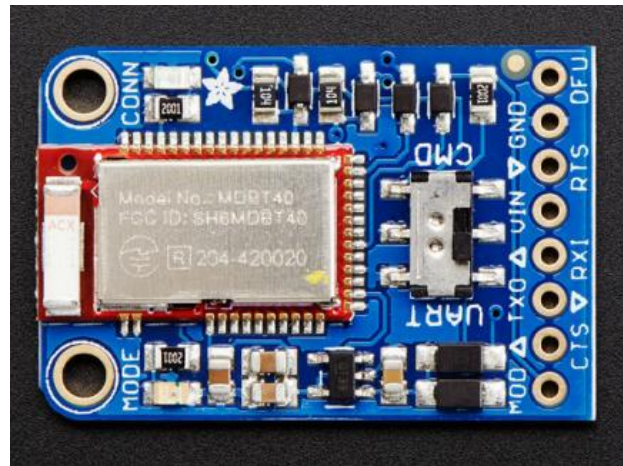


Figure 3.8 Bluefruit LE UART

The specific UART pins that are going to be used are the RTS/CTS. RTS stands for (Request to Send) and CTS for (Clear to Send). These two lines allow the receiver and the transmitter to alert each other to their state. A transmitter raises its RTS line which causes an interrupt on the receiver to ask if more data can be sent. If more data can be sent then the CTS line will be raised meaning that more data flow can take place. The CTS will be used for sending the data from the MCU to the Bluetooth module also this pin is set to high by default so it must be set to ground in order to enable the data transfer. The main reason for using the RTS and CTS pins are because of the data loss prevention.

3.9 Generic Attribute Profile

As explained in the above section the importance of Generic Attribute Profile (GATT) which defines the process for two Bluetooth low-energy devices to transfer data back and forth. The data transfer is achieved by using concepts called services and characteristics, which utilized a generic data protocol called Attribute Protocol (ATT) that allows the storage of services, characteristics, and data in a table using 16-bit ID's for every entry. GATT is utilized once a connection has been established between two devices, which states that the advertisement process which allows two low-energy devices to see each other prior to connection is terminated since two devices already established a connection. In this section the connected network topology will be discussed which explains how Bluetooth low-energy devices perform in a connected environment along with GATT transactions which will explain the Client/Server relationship with the use of services and characteristics.

3.9.1 Connected Network Topology

This section will explain the process of how Bluetooth low-energy devices work in a connected environment. A peripheral device can only establish connection to one central device but the central device can establish connections with multiple peripheral devices. In our case the peripheral device is the microcontroller and the central device is the Android smart-phone. Once a connection is established between the microcontroller (peripheral device) and the Android smart-phone (central device) the communication can take place in both directions, but for our project we only need one way broadcasting approach since the microcontroller is taking commands from the keyboard and touchpad and using the Bluetooth module to send those commands to the Android smart-phone. Given below is a figure that illustrates the above explanation.

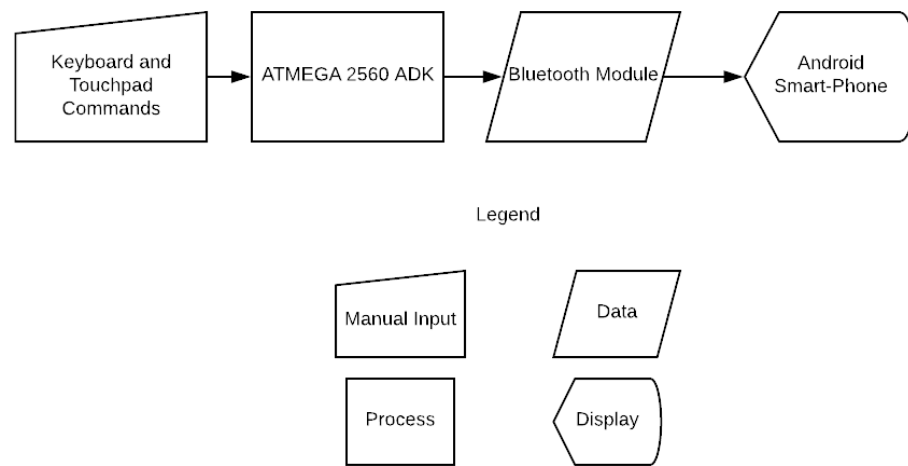


Figure 3.9.1 Network Topology

3.9.2 GATT Transactions

GATT transactions focuses on the client/server relationship between two Bluetooth low-energy devices. In our case the microcontroller connected to the Bluetooth module will be the GATT server which consists of the Attribute protocol (ATT) containing data, service and characteristics definitions and the Android smart-phone will be the GATT client that sends requests to the server. The data exchange process is initiated by the GATT client which receives responses from the GATT server. The whole data exchange processes is carried out in intervals which are called connection intervals. This whole process is carried out in a master slave configuration where the client is the master and server is slave so in a connection interval the client sends request for data and the server responds by sending data. It is crucial to keep in mind that the data transfer can only take place in the connection interval because the interval is what defines which peripheral is sending data to the central device. These GATT transactions are based on objects which are called profiles, services, and characteristics. Each transaction consists of a profile, the profile consists of several services and each one of the services possess a different characteristic. Services are used to break up a set of data and the specific chunks of the divided data are called

characteristics. A service may consist of different characteristics but each service is different from other services based on a numeric ID called UUID. Similar to services each characteristic is different based on a pre-defined UUID.

In conclusion the GATT transaction process is how the data is transferred from the peripheral (MCU connected to Bluetooth) to the central device (Android smart-phone). First the entire set of data is taken then broken down into logical entities using services but these logical entities consist of certain chunks of data called characteristics which encapsulate a single data point and through this data point the central device can interact with the peripheral to read or to write data. In our case the Rx and Tx pins on the Bluetooth module are characteristics that are used to receive and transmit data between the microcontroller and the Android smart-phone.

3.9.3 Sentio Desktop Software

The software we are going to use to simulate a windows like environment on our laptop through the android operating system is called “Sentio Desktop”. It is free and available through the google play app store from a Los Angeles based company named Sentio. The software is compatible with any android device regardless of manufacturer. The current version of software available in the google play store has amassed over one million downloads. Below we have listed all of the most prominent features available.

3.9.4 Home launcher

Setting Sentio as your primary launcher is fairly tedious, but the benefits are tremendous. As a launcher, Sentio is empowered with new abilities that help you work better. Sentio will proxy your preferred launcher when you don’t want to use the desktop environment, so it will still feel like your normal phone. As your primary launcher, Sentio will convert your home button into a “Show Desktop” button. Don’t worry, you can always exit Sentio by looking at the Task Bar, clicking the Settings icon, and clicking Logout. The next benefit of being your launcher is unlocking the right click menu. It adds quick actions via right click and is a great feature for productivity. Setting Sentio as your home launch takes several steps. First, when Android asks who to use for your home launcher, select Sentio and click “Always”. Don’t worry, you can always change this later under the Android Settings if you change your mind. Then select the preferred launcher you want to use when not inside the desktop environment. This is typically your previously selected launcher. Limitations: Not all custom Google shortcuts will work; many were not designed for the multi-window environment. Secondly, Sentio does not have control of the apps that are opened with these shortcuts. Any crashes or bugs that happen are due to the app’s inability to operate in multi-window mode.

3.9.5 Right click menu

Most of the icons in the Sentio Desktop have a right click menu associated with them. This menu is triggered with either a right mouse click or a long press. Each one has a unique menu that is contextual to the use case. If you are on Android 7.1 and above, you also get custom app shortcuts! Limitations: The right click menu is a compelling feature of the Sentio Desktop, but it only works inside of Sentio. It cannot be added to the other apps on your phone.

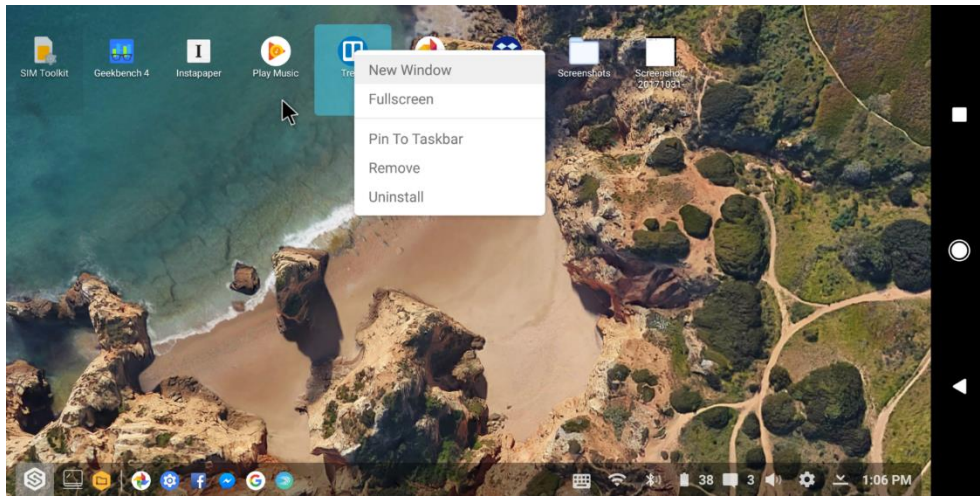


Figure 3.9.3.2 of Right-Click Menu

3.9.6 File hyperlink

With the Sentio File Explorer, you will be able to put your favorite files and folders right onto your desktop. Finally! Proper file management on Android! You will have all the same functionality as if you are opening the file/folder from the File Explorer. Limitations: We are still building file editing on the Sentio Desktop.

3.9.7 App Chooser

The Sentio App Chooser is a beautiful redesign of the original android App Chooser. We added several smart features to make your productive life a bit easier. We have added a new “Open With” option under the right click menu. You can easily switch the default app for different files and select which app to use at that time. The Sentio App Chooser gives you the ability to create a sub-list of apps that you want to see when open different file types. You can hide the ones that you do not use and change the list as you install new apps on your device. E.g. Hiding Alipay from the list of apps that can open a photo. Once hidden, they won’t show up in your “Open With” list unless you click “See all apps”. Limitations: The Sentio App Chooser will only work while opening apps within our desktop environment. For now you will only see this UI within Sentio Desktop and File Explorer.

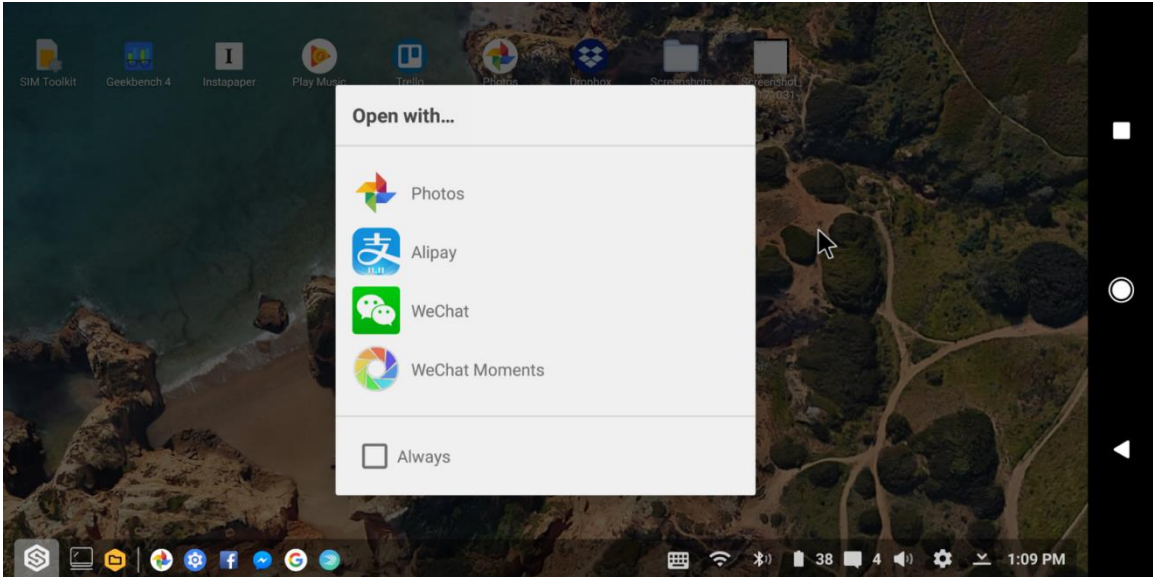


Figure 3.9.3.4 of App Chooser Menu

3.9.8 Wi-Fi

Sentio allows you to quickly change your Wi-Fi within the app. Here, you can connect, disconnect, toggle, and see more info on all of the wifi networks without ever needing to leave Sentio. Limitations: We currently only support basic connection types. More complicated configurations must go to the Android Settings.

3.9.9 Bluetooth

Sentio also allows you to quickly change and connect to different Bluetooth devices. You can save or remove Bluetooth devices once connected. Limitations: Bluetooth on Android differs by device. Some devices have difficulty connecting and may even error. Sentio works hard to account for all of these nuances, but sometimes it is beyond our ability to fix. In these cases, you should use Android's Bluetooth Settings.

3.9.10 Auto Force Close Third-Party Apps

One of the limitations of Android is that once an app is full screen, it cannot go back to a multi-window without being closed first. To solve this, Sentio has the ability to force close these apps, but only if you want to do so. This setting is found under All Settings in the Sentio Settings Panel. Auto closing apps allows Sentio to open the Android Settings screen and click "Force Close" on the app. This way, the next time you launch the app, it will be able to open in multi-window mode. If the feature is disabled (default state) then you will see the action button on the left. The yellow minus—button means that the app will minimize and the user will go back to the desktop. The red x button means that the app will be force closed when you click the button and you will be brought back to the desktop. Limitations: At times, the force close becomes stuck. This happens when Sentio cannot find the correct screen to force close in Android Settings. This feature is intended to help

you automate the force close process. Ideally, we would like to close the app, but there is currently no API to do so.

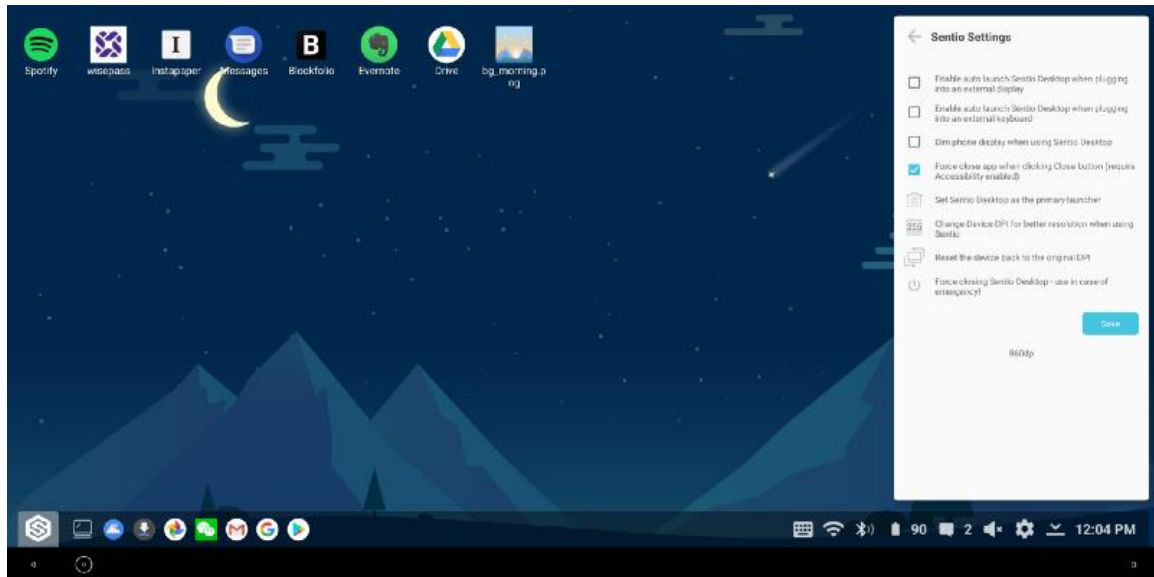


Figure 3.9.6 of Auto Force Close Setting

3.9.11 Force Close Sentio Desktop

Another feature is the ability to force close the Sentio Desktop. Think of this as the Ctrl+Alt+Del on Windows. Note that this is different that auto force closing third-party apps. You can find the force close button at the bottom of the Sentio Settings panel. This will kill the app process. It will completely restart the Sentio Desktop, just like Force Close in the Android Settings. Limitations: This does not always fix all of the potentially strange or weird state. This only fixes Sentio Desktop, but does not extend to other apps on your device. For other apps, you will need to go into the Android Setting screens and click Force Close. In the worst case, you may need to reboot the device.

3.9.12 Pinned Apps/Recent Apps

Every app in Sentio can be pinned to the task bar. This gives a super quick way for users to access their favorite app whenever they want. To unpin an app- just right click and remove! A pinned app functions more like an app from the desktop or start panel. Alternatively you can drag and drop the apps to the task bar and it'll automatically add to the pinned apps as well. This feature is built for the users who don't have a mouse and does not want to long click all the time. The recent apps shows you all the recent apps that's been opened. The recent apps need to be enabled for this to work. You can enable the recent apps through the Sentio setting panel or by right clicking the task bar. When you enable the feature, you'll need to grant Sentio data usage permission so that it queries the recent apps. Limitations: You have a limit of 7 apps for both pinned apps and recent apps. Sentio can't show active apps because android doesn't allow that functionality anymore. This also means the custom Sentio task manager that we use to have had to be removed.



Figure 3.9.8 of Alt-Tab Menu

3.9.13 Alt + Tab

Sentio allows you to use the key combination Alt + Tab to open up a list of recent apps. This will show you the same apps as our recent apps on your task bar. The great thing about alt tab is that it allows you to quickly switch between apps using keyboard shortcuts. You can use your mouse to select the app or go through them using Alt + Tab or Alt + Shift + Tab. To enable Alt + Tab experience, all you have to do is go to the settings panel and give us the associated permissions that we need. Give it a try and see how much your productivity improves by. Limitations: Sentio can only show recent apps because of the previously stated reasons. Alt + Tab needs accessibility permission because it will give us the ability to see keyboard events. We won't use the keyboard events to for anything malicious. For some phones, accessibility permission messes up with some interaction with Sentio because there are so many system things going on all at once.

3.9.14 Change keyboard

In Sentio, you can directly change the keyboard you use. This allows you to type in the language and setup you want. The biggest benefit of keyboard change is that when you plug in a hardware keyboard, you can immediately turn off virtual keyboard. This means you can take back half your screen space when you're now working and typing away. Limitations: Sentio can't help change language of the same keyboard that easily.



Figure 3.9.14 of Change Keyboard

3.10 Bluetooth Low energy

There are multiple technical standards from today's modern technologies involved in our project. To connect both our keyboard and touchpad to the phone we will be using Bluetooth technology, specifically Bluetooth low energy. The Bluetooth Low Energy (LE) radio has been designed and optimized for very low power operation. To enable stable and reliable operation in the 2.4 GHz frequency band, it leverages a frequency-hopping spread spectrum approach that transmits data over 40 different channels. The Bluetooth LE radio provides developers a good amount of flexibility, including many PHY options that support data rates from 125 Kb/s to 2 Mb/s, multiple power levels, from 1mW to 100 mW, as well as multiple security options up to government grade for those who need it. Bluetooth low energy makes for an ideal choice for our project being that it is battery operated and that both our keyboard and touchpad will not be in constant use, making good of on of BLE's main notable technology improvements, sending data in bursts when in use.

3.11 Wifi Direct Technology

Another modern technology made very useful in our project is wifi direct. This technology was crucial for our project because one of our goals was to be totally wireless and bluetooth is incapable of transmitting data at the bandwidth needed for a high resolution display. This is where WiFi-Direct fit perfectly into our project. Wi-Fi CERTIFIED Wi-Fi Direct® is a certification mark for devices supporting a technology that enables Wi-Fi devices to connect directly, making it easy and convenient to do things like print, share, sync, display and much more. Any product bearing the Wi-Fi Direct certification mark can connect to one another without joining a traditional home, office or hotspot network. This will be used to connect our android smartphone's display to our pcb design, which will output that image to our laptop screen.

3.12 Android Operating System

Android is a popular mobile operating system developed by Google, based on a modified version of the Linux kernel and other open source software which was designed mostly for any touchscreen mobile device such as a smartphone, tablet, or television. In addition, Google has now further developed Android Auto for cars, Android TV for televisions, and Wear OS for smart watches, each with its own customized user interface. Different versions of Android are also used on small game consoles, digital cameras, laptops, and other assorted electronics. This operating system was actually initially developed by Android Inc., which Google bought back in 2005, Android was unveiled as a google product in 2007, with the first commercial Android device launching in September 2008. The operating system has gone through many major releases, all of them being named alphabetically, with the current version being 9.0, known as android "Pie", released in August of 2018. The core Android source code is also known as Android Open Source Project (AOSP), and is primarily licensed under the Apache License Group. Android is also associated with many other versions of the proprietary software developed by Google, called Google Mobile Services that most often comes pre-installed in devices, which usually includes the Chrome web browser and Google Search and always includes core apps for services such as Gmail, as well as the application store and digital distribution platform Google Play, and associated development platform. All of these apps are individually licensed by manufacturers of Android devices certified under standards imposed and enforced by Google, but AOSP has been used as template for most of competing Android ecosystems, such as Amazon.com's Fire OS, which uses their own equivalent to Google's GMS. Android has been the best-selling operating system worldwide on smartphones since 2011 and on tablets since 2013. As of May 2017, it has over two billion monthly active users, the largest installed base of any operating system, and as of June 2018, the Google Play store features over 3.3 million apps.

3.13 LCD Power Design

In order to supply power to an LCD, several components are needed to operate the LCD. The components are as follows: inverter board, on/off buttons, LCD controller board, and LVDS cable. The sections below will go into more detail about each component required to power an LCD, as well as explain the theory and function behind an LCD.

3.13.1 LCD Inverter Board

An LCD inverter board is a device used to convert DC voltage to AC voltage. The board has 4 basic functions: VIN (input voltage), GND (power ground), ENA (ON/OFF), and ADJ (dimming control). If there is no label on the PCB board to what pin is what, then a multimeter inspection must be done to determine each pin. Locate the surface mount fuse (SMD) and measure the resistance from the fuse to the input connector pins. The resistance will be zero ohm. This is the power ground pin.

3.13.2 LCD Controller Board

A controller board comprises of hardware used to display images on the LCD screen and provides the appropriate communication to drive backlight on the LCD. The controller

board is connected directly to the LCD and inverter board. As stated before, the LCD panel requires AC voltage, which is why the inverter board is needed. In order to understand how a controller drives an LCD, one must understand what an LCD is comprised of and several key terms. The LCD glass is comprised of two polarized filters, between that are two electrodes, and between electrodes is the liquid crystal. When a low electric field is passed, the molecules in the liquid crystal form a helical structure, which induces a rotation in the first polarizer. From there, the light is passed through the second polarizer and reflected to the viewer. When a large enough voltage is applied the molecules in the liquid crystal realign, so there is no rotation in the polarization through the second polarizer, which means the polarizer cancels out the light coming in, also seen as black or nothing. Therefore, the controller controls the voltage going into the LCD panel.

3.13.3 Low Voltage Differential Signaling (LVDS) Cable

LVDS cables are used when dealing with low voltage signals, which mean they operate at low power. LVDS cables operate with respect to the difference between the voltages on a pair of wires and then compared at receiver. A transmitter or driver sends current through one wire. Between the cables and receiver there is a terminating resistor that allows current to flow through the resistor and back in the opposite direction through the second wire. From ohm's law the voltage can be determined at the termination resistor. At the terminating resistor is the receiver, which senses the polarity of the voltage. Due to the tightly coupled wires and constant current in opposite direction, the magnetic fields cancel each other out, which result in low noise. Also, common mode noise is nonexistent due to the differential voltage.

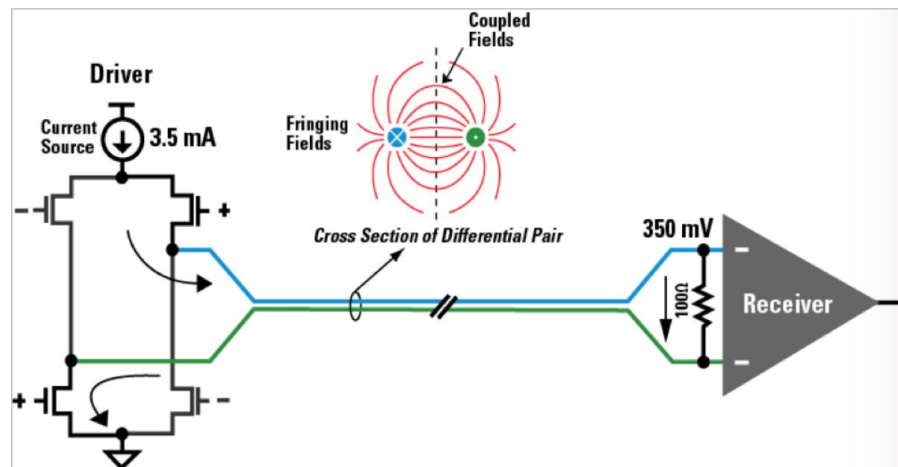


Figure 3.13.3: Typical LVDS Schematic

3.14 Wireless Charging

Wireless charging uses the concept called inductive charging. Inductive charging is the transfer of energy through inductive coupling. In order to create inductive coupling, one must use an inductor, which creates an electromagnetic field when a current is flowing through the coils. This idea is not new; however, it has become more profound in the consumer technology market.

