Handheld Emulation Station

Project Plan

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Version 3.0

Updated: 12/2/2018

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1 Introductory Material

1.1 Acknowledgement

We are not a professional thus this will be a large learning experience. We would like to thank Iowa State University for this self-guided learning experience. It is really cool to be given the green light for a project fueled by passion rather than the desire to get a good grade.

1.2 Problem Statement

People who like video games understand the problems that come with trying to play on a touch screen. They do not want to rely on their cell phone battery to emulate games, and many gamers prefer to have a dedicated system to play there games on. A lack of haptic feedback from no physical buttons can make gameplay frustrating, especially in real-time games. We want to make peoples emulation experience as nice and fluid as possible, all while being a mobile solution.

Our plan is to create a portable emulator with great battery life and physical buttons for haptic feedback. We want the emulation experience to be ideal for on the go gamers, as well as be an enjoyable experience to play at home as well. We plan to take a small computer, attach it to a battery and some buttons, and put it all in a nice package that can fit in your pocket! This will be a great way for you to enjoy your games at home or on the go!

1.3 Operating Environment

The environment that our device is intended to be utilized within is that of an individual user operating the device without any peripherals in particular in mind. While a potential goal is to allow exporting ROMS and save states to an external device, we do not necessarily require a particular outside environment. The device and its systems are, before all else, self-contained and built to last. Generally speaking, the device should be treated as a standard handheld electronic device in the sense that it’s not waterproof by default and not designed for particular stress or abuse. At no point should an external device be necessary for usage of the device. It may be beneficial to have a device outside of the environment with which to load ROMS, but to that end this should not be strictly necessary.

1.4 Intended Users and Intended Users

We are planning on the users of our handheld emulation station to range in a wide variety of knowledge for users. We plan on making the interface and backing up of game files extremely easy for users. A few possible roles of users are as follows:

- Tinkerer: Users who will add support for more emulators and/or will want to make manual backups of their game files.
- User: User who will own play games and will use only built in functionality.

1.5 Assumptions and Limitations

We will be limited by the materials that we are using. For example, in our price range we will not have the top of the line materials to make latency and performance as optimal as possible. We will create a product that the average person would be able to spend money on for what it provides. We are also limited by only having five engineers who have little full time experience. We will also be limited by only having two semesters to make the product that we set out to make.

1.6 Expected End Product and Other Deliverables

We are looking to have four deadlines that we would like to follow for our project. We want to have a schematic, a prototype, a working model, and an optimized model. The idea behind these are that the schematic is an on paper solution that we have mathematically thought out and think is the best solution on paper. The prototype will be the first solution and it will be basic construction with working LCD, running off of a custom battery, and first iteration PCB design. Our working model will consist of a more refined prototype with various beta-mode features such as dock and play compatibility. Finally, after a rigorously iterative design process, our optimized model will be the best version of the product we think we are able to make, with full feature implementation. Below is a list of more specific features for each deadline, along with dates.

- Schematic - December 3rd, 2018
    - Drawing of project design based on mathematical computations by the team.
    - An accurate rendering of our PCB board design for the prototype.
    - All connections needed to connect the battery, raspberry pi, PCB, LCD, and buttons.
    - First draft ideas for how we want to dock our system for plug and play, as well as other features.
- Prototype - February 4th, 2019
    - An LCD, battery, raspberry pi, and buttons all connected to the PCB board.
    - Basic design of the PCB board.
    - Basic working functionality, not necessarily optimized to emulate, but able to run.
    - No plug and play or battery life optimizations in this design.
    - Size does not necessarily matter at this stage.
- Working Model - March 8th, 2019
    - Improved upon design of the PCB board.
    - Ability to emulate games at a somewhat playable framerate.
    - First edition of plug and play solution.
    - Better battery life than the prototype.
    - Any redesigns made from the prototype.
    - Smaller and more compact than the prototype.
- Optimized Model - April 22nd, 2019
    - Final PCB Design.
    - Finalized product with desired button placement, all components in a neat, compact case.
    - Fully compatible plug and play solution.
    - Optimized battery life.
    - Small and compact solution.

