MULTIDISCIPLINARY SENIOR DESIGN PROJECT
GE 497
COLLEGE OF ENGINEERING
VALPARAISO UNIVERSITY
VALPARAISO, INDIANA

Final Design Report
for
Vertigo-Imbalance Detector

Date: 12/4/2018

Prepared by:	**Balance of Forces**	
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Total Number of Pages: 23

Executive Summary

This document pertains all the the pertinent information for the imbalance detector created by the Balance of Forces Team. Using a threshold data system, the device will detect if an individual has lost their balance and send an alert. The system will be attached modularly to the user's chest, ankles, and shoe insoles with the intention of measuring the motion of the user's torso and the pressure beneath their feet. The entire system will communicate wirelessly and has a budget of $600.

Honor Code Statement

I have neither given or received, nor have I tolerated other's use of unauthorized aid.

Alex Helander	Nicholas Kwiecinzki
Isaac Lane	David Mackey
Noah Kraus	

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1 Introduction

1.1 Report and Project Summary

The team was tasked with designing a prototype for a balance detection system that will alert the when they approach a balance threshold that is determined after several tests and simulations.

2 Problem Definition

2.1 Problem Statement

The balance assistance device will detect a user's vertigo-induced imbalance during daily activities and provide sufficient indication to assist the user in regaining stability.

2.2 Project Objectives

1. Measure the general dynamics of the user's body during daily activities
2. Detect conditions where user approaches a balance threshold
3. Provide notification when the user approaches a state of imbalance
4. Be nonintrusive and lightweight on the user's body
5. Be safe and easy to operate
6. Sustain operation effectively throughout a typical day

2.3 Problem Background

Parkinson's Disease is a neurodegenerative disorder that affects over 7 million people worldwide. Symptoms include tremors, rigidity, and imbalance. Our customer,a retired pastor named Joe Schlawin, has been diagnosed with Parkinson's and experiences imbalance while standing in place. Mr. Schlawin cannot sense himself losing balance and is prone to falling. The purpose of this project is develop a device that tracks the acceleration and angle of his center of gravity with inertial measurement units (IMU) and uses a pressure mapping system to detect if he is shifting his weight. After tests and calibrations we will determine the behavior of the center of gravity before he falls and then the device with alert Joe that he is losing his balance.

3 System Overview

3.1 Vertigo-Imbalance Detector

3.1.1 General Functionality

This device will be individually calibrated for the user and will be attached under their clothing to avoid entanglement and reduce intrusiveness of our device. The device will collect the required balance measurements and while the user is standing still, it will determine whether they are stable or if they are starting to fall by comparing the collected data to the calibration boundaries. If a potential fall is detected, the device will produce an audio alert to notify the user to correct balance immediately and inform those around the user to assist the user.

3.2 Critical Subsystem Roles

3.2.1 Data Acquisition

The data acquisition subsystem is where data measurements will occur including the collection of pressure, acceleration, and angle of balance measurements using resistive force sensors and inertial motion units that utilize accelerometers and gyroscopes.

3.2.2 Data Analysis

The Data Analysis System, through the use of a microcontroller and detection software, uses the data collected from the sensors to conclude that there is a high probability for a fall to occur. This detection will only occur while the user is standing still. Several fall simulations will be conducted to determine sensor thresholds, that if exceeded the user will fall. Once the user is approaching these programed thresholds, the device will then send a signal to the notification system in order to indicate that the user' is in a state of imbalance.

3.2.3 Node Connections

The nodes will be connected to each other through radio frequency transceivers. This will allow the sensors to communicate with the main node microcontroller and transmit the collected data.

There also will be connections between each node and the users. The physical connection between the main node and the user will be a chest harness and protective 3D printed plastic case with the node centered over the user's sternum. The two secondary nodes will be attached to the user's ankles with an ankle strap and protective 3D printed plastic case. These nodes will also include the pressure sensors embedded in each insole.

3.2.4 Notification System

When a calculated threshold is reached by the sensors and detected with the programming with the microcontrollers, a signal will be sent to sound a piezoelectric buzzer. This will be loud enough for the user to alerted that they are losing their balance.
Also, at each node there will be an LED. The LED turning on will notify the customer that they need to recharge the battery system.

3.2.5 Power Supply

Each node will be powered by a rechargeable 3.7 V battery. There also will be USB ports located on each node that the user to easily recharge the battery.

3.3 Solution Benefits and Impacts

This solution will allow our customer, Joe Schlawin, to counteract his parkinson's symptoms. He can wear our device under his clothes on a daily basis and it will inform him of any potential falls if he starts to sway. This will positively impact his life by allowing Joe to concentrate on other topics rather than constantly worrying about losing his balance and not realizing it until it is too late to regain balance. This specific solution will also be unobtrusive and will be accurate enough to predict any potential falls.

4 Alternative Solutions Analysis Review

4.1 Adafruit Feather M4 Express

The Adafruit Feather M4 Express is the updated alternative solution analysis component for the microcontrollers. The Arduino Zero was the microcontroller chosen in the first analysis outlined in Table 1. It scored closely with the Raspberry PI Zero W but the difference was its function. The Arduino was meant for a more hardware level control of memory, where as the Raspberry PI acts as a microcomputer. This means that the Arduino would be better for processing analog signals from the pressure sensors that will be implemented in the design and it can serve as a voltage regulator for the various components. Also, the Arduino community is larger. It has a greater support system and there are many sample codes for sensors like the IMU that will be implemented, saving time in the programming aspect of the design.

The Arduino at the time most closely matched our goals. The Feather M4 Express ended up chosen over the Arduino Zero because its cost, clock speed, and amount of storage. The Feather M4 Express is $23 compared to the Arduino Zero's price of $43 and also has a clock speed of 120 MHz compared to the Zero's 48 MHz. The Feather also has 2 MB of on-board storage which is useful for data logging. Based on the fact that that the Feather M4 Express has all of the same functions as the Arduino Zero but with some being better applicable features. In future alternative solutions analysis, in order to prevent changes, all possible components need to be considered before making final decisions.

