PPE and Worker Tracking System

Team 31 — Dennis Wong and Joydeep Ganguly
ECE 445 Project Proposal — Spring 2017
TA: John Capozzo

1 Introduction

1.1 Objective

Workplace safety is a serious concern. Without proper protection, workers are a risk. A risk to themselves, their coworkers and their employers. However, a common issue in moderate risk workplaces is a lack of personal protective equipment. Workers do not wear this equipment for a variety of reasons, and this leads to liability for employers.

A solution to this problem would be to create a line of wearable devices to gather worker position relative to area that require protective equipment, working conditions, and worker health data to enable better management decisions in warehouse or factory environments. The concrete product that we would like to make is: a wearable vest with embedded sensors to track worker position and working conditions, including but not limited to temperature, luminosity, humidity, and the presence of safety equipment in designated “unsafe” areas, e.g. “hard hat zones”.

To track if the proper equipment is worn at a certain time a system we will create a wearable device that can integrate itself into a glove or helmet to detect if it is in use. Each of these wearable devices will have a memory unit, a processing unit, a small battery, and a wifi chip for wireless communication to the server. Effective data gathering on worker safety habits also has the potential to significantly reduce company liability, and lead to safer workplace practices.

1.2 Objective

According to the National Safety Council, a worker injury can cost the company up to $30,000 in damages and an OSHA fine can cause a company up to $7000 for minor infractions, including not wearing personal protection equipment (PPE) or operating machinery in an unsafe way[1].

Regardless of how serious the infringement or injury is, the company’s reputation for having safe working conditions will deteriorate with each infraction. Common solutions to this problem is by using signs that say things along the line of “no ppe, no work, no pay”. The problem with this is that in a bigger warehouse, managers can not keep tabs on everyone so sensing workplace conditions on each worker allows management to make intelligent on the fly decisions about the amount of break time, and adapt working conditions.

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[1] http://www.safetyservicescompany.com/industry-category/construction/top-10-osha-fines-for-small-companies/

1.3 High Level Requirements

- The system must be able to recognize when a worker is within 1 meter of a station that requires PPE
- The wearables must cost less than $500 per unit
- The wearable must be able to report a full 8 hours of working conditions data from the sensors embedded into the PPE.

2 Design

2.1 High Level System Block Diagram

As shown by figure one below, the PPE tracking project has four main components which consists of three wearable devices and a bluetooth tracking module. Each separate module has a power component which is a lithium ion battery that is built with protection to ensure the battery stays between 2.8V and 4.2V. The power component also includes a power circuit to charge the battery using usb and a buck-boost converter so that the battery can continue to power the wearable even when it is below 3.3V. The microcontroller will be a P1 WiFi enabled microcontroller which serves as a preprocessing unit to collect sensor data before sending to a web server where analysis occurs before sending to a UI.

Block diagrams for each module below will be broken down further for a more detailed description in Figures two and three.

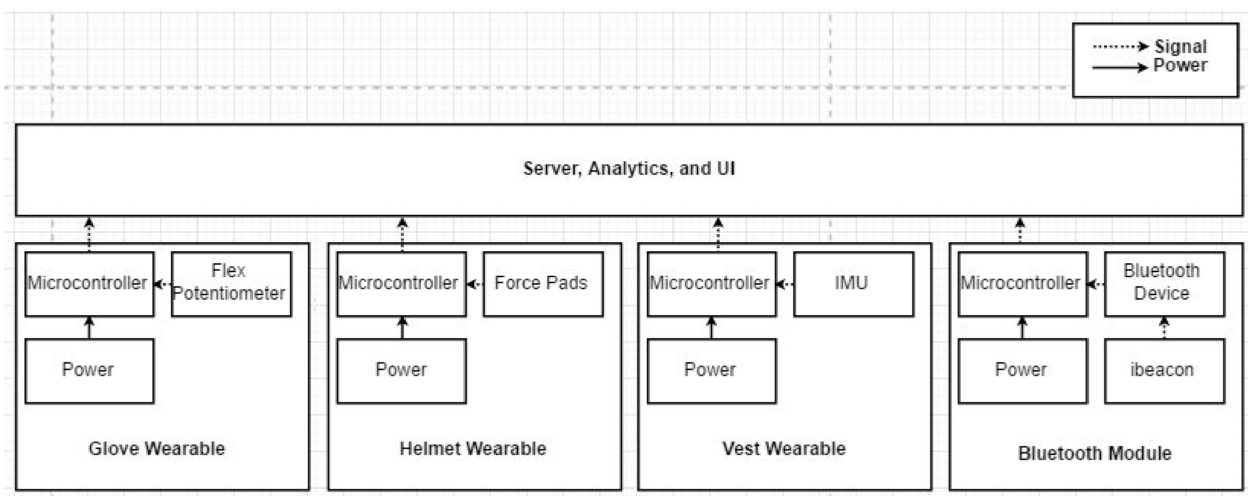


Figure 1: High Level System Block Diagram

2.1.2 Glove Wearable Summary

The purpose of this wearable is to collect data from the flex sensors to detect whether someone is wearing the glove after information has been sent to a server and has been analyzed.

There will be flex sensors sewn into the fingers of the gloves and directly connected to the MCU. The housing for the MCU and power circuit will also be sewn in between the layers of the gloves on the back of the hand. Dimensions and electrical properties for the PCB, battery, and flex sensors will be provided later in section two.

The flex sensor readings are analog and will be read by the microcontroller and stored into the on-chip flash memory. The readings will then be sent out to the server periodically with a timestamp to the server to determine when the person was wearing the glove. The reason packets of data will be sent out rather than continuously sending data is to save battery life by utilizing the on chip memory and sending once every five minutes. This would increase efficiency of the battery immensely.

The flex sensors have a straight resistance of 10kOhms (+- 30%), with a bend resistance at minimum of double this. Each flex sensor is 4.5 inches in length, and cannot be bent past 90 degrees without permanently damaging the sensor. To avoid these problems, the flex sensors will be place such that one end is on the middle of the hand, while the other end stops before the second knuckle. The resistance increases linearly with the bend degree, up to a maximum of around 90 kOhms. During initial testing, the resistance was measured (by using a voltage splitting circuit) while the sensor sat idle, and while the sensor was manipulated, similar to a human figure. It was found that the resistance readings of the sensor had significantly higher standard deviations than the idle circuit, and this will be the basis for human-detection from gloves.

To power this wearable, a 3.7V 2000mah lithium ion battery will be used. The microcontroller and flex sensors can be powered with 3.3 volts with a maximum current draw of just over 600ma when it is initially starting up with the WiFi chip. On average, the P1 Microcontroller will draw between 80-100ma of current at 3.3V with the Wifi on and current draw from the flex sensors are negligible. A more detailed power calculation will come in the battery section.

