Bluetooth Enabled E-Walker

ECE 445 Final Paper

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Abstract

This paper explains the design process and results of the Bluetooth Enabled eWalker, which seeks to give simple medical walkers smartphone capabilities that will make communication quicker and more effective in emergency situations. This paper begins with a discussion of the problems the Bluetooth Enabled eWalker intends to solve as well as a description of the overall design. Design alternatives are presented next along with requirements and verifications for the major subsystems. Final accomplishments and future ideas conclude this paper. Overall, the Bluetooth Enabled eWalker was a successful design that has calling and texting capabilities to two configured contacts as well as any emergency services per the user's choice.

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1 Introduction

1.1 Purpose

Walkers are primarily used by people over 65 years old with musculoskeletal or neurological problems, and some conditions that require a person to use a walker include arthritis and Parkinson's disease [1]. While using a walker, one or both hands are occupied which makes it more difficult to access smartphone features in times of emergency. In the last decade, more devices have become smart devices paired with smartphones for additional features, but walkers and walking canes have been left behind. When looking for existing solutions, we have found some walkers that support lighting and charging, but none with the internet of things (IoT) included.

Our solution is to bridge the gap between features that would be used on a smartphone in times of emergency and walker aids themselves. We will be implementing an easily accessible contact system on the walker that can be used in an emergency situation when the user might struggle to use their smartphone. This includes a Bluetooth connection between the walker and a smartphone allowing for a 911 call as well as texts and calls with two configured contacts. These will be prompted through push buttons and when the walker detects a fall or emergency situation. Overall, this design should make communication quicker and more effective in emergency situations.

1.2 Visual Aids

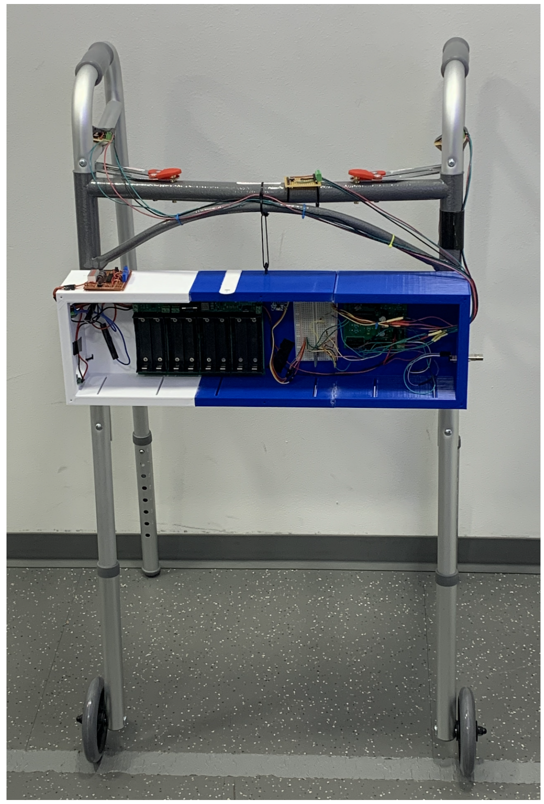

Figure 1: Bluetooth Enabled eWalker Visual (Without Front Lid)

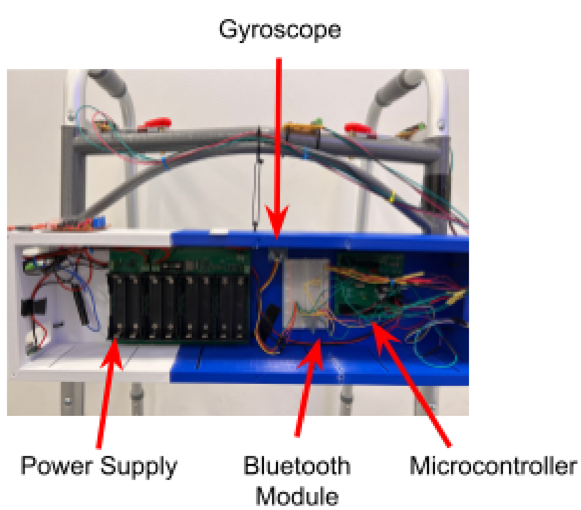

Figure 2: Enclosure Contents

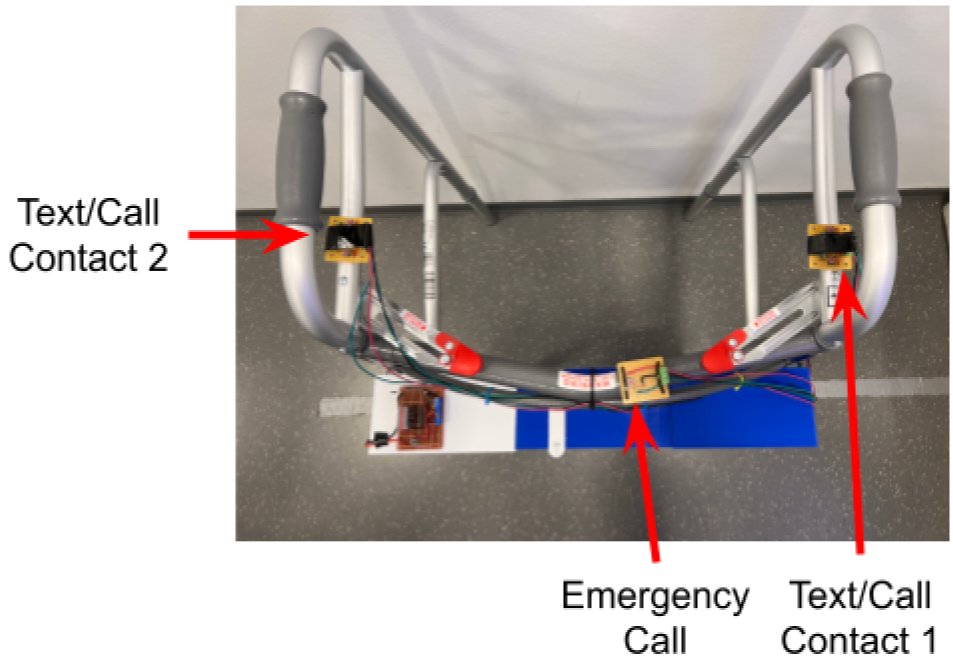

Figure 3: Aerial View

1.3 High-Level Requirements and Functionality

Button Functionality

- Initiate calls/texts within 8 seconds

Messaging System

- Send different text messages based on the severity of the situation

Power Unit

- Rechargeable battery pack with 20800mAh capacity
- 5V 2A USB Type A charging port
- Provide 9V 1A to the control unit

The Bluetooth Enabled eWalker must first be turned on with a power switch which will allow for the entire system to be functional. The user will also be able to charge a smartphone via a USB port near the power switch. The user will then be able to connect via Bluetooth to the walker and can make calls and texts to two configured contacts or emergency services. The Bluetooth Enabled eWalker is able to initiate calls and texts in about 3 seconds consistently which fits the requirement constraints.

The text messages being sent through the push buttons are for less serious situations enabling the user to communicate with configured contacts when in need of assistance. If the walker falls in any horizontal orientation, the walker will automatically send a more serious emergency text message to both configured contacts requesting immediate assistance with GPS coordinates.

