Auto Fall Detector

Senior Project

COMPUTER ENGINEERING DEPARTMENT

California Polytechnic State University

San Luis Obispo

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In Partial Fulfillment

of the Requirements for the Degree

Bachelor of Science in Computer Engineering

By

Nhut Thanh Ho

Acknowledgement

Dr. Slivovsky – Thank you for your advices and all your valuable hours you've spend to help me complete this project. All your works will always be appreciated.

Jackie – Thank you for all your endearing help and endless support.

My Friends – Thank you for your suggestions, ideas and helps from you.

Contents

Abstract

The fall detector project was divided into three different sections: hardware, software, and testing. The first section including selecting parts, components, and building PCB are all finished. The final device was tested, and fulfills all the project requirements. Due to some transceiver's difficulties and complexity, the software section was not able to run so the device did not work properly and meet the design requirements. Therefore, the project was not tested in all of it functionalities.

Introduction

In 2009, [1]the Centers for Disease Control and Prevention (CDCP) states that 2.2 million nonfatal fall injuries were among older adults, and more than 581,000 of these patients were hospitalized and sent to the emergency departments. Every year, 1 out of 3 elders over 65 years old have fall injuries. Two-third of those elderly patients who experienced the fall will likely encounter another fall injury within 6 months. The fall injuries are mostly due to the increasing of age, decreasing of bone density, and a lack of physical exercise. People who have fall injuries suffer moderate to severe injuries, such as, lacerations, hip fractures, or head traumas. These injuries can make it difficult for those to get around, live independently, and can increase their risk of an early death. Annually, 1,800 falls injuries are directly resulted in death. Approximately, 9,500 deaths in older Americans (over the age of 65) are associated with falls each year. In addition, about 700,000 Americans have a stroke each year, and among of these stroke patients 160,000 will result in death. When a person has a fall injury, stroke, or heart attack it is vital to have an alert system to signal for help. In order to give quick and appropriate help, I have built a fall injury auto-detection device. This will be a small portable device that will be strapped onto elders, and it will send alert signals to surrounding people who may provide immediate help.

Product Definition

This device is named, Cardea, the goddess of health in roman Mythology. The Cardea will be attached to the waist of the individual's body to detect any falls, and will send out alarm signals to people in the surrounding area. The end goal of this project is to provide a helpful and friendly device for the elderly and their families. It is easy to maintain and dependable for long term use.

Intended End Users

There are two main groups of end users. The first main user is an elderly or individual who has a higher risk of fall injuries, such as, a heart disease patient. The Cardea must be worn on the waist; therefore, the device must be light-weight and compact so it does not interfere with daily activities. In addition, the Cardea must be strong enough to sustain the body weight of an individual in case they fall on top of the device.

The second main user is the helper who will provide quick and immediately assistance to the first main user. The Cardea system must send loud alerts to get the helper's attention; therefore, it will be easy for the helper to find and locate the injured victim.

Marketing Requirements

1. The Cardea must be durable.
2. The Cardea must easy to operate.
3. The Cardea must be light weight.
4. The Cardea must be small and portable to carry.
5. The Cardea must be strong for heavy impact.
6. The Cardea must be safe to use.
7. The Cardea must be easy to find in the dark.
8. The Cardea must be easy to find by following loud emergency signals and noises.
9. It has LED indictor for the connection between receiver and transmitter.
10. It must be friendly with the environment and consumes little power.

Engineering Requirements

In order to successfully archive all the marketing requirements above, there are some technical and engineering requirements that this device must have:

Marketing Requirements	Engineering Requirements	Justification	Taxonomy
1,10	The Cardea must have low power dissipation. It's powered by 9v battery, and battery should last for 3 months.	This is a small device and it attached to user body. It needs to be powered by a battery.	Environment Energy Economy
5,3	It must be able to withstand heavy body weight (up to 200 lbs) It must be able to work after a strong impact.	Users may fall on the device, so it must be dependable to tolerate a strong impact.	Functionality Health Safety
3,4	The Cardea must be easy to carry, and should be weight about 100 grams, and be small enough to be attached to the body.	Users of Cardea are mostly elders who are over 60 years old. Therefore, they cannot carry a heavy device.	Functionality Safety
2,6,7,8	The Cardea must be easy to use. It has a low battery LED indicator. It is a "plug and play" device.	This device is designed for elders, and any consumers. Therefore, users do not need to have special engineering knowledge to operate this device.	Functionality Operational
6	The project must be well documented for non-engineers to read.	We will provide operational guidelines and a user's manual.	Functionality Operational
9	This a indoor device so it must be operate in a range of 50 meter.	Most of the fall injuries occur indoors; therefore, it should transmit the signals indoors only	Functionality Operational

Table 1: Engineer Requires

Use Cases

User drops the device

1. User plugs Cardea receiver to 110V, and battery to mobile device.
2. User unintentional drops the Cardea, and activates the sensor that turns the alarm on..
3. User has 15 seconds to press reset button.

User feels unwell

1. User feels unwell.
2. User presses the emergency button.
3. The LED and alarm turn on, and send out a signal to the receiver.
4. The helper will follow the alarm signals to find the User.

User has a stroke

1. User has a stroke and falls. The transmitter alarm will turn on.
2. After 15 second, if the user has not press the reset button. The transmitter will send out emergency signals to a receiver.
3. The receiver alarm is on, and the helper will follow the emergency signals to find the user.

Device is not working

1. User plugs the receiver to a 110V, but the user forgets to place a 9V battery into the mobile device.
2. The LED on the receiver will flash lights indicating that there is no signal from the transmitter. There is no connection.
3. User checks the transmitter, and places a battery in the transmitter.

Battery is low

1. The LED on the transmitter will flash.
2. This indicates the battery is low battery.
3. User replaces the battery, and the LED flashing will disappear.

Study of The Fall

There are different types of fall injuries that are detected. It is important to analyze the acceleration of unintentional falls. If the sensor can detect any value greater than the threshold value, it will set that as a fall injury [2]. Also, there are other solutions using the accelerometer, and the body movement sensor to detect any falls. The accelerometer could detect any value which could indicate a fall combine with the change of body gestures as a legitimate fall injury [3].