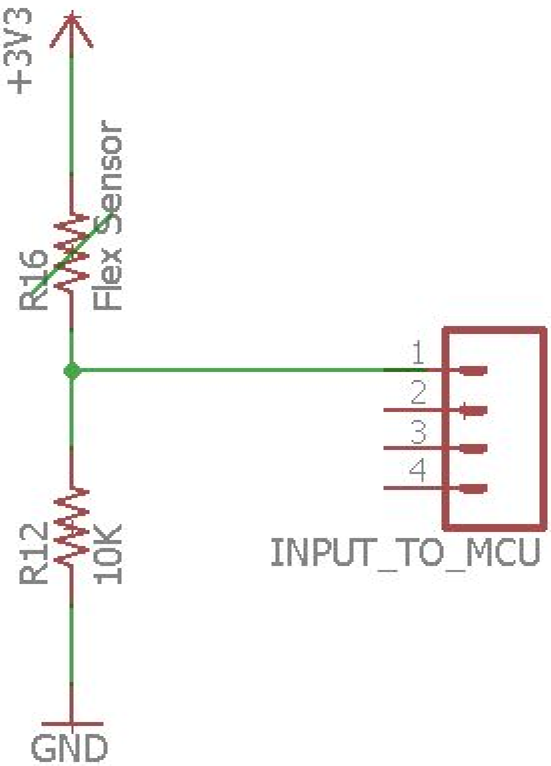
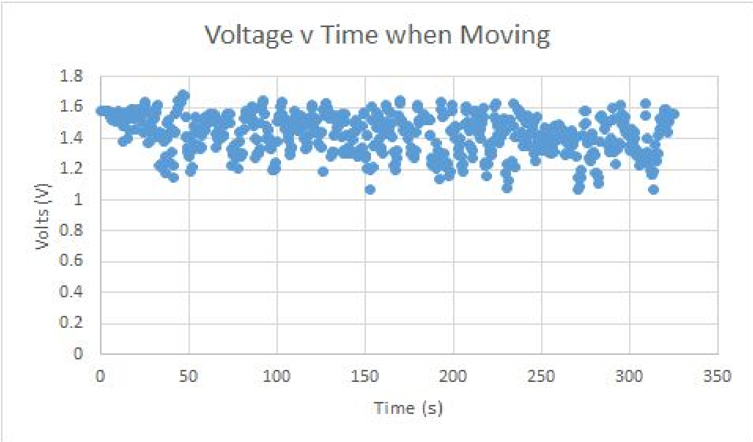
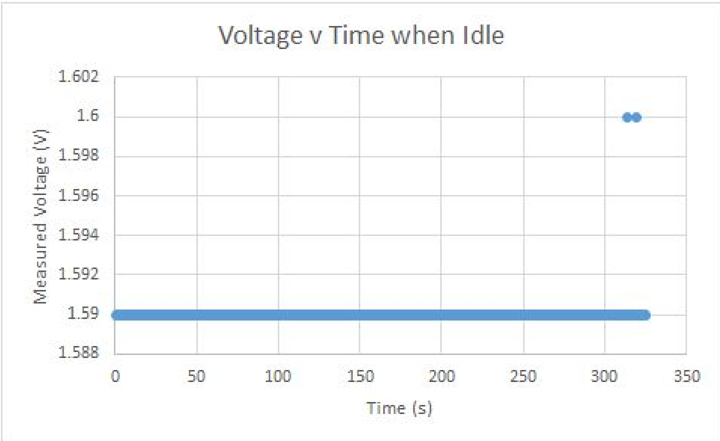


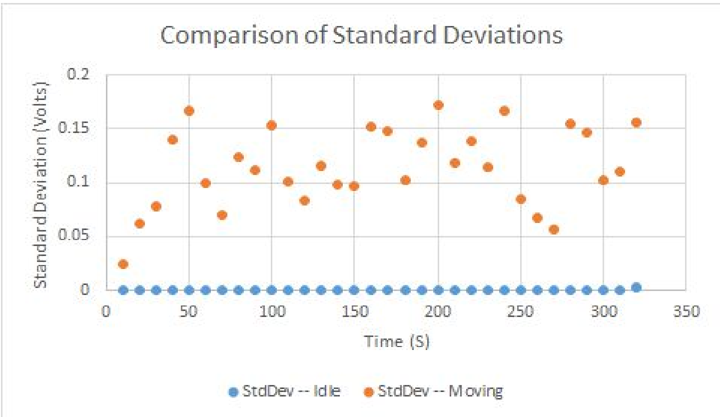
Figure 2: The configuration for the glove wearable sensor block. The other sensor packages are similarly set up, with different resistance values

Supporting Details

The following graphs are a comparison of the raw resistance data, and the standard deviation of this data. It shows that when in use, the flex sensor is very accurate and has a highly variable resistance, and when idle, it does not. This suggests that a time-sliced standard deviation is a good way to detect if a human is wearing a glove.







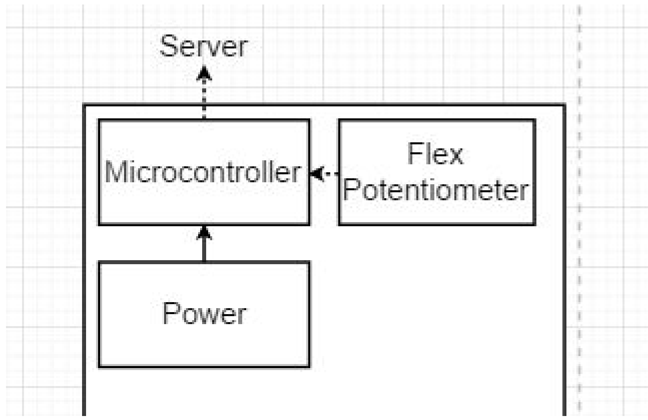


Figure 3: Glove Wearable Block Diagram

2.1.3 Helmet Wearable Description

The purpose of this wearable is to collect data from the force sensitive pads to detect whether someone is wearing the helmet after data has been sent to a server.

Similar to how the glove detection circuit works, there will be 5 force sensitive pads on the inside of the helmet which will be calibrated to each worker when the helmet is first used. The reason for this is because every worker will fit into their helmet differently so it would be important to get this benchmark reading. The most important sensor will the on the top of the head to measure the weight of the helmet when it is in use.

Each of the force sensitive resistors will be placed inside the helmet with the sensitive region facing outward so when the head presses on it a reading will be taken. The force sensors have a property where the resistance decreases as more force is applied on it. Since the average hard hat can weigh anywhere from three-fifths of a pound to a pound, an assumption that the hard hat weighs an average of four-fifths of a pound will be made. Figure 4 below shows the relationship between weight on the sensor and its resistance.

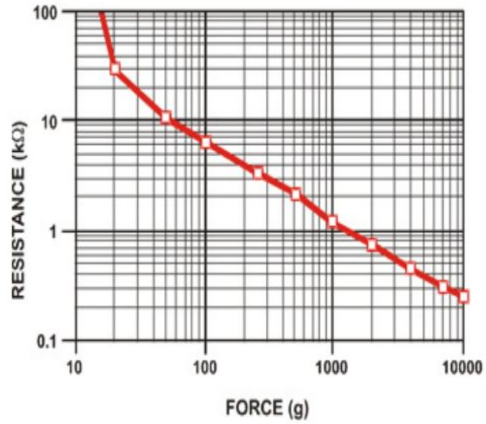


Figure 4: Resistance vs. Force Applied Graph

To choose an optimal resistance value for the force sensor, we look at 362 grams (approximately.8 pounds) and we can see that it intersects with the curve at 3 kilo-ohm which is where the analog read will measure half the maximum input values from analog read.