Table 1 : Alternative Solution Analysis of Arduino Zero, Raspberry Pi Zero, and BeagleBone Black

Evaluation Criteria	Required Criteria	Alternative 1: Arduino Zero	Yes/No	Alternative 2: Raspberry PI Zero W	Yes/No	Alternative 3: BeagleBone Black	Yes/No
R1	Less than 5V Power Supply	3.3 V Power Supply	Yes	3.3 V Power Supply	Yes	3.3 V Power Supply	Yes
R2	Input/Output Pins	1, 10-bit DAC/6, 12-bit ADC	Yes	40 GPIO	Yes	6 pin UART	Yes
R3	Programmable	On-board Memory is programmable	Yes	On-board Memory is programmable	Yes	On-board Memory is programmable	Yes
R4	Peripherals	USB ports are on the board	Yes	USB ports are on the board and Bluetooth	Yes	USB ports are on the board and Ethernet	Yes

	Desired Criteria	Value	Information	Score	Weighted Score	Information	Score	Weighted Score	Information	Score	Weighted Score
D1	Small Form Factor	6	68 mm x 53 mm	9	54	65 mm x 30 mm	10	60	86 mm x 53 mm	6	36
D2	Native Sensor Availability	7	Extensive Sensor Marketplace	10	70	Extensive Sensor Marketplace	9	63	No Sensor Marketplace	3	21
D3	High Clock Speed	5	48 MHz	8	40	1 GHz	9	45	1 GHz	9	45
D4	Memory Storage	1	256 KB	4	4	SD Card Slot	10	10	2 GB	8	8
D5	Price	2	$42.90	7	14	$10.00	9	18	$62.00	4	8
D6	Light Weight	4	12 gr.	8	32	9 gr.	9	36	39.6 gr	5	20
D7	Hardware Level Control	8	Easy access	10	80	Limited access	7	56	Limited access	6	48
D8	RAM	3	32 KB	8	24	512 MB	9	27	512 MB	10	30
	WEIGHTED TOTAL:				318			315			216

5 Virtual Prototype

5.1 Node Breakdown

The main node contains the Adafruit Feather M4 Express microcontroller with the team's detection software, a LSM9DS0 inertial motion unit, piezoelectric buzzer, a LED light, a NRF24L01 wireless transceiver, and a Lithium Ion Polymer Battery - 3.7v 2500mAh battery all surrounded by a 3D printed plastic protective case.

The secondary nodes contain a Adafruit Feather M0 microcontroller, a LSM9DS0 inertial motion unit, a NRF24L01 wireless transceiver, and a Lithium Ion Polymer Battery - 3.7v 1200mAh battery all surrounded by a 3D printed plastic protective case. This node also include 4 embedded piezoresistive FlexiForce sensors inside of each shoe insole with wires traveling up the side of the shoe to the microcontroller in the case.

When the pressure sensors are engaged equally on the foot, it is determined that the user is standing. Then the pressure on the feet to monitored if the wight gets shifted forward and the IMU will be monitored the user's trunk to verify its position and speed. If the user leans too much forward or if the weight on the feet is shifted significantly to the front, the alert will sound. The specific number for these thresholds will be determined up further testing.

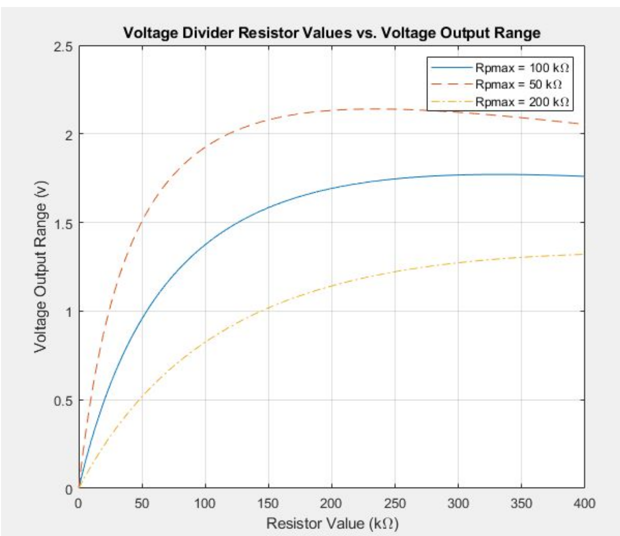
5.2 Critical Subassemblies

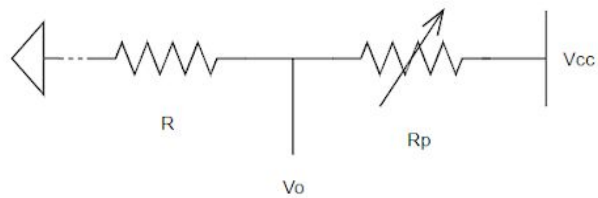
5.2.1 Data Acquisitions

5.2.1.1 Pressure Map

The pressure map will be created by the team by embedding two FlexiForce Pressure sensors inside of a shoe insole. These insoes will be placed inside the user's shoes and will detect the magnitude and positions of the user's weight as it shifts between sensors. In order to properly measure the output voltage of the FlexiForce sensor a voltage divider must be created.

Figure 1 shows required voltage divider as well as the equation that defines the output voltage range. After a series of tests we will determine the minimum amount of resistance we can attain from the force sensor and use that to determine our voltage divider resistor.





$$\Delta V_o = \frac{V_{cc} R (R_{pmin} - R_{pmax})}{(R + R_{pmax})(R + R_{pmin})}$$

Figure 1: Voltage Divider Analysis

5.2.1.2 Center of Gravity Tracking

The user's center of gravity will be positionally determined by securely attaching the system's main node to the user's sternum as shown in Figure 2. This main node will contain a LSM9DS0 inertial motion unit which contains an accelerometer and gyroscope. This will collect acceleration and angle data at the location of the user's center of gravity as shown in Figure .

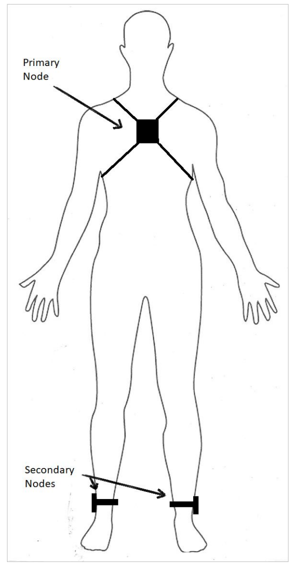


Figure 2: System placement on user including sternum harness

5.2.1.3 Design Constraints

The pressure sensors must have a high enough maximum range to withstand the entire weight of the user without becoming oversaturated. The location of the main node to track the user's center of gravity was selected by using a conservative assumption. The user's actual location of their center of gravity will be about 53% of their height which should line up around their waist. The sternum was selected as the location for the main node because it is higher than the estimated center of gravity and is a safer location to place delicate sensors without getting in the way of the user's daily activities.

5.2.2 Data Analysis

5.2.2.1 Microcontroller

The data analysis will be performed by the primary microcontroller in the primary node. This microcontroller will receive multiple streams of data from the secondary nodes as well as the local IMU. This will be performed at a synced rate in order to maximize data intake. Data will be temporarily stored for analysis as the detection software analysis and predicts trends. This local data storage will be managed by the primary microcontroller.

