CENTURY
SOLUTIONS

March 8, 2012

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC
V5A 1S6

Re: ENSC 440 Design Specification for *Fall Assist:* a device to detect elderly people who have fallen

Dear Dr. Rawicz:

The enclosed document from *Century Solutions* is the design specification for our product *Fall Assist*. This product is in correspondence with the ENSC 440 project. *Fall Assist* will allow at risk of falling seniors to keep their independence of living alone by contacting the appropriate assistance when it is needed.

This design specification outlines how we will achieve the specifications listed in our previous document: Functional Specification for *Fall Assist.* Furthermore, this document only outlines how we will create our proof-of-concept model and will not discuss in detail the specifications that were listed for only the final product.

Our company, *Century Solutions*, consists of five senior engineering students: Ashish Agarwal, Richard Cho, Mahsa Dabirvaziri, Paven Loodu, and Alysha Sue. If you have any questions or inquiries about our functional specification please feel free to contact our designated contact person Alysha Sue by phone at (778) 688-7412 or by email at ams34@sfu.ca

Sincerely,

Ashish Agarwal

Ashish Agarwal
Chief Executive Officer
Century Solutions

Enclosure: Functional Specification for *Fall Assist*

CENTURY SOLUTIONS

Design Specification for Fall Assist:
a device to detect elderly people who have fallen

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ISSUED DATE
March 8, 2012

Executive Summary

The design specification for *Fall Assist* provides a detailed description for each component of the proof-of-concept model. Therefore, this document will provide the design considerations for the functional requirements marked I or II as specified in our previous document *Functional Specification for Fall Assist: a device to detect elderly people who have fallen* [1].

This document provides an overview for the entire system of *Fall Assist* as well as the justification for our design. We will describe our chosen design as well as other designs that were considered in the process and explain why we chose these particular design solutions. Some factors that were considered in making our decisions were complexity, time, and cost.

The overall system design is then separated into four separate components which are discussed in further detail. These components consist of the microcontroller design, the accelerometer design, the wi-fi design and the web application design. Furthermore, we will explain why we chose these particular components and models to implement our design.

In addition, this document outlines our system test plan that we will follow during the testing stage. This plan focuses on not only testing the entire device, but each component individually to ensure that every aspect of *Fall Assist* is in working order. This plan will ensure that all of the requirements of the device are met and that the device is able to function properly in any situation.

This design specification for *Fall Assist* includes detailed descriptions for the components required to complete our design as well as the schematics for each component. This document, along with our previous document *Functional Specification for Fall Assist*, will be used throughout the development and testing stages to ensure that all the functionality and safety requirements are met. Furthermore, our proof-of-concept model is on schedule to meet the targeted delivery date of early April 2012.

Table of Contents

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Glossary

A Fall	When an elderly person has somehow ended up on the floor and is unable to get up on their own without assistance
ADL	Activities of Daily Living
ARM	Advanced RISC Machines
I2C	Inter-Integrated Circuit
IC	Integrated Circuit
LPC	Low Pin Count
RAM	Random Access Memory
RISC	Reduced Instruction Set Computer
SMS	Short Message Service
SPI	Serial Peripheral Interface
TFT	Thin Film Transistor
UART	Universal Asynchronous Receiver/Transmitter
USB	Universal Serial Bus

1. Introduction

Fall Assist will give seniors back their independence and ability to live alone by eliminating the fear of falling. It will automatically detect when a fall has occurred and alert an emergency contact via text message that their assistance is needed immediately, thus reducing the time spent waiting for help to arrive. Consequently, *Fall Assist* will lessen the severity of injuries sustained during the fall by ensuring that help is brought to those injuries immediately before they have time to worsen. This design specification will describe the requirements for our proof-of-concept model in detail and will outline our testing plan.

1.1 Scope

This document outlines the design specifications for our proof-of-concept model for *Fall Assist*. The design specification illustrates how we intend to achieve our functional specifications outlined in our previous document: Functional Specification for *Fall Assist* [1]. This document will focus on the requirements for our proof-of-concept model and will not go into detail about the requirements for our final product.

1.2 Intended Audience

This design specification is to be used by all members of *Century Solutions* during the design, development and testing stages of *Fall Assist*. This document will be used to ensure that all the design requirements are met during the design and development stages and the test plan outlined in this document will be used during the testing stage. Furthermore, progress will be measured against this document throughout the completion of this project.

2. System Specification

Fall Assist will allow seniors who are prone to falling gain back their independence of living alone. With *Fall Assist*, seniors can live their lives without the worry of falling and having to wait hours or days until someone finds them. *Fall Assist* is a device that is worn around the waist that will automatically detect when a fall has occurred and contacts help. The fall is detected by an accelerometer that is located in the belt buckle of the belt. Once a fall is detected, the microprocessor sends a text message to the user's emergency contact that their help is needed immediately using wi-fi. The user has the ability to easily setup and change their emergency contact's phone number using a simple easy to use web application. *Fall Assist* works wirelessly and without the need of input from the user. This simple and automatic device has the ability to allow seniors' to live worry free in their own homes.