Noise is a concern when using this sensor. However, since the analog read capabilities of the P1 MCU can range from 0 to 4095 at 3.3V, there is enough information to distinguish whether someone is wearing the helmet.

To power this wearable, the same method used to power the glove will be used because of its small size and ability to recharge via usb while having enough power to keep the system running for over an entire workday.

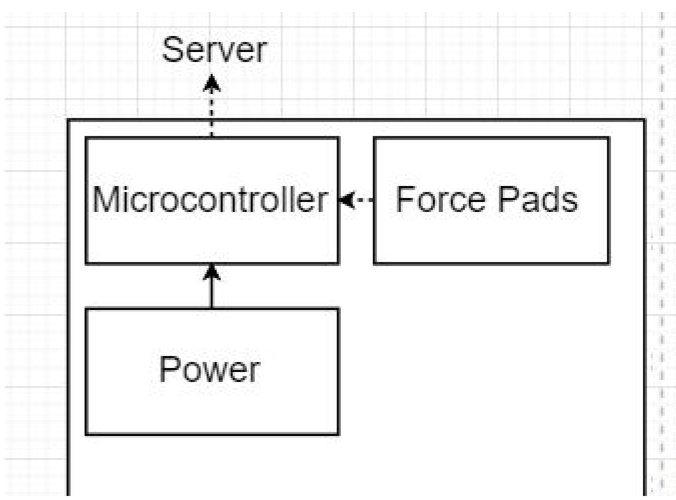
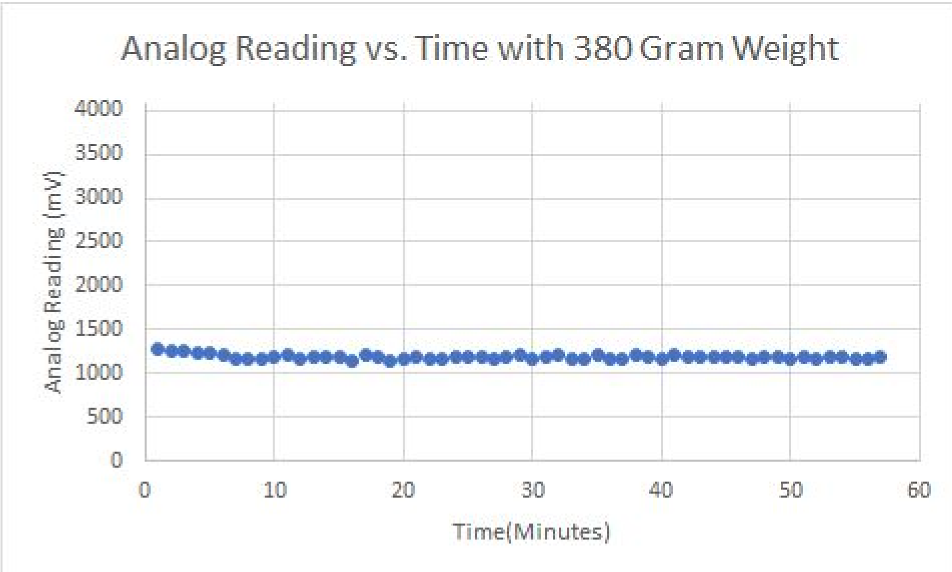
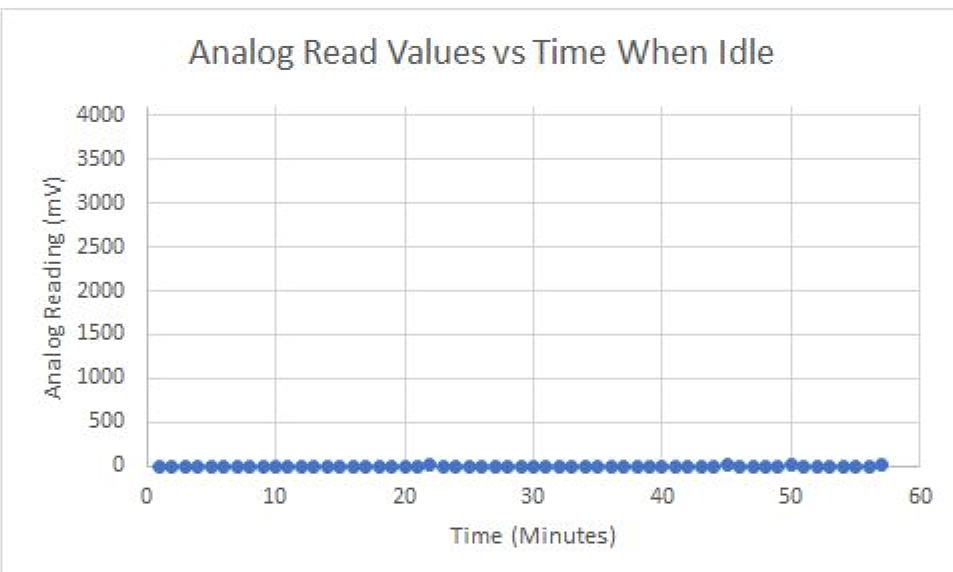


Figure 4: Helmet Wearable

Supporting Details





2.1.3 Vest Wearable Description

The purpose of the vest wearable would be to gather data on the working conditions of each worker. The data that will be gathered will be I but not limited to luminosity, temperature, and acceleration.

The same scheme where the microcontroller takes inputs from each sensor, stores it, and send it out periodically will be used as a means to conserve battery life. The purpose of the temperature and luminosity sensor would to to provide worker data on working conditions and the IMU will be used to detect impact that could lead to serious injury.

In terms of how portable and ergonomic this wearable will be, there will be a small case attached to the front of the shirt where a pocket would normally be. The casing will have a small hole for the luminosity and temperature sensor. The accelerometer and all other devices will be inside the casing.

To power the wearable, a 2000mah 3.7V lithium ion battery will be used with the same power electronic circuit to both provide charging capabilities and to keep the output at a constant 3.3V.

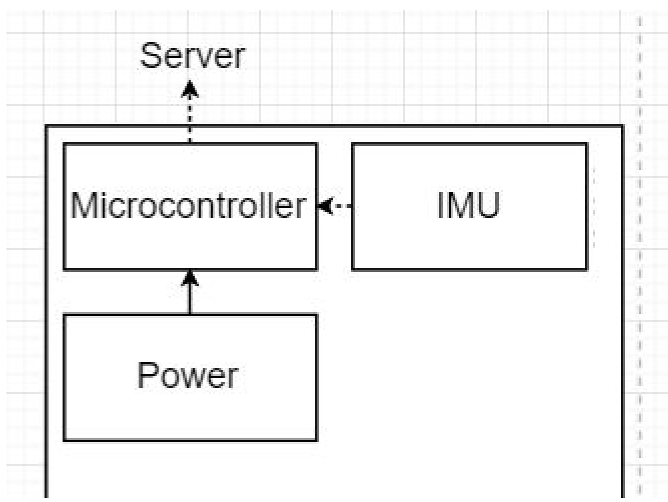


Figure 5: Vest Wearable

2.1.3 Bluetooth Module Description

To detect whether a worker is in proximity of a station that requires protective equipment, a microcontroller and a bluetooth low energy module will be at the station. The bluetooth module will use iBeacon technology to determine the proximity to various areas demarcated within buildings. iBeacon is built on low energy bluetooth that can run for up to three months on a single coin battery, meaning that once beacons are placed, there will be minimal replacement; the cells also have a range of up to 100m which is sufficient for this project’s needs (iBeacon). With the correct low power settings, this system will draw .18mA at 2 to 3.7V. A single coin-cell battery has around 670mAH, at 3.5V, so this will last almost 3000 hours, or 3 months.

iBeacon Technology (iBeacon)

iBeacons periodically broadcast a message with four parts: a unique identifier, a major and minor -- for hierarchical ordering, and the power the message was broadcast with. The receiver can calculate the power the message was received with, and based on attenuation, estimate the distance to the beacon (iBeacon).

