Bluetooth Enabled E-Walker

ECE 445 Design Document Draft

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1 Introduction

1.1 Problem

Walkers are primarily used by people over 65 years old with musculoskeletal or neurological problems. Some conditions that require a person to use a walker include arthritis and Parkinson's disease. When a person uses a walker, one or both hands are occupied supporting themselves with the walker which makes it more difficult to access smartphone features in times of emergency. In recent years, more devices have become smart devices paired with our smartphones for additional features, but walkers and walking canes have been left behind. When looking for existing solutions, we have found some canes that support lighting and charging, but none with IoT. We believe this is the next logical step in innovation to support people with conditions that struggle to interface with touch screen displays.

1.2 Solution

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 where time is of the essence and the user might struggle to use their smartphone. This includes a connection between the walker and a smartphone via bluetooth allowing for a 911 call as well as texts and calls with two specific contacts. These will be prompted through push buttons and when the walker detects a fall or emergency situation.

1.3 Solution Visual Aid

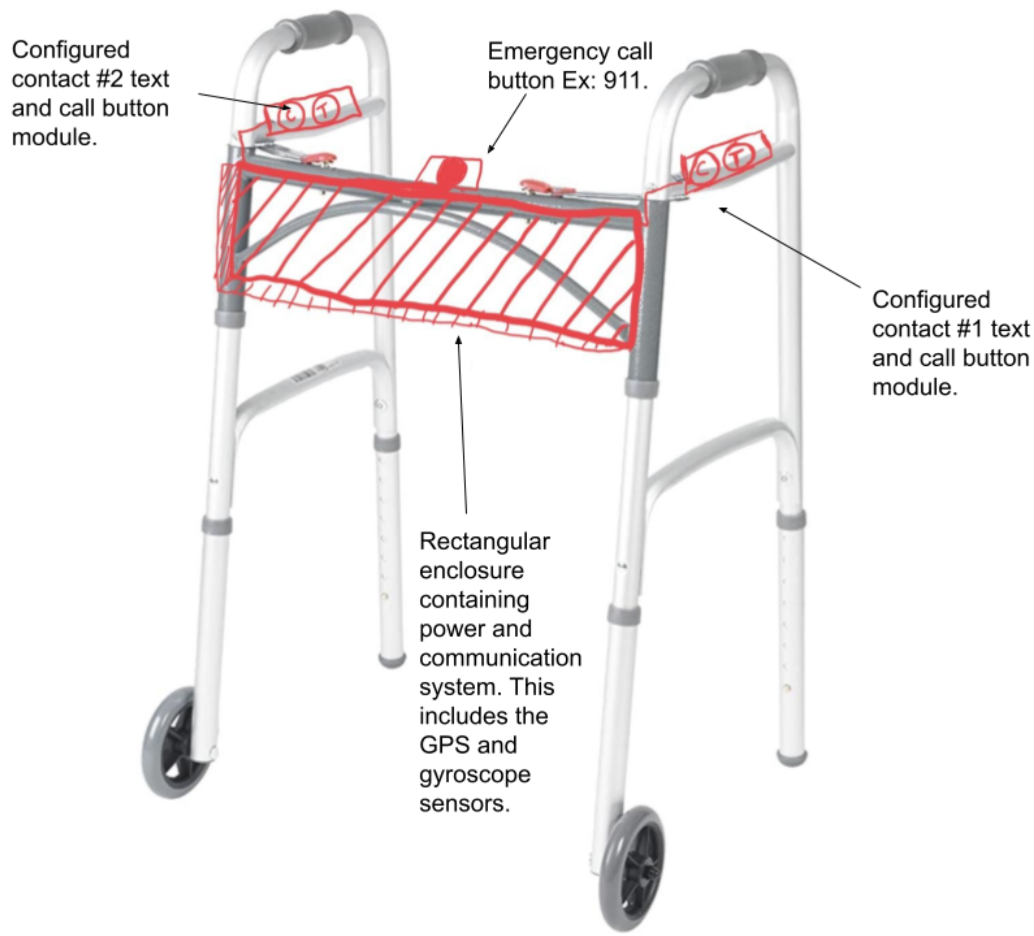

Figure 1: Bluetooth Enabled eWalker Visual

1.4 High-Level Requirements List

Button Functionality

Our push buttons must be able to initiate calls and texts to two configured contacts as well as calls to emergency services such as 911 within 8 seconds of being pressed.

