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February 16, 2009

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RE: Design Specification for the Smart Crutch

Dear Patrick:

Attached is the design specification document for the Smart Crutch system. The Smart Crutch provides a safe alternative to normal axillary crutch users by providing several levels of prevention and protection against user accidents such as falls and slips.
The three levels of safety features in the Smart Crutch system includes the warning system for avoiding slippery surfaces, the fall-prevention mechanism for stabilizing user composure in case of small slips and the remote emergency alarm system for notifying other people if accident happens.

The design specification outlines the high level system design for the Smart Crutch system. It specifies the design details in each of the following systems: the user interface, the microcontroller unit, the friction sensor, the motion sensor, the fall-prevention mechanism, the warning system and alarm system. In addition to the verbal explanation for each system, this document also provides detailed graphical description and schematics for parts arrangement in the Smart Crutch. It will be used as a valid reference for all of our design engineers during the product development and the final product testing phase.

ASA Concepts is composed of 5 engineers with a diverse background on mechanical, electrical and software skills. The following tasks are assigned for each engineer as follows: Amir Sadeghi – friction sensor development; Ben Lush – fall-prevention system development; Chien-Wen Lin – motion sensor development; Ming-Cheng Lin – hardware and microcontroller unit design; James Guerra – software development.

For any further questions please feel free to contact us through email, ensc440-asaconcepts@sfu.ca or through my phone

Yours truly,

Ming-Cheng Lin
Chief Executive Officer
ASA Concept

Design Specification for the Smart Crutch

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Executive Summary

The design specifications for the Smart Crutch outlines the detailed design description of the whole Smart Crutch system and detailed design descriptions of each individual component. The document doesn't specify any specific part components in terms of make and part number unless deemed necessary but specifies the requirements for each individual component. Mainly specifying design requirements allows the designers to have a flexible design approach and component choice.

The document is divided into several parts according to the main modules that make up the Smart Crutch including the high level system design. The main modules of the Smart Crutch includes the user interface, the microcontroller unit, microcontroller unit board, the friction sensor, the motion sensor and the fall prevention mechanism. The detail descriptions of the said modules are provided together with some proof-of-concept models or experimentation done.

System operation for the Smart Crutch starts at power on and user input of user information using pushbuttons and LCD display. During the normal operation, analog signals coming from the friction sensor and motion sensor are sampled by the microcontroller unit. Through average of the samples, a slippery surface is determined by the angle of the crutch with respect to the ground and the friction detected by the friction sensor. Based on the calculation for the stability of the crutch, the microcontroller unit then activates the necessary mechanism to help or prevent the user from falling which includes the warning system, the fall-prevention mechanism or the remote alarm system. If the remote alarm system is activated, a beeping alarm device will be activated using a radio frequency signal. If the fall-prevention mechanism is activated, a tripod mechanism will be released to stabilize the crutch and prevent the user from completely falling into the ground. Lastly, if the warning system is activated, buzzers and LEDs embedded on the crutch will be activated warning the user of potential slippery surface or crutch mishandling.

The high level system design of the Smart Crutch is included in this document. The high level system design includes the considerations for system integration and operation, overall electrical and mechanical aspects of the design and the system state operation of the device.

This document will be a basis for the current design of the Smart Crutch system. ASA Concepts' engineers however will not strictly base their design on this document. Flexibility on the part of the designer is encouraged as future problems with the design may be encountered but the functionality of the design is strictly enforced.

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Glossary

ADC	Analog to digital converter
ASK	Amplitude shift keying
Axillary	Armpits
BJT	Bipolar junction transistor
EMI	Electromagnetic interference
FCC	Federal Communications Commission
FPM	Fall prevention mechanism
IC	Integrated circuit
IEEE	Institute of Electrical and Electronics Engineers
IO	Input / output
LCD	Liquid crystal display
LED	Light emitting diodes
MCU	Microcontroller unit

1 Introduction

The Smart Crutch is a pair of underarm crutches equipped with friction and motion sensors that will teach the crutch user how to crutch properly to avoid sliding. With the friction sensing motor that measures the friction force and the motion sensor that measures the angle position of crutches, the system will undergo a detailed calculation based on these measurements to conclude if the user is prone to falling. By using a buzzer and LEDs as the warning message indicator, the Smart Crutch will instruct the user to reduce the crutch's angle in order to produce a bigger friction force to avoid sliding. The Smart Crutch is also equipped with the fall-prevention mechanism and the emergency remote alarm system for the user's safety concern. The design details for the Smart Crutch, as proposed by ASA Concepts, are described in the following design specification.