In this study, I am following the first approach by using one accelerometer and some threshold values to detect a fall. However, to make it more accurate, and to detect various types of falls, I will use 3-axis accelerometer to detect the change of the velocity, and the direction of the velocity vector to determine the fall. Primarily, the Cardea will be attached to the user's waist, and it will define the position of the waist in space. When the user moves, it will calculate the change of velocity and define a new position.

The accelerometer will detect the velocity change in each axis: x, y and z. The change will be vx, vy and vz. And the final velocity will be:

$$Vf=\sqrt{vx^2+vy^2+vz^2}$$

And the angle between the total vector (vf) and the z-axis will indicate the change of the hip before and after the fall:

$$\alpha=\frac{vz}{vf} \Rightarrow \alpha=\text{arccosine}\,(vz/vf)$$

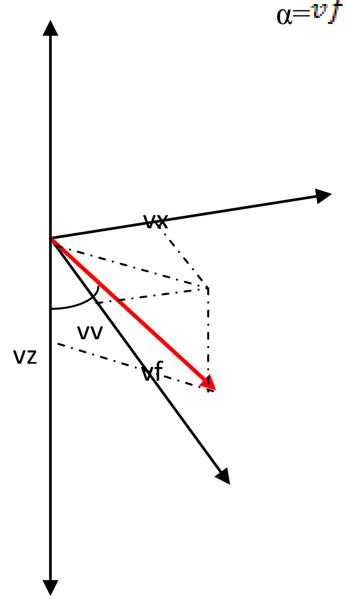

Figure 1: Accelerometer vector

Detecting The Magnitude of The Velocity

The big challenge in this project is to find a right threshold value that will differentiate the fall injury and other Activities of Daily Living (ADL). ADL, such as, sitting on the floor, lying on the bed, or bending down could be sent by the accelerometer and it could trigger faulty signal alarms. According the paper published by a group of UC Berkeley's students, the ADL could only generate the small acceleration changes [3]. They do not exceed 3G (29.4 m2/s)

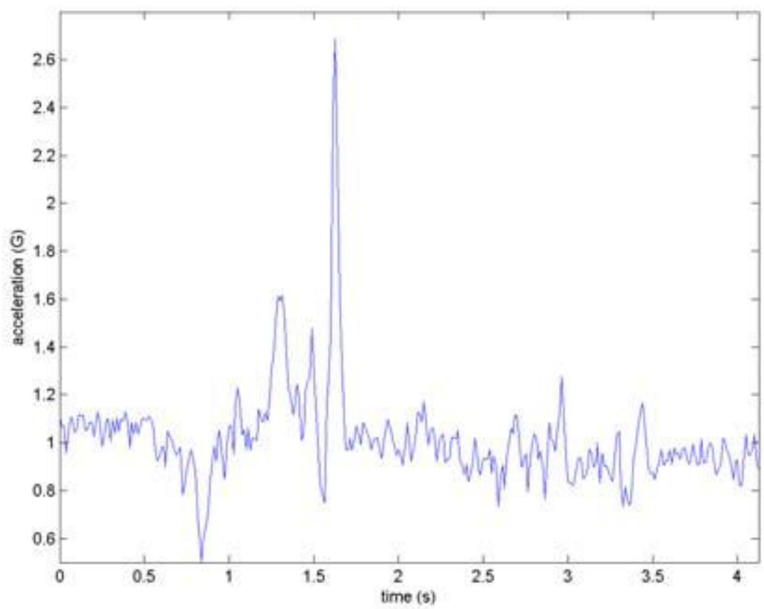

Figure 2: Acceleration observed while sitting

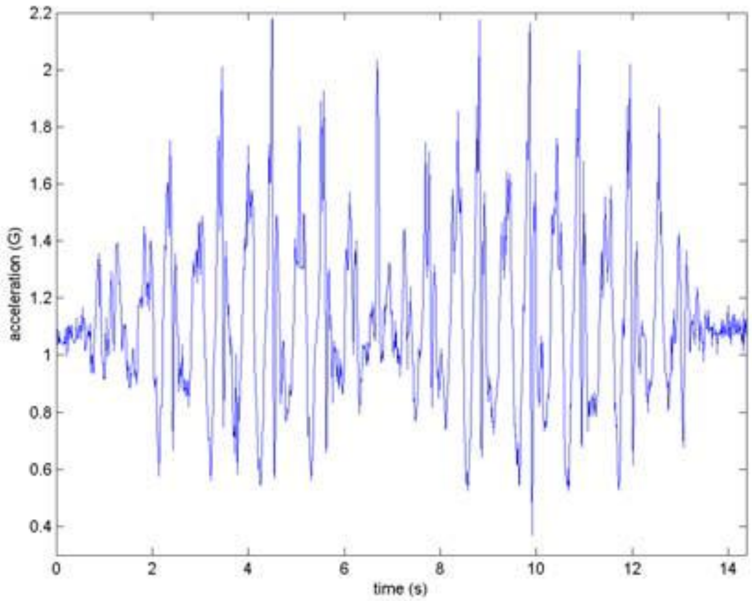

Figure 3: Acceleration observed while walking

Base on the UC Berkeley's research, any value below 3G can be eliminated.

What is The Threshold Value?

UC Berkeley researchers had 10 martial art students test the fall device. The students demonstrated all the unintentional falls that may happen daily, such as, forward falls, backwards falls, and side falls. Then the device will record all the data, and the result shows the backward fall could generate the signal up to 6.9G [3]. The sideway falling has 12.7 G.