Figure 6: From iBeacon.com demonstrating basic iBeacon Functionality

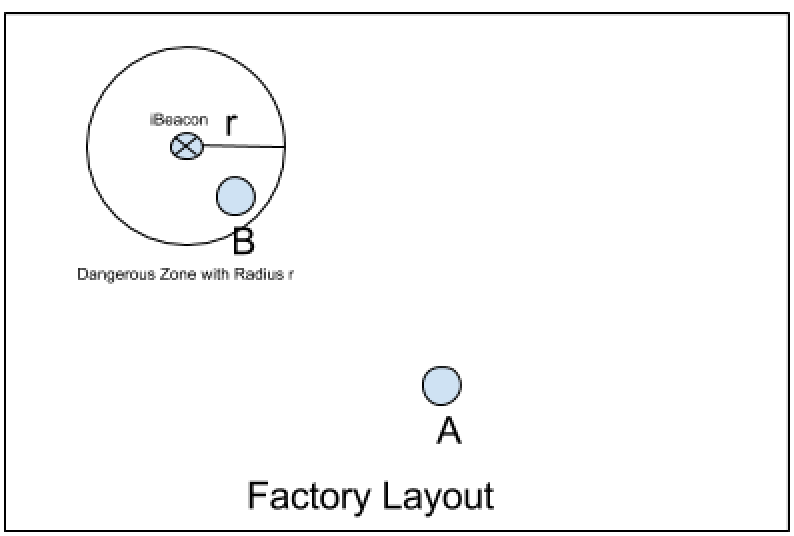


Figure 7: If workers A and B have iBeacon receivers, A will not be alerted, but B will.

With a configuration like the one shown above, worker B's iBeacon reader will alert the MCU on the worker's vest that he is in a dangerous area. This will trigger a message to the data-collection server as well as an indicator to the worker that he or she needs to wear protective equipment. iBeacons will be placed near the center of "dangerous" areas, such as areas of heavy machinery, and as iBeacon receivers can calculate RSSI, which follows an inverse square law, and thus calculate distance.

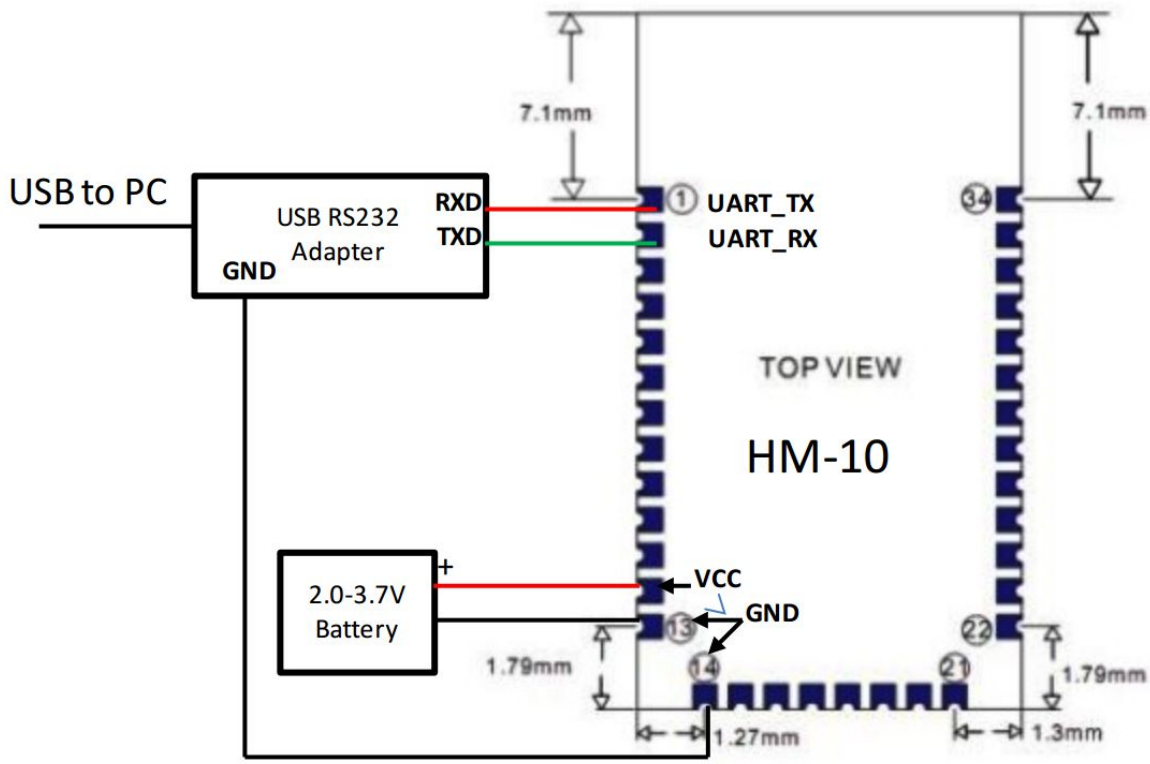


Figure 8: The wiring diagram for programming the HM-10 devices as either beacons or receivers. Source: HM-10 as iBeacon

2.2 Power

2.2.1 Lithium Ion battery

To power each wearable, a 3.7 volt 2000mah lithium ion battery from sparkfun will be used. The reason for picking this battery is because it is lightweight, thin, and 2000mah is more than enough to power the wearables for at least 8 hours. The physical dimensions of this battery is .25 inches by 2.1 inches by 2.4 inches and can be slid into a construction glove with minimal distraction to the user (Sparkfun).

Figure 9: Size comparison of the battery to a quarter

Additionally, this battery comes with build in protection to ensure that battery stays in between 2.8-4.2 volts (Sparkfun). Other options we looked into are cylindrical versions of the same battery but those do not come with overcharge protection are are more bulky. 12V batteries were also an option for the vest wearable but would not work because of the bulkiness and how heavy it is. Mobility is very important for the workers and the smaller the battery the less distracting the device will be.