5.2.2.2 Detection Software

The software will determine whether the user is falling or will fall by comparing the collected information to precalibrated data. Using the user's height, shoe size, and average shoulder width, the position of center of gravity and the dimensions of the base of support can be found. These general dimensions can be used to determine an optimal balance angle along with a critical balance angle. Figure 2 shows the coefficients of balance developed by other balance researchers. K1 is a function of the height of the user's center of gravity (Y_cg) and half of their shoe size (R). K2 is a function of the same R value and the distance between their feet which is can be approximated to be the same distance as the average shoulder width (X_cg). K3 is a function of the X_cg and Y_cg. These three coefficients can be calculated and calibrated into our system for the test user using the developed graphs in Figure 3. The graphs show the dependence of the critical and optimal angles of a standing model relative to the previously discussed coefficients. These will be the boundary conditions that the software will compare the current data against to determine if a fall is occuring. The software will also recall the acceleration, measured by the IMU, of previous data points, stored in the microcontroller, to determine the possibility of the continued motion carrying the user's center of gravity past the base of support boundaries.

$$\alpha'_{cr} = \arcsin\left(\frac{1}{k_1} \cdot (1 + k_2)\right) \tag{4}$$

$$\alpha''_{cr} = \arcsin\left(\frac{1}{k_1} \cdot (1 - k_2)\right) \tag{5}$$

$$\alpha_{opt} = \arcsin(k_3) \tag{6}$$

Where k_1, k_2 and k_3 are coefficients determined by the following equations:

$$k_1 = \frac{|O'M|}{|OA|} = \frac{|O'M_1|}{|OA|} = \frac{|O'M_2|}{|OA|} = \frac{|O'M_3|}{|OA|} = \frac{Y_{CG}}{R} = \frac{l}{R} \tag{7}$$