The power unit enables the system's functionality when mobile for just under 2 days of continuous operation. It provides 9V and 1A to the control system printed circuit board (PCB) which powers the other components within the unit. The user must be sure to recharge the walker when necessary and can see how much charge is remaining through a battery life LED indicator mounted on the walker’s electrical enclosure.

1.4 Subsystems Overview

The Bluetooth Enabled eWalker is divided into three major subsystems: Smartphone, Control, and Power Supply. The block diagram below in Figure 4 displays how each subsystem interacts with the other.

1.4.1 Block Diagram

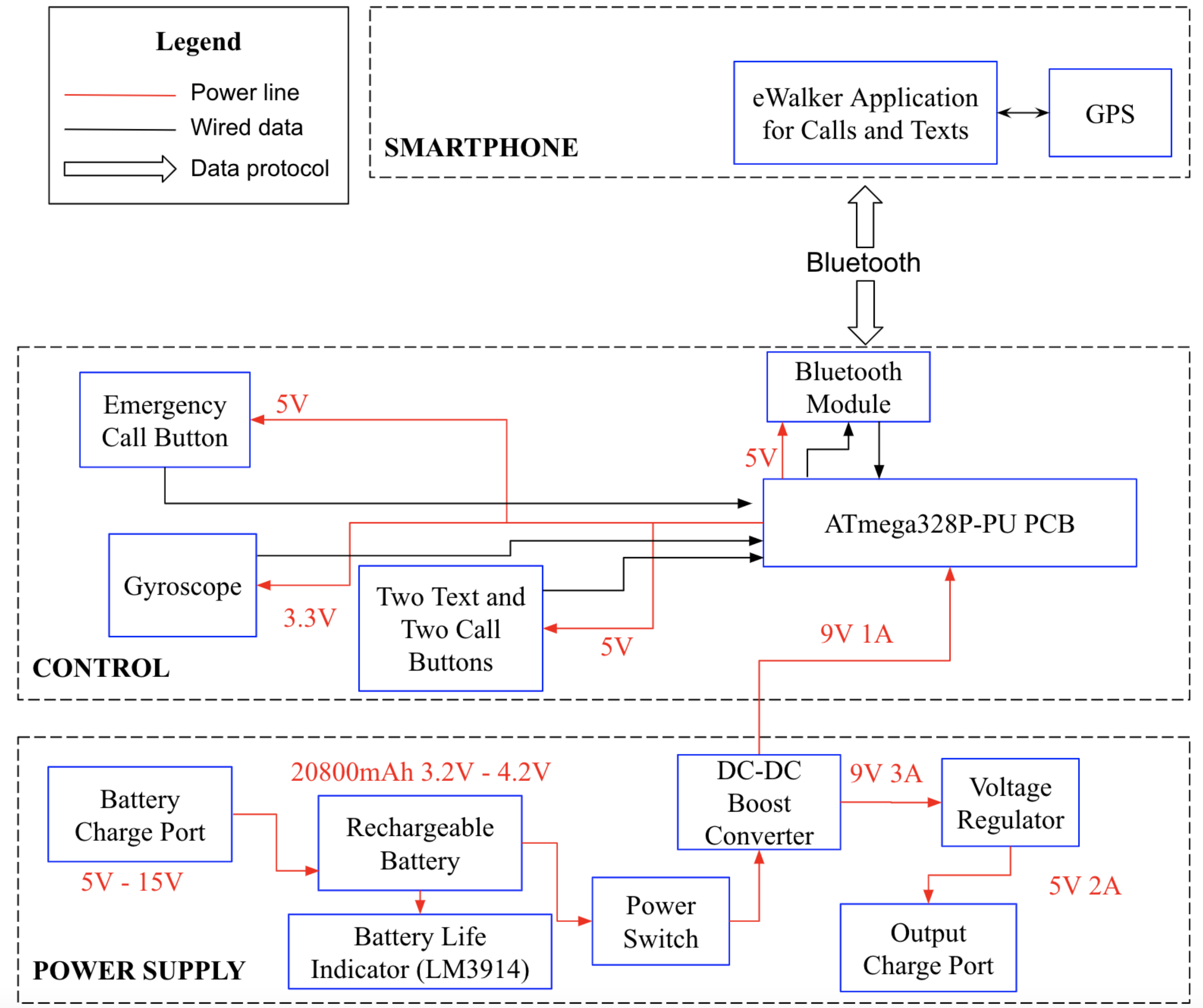

Figure 4: Block Diagram for Bluetooth Enabled eWalker

1.4.2 Smartphone Subsystem

The smartphone subsystem consists of an Android smartphone with GPS, cellular, and Bluetooth capabilities. The smartphone must also have an application installed that our team developed called “eWalker.” The smartphone application first collects user data through text inputs to configure two different text messages. One text message is configured for the event when a button is pressed and another emergency text message is configured for the event the walker is detected in a horizontal direction. Next, the smartphone allows the user to configure contacts with phone numbers. Lastly, the smartphone reads sensor data received from the HC-05 Bluetooth module and sends a text or call depending on the data.

1.4.3 Control Subsystem

The control subsystem consists of a PCB containing the ATmega328P-PU microcontroller, two texts, two call push buttons, a gyroscope module, an emergency call button, and a Bluetooth module. The PCB is the central component that powers the subsystem and transfers data to and from other subsystems. Any signals sent from the gyroscope and push buttons are interpreted by the PCB microcontroller, formatted in Bluetooth protocol, and sent to the Bluetooth module which prompts texts and calls from the eWalker application. The PCB is powered by the power subsystem.

1.4.4 Power Subsystem

The power subsystem consists of a PCB with four dual 18650 battery holders connected in parallel, the BQ2057 lithium battery charging circuit, the LM3914 Battery Life Indicator unit, a power switch, and the MP3429 DC-DC boost converter circuit. The power subsystem can power the control subsystem PCB and the output charging port with the 9V 3A output provided by the DC-DC boost converter, which takes the battery pack voltage that ranges from 3.2V to 4.2V as input. The control subsystem PCB will draw up to 1A, whereas the output charge port will draw up to 2A, limited to the L78S05 regulator.

2 Design

2.1 Smartphone

2.1.1 Design Description & Justification

Smartphone

The smartphone pairs with the Bluetooth module from the control system so data can be received and utilized to trigger calls or text messages on the smartphone. The smartphone must also send Bluetooth data so contacts can be configured on the control system.

eWalker Application for Calls and Texts

When the Bluetooth module sends over the correct data indicating a text message or phone call should be made, the eWalker application will trigger phone calls directly and text messages through an application programming interface (API) to an external service. Initiating a text message directly with the smartphone through Bluetooth requires approved permissions from smartphone manufacturers, so our team will utilize Twilio's API service to send texts [2]. This will result in text messages being sent out from a phone number that is different from the user's phone [3].

2.1.2 Design Alternatives

Given different time constraints our team would focus on getting the required permissions to directly send text messages from the smartphone without being reliant on a cellular service API like Twilio. This would allow the configured contacts to receive text messages directly from the user's contact instead of a random phone number. Ultimately this would cause less confusion on the recipients' end and reduce the chance the text message is ignored in an emergency. Another design alternative would be implementing the smartphone application for Apple IOS devices. Currently, we can only support Android smartphones which limit the number of users.