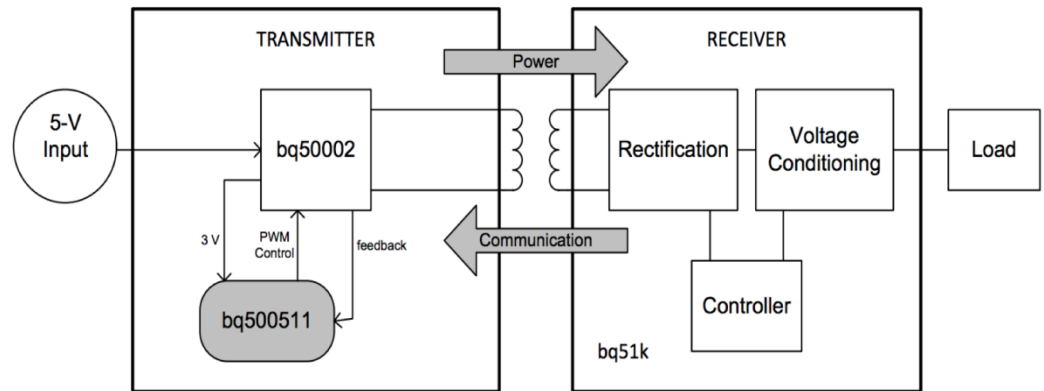


Figure 3.14: Block Diagram for TI's Chip

3.14.1 STMicroelectronics

STMicroelectronics provides a digital controller that is Qi compliant with all of the appropriate ratings. However, this company does not provide a typical application circuit to build, which means there are not graphs or numbers that describe what this chip can do. For example, efficiency and output current are not given, and must be determined. This approach is not reasonable, and requires more time than we have. However, there are other companies that provide circuits and all necessary information.

3.14.2 Integrated Device Technology

IDT provides all the appropriate ratings, a typical application circuit, and Qi compliance. All of which are necessary to develop a wireless charger. Furthermore, IDT provides integrated current sense, over-current protection foreign object detection (FOD), input over-voltage protection, and I2C communication. While, IDT provides enough information to build a wireless charger, Texas Instruments provides a circuit with fewer components.

3.14.3 Texas Instruments

TI has everything IDT has and more. TI provides two chips that will be used in the implementation of the wireless charger, which means less board space. The two components are a controller and analog front end chip. Texas instrument integrates many features into their circuit to provide the user with the most efficient and safe design. Some key features include analog front end, ultra-low standby power, Dynamic Power Limiting (DPL) TM, system LED indication, trickle charge, I²C, and foreign object detection. The *Table* below shows a comparison of all the possible wireless charger companies.

Features	Texas Instruments (BQ50011)	STMicroelectronics (STWBC)	Integrated Device Technology (P9038)
Foreign Object Detection (FOD)	✓	✓	✓
Ultra-Low Standby Power	✓		
Dynamic Power Limiting (DPL)	✓		
System LED indication	✓	✓	✓
Trickle Charge	✓		
I2C	✓	✓	✓
Analog Front End Chip	✓		
Typical Circuit	✓		✓
EEPROM		✓	✓
UART		✓	
Qi Standard	✓	✓	✓

3.14.4 Why TI's Chip was Chosen

As seen in table above, TI's chip has more features than the other two companies. Not shown in the table is board space or how many components are required to build the circuit. In TI's case they included the bq50002 chip, also known as the analog front end chip, which communicates to the bq50011 chip, known as the controller. With the addition of bq50002, all the analog components are integrated into this one chip, reducing the schematic size and components required to build the circuit.

Design features in BQ50002:

- Voltage sense
- Current sense
- Temperature sense

- Voltage peak sense
- LED mode selection
- Foreign object detection threshold
- Foreign object detection calibration

All these sensors communicate with the controller. Moreover, analog front end chip provides a full bridge power stage to drive the primary coil with higher efficiency and power for a given voltage.

3.14.5 Voltage Sense

Voltage sense is used with foreign object detection function to calculate power, and to detect a weak voltage when the bq50011 is receiving power. Used to detect voltage at the primary coils. Also used with the foreign object detection function to detect loss in power.

3.14.6 LED Mode Selection

LED modes are used to indicate operational status to the user. There are 10 different types of modes that can be implemented to drive three LEDs.

3.14.7 Foreign Object Detection Calibration and Threshold

FOD is used to prevent heating of metal objects from the coils. When losses exceed a threshold, which is tested and set by the user, a fault is set and power is stopped. Calibration is used to determine a normal amount of losses, and set accordingly depending on a test with no foreign object.

3.14.8 BOM Wireless Charger

Table 3.14.8 – Bill of Materials

Manufacturer	Part Number	Qty.	Price (\$)	Description
Wurth Electronics Inc.	760308111	1	0.29	TX 1 Coil 1 Layer 6.3uH 13A
TDK	BQ500511RHAT	1	0.31	IC Wireless Transmitter
Vishay-Dale	BQ0002RHBR	1	0.56	IC Wireless Transmitter

3.15 Voltage Regulators

A voltage regulator provides a consistent/controlled DC voltage at the load, given a variable input voltage. This can be used for the wireless charger, LCD, touchpad, and track pad. All components need a certain input voltage; therefore, this is how to go about solving that problem. Moreover, voltage regulators work by using a feedback loop that compares

the output voltage to the input voltage. If the output is not achieved, the input is amplified to achieve regulation. Furthermore, there are two types of voltage regulators, switching and linear voltage regulators. The content below will explain further about both regulators.

3.15.1 Linear Voltage Regulator

A linear voltage regulator takes in a variable input voltage and outputs a low noise DC voltage. Usually, linear voltage regulators require a high input voltage to achieve a certain output voltage, which results in low power efficiency. This is achieved by using a closed-loop feedback system, which uses a voltage reference and feedback control to achieve a desired output. In order to understand how a linear voltage regulator works, one must understand the four components that make up the regulator, which are shown in *Figure 3.15.1*. The four components are internal reference voltage, pass element or Darlington transistor shown in *Figure 3.15.1*, error amplifier, and feedback voltage divider.

First, the pass element or Darlington transistor provides current to the error amplifier, which is controlled by the error amplifier. The error amplifier compares the feedback voltage to the reference voltage. If the output voltage is less than the referenced voltage, then the error amplifier allows more current to pass through the transistor. However, if the feedback voltage is greater than the referenced voltage, then the error amplifier limits the amount of current passing through the transistor.

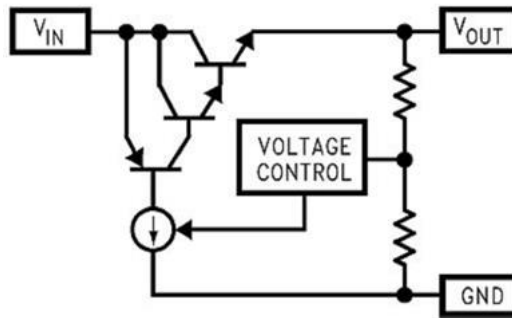


Figure 3.15.1-
Linear Voltage Regulator showing Darlington Pass Element

3.15.2 LDO Voltage Regulator

Another type of linear voltage regulator is a low dropout linear regulator (LDO), which uses an input voltage that is close to the output voltage. There are two main advantages to LDO's. The first advantage is that LDO's have a higher efficiency due to a lower supply voltage. The second advantage is that LDO's are low noise devices even when the input has high noise. The figure below shows a closed-loop feedback network that allows the input voltage to be independent from the output voltage, due to the reference voltage. The only difference between a linear voltage regulator and an LDO voltage regulator is the pass element. An LDO voltage regulator uses a one transistor, while the linear voltage regulator uses a Darlington transistor.

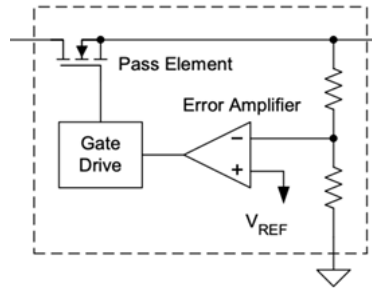


Figure 3.15.2 - Linear Voltage Regulator (LDO) w/ Closed-Loop Feedback

3.15.3 Switching Voltage Regulator

A switching voltage regulator works by taking chunks of energy from the input voltage, and sending it to the output. In order to do this, an electrical switch and controller are used to regulate the transfer rate of energy to the output. By doing this, energy is conserved by sending chunks of energy in a switching manner. In fact, switching regulators are much more efficient than linear regulators, and are proven to typically have around 85% efficiency. Since efficiency is the amount of power out divided by power in, this means switching regulators can power lower powered devices with very little loss, from a high power input. Moreover, switching regulators can also step up and step down voltage, where linear voltage regulators cannot.

3.15.4 Transformer Operation

Before talking about step up and step down switching regulators, one must understand the operation of a transformer. Transformers are two inductors that are magnetically coupled. The voltage and current depends on the number of windings in the primary and secondary side. If the primary side has a lower number of windings than the secondary side, then this is called a step transformer. Due to the fact that no power is gained, the secondary side with the higher voltage will have a lower current.

3.15.5 Buck Converter (Step Down)

According to Texas Instruments, Buck converters are the most commonly used switching regulators. The idea of a buck converter is to step down an input DC voltage to a lower output DC voltage of the same polarity. This type of converter is used in many electronics devices, such as phones, laptops, battery chargers, and brushless motors. For example, battery chargers are usually used for a long time depending on how long the device needs to be charged. A buck converter regulates the voltage into the phone and limits the current accordingly, with very minimal power loss or minimal heating. In a simple buck converter is shown. The transistor acts as a switch, which connects and disconnects the input voltage to and from the inductor. When the switch is connected, the inductor and input voltage are now in a closed loop. The difference between the input and output voltage across the inductor, creates a current flow that increases. When the switch is disconnected, the input is no longer connected to the inductor. However, since current cannot change instantaneously in an inductor, the voltage across the inductor will change to hold the current constant. However, if the voltage across the diode is not equal to the turn on voltage, no current will flow until that voltage is reached. Due to the decreasing current, the voltage

turns negative. Once the turn on voltage is reached across the diode, current begins to flow through the diode and back through the inductor, capacitor, and load. Finally, the capacitor discharges during this time when the switch is disconnected. Therefore, this process of turning the switch on and off creates a ripple output current effect at the load, which is shown in *Figure X*. Lastly, pulse width modulation control, can be used to digitally control the output voltage to the load. Pulse width modulation is used in a feedback loop, where PWM controls the ON time of the transistor.

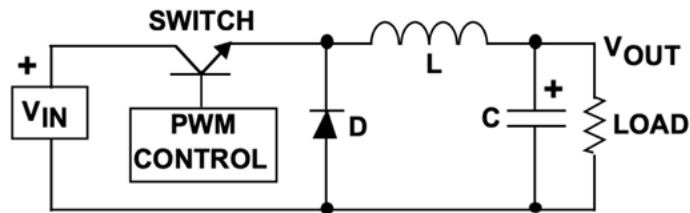


Figure 3.15.5 - Buck Converter

3.15.6 Boost Converter (Step Up)

A boost converter is another type of switching regulator that steps up DC input voltage to a higher, DC output voltage. In this case, the circuit is very similar to the buck converter; however there are some minor changes. In *Figure 3.15.6*, a circuit of the boost converter is shown.

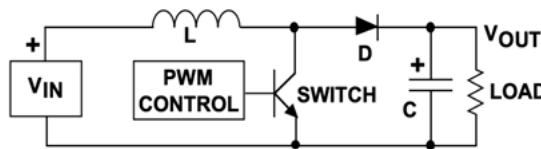


Figure 3.15.6 - Boost Converter

When the switch is ON or connected, the inductor experiences a voltage across it from the input voltage. The voltage across the inductor produces an increase in current through the inductor.

When the switch is turned OFF or disconnected, the current in the inductor begins to decrease. The diode is then turned on due to forward bias from the inductor, and current continues to pass through the capacitor and load. The capacitor then charges up to a voltage that is higher than the input voltage, which creates a step up in voltage.

The output current will always be less than the input or switching current because the input voltage is less than the output voltage, and no power is gained in a transformer.

3.16 Human Interface Device (HID)

As many people know, there used to be a multiple types of connectors before the USB came around. For example, a mouse two decades ago required a PS/2 connector and a printer required a big DIN connector. Using multiple connectors could become a hassle and take up more space than what is needed, which is why people needed something that would be universal. Space is not the only reason why PS/2 and DIN connectors were

replaced. In fact, data was another common issue because different drivers needed to be installed to the computer in order for the device to be compatible with the host. This is why a standard was developed to make connecting to peripherals easier. The next section below, talks about USB as an human interface device and how the communication is made with the host.

3.16.1 USB HID Interface

USB HID interface is shorthand for USB human interface device. USB HID is a type of device class for computer peripherals such as a mouse, keyboard, and even Bluetooth. From now on, I will be using HID as another way to say USB HID, as they are the same.

3.16.2 HID Protocol

The HID protocol consists of two factors, that generalize how the user and computer interact with the device. The two factors are “host” and “device”. A device is what humans interact with, such as a keyboard or touchpad. The host is what communicates to the device, by receiving information from the user is doing, with respect to the device. In fact, one can consider the PC as the host to the devices in the examples previously stated. In *Figure X*, a block diagram shows how the USB device interfaces with the PC.

When a device communicates with a host, certain procedures happen to make a successful communication. When a device sends data to a PC, the data travels to an endpoint [C6]. From there, the PC knows that information is being sent over through data packets or descriptors from the device. A descriptor basically has all intermediate information about the device, such as the device’s capabilities. If the descriptors do not follow a certain format, then the device is incompatible with the PC and information cannot be sent through USB.

On the other hand, if a device is compatible and has all the appropriate descriptors, then what happens next? Well, a descriptor is a form of memory and contains bytes. The length of the descriptor is described in bytes, which includes the byte that stores the length. The next byte is the type of descriptor which allows the host to read the rest of the data form the descriptor.

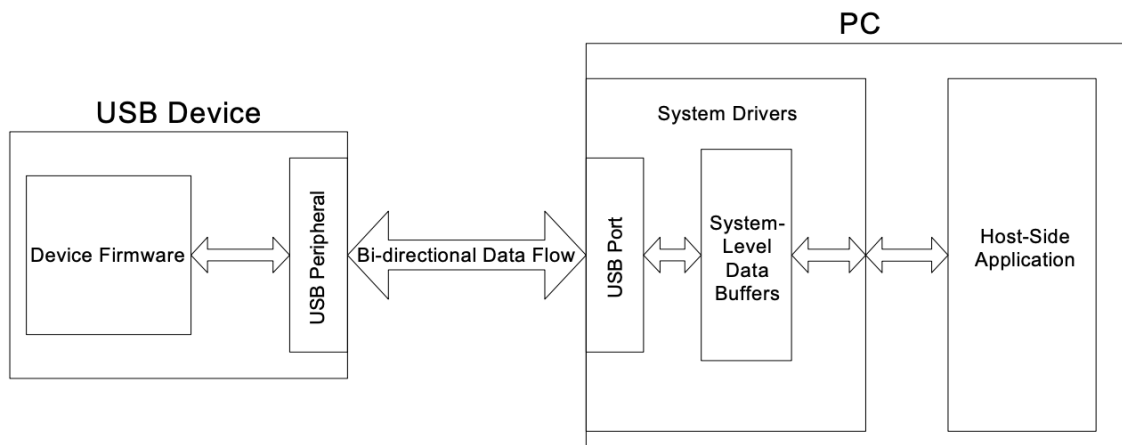


Figure 3.16.2: USB Interface with PC

3.17 Synaptics Touchpad

In a computer, there are two protocols to connect a touchpad to a computer. The first way is through PS/2 and the second way is through USB. In this case, our touchpad requires a PS/2 interface. While the serial number on the touchpad does have the letter “P” in the code, that does not mean the touchpad cannot use a PS/2 interface to communicate with. Furthermore, most Synaptics touchpads use PS/2 to communicate, which means a simple USB to PS/2 adapter can be implemented to achieve an easy connection. In the figure below, one can see that each letter and number from the serial number has its own unique feature that corresponds to the touch pad. Due to the fact that the picture in *Figure 3.17* below, was last revised in 1998 means that the serial configuration has definitely changed since then. The touchpad that is used in this project has a similar serial number, however it does not match the one shown in the figure below, and there are now files online that describe the newer serial numbers. The touchpad used in this project is from an Asus G50V, which was released in 2008. Nevertheless, the touchpad uses PS/2 to communicate. In *Figure 3.17* one can see the classification of the serial number for an older Synaptics touchpad. The most important letter in the serial code is the host protocol.

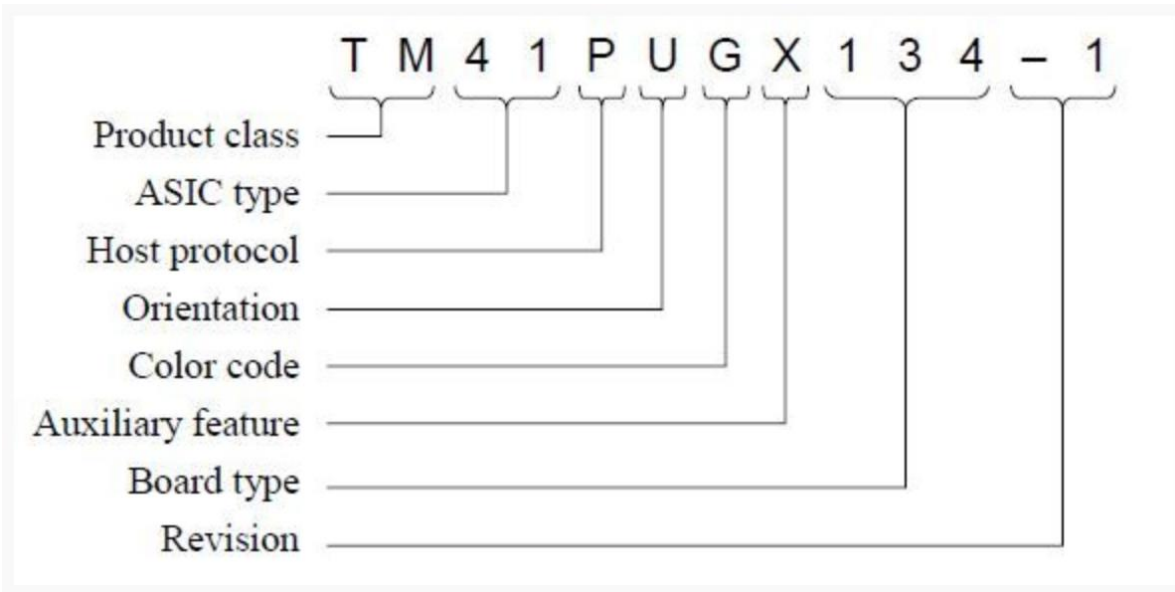


Figure 3.17: Serial Number Classification

3.17.1 Electrical Interface

As said before, the Synaptics touchpad uses a PS2 communication protocol. PS2 consists of two bidirectional wires, called clock and data, as well as a power and ground. Usually older PS2 Synaptics operate on 5 volts, however the touchpad used in this design is a newer model, which will operate at 3.3 volts. The clock and data lines operate as an open collector signal, where the signal is held high when there is no input. This is done by using a pullup resistor between the transistor and Vcc. However, when there is an input or “1” state, the transistor sinks the signal to ground, creating a “0”. In the transistor is not shown, because

it's not part of the design, however it is part of the circuit, and plays a big role by acting as a switch to ground. In fact, the Synaptics touch will be programmed to operate as such, which includes manipulating the clock and data to receive and send data. This is discussed in the later section, "*Touchpad Communication*". Another note to make is how the left and right buttons operate in the circuit. When the button is pressed, the switch is closed and the connection is grounded. When the button is open, nothing happens.

3.17.2 Byte Transmission

Before programming the communication between the Arduino and Synaptics touchpad, byte transmission must be considered. There are 11 bits of data that are used in transmitting data between the host and device. The first bit is the start bit with a "0" logic, next is eight data bits with least significant bit first, after that is a parity bit (odd parity), and lastly a stop bit with a logic "1" value. After that, one can find the bus in one of three states, which are Idle, inhibit, and request to send. All three states are used in the program very frequently, which will be described in more detail in the later section, "*Touchpad Communication*".

Each state plays a unique role and the all the states are as follows:

- Idle - When clock and data are high, nothing is happening.
- Inhibit – Host pulls clock low, data will be pulled high to inhibit communication.
- Request to send – Host pulls data low, then releases clock. Ready to transmit state.

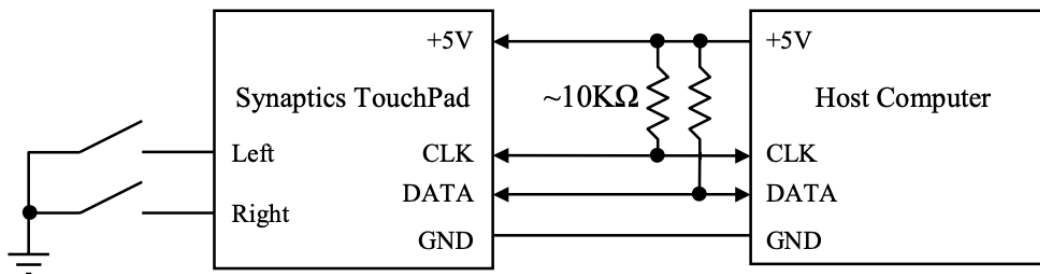


Figure 3.17.2: PS2 Communication

3.17.3 Command Modes

The last section worth knowing before writing the program, are all the various command modes that PS2 accepts. There are 16 command modes, however this section will only talk about the important command modes used in the code. The three command modes used in the code are as follows (values are displayed in hexadecimal form):

- \$FF Reset – Reset is performed when the device is powered. If successful, code \$AA and \$00 appears. Power on takes anywhere between 300 – 1000 milliseconds. No code is allowed to execute during that time frame.
- \$F0 Set Remote Mode – Data packets are only sent when the touchpad is being used. The read data command is used with this mode, as a way to get data from the touchpad.
- \$EB Read Data – This is how a packet is received in remote mode. The device responds with an acknowledge, and depending on what mode the program is in, three or six bytes follow that byte. In this case, three bytes will follow the acknowledge byte.

- \$EA Set Stream Mode – Stream mode is the default mode of operation. Stream mode operates similar to remote mode, in a sense that data packets are only sent when finger motion or button events happen.

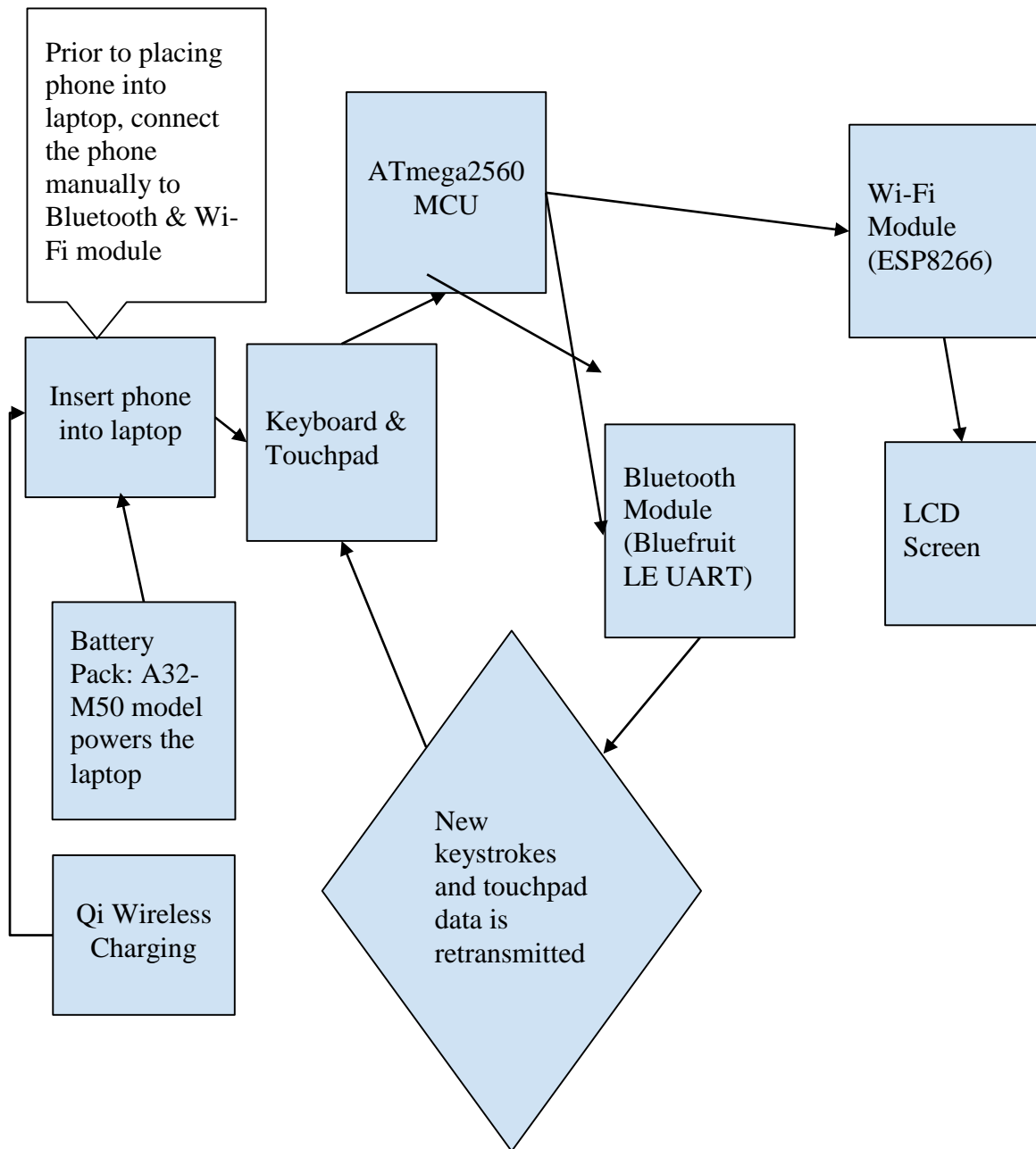
While, all the above modes are used in the testing of the touchpad, except stream mode, there is one more mode that may be beneficial to our final design. This mode is called stream mode. Stream mode is recommended by Synaptics, and mostly all pointing devices operate in stream mode. The reason why devices operate in stream mode is because everything revolves around it. When the user sets defaults, the device is now in stream mode, when the user send a disable command, it really means stream mode is disabled, and when the enable command is sent, the device is in stream mode. Altogether stream mode and remote are one in the same.