$$k_2 = \frac{X_{CG}}{|OA|} = \frac{X_{CG}}{R} \tag{8}$$

$$k_3 = \frac{X_{CG}}{Y_{CG}} = \frac{X_{CG}}{l} = \frac{k_2}{k_1} \tag{9}$$

Figure 3: Derivation of Balance Coefficients

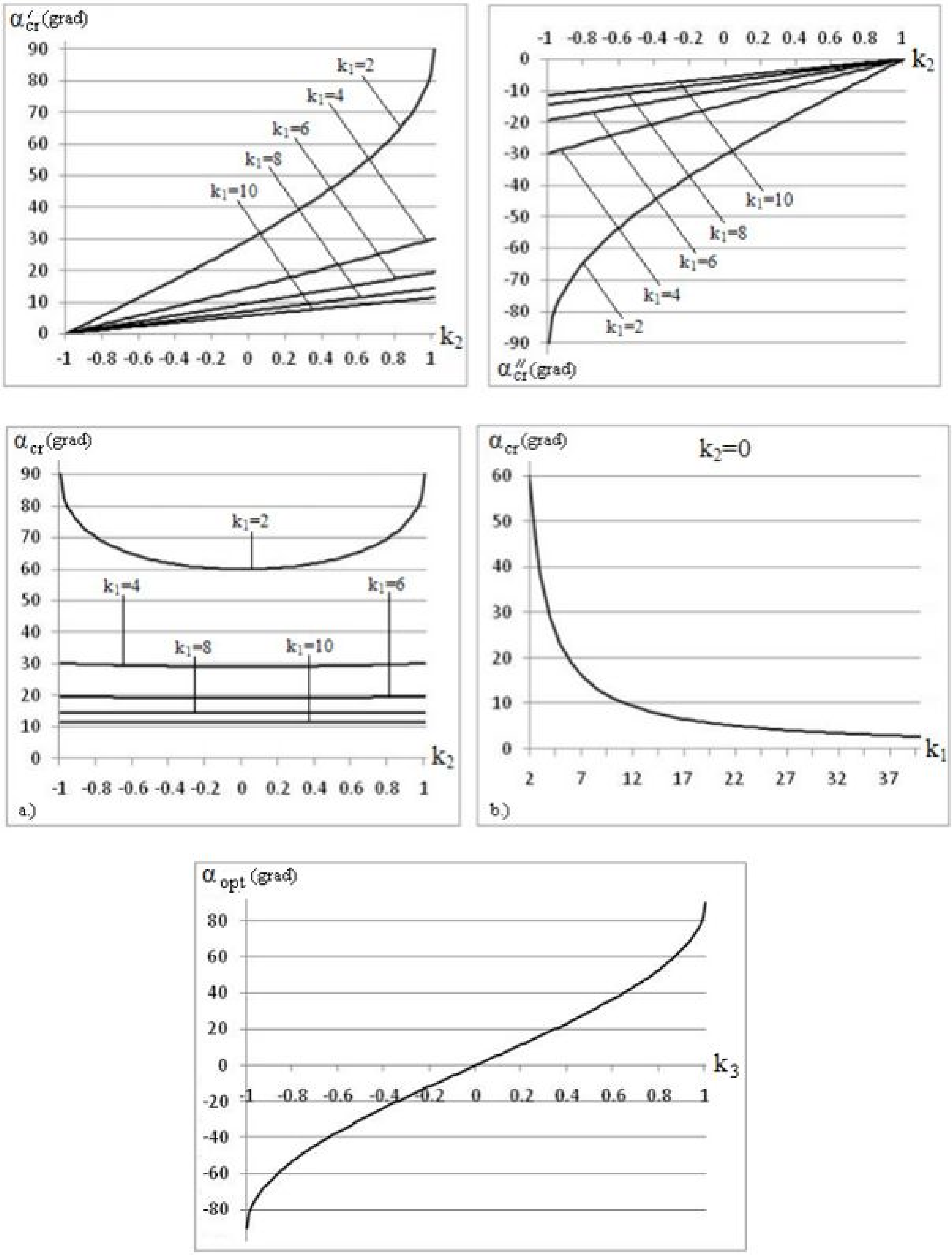


Figure 4: Dependence of αop, αcr, αcr’, and αcr’’ on k1,k2, and k3

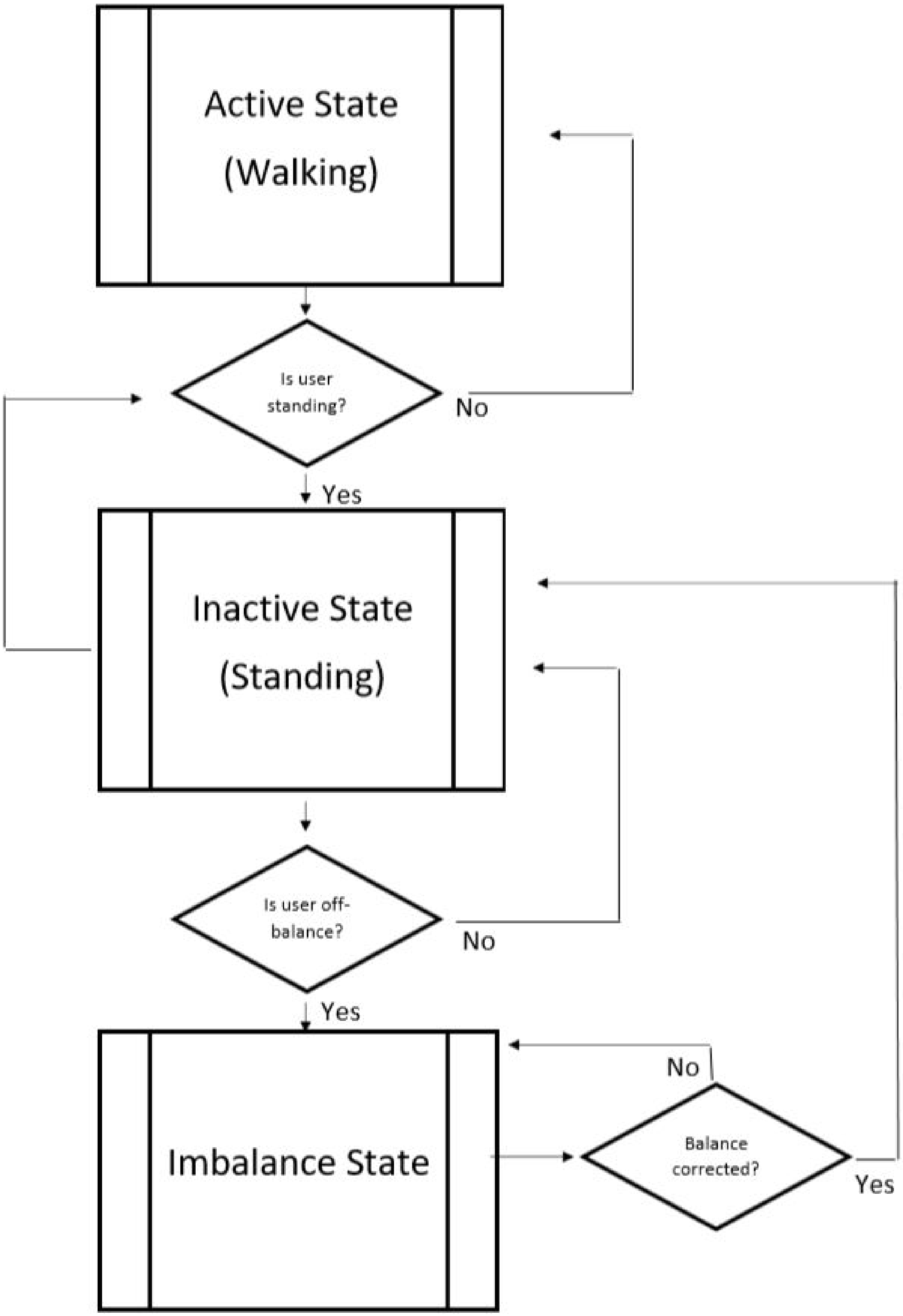


Figure 5: System Operation Flowchart

5.2.2.3 Design Constraints

The microcontroller will perform routine calibration of the IMUs and the pressure sensors to insure maximum accuracy. The detection software will be able to analyze all of the data and sample out what is necessary and what is extraneous in order to make a decision about if the notification will sound. An example of this would be the software will be able to see that the pressure data does not line up will falling characteristics so even if the acceleration indicates rapid changes due to inapplicable situations.

5.2.3 Node Connections

5.2.3.1 Wireless Communication

The different microcontrollers will communicate with each other via radio transmission from the NRF24L01 transceivers. The device is capable of sending and receiving data at the max rate of 2MB/s. The device allows sufficient speed and enables all the devices to communicate on a common frequency.

5.2.3.2 Physical Apparatus

The device will be composed of three nodes. The main node will be held stationary over the user's sternum by a chest harness and contained within a protective 3D printed plastic case that features a snap fit design. Figures 6 shows the closed main node case which has dimensions of 80x65x22 mm. Figure 7 and 8 visualize the bottom and top portions of the main node protective case with illustrated components. The two secondary nodes will be connected to the user through ankle straps and protective cases as well. The secondary nodes will also include the pressure sensor embedded shoe insoles. The circuit diagrams for both the main and secondary nodes are found in Figure 9 and 10.

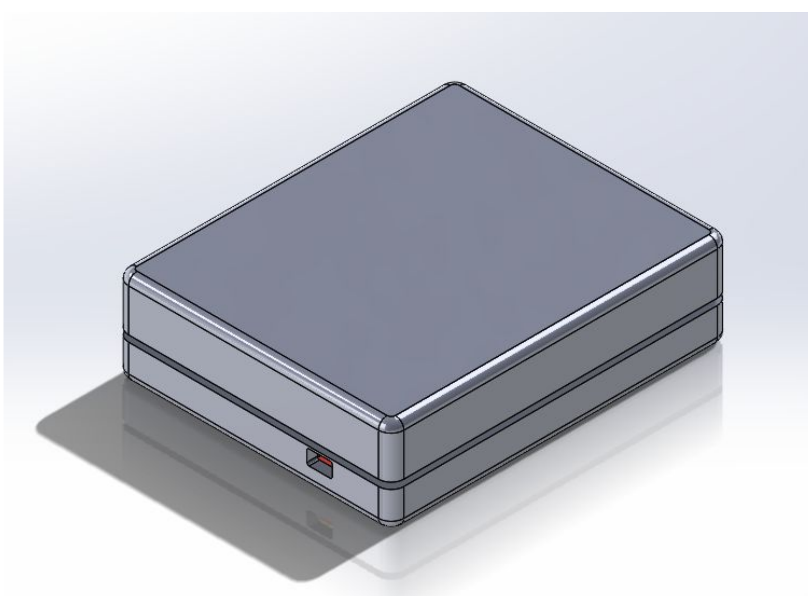


Figure 6: Main Node Case (Closed)