2.2.2 Power analysis

Device	Operating Mode	Number of Devices	Current Draw	Usage Percent When Not Charging
P1 Microcontroller	Active mode, WiFi off	1	40mA	95%
P1 Microcontroller	Active mode, WiFi on	1	80mA	5%
Flex Sensor	Active mode	3 (only for Glove)	Decreases depending on amount of bend. Can range from .33mA to .033mA	100%
Force Sensitive Resistors	Active mode	5 (only for helmet)	Changes depending on amount of force Can range from .33mA to 3.3mA	100%
Buck-Boost Converter	Active mode	1(all wearables)	80uA quiescent current	When not charging
USB Charger IC	Active mode	1 (all wearables)	N/A	While charging
Accelerometer	Active mode	1 (only vest wearable)	1uA	100%
Temperature Sensor	Active mode	1 (only vest wearable)	50uA	100%
Luminosity Sensor	Active Mode	1 (only vest wearable)	.24mA	100%
HM-10 Bluetooth	Active Mode	1 (only vest	8.5mA	100%

		wearable)		

Given each part's current draw we can calculate the theoretical battery life of the 3.7V lithium polymer rated for 2000mah following this equation:

$$Estimated\ battery\ life\ = \frac{Battery's\ capacity\ in\ amp-hours}{Current\ draw\ of\ each\ \ device}$$

Glove Wearable:

$$42\ hours\ of\ battery\ life\ = \frac{2000mah}{40ma * .95 + .05ma * 80 + 3 * 1ma}$$

Helmet Wearable:

$$34\ hours\ of\ battery\ life\ = \frac{2000mah}{40ma * .95 + .05ma * 80 + 5 * 3.3ma}$$

Vest Wearable:

$$37\ hours\ of\ battery\ life\ = \frac{2000mah}{40ma * .95 + .05ma * 80 + 1ma + 1ua + 1ma + 8.5mA}$$

Our current pick for a lithium ion battery is rated for 2000mah hours at 3.7 volts. An option to make the wearable more ergonomic would be to minimize the size down to 1000mah which would roughly halve the expected battery life. A reason to stick with the 2000mah battery is in case the worker forgets to charge the wearable, the wearable can still function for another work day.

2.2.2 USB Charger

To provide charging capabilities to the battery the max1551 USB adapter integrated circuit will be used to output a constant 100mA of current to charge the battery. This chip is ideal for the wearable application because it can safely take between 3.7V-6V usb voltage range to a safe 4.2 volts and charge the battery at a safe current draw of less than .5C.

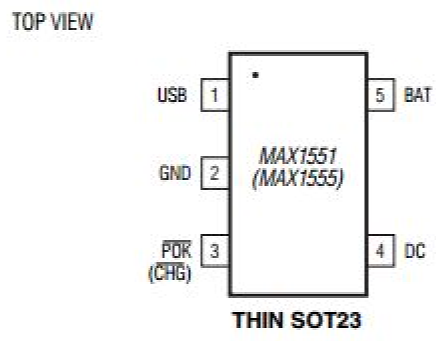


Figure 10: Pin mapping of the Max1551 IC

Figure 11: Picture of the IC

2.2.3 Buck-Boost Converter

Since the lithium ion battery has a voltage that decreases as it discharges, any voltage outside of the acceptable voltage range of 3 to 3.6 volts is useless. Any voltage above 3.6 volts could burn out the microcontroller and anything lower would just not power it. Additionally, the P1 microcontroller has a very large inrush current when first starting up. Using any chip not rated for such a high current draw could cause the chip to overheat. Because of these reasons, a chip that fits all these requirements is the TPS63000-Q1 high efficiency buck-boost converter which can handle over 2 amps of current draw.

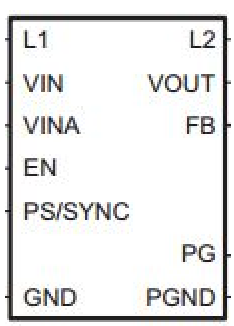


Figure 12:Pin mapping of the TI63001 IC

Figure 13: Picture of the IC

2.2.4 Power Circuit Schematic

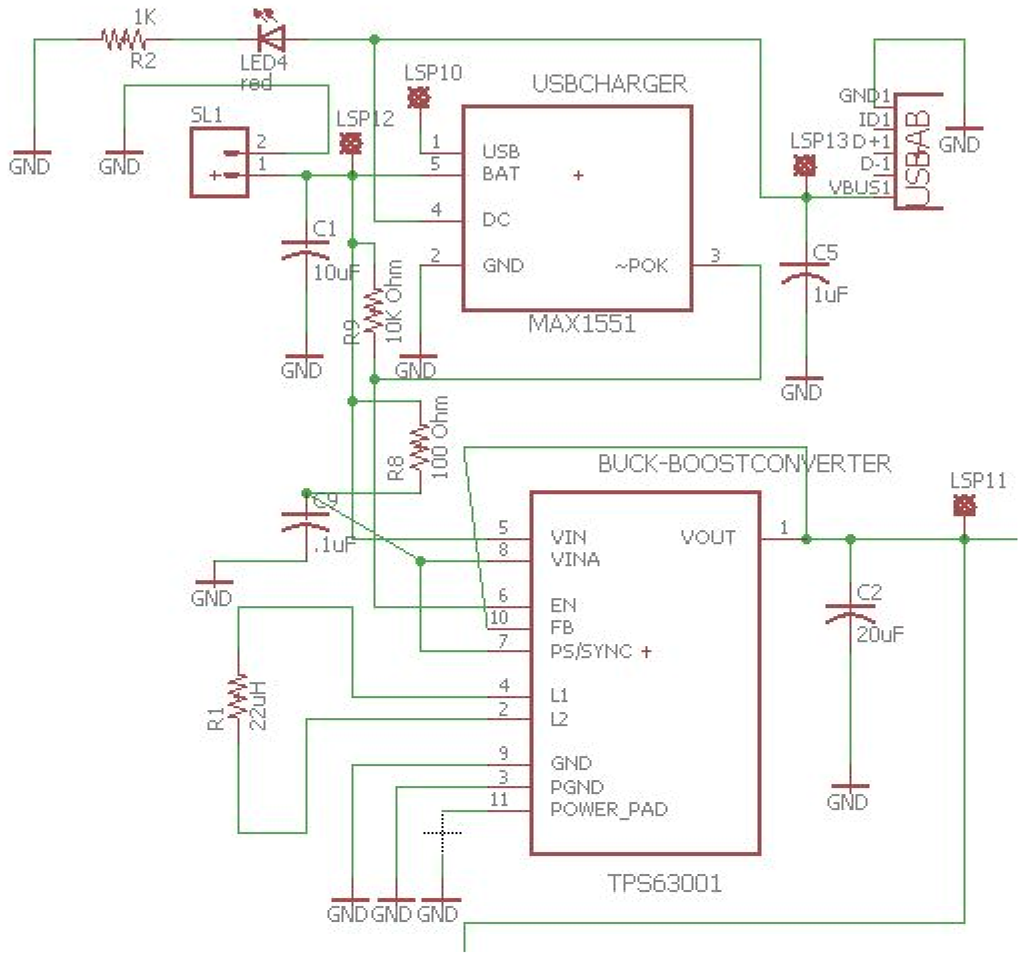


Figure 14: Power Circuit Schematic

2.2.5 Circuit Design

When designing the power circuit, the requirements were that voltages above 3.6 volts and below 3 volts were not useful to the operation of the microcontroller. To fix this, a buck-boost converter is needed since the lithium ion battery can range from 2.8-4.2 volts. Additionally, in the workplace the wearable needs to be able to fit onto the safety equipment with minimal distraction to the worker. This implies a smaller battery to power the wearable and having the ability to recharge it would be much cheaper than getting a new one once it dies.