1.1 Scope

The scope of this document is to outline all the design details of the Smart Crutch in the current development stage. This document addresses the high level design and operation of the Smart Crutch. The specified mechanical design methodology with the graphical description for the friction sensor and the fall-prevention mechanism is also included in this document. The detailed part arrangement for the prototype including the alarm system, the motion sensor, and the microcontroller is also addressed in this document. The test plan is included in the end of the design specification and should be carefully followed in the final production phase.

1.2 Intended Audience

The design specification is intended for use by all the design engineers in ASA Concepts. All the engineers in this team should refer to this document to ensure that all the design requirements are met in the ongoing development stage. All the design guidelines discussed in this document should be followed carefully by the design engineers to achieve a favorable result in the final testing stage.

2 System Specifications

The Smart Crutch is intended for users properly using a regular axillary crutch in a one-point, three-point or four point gate procedure [1]. The Smart Crutch will have three basic functionalities: warn the user for slippery surfaces, prevent the user from falling and notify other people in case the user falls. The user will get notified using LEDs and buzzers in case a slippery surface is detected between the crutch and the ground. The tripod mechanism will be deployed in case the system detects that the user slips. In case the user completely falls with the crutch, an emergency RF signal will be sent to a remote alarm system of up to 100m away from the user.

The Smart Crutch will have three separate working units controlled by a microcontroller unit. The friction sensor which detects the friction between the ground and the crutch; the motion sensor which detects the angle of the crutch with respect to ground necessary for friction calculations and fall detection; and the prevention mechanism which will be deployed to help prevent the user from completely falling.

3 System Design

The following subsections describe the Smart Crutch overall system design. Detailed descriptions of the fall prevention mechanism, friction sensor, motion sensor and user interface are not included in this section.

3.1 High level system design

A microcontroller unit (MCU) will be used to control and monitor system operation. Based on the data taken from the friction sensor, motion sensor and the weight of the user, the microcontroller unit will determine the friction between the ground and the crutch, the instance of the crutch slipping or the instance of the crutch completely falling into the ground. Figure 1 shows a high level system diagram of the Smart Crutch while Figure 2 shows a simple picture of the Smart Crutch.

