Senior Design 1: Divide and Conquer

Group 24
M.A.P.S. (Multi Adjustable Port Station)

Report Authors:

Hunter Volonino	*Computer Engineering*
Sebastian Sotomayor	*Computer Engineering*
Siya Sharma	*Electrical Engineering*
Jonathan Luna	*Electrical Engineering*

Review Committee:

Dr. Avra Kundu	*ECE Department*
Dr. Sonali Das	*ECE Department*
Dr. Nazanin Rahnavard	*ECE Department*
Dr. Azadeh Vosoughi	*ECE Department*

Advisor:

Dr. Saleem Sahawneh

Chapter 2: Project Description

2.1 Motivation and Background

In the age of technology, the amount of portable electronic devices has grown significantly and changed over time. Device hobbyists that collect various types of electronics exist to use and enjoy different portable electronics from different points in time. In particular, any device hobbyist with a large amount of mobile or portable devices must keep them charged if they desire to use them. Most portable electronic devices contain rechargeable lithium-ion batteries, which carry a set of risks in use. However, keeping a device plugged in all of the time while it is unused can degrade the battery and even cause it to expand. Charging a battery to 100 percent of its capacity also can eventually cause accelerated wear over time, and keeping a battery in a low state of charge is perhaps even more detrimental [1].

Our senior design project is designed for such hobbyists with various different devices that they use on a semi-regular basis. A device may be desired every few days, or every few weeks. To use the devices, they must be charged to a usable capacity, but not kept charging to the point where excessive battery wear happens.

Another important consideration is that, as this project is designed for various different types of devices, the battery's capacity cannot be read in a direct and standardized manner over USB or any other charging medium. Thus, the only things that can be directly read are voltage, current, and power draw while charging. It is up to the user to configure the charger based on that data, so the charger can be optimized to the user's preferences.

2.2 Goals and Objectives

2.2.1 Goals

Our basic goals consist of:

- Create a device charger that takes in a DC input
- Distribute charging current to multiple portable devices over USB.
- Be able to turn current to each device on and off individually and with automation.
- Inform the user of the current charging statistics.
- Charging portable devices safely based on their profile (current/voltage/power)

Our advance goals consist of:

- Ability for the user to optimize their charging for the least possible impact on battery health.
- Ability for the charger to immediately start when a device is connected.
- Show charging statistics using a Web-accessible interface

Our stretch goals consist of:

- Be able to set a current limit for each individual device

- Be able to estimate the device's battery capacity based on charging current trends, and adjust charging current based on that
- Build a fully custom enclosure for the device charger

2.2.2 Objectives

Our basic objectives consist of:
- Integrating the device with a DC power source as input.
- Display whether a device's USB charging port is on or off.
- Read the voltage and current at each USB charging port
- Display the voltage, current, and power going to each device in real time.
- Once the charging current for an individual device drops below a user-set threshold, shut off current to the device.

Our advance objectives consist of:
- Create safety thresholds that will automatically shut off current to the device if overvoltage or excessive current is detected.
- Create a user interface where the user can set a minimum allowable current, and the time to wait until charging starts again.
- Be able to detect if a device is plugged in or not.
- If a device is plugged in, immediately start charging it until it hits the user-set threshold.
- Web-based interface monitoring the charging status of the multiple devices alerting notifications in reference to if fully charged, charging conditions, etcetera.

Our stretch objectives consist of:
- Design and 3d print enclosures for both the charger and its control unit.
- Analyze the voltage, current, and power data collected to determine automatically how to regulate charging.
- Create circuitry to limit the current to a user-specified value.

2.3 Description of Features/Functionalities

The primary function of our project is to improve and automate how users manage the devices they are charging. The charger will take a 12V DC input and distribute it across four different outputs. Each output will supply 5V through a USB-A port, allowing multiple devices to charge at the same time.

One of the key features of our project will be a user interface. The interface will display information about each of the devices being charged, such as the voltage, current, and power draw. The user can set the minimum allowable power draw per device and set each device's time in between charges. When a device drops below the minimum allowable power draw (indicating a battery with a high state of charge), the charger stops charging the device. If the device is then unplugged and plugged back in, it will start charging again until the power once again drops below the user-set threshold.