3. Overall System Design

This section provides an overview of the *Fall Assist* system. Each component is discussed further in detail in later sections of this document.

3.1 System Overview

An accurate fall detection device will consist of sensors which detect linear acceleration along one of its axes and also angular acceleration. An accelerometer is used to detect the linear acceleration and a gyroscope is used to detect angular motion. To get the most accurate results, the fall detection device should be worn on the part of the human body that has the lowest movement and flexibility. These areas would be the collar, the chest and the waist. The device when worn at the waist will be most comfortable for the user and hence *Fall Assist* will be attached as a belt buckle to a leather belt. This is shown in figure 3.1 below.

There are a number of algorithms which have been researched to detect a human fall. These are described below:

Algorithm 1 – Estimating Velocity
A 3-axis accelerometer has been used in *Fall Assist* which detects fall in the X, Y and Z axes. The velocity in the downward direction can be accurately estimated by the equation:

$$v_{ve} = \int (RSS - 1g).dt \tag{1}$$

where v_{ve} is the velocity during impact
RSS is the resultant vector signal
g – acceleration due to gravity

Algorithm 2 – Detecting Posture
In a number of cases, people fall during an activity which is preceded by a prolonged period of lying down. The posture is determined by measuring the angle of the vertical axis of a 3-axis accelerometer. The equation used to detect this angle is:

$$\Phi_{z-axis} = \cos^{-1}\left(\vec{g}_{SEC\,Z}(t)\right) * \frac{180}{\pi} \tag{2}$$

After lying down, if the waist is at an angle greater than 60 degrees from the "normal" (here normal would vary from person to person) vertical axis then it would be described as a fall.

Algorithm 3 – Impact Detection (Acceleration)
A number of studies have been carried out related to activities of daily living (ADL) and the net acceleration in the downward direction has been calculated for each ADL. Also, a number of falls have been simulated in research laboratories and it has been observed that falls have an acceleration of 6g. None of the other ADL have a similar acceleration and this approach can be used to detect falls to an accuracy of 98-100%.

Algorithm 4 – Impact Detection (Angular acceleration)
This is similar to algorithm 3 but the only difference is that a gyroscope, which is attached to the sternum or thigh, is used instead of an accelerometer. A number of studies were conducted and it was observed that the angular acceleration for the ADL is in the range of 1 – 2 radians/second. However, the angular acceleration if a fall is detected is 3 radians/second.

3.1.1 The Design Approach Chosen for *Fall Assist*

For this project we are using algorithm 3 – which detects a fall using linear acceleration. We believe that both linear and angular acceleration are essential to be able to detect a fall accurately in all conditions. It is also possible to attach a GPS chip to the device which will also inform the emergency contact the location of the person who needs assistance. However, due to the time constraint of this project we will only be able to proceed with algorithm 3.

3.2 Mechanical Design

The design of the Fall Assist device does not require mechanical parts since the parts used consist of electrical sensors and control units. Therefore, in this section we will outline the physical characteristics such as the dimensions of the device. In the prototype version the dimensions for the device alone will be no larger than 10 cm by 10 cm by 3 cm. However, in the final product the dimensions will be reduced since in the final product only the individual components will be present, such as the analog to digital converter, the accelerometer, and the processor, as opposed to the entire microcontroller board. The weight of the microcontroller board is 50 grams. Figure 3.1 shows the maximum dimensions for the prototype device.

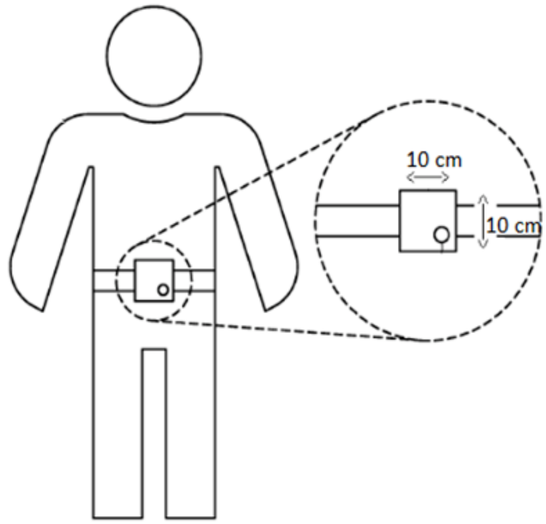

Figure 3.1: Maximum Dimensions for the *Fall Assist* Device

In the final product the belt which the device will be embedded in will be capable of fitting various waist sizes. The circle in the bottom right corner is a button that will be pressed to signal a false positive of a fall or if the user fell but does not need assistance. The button will be no larger than 1 cm by 1 cm.