Messaging System

Our messaging system must be able to send different text messages based on the severity of the situation being level 1 or level 2. For example, if the walker is in a fallen orientation, an automated level 2 text would indicate a fall and request urgent help. If the walker is in an upright orientation, the level 1 text will be less severe and request a call or assistance when available.

Power Unit

The power unit of our design must consist of a rechargeable battery pack of 20800mAh capacity that will be capable of charging two devices through 5V 2A USB Type A ports, while providing power to the control unit.

2 Design

2.1 Block Diagram

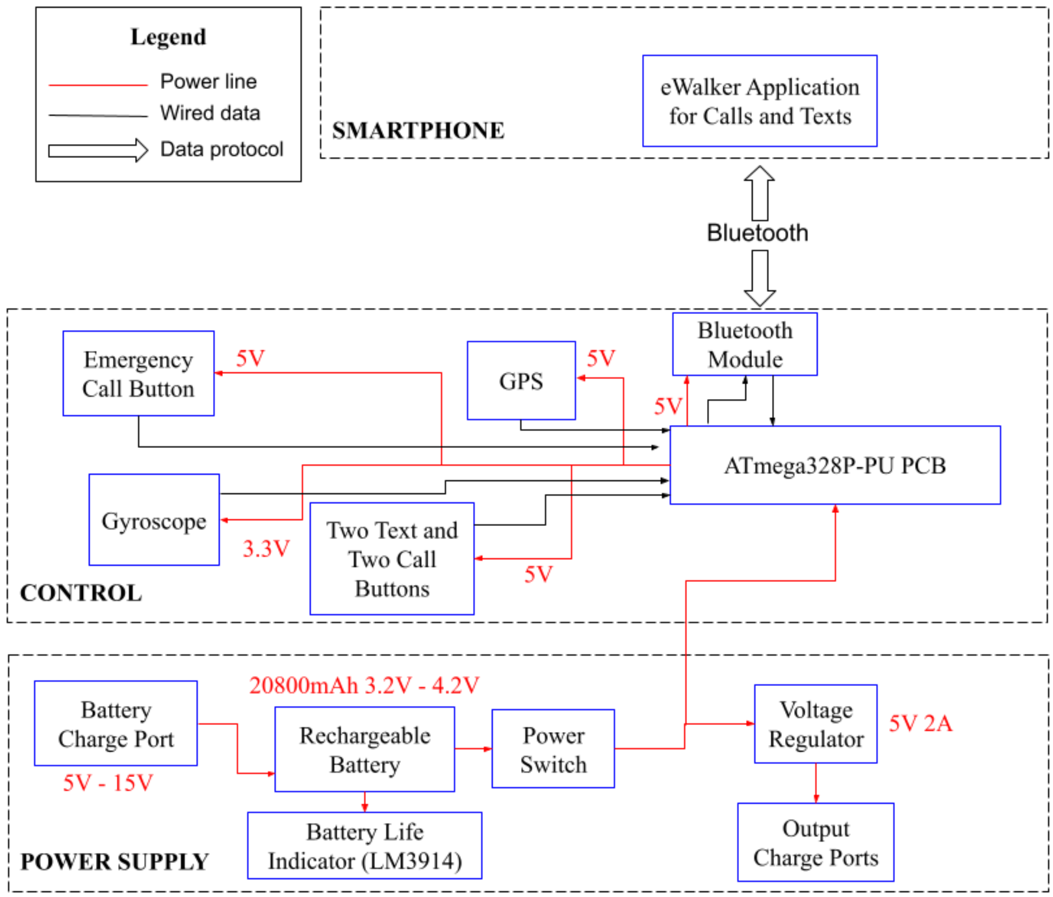

Figure 2: Block Diagram

2.2 Subsystem Overview

2.2.1 Smartphone (Physical Components Out of Scope)

- The smartphone pairs with the Bluetooth module that is part of 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.