2 Proposed Approach and Statement of Work

2.1 Objective of the Task

The objective of our project is to design and ideal, pocket, plug and play solution for all gamers to enjoy their favorite retro games. Instead of having to rely on a cell phone with battery drain, the user can have a pocket sized solution to play there retro games on the go. If they feel like playing at home, they can simply dock it onto the at home station which allows the user to play on a TV or computer monitor.

2.2 Functional Requirements

We only have one target user group for our Handheld Emulation Station, which is gamers who want a retro experience in there pockets. Since we only have one user group, our functional requirements and uses cases are targeted towards their experience of the product. Our functional requirements for the user are as follows:

- Long lasting battery life
- Universal Save Files across various emulation platforms
- Plug and play solutions
- Select various games to be able to play
- Load and Save game data
- View device stats such as battery life

2.3 Constraints Considerations

The major constraints of the project will be the size of the product as it is meant to be a mobile platform that is easy to carry on one's person. Thus we are using a raspberry pi zero to build the platform around. The biggest challenges with this restraint will be maximizing the battery life due to the limited size of the device including all of the necessary components and then the largest battery possible to accommodate the longest life of the product. Other constraints for the project will be making the user interface and controls as user friendly as possible. An important part of the product will be latency between input, processing, and displaying. This will be an important constraint for the project.

2.3.1 Relevant Standards and Specifications

There aren't many standards or specifications which we must adhere to for our project as it is a primarily original project that aims to design its own specification for both ROM storage and how it operates. The primary standards we'll have to keep in mind are the ROM formats for the various systems our emulator platform may support. We will most likely need to become familiar with the Gameboy and Gameboy Advance ROM formats aka .gb and .gba file formats. These are fairly well documented and well-described standards that we believe will not be terribly difficult to implement processors for. While there is no official documentation for these standards, we should be able to find enough documentation to reliably process the files without any major barriers to implementation.

We will have to adhere to the international standards for lithium batteries as they provide a great framework for battery handling and testing of circuits that include lithium batteries. One such standard is the UL 1642. We also must follow a standard created by the United Nations on safe transportation of dangerous goods, including lithium batteries, see ST/SG/AC.10/27/Add.2. We also must follow BS EN 60086-4:2000 and EC 60086-4:2000 since lithium batteries will be our primary power source.

2.4 Previous work and literature

2.4.1 Existing Tools

There are many available emulation solutions on the market today but many of these solutions have major downfalls. One of the most popular of these solutions is smart phone based emulation. Some popular android emulators are; My Boy, EmuBox, ClassicBoy and GBA.emu to name a few. The biggest downfall with this solution is that the touch screen does not provide good controls due to no tactile feedback as well as emulators draining your phones battery. There are also other standalone emulation devices but many of these suffer from emulating only one platform. Yet another pitfall of current solutions is that they come with a set of games and don't give the flexibility to load new games or remove old ones such as the Retro Mini 2 which is cheap but comes with a built in 168 games. Other options such as the Game Boy Micro put it outside of the price range that some people are willing to spend.

2.4.2 Relevant Literature

Links to relevant literature can be found in Section 4.2.

2.5 Proposed Design

Refer to Image 1.0 in our appendix, Section 4.3.

The project consists of creating a PCB, power circuit, a kernel module, magic software, and the assembly of components.

The magic software will scan for when the user saves their game within the game and making a snapshot with the emulator and if connected to the internet will upload them to a data backup service. The current plan for the prototype will be with either Dropbox or Google Drive. CLI and/or API access will be the big determiner with which provider we use. It is within our team's skillset to securely setup a storage server for hosting our own backup service.

The kernel module will be doing interrupt-like low level calls to libusb for enabling interrupts in order to cut down input latency to tolerable levels [4].

The power circuit needs to be tolerant and protect against short circuits, overcharge, and overdischarge.

The PCB will house the power circuit, the button, and the connection to the Raspberry Pi, battery, and LCD.

The assembly of components will be difficult since our goal is specifically to be extremely thin. We need to find a thin but large battery that is also not too heavy. The LCD will end up being in the neighborhood of 640x480 since most older games could not output anything larger than SD at the time. The case could be made out of plastic or metal for durability. The current plan is using a 3D printed case.