Lastly, there is one other mode that gives the user more information than stream or remote mode. This mode is called absolute mode. Absolute mode give the user more detailed information from the touchpad, such as where exactly the finger/hand is placed on the touchpad. This is read by an x and y coordinate system. Also, there is an origin, which acts as a reference point for this mode. Another great feature is the finger pressure coordinate, which is along the Z-axis. The “Z” values are actually very sensitive, and can tell when no finger is present to when a finger is hovering over the touchpad to when a finger is laying flat on the touchpad to when the whole palm is on the touchpad. This mode will be implemented for testing purposes, however it is not the most practical because packets are continuously being sent whenever a finger is near the touchpad.

3.18 Hardware

The laptop’s hardware components are as listed, there is a microcontroller, a Qi wireless charging module, a Bluetooth/Wi-Fi module, and a printed circuit board to house all of the components and connect all of the electronic components together. Below are the methodologies on how we designed, or applied, each component to fully design and complete our initial design of the cell-phone powered laptop.

3.18.1 Block Diagram – Hardware



In the hardware block diagram above, we first acknowledge the input of the system which is the phone being inserted into the allotted slot in the laptop. But, prior to inserting the phone into the laptop we must first connect the phone to the Bluetooth and Wi-Fi modules. Once the phone is connected to both modules, we can then insert the phone into the laptop. Once the phone is completely inserted, we can then transfer our attention to the next input which is the keyboard and touchpad. The keyboard and touchpad will be connected via Bluetooth connection and each keystroke and touchpad gesture will be transmitted to the MCU to transmit to the Bluetooth module to transmit to the phone then back to the MCU to then display to the LCD screen via the Wi-Fi module. While all of this is happening, the

battery pack will be powering the laptop and the Qi wireless charging pad will be charging the phone that was previously inserted into the laptop.

3.19 DC Power Socket

The next topic will go over the overall layout and integration of the DC power socket that we will use directly from the laptop.

3.19.1 Power Connector Terminology

DC Power sockets are mainly used to transfer DC power to connection devices, like a laptop. The power is drawn in from the wall outlet at 120 Volts AC and is converted to DC power through the AC adapter, then the AC adapter is then plugged into the DC power socket to transfer the power to the laptop's battery pack. There is some terminology when it comes to understanding power connectors and exactly how they function. There are also other types of power connectors, but the main one we are going to focus on is the barrel connector. A barrel connector is usually the most basic form of a power connector that is very cheap to buy and mainly used in unison with an AC adapter, or a "brick" type of charger. Barrel connectors are also mainly used in smaller projects to deliver power to electronics. Barrel connectors are usually female and can be bought at the store surface mounted, cable mounted, or through hole mounted. In a female barrel connector, there are other external contact points that can detect whether or not a power supply is plugged into the barrel connector or not. This external feature of the barrel connector allows the device to bypass the battery pack and actually extend the battery life when operating on an external power source. This is called the insertion detection pin, so when no adapter is plugged into the jack then the insertion detection pin will be shorted to the sleeve pin.

On the other hand, male barrel connectors, or the plug of the adapter, can come in all types of diameters and thicknesses. Barrel connectors can only be used for two connections, and those two connections are a pin or sleeve type of connection. As mentioned before, male barrel connectors can come in a variety of diameters and thicknesses, for example the different diameters are inner diameter, outer diameter, and the polarity of the sleeve. The inner diameter describes the diameter of the pin inside the socket, the outer diameter describes the diameter of the sleeve that is on the external part of the plug, and the polarity determines whether or not the sleeve voltage is above or below the tip voltage.

3.19.2 DC Power Socket Selection

In order to charge our ASUS G50V – A32-M50 battery pack, the original laptop uses a DC power socket to transmit the power from 120 Volts AC to the laptop's power adapter where it is converted from AC to DC then the DC power socket is the connector for the laptop's power adapter and the laptop's battery pack. But, there arose an issue where our original model of the ASUS laptop had the DC power socket soldered onto the motherboard of the laptop. This poses as a problem because we are completely removing all of the ASUS laptop's innards, motherboard, RAM, CPU, etc. So if we are not utilizing the laptop's motherboard then we cannot use the DC power socket. In order to fix this issue, we must

redesign the DC power socket so that we can have the 120 Volts AC that is converted to DC voltage and brought to the laptop’s battery pack to charge for longer uses.

Furthermore, we can buy a new DC power socket at an online seller. The seller can be from Newegg.com and they are selling this component for about \$8.09. We chose this type of component from this specific seller because this DC power socket is compatible with our ASUS G50V model of laptop that we are using for our design, which makes this DC power socket compatible with the original AC adapter from the original ASUS G50V laptop.

Table 3.19.2 – DC Power Socket Component Comparison

Name	Price	Seller/Manufacturer	Compatible with Laptop & AC Adapter?
AC DC IN Power Jack Socket Connector	\$8.09/ Free shipping	Newegg/HOYAN	YES – G50 models and more
AC DC Power Jack IN Socket Connector Plug	\$4.35/ Free shipping	Newegg/e Square Parts	X54 models
DC Power Jack Connector Socket Motherboard	\$4.99/ Free shipping	eBay/mltparts	F50 models

In Table 3.19.2, we compare three different DC power socket connectors for an ASUS laptop. But, there can only be one choice among the three that we can utilize in our project. The ‘AC DC IN Power Jack Socket Connector’ from Newegg and manufactured by HOYAN is the best selection because of its compatibility with our G50V model from ASUS. Although the price is a bit more expensive, the ‘AC DC Power Jack IN Socket Connector Plug’ from Newegg and manufactured by ‘e Square Parts’ and the ‘DC Power Jack Connector Socket Motherboard’ from EBay and manufactured by ‘mltparts’ were not going to be compatible with our current ASUS G50V laptop model. So, the choice is simple in this situation.

Figure 3.19.2 – DC Power Socket Selection



Now that we have selected our new component, as shown in Figure 7.3.3, for our DC power socket connector, we can move onto the next step which is how we are going to implement

this into our overall design. First we can design either a separate printed circuit board that can attach to the battery pack’s printed circuit board which already houses the smart protection circuit. Or we can refabricate the smart battery protection circuit to house the DC power socket connector by making one printed circuit board that houses all of the essential components for battery management.

Another alternative that would require a lot less soldering and money would be to create the overall design of the printed circuit board and add in the DC Power Socket component in the schematic editor of the printed circuit board design software. This will be the best option and the most cost effective option as well.

3.19.3 – AC Adapter

In order to charge the battery pack, A32-M50 model, of the laptop we will need an AC adapter. The AC adapter will be plugged into the wall outlet of a home, office, any building that has a wall outlet and the AC adapter will convert the 120 Volts AC to DC voltage in order to charge the laptop’s battery pack. The AC adapter that we will be using is the original AC adapter that came with the ASUS G50V laptop. In Table 7.3.3b, there shows the different AC adapters that we came across and compared them to choose the best and most efficient AC adapter to fit our project needs.

Table 3.19.1 – AC Adapter Comparison

Name	Voltage	Frequency	Price	Seller/Manufacturer
ASUS G50V – AC Adapter	120/230 V (AC)	50/60 Hz	FREE	ASUS
LVSUN Universal Laptop Charger	12-24 V (DC)	60 Hz	\$29.98 / Free shipping	Amazon/LVSUN
ZOZO Universal Laptop Power Adapter Charger	15-20 V (DC)	60 Hz	\$22.90 / Free shipping	Amazon/ZOZO

Table 9.3.2 shows the three different AC adapters that were looked at and found to be compatible with our laptop’s overall components. Mainly the DC power socket is the concern because the AC adapter has to have the correct plug diameters to fit the socket well in order to even charge the battery pack and keep the AC adapter from shaking loose. All of these selected power supplies are compatible with the ASUS models, but differ in

the amount of wattage they output to the battery pack which can cause an increase in battery charge time. The LVSUN universal adapter is a good choice, but it is too weak in power and will increase the battery charge time. Along with the LVSUN, the ZOZO universal power supply is even weaker to supply the correct amount of power to have an efficient battery charge time. So, the optimal choice for complete compatibility and efficient battery charge times has to be the original ASUS G50V AC adapter that originally came with the laptop.

3.20 Hardware – LCD Display

The LCD display for the ASUS G50V laptop is standard resolution of 1680 x 1050. It also has a widescreen display of about 15.4". The LCD also has features like Color Shine, Zero Bright Dot, and glare. The LCD controller will be the one to power the LCD screen and there is an LVDS cable, 30-pin. Most video connectors are not interchangeable so we will be using the original video connector. More commonly known as the 30-pin eDP, this is the main modern connector.

3.21 Software Design

In this section the software portion for the smart phone powered laptop will be discussed. The design methodology will be explained along with the developmental tools used for programming the MCU to communicate with the Wi-Fi and Bluetooth modules. The ATmega 2560 ADK will be used since it has a USB host interface to connect to human interface devices.

3.21.1 Development Tools

During the software development process it is necessary to take advantage of available tool, which will result in an easier, shorter, and simpler developmental process. The tools used to develop the smart phone powered laptop will be discussed in the following sections which are the IDE (Integrated Development Environment) and the VCS (Version Control System).

3.21.2 Integrated Development Environment

An IDE is referred to as an Integrated Development Environment which is an application that consists of a code editor, code builder, and debugger. The integrated development environments are designed to maximize the productivity of a programmer. The smart phone powered laptop will be prototyped using the ATmega 2560 ADK microcontroller, the IDE of choice is the Arduino Software IDE version 1.8.7. The environment is written in java and can be used with any Arduino board.

The open source Arduino software (IDE) comes with built in support for all Arduino products. To start programming the Arduino development board simply download the Arduino IDE on the desired platform Windows or MAC then simply plug in the USB cable connected to the development board into a computer. The most important aspect of using this IDE is that it comes with a tools to burn the Arduino bootloader onto other microcontrollers. This function is very crucial since it will make code from the initial

prototype compatible with hardware even if the ATmega is switched out for a final PCB and custom microcontroller combination. Furthermore Arduino projects are referred to as sketches and are written in the Arduino language based on C or C++. This is very convenient since every team member of the smart phone powered laptop has prior experience with these languages. The most important aspect is that there are a lot of coding examples on the internet for programming the Atmega 2560 ADK. This is very useful due to the fact that no team member of the smart phone powered laptop have any experience programming an Arduino board. Based on the coding examples on the internet a crucial discovery was made that an Arduino sketch consists of a setup function that runs at every start-up or reset. This function is used to initialize variables and pin modes.

The sketch can be uploaded into the Arduino microcontroller through the IDE. Another reason for using an Arduino device is that the ESP8266 Wi-Fi module and Bluetooth module come with integrated libraries specifically the ESP8266 is pre-programmed with AT command set firmware which means a simple connection is to be made between the MCU and the Wi-Fi module using the Rx and Tx pins and then the AT command can be used in the Arduino IDE to program the Wi-Fi module. For the Bluetooth module the library is already built into the Arduino IDE which is just a regular Serial, same as the Wi-Fi module the Rx and Tx pins are used to establish a connection between the MCU and Bluetooth module.

3.21.3 Version Control System

Version control systems are software tools that aid a software team to manage changes to source code over time. The version control system's primary purpose is to keep track of every modification made to the source code in a set database. If an error was made in the development process the version control system keeps copies of earlier versions of the source code which helps the development team to determine what caused the issue and fix the error without making extensive changes to the source code and therefore not disrupting the workflow of any team members. There are many version control systems but for our project the three most popular VCS that were researched are CVS, SVN, Mercurial and GIT.

CVS stands for Concurrent Versions Systems and is also one of the oldest version control systems. This version control system originally handled conflicts between two programmers by only allowing the latest version of the source code to be worked on and updated. Hence it was enforcing the first come first serve algorithm where one developer must commit and push changes before the significant other. The CVS system is considered to be one of the most mature version control systems due to the fact that it has been developed over a large period of time. Although CVS has advantages, it is not without some drawbacks; the first one being that the process of moving or renaming files does not include a version update, the second issue being that there are security risks from symbolic links to files, and lastly the fact that branch operations are expensive as they are not designed for long-term branching.

SVN is considered an Apache Subversion which was created as an alternate solution to CVS. Similar to CVS, SVN is also open source but is distributed under the Apache license. Many users have made a transition to SVN since it is a newer technology that incorporates the best features of CVS and improves upon them. The benefits of using this version control

system are; first it includes atomic operations which means no partial changes will break the original source, and another primary advantage is that it allows for cheaper branch operations along with a wide variety of plug-ins for IDE's. Last but not the least this version control does not use the peer to peer model. SVN also consists of significant drawbacks such as insufficient repository management commands, slower comparative speed, and it still consists of bugs relating to renaming files and directories.

The Mercurial version control system began very close to the same time as Git and is also a distributed revision control tool. It was originally designed to compete with Git over the Linux kernel also it is different from other version control systems because Mercurial is primarily implemented in python instead of C. Furthermore Mercurial allows non-core developers to have easier access to creating new trees and reverting changes made to the source code. Many users that use Mercurial have noted that it shares some of the features of SVN along with a distributed system. Due to the similarities between Mercurial and SVN version control systems it is noted that developers that are familiar with SVN don't tend to struggle as much in the learning aspect. One major drawback of using Mercurial is that it does not allow for two parents to be merged and it uses an extension system rather than being scriptable. Some of the advantages of using Mercurial are that it is easier to learn than Git, provides better documentation, and is a distributed model.

Git is considered to be faster and more modern in regards to distributed version control systems. It is primarily developed for Linux since there is a significant improvement in speed. Git does not use a centralized server therefore it does not lend itself to small teams because the code may not be available when using a non-repository computer. Some advantages of using Git as a version control system are that it can operate at a high speed, has cheap branch options, and the distribution is peer to peer model.

Concluding on the above descriptions of GIT, CVS, and SVN. GIT was chosen as the optimal choice for a version control system. The primary reason for choosing Git was that most of our team members have prior experience using Git. The second reason is that Git is faster and more modern than both CVS and SVN. Furthermore, Git offers two repositories public and private the public repository has no security which means any individual can access our repository and view our source code the private repository option has security measures which only allow the developers to view or modify the source code. Since this project is not a government affiliated or sponsored project the usage of public repository does no harm.

3.22 Printed Circuit Board (PCB)

Before diving into our design for the printed circuit board for our project, we must first understand what exactly a PCB is. A printed circuit board is essentially where all of the electronic components meet and is connected. There can be multiple layers, or sheets, of a non-conductive substrate that can contain the necessary wiring needed for the other components to be soldered onto the PCB. Soldering is important because this is the method used to electrically connect the electrical components to the PCB. This method also holds all of the wiring in place so the connections can be stable. PCB's can also be single-sided or double sided, either one copper layer or two copper layers, and even multi-layered. PCB's are mainly used because they are inexpensive to produce and is the most efficient way of mounting components to electrically connect them while only needing to be

soldered. A PCB will be very necessary in our design because we need to electrically connect the microcontroller to other components of the laptop like the Wi-Fi/Bluetooth module and the battery pack, and other basic elements of the laptop like keyboard and track pad.

3.22.1 Composition of PCB

The composition of a Printed Circuit Board is divided into different layers that are composed of different materials. These different materials are then laminated together to results in a flat, single object.

3.22.2 Substrate Layer

Normally called FR4, this layer is composed of fiberglass. This hard substrate gives the PCB the thickness and its density. There are also other plastics that can give the PCB a more flexible type of feel to it, usually this plastic is called Kapton. These plastics can actually retain their shape at high temperatures, making the PCB very durable at operating at a high temperature environment. There are cheaper alternatives to the FR4 fiberglass option, like epoxies and phenolics. But, the tradeoff here is that the epoxies and phenolics materials lack the ruggedness of the FR4 fiberglass, but they are less expensive. Another minor tradeoff will be the smell that comes from the PCB when soldering to it, if the smell is a strong bad odor then the material is most likely a cheaper type of epoxy or phenolic or Kapton.

3.22.3 Copper Layer

The next layer after the substrate layer is the copper layer, which is the thin layer of copper foil. The copper foil is also laminated to the board just like the substrate layer. Commonly for double-sided PCB's, the copper foil is laminated to both sides of the PCB. However, in a single-sided PCB the copper foil is only applied to a single side of the PCB. When referring to a single sided or double side, we are referring to the number of copper layers that the PCB has. There can be as many as one layer or up to sixteen or more layers in a PCB. Although the copper layer is relatively thin, the thickness of the copper foil can vary with the weight of the actual copper. Commonly, the average PCB has about 1 ounce of copper per square foot. Other PCBs that have to handle high amounts of power typically contain 2 to 3 ounces of copper per square foot. Each ounce of square foot of copper equates to about 35 micrometer of an inch of copper thickness.

3.22.4 Soldermask Layer

The soldermask layer is the layer above the copper foil layer. This layer is used to insulate the copper foil layer. The copper foil gets insulated by the soldermask layer in order to prevent the copper foil from coming into contact with other metals or solder. Also, the soldermask layer helps us solder the correct components to the appropriate locations. Soldermasks are typically green in color and other colors can be red, yellow, and a variety of other colors.

3.22.5 Silkscreen Layer

The silkscreen layer is the final layer that is above the soldermask layer. The silkscreen is used to print the letters and numbers so the user can see where all the labels are for the components that need to be soldered. This layer is important to the PCB because it gives the user an advantage in knowing where all of the electronic components have to be exactly where it was modeled on the PCB design. Typically these labels on the silkscreen are used to indicate the function of a component on the PCB. Also, the silkscreen ink is typically white in color, but can be printed in a variety of colors. Normally, there is only one main color that is used throughout the board to maintain consistency throughout the PCB.

3.22.6 PCB Design Software

There are many circuit design software on the market nowadays. Choosing PCB design software can be chosen through the level of friendliness for first time users, like an easy-to-read user interface. Another key factor in determining PCB design software to use is how much you are willing to spend. There is a variety of free PCB design software out there, like Easy EDA. Easy EDA, or Easy Electronic Design Automation, is designed to be very user-friendly and is even free to download. Easy EDA also has their own PCB manufacturing company, so once the PCB design is completed on the software, the design can be imported to the PCB design manufacturing company to build immediately. Other PCB design projects, from Eagle, Altium, kiCad and LTspice, can be imported to Easy EDA as well. Moreover, Easy EDA's libraries have over 300,000 components to choose from in PCB designs.

Altium Designer is unbeatable the best PCB design/EDA software on the market now. Altium Designer is ranked very highly in the PCB design world and is used by the majority of circuit companies. Many universities even have courses dedicated solely to teaching students on how to use the PCB design software. When the PCB design only requires one to two sheet layers, then Altium Designer is the best choice. But, when the design calls for multiple layers, more than four layers, then the program can be a big difficult to use.

Eagle is the most thorough kind of PCB design software out there currently. Although they have three packages to choose from, they do have very useful additions/features to the software interface that can prove to be very useful for first time users. For example, the Electronic Rule Checking feature is a tool where it can verify the schematic design with tons of checks that the Eagle software runs on the schematic diagram. There is also a SPICE simulator that can be run on the design schematic to test the circuitry.

Table 3.22.6 - PCB Design Software Comparison

	Price	Features	Uses
Eagle	<u>EAGLE Free</u> - FREE <u>EAGLE Standard</u> - \$100/yr <u>EAGLE Premium</u> - \$510/yr	<u>Free:</u> <ul style="list-style-type: none"> • 2 Schematic sheets • 2 signal/plane layers <u>Standard:</u> <ul style="list-style-type: none"> • 99 Schematic sheets • 4signal/plane layers • 160 cm² board area <u>Premium:</u> <ul style="list-style-type: none"> • 999 Schematic sheets • 16 signal/plane layers • Unlimited board area 	<u>Free:</u> Single-sided or double-sided PCB layouts basic schematics <u>Standard:</u> Product designs multilayer PCB layouts multispeed schematics <u>Premium:</u> Complex multilayer PCB layouts production-level products advanced board designs
Altium Designer	<u>Free Trial</u> - 15 day trial <u>Premium</u> - \$1000/yr	<ul style="list-style-type: none"> • Rigid Flex design for a 3-D view • Hierarchical schematic design 	All design aspects are interconnected for easy maneuvering between each process Multilayer PCB design, advanced board designs
Easy EDA	<u>Easy EDA</u> - FREE	<ul style="list-style-type: none"> • Capture, • SPICE circuit simulator, • Import other PCB/Schematic files 	<ul style="list-style-type: none"> • User-Friendly interface • easy design • tools/components library • Multilayer PCB design • up to 4 layers

Out of the three PCB design software to choose from, we are choosing Altium Designer. We chose Altium Designer because we have outside access to the software free of charge and Altium Designer is the top-of-the-line PCB design software in the market.

3.22.7 PCB Design Terminology

It is important to understand the terminology when designing a PCB because when using the design software we must familiarize ourselves with the industry terminology so we can know how to use the software properly.

- Annular Ring- The annular ring is the circular ring of copper around a plated through hole in a PCB.
- DRC- As explained the design constraint section of the report, the DRC, or Design Rule Check, is where the PCB design software validates your work to make sure the design does not contain any errors where the traces made do not touch, traces are too narrow, or the drill holes are too small.
- Drill hit- As explained in a previous section, the drill hit is the location on the PCB design where a hole will be drilled into the board. Inaccurate drill bits are mainly the result by dull bits that are used by the manufacturing company that produces the PCB design into a board.
- Pad- A pad is a portion of exposed metal on the surface of the PCB where an electronic component is to be soldered to.
- Paste Stencil- A paste stencil is a thin, metal stencil that is on the surface of the board. This stencil allows the user to deposit the solder paste in certain areas of the PCB.
- Plated-Through-Hole- A plated through hole is a hole that is in the board which has an annular ring and is plated all the way through the PCB. This plated-through-hole can be used for an electronic component connection point, can be used for mounting, and even to pass a signal through the hole.
- Slot- A slot is a hole in the PCB that is not a rounded hole. Slots could be either plated or could not be plated. However, these slots can add additional cost to the PCB because they require more time to cut out the excess board material.
- Solder Paste- Solder paste are small balls of solder that are stored in a gel-like medium which is applied to any surface mount pads on a PCB. There is another concept called Reflow that helps with the creation of electrical and mechanical joints between the pads and the electronic component. Reflow is the process where the solder inside the paste melts.
- Trace- A trace is simply a continuous path of copper on the PCB. A trace is literally traced in the implementation state of the PCB design process, usually done after the schematic/wiring is done on the PCB design software.

3.22.8 Soldering Standard

The only remaining standard in the soldering industry is called the J-Standard. The J-Standard is the soldering standard referring to IPC J-STD-001C. The IPC, founded in 1957, is the Institute for Printed Circuits. IPC's mission is to dedicate its efforts to building and establishing international standards that can guarantee quality electronic circuits that comply with government regulations. The J-Standard covers the requirements for electronic and electrical assemblies, in terms of their assembly. This standard is worldwide where it describes the materials, the methods and the verification criteria for producing a printed circuit board assembly. There's also a certification that a user can get to be certified in the J-Standard soldering standard.

3.22.9 PCB Design Recommendations

It is one thing to have the circuitry and schematic designed perfectly, but the PCB design is what can really make or break the component selection and the advanced intricacy of the circuit. This can lead to a perfectly build circuit and perfectly selected components to not run as well as it were initially intended to run. The design can actually pose as an issue to the manufacturer to fabricate the design.