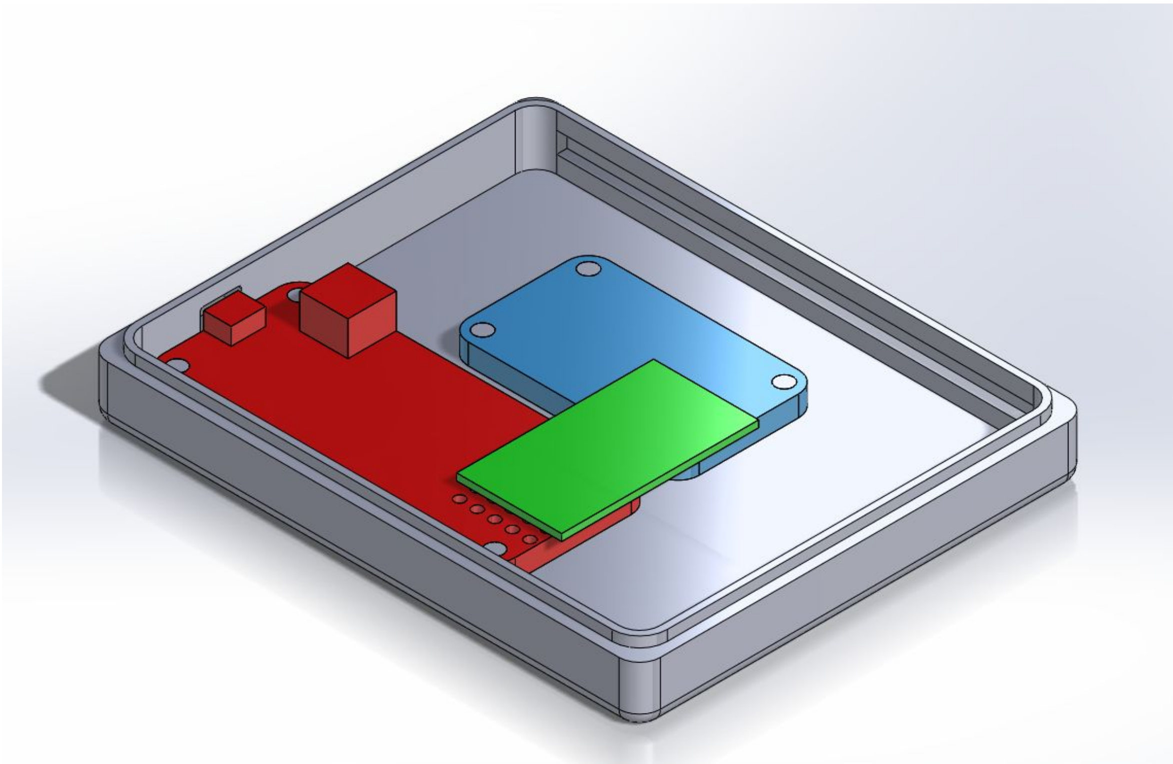


Figure 7: Bottom Main Node Case Model

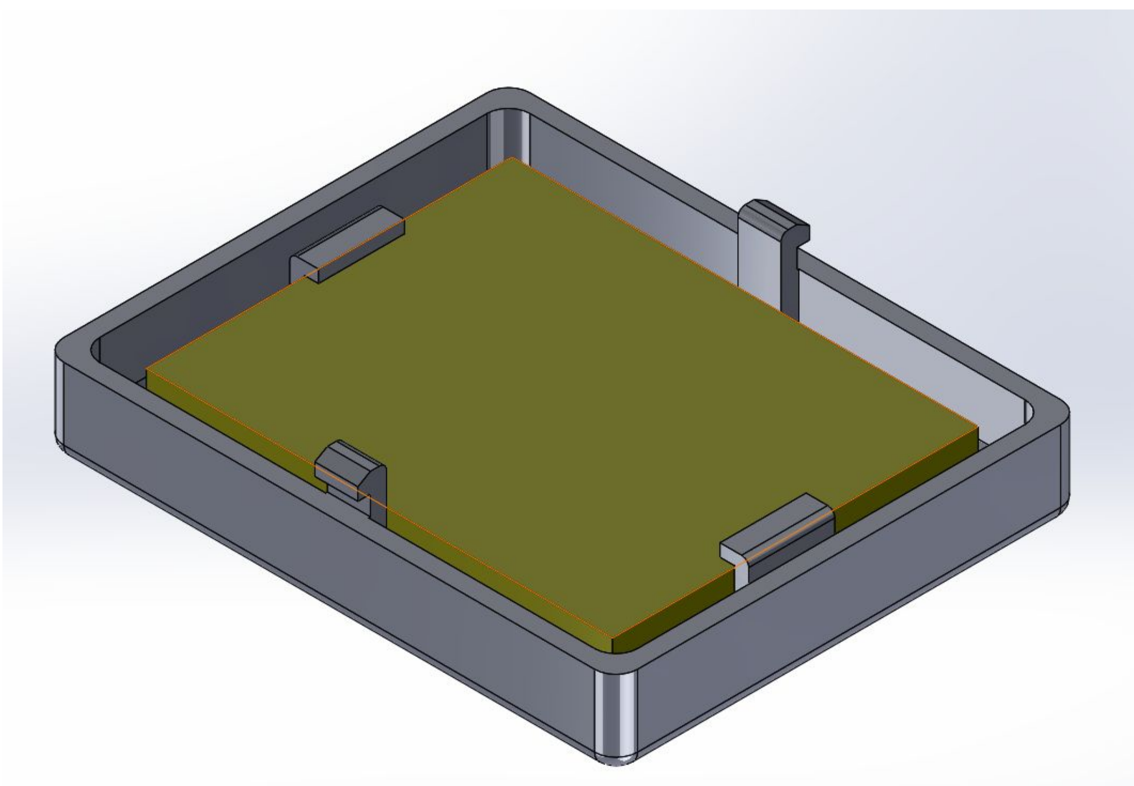


Figure 8: Top Main Node Case Model

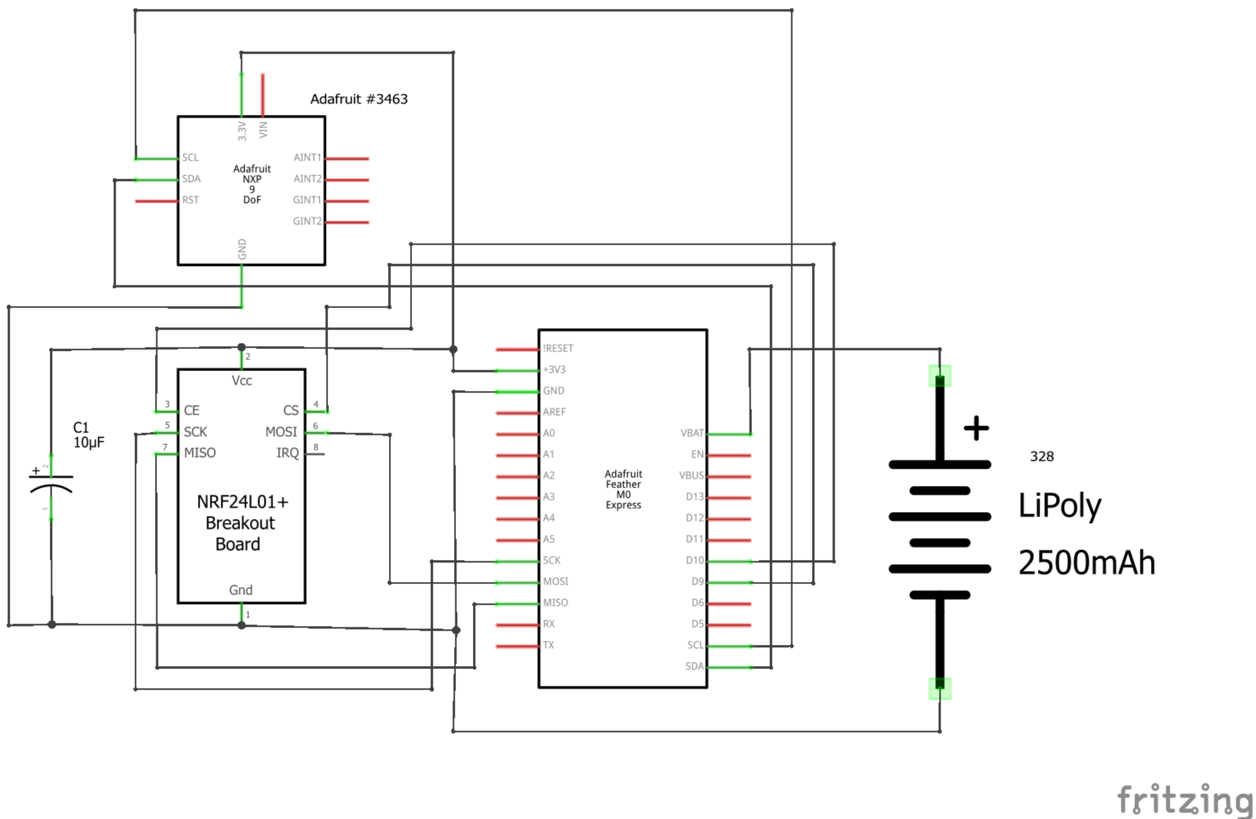


Figure 9: Main Node Circuit Diagram

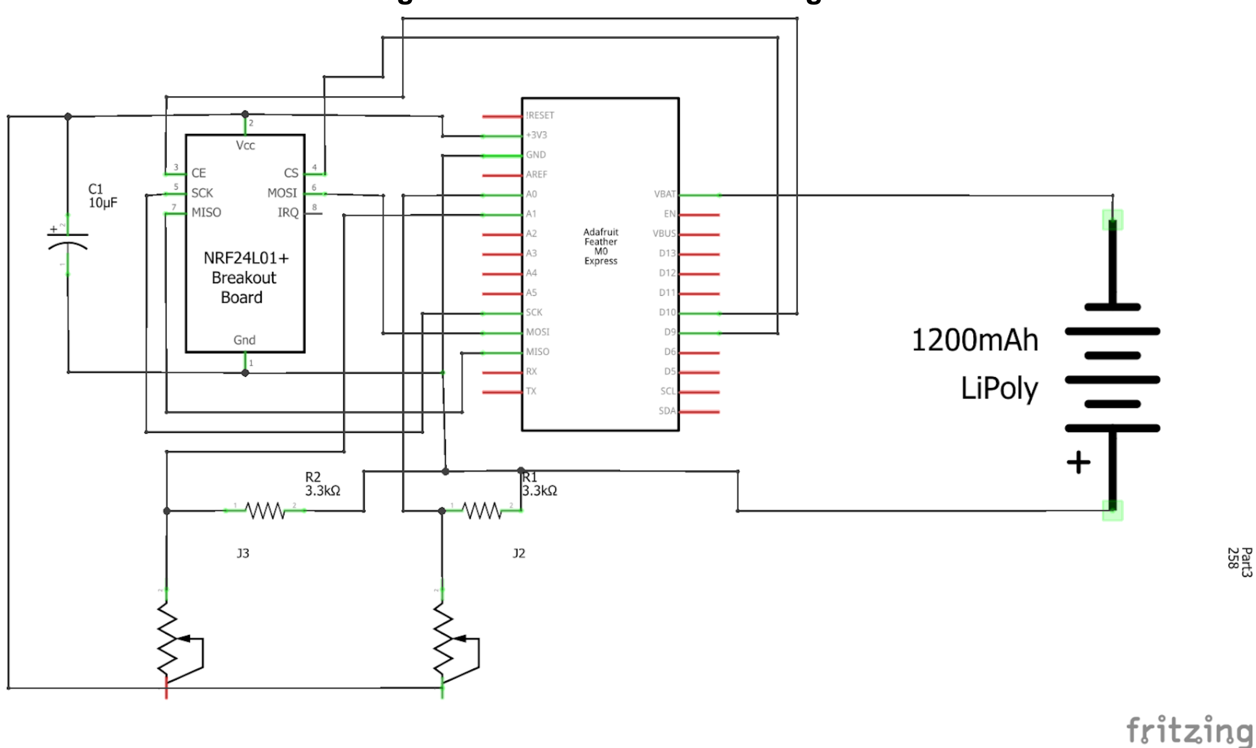


Figure 10: Secondary Node Circuit Diagram

5.2.3.3 Design Constraints

Node connections should not cause entanglement or discomfort to the user, and should communicate with minimal delay or interference.

5.2.4 Notification System

5.2.4.1 Audio System

The audio system will be a piezoelectric buzzer that will generate a noise loud enough for the user to alerted that they are using their balance. This buzzer will sound when a signal is sent from the main microcontroller.

5.2.4.2 Visual System

There will be LEDs on each node, attached to the battery system, that turn on when the battery reaches a threshold to be charged.

5.2.4.3 Design Constraints

The piezoelectric buzzer needs to be loud enough for the user to hear it. The buzzer will need to last a sufficient life cycle. The LEDs are clearly labeled for the user. The LEDs also need to be durable and have a lifetime that lasts at least a year.

5.2.5 Power Supply

5.2.5.1 Main Node

The main node will require a 2500 mAh 3.7 V Lithium Ion Polymer battery with a rechargeable system embedded on the microcontroller board.

5.2.5.2 Secondary Node