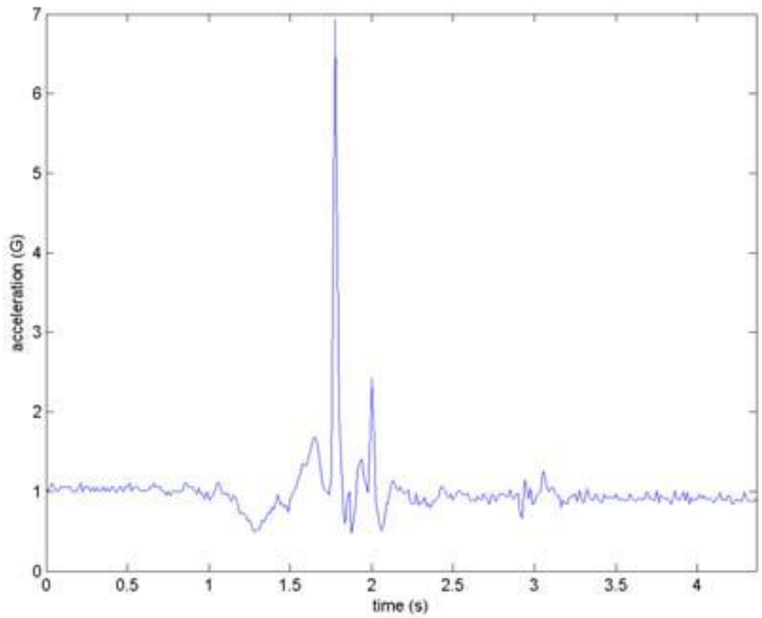

Figure 4 : Acceleration Observed While Falling Backwards

These results helped scale down the range of the threshold voltages. I will set threshold value is about 6G which is high enough to eliminate all ADL and capture the fall.

There are many accelerometers that could be used for this project. Some accelerometers can measure from +/-2G up to +/-250G. The high range of measurements that has a big resolution will not be used for this particular project. However, a small range acceleration sensor could record changes up to +/-16G. This sensor's range is enough to recode all unintentional falls. In case the signals exceed the range then it will be considered a legitimate fall. The device will activate immediately, and will send emergency signals.

I use BMA180 from Bosch Company for this particular project.

The BMA180 has:

- Wide variety of measurement ranges (±1g, 1.5g, 2g, 3g, 4g, 8g and 16g)
- 14- or 12-bit ADC conversion
- 2 selectable I^2C addresses
- 2 main standard modes: low-noise and low-power
- Sleep mode
- Wake-up mode
- Self-test capability

The BMA180 will be able to detect most of unintentional fall with the range up to 16g. It has a sleep mode for power saving and 2 I2c line which could input to the Atmega328P.

For the Transceiver I am using the RFM22B-S2 SMD Wireless Transceiver

- Frequency Range: 433/868/915MHz ISM bands
- Sensitivity = -121 dBm
- Output power range: +20 dBm Max
- Data Rate = 0.123 to 256 kbps
- FSK, GFSK, and OOK modulation
- Power Supply = 1.8 to 3.6 V
- TX and RX 64 byte FIFOs
- Low battery detector
- Temperature sensor and 8-bit ADC
- –40 to +85 °C temperature range
- Integrated voltage regulators

The RFM22B has a range up to 100m that is wide enough for this device, and has a low battery detector that will notify the user when there is low battery. In addition, there is a build-in antenna.