The Max1551 IC was chosen for this because it can charge the battery at a safe 300ma at 4.2 volts, has an input to charge the battery via usb at 3.7 volts to 6 volts, and a power ok output pin that feeds into a logic rail to turn off the converter when charging the battery. The power ok pin pulls low when either charging source is present and since this is connected to the Enable pin, it will also pull low, turning off the converter. When no USB or DC power source is present, the power ok pin is an open circuit and the power from the battery will drive the enable pin high on the power converter and put it in active mode. The capacitor in parallel with the battery is a sufficiently large decoupling capacitor.

The buck-boost converter IC that is used in this circuit is the TPS63020-q1. The IC is rated to withstand up to three amps of current draw and deliver 3.3 volts with is within the required 3-3.6 volts to power the microcontroller. Another advantage to using this converter is that the output voltage can be reconfigured according to this equation which can be obtained by using a voltage divider and replacing the resistors at the output.

The 3.3 volt output will be used to power the microcontroller, bluetooth chip, and sensors. The microcontroller will have three status led’s to show the connectivity status and also buttons to enter different device modes.

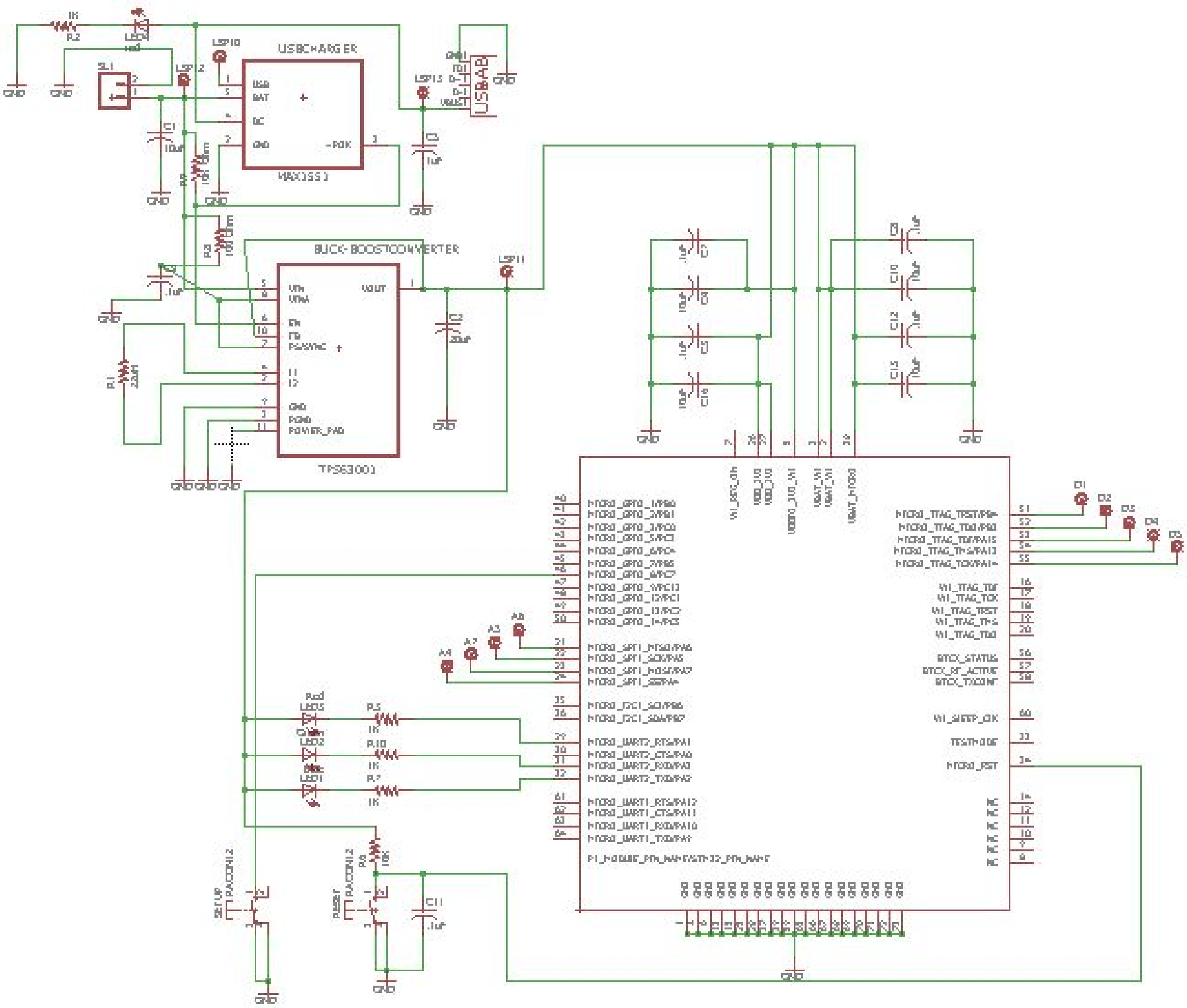


Figure 15: Power Circuit and MCU Schematic

3 Block Level Requirements and Verification

3.1 All Data Collection Blocks

Requirement	Verification
Microcontroller must store at least 1 hour of data	● Size: Declare an array of the read in datatypes of the appropriate size. Compare this to on-board memory ● Contents: Record the data from a sensor for an hour, stored on mcu and serially read. Compare the two lists, looking for any differences
Data should be corrupted less than 1% of the time when stored onto flash memory	Declare a fixed dataset with known values. Write this to the MCU's flash memory, then read into separate array, and look for differences. Repeat this procedure several hundred times, to ensure reliability
Sensors should be able to detect more than 10 degree changes in flex	The sensor will be bent in 10 degree increments from 0 to 90 degrees. The resistance, or voltage across the circuit will be measured for each point Each pair of adjacent values must be different by more than the error values, or experimentally determined noise
The worn data and not-worn data should be different enough that the algorithm is correct > 75% of the time	5 hours of data will be generated while wearing the glove and not wearing it. Timeslices of both sets will be interspersed, and when the classifying algorithm is run, it must be correct more than 75% of the time
Data should be transmitted every 5 minutes	Timestamps will be sent accompanying each message. Adjacent timestamps will be compared on the server to ensure that the data is sent every 5 minutes
Form Factor: The apparatus should not be distracting to the user	● Weight: All the components together should weigh less 100g ● Dimensions: The MCU, PCB and bluetooth module (if necessary) and battery should fit within a 3" x 3"

	square
Safety: The circuit must be waterproof, and cannot run at a temperature over 50C	• Waterproof: The circuit will be submerged in 6 inches of water with case, then tested for functionality • Temperature: The circuit will be allowed to run for a day, with the temperature logged, and checked against the maximum
Accuracy: The sensors must be accurate to within 5%	All sensors' inputs will be compared against the room's conditions, or a reference sensor, and must be accurate to within 5%

3.2 Localization

Requirement	Verification
The error in localization must be no more than 1 meter	Readings will be taken at fixed distances from an iBeacon. The calculate distance will be compared to the physical distance
Speed: Calculating whether a worker is in a "dangerous" location should take no more than 10 seconds	The receiver will receive a series of broadcasts, or more from beacon to beacon. It should register the presence of each new beacon within 10 seconds, as measured by an external stopwatch, or by comparing send timestamps on the iBeacon with received timestamps