3.22.10 Component Placement

The component placement process of the PCB design is about efficiently using the entire space you have on the PCB. For our design, we can make the PCB bigger than the average PCB design due to the ample space in the laptop shell. The orientation of similar components should be in the same direction because this will help with soldering more efficiently and reducing the error in soldering a component the wrong way. Also, avoid placing components on the solder side of the board that would be in the way of through-hole components. Organization is important as well when it comes to placing the components because when placing surface mounted components and through-hole components, it is important to place all of the surface mounted components on the same side of the printed circuit board and all of the through-hole components on the top side of the printed circuit board. Doing this minimizes the number of steps in the assembly step of the design process.

3.22.11 Power, Ground & Signal Traces

Once the components have been placed, it's important to know where the most optimal paths for power delivery, grounding, and signaling go on the board. One key thing to know is the orientation of power and ground planes. To help the board from not bending we must place the power and ground planes in the internal of the board while also being symmetrical. To power our IC's it's recommended that we use common rails for each supply. Avoiding daisy-chain power lines can help minimize power loss and reducing the complexity of the PCB. Furthermore, we will place our components just like we place our traces. This means that we will place our traces as close and as short of a distance as possible between components. If we have a component placed in such a way where we must create a horizontal path, then we can place traces vertically on the opposite side of that horizontal trace. Also, there can be different nets in the PCB that can carry different amounts of current. This directly affects the width of the net. It's recommended that there be 0.010" width for low current analog and digital signals. When the traces carry more than 300 mA then it should be wider.

3.22.12 Separating Components

Commonly there can be issues with the large voltage in power circuits and current spikes can interfere with the lower voltage and current control circuits. To avoid this common issue we can start by making sure to keep the power ground and control ground separate. When placing a ground plane in the center layer of the PCB, make sure to place a small impedance path to reduce the risk of any interference to help better protect the control signals. The digital and analog grounds will be separate following the same logic as previously stated.

3.22.13 Heat Dissipation

Heat dissipation can pose as a potential threat to the overall performance of a system, especially one that has enclosed spaces like the laptop. The first step is to identify which components in our design will be causing the most heat generation; the ATmega2560 usually does not run hot when operating within datasheet specified values. But, adding thermal reliefs can tremendously reduce the amount of heat dissipated by certain components, also adding heat sinks can help mitigate high powered components from giving off too much heat.

3.22.14 Soldering

As mentioned briefly in the PCB design section, soldering is where you join two pieces of any equipment together by melting a filler metal so the filler metal can fuse both pieces of equipment together. The filler metal, solder, has a lower melting point than the objects so when the solder has completely melted, the heat source is removed and the solder quickly hardens adjoining both metals together. Solder is a fusible metal alloy used to create a permanent bond between metal equipment components. The fusible metal alloy that's used is usually tin and lead with a melting point of 183 degrees Celsius or 361 degrees Fahrenheit. In order to melt the solder efficiently and in a controlled fashion, a soldering iron must be used. The soldering iron is like a pen and the tip gets heated through a controller where the temperature of the top of the solder pen can be changed. Soldering is important in electronics because we need to make electrical connections to resistors, capacitors, and other electrical components to the printed circuit board. We also need to make mechanical connections so the electronic components do not move around or shift positions. Soldering is how we achieve this so we can make a long lasting bond between the electronic components.

3.22.15 Steps to Solder

The first step to solder a component on a printed circuit board is to first clean the tip of the soldering iron. We can clean the tip of the soldering iron by using the sponge that has been soaked in water. Once the tip of the soldering iron is clean and free of debris, the next step will be to tin the tip of the soldering iron, more normally called 'tinning the tip'. Tinning the tip is where the tip of the soldering iron touches the solder which makes the tip of the soldering iron transfer heat much faster. If the heat transfer is faster than the soldering process is faster and easier to handle. Soldering wires together is a simple process because we need to first tin the wires by adding the solder to an exposed piece of each wire tip. As much tinning is added until the entire tip of exposed wire is soaked in solder. Then, the two wires that have been tinned are held together and heated up by the soldering iron. The two wires are then adjoined together after the solder is heated.

3.22.16 Soldering on a PCB

Soldering on a PCB is soldering through-hole components into the printed circuit board. Through-hole components are electronic components like resistors, capacitors, integrated circuit chips, and more. We first take the electronic component and place the leads through the drill holes as far through the drill-hole as possible. Once the electronic component is

placed correctly, we place the soldering iron to where the tip of the soldering iron is touching both the electronic component and the drill hole, so both pieces of equipment are being heated up. Then, begin to touch the solder to the bottom side of the printed circuit board to solder the electronic component to the PCB. Also, when soldering integrated circuit chips it is important to use an integrated circuit chip socket because applying the soldering iron directly to an integrated circuit chip, like the ATmega2560, the integrated circuit chip will break due to the excess heat. A good tip to check our work when soldering properly is to observe the shape of the solder joint. A good solder joint should have the shape of a cone. But, one big problem of soldering is that sometimes a solder joint doesn't completely surround the joint of the drill hole and leaves a gap. This can cause current to not flow through the electronic component.

3.22.17 Soldering Standard

The only remaining standard in the soldering industry is called the J-Standard. The J-Standard is the soldering standard referring to IPC J-STD-001C. The IPC, founded in 1957, is the Institute for Printed Circuits. IPC's mission is to dedicate its efforts to building and establishing international standards that can guarantee quality electronic circuits that comply with government regulations. The J-Standard covers the requirements for electronic and electrical assemblies, in terms of their assembly. This standard is worldwide where it describes the materials, the methods and the verification criteria for producing a printed circuit board assembly. There's also a certification that a user can get to be certified in the J-Standard soldering standard.

4. Design Constraints and Standards

The utilization of standards in the development of modern technologies plays a major role in the economy and efficiency aspect of the world. Standards also help everyone “get-on-the-same-page” when it comes to matching different engineering specifications and requirements because there are engineers around the globe that are building similar technologies and the usability of the product must meet the standards of the consumer. By standards of the consumer, I mean the product must be easily accessible for someone in different regions, like different states for example. Along with specific national and international standards, there are also environmental standards that we must take into consideration. But, environmental standards are not mandatory unless they are regulated by the government. These environmental standards are important in this project because we are using batteries to power the laptop and we must familiarize ourselves with how to properly dispose of a battery and how to recharge a battery so we use its full life potential.

With every project, there are realistic constraints that limit one or a group of people to what can and can't be done due to time, economics, environmental, social, political, ethical, health and safety, manufacturability, and sustainability. The information below describes each subject in great detail, while describing and proving our projects feasibility with each constraint. Moreover, constraints are there to guide people in a realistic direction depending on the project and resources.

4.1 Environmental Regulation Standards

An example of an environmental standard would be the EPA's Battery Act. With rechargeable batteries being a great technological advancement for energy storage, they do come with harmful chemicals. Although these chemicals aren't harmful to humans, they are certainly harmful towards the environment. In order to prevent the release of harmful substances into the environment, the Battery Act was signed into law on May 13th, 1996. Prior to the Battery Act, some manufacturers of rechargeable batteries and consumer products were not complying with the Mercury Containing Rechargeable Battery Act, 42 U.S.C. 14301-14336. The Battery Act serves a purpose of protecting the environment by regulating the correct disposal of rechargeable batteries. Also, the Battery Act serves as a means to provide for efficient and cost-effective collection and recycling of used Nickel Cadmium batteries, lead acid batteries, and Lithium-Ion batteries. Along with protecting the environment, the Battery Act also establishes national uniform labeling requirements for all types of batteries.

4.1.1 Environmental Constraints

Our smartphone powered laptop could definitely have some potential positive impacts on the environment. This is because our project has been designed with a recycling sense of mind. We essentially created our project because consumers purchase laptops that have many expensive components that almost all of these consumers already have in their phone. Computers are already a major waste issue with how fast they become outdated and become massive majority of dumps. Electronic waste represents two percent of america's trash but

it represents an astounding seventy percent of all toxic waste. In 2009 electronics totaled about 2.37 millions tons, and will only continue to massively grow. Major use of our laptop would dramatically reduce this being that wouldn't need to update your laptop, but just your phone. This would dramatically increase the average lifespan of a laptop device and reduce the amount of components used.

4.2 Wi-Fi IEEE Standards

Now that we know the manufacturability and sustainability constraints of Wi-Fi and Bluetooth, we must understand the Wi-Fi engineering standards. There are many standards that have changed throughout the years regarding Wi-Fi and have been produced by IEEE.

4.2.1 802.11a Standard

The 802.11a Standard is a standard that uses a 5 GHz frequency band on the spectrum of a radio wave. This frequency has the ability to transmit up to 54 Megabits per second. The frequency also uses frequency-division multiplexing. Frequency-division multiplexing is where the radio signal is split into other smaller signals in order to reduce the amount of signal interferences.

4.2.3 802.11b Standard

The 802.11b Standard is the most notable Wi-Fi standard, but it is also the slowest frequency band. The 802.11b Standard's frequency band operates in the range of 2.4 GHz and can only transmit and receive data at a rate of 11 Megabits per second.

4.2.4 802.11g Standard

The 802.11g Standard is similar to the 802.11b standard because this standard works at the same frequency of 2.4 GHz. But, unlike the 802.11b standard, the 802.1g standard is significantly faster at a rate of 54 Megabits per second.

4.2.5 802.11n Standard

The 802.11n Standard is the best Wi-Fi standard because it is backwards compatible with the 802.11a, 802.11b, and 802.11g standards. The data transmission rate is significantly higher transmitting data and receiving data at around 150 Megabits per second. There can be as many as up to four streams of data at any given time as well.

4.2.6 802.11ac Standard

The 802.11ac Standard is the newest standard, currently being reviewed by the Institute of Electrical and Electronics Engineers (IEEE). This standard will soon be replacing the 802.11n Standard making the 802.11ac Standard backwards compatible with the 802.11a, 802.11b, and 802.11g standards as well. With a transmission rate of speeds of up to 450 Megabits per second. The 802.11ac Standard can also work on both the 2.4 GHz band and 5 GHz band.

4.3 Qi Standard & IC

Wireless charging chips are everywhere and can be implemented fairly easy with proper documentation. Proper documentation consists of datasheets and implementation of Qi standard. A proper standard for wireless chargers is called Qi. It is a standard developed by Wireless Power Consortium (WPC), a company that promotes worldwide market adoption of its Qi interface. The next thing to know about wireless chargers is that they all comprise of a transmitting and receiving circuit. Texas Instruments offers a variety of wireless charging chips, which will be used to build the wireless charging circuit. Other companies that offer are STMicroelectronics and Integrated Device Technologies.

4.4 Soldering Standard

The only remaining standard in the soldering industry is called the J-Standard. The J-Standard is the soldering standard referring to IPC J-STD-001C. The IPC, founded in 1957, is the Institute for Printed Circuits. IPC's mission is to dedicate its efforts to building and establishing international standards that can guarantee quality electronic circuits that comply with government regulations. The J-Standard covers the requirements for electronic and electrical assemblies, in terms of their assembly. This standard is worldwide where it describes the materials, the methods and the verification criteria for producing a printed circuit board assembly. There's also a certification that a user can get to be certified in the J-Standard soldering standard.

4.5 Economics and Time Constraints

Economics constraints determine which parts are realistic for the design of the project. There are many parts that will work with our project, however due to a limited budget from our group; there must be alternative parts to pick from. Our budget as a group is roughly \$100 per person, or \$400 total. While parts may not cost \$400 initially, there is always room for error, which in return will require our group to buy duplicates of the same parts. Furthermore, \$400 may not seem like a lot for what we are doing, however one of the goals for this project is to be cost friendly to any consumer wanting to buy this type of product. Time constraints also play a role in affecting the outcome of a project. As known, this project has a time constraint of about 2 full semesters, including holidays. Therefore, ideas must be doable in this time, and one must technically know/already know about his/her project, otherwise there will be too much time spent researching or trying to figure out how to implement it. Our group is set to finish all research and design before December 4th, 2018 and use winter break to get ahead by completing testing and beginning the final prototype design, which will be more for looks and presentation. After testing, PCB board design will be placed and then tested, which allows us the entire semester to fix design flaws or problems that we run into. Time constraints give us a realistic approach and allow time for error.

4.6 Social and Political Constraints

When designing a project, there are social impacts that must be considered. One of the first social impacts is that this project can spark positive interest to other computer and electrical

engineering college students at the University of Central Florida. Another constraint that must be considered is political constraints. As known, smartphone powered laptops are not readily available on the market, which plays a big factor in the sense that this is something new and possibly an idea that people might want to take to the market. Moreover, this is an idea to help people spend less money on computers for an average user or student, which may affect the market for other devices such as tablets that only play the role of portability. Overall, this project is for academic purposes, therefore political impact will not play a big role without project.

4.7 Ethical, Health, and Safety Constraints

While our project does not adhere to profound safety concerns, there are a few minor concerns that need to be addressed. The first concern deals with the wireless charger, and its inductive coupling concept. As stated before, inductive coupling is created when current is sent through a coil, which then creates a magnetic field that couples with another coil on the receiving end. When another object such as a coin, paper clip, or foil is accidentally placed between the transmitting and receiving coil, they absorb energy in the form of heat called parasitic heating, and can heat up above normal operation conditions. Since there is a power loss in the system due to the foreign object, this can cause the transmitter to supply more power than what is needed, eventually leading to power failure or damage. For our case, a 5 W charger is considered low power; however there is still a possibility of overheating. On the bright side, Wireless Power Consortium developed a standard called Qi, which requires companies to implement foreign object detection into their design, preventing any bad parasitic heating within objects. With safety, this brings ethical concerns. According to “IEEE Code of Ethics”, our project does not violate any rules. As a group, we understand all ethical responsibilities and adhere to the code.

Lastly, health goes hand in hand with safety and ethics. It is known that with any design or project, we are ethically responsible for the safety and health of our customers. Wi-Fi plays a health concern due to the emitted electromagnetic waves in the microwave frequency range. While there is no absolute evidence that Wi-Fi is harmful, our project does not provide any health concerns to users.

4.8 Manufacturability and Sustainability Constraints

Manufacturability is the ability of a system to be produced with as few resources possible as its parts, labor, or maintenance alludes to a system’s manufacturability [C1]. Moreover, sustainability and manufacturability can be related by no correlation, negative correlation, or positive correlation. In our project, we are salvaging certain components from a laptop and stripping the rest. The only components that are being kept are the LCD, touchpad, and keyboard. In this case, manufacturability negatively relates to sustainability. The relationship is negative because we are salvaging used components that may not last for as long as a new part, however on the other side we do not have to manufacture any because everything is already provided from the stripped laptop. Taking manufacturability constraints into account when choosing a wireless charging circuit, Texas Instruments is a better option due to the extra chip needed to build the circuit. This extra chip is called, bq50002, which controls all the analog components and allows for more room on the PCB board along with fewer components. In this case, sustainability and manufacturability are

not directly correlated with the wireless charger. Sustainability is the same for all wireless charging chips.

Next, we must consider Wi-Fi and Bluetooth and how they relate to one another through manufacturability and sustainability constraints. If our project did not use Wi-Fi to communicate and power the LCD, and Bluetooth to power and communicate with the touchpad and keyboard, there must be cables to support power and communication. Cables are not sustainable and will eventually wear out. One can think of cables as old technology when dealing with transmission of power through a short distance. Wi-Fi and Bluetooth provide easy hands-free communication from the phone to the laptop, and is guaranteed not to wear out over time.

4.9 PCB Constraints

A design constraint for designing the printed circuit board is the Design Rule Check, or DRC. This is a rule which means that it is a software check of the final design of the PCB such that the PCB does not contain any errors. These errors can be anything from traces that are incorrectly touching, traces being too narrow, and the through holes or drill holes being too small in size. A manufacturing constraint for manufacturing a printed circuit board that is of high quality is the quality of the drill hit. A drill hit is/are the locations on the PCB where holes should be, or already are drilled. The quality of the drill hit is determined by the manufacturer's quality of the drill bit's head. Meaning that the duller a drill bit becomes the quality of the drill hit reduces and can cause inaccuracy in the drill hits.

4.10 Voltage Regulation Constraint

Voltage regulation must also be taken into consideration when thinking about prototyping and testing. There are many types of voltage regulators that serve different purposes, physically and electrically. In this case, I will talk about physical constraints.

Physical constraints consist of prototyping on a breadboard and overall design on a PCB. When testing a regulator, it's best to buy through hole components, however this cannot always be the case. The parts chosen for this experiment do not have through components, which means breakout boards or soldering must be implemented for testing.

4.11 Constraints for Overall Design

When powering/designing the microcontroller, there are a few constraints that must not be overlooked. Some of those constraints are:

- Overall size of the circuit is limited to the laptops size
- The power supplied to the circuit is limited and the battery life is crucial

4.11.1 Overall Size and Power Supplied

When looking at the size of the laptop, the space where the PCB and all other components will go are limited to just 2 inches . All other components include:

- DC Fan
- Wireless Charger
- Touchpad
- Keyboard
- Battery
- Wi-Fi Module
- Bluetooth Module

4.11.2 DC Fan Constraint

Our design includes two DC fans to help cool the internal part of the laptop, however some problems can arise. One of the problems is that the DC fan can present noise to the power supply and microcontroller, therefore tests must be made to determine if a fan is necessary in the design. However, there will be heat dissipated from the actual circuit, which can be controlled using the fan. Another great feature about the fan is that it is “16mm X 13mm” with a width of 4.5 mm. This is a very small fan, which should be able to fit into the laptop. However, due to the limited amount of space within the laptop, this could be a problem when considering everything altogether. Furthermore, the DC fan is a stretch goal.

4.11.3 Wireless Charger Constraint

Next is the wireless charger. The circuit for the wireless charger is fairly big, and again space can be an issue. Another issue with the wireless charger is that it is rated at 5W, which can be a lot for a low power system. The last problem with implementing a wireless charger is that testing it on the breadboard will be extremely difficult due to the complexity of the circuit and the size of the chips. The chips are only surface mount made, which means a breakout board must be bought to develop and test the prototype. This can be expensive and timely, because a custom PCB might need to be made, which means a schematic and footprint must also be made. According to my research there are breakout boards that could possibly work for both chips, which we might use in the testing of the wireless charger. However, the wireless charger is a stretch goal, as well.

4.11.4 Touchpad Constraint

The touchpad is a great feature within the laptop and does not negatively affect the overall power consumption or space within the board. However, the touchpad is not perfectly compatible with the PCB design. What this means is that the touchpad does not have an input where a ribbon cable can be implemented easily, instead wires must be used in the final design of the project. This may not look professional and the wires can be easily damaged due to the limited space on the touchpad board where the connection is made. In *Figure 4.11.4* below, one can see the limited space on the board that will be used to solder a wire onto.

For option 1 and option 2 the connection can be made directly to the “T” pads or directly to the MCU. The “T” pads provide more room and less chance for error. The MCU pins would be very difficult to solder onto because there is no room, but it’s still an option.

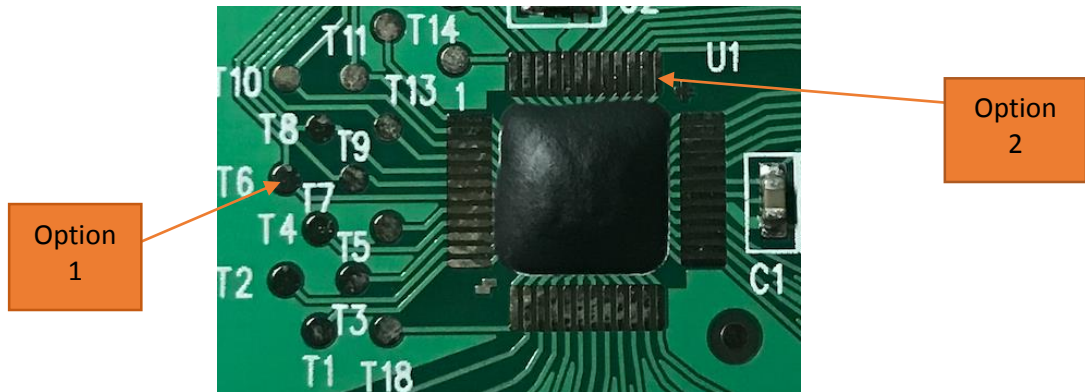


Figure 4.11.4 Touchpad Solder Connections Option 1 and 2

Option 3 is to solder onto the ribbon cable connector. This way is very feasible because each connection has two pins which are both right next to each other which means there is more space to solder and more solder can be placed in that area. The cable connection cannot be used because it is already used to connect to the board with the left and right button. However, bridging can be a problem with option 3.

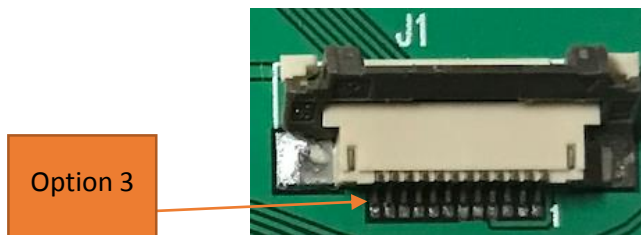


Figure 4.11.5: Touchpad Solder Connections Option 3

4.11.5 Keyboard Constraint

The whole idea behind the development of our project was to utilize every single part of the laptop shell which included the touchpad, keyboard, and LCD screen. The touchpad and LCD screen did not raise any issues however some issues presented themselves when evaluating the feasibility of the keyboard in our design. The keyboard is embedded within the laptop shell, and consists of a ribbon cable. Prior to the dismantling of the laptop, this ribbon cable was attached to a keyboard controller which was directly attached to the motherboard of the laptop. Upon doing further research it was determined that the keyboard controllers are not sold as a separate part. To overcome this issue the decision was made to purchase a miniature keyboard that is microcontroller friendly the specific part purchased was the 875 miniature MCU friendly keyboard with USB and PS2 connections. With the purchase of this keyboard arose another issue regarding the wire that was attached to the

keyboard. Taking into consideration the small space underneath the keyboard where the motherboard lies the wire of the 875 miniature keyboard was simply too large.

To tackle this issue a fair amount of research was done which led to the idea of creating a 3D printed mold of the original keyboard section where the miniature keyboard will fit inside the mold. Also, the mold would have to be hollow from the inside so that the wire of the miniature keyboard can be placed inside the hollow part of the 3D printed mold.

4.11.6 Bluetooth Module Constraints

The Bluetooth module chosen for this design is the Bluefruit UART LE, described in the other sections and more information can be found in the other sections. One of the constraints with the module is space. The bluefruit has 8 breakout pins that must be soldered onto the PCB. The problem is that since there is no direct fit onto the PCB and we must decide if the entire module will sit on top of the board or if the pins will be the only part sitting on the board. Both options affect the height of the PCB. In the first option, the PCB must be made to fit the entire Bluetooth module, which will take up a decent amount of space on the board. The length is 1.25 inches and the width is 0.84 inches. In the second option only the pins will lay on the board, which means the board can be slightly smaller and cheaper. The final design will be option 1 because it present a more professional look on the board and the module itself does not take up a lot of space to begin with. If space becomes very crucial then option 2 will be implemented.

4.11.7 Schematic Constraints

In a schematic, all components are not accessible through the Altium library online, which means we must create a part or download Ultra Librarian. Also, Texas Instruments Web Bench, also has an export option, where the schematic can be exported directly to Altium for certain schematics.

In order to use Ultra Librarian, a .bxl file must be available from the supplier, which is not always the case. Therefore, parts selected must have .bxl file or be a design already built in Web Bench, compatible with exporting to Altium. If none of those options work, a part must be created. This can be done by looking at the footprint of the component.

4.11.8 Testing Constraints

As you know, electrical components come in two main forms which are surface mount and through hole components. Through hole components make it easier to test directly on a breadboard. However, a lot of parts are only sold as an integrated device, which means breadboarding them might take more effort than needed compared to the through hole components. Therefore, in our design, all integrated devices chosen will look like the *figure 4.11.8* below, instead of the other *figure 4.11.9*, which only has pins that are fit to the size of the chip. This will make testing a little easier, because there is enough room to solder wires onto the pins using a microscope. Another consideration for testing the part shown in *figure 4.11.9*, would be to buy a breakout board. The only problem with that is money, and multiple breakout boards must be bought to test all the parts. Breakout boards cost

around \$5 - \$10 making it very expensive when using multiple chips. Therefore, *figure 4.11.9* is a more suitable choice.



Figure 4.11.8: Chips that cannot be used in testing



Figure 4.11.9: Chip used in Testing

4.12 PCB Constraints

When designing the PCB, noise can be a big problem. Noise can create spikes in current, and unstable voltage signals. This can damage the microcontroller, and the overall operation of the circuit. The section “Constraints for Microcontroller Design” talks more in depth about this subject. However, when designing the PCB decoupling capacitors must be close to the input and ground. Another constraint is space, the laptop is limited underneath the keyboard, where the entire PCB will be placed. Therefore, the PCB must not be thick.