Hardware Design

Outside look

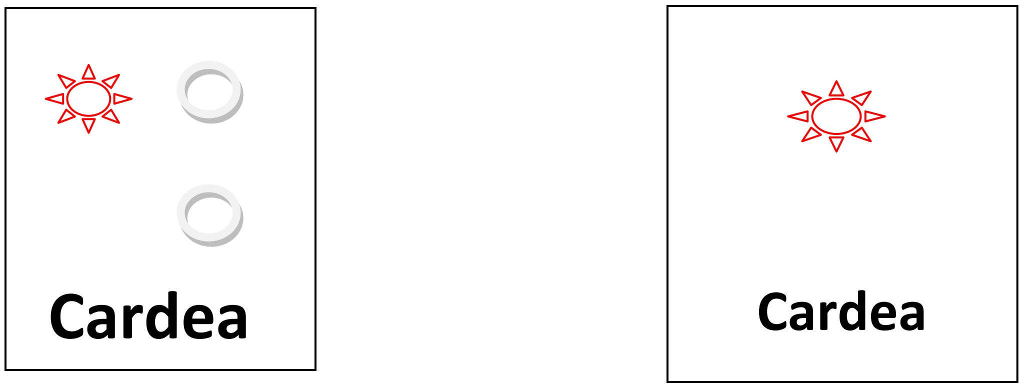

Figure 5: Transmitter Device and Receiver Device

Mobile Device inside Look

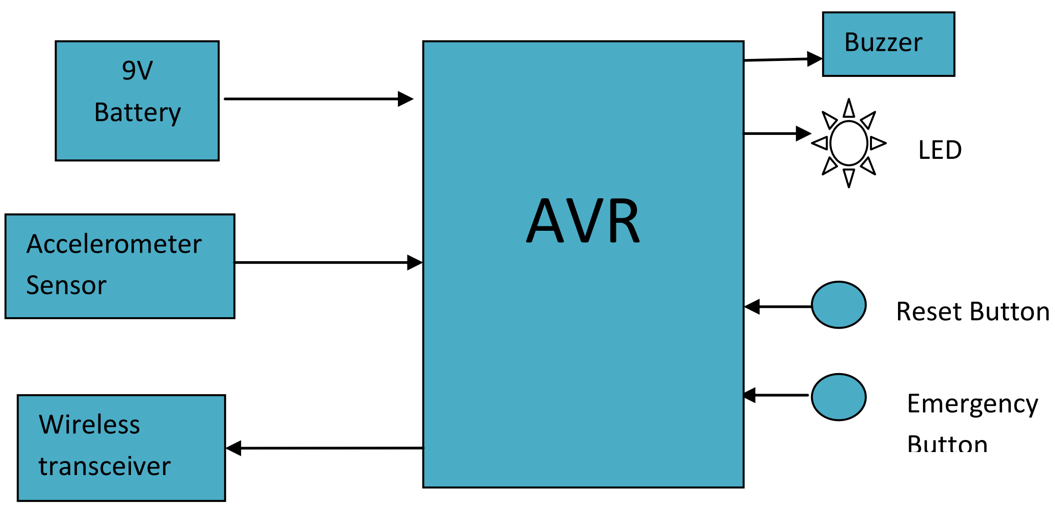

Figure 6: Transmitter Hardware Diagram

Receiver inside Look

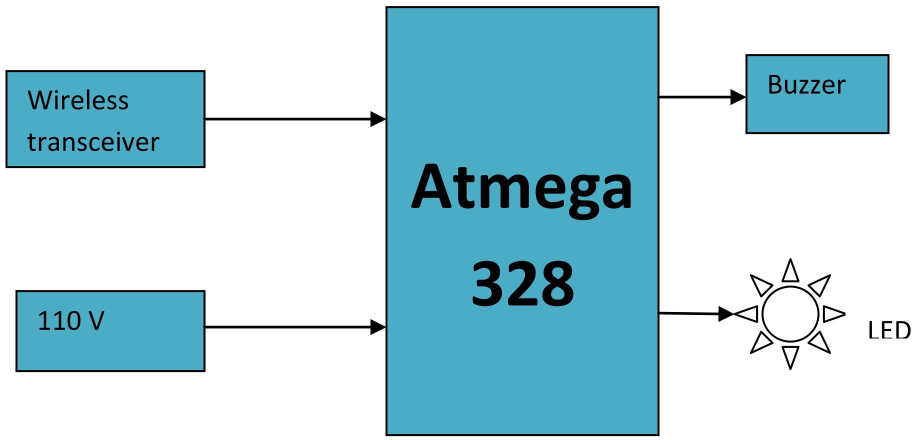

Figure 7: Receiver Hardware Diagram

Functional Decomposition

Transmitter Level 0:

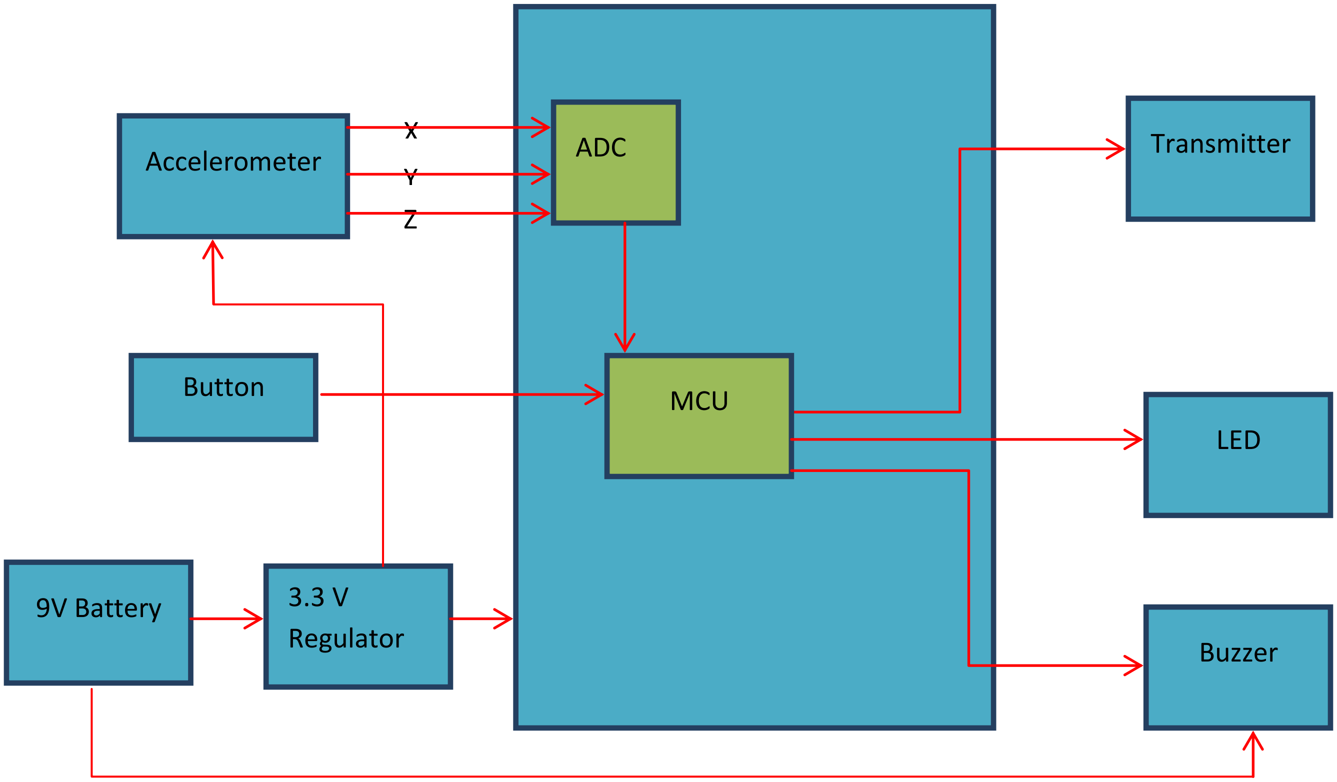

Figure 8: Transmitter Hardware Diagram at Level 0

Module	Function
Accelerometer	Records movement of the hip and sends analog signals to ADC.
9V Battery	Provides power for the system and a buzzer.
3.3V	Provides power for accelerometer, transmitter, LED, and MCU.
Buzzer	Needs 9v power, and triggered by MCU, send out alarm sound.
Button	Reset button and the emergency button.
LED	Indicates low battery or when there is a fall.
Transmitter	Sends out a fall signal to receiver.

Receiver level 0:

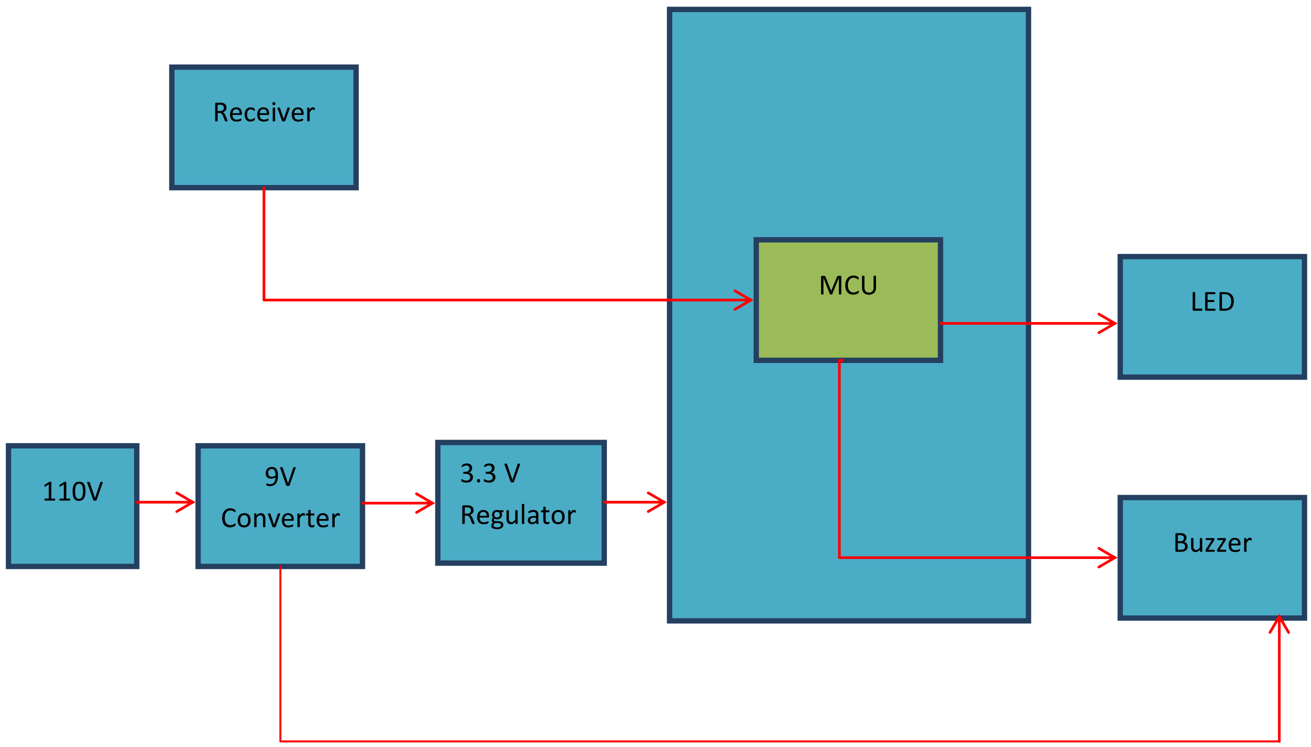

Figure 9: Receiver Hardware Diagram at Level 0

Module	Function
110V	Powered from the wall.
9V	Converts from 110 v to 9v for buzzer.
3.3V	Power the Receiver, LED, and MCU.
Receiver	Receives fall signal from transmitter then trigger the buzzer and the LED.
LED	Indicates when a fall will occur.
Buzzer	Sends out alarm sound.