2.2 Control

2.2.1 Design Description & Justification

ATmega328P-PU PCB

We utilized the ATmega328P-PU microcontroller and mounted it on our PCB design based on an Arduino UNO schematic that reduces the amount of surface-mount components [4]. The ATmega328P microcontroller replicates the functions of the Arduino Uno board with the respective features of 9V power input, 3.3V and 5V output, Digital and Analog I/Os, and USB programming port [5]. The PCB and ATmega328P together collect and process data from the buttons and gyroscope, power the modules, sensors, and inputs, and format the processed data into a serial packet that can be transmitted by the Bluetooth module. Visuals of the schematic and PCB layout can be referenced in Appendix C.

Bluetooth Module

The HC-05 Bluetooth module allows for two-way Bluetooth communication and is compatible with the Arduino Uno. The HC-05 Bluetooth module will send the prepared packet as serial data on the TXD pin which allows serial data to be transmitted via Bluetooth [6]. The module does not need to receive data from the smartphone device.

Two Text and Two Call Buttons

All four buttons are the E-Switch TL1105AF100Q model. These buttons are mounted on the horizontal bars directly below the handles of the walker. The two buttons on the left side prompt a call and text for one configured contact, and the two buttons on the right are for the other configured contact. These buttons interface with PCB to prompt calls and customized text messages from the cellphone through the Bluetooth module.

Emergency Call Button

This button is used specifically to call an emergency contact such as 911. The emergency call button is also the E-Switch TL1105AF100Q model and is mounted on the center rail of the walker. This button also interfaces with the PCB to prompt a call from the cellphone through the Bluetooth module.

Gyroscope

Our team used the GY-521 MPU6050 model gyroscope from HiLetGo. It is a 6-axis accelerometer gyroscope sensor (ie. 3 axes each for the accelerometer and gyroscope). The sensor is placed on a mounted breadboard within the enclosure shown in Figure 2 above in order to detect the orientation of the walker. The gyroscope interfaces with the microcontroller and Bluetooth module by providing data that prompts an emergency text when the fallen horizontal orientation is detected.

2.2.2 Design Alternatives

Possible design alternatives for the control subsystem are using a physical Arduino Uno board and using a GPS submodule. Using a physical Arduino Board would be more cost-effective than a PCB and its components. It would be easily integrated into our system as well since we used an Arduino Uno to test our design while our PCB was being ordered. The GPS submodule we considered was the GPS NEO-6M module which utilized satellite data to find its current position. It would have been placed in a fixed position near the top of the enclosure so the data is accurate and the module can receive a strong connection. Power for the GPS module would have been supplied by the PCB microcontroller, and data from the GPS would have been sent to the Arduino Uno pin utilizing a USB-TTL cable.

2.3 Power Supply

2.3.1 Design Description and Justification

Rechargeable Battery

Our rechargeable battery pack was implemented with the use of four dual 18650 lithium battery holders, which are connected in parallel to the power supply PCB [7]. The use of the battery holders allows for the batteries to be removable, as we needed to manually balance the batteries before installing them on the PCB. Furthermore, the use of the battery holders also allows for changing battery capacity if desired. Our eight batteries total 20800mAh, each having 2600mAh. A lower or higher capacity depending on the customer preferences can be factored into the overall build price if it was to be marketed as a product.

Battery Charging Port

Our battery charging port is a USB Type C port that provides a supply voltage to the BQ2057 charging circuit. An external charger or power source is required that can connect to our charging receptacle. The circuit design for this unit uses the typical application 0.5A charger circuit provided in the BQ2057 datasheet [8].

Power Switch

We used an SPST illuminated rocker switch that turns on an LED when the switch closes, and off when the switch is open. For added safety, we installed a fuse holder that houses a 5A fuse in line with the switch to protect the rest of the system in the case of battery malfunction.

DC-DC Boost Converter

We used an MP3429 DC-DC Boost converter to step up the voltage to 9V with up to 3A output, using the manufacturer's reference DIY schematic [9,10]. The 9V will provide sufficient input voltage for the L78S regulator [11] that will be used in our output charge port, as well as those in the microcontroller PCB.

Output Charging Port

We have one USB Type A port that provides 5V and up to 2A for charging smartphone devices. The accepted input current by the smartphone will vary across different manufacturers.

Battery Life Indicator

The circuit design for this unit is based on the schematic found in an adjustable LM3914 battery indicator [12]. As long as the push button is pressed, the battery pack voltage is displayed on the 10-segment red LED bar graph.

Power Supply PCB

The schematic and PCB layout for the power supply can be found in Appendix C.

2.3.2 Design Alternatives

Using a USB type A receptacle to provide a supply voltage to the battery charging circuit would allow the user to reuse currently owned 5V USB adapters or find other adapters with ease. Another design alternative would be using another DC-DC boost converter instead of a voltage regulator to provide the required 5V charging at 2A. This second alternative would allow for a more compact design in the power subsystem PCB and allow for much greater efficiency when stepping down voltages.

3 Cost and Schedule

3.1 Cost Analysis

Reference Cost Analysis Table in Appendix A

<u>Total Product Cost = $367.34</u>

The average ECE UIUC Graduate makes a starting salary of about $93,000. [13] This comes out to about $44 per hour. We estimate each member of our group will be working about 12-15 hours per week for 10 weeks on the project which would give a minimum and maximum cost of

44 x 2.5 x 12 x 10 = $13200 per person to

44 x 2.5 x 15 x 10 = $16500 per person.

<u>This gives a range of $39,600 to $49,500 for total labor cost.</u>

We also 3-D printed an enclosure for our design which did not require any outside labor, so our total cost came out to our total labor added to the product cost of $367.34.

<u>This final range would be between $39,967.34 and $49,867.34.</u>

3.2 Schedule

See schedule in Appendix B

Our team stayed on schedule on a weekly basis which allowed us to complete the project with full functionality on time. Despite having some difficulties with order times and design flaws, we were able to correct them and move forward.

4 Requirements & Verifications

4.1 Smartphone

4.1.1 Smartphone

- The smartphone must have Bluetooth connectivity.
- The smartphone must show GPS coordinates.
- The smartphone must have a SIM card that can access a cellular network.

We used an Android smartphone device that had Bluetooth, GPS, and a SIM card. These requirements are outside the scope of our design implementation and each unique user is responsible for the verification of these requirements.

4.1.2 eWalker Application

- The eWalker application must read Bluetooth data sent from the paired Bluetooth module on the control system.
- The eWalker application must process the Bluetooth data and upload this data to an external web service application that can trigger phone calls and text messages.

To verify the first requirement we visually matched the output flags from Figure 9 below to the output of the eWalker application on the smartphone. There was 0% variation in the content section of the Bluetooth packet between the sender and receiver.

To verify the second requirement we checked if another smartphone device received a text from a Twilio phone number after sending an API call with the Bluetooth content. An example of a received text message can be seen below in Figure 5.