Another feature of our project will be internet connectivity. Through the interface, the user will be able to connect to Wi-Fi. Once connected, the charger will transmit statistics for all devices to a web interface. This web interface allows for direct interaction between the user and the device. The user will then be able to monitor the devices that are being charged, track their charging status, and ultimately optimize battery health and performance by setting the minimum power.

2.4 Existing Products

2.4.1 Chargie

On the current market, few companies are producing an external method for battery management. One of these companies: Chargie by Lightly Electronics are offering a charging regulator that allows users to set max battery to charge, provides warnings of excess temperature, and allows you to set custom deadlines (i.e. Tell the app to charge your phone up to 70% by 3:30 P.M.). While this device is great, there are a few shortcomings. The device being an external piece of equipment and not integrated into the charging brick, it is more likely to be lost as well. Furthermore, since the device has one input, one output this results in having to purchase three Chargie's to ensure that three devices get charged. Lastly the Chargie doesn't have the option to switch back to fast/regular charging. This can lead to a situation where you need your phone to charge quickly but are not near it so you are unable to adjust the rate of charge [2][3].

To bypass needing the app, The Chargie uses a proprietary program that measures power and use that measurement to cut off charging [4], While this feature does bypass the need to use the app which is great to devices such as wireless headphones that cannot simply install an app, the feature is barebones and can be confusing for people who are not tech savvy.

2.4.2 Smart Outlets

Another potentially comparable example is smart plugs and relays. Various different brands of smart outlets exist, but they are all typically controlled by a computer or mobile device. The relays can be turned on and off based on set parameters in a mobile app or configuration server. The outlets can measure power draw. This could be integrated and automated with a solution such as Home Assistant [5]. However, this is more of a general-purpose solution and is not designed for device charging. Additionally, for our purpose, this limits the charging ability of one AC outlet to only one device. For example, to charge four devices, four AC outlets would be needed.

For individuals who need to charge multiple devices. Some products on the market are the Anker 735 Charger which allows for fast charging of up to 3 devices [6] while this does allow for less overall time required to charge the device, it lacks the features on previously discussed products where it doesn't allow the user to set limits on the charging, This can introduce more stress on the battery which can reduce overall battery capacity on the device.

2.4.3 eMpower

As for past senior design projects, there has been one previously done with some similarities to ours. During Fall 2012 and Spring 2013, one group created a device charger called eMpower. It contained many USB ports, and was intended to be powered by a solar panel. The USB ports were intended to be turned on and off by the amount of energy consumed over time by a device connected. Energy credits were intended to be monetized, and the USB ports' status depended on the amount of energy remaining from the user's quota. The master unit was intended to interface with multiple sub-units that also included USB ports [7]. By contrast, our project does not intend to monetize the charging ports, and instead turns on and off USB ports based on the voltage, current, and power provided to each port. It is also only intended to work as a single unit; users who wish to charge more devices could simply use multiple chargers for that purpose. Overall, our project is designed more for the device hobbyist rather than an institution.

2.5 Engineering Specifications Table

Table 1: Requirements Specification

Parameter	Description	Value
USB charging port voltage regulation	The charger must output an acceptable voltage to charge devices over USB.	5V ± 0.25V
Amount of USB charging ports	The multi-device charger must be able to charge a reasonable amount of devices at a time.	At least 4
Power Supply Input Voltage Regulation	The input voltage to the charger must be sufficiently regulated.	12V ± 0.5V
Maximum Output Current per Port	The charger must output an acceptable amount of current to charge devices over USB.	750mA ± 250mA
Minimum Charging Power Range (User-Set)	Range over which the user can set the minimum allowable charging power.	0.05W - 5.5W
Charging Delay (Initial Plug-in)	When a device is plugged in, the charger must respond to the input quickly to start charging the device.	<5 seconds