3.3 Power System Requirements

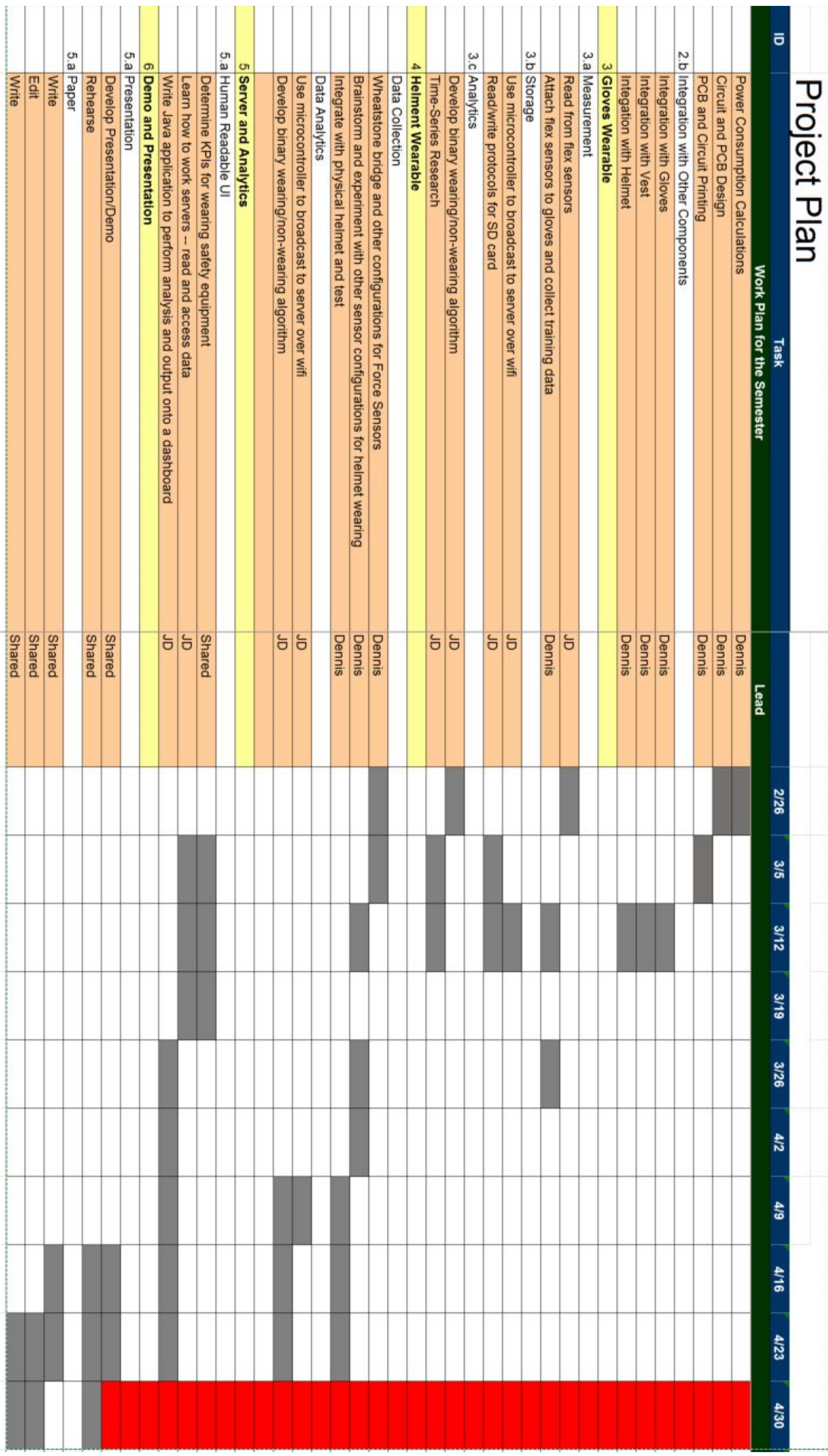
Requirement	Verification
The Lithium Ion battery will be able to power each wearable for a full 8 hours.	With each wearable functioning as intended which is WiFi on when sending data and WiFi off when collecting data the battery voltage will be measured after 8 hours to check if the voltage is above 2.8 volts. 2.8 volts is when the battery is fully discharged to a safe

	voltage and will no longer supply any power because of the built in safety circuit to prevent discharging the battery past 2.8V
The Lithium ion battery will not charge past the safe 4.2 volts.	To test this, the battery will be charged by the microusb and data points of the voltage of the battery will be taken. Once it reaches a constant value of roughly 4.2 volts, we will hold it there for a day, the battery will be discharged to about 3 volts the experiment will be repeated for a week to ensure that overcharging is not a problem.
The Buck-Boost Converter shall be able to convert input voltage ranges from 2.8 volt to 4.2 volts to a constant 3.3V with a 5% tolerance	Using an oscilloscope, the input voltage and output voltage will be plotted against each other to verify that a 3.3V output voltage is kept constant as the battery is discharged to 2.8 volts. A sample reading will be taken every .5 volts and plotted to show the efficiency as well.
The USB Charger shall be able to charge the lithium ion battery at or below .5C (1000ma)	When the lithium ion battery is fully discharged, we will use an oscilloscope to measure the current delivered to the battery while the IC is charging the battery through an usb input. The measured current will be less than 1000ma and the charging voltage will be less than 4.2volts.
The P1 Microcontroller will be powered efficiently when supplied an average 80ma current draw and 3.3volts	The P1 micro controller will have status led's which will flash a deep blue color to show that it is sufficiently powered.
The Buck-Boost Converter shall be able to safety withstand a maximum current draw of 1.2 A.	To test this, we will have the microcontroller connected to the battery and repeatedly connect and disconnect from the WiFi to cause a current spike form 600ma to 1000ma. Further testing includes powering up two microcontrollers so max current draw is 1200ma-2000ma for an entire work day and seeing if the chip will overheat or breakdown.
The lithium ion battery will not power the MCU and data collection sensors when charging.	When the micro usb cable is plugged in, the voltage converter will shut off through connect a shutdown pin to a logic rail. The voltage to this pin to shut it off will be .3volts to 6.3 volts. This will be tested by connecting

	the output to an oscilloscope to ensure no current is supplied.