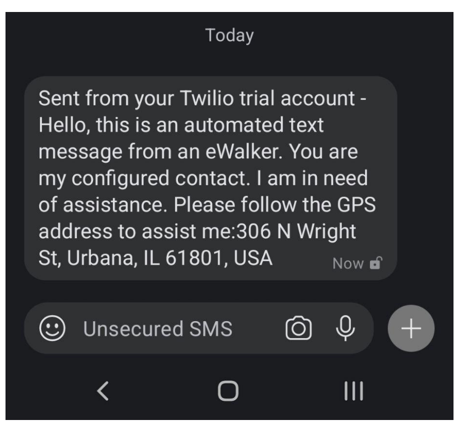

Figure 5: Text Message Through API

4.2 Control

4.2.1 ATmega328P-PU PCB

Visuals of the schematic and PCB layout can be referenced in Appendix C

- Take 9V +/- 2% input and provide 3.3V and 5V +/- 5% outputs to each appropriate sensor and input.

We probed both the input of the PCB from the output from the power system to measure the correct voltages on a multimeter. We received a value of 9.013V which verified our requirement.

Figure 6: PCB Input Multimeter Reading

We also probed the outputs of our regulators to ensure we were receiving 5V and 3.3V at the outputs of our PCB. We received an elevated value for our 3.3V output, but we actually did not need a 3.3V output from our PCB in our final design.

Figure 7: PCB 5V Output Reading

Figure 8: PCB 3.3V Output Reading

4.2.2 Bluetooth Module

- Transmits packets received from the microcontroller without packet loss.

No packet loss was identified after sending five packets with unique content data one second apart received from the microcontroller to the eWalker smartphone application. The test was performed within five feet of the Bluetooth module to simulate the distance between the Bluetooth module and the smartphone on the walker.

4.2.3 Text/Call Pushbuttons

- Pressing the text and call buttons must output a high signal that can be read by the microcontroller which would initiate the desired call or text function.

We outputted the push button signals to the Arduino integrated development environment (IDE) serial monitor and compared the signals to our desired flag values for the eWalker application.

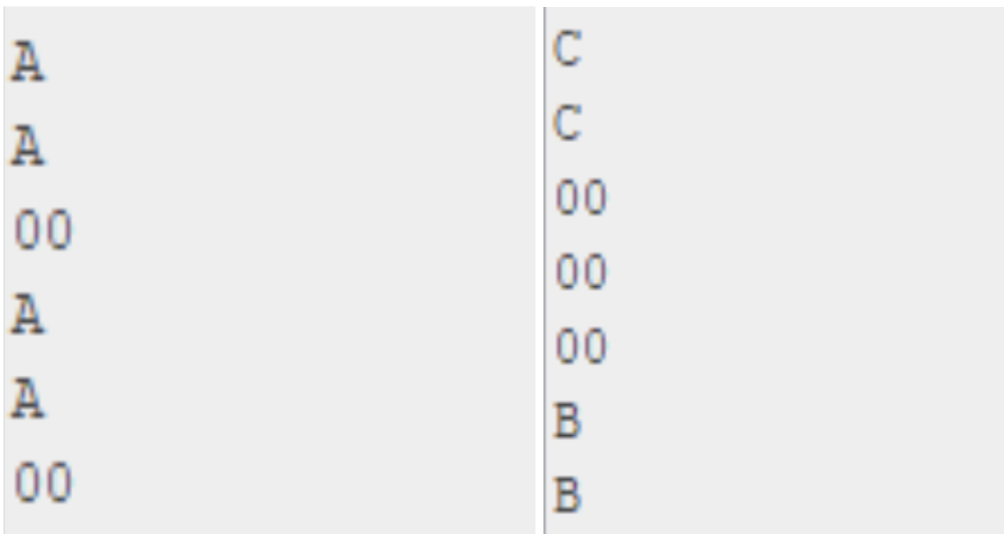

Figure 9: Push Button Signals From the Arduino IDE Serial Monitor

4.2.4 Gyroscope

- The model should be able to detect orientations from straight and upright to horizontal on all sides.
- The model should be able to withstand any sudden movements or collisions the walker may encounter.

We used the source code provided with the gyroscope module for our design. We displayed the different degree measurements through the Arduino IDE that were detected by the Gyroscope in multiple orientations. Using the variables aY and aZ, we set a threshold of greater than 15000 or less than -15000 as indicating a fallen orientation. As seen below in Figure 10, when aZ read 18008, we sent a high signal to the microcontroller to indicate a fall which necessitates an emergency text. The following measurements did not trigger a high signal as we did not want to continually send text messages while the walker is in a fallen orientation.

```
aX = -15932 | aY =    160 | aZ =   1068
aX = -15648 | aY =     48 | aZ =   1124
aX = -15880 | aY =    128 | aZ =   1256
aX = -15844 | aY =     20 | aZ =   1296
aX = -15772 | aY =      0 | aZ =   1260
aX = -15808 | aY =    160 | aZ =   1300
aX = -15748 | aY =     16 | aZ =   1132
aX = -15784 | aY =     68 | aZ =   1252
aX = -15848 | aY =   -564 | aZ =   1612
aX = -18572 | aY =   -816 | aZ =   1540
aX = -14776 | aY =    148 | aZ =   4680
aX = -12832 | aY =   -356 | aZ =  10776
aX =  -6872 | aY =   -300 | aZ =  14232
aX =  -7836 | aY =   -892 | aZ =  18008
signal high
signal low
aX =  -1764 | aY =   -428 | aZ =  17400
aX =  -1604 | aY =   -464 | aZ =  17340
```

Figure 10: Gyroscope Measurements From the Arduino IDE Serial Monitor

4.3 Power

A tolerance analysis was conducted and can be referenced in Appendix D.

4.3.1 Rechargeable Battery

- The 18650 8P battery pack must have 20,800 mAh +/- 5% capacity with a nominal voltage of 3.7V.
- The battery pack must have easily removable batteries in the case of cell or charging failure.

The capacity of each battery was assumed to be within spec regarding the 2600mAh. Each battery was fully charged to 4.2V using a dedicated lithium-ion battery charger before use. After some light testing, when all eight batteries were inserted into the battery holders, we got the resulting pack voltage of about 4.10V as shown in Figure 11.

Figure 11: Battery Pack Voltage Reading

4.3.2 Battery Charging Port

- The charging port must not operate or charge the battery pack when any of the lithium batteries are 4.2V.

Unfortunately, it was after testing the charging circuit that we realized that the circuit we designed was for the same chip with a different package and the port did not end up working. The chip we used, BQ2057CSNTR, has a different arrangement of pins compared to the schematic we designed, which was actually for the BQ2057CDGK variant. Figure 16 in Appendix C shows the corrected BQ2057 IC circuit after the error was found.

4.3.3 Power Switch

- The power switch safely disconnects the battery from the DC-DC boost converter.

When the switch was open, there was no voltage reading to the input of the DC-DC boost converter. After the switch was closed, the measured voltage as shown in Figure 12 was found to be nearly the same as the battery pack voltage.

Figure 12: MP3429 Input Voltage Reading After the Power Switch is Closed

4.3.4 DC-DC Boost Converter

- The boost converter takes 3.2V-4.2V input to produce +/- 5% 9V 3A output.

Using the battery pack voltage of about 4.10V as input, the measured output of the boost converter was found to be 9.01V as shown in Figure 13, which is well within +/- 5% 9V.