4.12.1 PCB Manufacturing Standard

The IPC, or the Association Connecting Electronics Industries standards are the essence of PCB manufacturing standards. IPC has a detailed checklist named the PCBA-Checklist that goes through every single procedure that every PCB developer should know in order to produce a very effective printed circuit board. This also helps the manufacturers produce a printed circuit board as efficiently as possible mitigating any confusion when it comes to the PCB designer to the PCB manufacturer. These standards and checklist stems from mainly the CAD perspective of printed circuit board designing. Not only does the IPC discuss the topics of PCD designing, but they also have standards on requirements for soldered electronic assemblies. Moreover, there are inspections and testing of electronic enclosures, along with the cable and wire harness assemblies.

I believe that the IPC is very important in determining the effectiveness of printed circuit board designing and manufacturing because these standards and requirements can limit the confusion between the designer and manufacturer. When there is a strict checklist to follow, I think it makes the process of designing to manufacturing very simple and can minimize the amount of errors the manufacturers can potentially make because of the number of factors that go into designing and manufacturing a printed circuit board. Even in any printed circuit board design software this can be applied, like our software that we are utilizing for this project Altium Designer 18.

4.13 Power Supply Standards

Power supply safety standards are primarily the standards that govern the power supply engineering standards, more specifically towards electrical safety standards. The institutes that govern these standards are ruled by the International Electrical Commission (IEC) and the International Organization for Standardization (ISO).

The IEC 60950-1: Power Supply Standard corresponds to the mains, or battery-powered information technology equipment and office machines with a rated voltage not going over 600 V. This standard is to prevent any harm that can be done to someone like any harmful shocks, fires, and mechanical instability. Also shown in Table 4.X below, we can identify the different classes of equipment. These different classes show the standardization of how to properly provide protection of the circuits being used in power supplies.

Table 4.13 – Classes of Equipment

Type of Class	Protection Description
1	Equipment achieves electric shock protection through basic insulation and protective earth grounding. This requires all conductive parts that could assume a hazardous voltage in the event of basic insulation failure to be connected to a protective earth conductor.
2	Equipment provides protection using double or reinforced insulation and hence no ground is required.
3	Equipment operates from a safety extra low voltage supply circuit, which means it inherently protects against electric shock, as it's impossible for hazardous voltages to be generated within the equipment.

Knowing these standards are important to powering any type of equipment in order to prevent hazardous dangers. The cell-phone powered laptop would have to follow at minimum Class 1 with the battery protection from overcharging or short circuiting.

Along with the different classes of equipment, comes with the different types of insulation and protection for electric components. Also, the different circuits to protect against higher voltages, as shown in the table 4.X.

Table 4.13 – Voltage Protection Circuits

Type of Circuit	Circuit Definitions
Hazardous Voltage	Any voltage exceeding 42.2 V _{AC} peak or 60 V _{DC} without a limited current circuit.
Extra-Low Voltage (ELV)	A voltage in a secondary circuit not exceeding 42.4 V _{AC} peak or 60 V _{DC} the circuit being separated from hazardous voltage by at least basic insulation.
Safety Extra-Low Voltage Circuit	A secondary circuit that cannot reach a hazardous voltage between any two accessible parts or an accessible part and protective earth under normal operation or while experiencing a single fault.
Limited Current Circuits	These circuits may be accessible even though voltages are in excess of SELV requirements. A limited current circuit is designed to ensure that under a fault condition, the current

From Table 4.X, the cell-phone powered laptop will be drawing about 120 V_{AC} from the power outlet in the wall. So, in order to step down the 120 V_{AC} we will use the AC adapter from the original laptop to convert the AC power to DC power and make sure the current and voltage are operating at a safe level for the laptop to function properly. So, a protection circuit for the battery of the laptop is essential to preventing a short circuit or any type of electric shock for the user of the laptop as well. In other words, the ‘Hazardous Voltage’ circuit will fall under the protection circuit we will be utilizing for the protection of the battery for the laptop.

4.13.1 Power Supply Standards: Voltage Regulation

The definition of voltage regulation can be said as an identification of a long-term variation in voltage. So, variations that last longer than 10 seconds and can withstand voltage variations within $\pm 10\%$, as stated by the Information Technology Industry Council (ITIC), is deemed reasonable. The national standard in the United States of America can vary from state-to-state and utility-to-utility, but ANSI-C841 states that voltage regulation is defined into two categories. Those two categories are defined by Range A and Range B. Range A describes the normal conditions such as 120 V base that must be regulated at about $\pm 5\%$. Range B is for the shorter variations and not generally used as much as Range A, but must be regulated from -8.3% to +5.8%. These ranges are important to know when dealing with 120 V_{AC} voltages because this is a primary source of power for the cell-phone powered laptop, so the higher rated voltages must be regulated properly to ensure the laptop operates in a safe environment.

4.14 Software Testing Standard

The standard, ISO/IEC/IEEE 29119, is a combination of software testing standards. The use of this standard is designed to define an internationally-agreed set of standards for software testing that can be used by any organization when performing any form of software testing. The contents of this standard are used as an aid to ensure proper testing processes, techniques and documentation of software. Direct reference to this standard will allow for software development that not only meets this industry standard, but also is properly tested to ensure functionality.

4.14.1 Part 2: Test Process

ISO/IEC/IEEE 29119-2 is a section of the standard which specifies test processes that can be used to govern, manage and implement software testing. The test process is split up into three separate groups, organizational test process, test management processes, and dynamic test processes.

The organizational test process section is made up of procedures for the creation, maintenance and review of the organizational test specifications. In terms of this project, the organizational test process refers to the three group members as the organization, since the project performed is a group based project, and not included in an actual organization.

Test management process is broken up into three separate processes, test planning, test monitoring and control, and finally, test completion. There may be several different test plans, such as a reliability test plan, system test plan, and acceptance test plan. These test plans may be tested separately or combined into one overall test, the following procedure will remain unchanged regardless of the decision regarding test plans. After a test plan is established and testing begins, test monitoring and control will allow for any unplanned results that may arise to be addressed, and used to alter the original test plan. The test plan should meet organizational test process guidelines and be evaluated to ensure all criteria is met. Once the test plan is altered as to account for all unplanned results, the group may move to the test completion process.

Incorporated into the test completion process is the dynamic test process, which includes test processes related to test design and implementation, test environment set-up and maintenance, test execution, and test incident reporting. The role of this process is to ensure that the test completion process is performed correctly and all contributing members are aware of testing results with respect to the set guidelines of the process and final result.

A summary of the three test processes included in standard ISO/IEC/IEEE 29119-2 and the relationships between them are included in below. The image is contained in the standard and is copied here to display the overall guidelines to this section of the standard.

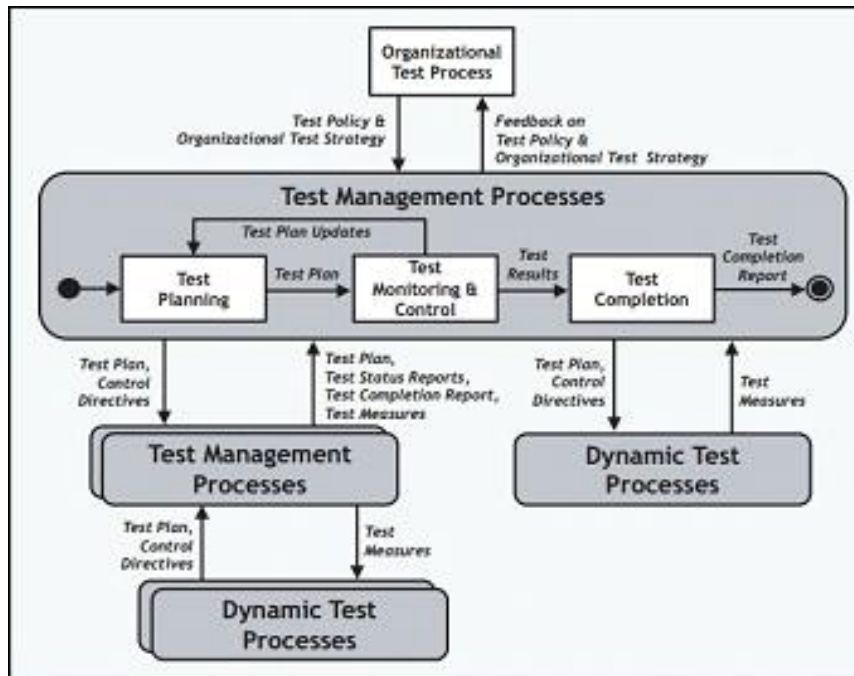


Figure 4.14.1: Test Process

4.14.2 Part 4: Test Techniques

ISO/IEC/IEEE 29119-4 is a section of the standard which defines test design techniques that can be used during the test design and implementation process that is defined in Part 2: Test Process. This section of the standard provides test design techniques for three separate classes of testing. These techniques are applied to specification-based testing, structure-based testing, and experience-based testing. Each of the three classes of testing include multiple different possibilities that may be applied in order to complete testing. Each case portrayed is defined in terms of derivation of test conditions, test coverage items and test cases.

Specification-based test design techniques primary source of information, to apply towards the test basis, is gathered from the requirements, specifications, models, or user preferences. The standard provides over ten different techniques that may be used to satisfy specification-based testing. Consideration to each of the techniques will allow for the best fit technique to be used.

Structure-based test design techniques primary source of information is gathered from source code or the actual structure of a model created. Again, there are multiple techniques which can be best fit towards the project in question.

Experience-based test design techniques are limited to the knowledge and experience of the tester, which is used as the basis of the test case design. A general guideline for experience based testing is explained in this standard, however, due to varying experience levels, it cannot be limited to one definition. The standard applies error guessing as an experience-based testing technique, which requires a set of defect types to be determined by the tester. The tester uses previous experience to predict inputs to the item being tested that may cause failures. Each defect type considered is included as a test condition.

4.14.3 Design Impact of Software Testing Standard

Through consideration to standard *ISO/IEC/IEEE 29119*, there are several aspects of the our laptop design that will be impacted. Following this standard exactly and demonstrating that all requirements have been satisfied will allow for our group to claim full conformance to this standard. However, there are many techniques that are included in this standard which are not necessary to the our design, and for that reason tailored conformance can be claimed. Tailored conformance can be claimed by demonstrating that the requirements chosen by our group have been satisfied.

Organizational test processes will impact the design of software in the sense that each group member will have to review and approve the coding. Since the organization is essentially the four group members, the organizational test policy and strategy will be created and applied by the group.

Test techniques will follow requirements set by the standard as well as those defined by the group itself. In order to assure that all testing is performed adequately, the testing techniques which are specified will be applied to each set of testing that is performed.

4.14.4 Programming Languages – C

ISO/IEC 9899 is an International Standard which specifies the form and establishes the interpretation of programs written in the C programming language. The standard covers several very important aspects which are related to the software section of our PCB design. Coverage includes: representation of C programs, semantic rules for interpreting C programs, and representation of input/output data processed/produced by C programs, as well as, the syntax and constraints of the C language. While the standard, in its entirety, applies to the software design, the aspects of the standard which most closely relate to the software section of the our smartphone powered laptop design are summarized below.

As with any language, there are definitions, notations, concepts, conversions, and many other contributions which construct the language. Notations described in the standard include the italic type, which represent the nonterminals, and the bold type, which portrays the terminals. A colon which follows a nonterminal introduces its definition. In the main text, syntactic categories are not italicized and spaces are used in place of hyphens. An overall summary of the language syntax is included in annex A of the standard.

Included in the concepts section of the standard are the scopes of identifiers, types and their representations. “An identifier can denote an object; a function; a tag or a member of a structure, union, or enumeration; a typedef name; a label name; a macro name; or a macro parameter”. The identifier can only be used within the its scope of the program. A scope can be categorized into four different types: function, file, block, and function prototype. The standard explains how each of these scopes are to be used and what may be applied to them. The type of expression used creates a value which will be stored as a result. The type refers to integer type, character type, Boolean type, floating types, array structure types, and pointer types. Each type is categorized into a group with which the types share common characteristics.

4.14.5 Design Impact of Programming Languages – C

There are several impacts that this standard will have on the software design of our PCB. Code which is written by members of the group will be reviewed and compared to the various shall statements included in the standard. “Shall” statements are a list of requirements or guidelines that must be met in order to claim conformance to this standard.

As well as guidelines that need to be met, associating this standard to our design will allow for definitions as well as coding to be incorporated into the design which may have previously been unknown to the software designer(s). While the C language is not taught throughout this standard, with use of information previously acquired on how to implement the language, new programming techniques can be learned. There are several different sections which explain the priority, or rank, that one type may have over the other. This is important to keep in mind and will impact the structure of the software designed, in order to meet requirements.

The software that is to be implemented in our smartphone powered laptop design is very heavy on arithmetic. Calculations must be performed to produce delays, for example in Pulse Width Modulation, which rely on arithmetic to be performed. Using the incorrect method of arithmetic or loop structure may result in undesired results and very inefficient software. For this reason, the standard on C language will be very beneficial in order to use correct arithmetic techniques and program structure. Included in arithmetic are the integer types which make up the numbers used for calculations. The use of the correct integer type is also very important, due to rounding errors, as well as, format errors in which two different types may not be compatible. As previously explained, different types included in a main group will have rank or priority assigned to each of the included types. Using the integer type as an example, if two different integer types are used together in arithmetic, the result will be of the integer type with higher rank. Therefore, it is important to realize which type to use for each application and to match operands accordingly.

Overall, all aspects of the software design implemented in the smartphone powered laptop, which relate to the C language, are impacted by this standard.

4.15 Project Design Issues

As with any project, we have run into many roadblocks on the way during multiple phases of our senior design project. We documented these issues to see how to possibly prevent others in the future and increase our efficiency in solving them. While all the problems listed below all fall in the category of hardware issues, we believe we will also run into software issues during the course of senior design. We are truly unable to implement at test our theorized software until we have a general working design of all of our hardware connected together. We have done additional research on the software and investigated potential issues we believe we might have in preparation for the possible roadblocks ahead.

4.15.1 Bluetooth Bandwidth Problem

As we progressed in senior design 1 with our project design, the list of connection we desired to make with the phone kept growing larger and larger. In a normal environment this might not be an issue, but because we have decided to go completely wireless for our

project, there is a major roadblock: bandwidth. From keyboard and touchpad to speakers to cameras, there are many connections that would make for an ideal laptop. The issue lies in the fact that wifi direct can only establish one connection and we have prioritized that for our display since it will have the most data transfer. From a wireless perspective that leaves all of our other wireless connections to be established over bluetooth. But bluetooth was not designed with this purpose in mind. It was to be a very efficient, battery-light way of data transfer. Because of this the amount of data that can be sent or received at any one moment is very limited. We foresee in the future either a modified high power variant of bluetooth that will allow many simultaneous connections or a completely new wireless standard designed to manage multiple wireless connections like this. Due to this issue we are severely limited on our stretch goals choices and will have to prioritize only the most critical of peripheral devices to maintain the integrity of the bluetooth connection.

4.15.2 Custom Connection Problem

Being that our project is using old prefabricated technology and new custom pcb designs, we knew there would be challenging levels of complexity. When looking and researching into the connection type of both our touchpad and keyboard of our asus gaming laptop, we assumed there would be popular standardized connection used that would be easy to identify and order our own connection cables. This was a very false assumption. We learned that many laptop manufacturers use their own proprietary connections that have no well known name or part number. This became a major roadblock in our timing projection for ordering parts for our project. For most of these connections we will end up manually soldering connections and creating our own custom interface.



Figure 4.15.2 - Laptop design comparison

4.15.3 Initial and Final Design Problem

Our initial design for the smartphone powered laptop is using the shell of the 2007 asus gaming laptop model asus g50v. We had to design and implement a multiple custom connections between our pcb and certain parts of the laptop. The main connections were to the keyboard, touchpad, and laptop screen. While we have most of the design issues for this configuration figured out, they took the most time of all the topics we've had to figure out for the project. This is where the issue lies. For senior design 2, we planned on using a completely different laptop shell and an optimized design. The plan was to use a very thin ultrabook style dell laptop model P69G for this shell. The issue here is that this laptop uses

a completely different touchpad, keyboard, and screen. The difference is not only in appearance and style but in connection type, which makes sense given that they were manufactured over ten years apart. This fact alone meant we would essentially have to redesign our project for the second, final iteration with the dell ultrabook laptop. With the limited time we will have in senior design 2 (one semester) and our limited financial means, we decided as a group to forego the second design and focus on initial design with the asus gaming laptop. This will give us more time for troubleshooting and a smoother final product. We will also use this time to address and attempt our many stretch goals with we think will make our overall product more successful than the second laptop design.

5. Design

Following the design constraints and standards section comes the design section where we display our methodology and implementation of how we are going to do this project and make it come to life. We go over many design components for hardware and software components and schematics and diagrams that illustrate the flow of the software and the flow of the hardware. From voltage regulation to powering the Bluetooth/Wi-Fi module and from constructing a UDP web socket to the android user interface, we will talk about all of this.

5.1 Proof of Purchase

In Figure 5.1 and Figure 5.1.1, we have laid out all of the components we purchased for the design project. The parts are listed below as:

- Laptop shell – ASUS G50V model
- AC Adapter – ASUS G50V adapter
- Battery pack – A32-M50 model (ASUS G50V standard)
- Bluetooth Touchpad
- Bluetooth Keyboard
- Arduino board – Atmega2560
- LCD screen – ASUS G50V standard
- Qi Wireless Charging Pad
- Voltage Regulator – LMR14010A
- Bluetooth Module – Bluefruit LE UART
- Wi-Fi Module – ESP8266 model
- VGA/HDMI/USB ports
- Serial to USB adapter

Figure 5.1 – Proof of Purchase Picture 1



Figure 5.1.1 – Proof of Purchase Picture 2



5.2 Voltage Regulator: Battery to Microcontroller

The microcontroller that will be used in the design of the smartphone powered laptop is the Arduino Mega 2560 ADK. The Arduino microcontroller input voltage according to the datasheet is recommended 7 to 12 volts. The battery chosen to power the smartphone powered laptop is rated at a value of 12 volts. Moreover, the operating voltage to the Arduino is 5 volts, which means the Arduino has a built in regulator on the board already that supplies 5 volts from an input of 7 to 12 volts. However, when the final product is designed and placed on a PCB, only a microcontroller chip will be used, and there must be voltage regulator designed to regulate the input voltage to the microcontroller to 5 volts. Since, we are reusing the battery pack from the salvaged laptop; there is no need to design a battery at 5 volts. As discussed in the previous sections, the switching regulator is more efficient than the linear regulator, however a test must be done to compare the results and make a final decision.

5.2.1 TPS62172A Buck Converter

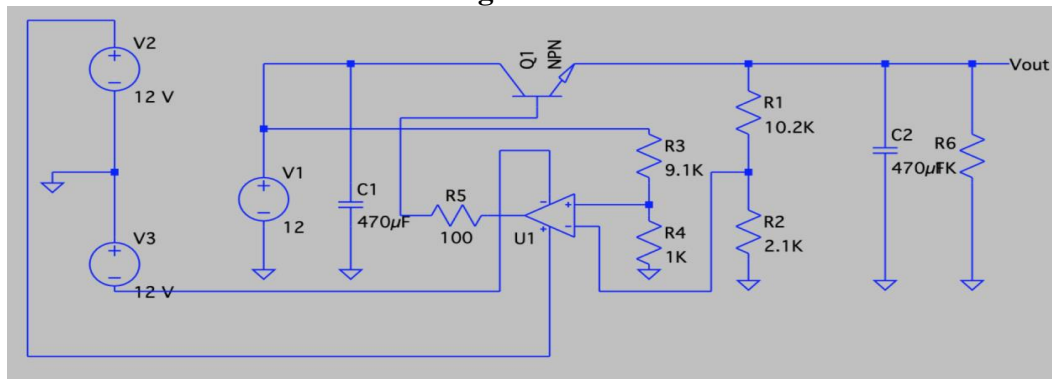
Texas Instruments provides a step down converter with an input voltage that ranges from 3 volts to 17 volts and delivers an output voltage of 0.9 volts to 6 volts. A minimum of 3-volt input gives a lot of room for voltage drop and calculation error, just in case the input voltage from the microcontroller experiences a voltage drop due to the on resistance seen by the pins in the microcontroller. The pin on the microcontroller will not see a 2 volt drop, however there may be a 1 volt drop, therefore the circuit will still be able to step down, if that is the case. As stated before, switching regulators are very efficient, and in this case the Buck converter provides the user with a maximum efficiency of approximately 92% at 5 volt input.

In order to design this circuit, Web Bench is the best approach to find a circuit with the appropriate ratings. In fact, no design is necessary because TI already provides the customer with a schematic. This circuit will be fairly straightforward to implement, due to the simple fact that there are only 5 components to the circuit, the main component being the chip provided by TI. There is one last specification that must be considered, which is the output current from the step down converter. The next section will discuss the Wi-Fi module current requirements, and how the current changes depending on the type of communication protocol.

5.2.2 Linear Voltage Regulator with Op Amp

A linear voltage regulator is designed, which is shown in *Figure 5.2.1*. In this circuit, a TL-084 op-amp is used with an NPN bipolar transistor. Let's say the output voltage drops below the regulated voltage. V^- will decrease and V^+ is now greater than V^- . We know the output is equal to $A_{od}(V^+ - V^-)$. Therefore, the output from the input increases, which will increase the voltage across the transistor, and finally increase the output voltage. In this case, the output is a function of V_{cc} , R_1 , R_2 , R_3 , and R_4 . The capacitors act as bypass capacitors, which shorts any AC to ground and helps remove any AC from appearing on a DC signal. Also, the capacitors help block any AC signal from showing on the input and output. However, this circuit requires three sources. One source for the input voltage and two sources for V_{cc+} and V_{cc-} . Therefore, the LM7805 is more practical to implement due to its simplicity and because it is readily available. However, LM7805 is obsolete, but is sufficient enough to run tests.

Figure 5.2.1



5.2.3 Switching Voltage Regulator LMR14010A

In the previous sections, switching voltage regulators were discussed, and the conclusion is that switching voltage regulators are more efficient, which makes them better regulators. Therefore, a switching regulator is used in the microcontroller design for the smartphone powered laptop. According to the datasheet from Texas Instrument, the efficiency of the LMR14010A is typically 91%, with an input voltage of 4 to 40 volts. This switching regulator regulates the output voltage at 5 volts. Furthermore, the switching regulator has an output maximum current of 1 Amps, which is much greater than the allowed current through the Vcc and ground pins, but will not affect the microcontroller because the microcontroller only pulls the current it needs. Due to many considerations and complications on the Arduino, an input current from the supply has a maximum value of 800 mA. This is not found in the datasheet, however multiple people on Arduino’s forum confirm this is the maximum value. This circuit shown in *Figure 5.2.2a* only has 8 components, including the switching voltage regulator chip. This makes building the circuit easier and also helps reduce the amount of space taken on the PCB. *Figure 5.2.2a* shows the model of the circuit given by Texas Instruments, which is used in the design of the microcontroller.

During the initial test, an Arduino AT Mega 2560 ADK will be used, which means there is no need to setup a switching circuit to regulate the voltage since the voltage regulation will be done by the board. In fact, the board has a voltage regulator already built in, and can regulate an input of 7 to 12 volt. After testing the circuit on a breadboard, the microcontroller from the board will only be used in the design of our circuit, along with a voltage regulation circuit to provide the appropriate voltage to the microcontroller.

Another difference between our initial test and final prototype is the type of switching regulator used. Since the LMR14010A is only surface mount available, initial testing will be done by soldering wires to each pins under a microscope. After that, the surface mounted device will be used in our PCB prototype.

Figure 5.2.2a – Voltage Regulator Prototype Circuit

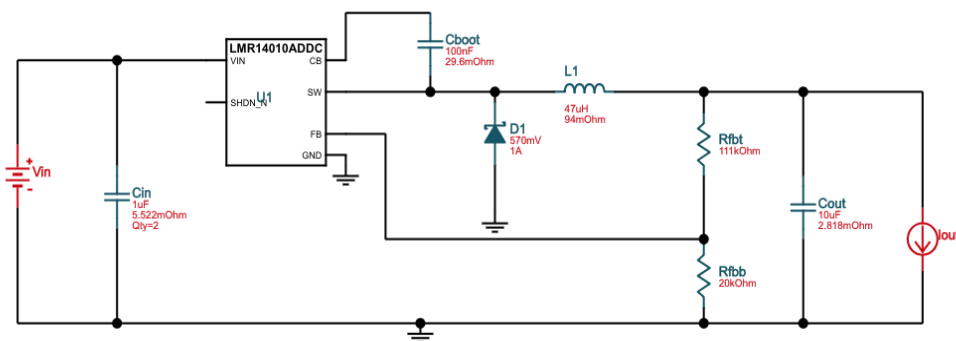


Table 5.2.2b lists a couple of features and Table 5.2.2b lists the price of four regulators for the PCB design. As seen, the Switching Voltage regulator is more expensive than the linear

voltage regulator, but provides great efficiency, which is much better than the linear voltage regulator. Furthermore, the switching regulator provides a 91% efficiency.