4 Costs and Schedule

4.1 Schedule



Project Plan

ID	Task: Work Plan for the Semester	Lead
	Power Consumption Calculations	Dennis
	Circuit and PCB Design	Dennis
	PCB and Circuit Printing	Dennis
2.b	Integration with Other Components	
	Integration with Gloves	Dennis
	Integration with Vest	Dennis
	Integration with Helmet	Dennis
3	**Gloves Wearable**	
3.a	Measurement	
	Read from flex sensors	JD
	Attach flex sensors to gloves and collect training data	Dennis
3.b	Storage	
	Use microcontroller to broadcast to server over wifi	JD
	Read/write protocols for SD card	JD
3.c	Analytics	
	Develop binary wearing/non-wearing algorithm	JD
	Time-Series Research	JD
4	**Helmet Wearable**	
	Data Collection	
	Wheatstone bridge and other configurations for Force Sensors	Dennis
	Brainstorm and experiment with other sensor configurations for helmet wearing	Dennis
	Integrate with physical helmet and test	Dennis
	Data Analytics	
	Use microcontroller to broadcast to server over wifi	JD
	Develop binary wearing/non-wearing algorithm	JD
5	**Server and Analytics**	
5.a	Human Readable UI	
	Determine KPIs for wearing safety equipment	Shared
	Learn how to work servers -- read and access data	JD
	Write Java application to perform analysis and output onto a dashboard	JD
6	**Demo and Presentation**	
5.a	Presentation	
	Develop Presentation/Demo	Shared
	Rehearse	Shared
5.a	Paper	
	Write	Shared
	Edit	Shared
	Write	Shared

4.2 Costs

Glove Wearable (both hands)			
Product	Quantity	Price per Unit	Price
Max 1551	1	2.03	4.06
TPS 63020-q1	1	1.9	3.8
P1 Microcontroller	1	12	24
Lithium Ion battery 2000mah	1	12	24
LED- blue	1	0.5	1
LED - green	1	0.5	1
LED - red	1	0.5	1
ceramic Capacitor- 10uF	4	0.13	1.04
ceramic Capacitor- .1uF	6	0.1	1.2
ceramic Capacitor- 1uF	2	0.1	0.4
ceramic Capacitor- 20uF	1	0.17	0.34
ceramic Capacitor- 100uF	1	0.13	0.26
Resistor - 1M ohm	2	0.1	0.4
Resistor - 10K ohm	1	0.1	0.2
Resistor - 180K ohm	1	0.1	0.2
Resistor - 1K ohm	1	0.1	0.2
Resistor - .1K ohm	3	0.1	0.6
Micro USB Female Connector	1	1	2
Flex Sensor- 4.5"	3	12.95	77.7
		Total	143.4

Helmet Wearable			
Product	Quantity	Price per Unit	Price
Max 1551	1	2.03	2.03
TPS 63020-q1	1	1.9	1.9
P1 Microcontroller	1	12	12
Lithium Ion battery 2000mah	1	12	12
LED- blue	1	0.5	0.5
LED- blue	1	0.5	0.5
LED- blue	1	0.5	0.5
ceramic Capacitor- 10uF	4	0.13	0.52
ceramic Capacitor- .1uF	6	0.1	0.6
ceramic Capacitor- 1uF	2	0.1	0.2
ceramic Capacitor- 20uF	1	0.17	0.17
ceramic Capacitor- 100uF	1	0.13	0.13
Resistor - 1M ohm	2	0.1	0.2
Resistor - 10K ohm	1	0.1	0.1
Resistor - 180K ohm	1	0.1	0.1
Resistor - 1K ohm	1	0.1	0.1
Resistor - .1K ohm	3	0.1	0.3
Micro USB Female Connector	1	1	1
Force Sensor	3	6.95	20.85
		Total	53.7

Vest Wearable			
Product	Quantity	Price per U	Price
Max 1551	1	2.03	2.03
TPS 63020-q1	1	1.9	1.9
P1 Microcontroller	1	12	12
Lithium Ion battery 2000mah	1	12	12
LED- blue	1	0.5	0.5
LED- blue	1	0.5	0.5
LED- blue	1	0.5	0.5
ceramic Capacitor- 10uF	4	0.13	0.52
ceramic Capacitor- .1uF	6	0.1	0.6
ceramic Capacitor- 1uF	2	0.1	0.2
ceramic Capacitor- 20uF	1	0.17	0.17
ceramic Capacitor- 100uF	1	0.13	0.13
Resistor - 1M ohm	2	0.1	0.2
Resistor - 10K ohm	1	0.1	0.1
Resistor - 180K ohm	1	0.1	0.1
Resistor - 1K ohm	1	0.1	0.1
Resistor - .1K ohm	3	0.1	0.3
Micro USB Female Connector	1	1	1
Tmp36	1.5	1	1.5
adxl377	11.2	1	11.2
		Total	45.55

Labor Estimates			
	Hours	Rate	Totals
Glove	80	30	2400
Helmet	40	30	1200
Vest	100	30	3000
Analysis	20	30	600
		Total	7200

Total Cost	
Total Material Cost	242.65
Total Labor Cost	7442.65
Total Cost	7685.3

5 Ethics and Safety

There are several potential safety hazards in this project. Lithium ion batteries can become dangerous when overcharged or brought to extreme temperatures so a regulator circuit is needed so that it does not charge to over 4.2 volts. In addition, it should also be noted that the battery should not discharge when the voltage is under 2.8 volts because irreversible damage to be battery can occur. During the prototyping and design phase, care will have to be taken to ensure that soldering is done in a safe way as well. However, because the currents and voltages are relatively low, standard lab safety protocols should ensure that the development of this project is safe.

Since this set of wearable devices has to be able to function both indoors and outdoors it has to adhere to IP67 guidelines so that no moisture can get into the circuit which can damage it. In addition, the workers will be wearing this while operating machine tools so it can not impede everyday usage of tools in a dangerous way. This means that the end product also has to be ergonomic in nature to minimize distractions to the worker.

When accidents happen to the device by dropping it or taking blunt damage the external casing must be able to shut off the device properly and disconnect the battery to minimize the risk of short circuits and exploding batteries.

This product is by no means a complete solution to the issue of workers not wearing PPE since it is still a prototype. It is simply a monitoring device that relays information to the manager to track how often safety equipment is used by each worker and to provide diagnostics on the workers safety. If the worker is not using safety equipment frequently and has become an issue in the workplace, the manager must take action and purchase less distracting and more ergonomic PPE.

To ensure the data gathered from the detection circuits are as accurate as they can be with limited time to prototype, the sample data samples gathered for machine learning will not be as thorough and more sample data will need to be collected for Bayesian machine learning. This data will be used with IBM bluemix.

A final concern for this product is that to prototype with workers successfully before selling, there may not be wifi access due to security reasons so a wifi module may be needed.

This project furthers parts of the IEEE code of ethics -- specifically, part 1 “[disclosing] factors that might endanger the public or the environment” (IEEE). Our product seeks to do this for workers in the workplace. One area of the IEEE code of ethics that should be watched out for is part 9 (IEEE). Though our product seeks to help increase accountability for workers, we should ensure that our “wearing” algorithm is as accurate as possible. This will reduce the chances of false-negatives that lead to negative consequences for workers.

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By signing below, you acknowledge that you have read this document and agree to follow the ECE 445 Course Staff's guidance regarding high capacity batteries and will complete all necessary safety training and adhere to the guidelines set forth in this document as well as additional guidelines as the course staff deems necessary.

Dennis Wong

Print Name

2-24-17

Date

Signature

2-24-

Date

TABLE II: History of Revision

Revision	Date	Authors	Log
A	3/19/2016	Lenz	Creation
B	3/28/2016	O'Kane	Additonal Information, General Revision
C	3/29/2016	SP16 Staff	Collaborative Revisions
D	4/7/2016	Salz	General Revision

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Joydeep Ganguly

Print Name

2/24/2017

Date

[signature]

Signature

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