Parameter	Description	Value
Charge Cut-off delay	When a device drops below its set minimum charging power, the charger must respond reasonably quickly.	< 1 minute
Size (Charger)	The charger must be small enough that it could sit on a floor, table, shelf, or under a table.	< 40cm x 40cm x 40cm
Size (Control Module)	The control module must be reasonably small such that it can sit on a desk or table without using excessive space	< 30cm x 20cm x 10cm
Weight (Combined)	The charger must not be excessively heavy.	< 5 lbs

2.6 Hardware Block Diagram

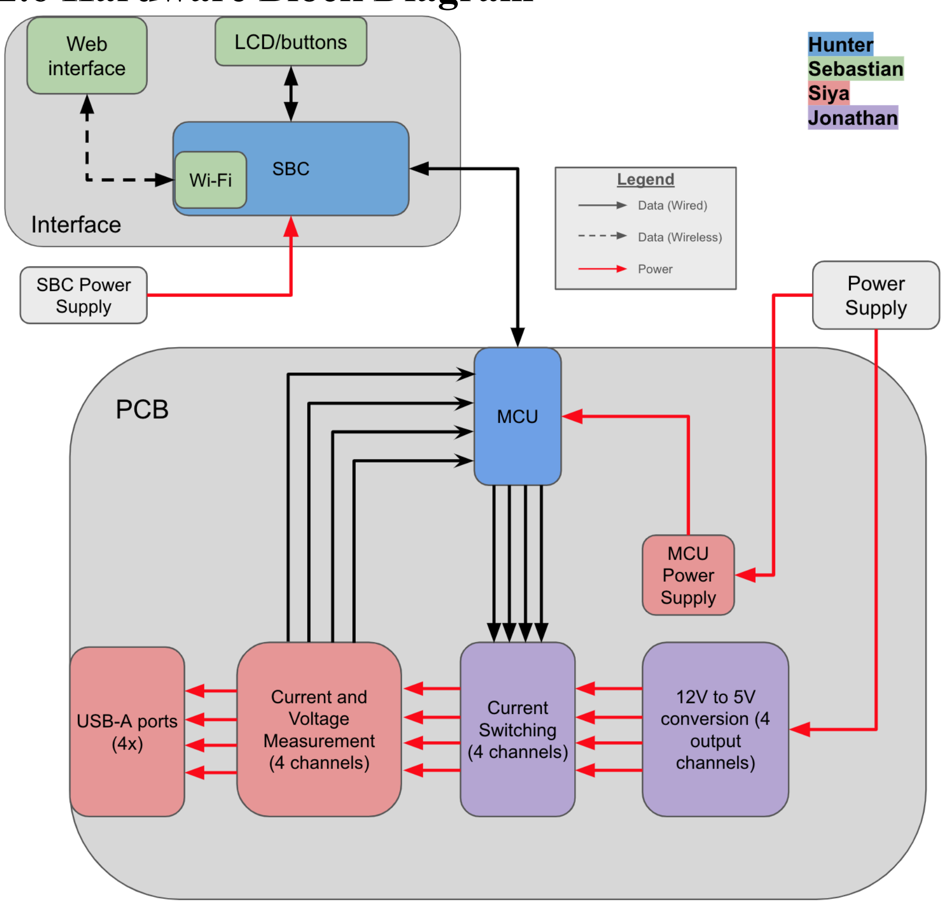


Figure 1: Hardware Block Diagram

2.7 Software Block Diagram

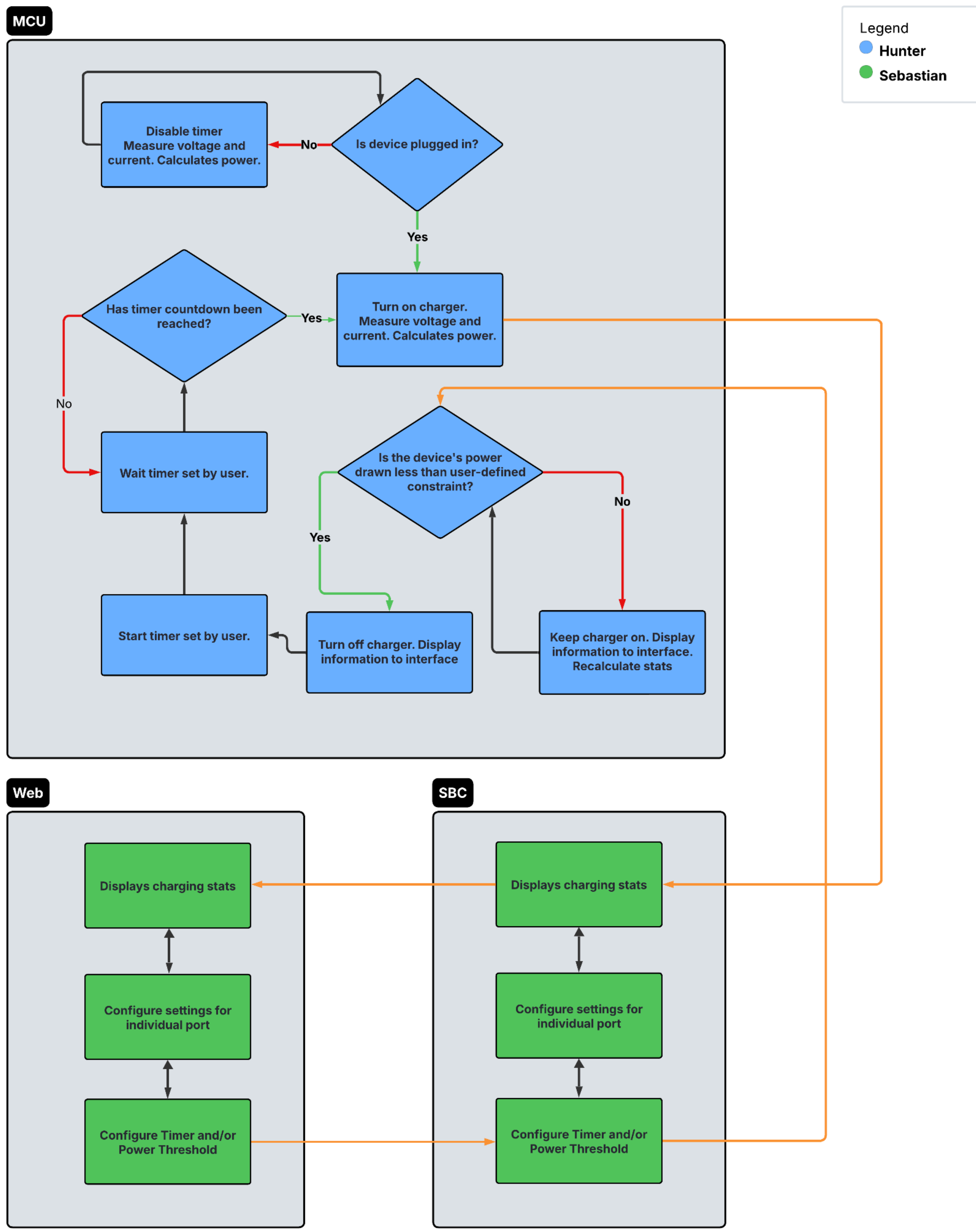


Figure 2: Software Block Diagram

2.8 Prototype Illustration

The Smart Device Charger can be seen below as the following illustrations.