The loading of the games will occur in our emulator. We will parse the file format, (header, data, opcodes) jump to the opcodes, and emulate these instructions. We will obtain our files from a hardware utility one of the team members owns that dumps the ROM from physical cartridges [2]. We have the ability to dump NES, SNES, GBA, GB, and a few more. We do not plan on implementing anything other GB/GBA games for this project.

Figure 2.5.0 Our proposed dimensions are ad drawn. Raspberry Pi Zero W for scale.

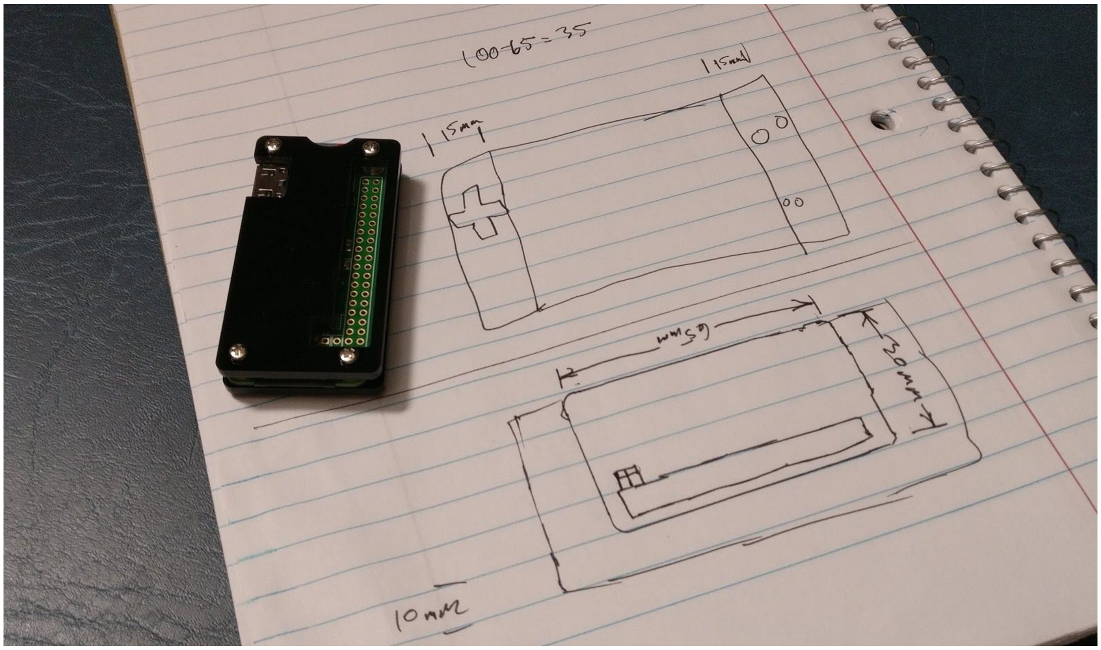


Figure 2.5.1 Our proposed thickness is slightly larger than the pictured Raspberry Pi with case at 0.25”.