Table 5.2.2b – Voltage Regulator Comparison

	Linear Voltage Regulator (TI)	Linear Voltage Regulator (TI)	Switching Voltage Regulator (TI)	Switching Voltage Regulator (ON)
Features	296-47192-ND	LMR14010A	LM2576T-5.0/NOPB-ND	LM2576TV-ADJGOS-ND
Input Voltage	0-35	4 - 40	1.23 - 37	1.23 - 37
Output Current (A)	up to 1.5	1 max	4.2 - 6.9	3
Output Noise Voltage (μ V)	40		N/A	N/A
Output Voltage	4.8 - 5.2	5	3.3, 5, 12, 15	3.3, 5, 12, 15
Dropout Voltage (V)	2	N/A	0.5 at 200mA	1 at 200mA
Output Resistance (m Ω)	1	N/A	N/A	N/A
Efficiency (%)	N/A	91	approx. 77	approx. 77
Price	\$1.54	\$2.76	\$2.77	\$2.24
Description	Linear Voltage Regulator	Switching Regulator	Switching Regulator	Switching Regulator

5.2.4 Switching Regulator Design for Wi-Fi Module

As stated before, the Wi-Fi module being used for the powering of the LCD is the ESP8266-01 module. According to the datasheet, the operating current of the module depends on certain parameters, which can change depending on the function of the Bluetooth module. In our case, the Bluetooth module is a transceiver and acts as a receiver and transmitter. This means, the current consumption will vary from 56mA to 170mA [C4], depending on what the Bluetooth module is doing. According to the datasheet, a transmitting signal consumes much higher current than when the Bluetooth module is receiving.

This is a problem, because the maximum current output from the AT Mega 2560 is 40mA [C5]. Furthermore, another problem arises, as the continuous current is not 40mA. To be

safe the output current from one of the pins should be around 20mA. Furthermore, the total current output from the pins must not exceed 200mA, which means only 10 pins at 20mA can be used at once. In order to solve this problem, an amplification in current must be implemented to produce such currents.

In order to amplify the current, a circuit from TI's Web Bench is provided and implemented. The circuit provided by TI has a max output current of 500mA. While, the Wi-Fi module will not consume more than 200mA, 500mA is not needed and does not represent the what the Wi-Fi module is consuming. Another factor to consider, is the input current from the Arduino module, which cannot exceed 20mA, as we are trying to utilize as many pins as possible. A resistor placed at the input will reduce the input current from the Arduino, which will solve the problem of exceeding the rated current at the pins. Another way to solve exceeding the current from the ATmega 2560, is to place resistors in parallel, if one resistor is not enough.

Lastly, the table below shows the bill of materials used to implement this circuit on a breadboard. However, the final step would include designing this circuit onto a PCB, as the final prototype.

Table 5.2.4 – Components Used in Design

Part	Manufacturer	Part Number	Quantity	Price (\$)	Footprint (mm ²)	Description
Cin	MuRata	GRM31CR71E106KA12L	1	0.29	10.92	Cap: 10 μ F Total Derated Cap: 2.8 μ F ESR: 1 m Ω
Cout	TDK	CGA5L1X7R0J226M160AC	1	0.31	10.92	Cap: 22 μ F Total Derated Cap: 10 μ F ESR: 1.87 m Ω
L1	Vishay-Dale	IHLP1212BZER2R2M11	1	0.56	19.32	IDC: 3 A L: 2.2 μ H DCR: 46 m Ω
Rpg	Panasonic	ERJ-6ENF1003V	1	0.01	6.75	Tolerance: 1.0% Resistance: 100 k Ω Power: 125 mW
U1	Texas Instruments	e62172DSGR	1	0.51	9.61	

5.3 Bluetooth Module

The Bluetooth module used in this design is the Bluefruit LE UART, which makes connecting to anything with a hardware or a software serial port easy. In order to power the Bluefruit LE UART, careful considerations must be made. The sections below will go into detail about powering the module, as well as testing the module on a breadboard.

5.3.1 Bluetooth on Breadboard

The Bluefruit LE UART is a ready to go PCB that is very user friendly, and requires minimal soldering to achieve a breadboard configuration. In fact, pins can be soldered directly to the through holes on the board, this is also known as a breakout board. From there, the Bluetooth can be connected directly to an Arduino, in this case we will be connecting to an Arduino UNO. Each pin on the Bluetooth module must be connected to a specific pin on the Arduino to make sure everything is working properly. The corresponding pins are:

- MOD to Pin 12
- CTS to Pin 11
- TXO to Pin 10
- RXI to Pin 9
- Vin to 5 V
- RTS to Pin 8
- GND to GND

After the pins are connected we can now setup the communication protocol, in this case UART is used to preform communication between the computer and microcontroller. Next, communication can be made through software or hardware. Software communication can be done by defining each pin on the Bluetooth to the corresponding microcontroller pins. Hardware communication is done by defining the “name” for the the serial connection.

After the pin configuration is setup, we can now setup the serial bus, which is UART. The code is available on the datasheet, and can be done by software or hardware.

Before the program is implemented into Bluetooth, there are simple ways to determine if the Bluetooth module has made proper connection with the Arduino. One of those ways is to do a factory reset. A code can be implemented from an open source library called “Adafruit Bluefruit LE library”. In that library there are examples, which one of them is factory reset. Once the reset is implemented, the serial monitor should give feedback if performed correctly.

5.3.2 Bluetooth Design Algorithm

In order to communicate the Bluetooth with the touchpad, the touchpad must first communicate with the microcontroller through Arduino. Section 11.3 talks about how to make proper connection with touchpad using PS2 protocol. After communication between the microcontroller and touchpad is complete, the Bluetooth must now communicate directly with the microcontroller. In this algorithm, the Bluetooth will request the state from the touchpad, which will be sent through the microcontroller.

States describe the byte packet being sent, X, Y, and Z position. This data will continuously loop in stream mode, sending data from the microcontroller back to the Bluetooth module.

5.3.3 Bluetooth Design for PCB

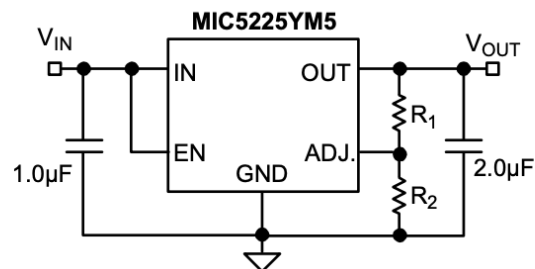
While using a Bluefruit LE UART board is practical and very easy to be implemented, it will not be used in our design. The Bluetooth module will be the only part taken from the Bluefruit LE UART in the PCB design of the circuit. The module used on the Bluefruit LE UART is the MDBT40 with the nRF51822 chip, which includes a built in antenna and is compatible with computer peripherals such as a mouse and keyboard. Nevertheless, powering the Bluetooth module is the first step to building a schematic for the Bluetooth module.

There are three ways to power the Bluetooth module. The first way uses an internal LDO setup, the second way uses a DC/DC converter, and the last way uses a low voltage setup.

The first way uses LDO, which is a linear dropout voltage regulator that supplies the appropriate voltage to VDD. The second way uses DC/DC converter which converts battery voltage to a lower voltage with very little loss. The converted voltage is then used at the input. When the supply voltage drops to the lower limit of the voltage range, the LDO can be used to supply voltage. This method is mainly used for applications that use batteries to power the module. When the supply voltage level decreases, the peak power drain is reduced by 25%, according to the datasheet. [C8] The last method is to provide a supply voltage at a steady 1.8 volts. After careful thought and consideration, the Bluetooth module will be power by an LDO setup. DC/DC is the most efficient, however our design does not need an external battery.

In order to power the circuit a voltage of 3.3 volts must be delivered to the module. Similar to the Wi-Fi module, Bluetooth requires the same voltage, except the current consumption is drastically less. Therefore, the voltage regulator used to power the Bluetooth module is a low dropout regulator, which can handle an input voltage in the range of 2.3 to 16 volts, while providing a highly accurate output and ultra-low ground current. In Figure 5.3.3a there's a typical circuit given by the manufacturer. In our design, the input is from the microcontroller, which is 5 volts.

Figure 5.3.3a: Micrel Low Dropout Regulator



Another consideration is the communication protocol. The Bluetooth module is capable of communicating using UART, therefore the appropriate pins must be designated to control the communication. Bluefruit LE UART uses 4 main pins which are TXO, RXI, CTS, and RTS. TXO describes the transmit data that is going out of the module to the microcontroller

and it is held to a 3.3 volt logic level. RXI describes the receiving data that is coming into the Bluetooth module from the microcontroller, which will be held to 3 volts. CTS is the clear to send hardware function that lets the Bluetooth module know that the data from the transmit pin can be sent back to the microcontroller. CTS is pulled high, but must be pulled low to send data out. RTS is read to send which has flow control of the data being sent out of the Bluetooth module and into the microcontroller. When this pin is low, data can be sent to the Bluetooth module, otherwise when it is high data cannot be sent. This pin is tied to the input of 3.3 volt.

Another factor to take into consideration is the current consumption. When dealing with wireless transmission and receiving the amount of current varies depending on the output power. According to the datasheet the maximum output power is 4dBm. In Table 5.3.3b below, one can see that the maximum current consumption at the maximum power is 16mA for transmitting data. When receiving data at a max of 2Mbps, the current consumption is 13.4mA. This is very important in our design, because our current limit at each pin is 20mA. This provides availability for more pins to be used on the microcontroller.

Table 5.3.3b: Radio current consumption for DC/DC disabled

Symbol	Description	Note	Min.	Typ.	Max.	Units	Test level
$I_{TX,+4dBm}$	TX only run current at $P_{OUT} = +4$ dBm.	1		16		mA	4
$I_{TX,0dBm}$	TX only run current at $P_{OUT} = 0$ dBm.	1		10.5		mA	4
$I_{TX,-4dBm}$	TX only run current at $P_{OUT} = -4$ dBm.	1		8		mA	2
$I_{TX,-8dBm}$	TX only run current at $P_{OUT} = -8$ dBm.	1		7		mA	2
$I_{TX,-12dBm}$	TX only run current at $P_{OUT} = -12$ dBm.	1		6.5		mA	2
$I_{TX,-16dBm}$	TX only run current at $P_{OUT} = -16$ dBm.	1		6		mA	2
$I_{TX,-20dBm}$	TX only run current at $P_{OUT} = -20$ dBm.	1		5.5		mA	2
$I_{TX,-30dBm}$	TX only run current at $P_{OUT} = -30$ dBm.	1		5.5		mA	2
$I_{START,TX}$	TX startup current.	2		7		mA	1
$I_{RX,250}$	RX only run current at 250 kbps.			12.6		mA	1
$I_{RX,1M}$	RX only run current at 1 Mbps.			13		mA	4
$I_{RX,2M}$	RX only run current at 2 Mbps.			13.4		mA	1
$I_{START,RX}$	RX startup current.	3		8.7		mA	1

1. Valid for data rates 250 kbps, 1 Mbps, and 2 Mbps.
2. Average current consumption (at 0 dBm TX output power) for TX startup (130 μ s), and when changing mode from RX to TX (130 μ s).
3. Average current consumption for RX startup (130 μ s), and when changing mode from TX to RX (130 μ s).

5.3.4 Bluetooth Clock

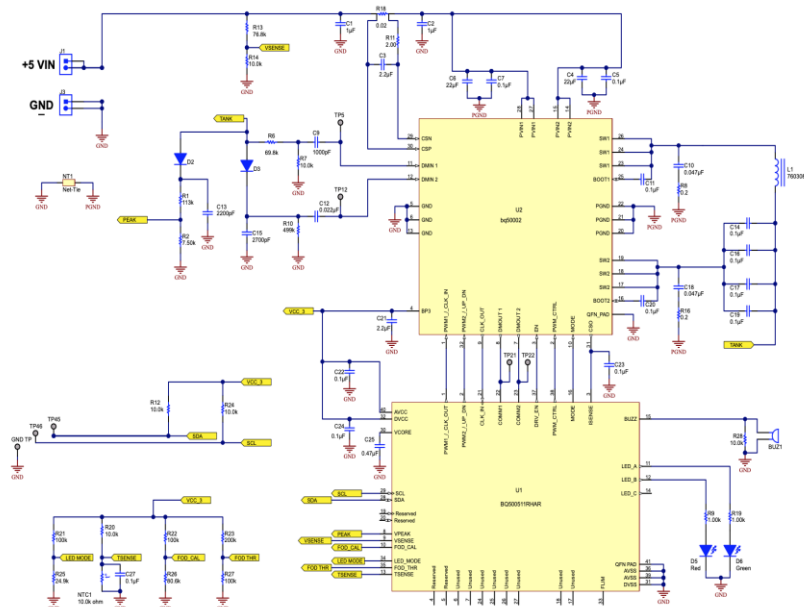
The Bluetooth chip has an external and internal clock management system that delivers the correct frequency, whether it is high or low to a specific module. The clocks ability to support high and low frequency management helps minimize latency by offering a second oscillator outside the module. Latency can be defined as the amount of time a clock signal takes for the clock to propagate to a specified register. Minimizing latency improves clock

tree buffer and less power dissipation. The Bluetooth module comes with a 16MHz crystal oscillator built in that acts as a high frequency clock and an external 32 KHz clock that acts as a low frequency oscillator that must be installed by the designer. According to the datasheet the external oscillator must have capacitors connected to both terminals to ground to achieve correct oscillation. The appropriate value is 12pF.

5.4 Wireless Charger

The wireless charger uses two chips, one acts as a wireless power controller and the other is an analog front end. Both chips have a typical circuit shown in *Figure X* below, which is provided by Texas Instruments in the data sheet. As one can see, the input voltage for the analog front end chip is 5 volts, while the supply voltage for the controller is 3 volts. According to the data sheet, the input voltage for the controller ranges from 2 to 3.6 volts. Therefore two pins must be used on the microcontroller to power the wireless charger. Since the analog front end chip is 5 volts input, there is no need to regulate the voltage from the microcontroller. However, the controller needs regulation from the microcontroller. Since the microcontroller operates at 5 volts, the input voltage to the analog front can also use that 5 volt regulation. This can also be applied to the controller, as the controller is able to operate at 3.3 volts, therefore the regulator that regulates the Wi-Fi module can be applied to this wireless charger.

Figure 5.4 – Schematic of Wireless Charger



5.5 Testing Procedure

To begin, testing plays a big role in many projects and requires a specific procedure. In the sections below, a procedure is developed and explained to show how our designed is tested and what we are looking for while testing the design. A testing procedure is very important as it allows our design to be compared with the datasheet to meet specifications. This allows

our projects final design to be prototype ready. The sections below describe the testing of voltage regulation to the Wi-Fi, Bluetooth and Microcontroller as well as testing the battery to make sure voltage supply is correct and test the ability to recharge the battery.

5.5.1 Power Testing

The first part to testing is to test and make sure all components are powered correctly with the sufficient amount of voltage and current. Also, noise is very important when powering all necessary components and will be measured for datasheet comparisons when the final design is built on the PCB.

The first two components that need to be tested are the voltage regulators used for powering the microcontroller, Bluetooth and Wi-Fi module. Since the Bluetooth and Wi-Fi module both require the same voltage only one regulator is needed. For both the Bluetooth and Wi-Fi module the voltage at the output of the regulator should be 3.3V with a 3% possible error according to the datasheet. The voltage can be measured simply by using a multimeter or oscilloscope. The output ripple voltage should be 1% and can be measured using the oscilloscope. The load currents will be measured when the Bluetooth and Wi-Fi module are turned on. The load currents are measured using an current probe with the oscilloscope. The *Table* below describes what the conditions are for testing all the voltage regulators. A test for the time spent using the product will also be implemented when testing the component.

Next, troubleshooting should be taken into consideration when building the PCB design and when testing on a breadboard. On a breadboard, the first thing to check is if the voltage supplied to the regulator is sufficient or over 4 volts. The test will be done using a multimeter, using the probes to test the voltage at the battery terminals. If there is no voltage at the battery terminals then that means the battery must be flat. Another way to test if the circuit is getting enough voltage is by setting a LED at the output of the battery terminal. If the LED is on that means the voltage at the battery terminal is 12 volts. Now, if the battery is supplying enough power to the input of the voltage regulation circuit, and there is still something wrong with the circuit, the next thing to check is the ground. Make sure all ground connections are at 0 volts by using a voltage probe and measuring the node at all ground connections. This should fix the problem.

Next, the same test structure is implemented, except on the PCB design. In this case, the main connections on the PCB must be made for testing purposes. By this I mean, a pad or via must be implemented into the PCB design as a test point. This connection is the battery supply, voltage regulation output, and ground. All pads or vias used for test points must be a certain distance away from the edge of the board to avoid problems. A good place for test points would be on the bottom or one side of the PCB. Placing the test points at easy access points on the test board helps reduce the amount of time spent troubleshooting for basic circuitry error. A test point provides the best access over the via and gives our group the ability to use a test probe with no problems. A via would require a pin to be soldered to it, which is not necessary. However, breakout pins can be used to do extensive testing on a

breadboard if a problem arises. Breakout pins can be used at the main pins of the Bluetooth module and Wi-Fi module. The main pins consist of the power, transmit, and receive lines. Another procedure that must be taken into consideration when using the test points to measure voltage is the tip and barrel method. This method makes sure that there is not a larger area at the probes positive and negative terminal on the probe to allow for noise to collect.

Table 5.5.1 – Testing Procedure

Description	Conditions	Results
Make sure the regulators convert voltages	The battery voltage must be connected to the input of the regulator to make a realistic test.	All voltage regulation must be within 3% at the output of the regulator. Battery voltage must be at least 4 volts.
Make sure the regulators load current is within range	Connect the Bluetooth and the Wi-Fi module to the output of the regulator. Current can now be measured. Make sure current is measured at power and communication lines	Current drawn must be within 3% of the data sheet results.
Make sure everything is working as a whole	Now connect everything for at least 30 minutes to ensure everything is operating correctly	No fluctuations at the output.

5.5.2 Microcontroller Hardware Testing

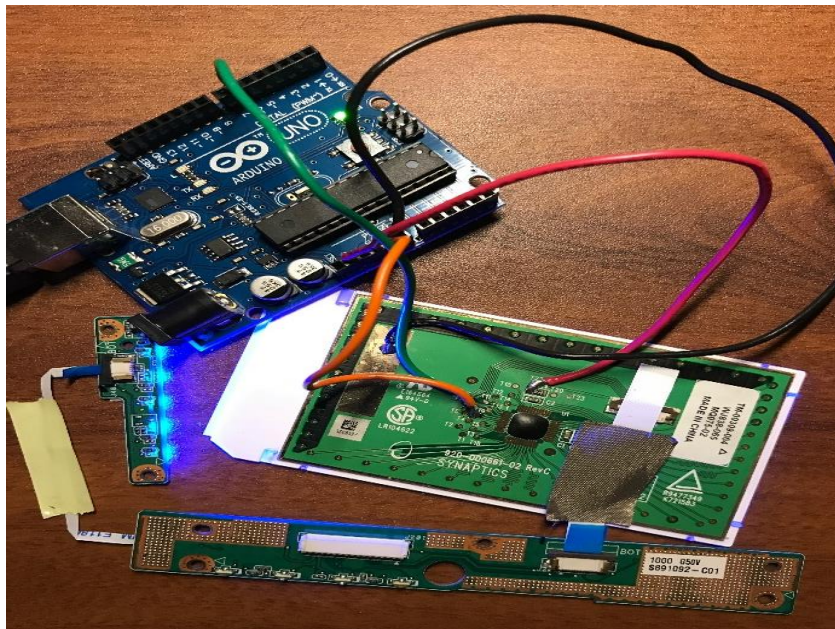
The microcontroller is designed with multiple bypass and decoupling capacitors to block AC signals and to provide consistent voltage levels to the supply pins during the operation of the circuit. The oscilloscope is used to measure the output voltage at the microcontroller when the capacitors are placed at the ground and supply pins. Lastly, the voltage of the overall system with the Wi-Fi module and Bluetooth module is tested from the microcontroller pins. Each pin can have noise associated with it, which means all pins must be measured to ensure the noise level is within specification. As said in the “Microcontroller Research for Design” capacitors are used to limit noise. Different values of ceramic capacitors will be used to determine the best value and size for the overall design. The current is also a major concern from the Wi-Fi and Bluetooth module, which means the microcontroller must be left on for 30 minutes to ensure that the current levels from the receive and transmit lines do not exceed the 20 mA limit at the pins on the microcontroller. This is also discussed in the “Microcontroller Research for Design”. Furthermore, a brown out detection circuit will be used to ensure no exceeding current

from the pins. Another test on the microcontroller is to ensure the external oscillator is oscillating correctly. A voltage probe will be used to calculate the frequency of oscillation.

5.6 Testing of Hardware Components

Before designing the necessary circuitry and schematics to power these electronic components, we must first test the capacities of each electronic component so that their functionalities are working as intended. First, we tested the mouse pad of the Asus laptop that we are utilizing and we used a Digital Multimeter to check the connections of each pin and try to map out the pin layout of the mouse pad. We then tested other pins of the touchpad for the 5V VCC and the GND pin. We took the Digital Multimeter and took the positive lead of the Digital Multimeter and placed it onto T22 of the Touchpad PCB. If the Digital Multimeter is set correctly to the appropriate setting then the continuity should be complete and the Digital Multimeter will emit a beep indicating that there is continuity in that lead. Testing the DC power socket involves the use of a multimeter and testing the leads of the inside of the jack to the soldering area that surrounds the DC power socket. First, we test the DC power socket by applying the negative lead of the multimeter to the top face of the DC power jack to test for continuity. Also, after testing the top face of the DC power socket, we can go ahead and test the bottom of the component, soldering points, for continuity. We can place the negative lead of the digital multimeter to a soldering point and place the positive lead of the digital multimeter on another component to test if there is continuity. If there isn't then the DC power socket is shorted and not connected properly or it is defective. Once the DC power socket is tested and is working properly then the AC adapter can be plugged into the DC power socket to deliver the appropriate amount of power to the ASUS G50V A32-M50 model battery pack.

Figure 5.6a – Touchpad Testing



In figure 5.6, we have set up the ASUS G50V touchpad and have hooked it up to the Arduino board. As shown in the picture, the blue LEDs have lit up so the Touchpad is being powered correctly. The green wire is connected to the clock of the Arduino, the red wire is the 3.3 V power from the Arduino, and the black wire is for ground. The touchpad is operating correctly, but the orange wires are for the left and right buttons for the touchpad. Essentially the overall touchpad is set for receiving data. Furthermore, the *Table* below shows all the pinout connections from the connector. We also ordered 3 touchpads in case of one failing. We believe that the buttons of the touchpad are currently not working due to the fact that the Arduino must be programmed.

Table 5.6b – Pinout for Touchpad

Pinout for Touchpad (1 starts on left side to 12 right)	Pin #
Supply	1, 2
T11	3, 4
T10	5
T10	6
GND	7, 8
T6	9
T13	10
T8	11
T9	12

5.6.1 Testing Bluetooth: Bluefruit LE UART module

We tested the Bluetooth module by first powering it on, by using the Arduino Uno: ATmega2560 board. As you can see in the figure below, we connected the Bluetooth module to the Arduino Uno board then the Arduino Uno board to a laptop to run the Arduino IDE software. First we soldered some male pins onto the Bluetooth module in order to use the module on a breadboard. We used a standard jumper cable for each pin connection and followed the pinout for the Bluetooth module to Arduino Uno board in Table 5.6.1a, as shown below.

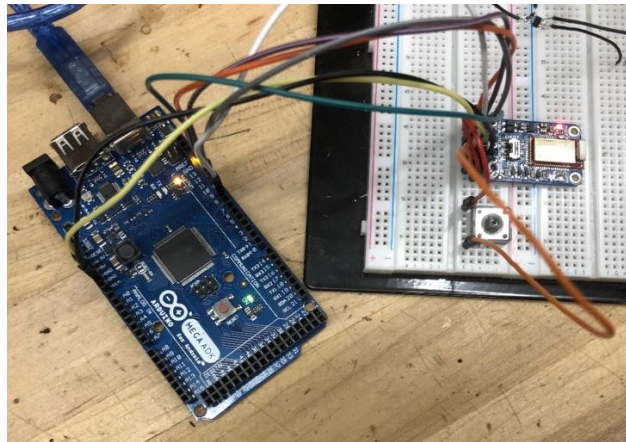
Table 5.6.1a – Pinout & Connections

Bluefruit LE UART Pin #	Arduino Uno Pin #
MOD	12
CTS	11
TXO	11
RXI	9
Vin	5V
RTS	8
GND	GND
DFU	GND

Following the pin connections from Table 5.6.1a, we also added a button for the factory reset of the Bluetooth module called the DFU pin. This button is connected to the DFU pin then connected to the common ground. In Figure 5.6.1b below, we illustrate how the Bluetooth module was wired and the LEDs are shown showing that the Bluetooth is working properly and being powered. We also did not program the Bluetooth yet due to complications in us having to flash firmware on the Bluetooth module so we will be leaving that for the winter break or Senior Design 2.