The secondary node will employ a 1200 mAh 3.7 V Lithium Ion Polymer with a rechargeable system embedded on the microcontroller board as well.

5.2.5.3 Design Constraints

We will need to have housings that protect the batteries and ensure that they do not overheat and cause damage to the system.

6 Hazard Analysis

6.1 Failure Mode 1

The first critical hazard is the notification system not being effective. The main potential cause of this hazard is the system predicts falling incorrectly. In order to reduce potential hazard a rigid testing cycle should be used to calibrate protocols to insure reliability. Also a calibration test should be done to start system operation

6.2 Failure Mode 2

The second critical hazard is the physical apparatus harms the user. The main potential cause of this hazard is the system burns or shocks the user through exposed wiring. In order to reduce the potential hazard, wires are designed for long term use with durable protection to prevent wear. Also placing all wires in a sleeve that would be in direct contact with the body will reduce the chances of the hazard occurring.

Table 2: Design Failure Mode and Effects Analysis

Balance of Forces

DESIGN FAILURE MODE AND EFFECTS ANALYSIS (DFMEA)

ITEM/SYSTEM NAME :	Vetigo Imbalance Detector	PROCESS RESPONSIBILITY :	Senior Design
ASSEMBLY P/N :	-	PREPARED BY :	A. Helander
YEAR/MODEL:	-		
CORE TEAM :	Alex H., Nick K., Isaac L., David M., Noah K,.		
KEY (PPAP) DATE :	-		
ORIGINAL FMEA DATE :	10/25/2018		
REVISION FMEA DATE(S) :	-		