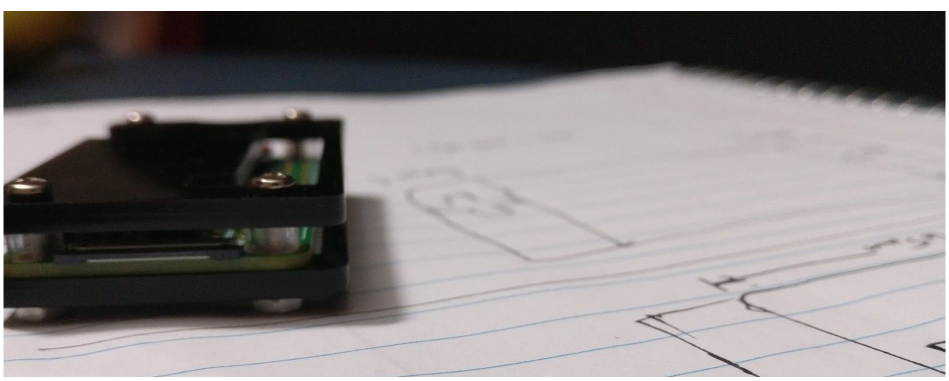
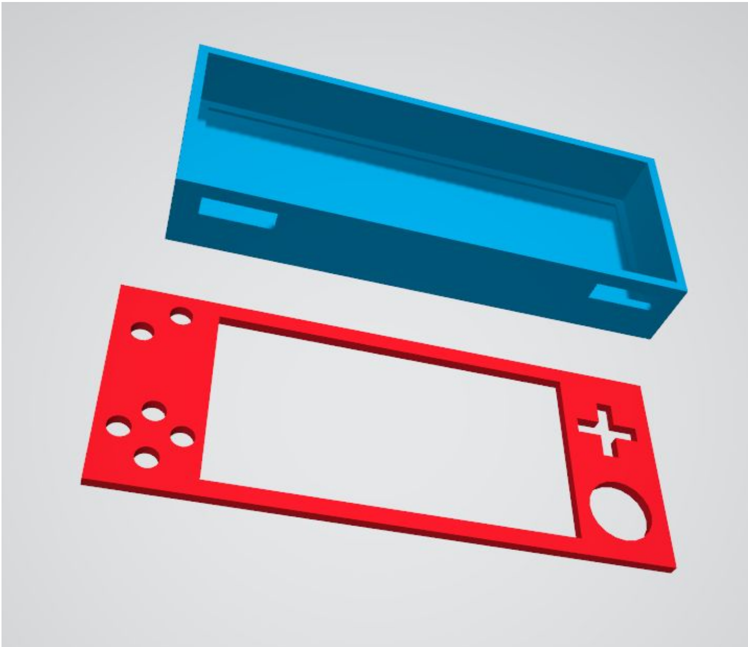


Figure 2.5.2 The current 3d design for our emulator case



2.6 Technology Considerations

Due to a goal of being thin and power efficient this will introduce a ton of added obstacles. We need to slim down whichever Operating System the Raspberry Pi is using in order to minimize power draw. We also need to make our power circuit as efficient as possible as well as making sure we only draw to the LCD the minimum required frames per second. If the display cannot output higher than 30fps, we do not need to try to render higher than the LCD supports. This could cause slight stuttering if the demand on the GPU spikes at any time however we believe it will be negligible.

We also need to consider the case as it needs to be thin yet durable. Metal is the obvious choice however short circuits become a huge issue when introducing more metal.

The desire to automatically search for file changes and upload them is mutually exclusive with power efficiency so finding a middle ground which helps the user out and still maintains a long battery life.

2.7 Safety Considerations

While this project is not expected to be especially hazardous to the user's health, it's important to consider the safety of the user in the design. Relevant topics of safety that could pose hazards include the battery and custom PCB. Both the battery, custom PCB, and all the custom electronics work we will have to do should be carefully examined for the safety of the user to be kept intact.

2.8 Possible Risks and Risk Management

The PCB for this project will be a new experience for us and therefore will have a learning curve to learn the software to design these boards as well as how to design them to our specifications. This could slow down our project because designing these boards will be a major part of the iterative process and will also take time as once they are designed they will have to be ordered and delivered.

Another hardware related risk will be soldering as our team has not been exposed to this and will therefore require the team to learn this skill. This risk could also cause some financial loss if in the process of learning this skill components or the PCB itself is damaged and need to be replaced.

2.9 Project Proposed Milestones and Evaluation Criteria

We hope to have the first iteration of a PCB done and all components soldered and assembled by Winter break. This will be a hard goal to hit but we will push forward with this in mind. We hope to have a working example kernel module working within a few weeks as well as a working example libusb wrapper by then as well. The integration will be hard to debug without hardware so the near final kernel module will come around the same time as a finished v1 prototype.

2.10 Project Tracking Procedures

We will use Gitlab for all project files including the code for kernel module, any project files for the PCB, as well as any diagram files we create for diagrams or layouts for components. We will also have a milestones document with a running todo list we can check off tasks as we complete or think of them.

2.11 Project Testing Procedures

Unit tests can be easily composed for the kernel module as well as the potential emulator. The upsides to these methods are that we can incrementally develop tests as well as the software itself. In the case of the kernel module, these would take the form of tests to quantitatively test whether we are getting rapid enough input for USB. In the case of the potential emulator, the tests would be in regards to accuracy of emulation. Ideally, speed would come naturally to a properly implemented and accurate emulator [3]. Potentially we may be able to test for speed in the emulator, but it is possible that this will not be practical in a unit test [5].