Table 1: Smartphone R&V Table

Smartphone Requirements	Verification
Requirement 1: The smartphone must have Bluetooth connectivity and be able to pair to a Bluetooth device. Requirement 2: The smartphone must have a SIM card that can access a cellular network.	Verification: We will be using an Android device. We will be sure to check the system settings and documentation for Bluetooth and cellular network connectivity. These requirements are outside the scope of our design implementation so verification is based on manufacturer information.

2.2.1.1 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 text messages and phone calls through an external service with an API. Initiating a phone call or text message directly with the smartphone through Bluetooth requires special approved permissions with smartphone manufacturers that our team might not have access to, so we will likely be utilizing this alternative approach.

Table 2: eWalker Application R&V Table

eWalker Application Requirements	Verification
Requirement 1: The eWalker application must be able to send Bluetooth data to the Bluetooth module on the control system. Requirement 2: The eWalker application must be able to read Bluetooth data sent from the paired Bluetooth module on the control system.	Verification 1: After the Bluetooth module on the control system sends the data to the PCB which is synonymous with our microcontroller, the PCB should print out the packet content data as debugging information to the console. Then the output from the PCB console should manually be cross checked with the Bluetooth eWalker application packet input and be the same. There should be 0%

Requirement 3: The eWalker application must be able to process the Bluetooth data and upload this data to an external web service application that can trigger phone calls and text messages.	variation in the content section of the Bluetooth packet between the sender and receiver. Verification 2: After the Bluetooth module on the control system reads data from the PCB and sends the packet out to the smartphone, the smartphone should print out the packet content data as debugging information to the smartphone app console. The output of the smartphone app console should manually be cross checked with the PCB packet input and be the same. There should be 0% variation in the content section of the Bluetooth packet between the sender and receiver. Verification 3: Another smartphone device should receive a text from a third party phone number. The contents of the text should contain the same data that was sent from the Bluetooth packet. The debugging output inside the smartphone app console should contain the Bluetooth packet content. This debugging output should manually be cross checked with the text message and be the same. There should be 0% variation in the content section of the Bluetooth packet between the text message and eWalker application.

2.2.2 Control

- The control unit collects data from sensors or inputs like the GPS, the gyroscope, and the five total input buttons and stores this data into the microcontroller where the data is processed. The processed data will first be formatted in the Bluetooth protocol in the microcontroller and then sent over to the smartphone with the Bluetooth module.

2.2.2.1 ATmega328P-PU PCB

- We will be utilizing the ATmega328P-PU microcontroller and mounting it on our PCB design based on an Arduino UNO schematic that reduces the amount of surface-mount components used [10] . The ATmega328P microcontroller will replicate 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 Type B programming port.
- More specifically, it will collect and process data from the GPS, buttons, PCB, and gyroscope. It will also power the sensors and inputs that it collects data from as well as the Bluetooth module where it will format the processed data into a serial packet that can be transmitted by the Bluetooth module.

Table 3: ATmega328P-PU PCB R&V Table

ATmega328P-PU PCB Requirements	Verification
Requirement 1: Collect and store serial data from GPS, PCB, and gyroscope.	Verification 1: We will display data from each inside the console as debugging information. - For the GPS, we will see if the coordinates given changes by physically moving the GPS sensor to different locations. - For the PCB, we will display signals given when push buttons are pressed. - For the gyroscope, we will display the degree outputs given from the walker

	being rotated in different orientations.
Requirement 2: Take 9V +/- 2% input and provide 3.3V +/- 2% and 5V outputs to each appropriate sensor and input.	Verification 2: We will probe both the input and output to each sensor and display on an oscilloscope to confirm the correct voltages.
Requirement 3: Compute a serial packet with proper heading and block information required for Bluetooth communication.	Verification 3: The MAC address of the android smartphone should be found within the Bluetooth packet.

2.2.2.2 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 read the prepared packet as serial data on Pin 5 which is the RX receiver. This pin allows serial data to be transmitted via Bluetooth. [1] The Bluetooth module will also receive transmitted data from the smartphone and send the serialized data to the microcontroller.