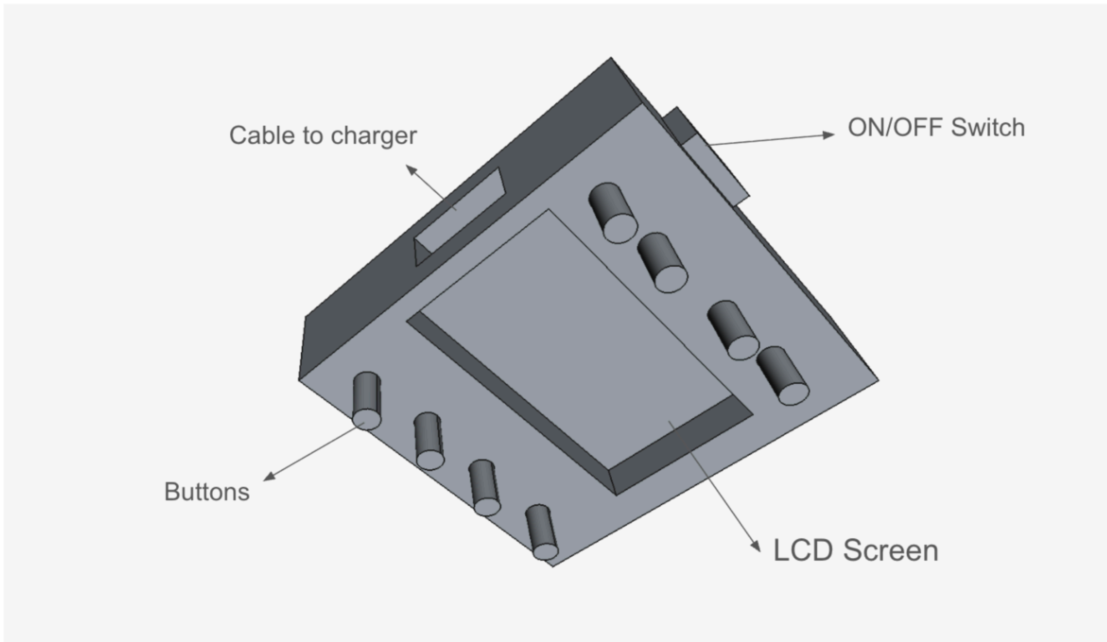


Figure 3: Control Module

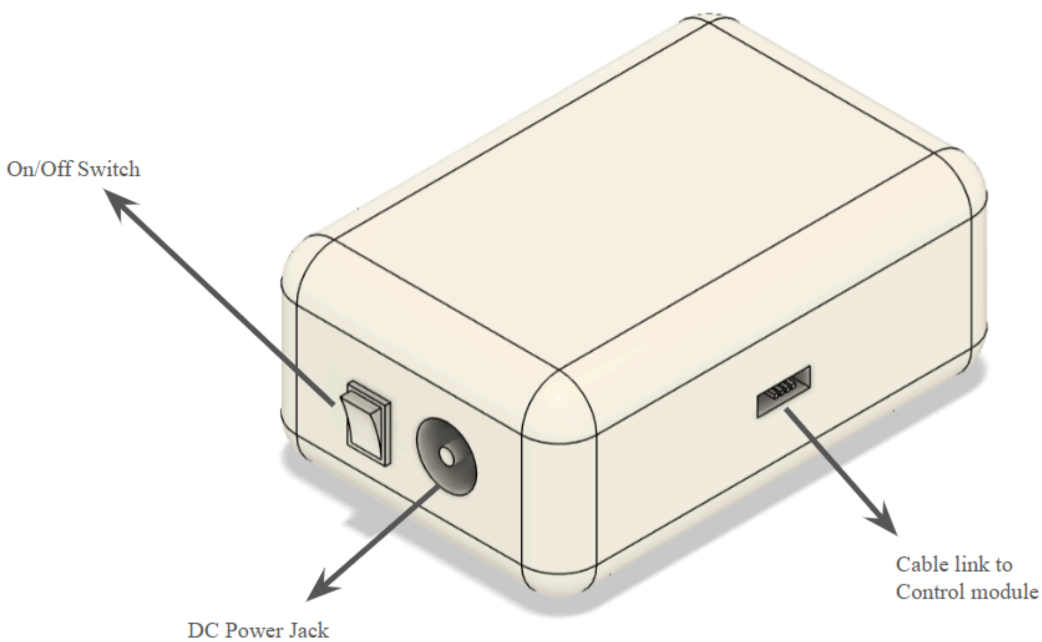


Figure 4: Isometric View of Charing Module (Front)