System testing will most likely have to be done manually with quantitative results being calculated where possible. Ideally, the system's unit tests should take care of accuracy, so system tests should be focused on attempting to measure performance and minimize latency within the system itself.

Testing for performance will in major take place in the system testing phase as it is an important part of our system's functionality. That is, real time performance is a goal of the project and is a functional rather than non-functional goal.

Security will be tested by attempting to breach or penetrate the protections of the emulation station and derive from that point what potential strengths or weaknesses are within the architecture of the project. Compatibility with existing systems is tested by the process of loading existing roms and comparing the performance and accuracy experience with existing systems to our system. Usability, similarly, takes root in comparisons to existing systems and the usability present there and comparing our system to the industry's creation.

2.12 Expected Results and Validation

Working is defined as movement through menus with buttons with low latency, battery powered, the ability to recharge the battery, battery life longer than five hours, screen displaying correct colors, and pass a six inch drop test. Our constraints will be to make this as thin and cheap as possible.

3 Project Timeline, Estimated Resources, and Challenges

3.1 Project Timeline

Figure 3.1.0 Semester 1 Timeline Gantt Chart

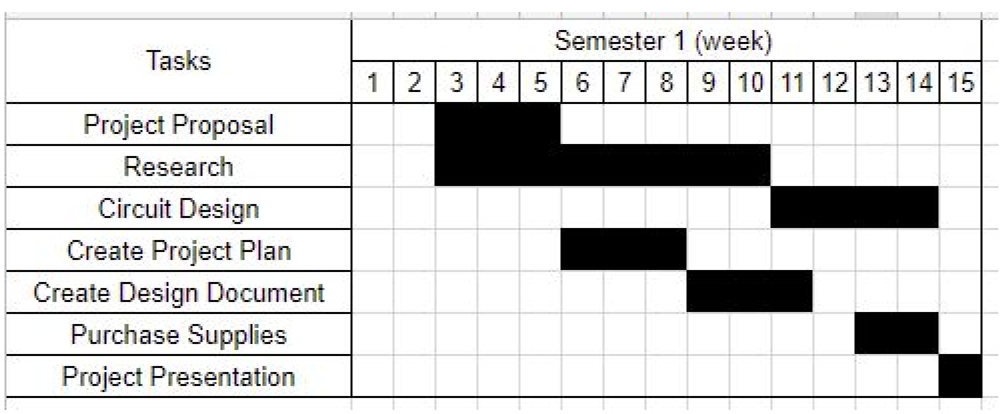
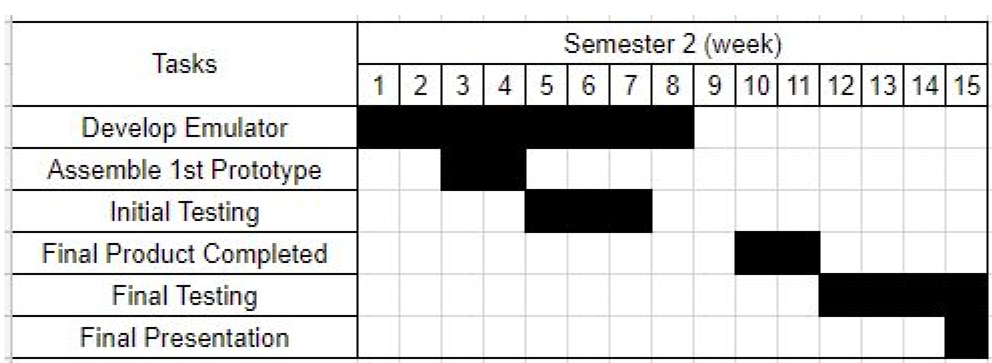


Figure 3.1.1 Semester 2 Timeline Gantt Chart



3.1.1 Phases of Project Development

Project Proposal

We started our project proposal during the third week and we figured it would take about three weeks to complete. Since our project was one submitted by one of our group members, we had a good idea of what the project entailed and what we wanted to do so it did not take as long as we expected.