3.3 Electrical Design

The microcontroller is at the center of our control system. The microcontroller will collect data from the accelerometer and output a signal to a Wi-Fi transmitter once a decision has been made as to whether a fall has occurred or not. The Wi-Fi module will transmit a signal to a web application on a computer. The system layout is shown in figure 3.2.

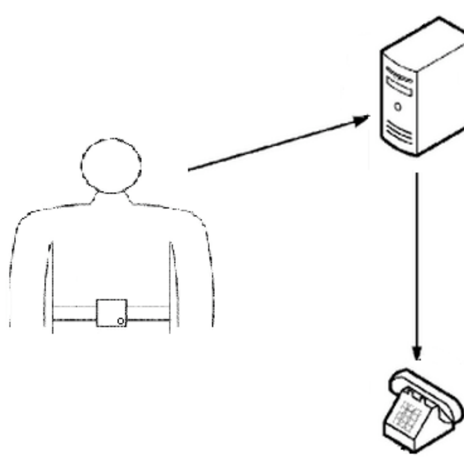

Figure 3.2: Figure Showing the Overall System Design

The microcontroller will be provided with power using a 3.7V Li-Polymer battery via an on board battery connector. The on-board battery charger circuit MCP73832 allows charging of the battery over a USB power source. The charging current value is approximately 250mA and charging voltage is 4.2V DC as figure 3.3 shows.

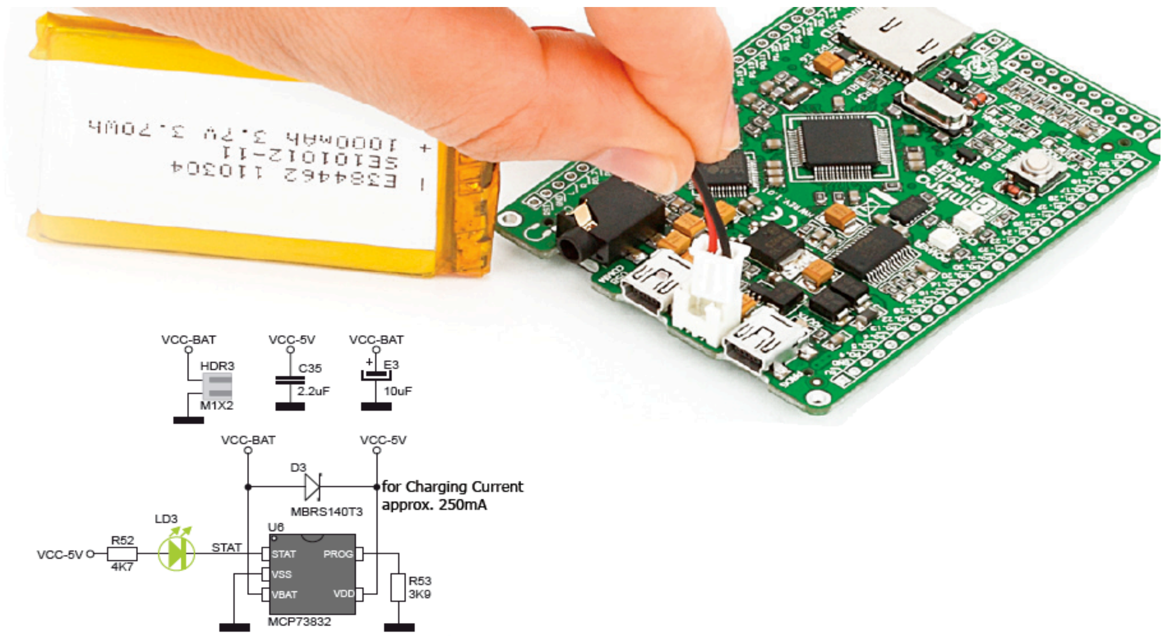

Figure 3.3: Figure Showing Battery Requirements and Charging Circuitry

The entire device will be placed in a water-proof case to prevent any damage and electrical shock. The EasyWi-Fi board is compatible with all mikroE development boards and is designed to use both 3.3V and 5V power. A voltage level jumper will be used to select the reference voltage from the device.

3.4 Power Design

The power is supplied through a USB cable of 5V DC. However, in our project our device will be portable and power will be supplied through a Li-Polymer battery. The microcontroller will be required to constantly be measuring the acceleration; however, when there are periods of inactivity the microcontroller will enter an idle state. In the idle state the microcontroller's power consumption is 50mA. In the power-down mode the oscillator is shut down and the chip receives no internal clocks. The state of the processor and registers and internal SRAM values are preserved throughout power-down mode. The power-down mode can be exited and normal operation resumed by either a reset or specific interrupts. The power-down mode reduces power consumption to nearly zero.