Hardware schematic

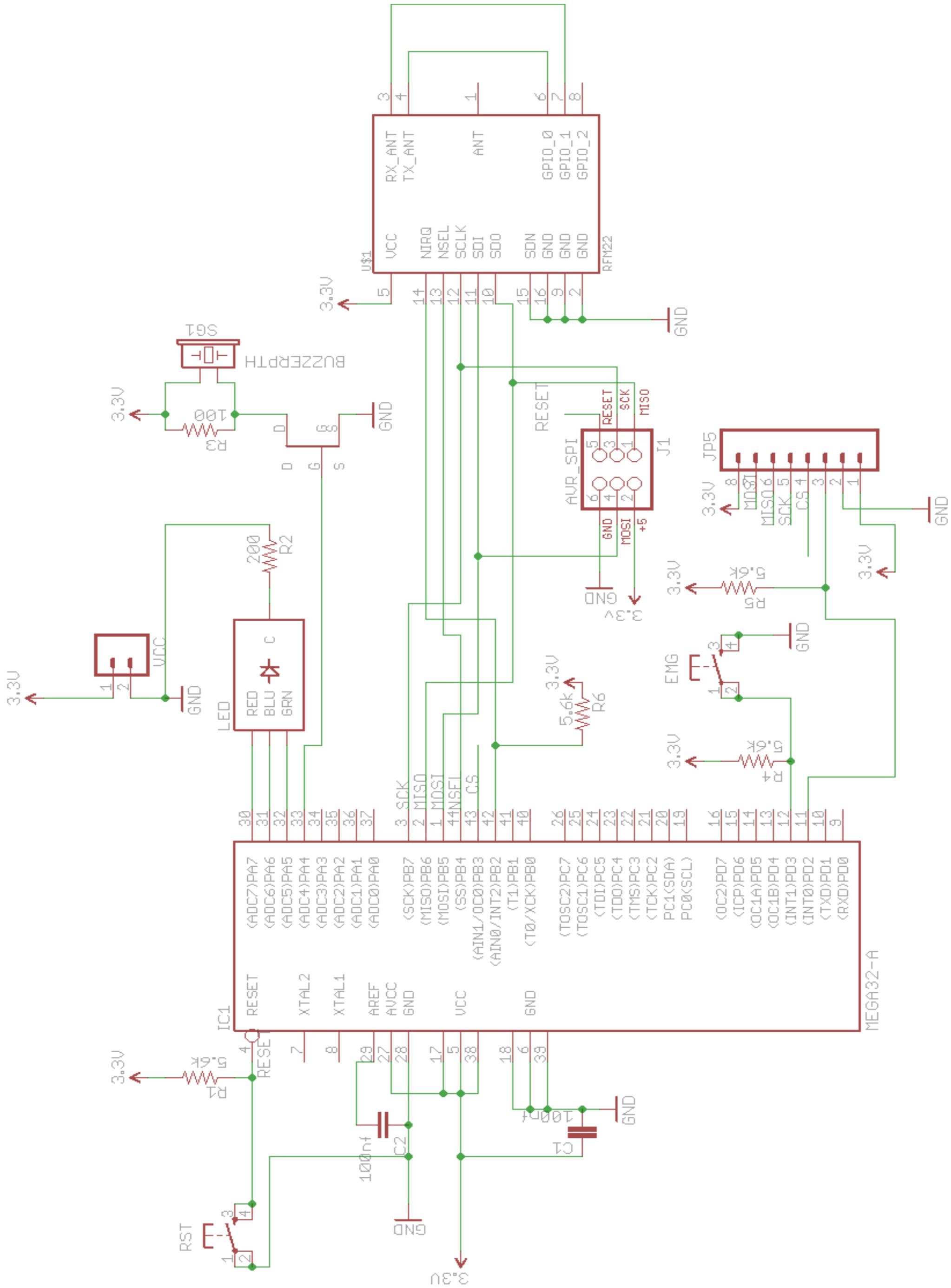

Figure 10: Mobile Device schematic

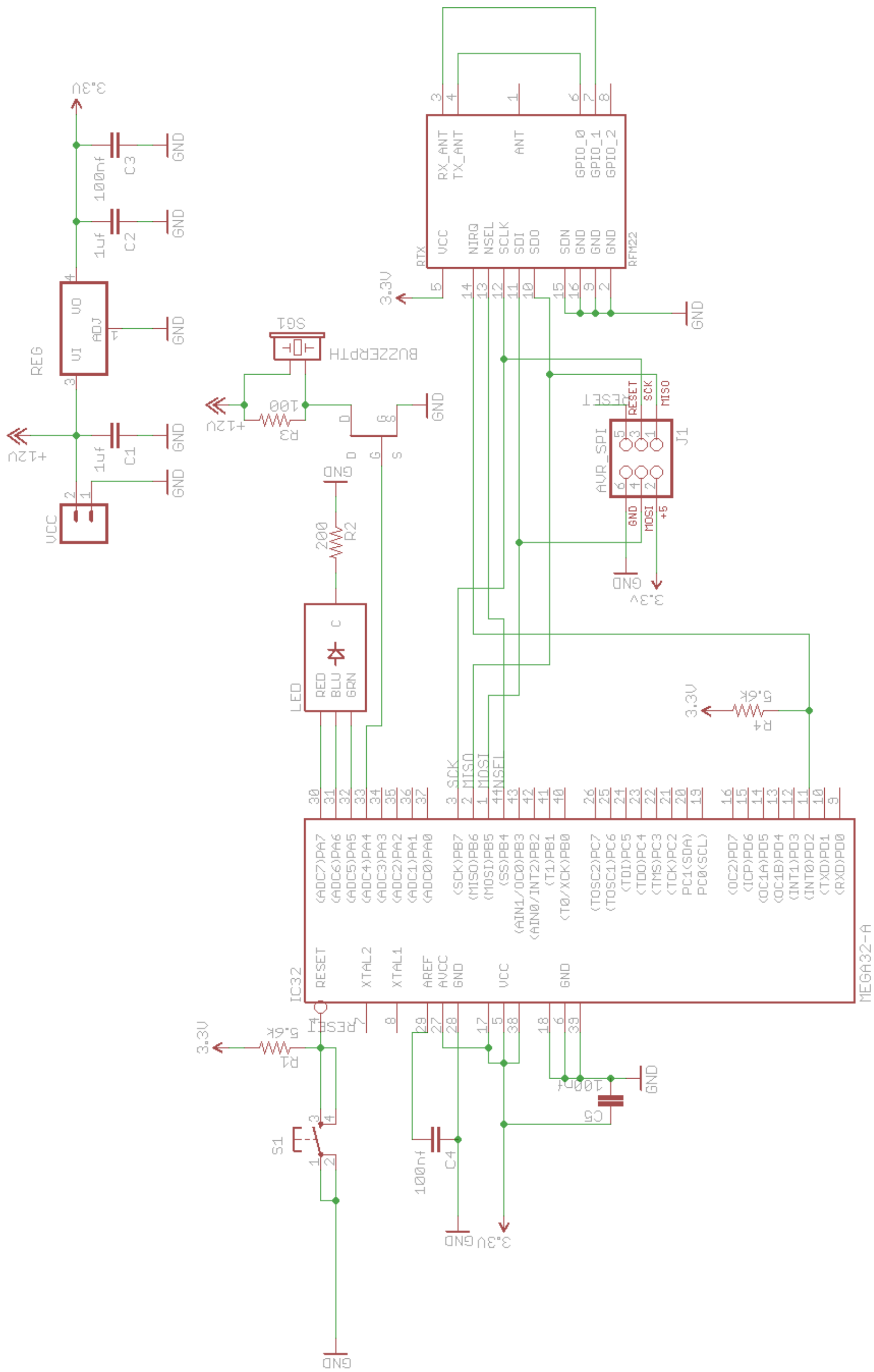

Figure 11: Receiver Device Schematic

Software Architecture

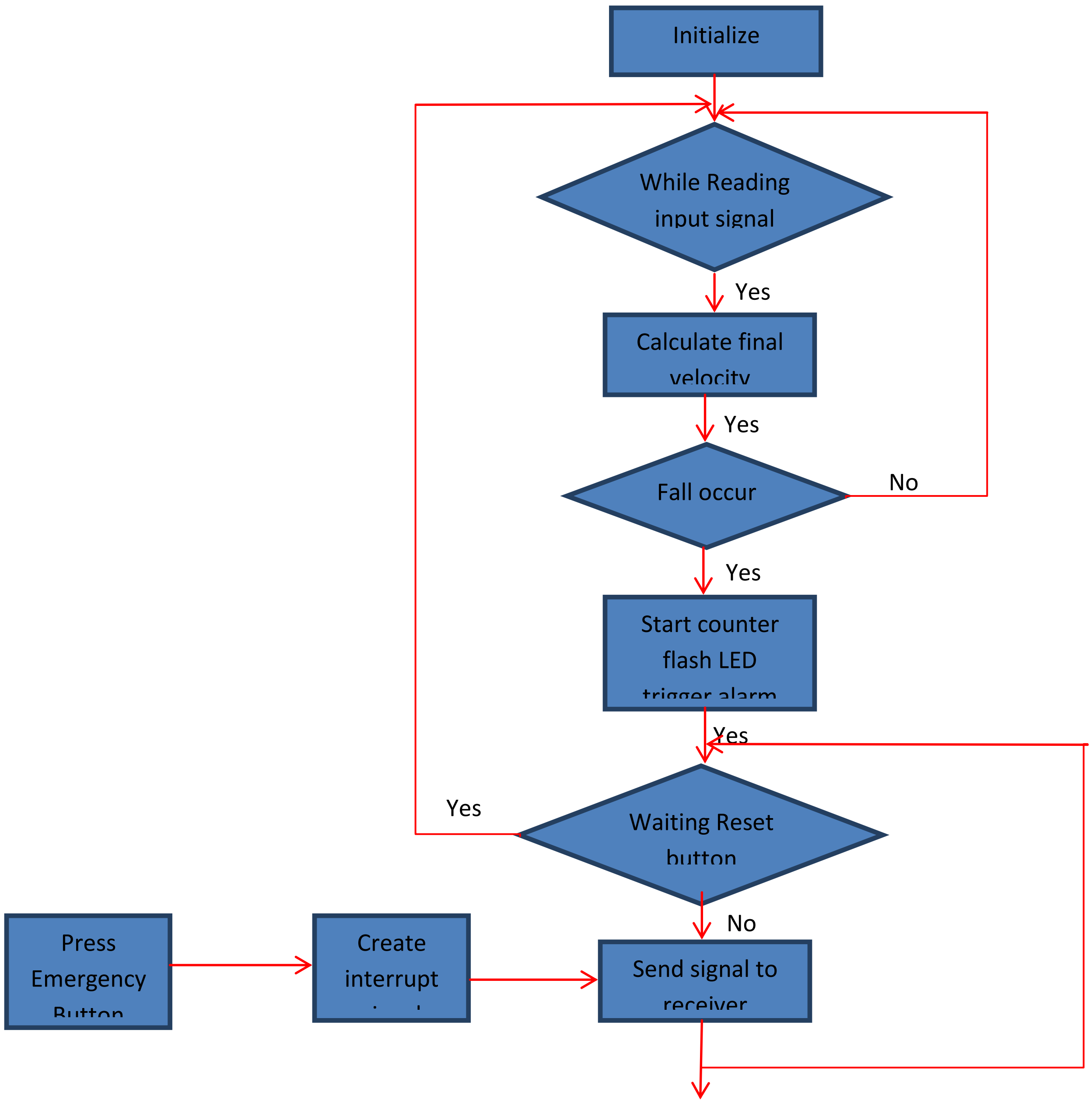

Figure 12: Transmitter Software Diagram

Transmitter Operation

The BMA sensor has a high threshold value and a slope threshold value. This is used to detect and generate any interruptions. The MCU will read x, y, and z values from the sensor, and waits for any interruption to occur. When the interruption happens, the RFM22 will send a value 1 to the receiver, and the MCU will activate the buzzer and LED. If there is no interruptions, the RFM22 will send 0 to the receiver every 1s. The interruption