Research

Most of this semester has been dedicated to research. We have been looking into what we want to do with our emulator, how to design custom kernel modules, how to design a custom PCB, how to optimize battery life, and other things that could be relevant to our project. Since not a lot of us have PCB design, CAD experience, or kernel module experience, we have dedicated a good chunk of time to that part of our project.

Circuit Design

As we are ending the research phase and switching to the design phase for our prototypes, the custom PCB we will be making for our project is a core component that we need to figure out before we can start the prototype building. We want to figure out how we want to design it and what we need on it. We are doing this in a tool called Eagle and figure it will take some time as we have never done PCB design before.

Create Project Plan

The project plan is the basis for our time in senior design and will help us achieve our end goal of creating the handheld emulation station. We thought we would spend a few weeks on it but it has been an iterative design, constantly being updated as we progress and learn more about the needs and requirements of our project.

Create Design Document

A design document is a crucial part of any project you are doing. The importance of a design document is so that all team members understand what needs to be done for the project, and that anyone you present it to can understand the technical specifications of the project. Our design document was started after the project plan, as we had a better idea of what we wanted to do on our emulation station, from a technical standpoint at the time. Like the design document, it has been an iterative design process so it has taken longer than we anticipated and we have been adding to it throughout the semester.

Purchase Supplies

We would like to have purchased some supplies close to the end of the semester. As the research phase ends and the second part of senior design begins, we want to be ready to start an intensive iterative design process right from the beginning, which would entail being ready to purchase supplies by the end of this semester.

Project Presentation

At the end of the semester, we would like to have our specifications on paper to present, along with CAD models, digital PCB circuit designs, as well as things like theoretical battery life ready to present. We plan to ideate and do prototype design during the second semester in 492, so we think that having all of the paper details to start the process is a good place to end 491 at.

Develop Emulator

To begin the second semester of the project we will be working on developing our own emulator for the Atari 5200 using Go. We plan to use Go and target our kernel module for maximum performance.

Assemble 1st Prototype

Once we have received sufficient parts to assemble a full prototype and completed testing on individual components we will construct our first full prototype. This will be helpful to us in accomplishing full system tests to ensure everything is working and begin optimizing the system.

Initial Testing

Once the prototype is complete we will begin our integration testing of the system on our hardware and make sure our software works on our hardware and iron out any bugs or flaws in our system as a whole.

Final Product Completed

We will have a completed product that has fully functioning hardware, including optimized battery, minimized input lag, and the best performance. This final product will be the culmination of all earlier prototypes and combining all the best aspects of them.

Final Testing

On completion of the final product we will be able to begin our final tests and benchmarking. This will be important to show the performance of our product achieved our goals and show perspective consumers the specifications and limitations of the system.

Final Presentation

The final presentation will be given to show all of our work throughout the project and allow us to show all we have learned. The final presentation will be an important milestone as to the completion of the final product.

3.2 Personnel Effort Requirements

Each member of the team will be expected to contribute at minimum 7 hours per week to the project. This can include but is not limited to research, programming, working on hardware, and communicating with the client or other team members. In addition to this each team member is required to be present for our weekly meeting that occurs Wednesdays at 7 pm. These meeting typically last for 1-2 hours long. All members should be active and contribute to the betterment of the project. If a team member can not make it to the weekly meeting, they should notify the team at least two days ahead of time via the team Slack and then review the meeting notes at their earliest convenience. Each team member is expected to put their full effort into this project that is needed to make the product that is expected of us.

3.3 Other Resources Requirements

The hardware that we will be using is a Raspberry Pi, touch screen, along with a PCB. As for software we will be working on the Linux kernel as well as coding in C to provide the emulation that we desire. We will continuously be in contact with our client to make sure that we are providing the product that they want.