3.5 Safety Design

Safety is an important requirement for the design and the following issues are addressed:

- Electrical shock
- Water-proofing
- Sharp edges
- Over heating

The circuitry will be thoroughly checked for short circuits or for any excessive amounts of current so that over heating does not occur. In the final product the entire device will be shielded and enclosed in a plastic case to prevent any electrical shock and the device will be water resistant. There will also be slits in the case to prevent overheating of the circuitry inside. Below, figure 3.5 shows the encasing.

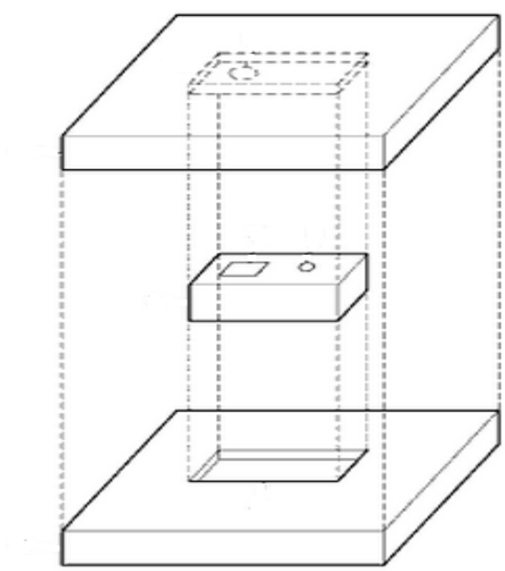

Figure 3.4: Plastic Encasing of the Electronic Devices

4. Microcontroller Design

4.1 ARM Microcontroller

The micromedia for ARM is a compact development system with a 32-bit ARM7 microcontroller LPC2148. Key microcontroller features are listed below [5]:

- 32-bit architecture
- Low power consumption
- 3D axis accelerometer
- Portable
- 512KB of program memory with external microSD card slot
- 32KB of RAM memory
- 64 pins
- 128 bit wide interface enables high speed 60 MHz operation
- USB 2.0 Full Speed compliant Device
- 2-UART,2-SPI, 2-I^2C

A few considerations were detailed when deciding what microcontroller we would like to work with. The first was choosing a development board with a three-axis accelerometer. This was essential since all our data we will be collecting will be coming from the accelerometer. Communication between the accelerometer and the microcontroller is performed over the I^2C interface. Secondly we would need a microcontroller that is small and lightweight so that it can be used as a portable device. The dimensions of the board are 8 cm by 6 cm and shown in figure 4.1.

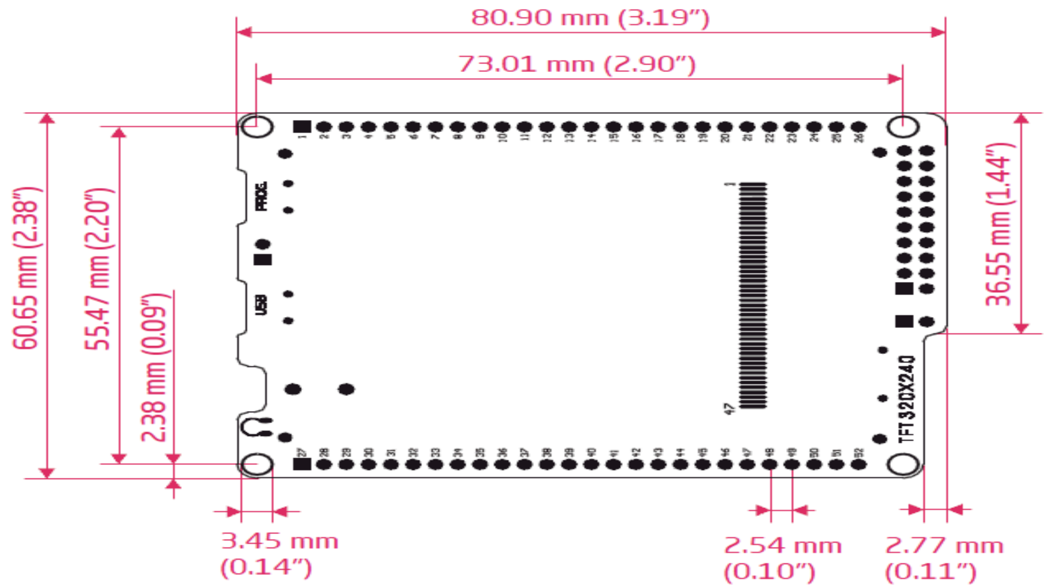

Figure 4.1: Dimensions of the Microcontroller

The weight of the board is approximately 50 grams allowing it to be a lightweight portable device. The last three important specifications were choosing a microcontroller board which contains a microSD card slot, an analog to digital converter (ADC), and architecture based on Reduced Instruction Set Computer (RISC) principles. The microSD card slot enables for large amounts of data to be collected from the accelerometer externally and uses Serial Peripheral Interface (SPI) for communication with the microcontroller. Also, the analog to digital converter was important to analyzing the data and the LPC2148 has a 10-bit ADC. Figure 4.2 below shows the ADXL345 accelerometer and the microcontroller.