Figure 13: MP3429 Voltage Output Reading

4.3.5 Output Charge Ports

- The output charge port must not operate when any of the lithium batteries are below 3.2V.
- The output charge port must be able to safely charge various smartphones while maintaining device functionality.

The output charge port was measured to provide a 5V output within 5% from the L78S05 regulator as shown in Figure 14. A test smartphone was able to be used normally while being charged by the battery pack. When the lithium batteries are below 3.2V, the L78S05 will not produce 5V since there will be no 9V output from the MP3429.

Figure 14: L78S05 and USB Receptacle Vbus Voltage Output Reading

4.3.6 Battery Life Indicator

- Requirement: The SoC of the entire lithium battery pack is displayed with each LED representing a 10% charge.

With the rechargeable battery pack installed, the voltage rail and the ground connections were connected to the Battery Life Indicator unit, and when the push button was pressed, 9 LEDs lit up as shown in Figure 15. Having the range of 3.2V to 4.2V for the battery pack, 4.10V makes up 90%, which is correctly displayed with the LEDs.

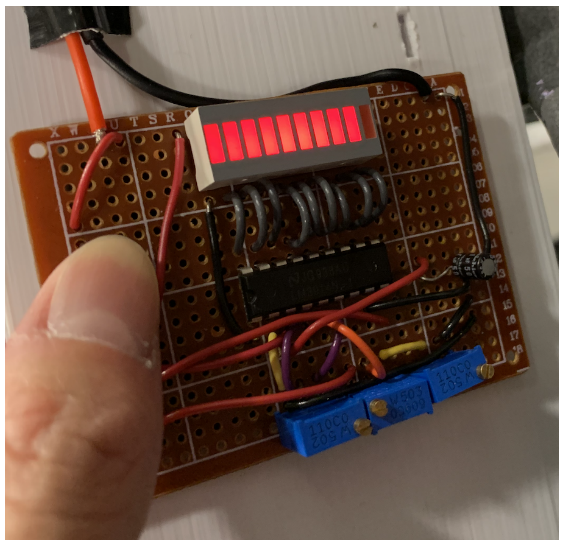

Figure 15: Battery Life Indicator Display

5 Conclusion

5.1 Accomplishments

Overall, the Bluetooth Enabled eWalker was a successful fully functional product that met our intended high-level requirements. It was also able to add some life-saving functionalities such as calls and texts through a push of a button while also keeping the walker's main functions unchanged and unhindered. The use of GPS coordinates is another great feature that makes the walker more effective in communicating during emergency situations. The design also included the ability to charge devices while using the walker and a working microcontroller PCB that mirrored the functions of an Arduino. Altogether, this is a smart and robust design that is extremely useful and can support additional functionalities in the future.

5.2 Uncertainties

The main uncertainties we have with our design are our charging capabilities and the weight of the design. Recharging the batteries for the walker as well as charging devices via USB is a bit of a slow process. We were not able to fully test our battery charging circuit, and we held true to our original 5V 2A USB device charging circuit which could be elevated to 9V 2A in the future. The second uncertainty is with the weight of our design as the addition of the electrical enclosure made the walker more front heavy which could hurt the balance of users depending on their strength level. We kept our enclosure as lightweight as possible, but it may be smart to look into lighter materials that allow users to have a better experience.

5.3 Future Work/Alternatives

Looking towards the future some changes we have considered include hidden wires, built-in buttons, and both a smaller microcontroller and electrical enclosure. All will add to the aesthetic of the walker and add to the safety and user-friendliness of it. Some major additions we have considered are a phone mount, a phone camera for live streaming, and an IR proximity sensor. The phone mount would allow users to not have to store their phone in their pocket or bag, and the camera would allow the configured contacts to see a live stream of the walker in an emergency. The IR proximity sensor would cover the case where the user falls, but the walker stays upright. In this event, both automatic and push-button communication are unlikely, so the IR proximity sensor would detect this and prompt emergency communication.

5.4 Ethical Considerations

We were very diligent in following the IEEE and ACM Code of Ethics throughout the creation of our Bluetooth Enabled eWalker. Safety was of the utmost importance in creating a new design without much precedence as there are many unexpected dangers that could have occurred. As a result, we followed IEEE I.1 which references the safety, health, and welfare of the public [14]. The privacy of users and possible test subjects was protected as we did not store any user contact information for any intention outside of the purpose of emergency calls. Unsolicited phone calls and text messages using user information were also not made.

Proper precautions were taken while wiring and conducting voltage and current analysis of the power system. This followed the ACM Code of Ethics section 2.9 which required the design and implementation of products to be secure and robust [15]. Our push buttons and gyroscope functionality were thoroughly tested to ensure calls and texts were made when prompted. This was of the utmost importance as users will be relying on our design as a form of life support.

We were also sure to seek and accept constructive criticism during the design and construction process while also awarding the proper credit to those involved as outlined in IEEE I.5 [14]. Being honest and trustworthy with our TAs and professors both in our procedure and data acquisition was also essential for us following ACM Code of Ethics section 1.3 [15]. This also extended to our transparency with the public. By creating a type of life support for individuals using our walker, we are not guaranteeing any help or assistance outside of the ability to communicate via call or text through our push buttons and signals given from our gyroscope. As the creators, we are not liable for what may occur when using the walker's functions for communication and emergency detection.

Finally, effective teamwork was paramount to the success of our Bluetooth Enabled eWalker, so we did not engage in any discrimination of any type and treated all persons and parties fairly and with respect [14].

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Appendix A Cost Analysis

Table 16: Cost Analysis

Component	Manufacturer	Part Number	Quantity	Price
Walker	Drive Medical	10210-1 Deluxe	1	$42.99
ATmega328P-PU	Microchip Technology	PPPC101LFBN-RC	1	$4.74
Bluetooth Module	HiLetGo	HC-05 8541554474	1	$9.99
Gyroscope Module	HiLetGo	GY-521 MPU6050	1	$3.33
Emergency Button	Grayhill	4001 SPST	1	$5.79
Generic Push Buttons	E-Switch	TL1105AF100Q	4	$0.56
Rocker Switch	E-Switch	R1966ABLKBLKEFBLU	1	2.26
GPS Module	MakerFocus	NEO-6M SN12SF83QOH11452IC	1	$12.79
Screws	Phillips	91772A833	8	$0.56
18650 3.7V 2.6Ah Lithium Battery	Ultralast	UL1865-26-2P	2 cells per pack x 4	$47.80
Lithium Battery Holder (2 cell)	MPD	BATT HOLDER 18650 2 CELL PC PIN	4	$24.88
Fuse holder	Keystone	PCB MOUNT	1	$0.58