As shown in Figure 5.6.1b, the LEDs are operating so the Bluetooth module is turned on and operating properly. We must flash firmware on the Bluetooth module in order to program the module, but as mentioned in the previous paragraph, we will do this in winter break or senior design 2. To connect the Arduino Uno board to our laptop, we used a Serial to USB adapter. For the software to program the Bluetooth module, we will use the Arduino IDE example test codes to program the Bluetooth module to see if its features are operational.

Figure 5.6.1b – Bluetooth connection to Arduino Uno board



5.6.2 Testing Wi-Fi: ESP8266 Wi-Fi Module

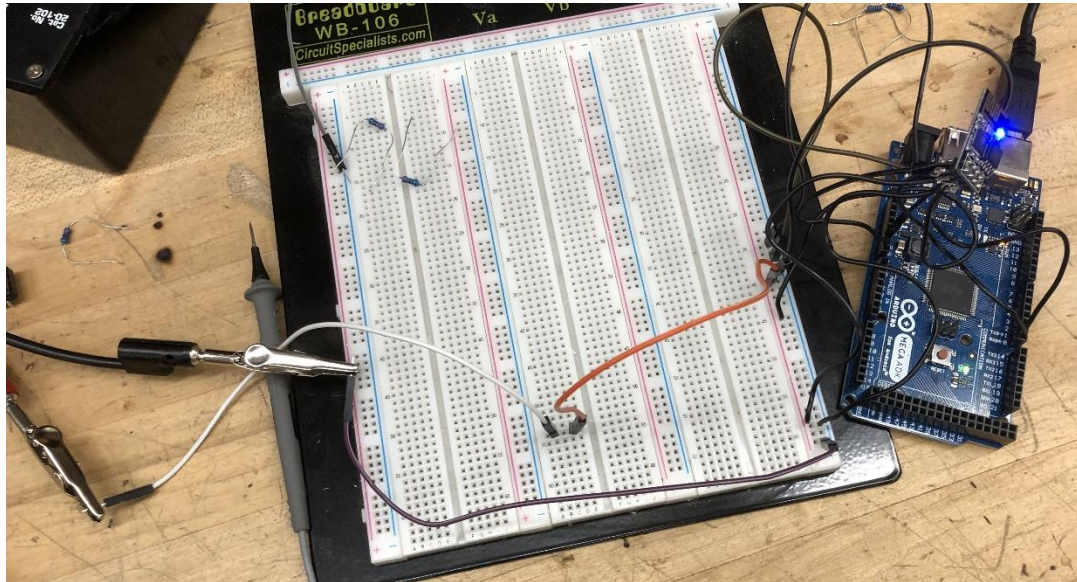
To test the Wi-Fi module we must first determine whether or not the Wi-Fi module is operational. So we must first analyze which pins we actually need to use for our specific type of application. The two GPIO pins will not be needed in this project so we kept those disconnected. But, the rest of the pins are going to be used in the project. Before wiring the ESP8266 to the Arduino Uno board, we have to be careful with the power demands of the Wi-Fi module. For the ESP8266, the maximum voltage that it can take is 3.3V so we cannot use the 5V pin on the Arduino Uno board. In order to prevent too much current draw from the Wi-Fi module, although the Arduino Uno board has a 3.3V pin we still cannot use this because the Arduino Uno board has a max current draw that is far below the operational current draw required to power the Wi-Fi module, we must use an external power supply to power the Wi-Fi module. In Table 5.6.2a, we used this pin layout from the Wi-Fi module to the Arduino Uno board and Power Supply of 3.3V. A common ground was also used for the connection of the ESP8266 module, Arduino Uno board, and the 3.3V power supply.

Table 5.6.2a – Pinout & Connections

ESP8266 Wi-Fi Module	Arduino Uno Board	3.3V Power Supply
GND	GND	GND
3V3	-	3.3V
RX	PIN 3	-
EN	-	3.3V
RST	-	3.3V
TX	PIN 2	-
GPIO1	(Not Used)	(Not Used)
GPIO2	(Not Used)	(Not Used)

Figure 5.6.2b below shows the connections of the ESP8266 to the Arduino board and 3.3V power supply.

Figure 5.6.2b – ESP8266 to Arduino Uno



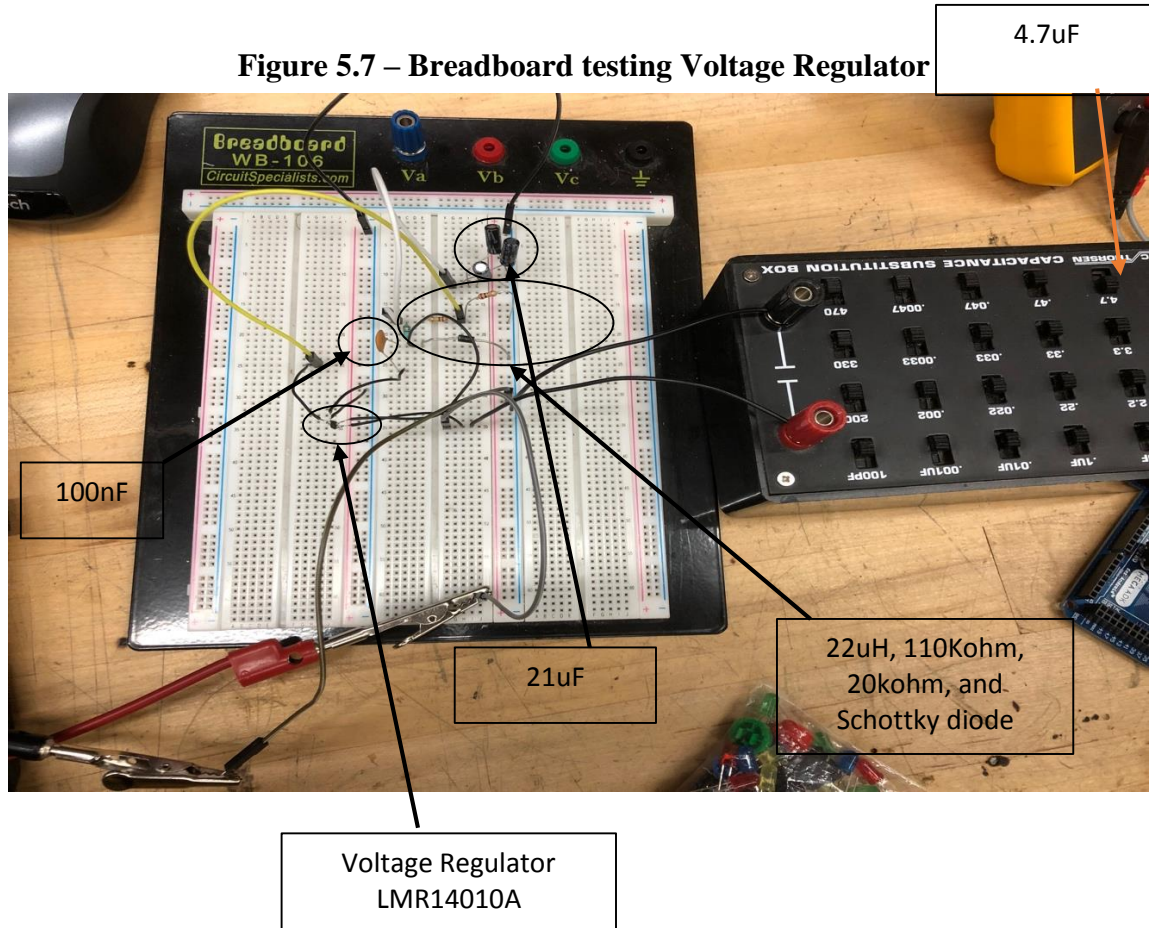
As shown in Figure 5.6.2b, the 3.3V power supply (alligator-clip shown to the left attached to the white jumper cable) is placed in a common node that shares the 3V3, EN, RST connections. The common ground (alligator-clip shown to the left attached to the dark-purple jumper cable) is placed in a common node, separate from the 3.3V power supply, and shares the GND connection of the ESP8266. Finally, the RX pin is connected to PIN 3 of the Arduino and the TX pin is connected to PIN 2 of the Arduino. These two pins are to receive and transmit data. As shown in Figure 5.6.2b, the blue LED is on which means the Wi-Fi module is operating. As for the programming portion of the testing, we need to run several ‘AT’ commands in the Arduino IDE along with the SSID of the network we want to join. We will use the sample SoftwareSerial code to program the WiFi module in Arduino IDE in order for the ESP8266 to locate different networks. But, we are going to do this during winter break or Senior Design 2.

5.7 Breadboard Testing Voltage Regulators

In our design, the microcontroller, Wi-Fi module, Bluetooth module, keyboard, and touch pad, all need voltage regulation from the 11.1 volt battery to operate. As said in the early sections, the microcontroller and keyboard operate at 5 volts and the Wi-Fi, Bluetooth and touch pad all operate at 3.3 volts. Therefore, two regulators are needed. The regulator in Figure 5.7 shows the schematic regulating for the microcontroller and keyboard. There is only one regulation circuit shown, because the regulator for 3.3 volts uses the same chip and schematic, except with different resistor and capacitor values.

In the Figure 5.7 below, the circuits 11.1 volts is from a DC power supply, and the output measured was approximately 10 volts. The output should be 5 volts, however when we were troubleshooting, the feedback voltage was reading 0 volts, which means the pin is

either damaged or the circuit is incorrect from Web Bench. The next steps will be to test on another brand new chip. This will be done during winter break.



5.8 Communication

The smart phone powered laptop is using two forms of communication, the first is a Bluetooth module Bluefruit LE UART and second is the Wi-Fi module ESP8266. The Bluetooth module will allow communication between the keyboard/Touchpad and the android device where the MCU will act as a middle man taking commands from the keyboard/Touchpad and sending them to the android device using the Bluetooth module. The Wi-Fi module will allow the MCU to establish an internet connection so that the contents of the android device can be streamed over the Wi-Fi module and be displayed onto the laptop LCD screen. In the sections discussed below a full explanation will be provided on how the two modules establish communication.

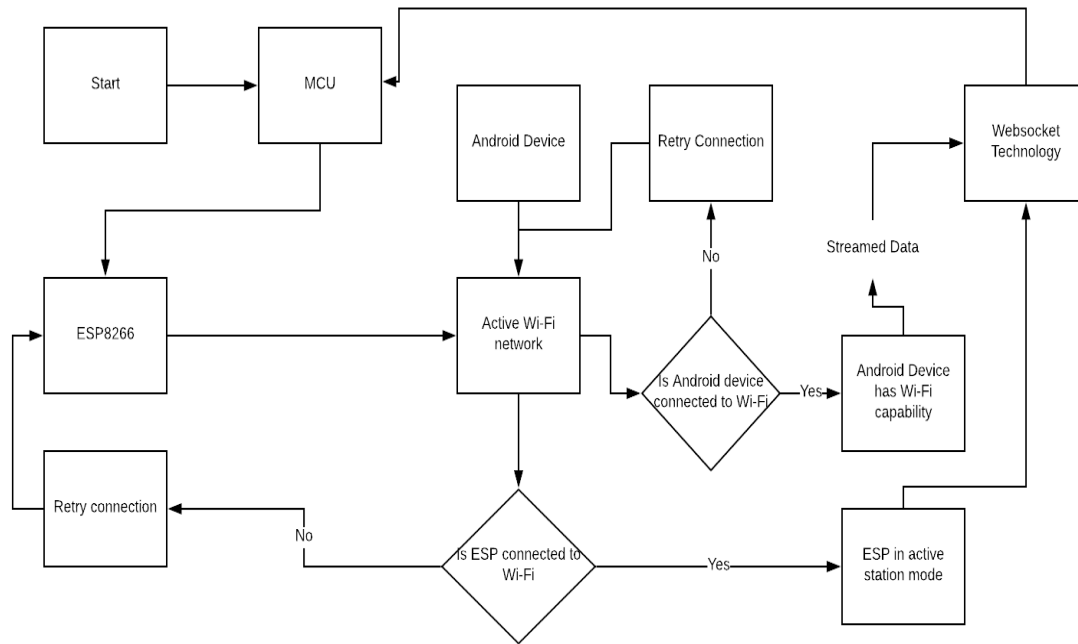
5.8.1 Wi-Fi Communication Procedure

The Wi-Fi module, ESP8266 is a very crucial component for the design of the smart phone powered laptop in that through the utilization of the ESP8266 the contents of the android device are going to be displayed on the laptops LCD screen. The entire process of how the internet connection will be established along with streaming the contents of the android device will be explained in this section. First to establish an internet connection to the MCU

the Serial 1 port of the MCU will be used to connect the ESP8266 to the MCU; the Rx from Serial 1 will connect to the Tx of the ESP8266 and the Tx from Serial 1 will connect to the Rx of the ESP8266. Once this is achieved, then in the Arduino IDE the code can be written so that the MCU will establish an internet connection. Firstly, the ESP8266WiFi library will be imported into the Arduino IDE, then the baud rate will be set to 115200. Next, the WiFi.begin() function will be used to hardcode the SSID and password to the network. This will be followed by a while loop which will terminate when the WiFi.status() function will return WL_CONNECTED; this indicates that a successful connection to the internet was established and using the Serial.println() function along with the WiFi.localIP() function the IP address of the network will be printed on the serial monitor this entire process will set the ESP8266 to station mode.

Now since an internet connection was established the next step is to use websocket communication using UDP internet protocol instead of TCP internet protocol. Websocket is a technology that keeps the TCP or UCP connection open so that data can be sent back and forth constantly between the ESP8266 and the android device. The reason for using UDP and not TCP is that sometimes while using TCP some packets that are sent from the client side never arrive on the ESP side which will cause the laptop LCD screen to freeze until the lost packet is redelivered to the ESP. This freezing is caused by the way that the TCP protocol works in that TCP acts as a pipeline protocol, where the packets are sent one at a time between the transmitter and the receiving device and once a packet is lost the receiver stops the accepting packets until the lost packet is received. In opposition, while using the UDP internet protocol packet loss is very minimum thus when the data is being streamed from the android device to the ESP, even with some packet loss the LCD screen will not freeze therefore allowing real time streaming without any disruptions. The other reason that UDP is being chosen over TCP is the fact that UDP offers a reduced latency in comparison to TCP. Another reason that UDP is preferred for live streaming is that it doesn't wait for acknowledgement from the client side and retransmission of lost packet i.e. utilize the pipeline protocol that was previously discussed for packet transmission. To go more in depth about using the websocket technology with the Arduino IDE the Arduino websocket library will be utilized. The ESP will have an open connection which means it will act as a listener and the android device will act as a closed connection stating that it is the transmitter. Through this websocket technology packets will be sent from the android device to the MCU delivered through the ESP. The figure below depicts a more clear understanding of the process explained above.

Figure 5.8.1: Wi-Fi communication procedure flowchart



Once the data transmission from android device to MCU has begun the VGA pin mapping schematic will be used to connect the VGA cable to the MCU. Using the VGA cable the data received by the MCU will displayed on the LCD screen since the other end of the VGA cable will be plugged into the LCD controller board which will display the streamed data on the LCD screen.

5.8.2 Bluetooth Communication Procedure

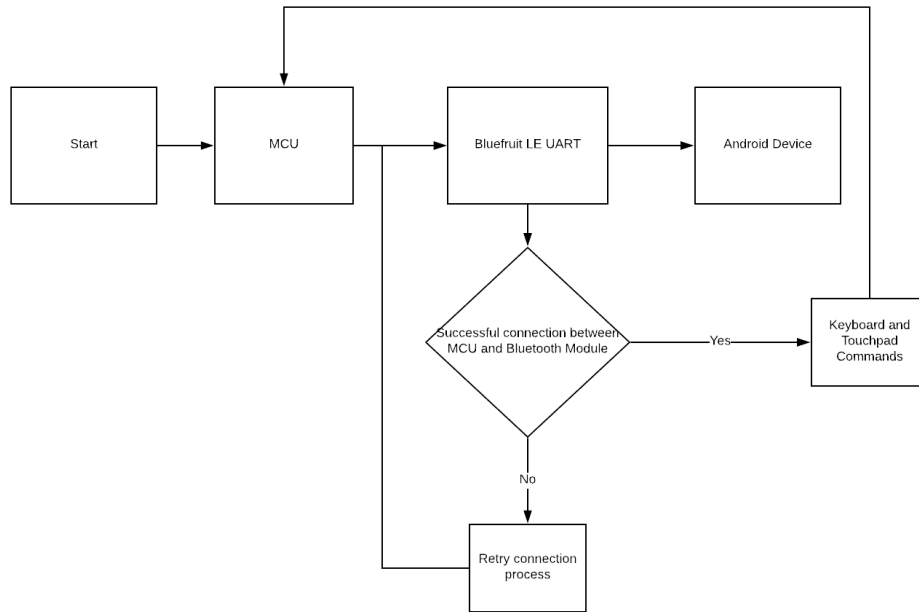
One of the major design requirements for the smart phone powered laptop is that the user operating the laptop should be able to use the keyboard and touchpad for typing and navigation purposes. This can be achieved by using the Bluefruit LE UART Bluetooth module. Since Serial 1 port was utilized by the ESP8266 Wi-Fi module Serial 2 port will be utilized by the Bluefruit LE UART Bluetooth module. To establish a connection between the Bluetooth and MCU the Rx pin from the MCU will connect to the Tx pin on the Bluetooth and the Tx pin from the MCU will connect to the Rx pin on the Bluetooth. To program the Bluetooth module the library is already built into the Arduino IDE which is just a regular Software Serial.

To successfully send keyboard and touchpad commands to the android device the Bluetooth module will act as a delivery personal. First the commands will be sent to the MCU via packets in which the least significant bit is first since the keyboard and touchpad will be connected to the microcontroller. There are four main USB packet types, which are token, data, handshake, and start of frame. Each packet is constructed from different field types such as SYNC, PID, Address, Data, Endpoint, CRC and EOP. The packets are bundled into frames to create a USB message. The USB token packet is used to access the correct address and endpoint, both the address and endpoint field must be correctly decoded

for correct operation. Once the microcontroller receives the commands, these commands will be sent to the Bluetooth module so that they can be delivered to the android device. The keyboard will connect to the MCU via the USB host interface MAX3421E already embedded on the ATmega 2560 ADK. The touchpad will be wired manually through the general purpose input and output pins. The communication protocol used between the MCU and the Bluetooth module is UART software Serial which utilizes flow control. Furthermore the Bluetooth module need to be bonded with the android device so next time around when the android device is in the specified rang of the Bluetooth module the android device will automatically connect to the Bluetooth module.

Once the commands from the keyboard have reached the MCU the microcontroller will make use of the AT commands through the Bluetooth module library to send the keyboard data to the android device. The AT+BLEKEYBOARD command will be used to send text data over the BLE keyboard interface. It can also send any valid alpha-numeric character along with escape sequences like carriage return, line feed, backspace, tab, and backslash. Also all of these commands will be in a sketch that will be uploaded to the MCU. The AT+BLEMOUSEMOVE command moves the mouse or scroll according to the specified number of ticks this command is used to send the mouse movement to the android device followed by the AT+BLEHIDMOUSEBUTTON which is used to send mouse clicks to the android device. Below is a figure that depicts the explanation above.

Figure 5.8.2 - Bluetooth communication Procedure flowchart

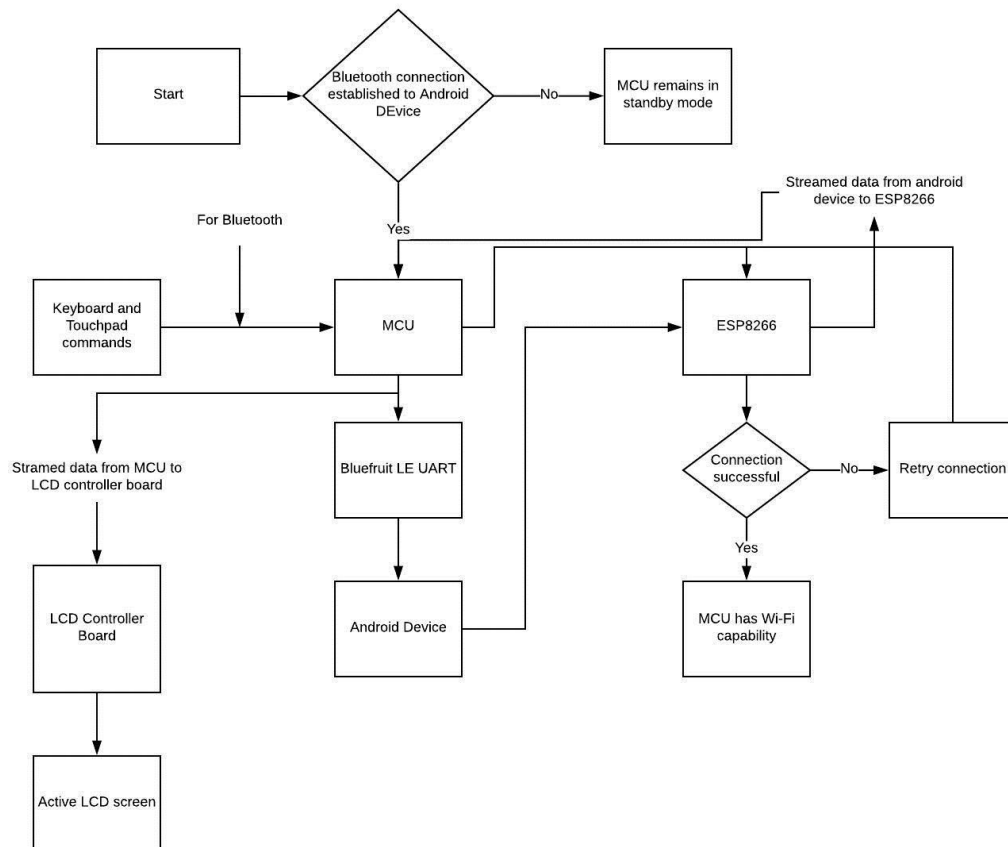


5.8.3 Overall Software Flow

The entire software flow is going to consist of integrating both the ESP8266 design and the Bluefruit LE UART design together. As mentioned above in the Bluetooth communication procedure section above that once the BLE is bonded with the android device next time when the android device is in the BLE's range the BLE will automatically connect to the android device. Once the BLE and android device have established a connection an interrupt will be programmed so that the MCU can come out of standby

mode into active mode. Since the MCU is in active mode the PCB will supply power to the ESP and BLE then an internet connection will be established. To establish an internet connection to the MCU the Arduino IDE will be used to write code in which the ESP will go into station mode and wait for the android phone to connect to the same access point that the ESP used. Once the ESP and android device are on the same access point the websocket technology will be implemented. Furthermore when both the BLE and ESP are ready using the websocket technology for real time data streaming will begin from the android device to the laptop LCD screen as explained in the Wi-Fi communication procedure. Once the streaming starts the user will be able to see the contents of his or her android device on the laptops LCD screen and can then begin to use the Touchpad or keyboard for navigational or communicative purposes. Below in the following figure is the flowchart diagram that further depicts the above explanation.

Figure 5.8.3 - Overall system flow flowchart



5.8.4 Algorithm Description

After gathering all of the hardware, the next step is to develop an algorithm to properly communicate the microcontroller with the touchpad and keyboard via Bluetooth, and LCD display via Wi-Fi. The keyboard and touchpad both will be communicating to the microcontroller and Bluetooth using PS2, which will be shown in the next sections.

5.8.5 Touchpad Communication

The touchpad uses a PS2 protocol to communicate with the microcontroller. According to the “Synaptics Interfacing Guide”, there is information on how the touchpad communicates with the host. The content below describes how this process goes about.

There are 7 main support functions that are used as dependent variables for all other variables in the code.

1. All variables are 8-bits or 1 byte
2. Clock is returned as 1 or 0
3. Data is returned as 1 or 0
4. Set clock to 1 or 0
5. Set data to 1 or 0
6. Wait function
7. Error function

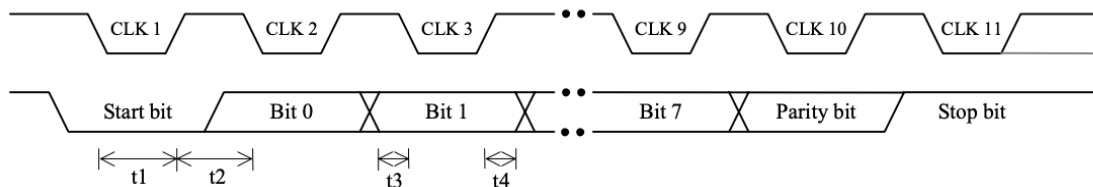
The error function waits for the clock, when the wanted clock level does not respond after a certain amount of time, an error is shown.

In order to read a byte, a simple algorithm is implemented.