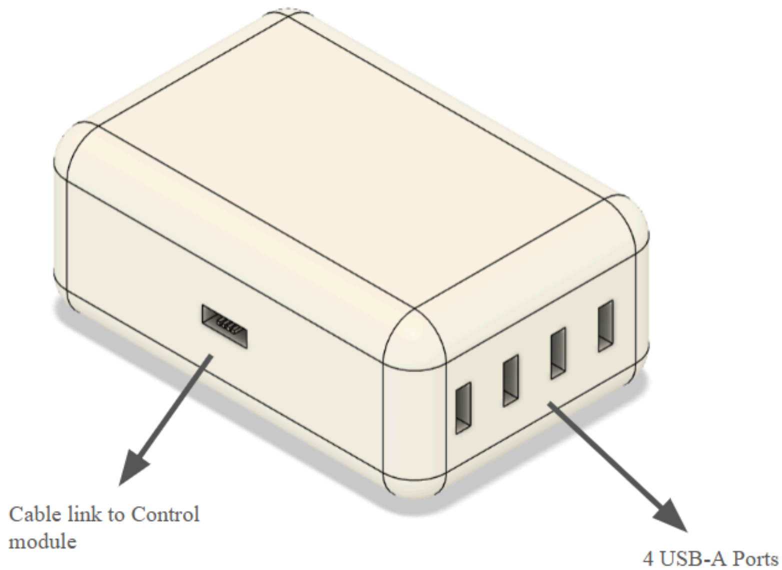
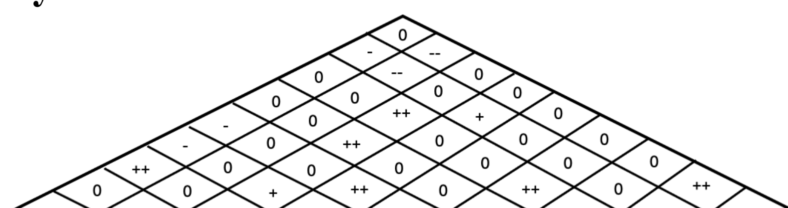


Figure 5: Isometric View of Charging Module (Back)

2.9 House of Quality



Legend Strong Positive Correlation: ++ Positive Correlation: + Negative Correlation: - Strong Negative Correlation: -- No Correlation: 0		USB Charging Port Voltage regulation	Amount of USB charging ports	Power Supply Input Voltage regulation	Maximum Output Current per Port	Minimum Charging Power Range (User-Set)	Charging Delay (Initial Plug-in)	Charge Cut-off delay	Size	Weight
		+	+	+	+	+	-	-	-	-
Cost	-	-	--	-	-	-	-	-	++	-
Durability	+	+	0	+	0	0	0	0	0	0
Device Compatibility	+	+	0	0	-	+	0	0	0	0
Simultaneous Charging	+	0	++	0	-	0	0	+	0	+
Safe Charging	+	+	0	+	-	++	0	+	-	-
Battery Health	+	+	0	0	-	0	0	+	0	0
Portability	+	-	--	-	0	0	0	0	++	0
Target Specifications		5V ± 0.25V	At least 4	12V ± 0.5V	750mA ± 250mA	0.05W - 5.5W	<1 second	< 1 minute	< 40x40x40 cm (Charger) < 30x10x20 cm (Control Module)	< 5 lbs

Figure 6: House of Quality

Chapter 10: Administrative Content

10.1 Budget and Financing

This charger will be created with an initial budget of $500, which will be paid privately by member(s) of this group. We will be keeping costs relatively low through borrowing various tools needed for the Smart Device Charger and reusing lab equipment where needed. It is, however, very possible that the budget for the device will exceed $500 in the end if multiple prototypes are needed or if the parts cost changes between the time of writing and the time we finalize ordering.

10.2 Bill of Materials

Table 2: Bill of Materials

Item	Unit cost	Quantity	Total cost	Part Number
ESP-WROOM 32	$8.99	1	$8.99	BO7WCG1PLV
RaspberryPi Zero 2W	$21.39	1	$21.39	B09LH5SBPS
USB Type-A single port straight	$0.43	4	$1.72	CU01SAV1S00
PCB			~$150	
PCB Components (est.)			~$50	
LCD display	$10.63	1	$10.63	TS-TFT3.5Z-ND
USB tester	$7.95	4	$31.80	MIS-TLUT658R
5V Regulator	$0.22	4	$0.88	TLV76050DBZR
3D Printing Materials			~$25	
Miscellaneous Costs			~$50	
Total Amount	–	–	~$350.41	–

10.3 Project Milestones

Our group formed towards the end of Spring. We have been collaborating amongst each other throughout the summer onwards in preparation for Senior Design 1 this fall. Below represents the table(s) indicating the timeline and milestones that we intend on accomplishing this fall for Senior Design 1.