ITEM/ FUNCTION	POTENTIAL FAILURE MODE	POTENTIAL EFFECTS OF FAILURE	SEV	POTENTIAL CAUSES OF FAILURE	OCCUR	EXISTING CONDITIONS: CURRENT CONTROLS: PREVENTION	DETECTION	DETEC	R.P.N.	RECOMMENDED ACTIONS	RESPONSIBILITY AND TARGET COMPLETION DATE	ACTION RESULTS: ACTIONS TAKEN	SEV	OCCUR	DETEC	R.P.N.
Main Power Source	Supply failure	Full system is not operational	8	Water damage.	2	Closed casing	Physical Observation.	4	64				8	2	4	64
				No charge	6	Provided charging station	Charged indicator light	3	**144**	Recommend having battery charged at night when not in use.			8	6	3	144
				Deffective battery	1	Ordering from a reliable source	Testing battery upon installation	1	8				8	1	1	8
				Puncture of battery casing	4	Hard protective case	Visual inspection	4	**128**	Make sure that battery casing is composed of materials that are very			8	4	4	128
Microcontroller Board	Loss of power Unresponsive	Alertion system is not operational User falls unaware of balance	8	Voltage Regulator has been blown	2	Power source monitoring	Behavorial Observation	3	48				8	2	3	48
				Defective components	1	Verify that the microcontroller board is an authentic part	Behavorial Observation	5	40				8	1	5	40
				Cracked or bent PCB board	5	Stress resistant casing Correct microcontoller placement	Physical inspection of case	2	80				8	5	2	80
Notification System	Notification not effective	User falls unaware of personal balance	9	Notification too slow	5	Fast microcontroller for detection	Behavioral observation that user falls	1	45				9	5	1	45
				Notification too weak	3	Ability to increase volume/brightness during calibration	Behavioral observation that user falls	1	27				9	3	1	27
				System determines fall prediction incorrectly	6	Calibration test to start system operation	Behavioral observation that user falls or false notification	7	**378**	Use a rigid testing cycle for the calibaration protocols to insure reliability			9	6	7	378

7 Requirements Verification

[See Appendix A for a complete list of design requirements.]

7.1 Balance Measurement Requirements

7.1.1 Calibration will be executed at request of the user, relying on IMU sensor readings for determining standard stance and requiring a user input for height and weight value.

7.1.2 The angular velocity of this pitch is monitored through constant analysis of ankle and chest IMU sensor readings.

7.1.3 Force exerted by the user's feet will be monitored through constant analysis of the readings measured by the force resistive sensors inside the user's shoe insoles.

7.1.4 Position and acceleration of the user's center of gravity will be monitored through a constant comprehensive analysis of all sensor data.

7.2 Imbalance Detection Requirements

7.2.1 Device programming will make constant equality comparisons between sensor readings and predefined thresholds for acceleration, velocity, and frame of balance. These thresholds will be determined upon calibration of device and will be unique to individual users.

7.3 Indication Requirements

7.3.1 The audio alert will be provided by a piezo buzzer.

7.3.2 Visual alert will be provided by a red LED.

7.3.3 Components of device have been selected to ensure that maximization of time between a triggered alert and potential fall is solely dependent on timeliness of device programming to make an accurate prediction. Timing concerns related to clock speed, node communication, and data sampling have been accounted for in device design.

7.4 Size And Weight Requirements

7.4.1 Current device design puts the maximum node weight at an estimated 500 grams and overall device weight less than 4 kilograms.

7.4.2 Current device design puts maximum node size at an estimated 300 cubic centimeters.

7.4.3 Implementation of wireless communication between nodes puts maximum wire length at an estimated 10 centimeters.

7.5 Safety Requirements

7.5.1 All the subsystems are capable of not heating to over 20 degrees Celsius.

7.5.2 All the components are silent in operation and shall make noise far less than 70 db within a 1 meter radius

7.6 Endurance Requirements

7.6.1 The rechargeable battery selected should provide sufficient kWh of power.

7.6.2 The charging port uses a usb mini that can be plugged into a standard wall outlet.

7.6.3 With the casing, everything will be able to withstand 300 kPA to all sides of the device.

7.6.4 With the harness, the device shall shift less than 5 centimeters during moderate jumping and movement.

8 Facilities and Equipment

The team only requires facilities and equipment covered by Gellersen Engineering and Mathematics Center and the Donald Fites Innovation Center.

9 Personnel Qualifications

9.1 Team Member Experience and Skills

9.1.1 Alex Helander

Alex Helander has experience analyzing signals from sensors, working with microcontrollers, designing PCBs, working with power systems and electronics, and with electronic testing materials.

9.2 Noah Kraus

Noah Kraus has experience working with microcontrollers and electric systems and will be able to design, operate, and test all electronic components.

9.3 Nicholas Kwiecinski

Nicholas Kwiecinski has experience with microcontrollers and integrated circuits and will be able to integrate digital systems into the project.

9.4 Isaac Lane

Isaac Lane has experience doing research in the human movement research lab and will have access to the lab and some of the sensors.

9.5 David Mackey

David Mackey has taken both ME253 (Intro to Manufacturing Lab) and ME457 (Adv. Manufacturing) and will be able to use equipment in both manufacturing labs to create product structures out of metals or plastics

10 Budget

Our total budget is $600. This budget is divided into the following 6 categories with their respective percentage of the total budget: Sensors, 36.7%, Casing 20.0%, Microcontrollers 15.0%, Harness 12.5%, Power System 11.7%, and Wireless Systems 4.2%. For a more detailed analysis refer to Table 3 and Figure 11 below.

Table 3: Proposed Budget

Section	Major Component	Description	Price	Quantity	Component Total	Section Total	Budgeted	Remaining Budget
Power System	Lithium Ion Polymer Battery - 3.7v 2500mAh	Rechargable Battery	$14.95	1	$14.95	$64.85	$70.00	7.36%
	Lithium Ion Polymer Battery - 3.7v 1200mAh	Replacable Battery	$9.95	2	$19.90			
	Miscellaneous	Extra batteries for testing, Charrging cord	-	-	$30			
Sensors	MPX5999D	Piezoresistive Pressure Sensor	$16.34	6	$98.04	$152.89	$220.00	30.50%
	Adafruit Precision NXP 9-DOF Breakout Board - FXOS8700 + FXAS21002	IMU	$14.95	3	$44.85			
	Miscellaneous	Connection Wires	-	-	$10			
Microcontroller	Adafruit Feather M4 Express - Featuring ATSAMD51 - ATSAMD51 Cortex M4	Main Node Microcontroller and Data Analysis System	$22.95	1	$22.95	$62.85	$90.00	30.17%
	Adafruit Feather M0 Basic Proto - ATSAMD21 Cortex M0	Secondary Node Microcontroller	$19.95	2	$39.90			
Casing	Main Node Casing	3D Printed Plastic Structure	$5.00	1	$5.00	$70.00	$120.00	41.67%
	Secondary Node Casing	3D Printed Plastic Structure	$5.00	1	$5.00			
	Shoe Insoles	Inserts for Embedded Pressure Sensors	$30.00	1	$30.00			
	Miscellaneous	Additional Manufacturing Costs	-	-	$30			
Harness	Chest Harness	Elastic	$20.00	1	$20.00	$50.00	$75.00	33.33%
	Ankle Strap	Elastic	$15.00	2	$30.00			
Wireless System	NRF24L01	(10 Pk) Wireless RF Transciever Chips	$11.98	1	$11.98	$11.98	$25.00	52.08%
					Total	$412.57	$600.00	