	Electronics	FUSE HOLDER 5x20mm		
5A Glass Fuse	AMPELE	5A Fast-Blow Fuse	20	$6.99
9V Boost Converter	Monolithic Power Systems Inc.	MP3429GL-Z	1	$2.97
5V 2A Regulator	STMicroelectronics	L78S05CV	2	$2.26
5V 1.5A Regulator	STMicroelectronics	L7805CV	2	$1.38
3.3V 1.5A Regulator	STMicroelectronics	LM317BT	2	$1.44
Lithium Battery Charging IC	Texas Instruments	BQ2057CSNTR	10	$30.73
Battery Life Indicator	Texas Instruments	LM3914N-1	1	$5.00
LED Display	Lite-On Inc.	LTA-1000G	1	$1.38
USB Type C Receptacle	CUI Devices	UJ31-CH-31-SMT-TR	1	$1.53
USB Type A Receptacle	Würth Elektronik	614004184726	2	$2.88
2-Port Side Mount Terminal Block	Phoenix Contact	1729128	1	$1.32
Female Headers 1x6	Sullins Connector Solutions	PPTC061LFBN-RC	1	$0.52
Female Headers 1x8	Sullins Connector	PPTC081LFBN-RC	2	$1.30

	Solutions			
Female Headers 1x10	Sullins Connector Solutions	PPPC101LFBN-RC	1	$0.68
Male Headers 1x3	Molex	0705430002	1	$1.12
Male Headers 1x5	Molex	0705430109	1	$1.69
Male Headers 1x6	Molex	0705430005	1	$1.41
Male Headers 1x8	Molex	0705430007	2	$3.94
Male Headers 1x10	Molex	0705430114	1	$2.32
Assorted Resistors, Capacitors, Diodes, and Transistors		N/A	ON HAND	
USB to TTL Module	HiLetgo	HiLetgo CP2102	1	$6.49
Power Supply SMD Components	Various		Various	$50.87
Power Supply PCB Fabrication	PCBway		5	$68.61
USB-C Breakout Boards	Treedix		4	$8.59
USB-Type A Breakout Boards	Walfront		10	$6.19
			Total	$367.34

Appendix B Schedule

Table 17: Schedule

Week	Deliverables	Lukas	Darren	Greg
9/25	Design Document Bluetooth Configuration	Design Document Bluetooth Configuration PCB	Design Document Power Supply PCB	Design Document CAD PCB
10/02	Design Reviews Weekly Check-In	Order Parts PCB	Order Parts PCB	Order Parts PCB
10/09	PCB Orders #1 Teamwork Evaluation Weekly Check-In	PCB Walker Mounting	PCB Walker Mounting Power Supply	PCB Walker Mounting
10/16	Weekly Check-In	PCB Push Button Tests Bluetooth Testing	PCB Push Button Tests Power Supply	PCB Push Button Tests Gyroscope Testing
10/23	Weekly Check-In	PCB Call/Text Testing	PCB Power Supply	PCB Call/Text Testing
10/30	PCB Orders #2 Individual Progress Reports Weekly Check-In	PCB Charging Ports	PCB Charging Ports	PCB Charging Ports
11/06	Weekly Check-In **Operational Walker**	Final Tests	Final Tests	Final Tests
11/13	Mock Demos Weekly Check-In	Final Tests Final Presentation Final Paper	Final Tests Final Presentation Final Paper	Final Tests Final Presentation Final Paper
11/20	FALL BREAK - Work as you please			
11/27	Final Demos Weekly Check-In	Final Presentation Final Paper		
12/04	Final Presentation Final Paper Checkout Procedures			