Table 5: Bluetooth Module R&V Table

Bluetooth Module Requirements	Verification
Requirement 1: Transmits packet received from microcontroller without packet loss.	Verification 1: 10 packets with numbered content data indicating 1-10 should be sent from the eWalker application and successfully received from the module then sent to the microcontroller. The Arduino microcontroller should print the ten packet's data in the debugging console. Any missing packet numbers would indicate packet loss. This test

	should be performed within 5 feet of the Bluetooth module to simulate the distance of the Bluetooth module and smartphone on the walker.
Requirement 2: Successfully receives packet from smartphone that can be deciphered for contact information by the microcontroller.	Verification 2: Converting bit values from the packet to ASCII characters should 100% match the ASCII input entered on the eWalker application. This test should be conducted after ensuring eWalker Application Requirement 1 is successful.

2.2.2.3 GPS

- The GPS NEO-6M module will utilize satellite data to find its current position. The GPS module will be placed in a fixed position near the top of the enclosure so the data is accurate and the module can receive proper connection. Power for the GPS module will be supplied by the PCB microcontroller. Data from the GPS will be sent to the Arduino Uno pin utilizing a USB-TTL cable.

Table 6: GPS R&V Table

GPS Requirements	Verification
Requirement 1: Data must be successfully transferred from USB to TTL serial data so the Arduino Uno can accurately read the coordinates.	Verification 1: We will be displaying the data readouts from the GPS Module to ensure that it accurately locates the walker's position.

2.2.2.4 Two Text and Two Call Buttons

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

2.2.2.5 Emergency Call Button

- This button will be used specifically to call an emergency contact such as 911. The emergency call button will be the Grayhill 4001 SPST normally open 1 Amp push button, and it will be mounted on the center rail of the walker to the left of the phone mount. This button will also interface with the PCB to prompt a call from the cellphone through the bluetooth module.

Table 7: Push Button R&V Table

Push Button Requirements	Verification
Requirement 1: Pressing the text and call buttons should output a high signal that can be read by the microcontroller which would initiate the desired call or text function. Requirement 2: Pressing the emergency button should output a high signal that can be read by the microcontroller which would initiate the desired emergency call.	Verification 1 & 2: We will probe the push button signals and the output of the PCB and display on an oscilloscope to ensure their signals match.

2.2.2.6 Gyroscope

- In order to implement the gyroscope, we will be using the GY-521 MPU6050 model from HiLetGo. It is a 6-axis accelerometer gyroscope sensor (ie. 3 axes each for the accelerometer and gyroscope). This will be placed on a mounted breadboard within the enclosure shown on Figure 1 above in order to detect the orientation of the walker. It will interface with the microcontroller and bluetooth module to prompt an emergency call and text when necessary.

Table 8: Gyroscope R&V Table

Gyroscope Requirements	Verification
Requirement 1: The model should be able to detect orientations from straight and upright to horizontal on all sides.	Verification 1: We will be displaying the different degree measurements through the Arduino IDE that are detected by the Gyroscope.
Requirement 2: The model should be able to withstand any sudden movements or collisions the walker may encounter.	Verification 2: We will display through the Arduino IDE what the gyroscope reads when a fall occurs to ensure the PCB will be able to send the correct signals based on the severity of the degree measurements.

2.2.3 Power Supply

- The power supply consists of a rechargeable battery that is able to deliver power to the control system and up to two external devices There are a total of three power ports: one charging input port to the battery, and two output charging ports to external devices. A power switch for the DC-DC converter is used as a way for the user to power on the microcontroller system. Lastly, the battery is connected to a LM3914 to display the state of charge of the battery.

2.2.3.1 Rechargeable Battery

- To make a rechargeable battery pack that is at least 20000mAh, we will make use of eight 18650 lithium 3.7V 2600mAh batteries in parallel. The 18650 batteries have a nominal voltage of 3.70V so a voltage regulator will be used to output 5V for the entire pack. The voltage regulator in use will be a L78S05CV, to step up the 3.7V voltage of the battery pack to 5V and output 2A.