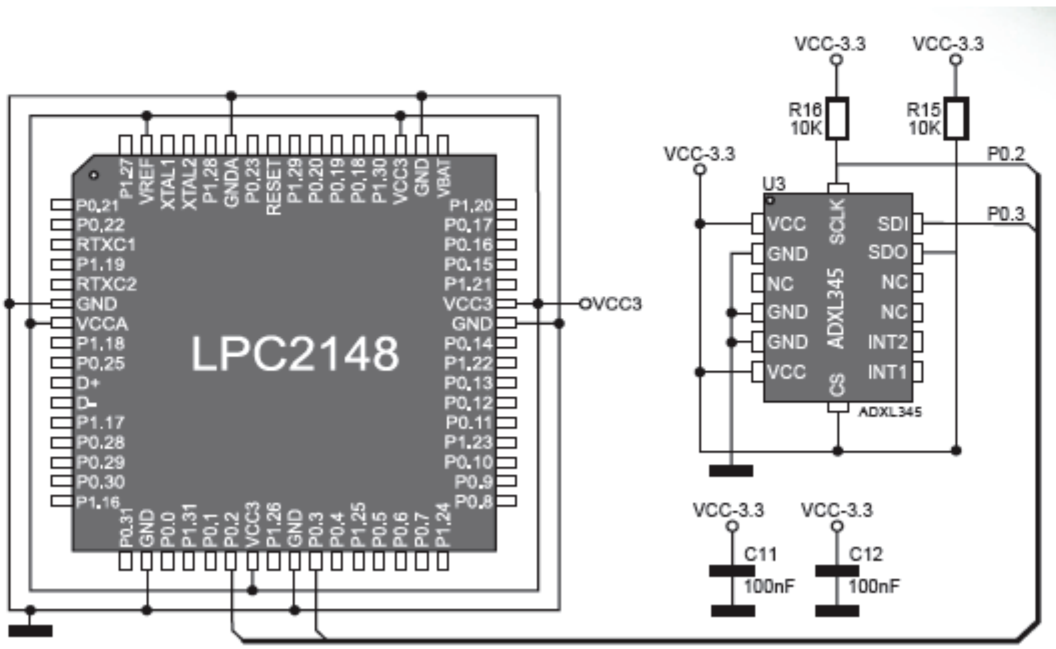

Figure 4.2: ADXL345 Accelerometer and Microcontroller

Since the software we will be using is free, we have a code size restriction of about 32Kb. Therefore, it is essential our algorithm is under these code restrictions. Since code size restrictions are of an importance the microcontroller board we chose also employs a unique architectural strategy known as Thumb. Thumb is a 16-bit super-reduced instruction set opposed to the standard 32-bit ARM set. The Thumb code is able to provide up to 65% of the ARM code while retaining performance because it operates on the same 32-bit register set as the ARM code.

5. Accelerometer Design

5.1 ADXL 345

The accelerometer is used to determine whether the detected fall is accurate. Since a person cannot fall in a unidirectional way, we chose to use a three-axis accelerometer to determine the acceleration vector. By using a three-axis accelerometer, we were able to detect the fall in three dimensions, which improved accuracy. When determining a fall, we had to take into account the fact that a person may fall at different accelerations and the person may become unconscious without hitting the ground. Thus, we had to use an accelerometer that is sensitive enough to detect a very small amount of change in acceleration in order to distinguish an actual fall from a false positive.

Following these requirements, we have chosen the ADXL345 accelerometer. Some of the desirable features in the ADXL345 are as follows [6]:

- High sensitivity (measurement up to ±16 g) that measures changes less than 1.0°
- Three-axis accelerometer
- Ability to measure static acceleration such as tilting and leaning
- Ability to measure dynamic acceleration such as sudden fall or shock
- Power efficient
- Small and thin design