Table 3: Senior Design I Project Report Milestones

Milestone	**Initial Date**	**Estimated Final Date**	**Duration**
Project Idea	Summer	Summer	0 Weeks
Finalized Project Idea	08/07/2025	08/14/2025	1 Week
Independent Background Research	08/07/2025	08/21/2025	2 Weeks
Divide and Conquer Report	08/25/2025	09/03/2025	1.5 Weeks
30-Page Milestone	08/25/2025	09/15/2025	3 Weeks
60-Page Milestone	09/16/2025	10/07/2025	3 Weeks
90-Page Milestone	10/08/2025	10/29/2025	3 Weeks
120-Page Milestone	10/30/2025	11/20/2025	3 Weeks
Final Report Draft	11/21/2025	11/28/2025	1 Week

Table 4: Senior Design I Project Design Milestones

Milestone	**Initial Date**	**Estimated Final Date**	**Duration**
Component-Level Design	09/03/2025	09/24/2025	3 Weeks
Component-System Design	09/25/2025	10/16/2025	3 Weeks
Breadboard Prototype	10/17/2025	11/07/2025	3 Weeks
PCB Design and Ordering	11/08/2025	11/29/2025	3 Weeks

Table 5: Senior Design II Project Design Milestones

Milestone	**Initial Date**	**Estimated Final Date**	**Duration**
PCB Testing	01/12/2025	01/26/2025	2 Weeks

System Integration and Evaluation	01/27/2025	02/17/2025	3 Weeks
Project Demo Practice	02/18/2025	03/04/2025	2 Weeks
Finalize Project Documentation	03/05/2025	03/19/2025	2 Weeks
Final Presentation Practice	03/23/2025	03/30/2025	1 Week
Final Project Presentation	TBA	TBA	TBA

10.4 Work Distribution

Table 6: Work Distributions

Electrical Engineering	Responsibilities
Jonathan Luna	12V to 5V Conversion
	Current Switching and Control Hardware
Siya Sharma	Current and Voltage Measurement
	USB Port Output
	MCU Power Supply
Computer Engineering	**Responsibilities**
Hunter Volonino	Microcontroller Setup and Communication
	SBC Setup and Communication
	Current Control Programming
	Charging Data Retrieval
Sebastian Sotomayor	SBC User Interface
	Web User Interface
	Database Storage

Appendices

Appendix A - Reference

[1] Battery University, “BU-808: How to prolong lithium-based batteries,” Battery University, https://batteryuniversity.com/article/bu-808-how-to-prolong-lithium-based-batteries (accessed Aug. 29, 2025).

[2] “Chargie a gold edition single,” Chargie, https://chargie.org/product/chargie-single/ (accessed Aug. 29, 2025).

[3] Ovidiu, “Why chargie beats Apple’s built‑in charge limiting,” Chargie, https://chargie.org/why-chargie-beats-apples-built%e2%80%91in-charge-limiting/ (accessed Aug. 30, 2025).

[4] Ovidiu, “How to use Chargie to future-proof any device’s battery (not just smartphones),”Chargie,https://chargie.org/how-to-use-chargie-to-future-proof-any-devices-battery-not-just-smartphones/ (accessed Aug. 30, 2025).

[5] Home Assistant, “Integrating individual device energy usage,” Home Assistant, https://www.home-assistant.io/docs/energy/individual-devices/ (accessed Aug. 31, 2025).

[6] “Anker 735 Charger (nano II 65W),” Anker, https://www.anker.com/products/a2667?variant=41581366575254&ref=a2697-anker-charger-140w-4-port (accessed Aug. 31, 2025).

[7] “Empower,” eMpower - Solar Powered Mobile Device Charger With Remote Control, https://www.ece.ucf.edu/seniordesign/fa2012sp2013/g32/ (accessed Sep. 1, 2025).