Table 9: Rechargeable Battery R&V Table

Rechargeable Battery Requirements	Verification
Requirement 1: The 18650 8P battery pack must have 20,800 mAh +/- 5% capacity with a nominal voltage of 3.7V.	Verification 1: Measure the capacity of each 18650 lithium battery cell using a battery capacity tester and get the sum of the 8 18650 cells, ensuring the total capacity is within 5% of 20800mAh.
Requirement 2: The battery pack must output 5V +/- 5% at 2A from the 3.2V to 4.2V input from the 18650 batteries.	Verification 2A: Connect the output of the L78S05CV voltage regulator to VDD in a constant-current test circuit. Verification 2B: Adjust the resistance in the circuit to output 2A to the load, measured by a multimeter using V = IR. Verification 2C: Measure the output voltage using an oscilloscope, ensuring that the output voltage is within 5% of 5V.
Requirement 3: The battery pack must have easily removable batteries in the case of cell or charging failure.	Verification 3: Ensure that each cell holder is appropriately connected in 8-parallel configuration by using a multimeter to verify 3.2V-4.2V across each battery and the entire pack.

2.2.3.2 Battery Charging Port

- To ensure that the lithium battery pack charges safely and efficiently, we will use one BQ2057 IC per lithium battery. Each IC, rated for max 15V input, is able to manage the voltage and current when each cell is being charged by the supply voltage, as well as battery temperature. The voltage input to the ICs will be supplied through a USB Type C port. The current supplied to each cell in the battery pack will be 1A at most.

Table 10: Battery Charging Port R&V Table

Battery Charging Port Requirement	Verification
Requirement 1: The charging port must not operate or charge the battery pack when any of the lithium batteries are 4.2V.	Verification 1: When any of the cells are at 4.2V, use a multimeter and put the positive probe on the CC pin (Charge Control output) and negative probe on the VSS pin (Ground) of the BQ2057 IC with the fully charged cell. Ensure that the voltage reading is at 0V, indicating no active charging operation. Verification 1a: When the entire pack is fully charged at 4.2V per cell, measure the charging input to the entire battery pack and ensure it matches the voltage rating of the charger being used. At this point, no power is being supplied to any of the cells but the charger is still functioning correctly.

2.2.3.3 Output Charge Ports

- Having 5V and 2A for 10W charging, each of the two USB Type A ports will be built with overcurrent and overvoltage protection.

Table 11: Output Charging Port R&V Table

Output Charging Port Requirements	Verification
Requirement 1: The output charge port must not operate when any of the lithium batteries are below 3.2V -2% depending on battery selection.	Verification 1: We will display on an oscilloscope the voltage being supplied to the output charging port as well as the voltage being supplied by the charging port. The output charge port should only function between 3.2V and 4.2V which is based on the voltage regulator. No output should be detected from the charger when supply voltage drops below 3.2V.
Requirement 2: The output charge port must be able to safely charge various smartphones while maintaining device functionality.	Verification 2: We will monitor the output voltage of the charging port when connected to a device. The device will also be used to test its functionality while being charged.

2.2.3.4 Power Switch

- To turn on the system, we will use an SPST illuminated rocker switch that has the light on when the system is powered, and off when the system is disconnected. For added safety, we will also use a 5V 3A fuse after the switch to protect the rest of the system in the case of battery malfunction.

Table 12: Power Switch R&V Table

Power Switch Requirements	Verification
Requirement 1: The power switch safely disconnects the battery from the DC-DC converter.	Verification 1: Voltage measurements will be taken from the output of the battery along with the input to the DC-DC converter to

	ensure 0V at disconnect and battery pack voltage when connected. A test LED may also be used to test the functionality of the switch.

2.2.3.6 Battery Life Indicator

- To display the current charge of the battery, we will use a LM3914 paired with a 10 segment LED bar graph display.

Table 13: Battery Life Indicator R&V Table

Battery Life Indicator Requirements	Verification
Requirement: The SoC of the entire lithium battery pack is displayed with each LED representing 10% charge.	Verification: With a multimeter, ensure that the current voltage of the pack matches the amount of LEDs that are turned on. 1 LED equals 3.2V, 2 LEDs equals 3.3V, and so forth until the final check of 10 LEDs equalling 4.2V.