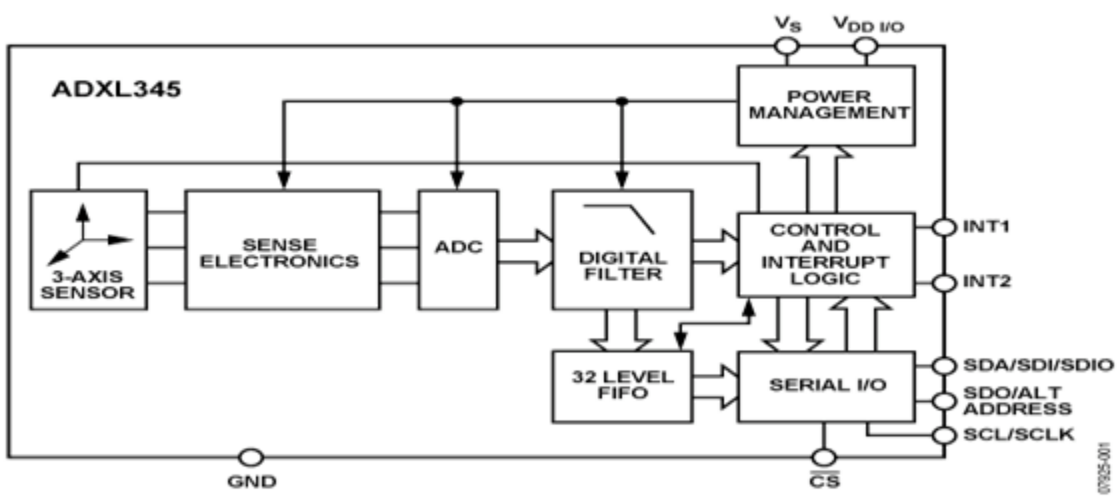

Figure 5.1: ADXL345 Functional Block Diagram

5.2 Other Designs Considered

5.2.1 Heat Sensor

Initially we considered using heat detectors to assist in fall detection. The basic idea was in conjunction with the accelerometer we would use heat sensors to detect that the person was on the ground. However, we have scrapped that idea because of the fact that a person may not need to fall onto the ground to lose consciousness. Moreover, this would have added additional components to the product which would make the initial setup and installation a lot more difficult.

5.2.2 Pulse Detector

A pulse detector would detect the heart rate from a user and use that information to determine the user's consciousness. However, a user that is in need of help does not always have to be unconscious. Also, the sheer complexity of such a method was too complicated for such a short time span and would result in a much higher cost.

6. Wi-Fi Design

6.1 EasyWifi Board

The *Fall Assist* device includes a wi-fi chip embedded in the device. The EasyWifi Board which has been chosen for our product is a 802.11b solution with high speed voltage transistors, which make it suitable for most microcontrollers. The board will communicate with the LPC2148 microcontroller using the SPI interface. The EasyWifi board can use either 3.3V or 5V voltage [6].

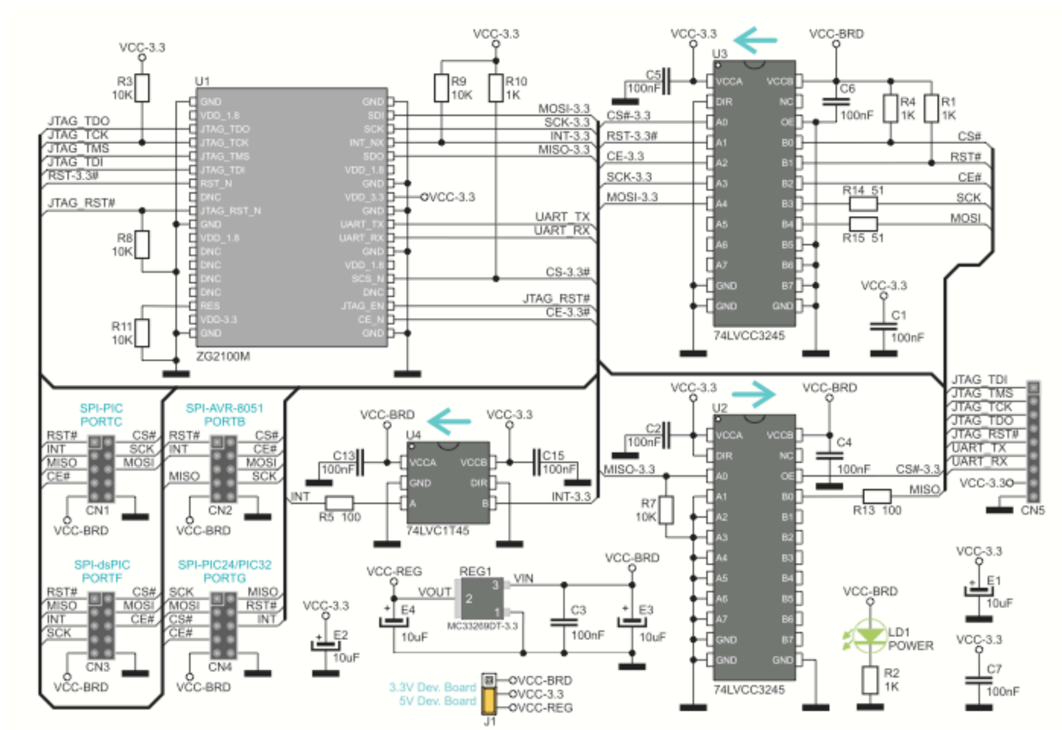

Figure 6.1: EasyWifi board connection schematic

Once the microcontroller detects a fall, it will send a message to the wi-fi board through the SPI interfaces. When the wi-fi board receives this message, it will contact to the web server that has been configured to and the web server will then contact the user.