can only be reset when the user presses the reset button. The device will goes back to the initial stage. Any user can activate the alarm by pressing the emergency button, which will make RFM22 send out 1 signal and turn on the buzzer and LED.

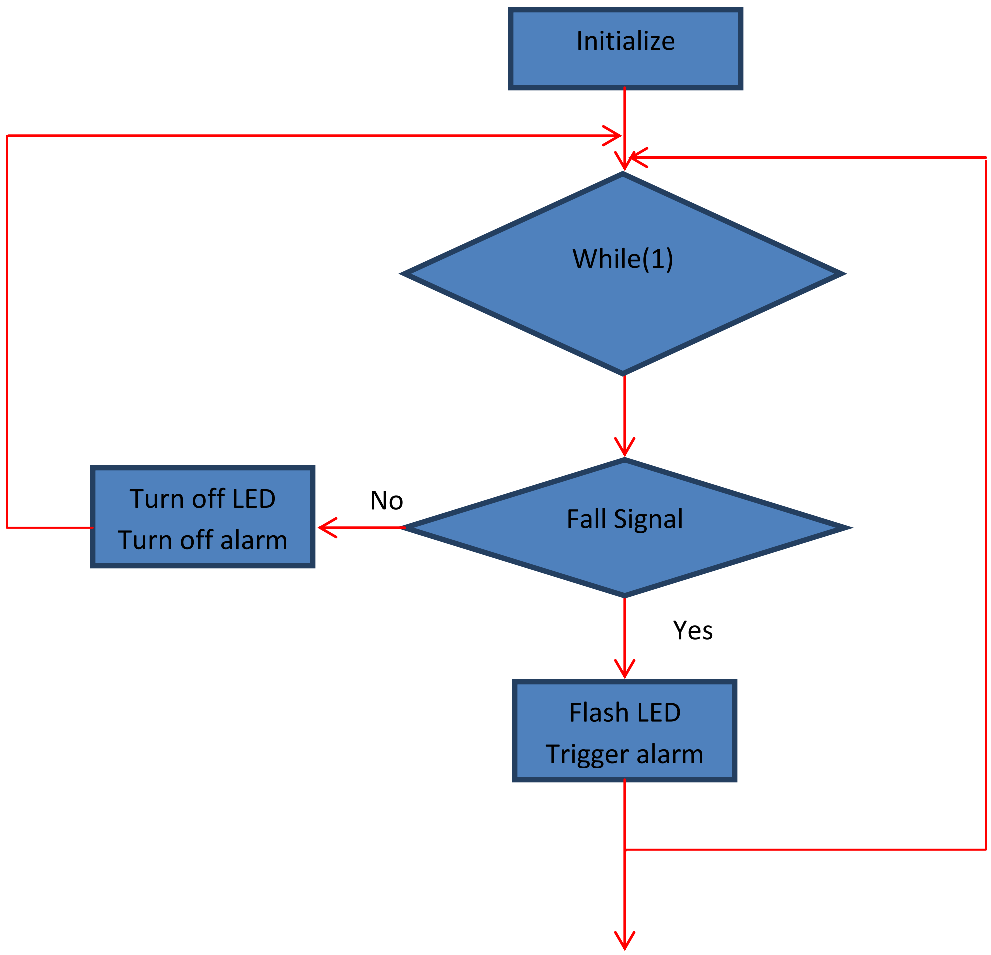

Figure 13: Receiver Software Diagram

Receiver operation

The receiver listens to transmitter every 1s. if the receiver is 0, then nothing will occur. If the receiver does not receive signals within 3 seconds, it will begin flashing red LED lights. This indicates that there is a disconnection between the transmitter and receiver. If receiver receives a 1 then the buzzer and LED will turn on. It will only reset when receiving 0 from the transmitter.