2.3 Circuit Schematics

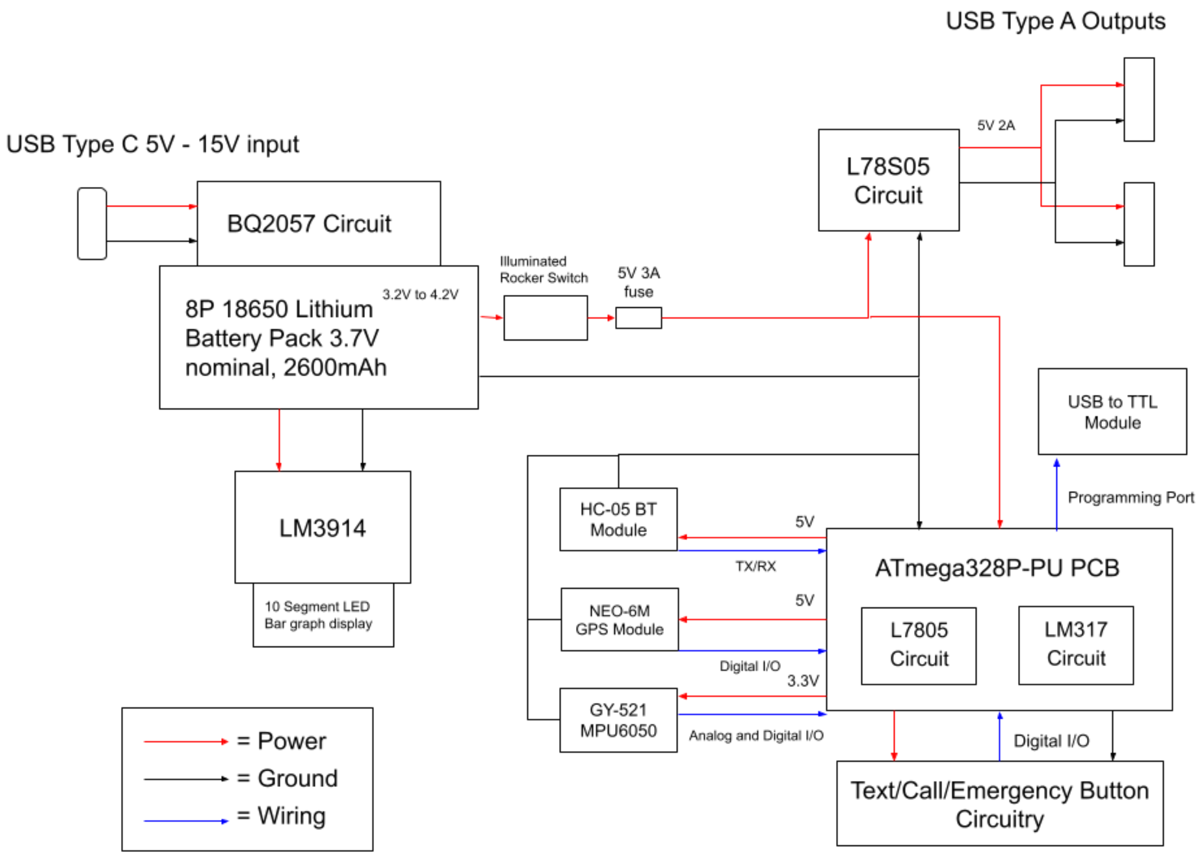

Figure 3: High-Level Power Circuit Schematic

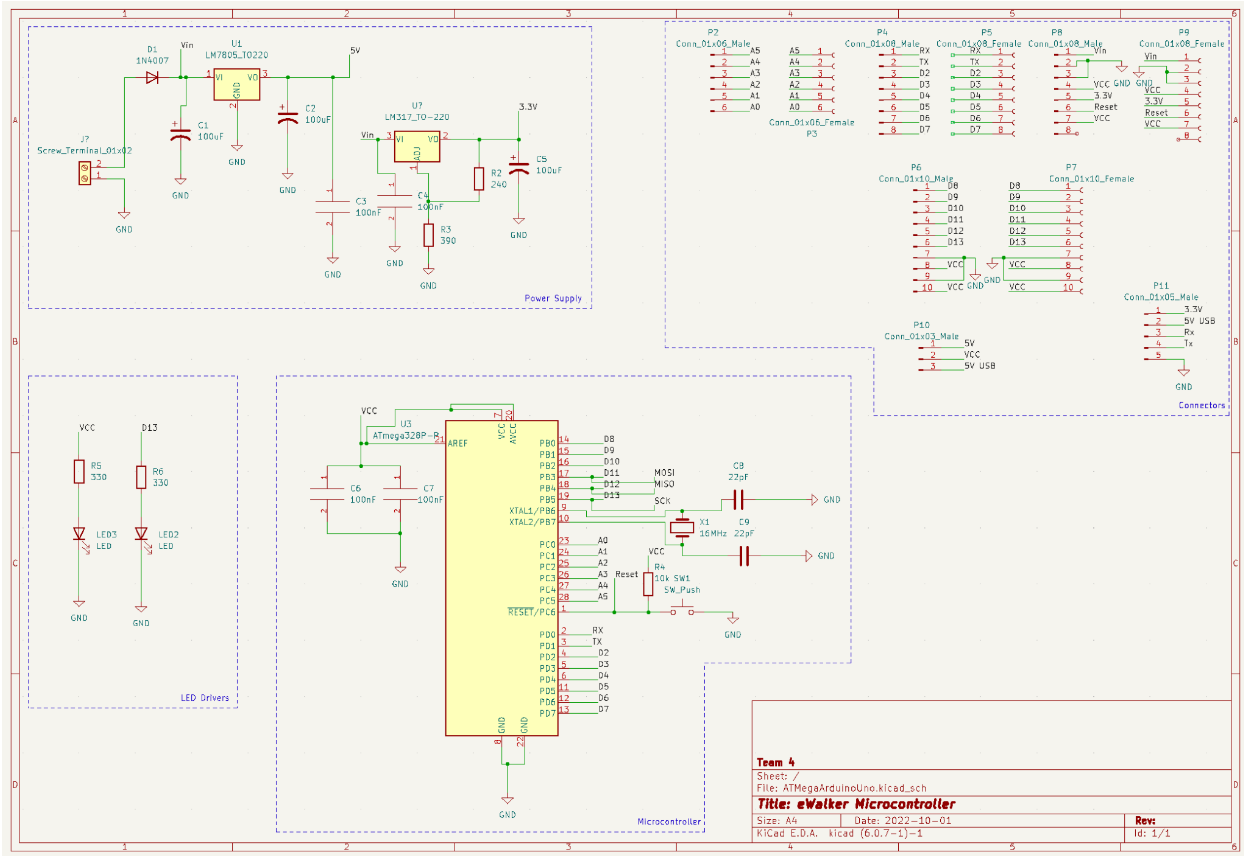

Figure 4: Microcontroller Circuit Schematic

2.4 Tolerance Analysis

The main constraints of our design will be the battery life and battery sizing. We will have to ensure our battery will be able to supply enough power to all of our subsystems as well as 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 in general. The calculations for ensuring the correct battery size and desired battery life are shown below. The main components drawing power from our battery will be the output charging ports, the battery life indicator LEDs, and our microcontrollers which are powering the rest of the control system.

The walker will have a power switch which will help to save battery, but we will be analyzing 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	GPS	Gyroscope	LED Bar Graph
Current Draw (A)	9.5mA	2000m(2A) per port	30m <100m	100m	3.6m	300m
Voltage Draw (V)	5V at 16MHz	5	5	5	3.3	2.1
Power Draw (P = V * I)	.0475W	10W per port	.15W min .5W max	0.5W	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 87.360Wh capacity. The power in watt hours was calculated using the Power Draw values in Table 15.

- With no charge ports active, the power draw ranges from 1.34Wh to 1.69Wh.
- With one charge port active, the power draw ranges from 11.34Wh to 11.69Wh.
- With two charge ports active, the power draw ranges from 21.34Wh to 21.69Wh.