Appendix C Schematics and PCB Layouts

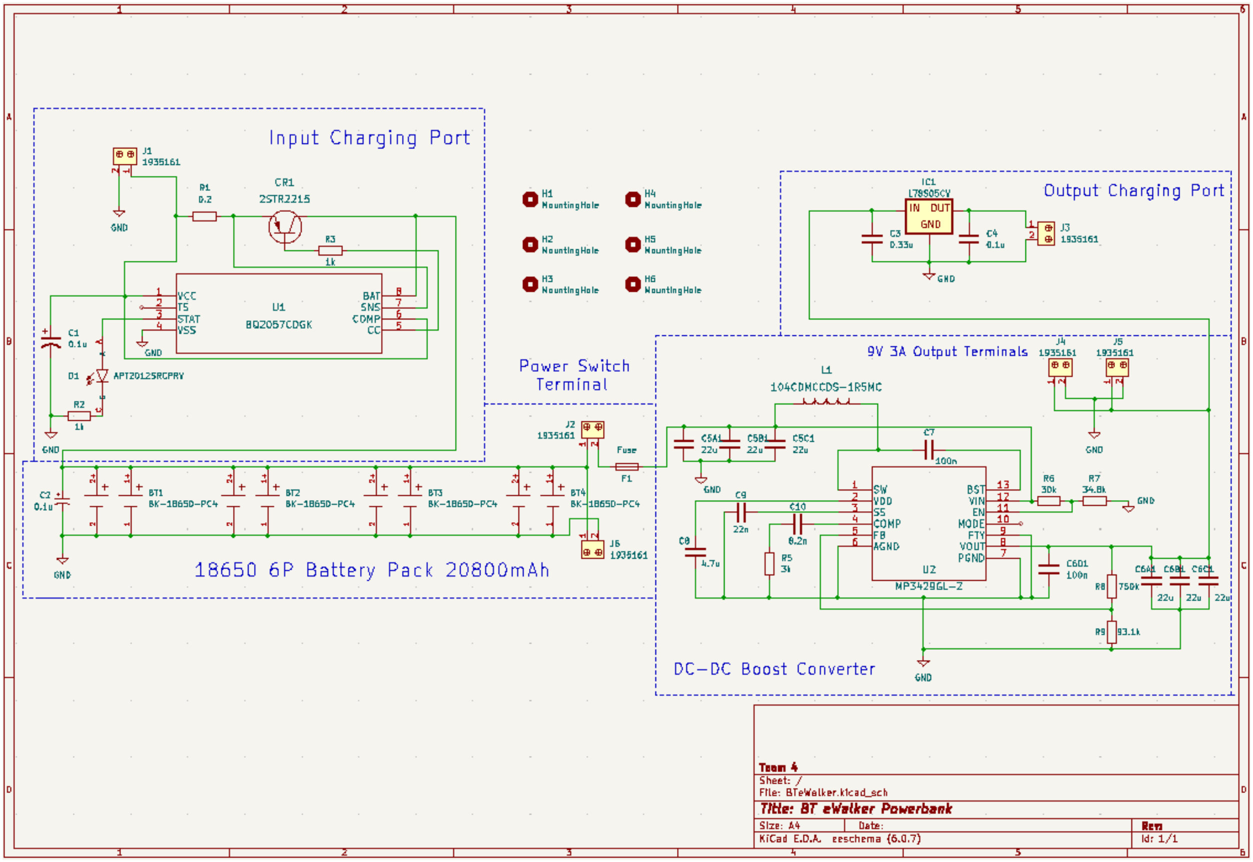

Figure 16: Power Supply Schematic

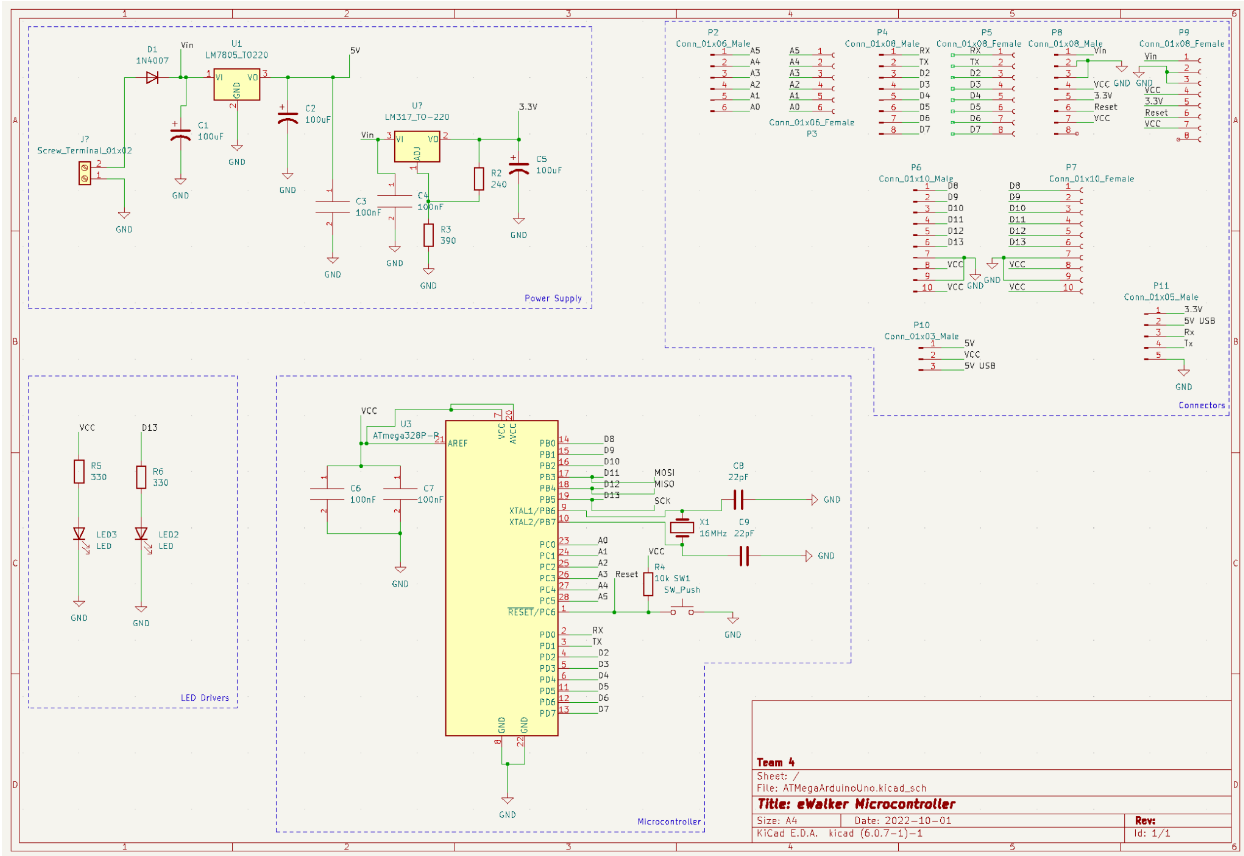

Figure 17: Microcontroller Circuit Schematic

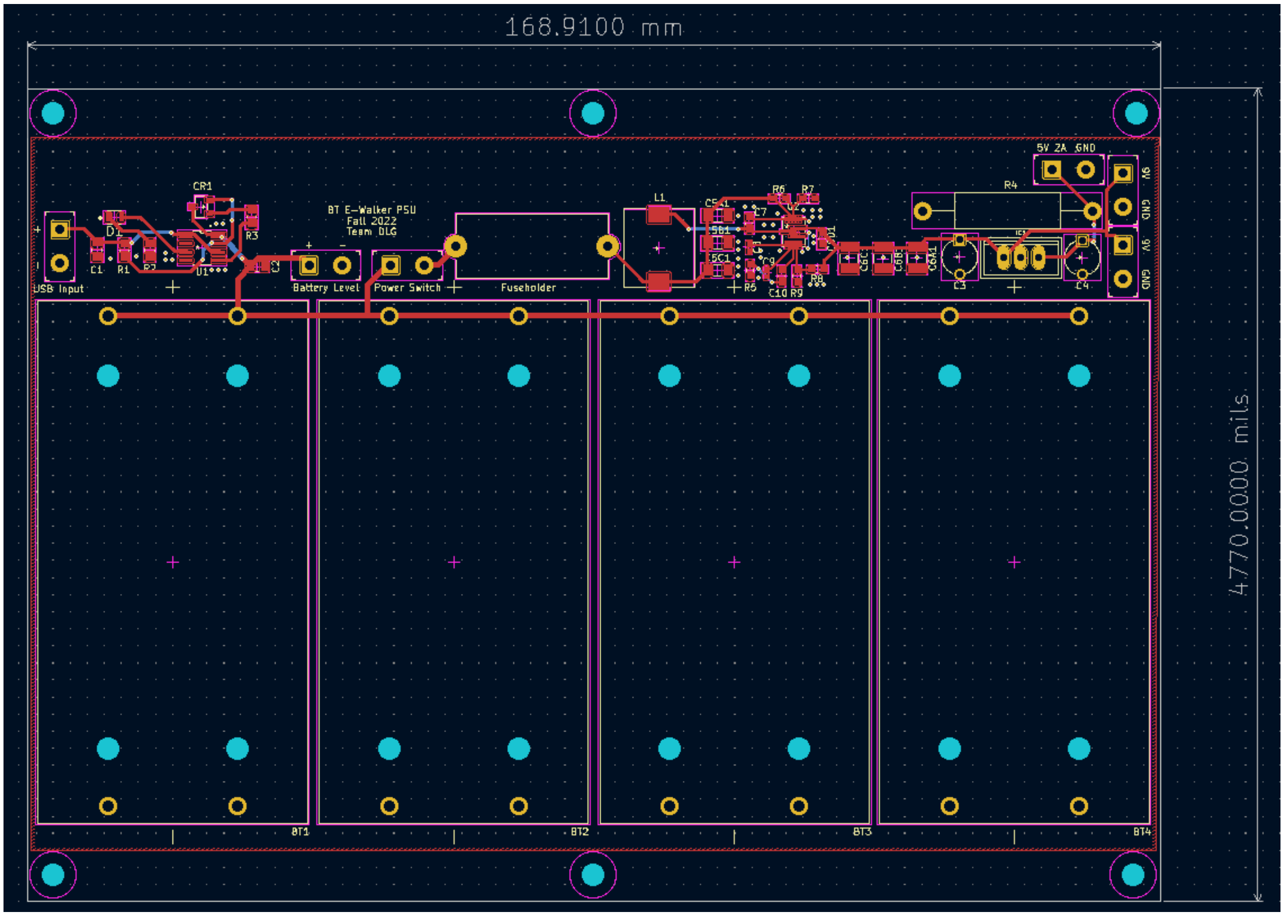

Figure 18: Power Supply PCB Layout

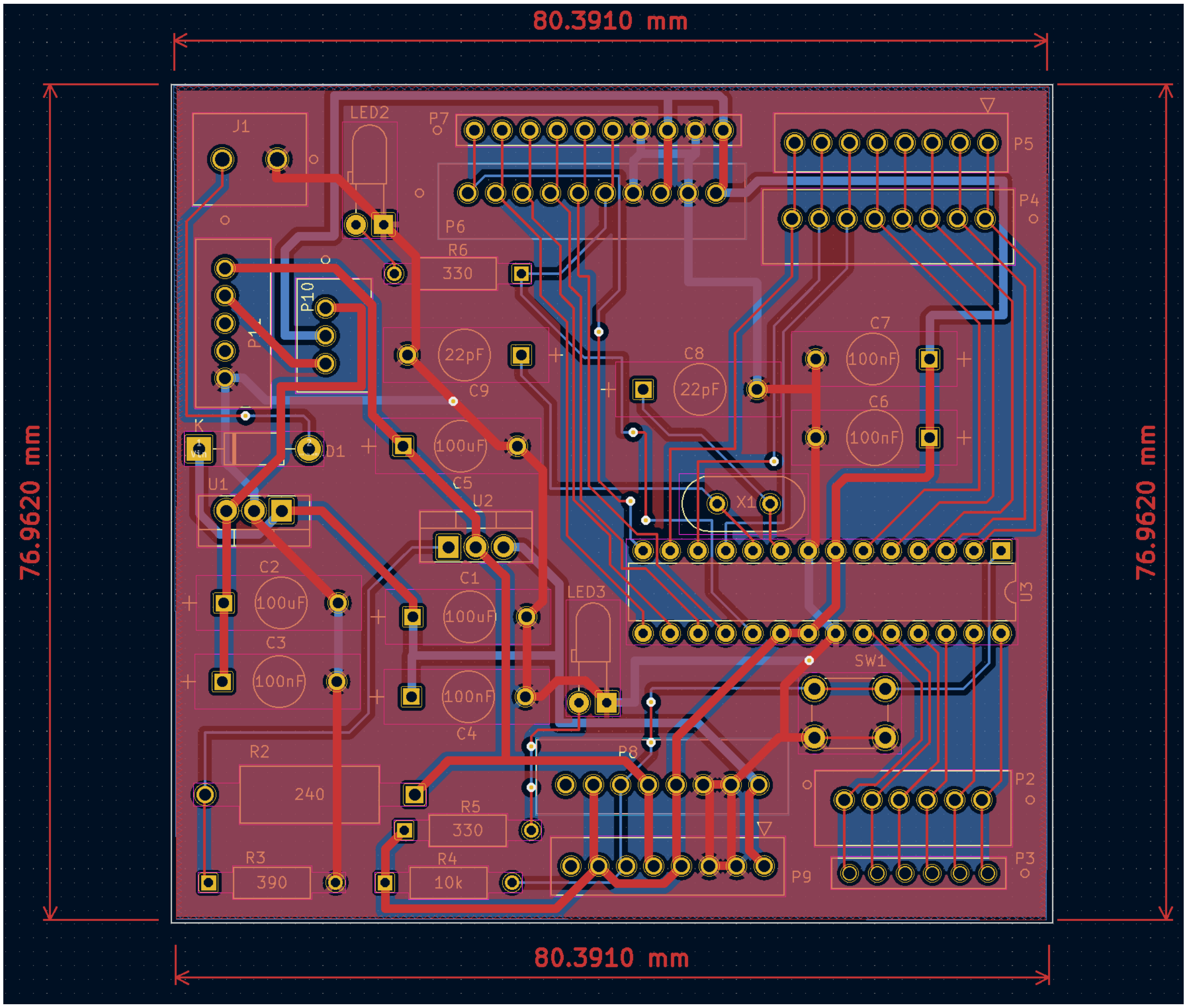

Figure 19: Microcontroller PCB Layout

Appendix D Tolerance Analysis

The main constraints of our design are the battery life and battery sizing. We want to ensure our battery will be able to supply enough power to all of our subsystems and last for at least one day. We want to minimize the possibility of having to charge the walker during the day while the user may be away from outlets or away from their charger. The calculations for finding the correct battery size and desired battery life are shown below. The main components drawing power from our battery are the output charging ports, the battery life indicator LEDs, and our microcontrollers which are powering the rest of the control system. The walker has a power switch which will help save battery but the analysis is required for how long a fully charged walker can be functional without being turned off.

Table 15: Power Draw Calculation Table

Components	ATmega 328P-PU	Charging Ports	Bluetooth	Gyroscope	LED Bar Graph
Current Draw (A)	9.5mA	2000m(2A) per port	30m <100m	3.6m	300m
Voltage Draw (V)	5V at 16MHz	5	5	3.3	2.1
Power Draw ($P = V * I$)	.0475W	10W per port	.15W min .5W max	0.01287W	0.63W

The 18650 3.7V 6P battery pack has 20800 mAh capacity and full state of charge is at 4.2V. This results in up to 87.360Wh capacity. The power in watt-hours was calculated using the Power Draw values in Table 15.

- Without the output charging port active, the power draw ranges from 1.34Wh to 1.69Wh.

- With the output charging port active, the power draw ranges from 11.34Wh to 11.69Wh.

Not using the charging port yields a very long running time for the walker system. The total current draw ranges from 443.1mA to 543.1mA, and with a battery capacity of 20800mAh, the system can continuously operate between 38 and 47 hours, which is approximately almost 2 days. The system run time was calculated by dividing the total battery capacity in mAh by the current draw in mA.

- In the scenario of continuous charging, the total current draw ranges from 2443.1mA to 2543.1mA, resulting in a running time that ranges from 8.2 to 8.5 hours.