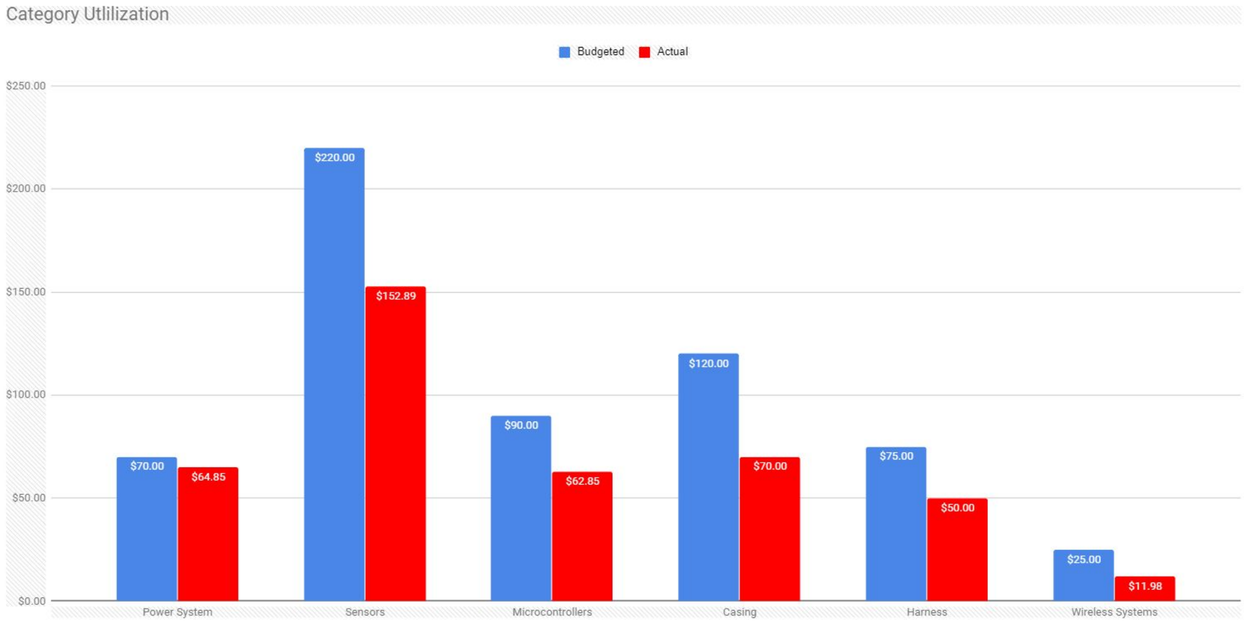


Figure 11: Actual parts cost compared to categorical allocation

11 Conclusion

Joe Schlawin cannot sense himself losing balance due to Parkinson's diseases. We will use IMUs and pressure sensors and processors to track the user's center of gravity and and alert them of an impending fall due to imbalance. After analyzing the datasheets of different sensors and microcontrollers we found affordable devices that will create a final design that fulfill our requirements. Though the purpose of this device is to protect the user, there are many hazards that we need to consider while designing and manufacturing the project. We will cover the minimal wires, use protective casing, and user friendly apparatuses to ensure the well being of the user. Using our teams collective knowledge and experience we will make a safe device that will alert a user if they are losing their balance in a prompt manner within a budget of $600.

12 Parts List

Table 4: Parts List

Lithium Ion Polymer Battery - 3.7v 2500mAh
Lithium Ion Polymer Battery - 3.7v 1200mAh
Charging Cord
FlexiForce Pressure Sensor - 100lbs
Adafruit Precision NXP 9-DOF Breakout Board - FXOS8700 + FXAS21002
Connection Wires
Adafruit Feather M4 Express - Featuring ATSAMD51 - ATSAMD51 Cortex M4
Adafruit Feather M0 Basic Proto - ATSAMD21 Cortex M0
Main Node Casing
Secondary Node Casing
Shoe Insoles
NRF24L01 Transceivers
Chest Harness
Ankle Strap

13 References

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14 APPENDICES

Appendix A --

System Design Requirements

Problem Definition

The balance assistance device will detect a user's vertigo-induced imbalance during daily activities and provide sufficient indication to assist the user in regaining stability.

Objectives

In order to achieve success the system shall

1. Measure the general dynamics of the user's body during daily activities
2. Detect conditions where user approaches a balance threshold
3. Provide notification when the user approaches a state of imbalance
4. Be nonintrusive and lightweight on the user's body
5. Be safe and easy to operate
6. Sustain operation effectively throughout a typical day

System Requirements

1. BALANCE MEASUREMENT REQUIREMENTS

1.1 The device will be able to run a calibration program to determine the user's optimal balance point accounting for the individual's standard stance, weight height, and shoe size.

1.2 The device will monitor the angular velocity of pitch in the user's center of gravity within 10 degrees per 50 milliseconds.

1.3 The device will monitor the force exerted by the user's feet up to 225 kilogram within 10 kilogram.

1.4 The device will monitor the acceleration of the user's center of gravity about the center of their feet position within 10 degrees per second-squared.

2. IMBALANCE DETECTION REQUIREMENTS

2.1 The device's detection software shall determine when the acceleration of the optimal balance point approaches a calibrated acceleration threshold.

2.2 The device's detection software shall determine when the angular velocity of the optimal balance point approach a calibrated angular velocity threshold.

2.3 The device's detection software shall detect in real-time if optimal balance point approaches the limits of the user's frame of balance by comparing the real time angle to the critical angle of tipping.

3. INDICATION REQUIREMENTS

3.1 The device shall provide a 50 dB to 70 dB audio alert to the user when an imbalance is detected.

3.2 The device will shall produce a 10 lumen to 80 lumen visual alert to the user when a battery is drained and needs to be charged.

3.3 The device will trigger indicated alerts 500 milliseconds prior to the user's calibrated center of mass exceeding the limits of the user's frame of balance.

4. SIZE AND WEIGHT REQUIREMENTS

4.1 Each of node of the device will each weigh less than 2 kilograms when attached to the user.

4.2 The total weight of the entire system will weigh less than 6 kilogram.

4.3 The device components will each be less than 0.2 cubic meters in volume.

4.4 The wires between device components shall be less than 50 cm.

5. SAFETY REQUIREMENTS

5.1 The device shall operate at a temperature less than 20 degrees Celsius.

5.2 In a normal operating state, the device shall generate less than 70 dB noise within a 1 meter radius.

6. ENDURANCE REQUIREMENTS

6.1 The device shall operate at full capacity for more than 6 hours after a full battery charge.

6.2 The device shall be able to charge through a standard USB port.

6.3 The device or each node of the device will be able to withstand a pressure of 300 kPa to all sides of the device.

6.4 Each node of the device shall shift less than 5 centimeters on the user during daily physical motions.