START

- Inhibit Communication - Pull clock low, host pulls data low releasing clock
- Request to send - Start generating signal pulses
- Read bits, data is transmitted one byte at a time:
 - Start bit – clock is 0
 - Read data bits from pin (8bits total)
 - 1 bit parity
 - Stop bit
 - Inhibit: clock = 0

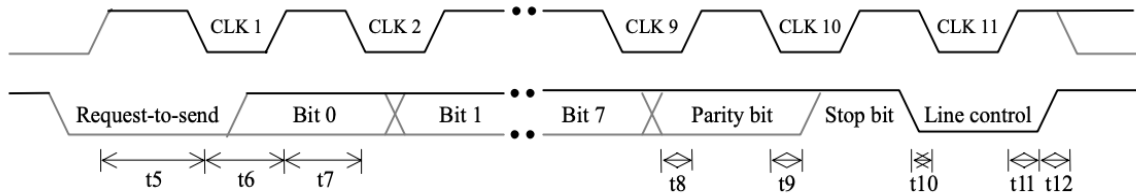
Figure 5.8.5a - Device to Host Communication



- Send a byte:
 - Set inhibit and set delay 100 microseconds – any ongoing transmission has time to be canceled
 - Data Pin = 0 , clock = 1 (request to send)
 - Loop: Send 1 bit at a time
 - Stop bit: clock = 0, data = 1
 - Device brings data low

- Device brings clock low
- Acknowledge bit
- Release data and clock

Figure 5.85b - Host to Device Communication



5.9 Design Methodology

In the process of developing the code for the smart phone powered laptop our team will be taking advantage of the agile development life cycle for developing the software. The other two life cycles for software development are spiral and waterfall. The spiral model is a combination of the waterfall model and iterative model, this particular model consists of several phases where each phase has four stages. The stages are planning risk analysis, engineering, and evaluation. Once a particular phase is complete it means that the phase has completed all the four stages and then the development team moves on to the next phase, this process is repeated until all the phases are complete hence this model is called the spiral model.

The waterfall model is less flexible and iterative since it consists of just five stages requirements, design, implementation, verification and finally maintenance. The development team using this model has to be very cautious because if a particular stage is complete the rest of the software is built on top of the previous stage hence if one of the stages before the verification stage is not programmed properly then it is very difficult to go back and reprogram the previous stages from scratch it also increases the time and resources spent for developing that particular software. The agile model allows for adaptive planning and development as the software is developed requirements or constraints may change due to new information gathered. This is the first time our team will be using the technologies to develop this product, it is very much possible that during the process of developing this product our team may discover the fact that once of the components being used is not compatible with the system or a particular library being used is not enough to support the application. Furthermore the agile model encourages its users to readjust their development process if any hurdles were to rise. The main reason to move forward with the agile development for our project is that it allows room for any errors to be fixed without causing to deplete a large amount of time and resources also the fact that other high level development teams have tons of experience developing software so they prefer models like waterfall or spiral where as our team has no experience in developing software.

To be more specific our team will be utilizing the scrum framework, the scrum model suggests that a project will progress through a series of sprints. Sprints are basically a time limit to achieve a goal and once the goal is achieved the team moves onto the next sprint, the sprints are most commonly two weeks long. The smart phone powered laptop system

will be split into multiple sprints each lasting two weeks depending on the complexity of the task. At the end of each sprint our team will hold a meeting to confirm the progress achieved and to discuss the necessary modifications.

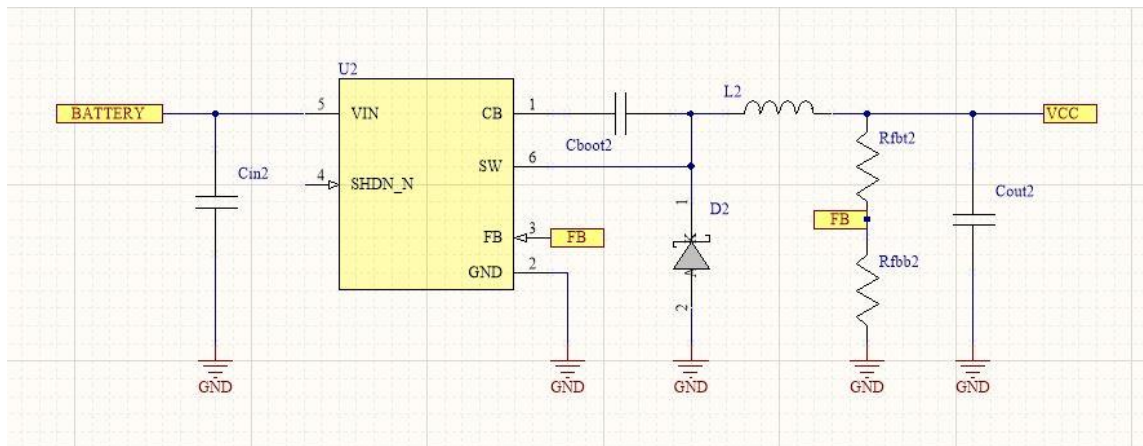
6. Overall Integration & PCB Design

Now that we have researched and designed, we now know how to implement each of the components to the overall integration part of the project. We can finally design the printed circuit board on Altium Designer 18 where we fully integrate each and every component onto one printed circuit board.

6.1 Voltage Regulator: Schematic

After choosing our voltage regulator from Texas Instruments in the previous section. We must now implement and design it in Altium Designer 18 and properly label each input and output accordingly to the ATmega2560 microcontroller. As shown in figure 6.1, we have designed the voltage regulator with the input coming from the battery pack that is rated for 11.1 V and the output will be the corrected voltage in order to power the ATmega2560 microcontroller. The LMR14010A switching voltage regulator will be connected as shown below in the Figure 6.1. The 'VCC' tag connects to the microcontroller's VCC. We used 3 capacitors, an inductor of 22mH, and 2 resistors. Along with a

Figure 6.1 – Power Supply Voltage Regulator



In the design below, the circuit is shown to regulate the voltage from the battery (12V) to supply 3.3 volts to the Bluetooth and Wi-Fi module.

6.1.1 Wi-Fi and 3.3V Regulator

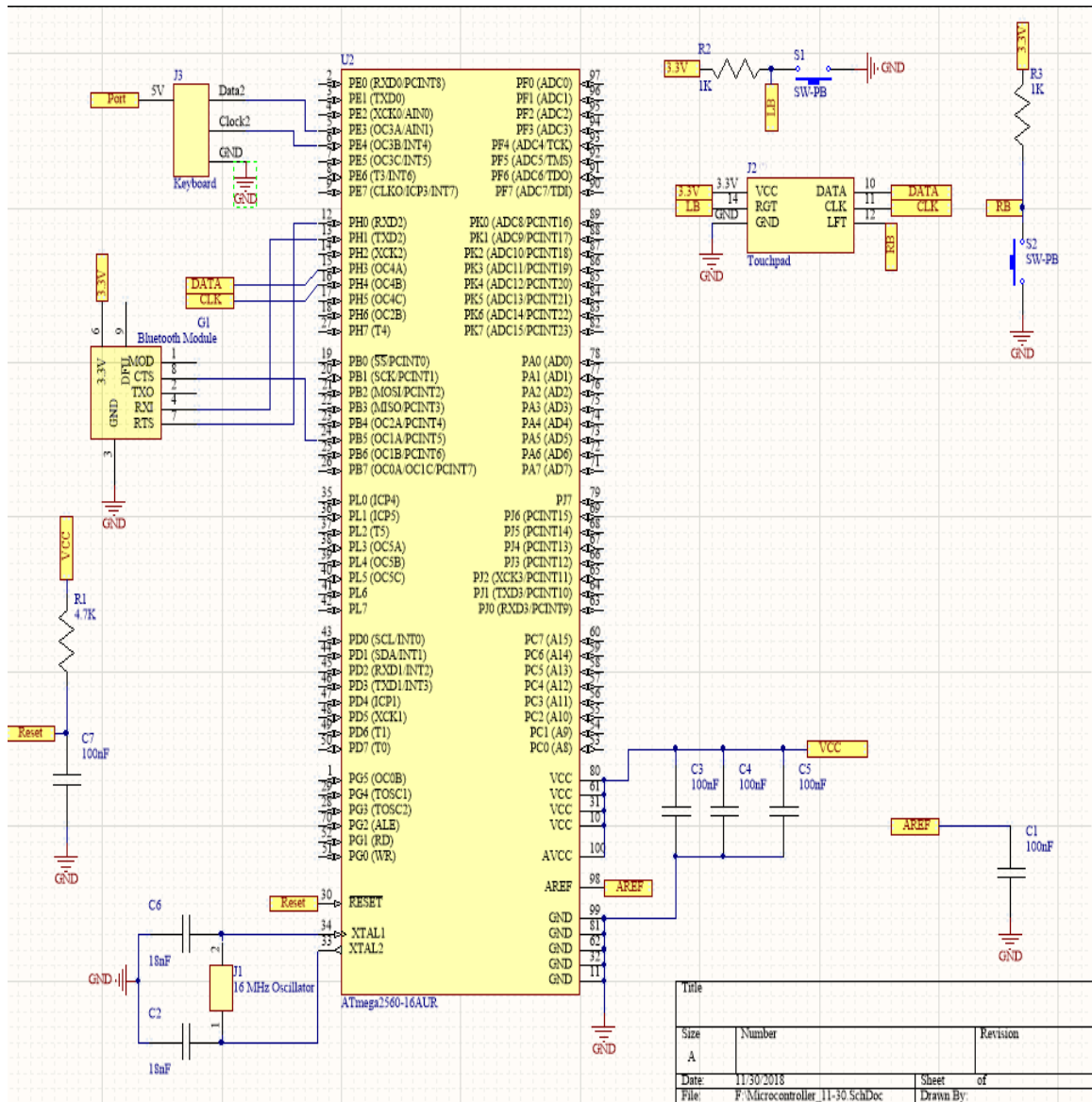
In the design below, the circuit is shown to regulate the voltage from the battery (11.1V) to supply 3.3 volts to the Wi-Fi module. The values for the regulator circuit are shown and were determined using Web Bench.

The Wi-Fi module is designed where we will be able to program it directly from the board if any problems arise, using the FTDI connector shown as “Programming Connection” in the schematic. FTDI communication will be inserted directly into a pin connector, which

which are PE3, PE4, PH3, and PH4. The touchpad also include a circuit for the left and right mouse buttons, which are active low, there for a pullup resistor is included to hold it high until pressed.

The Bluetooth requires multiple pins to communicate to the MCU, which are CTS, TX0, RXI, and RTS. The other pins are used to reset the Bluetooth module.

Figure 6.2 – Microcontroller Schematic w/ Bluetooth and Wi-Fi



7. Administration

7.1 Financing

Our team is fully funding this project ourselves. There is no predetermined maximum budget for us as a group. We will split the cost evenly between the four of us. At the moment, our project is approximately \$290. After our initial and final design, our project will be approximately \$400. Unfortunately for our project we weren't able to secure any sponsorships, which left us to fund the whole project ourselves. Being that we are college students and multiple members of our groups do not have a job, we were severely limited in the individual amount we were comfortable spending. This will cause us to sometimes choose parts that may not be ideal for our overall project design, but are parts that we can afford without completely compromising other sections of the project. This includes things such as our battery design, which could be super-efficient and small but simply doesn't fit into our budget.

Table 7.1 - Project Projected Budget

Projected Budget			
Description	Price	Quantity	Total Price
Wireless Charger	\$7	1	\$7
Battery	\$80	1	\$80
Microcontroller	\$20	1	\$20
Bluetooth	\$10	2	\$20
LCD Controller	\$25	1	\$25
LVDS Cable	\$8	1	\$8
PCB	\$100	1	\$100
Wifi module	\$15	1	\$15
Resistors, Capacitors, Transistors, Voltage Regulator, Switches, Diodes, Inductors etc.	\$50	1	\$50
Total			\$325

7.2 Milestones

This project has a lot of deadlines that must be met according to the class and deadlines that our group decided as whole. Senior Design 1 class has four major deadlines that must be met by student, which include Divide and Conquer, 60 page, 100 page, and 120 page. All other deadlines were implemented by our group to provide a basis to where our project will be by the end of the semester.

Table 7.2 - Project Milestone and Tasks

Milestones			Tasks			
No.	date	Milestone	No.	Start Date	End Date	Task
1	9/13/18	Divide and Conquer Report	1	8/20/18	8/27/18	Form Group and Finalize Idea
2	11/8/18	Final Schematic	2	8/28/18	9/5/18	Start Researching
3	12/4/18	120 Page Report	3	9/6/18	9/13/18	Finalize Divide and Conquer Report
4	TBA	Finalize Prototype	4	9/14/18	9/15/18	Strip Laptop
5	TBA	Faculty Presentation	5	9/16/18	9/23/18	Buy LCD Controller and LVDS Cable
6	TBA	Final Presentation	6	9/24/18	10/24/18	Bluetooth Keyboard Design
			7	10/24/18	10/31/18	Trackpad Design
			8	10/31/18	11/7/18	Wireless Charging Trackpad Design
			9	11/7/18	11/14/18	Speaker Design
			10	11/14/18	11/28/18	Final Schematic
			11	11/28/18	12/4/18	Finish 120 Page Report
			12	12/4/18	12/18/18	Order Parts
			13	12/18/18	1/18/19	Build Prototype
			14	1/18/19	2/8/19	Test Prototype
			15	TBA	TBA	Redesign
			16	TBA	TBA	Finalize Prototype
			17	TBA	TBA	Faculty Presentation
			18	TBA	TBA	Final Presentation

7.3 House of Quality

The table below relates marketing and engineering requirements, by giving a visual representation of each requirements correlation to one another. This gives our team a direction and shows what is practical for the design.

Table 7.3 - House of Quality

Senior Design HOQ			Correlations					
			Positive ↑					
			Negative ↓					
Row #	Column #	Engineering Requirements	1	2	3	4	5	6
		Marketing Requirements	Cost	Battery Life	Phone charging current	Size	Responsiveness	Laptop Resolution
1	Cost	+	•	••	•	••	•	•
2	Portability	+	•	•	•	••	••	••
3	Ease of Use	+	•	•	•	••	••	••
4	Reliability	+	••	••	••	••	•	••
5	Performance	+	••	••	••	••	••	••
	Target		<\$400	>8 Hours	500 - 1000mAh	17 inches	50-70ms	1280 X 720

Positive Correlation	•
Strong Positive Correlation	••
Negative Correlation	•
	••
Strong Negative Correlation	••
Positive Polarity	+
Negative Polarity	-

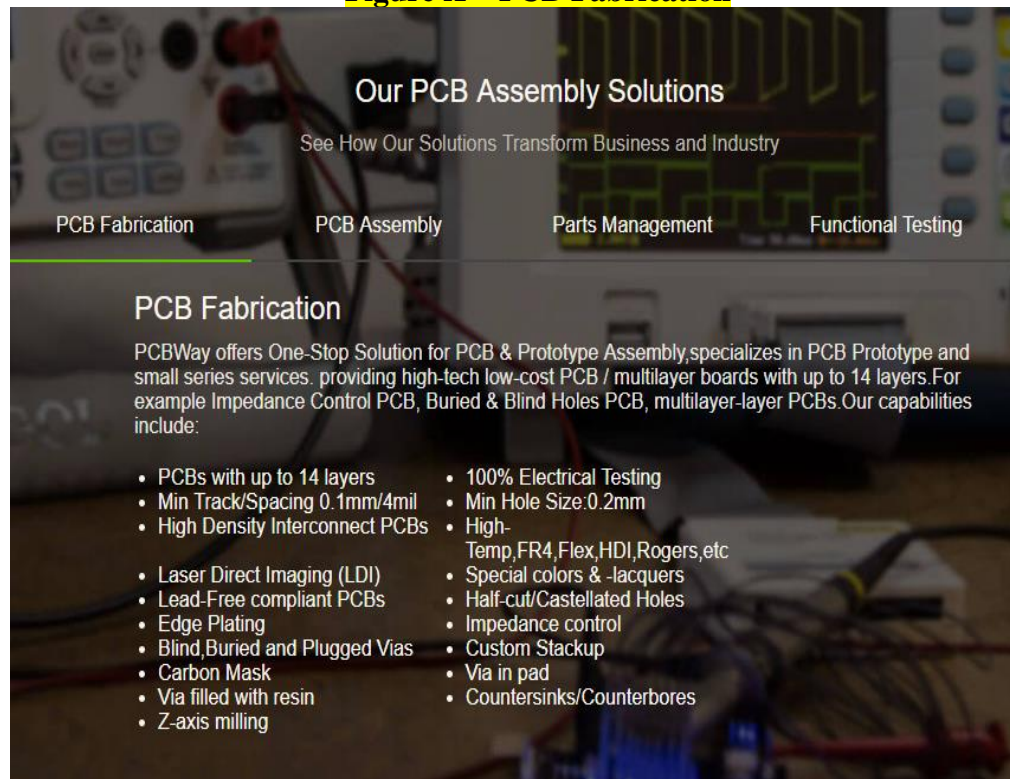
7.4 PCB Vendor

Choosing a vendor to construct our design on to a simplified PCB is an important task to consider. There are many qualities they must have, like great, reliable reputation as well as beyond high quality products that can be produced within a timely manner and at affordable cost to us as college students. Keeping this in mind, the PCB vendor that will take on designing our board will be pcbway.com. We believe that they are a reputable choice because of our own experience with using them to create other PCB designs. The site was the recommended choice for junior design (computer engineers) and worked out well with the standards we have chosen to enforce. With the outstanding, reliable production of prior boards for many students at UCF, we knew that we could entrust pcbway.com to design our final boards for our smartphone powered laptop.

The prices for producing PCBs from pcbway.com are as follows:

- 2 Layers Size $\leq 100 \times 100 \text{mm}$
FR4, 1.6mm, 1oz, HASL, Green Solder Mask, White silkscreen
10 pieces, \$5.00 usd
- 4 Layers Size $\leq 100 \times 100 \text{mm}$
FR4, 1.6mm, 1oz, HASL, Green Solder Mask, White silkscreen
10 pieces, \$49.00 usd

Figure X – PCB Fabrication



The image is a screenshot of the PCBWay website. At the top, it says "Our PCB Assembly Solutions" with the tagline "See How Our Solutions Transform Business and Industry". Below this are four navigation tabs: "PCB Fabrication", "PCB Assembly", "Parts Management", and "Functional Testing". The "PCB Fabrication" tab is selected and highlighted with a green underline. Below the tabs, the "PCB Fabrication" section is detailed. It states: "PCBWay offers One-Stop Solution for PCB & Prototype Assembly, specializes in PCB Prototype and small series services. providing high-tech low-cost PCB / multilayer boards with up to 14 layers. For example Impedance Control PCB, Buried & Blind Holes PCB, multilayer-layer PCBs. Our capabilities include:" followed by a list of capabilities.

Our PCB Assembly Solutions
See How Our Solutions Transform Business and Industry

PCB Fabrication PCB Assembly Parts Management Functional Testing

PCB Fabrication

PCBWay offers One-Stop Solution for PCB & Prototype Assembly, specializes in PCB Prototype and small series services. providing high-tech low-cost PCB / multilayer boards with up to 14 layers. For example Impedance Control PCB, Buried & Blind Holes PCB, multilayer-layer PCBs. Our capabilities include:

- PCBs with up to 14 layers
- Min Track/Spacing 0.1mm/4mil
- High Density Interconnect PCBs
- Laser Direct Imaging (LDI)
- Lead-Free compliant PCBs
- Edge Plating
- Blind, Buried and Plugged Vias
- Carbon Mask
- Via filled with resin
- Z-axis milling
- 100% Electrical Testing
- Min Hole Size: 0.2mm
- High-Temp, FR4, Flex, HDI, Rogers, etc
- Special colors & -lacquers
- Half-cut/Castellated Holes
- Impedance control
- Custom Stackup
- Via in pad
- Countersinks/Counterbores

7.5 Role Assignment

In this section the roles for the smart phone powered laptop team members will be discussed for Senior Design II. Our team consists of two Electrical and Computer engineers. The overall design for our project consists of two parts, the hardware and software design. The Computer engineers will work on the software design for this project because of their knowledge and experience with programming. The computer engineers will be tasked with designing a UDP websocket to ensure that the contents of the Android device can be displayed on the laptop LCD screen. In addition to that they are also responsible for programming the microcontroller to receive commands from the keyboard and touchpad and use the Bluetooth module to deliver the commands to the Android device. Once these two tasks have been completed by the computer engineers the software design portion for the smart phone powered laptop will be completed in that at this point the design will be capable of receiving both the keyboard and touchpad commands that can be displayed on the laptop LCD screen i.e. basically the user can use the keyboard and touchpad on the Android while the contents of the Android device are streamed to the LCD screen.

The electrical engineers are responsible for constructing a printed circuit board (PCB) that will house the microcontroller unit with the embedded USB interface MAX3421E which used SPI communication protocol to communicate with the MCU. In addition to the MCU the PCB will also consist of the Bluetooth module (Bluefruit LE UART) and the Wi-Fi module (ESP8266). The PCB design will have to be small because of the spacing issue discussed in the constraints section and also power efficient to achieve maximum throughput. Once the electrical engineers have completed their task our team will have developed a functional prototype of the smart phone powered laptop. Figure below illustrates the above explanation.

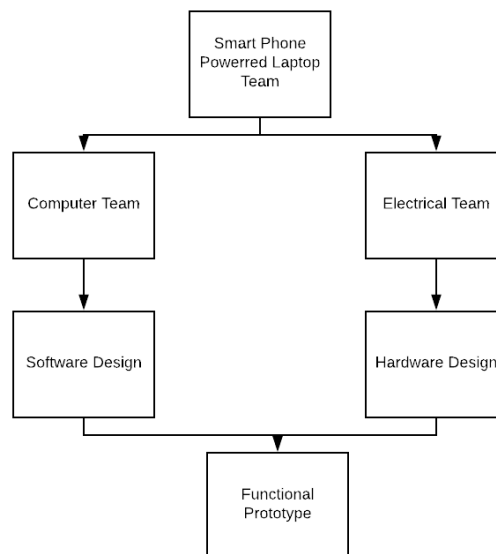


Figure 7.5 Demonstrating Role Assignment

7.6 Actual Budget

As mentioned above in the financing section that our project is self-sponsored meaning that any cost pertaining to this project will come directly from the smartphone powered team members. While researching certain design areas for our project there were certain hurdles that our team did not think of. The first hurdle was the keyboard constraint. As mentioned in the keyboard constraint section above the original plan was to use the keyboard that was a part of our shell laptop but due to the fact that it had a ribbon cable which was attached to the keyboard controller connected to the motherboard of our shell laptop we were forced to order a miniaturized microcontroller friendly keyboard with a USB connection. By ordering the miniature keyboard the total cost of our budget increased. The second hurdle that our team discovered was for the touchpad. Similar to the keyboard situation to actually use the touchpad of our shell laptop was to solder in onto the printed circuit board. As mentioned above in the touchpad constraints section soldering the touchpad to the printed circuit board can be very tricky and none of the team members of the smart phoned powered laptop team have experience in soldering keeping this issue in mind the team decided to order the Capacitive trackpad/touchpad component, all information on this component is mentioned above in the keyboard and Touchpad section. Again by ordering this component the total budget of this project was increased. Below is the table of the Actual budget for this project.

Actual Project Budget			
Description	Price	Quality	Total Price
Wireless Charger	\$20.83	1	\$20.83
Battery	\$80	1	\$80
Microcontroller	\$20	1	\$20
Bluetooth	\$10	1	\$10
LCD Controller	\$25	1	\$25
LVDS Cable	\$8	1	\$8
PCB (Projected)	\$100	1	\$100
Wi-Fi Module	\$15	1	\$15
Resistors, Capacitors, Transistors, Voltage Regulator, Switches, Diodes, Inductors etc.	\$50	1	\$50
Miniature Keyboard	\$29.80	1	\$29.80
Capacitive Trackpad/Touchpad	\$27.50	1	\$27.50
Total			\$395.86

8. Conclusion

As our group comes closer to finishing initial testing and initial implementation of the smartphone laptop design, we came across a few obstacles, that we were able to overcome. Our design still has a long way to go, but as a group we have been able to fully implement a process to go about completing our design in Senior Design 2. This project has not been done before by students, however parts of the project have been done that can be considered as a similar implementation. This gave us hope that the entire project design can be done.

With similar parts of the project that have been done before, our group decided to implement a laptop that would incorporate a touchpad directly from the laptop and LCD screen within laptop. The touchpad used directly from the laptop and implemented with Bluetooth was a great challenge that has not been done before. Also, implementing the LCD screen with Wi-Fi has not been done before and seems to be one of the toughest part of the project. This would make it very easy for any Android user to connect their phone directly to the laptop with the ability to communicate the phone directly to the LCD screen, with no wires needed. This design could be very affordable for students that need a laptop for school, but don't have the budget to buy one. A Smartphone Powered Laptop can fix this problem, and allow students to use programs such as Microsoft Word and Microsoft Excel.

As one can see, this project requires a lot of work, time, and gives us a great challenge as a team for our final project. The reason why our group decided to go with this project, was mainly because this project is different and gives us a challenge. We will learn about Bluetooth, Wi-Fi, and how to program a touchpad and keyboard directly to any phone. Furthermore, those are some of the major learning curves that our group will have to overcome.

Overall, this project has a lot of potential on the consumer market and can be known as the next tablet or laptop that is affordable and easy to use. Our goal is to implement everything we want , as well as our stretch goals. Lastly, we hope as a team to produce results that will inspire other engineers and students.

Appendix

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