Although the run time is drastically reduced, smartphone devices will likely charge to an acceptable range while the walker is in use. As a result, the current draw will not be fully continuous in a practical application.

- Consider a typical smartphone battery capacity of 4,000 mAh, charging from 20% (800mAh) to an almost full charge of 80% (3200mAh)
    - At a charge rate of 2A, 2400mAh of capacity will be charged in 1.2 hours.
    - The 20800mAh battery pack will consume approximately 500mA from the system plus the 2000mA from USB charging, resulting in an overall current draw of 2500mA for 1.2 hours, totaling 3000mAh.
    - After the smartphone reaches 80%, there will be 17800mAh capacity left, only consuming the 500mA from the system there on.
    - The system running time is now calculated to be 35.6 hours plus the 1.2 hours when the phone was charging while the system was operating, totaling 36.8 hours.

The battery pack will provide more than enough power to charge a typical smartphone of around 4,000mAh battery capacity or less from low charge to almost fully charged while keeping the main functionality of the Bluetooth Enabled E-Walker operating for a plentiful amount of time before the battery pack requires charging.

Our batteries are also analyzed intently to ensure safe working voltages and currents. They are tested with care to prevent any explosions and leakages that can endanger the public.

- Battery Storage
    - Protection from impact and contact with other elements stored in the designed enclosure.
    - Stored in the Senior Design Lab.
- Battery Transportation
    - Wires must not be exposed preventing the possibility of a short.
    - Battery packs must not have exposed parts that endanger users when packing or unpacking.
    - If being shipped, outermost protection must be nonconducting.
- Battery Usage and Charging
    - Ensure batteries are operating between manufacturer-tested lower and upper threshold voltages, which can range between 3.2 Volts and 4.2 Volts and the battery pack is outputting 5V +/- 5% from the voltage regulator.
    - Charging must not exceed 4.2V, and discharging must not go below the rated lower threshold of the battery.
    - Input current must not exceed the current ratings of the charging circuit.
    - Output current must not exceed 2A from the battery pack.
    - Batteries must be easily removable from the battery pack.