3.4 Financial Requirements

To properly fund the project we will need a limited sum of resources which should not be too strenuous to allocate. We composed a spreadsheet that generally describes what parts we will require and the rough estimate of what should be expected to paid as follows:

Item	Price	Link
Raspberry Pi 0 W	$10	http://www.microcenter.com/product/486575/Zero_W
Battery	$11.99	https://www.amazon.com/SUNKEE-3000mAh-Polymer-Battery-Rechargeable/dp/B01G5A7736?th=1
MicroSD Card	$9.87	https://www.amazon.com/SanDisk-Ultra-Micro-Adapter-SDSQUNC-016G-GN6MA/dp/B010Q57SEE/
Buttons	$3	https://www.ebay.com/p/10-Values-180pcs-Tactile-Push-Button-Switch-Mini-Momentary-Tact-Assortment-A7k1/28010007799
LCD	$16.88	https://www.amazon.com/LANDZO-Touch-Screen-320480-Raspberry/dp/B01IGBDT02/
PCB	$2	10 pieces for the price listed from https://jlcpcb.com
Boost Converter	$2	Price for circuit components from https://www.digikey.com/
Total	$55.74	

Overall, we believe that this should be a fairly inexpensive endeavour and should not impact our budget in a significant way. Part of the design of the project dictates that the project must be low cost and effective in its cost balance. We do not believe we will need extensive funding

4 Closure Materials

4.1 Conclusion

Currently there are many emulation platforms available but they have obvious flaws that we believe our solution will be the best emulation platform on the market and provide people with the chance to play any old video games that they love. Our solution will provide a system with high battery life, quality controls, low latency, and very portable with a robust amount of features.

4.2 References

[1] https://www.mpoweruk.com/papers/UN_Regs.pdf

[2] http://marc.rawer.de/Gameboy/Docs/GBCPUman.pdf

[3] http://bgb.bircd.org/pandocs.htm

[4] http://sdphca.ucsd.edu/Lab_Equip_Manuals/usb_20.pdf

[5]
http://www.staroceans.org/kernel-and-driver/The%20Linux%20Kernel%20Driver%20Model.pdf

4.3 Appendices

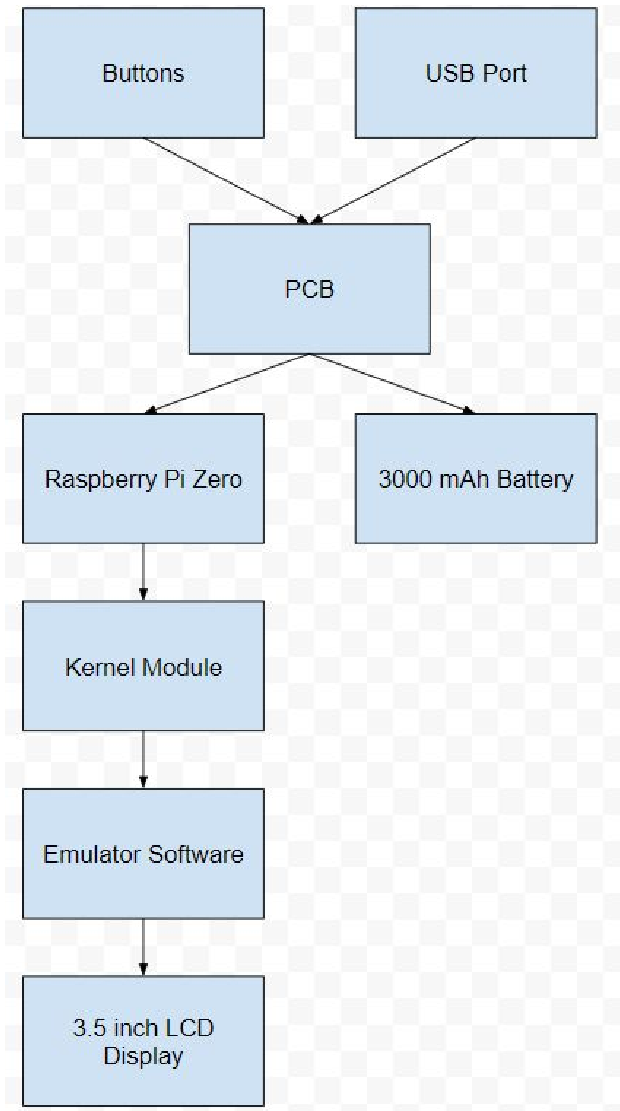


Image 1.0 Block Diagram for our Emulation System.