There are three disadvantages of this approach:

1. The users must have access to a wi-fi connection as the device will not work without it.
2. The users will have to setup the device once with their wi-fi settings before they can use it.
3. The device will not work once they are outside of wi-fi range.

These problems can be averted by replacing the wi-fi board with a 3G chipset. If a 3G chip is used, the device will also be able to detect falls outside the user's homes. It will also be possible to add GPS inside the device which will pin-point the location of the user outside their homes. However, this component is not possible to implement in the given time restraints and we settled on using a wi-fi chip for our proof-of-concept model.

6.2 Other Designs Considered

6.2.1 Bluetooth Design

We considered using a Bluetooth chip in the device to communicate with a smartphone in the users' house. The smartphone would have an app which would receive the message when transmitted by the device and then send a text message to the user's emergency contact. There are several disadvantages of using this approach:

1. This design will require that the user have a smartphone with them. One problem is that elderly people do not use smartphones. [8].
2. The design will use the concept of polling (i.e. constantly checking for updates from the fall detection device). This will cause the battery of the smartphone to wear out within a few hours.
3. Smartphones need to be charged often. Since the elderly usually don't have very good memories, they might forget to charge their smartphones. Furthermore, if the smartphone is switched off, the device will not be able to contact the emergency contact and the device would be rendered useless.

7. Web Application Design

7.1 SMS Application Design

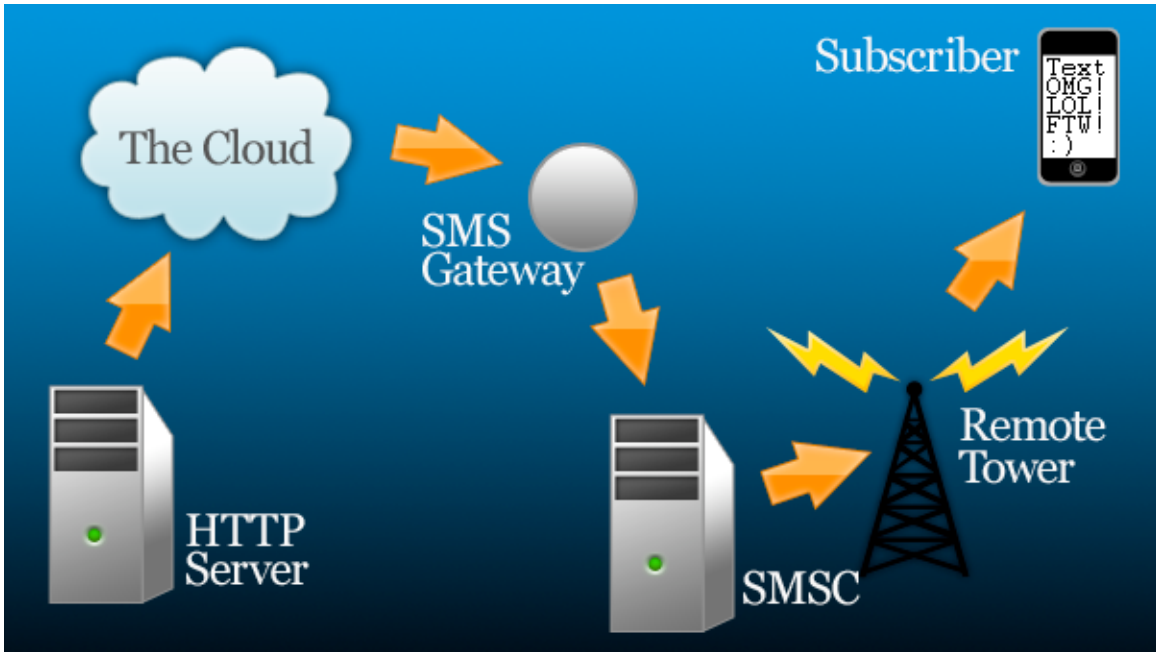

Figure 7.1: The communication between a web server and a cell phone

The following steps are involved in the sending of an SMS message over the web:

The message is composed using a web application which is installed on the website (www.ashishagarwal.com) and is sent as an email message. The web application consists of an HTML form and two PHP scripts. The email address depends on the carrier which the recipient is using and the following email addresses are used:

- If the carrier is Bell, an email is sent to phone_number@txt.bell.ca
- If the carrier is Rogers, an email is sent to phone_number@pcs.rogers.com
- If the carrier is Fido, an email is sent to phone_number@fido.ca
- If the carrier is Telus, an email is sent to phone_number@msg.telus.com

The email is received by a Short Message Service (SMS) Gateway which is owned by the carrier (one of the Canadian carriers – Bell, Rogers, Fido or Telus). The SMS Gateway then converts the message from an email message into an SMS message. The SMS message is then transferred from the SMS Gateway to a Short Message Service Center, which is also owned by the carriers. Finally, the message is then transmitted by the SMS Center to the users' cell phones.

7.2 Other Designs Considered

7.2.1 Smartphone App Design to Send a Message

Figure 7.2: SMS app on an iPhone

We considered making a smartphone application to send a text message to the user's emergency contact. The iPhone, Android and BlackBerry platforms were considered. This application constantly checks for a message from the Fall Assist device using Bluetooth. However, since Bluetooth is not feasible for this product, the idea was discarded.

8. System Test Plan

The test plan will be divided into two sub tests: a unit test and a system test. These tests will be carried out to ensure the device functions accordingly. In order for the device to function properly, it is critical that all the components are operating as expected and to meet this requirement the below milestones must be reached.

8.1 Unit Test

The unit test will ensure each component is working properly.

8.1.1 Microcontroller

The microcontroller must interact with the accelerometer, wi-fi chip, and the battery without bugs.

- Test the microcontroller so that all the major components are in sync with each other.
- Iron out the software so that it consumes less battery life.

8.1.2 Accelerometer

The Accelerometer must deliver the acceleration vector that defines the right fall.

- Be able to read the vectors.
- Fall testing: Wear the concept model and mimic a fall from a standing position. This will give us a sense of typical g forces that occur during a fall. The tester will not receive any external forces when falling (ie. pushing, shoving).
- Steady state testing: Wear the concept model and sit down or lie down naturally. The data samples acquired from this testing will give a range of acceleration vectors that are not to be considered a fall and are to be disregarded.
- Everyday testing: This will be explained further in system testing.

8.1.3 Wi-fi

The Wi-fi chip will maintain connection with a computer and correctly send packets when needed.

- Accomplish connection between the device and the computer, and maintain the connection throughout the house.
- Send a signal from the device and ensure that there is interaction with the web application.

8.1.4 Web Application

The web application is able to send a text message.

- Software can be properly installed onto a personal computer.
- Send a text message with the web application and ensure that the text message arrives and displays correctly.
- Test against various wireless carriers to make sure the text message can be delivered to anyone with cellular service in Canada.

8.1.5 Belt

The belt, which is the shell of the device, is functional and comfortable.

- Make sure the belt strap is comfortable and durable.
- Button to disable the device alarm is placed so that it is not accidentally pressed.

8.2 System Test

8.2.1 Overall System Functionality

Test the device's functionality as a whole.

- Test the overall device functionality: device alarm termination, alarm activation, sending a text message.

8.2.2 User Testing

Test the device on potential users to test its usability.

- Everyday testing: Wear the device and see if the device falsely alerts. The user will carry out his/her daily routine.
- Test the battery life to ensure that the battery life is substantial.
- Let the users perform actions, such as alarm termination, to ensure that users are capable of using the functionality when needed.

9. Conclusion

This document describes the design solutions to the requirements listed in the functional specification for *Fall Assist*. The components decided upon for these solutions were chosen based on their ability to closely match the requirements of the system while not going over budget. All specified functionality and safety requirements are expected to be met by the end of the development and testing process which is outlined above. Century Solutions fully believes that *Fall Assist* can improve seniors' living conditions and increase their happiness by allowing them to live independently in their own home for longer.

10. Sources and References

[1] Century Solutions, "Functional Specification for *Fall Assist:* a device to detect elderly people who have fallen" ENSC 305/440, February 6, 2012.

[2] M. Kangas, I. Vikman, J. Wiklander, P. Lindgren, L. Nyberg, and T.Jamsa, "Sensitivity and specificity of fall detection in people aged 40 years and over," Gait Posture, vol. 29, pp. 571-4, Jun 2009.

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[5] "ADXL345: 3-Axis, ±2 *g*/±4 *g*/±8 *g*/±16 *g* Digital Accelerometer" Internet: http://www.analog.com/en/mems-sensors/mems-inertial-sensors/adxl345/products/product.html [March 3, 2012]

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[8] Stuart Jeffries. "Do older people really struggle with technology?" Internet: http://www.guardian.co.uk/science/2007/aug/21/technology.news [March 1, 2012]