Using no charging ports 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 is able to 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 one port 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.
- In the scenario of continuous dual port charging, the total current draw ranges from 4443.1mA to 4543.1mA, resulting in a running time that ranges from 4.6 to 4.7 hours.

3 Cost and Schedule

3.1 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	Digikey	TL1105AF100Q	4	$0.56
Rocker Switch	GAMA Electronics Inc.	23G-B/R-12V	1	10.95
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 (4 cell)	MPD	BK-18650-PC8	2	$16.12
5V 2A Regulator	STMicroelectronics	L78S05CV	1	$1.13
5V 1.5A Regulator	STMicroelectronics	L7805CV	1	$0.69
3.3V 1.5A Regulator	STMicroelectronics	LM317BT	1	$0.72
Lithium Battery Charging IC	Texas Instruments	BQ2057WSN	8	$38.56
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	Allied Components International	AUSB1-4600	3	$3.30
2-Port Side Mount Terminal Block	Phoenix Contact	1729128	1	$1.32
Female Headers 1x6	Sullins Connector Solutions	PPTC081LFBN-RC	1	$0.52
Female Headers 1x8	Sullins Connector Solutions	PPTC061LFBN-RC	2	$1.30
Female Headers 1x10	Sullins Connector Solutions	PPPC101LFBN-RC	1	$0.68

Male Headers 1x3	Molex	0705430002	1	$1.12
Male Headers 1x5	Molex	0705530004	1	$1.69
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
			Total	$227.32

The average ECE UIUC Graduate makes a starting salary of about $93,000.[8] 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

$$44 \times 2.5 \times 12 \times 10 = \$13200 \text{ per person to}$$

$$44 \times 2.5 \times 15 \times 10 = \$16500 \text{ per person.}$$

This gives a range of $15,840 to $19,800 for total labor cost.

We are also 3-D printing some enclosures for our design which does not require any outside labor, so our total cost would come out to our total labor added to our product cost of $227.32. This final range would be between $39,827.32 and $49,727.32.

3.2 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	Order Parts	Order Parts	Order Parts

	Weekly Check-In	PCB	PCB	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			

4 Ethics and Safety

We plan to be very diligent in following the IEEE and ACM Code of Ethics throughout the creation of our Bluetooth Enabled eWalker. Safety is of the utmost importance in creating a new design without much precedence as there are many unexpected dangers that can occur. As a result, we will follow IEEE I.1 which references the safety, health, and welfare of the public. [2] The privacy of users and possible test subjects will be protected as we will not be storing any user contact information for any intention outside of the purpose of emergency calls. Unsolicited phone calls and text messages using user information will also not be made.

Proper precautions will be taken with wiring as well as voltage and current analysis of the power system. This will also follow the ACM Code of Ethics section 2.9 which requires the design and implementation of products that are secure and robust. [3] Our push buttons and gyroscope functionality will be thoroughly tested to ensure calls and texts can and will be made when prompted. This is of the utmost importance as users will be relying on our design as a form of life support. Our batteries will also be analyzed intently to ensure safe working voltages and currents. They will be 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 designed enclosure
  - Stored in Senior Design Lab
- Battery Transportation
  - Wires must not be exposed preventing the possibility of a short
  - Battery pack 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, that 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.
- Emergency
  - TA: Akshat Sanghvi; sanghvi8@illinois.edu

- Lab Coordinator: Casey Smith; (217)-300-3722; cjsmith0@illinois.edu
- Battery Fire: Extinguish and contact both above
- Battery Leak: Evacuate the Lab and contact both above
- Always utilize caution and contact both above for any questions

We will also be 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. [2] Being honest and trustworthy with our TAs and professors both in our procedure and data acquisition is also a requirement for us following ACM Code of Ethics section 1.3. [3] This also extends to our transparency with the public. We are essentially creating a type of life support for individuals using our walker, but 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 after the walker has successfully completed its functions of efficient and effective communication and emergency detection.

Finally, effective teamwork is paramount to the success of our Bluetooth Enabled eWalker, so we will ensure that we are not engaging in any discrimination of any type and treating all persons and parties fairly and with respect.[2]

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