Test Plans

Overview:

In order to meet all the marketing and engineering requirements, the Cardea must pass all the test cases. Those test cases were designed to test the Cardea's functionality, safety, environment effects, and energy efficiency.

Test case:

Number	Taxonomy	Description	Expecting result
1	Functionality	Press the emergency button and reset button on the transmitter 10 times	The red LED blinks, the alarm turns on 10 times. Then green LED turns on and alarm turns off 10 times
2	Functionality	Transmitter locates 10, 20, 30 and 40 feet away from receiver. Each case will be tested 10 times	10, 20 feet range (from room to room): alarm turn on all 100%. 30 feet range(from back yard to living room):alarm turn on 80% 40 feet range(house to house): alarm turn on 50%
3	Functionality	User falls forward 10 times while standing or walking.	Alarm turns on 10 times
4	Functionality	User falls backward 10 times while standing or walking.	Alarm turns on 10 times
5	Functionality	User falls sideward 10 times while standing or walking.	Alarm turns on 10 times

6	Functionality	User rolling off the bed 10 times while sleeping.	Depends on the height of the bed, alarm may turn on or not
7	Functionality	Transmitter locates in a concrete wall room and 20 feet away from receiver and transmits 10 times	Receiver must receive a signal 10 times
8	Functionality	Transmitter locates in a wood wall room, and 20 feet away from receiver and transmits 10 times	Receiver must receive a signal 10 times
9	Energy Environment	Use 9v battery to power receiver	The battery must last at least 30 days
10	Energy Environment	Use 2 AA batteries for transmitter	The batteries must last for 30 days
11	Safety	Transmitter plug in to 110v power outlet	It should be able to operate normally for at least 30 days

Table 2: Test Plans table

Conclusion

There are three sections in this project. The hardware section was finished. The PCB boards are completed, and passed all the functional testings. The current dissipating is about 100 mA; therefore, the batteries can last up to three months.
Due to some challenges and difficulties of the RFM22, the software section was not able to finish. The device is able to response to the emergency button and reset button, but it is unable to send out the signal to the receiver. There is a disconnection between the receiver and transmitter. Because the software section was not finished the device cannot do a final test with different types of falls and ranges of the transceiver.

Although, the final product did not work as originally planned, I learned a lot from this project. At first, I did not know how to design or create the PCB, but then I learned how within 2 weeks of this project. Now, I enjoy designing the PCB board. I also learned how to buy and solder surface mount component to the PCB. This is challenging because of the size of the components. Software design and implementation is not as challenging for me as before. However, I could not get the transceiver to work properly because the device did not have well-documentation or technical support. Thus, this made it difficult for me to program the device, and was one of the most important lessons I learn from this project. Therefore, I believe there is still a great amount of room for improvement. Such as, the PCB can be 50% smaller, and the transceiver must be something that is simple to implement to send on and off signals but not data. To improve the device even more, it could be connected to the internet through the home wireless which can allow for mobile applications that could be built to monitor senior citizens.

Bill of Material

This is an estimate bill compiled by the Digikey website. They have all the parts and components for building this device. This cost does not include the batteries and cases cost.

Index	Qty Ordered	Part Number	Unit Price	Extended Price
1	3	LMS8117AMP-3.3/NOPBCT-ND	1.58	$4.74
2	3	2N7002W-TPMSCT-ND	0.38	$1.14
3	4	ATMEGA32A-AU-ND	5.25	$21.00
4	4	338-2778-1-ND	1.05	$4.20
5	10	587-1134-1-ND	0.357	$3.57
6	10	RHM200BGCT-ND	0.225	$2.25
7	10	RHM5.6KBGCT-ND	0.225	$2.25
8	2	BH2AA-PC-ND	1.7	$3.40
9	2	ETU-ND	3.8	$7.60
10	1	80-6-5-ND	5.56	$5.56
11	2	SRCA10-2A-ND	8.54	$17.08
12	3	Receiver PCB	23	$69.00
13	3	Transmitter PCB	30	$90.00
			Total	$231.79

Table 3: Bill of Material

Analysis of Senior Project Design

Please provide the following information regarding your Senior Project and submit to your advisor along with your final report. Attach additional sheets, for your response to the questions below.

Project Title ________________Auto Fall Detector _________________________________

Student's Name ____Nhut Ho___ Student's Signature ______________________________

Advisor's Name ____ Lynne A. Slivovsky_________ Advisor's Initials ______________

Summary of Functional Requirements

The fall detector detects the human's fall then turns on the alarm and sends out the alarm signal to the receiver. It also allows user manually turn on the alarm when they want.

Primary Constraint

The device is able to detect and differentiate the falls from all other daily activities. It powers by 2 AA batteries and can last for 3 months. It can send out the alarm signal to the receiver in a range of 50 feet. It has to be compact to allow any user to perform daily activities, and has to be light weight to attach to users' waist.

Economic

The overall cost of the project was believed to be $455.

The example and prototype of the device were built for testing before the final design was sent out for manufacturing. There are two prototypes of the device that were built, one on bread board and one on PCB.

The final overall component cost of the project was $231. This amount is an estimate for the final PCB design.

If manufactured on a commercial basis:

It only cost about $75 per unit

The estimated retail price would be $100

And the profit is about $25(25%).

Environmental

This is a small device and it consumes only 1W. it is energy efficient and environment friendly.

Manufacturability

This device is easy to manufacture. I cost around 1 oz of lead to make this. It was challenging to make this device compacted. The device is really small so it is hard to do a surface mount soldering.

Sustainability

This device could be smaller. The size of the PCB could be reduced to 75% smaller by using different transceiver and accelerometer sensor.

It could be integrated with the internet via Wi-Fi connection.

Ethical

Misuse or forgetting to replace new batteries every three months could lead to the device malfunction. Sometimes, the device may generate false fall alarms which could be very distracting.

Health and Safety

This is a life improvement device. It makes monitoring people's falls easier. However, the users should not 100% depend on this system because malfunction or non-working devices could lead someone life to a dangerous situation. User should check their devices to make sure it works correctly within their location.

The loud noise from the buzzer could cause a headache after a prolonged amount of time.

Social and Political

There is currently no impact with political issues. However, the loud noises from the buzzer could cause a social impact on user's individual basis.

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