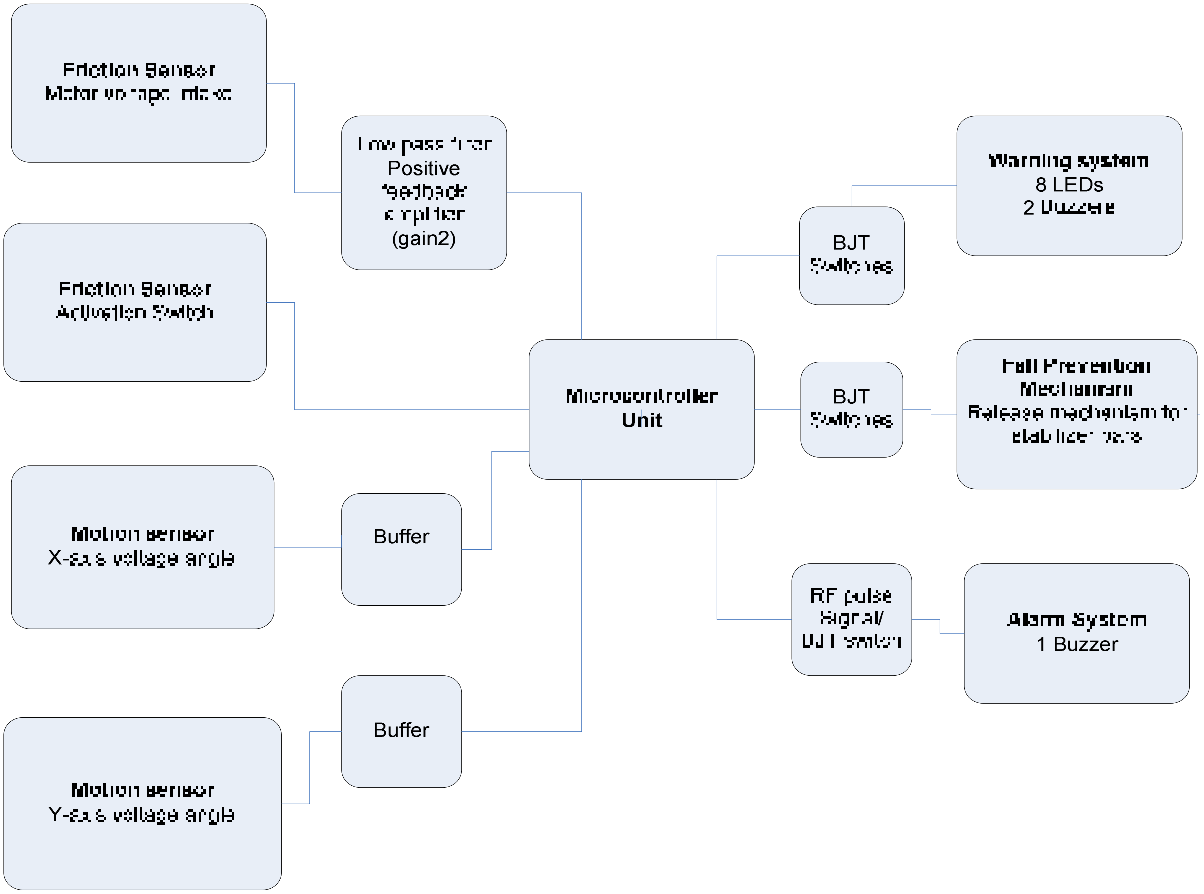

Figure 1: High level system design

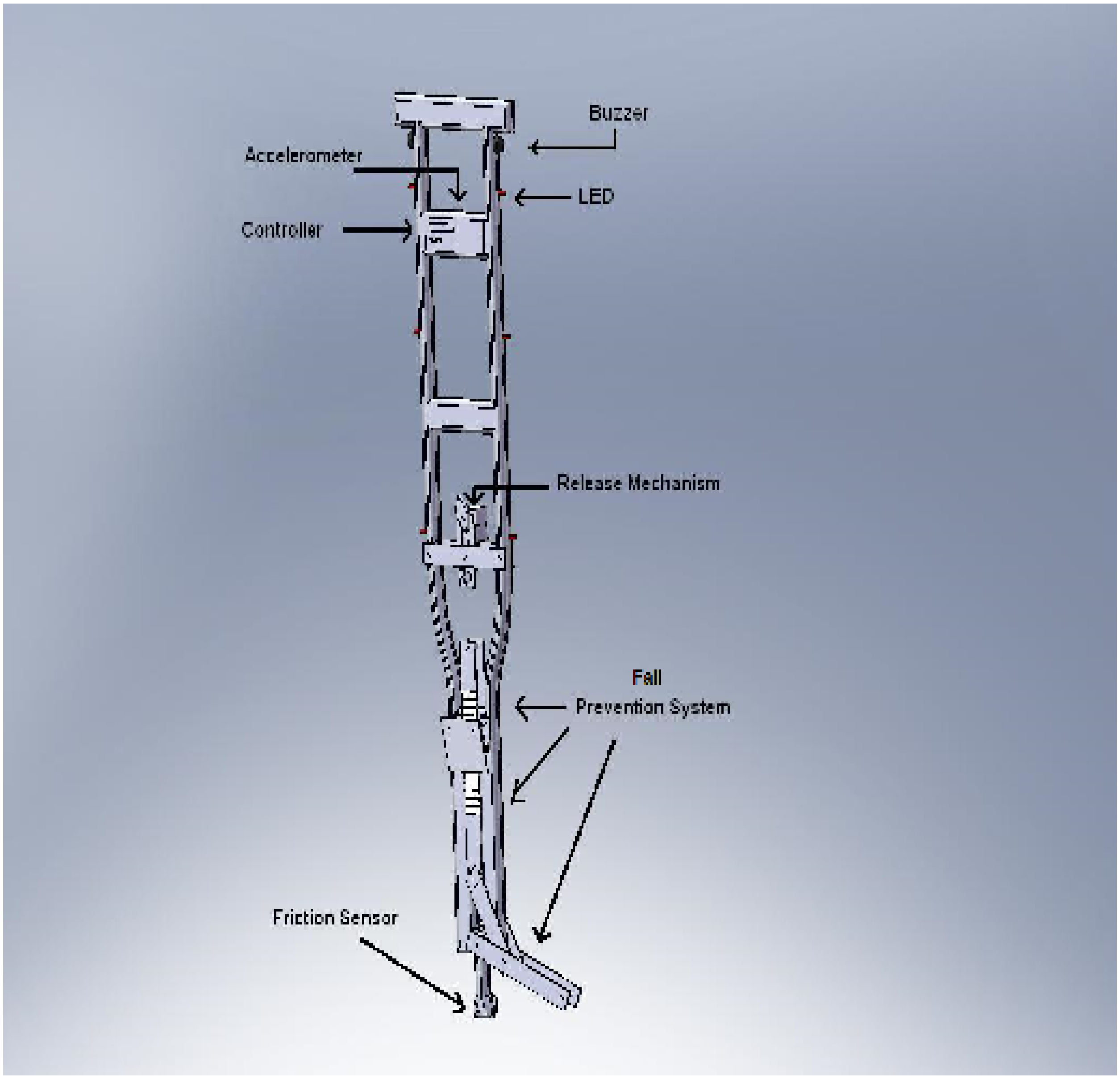

Figure 2: Smart Crutch system

3.1.1 Input components

Input signals coming form the friction sensor, motion sensor and user interface will be interpreted by the MCU. The input signal from the friction sensor will have a voltage range of 1.1V to 3 V after signal conditioning which includes an amplifier of gain 2. The motion sensor which consists of a 3-axis accelerometer will have 2 analog input signals to the MCU, one measuring the y-axis angle and the other measuring the x-axis angle of the accelerometer with respect to the ground. The input signals of the accelerometer to the MCU will have a voltage range of 0.7V-2.0V. Finally, the user pushbuttons will be used to power and reset the system, configuring system settings such as enabling friction sensor and remote alarm system and enter user information such as user identification and user weight.

3.1.2 Output components

Output signals consist of logic signals coming from the MCU which activates or deactivates the fall prevention mechanism, the buzzers and LEDs of the warning system and the transmitter for the remote alarm system. The logic signals serves as logic switches only that turn on/off the said components, e.g. a high signal coming from MCU turns on a BJT switch which turns on the LEDs. For the remote alarm system, pulses are sent from the MCU to turn on/off the remote alarm system producing a beeping pulse sound.

3.2 System state diagram

The Smart Crutch system will have a total of 5 distinct states. The IDLE state is the start state and the power saving state. It's activated upon power up before entering the USER_INFO state or if enough inactivity of the system is detected, i.e. 10 minutes of inactive significant value change from the motion sensor and/or friction sensor. The USER_INFO state is entered for entering user information after the IDLE state. The user information includes the user identification number and the user weight. User settings can also be optionally entered during the USER_INFO state. The SAMPLING state is activated after the USER_INFO state. The SAMPLING state is where the motion sensor and friction sensor are sampled by the MCU and values for the friction between the ground and the crutch is calculated or possible slipping detected. The WARNING state is activated if a slippery surface between the crutch and the ground is detected based on calculations done during the SAMPLING state. It is deactivated when a slippery surface is not detected between the crutch and the ground or if the user manually deactivates the WARNING state using a push button. The FALL_PREV state is activated when a minor slip has been detected between the crutch and the ground and deactivated after the logic signal used to release the fall-prevention mechanism has been sent. The ALARM_SYS state is activated if a sudden pulse (>1.9 V) is detected coming from the accelerometer's X and Y axis angles, i.e. there is a sudden fall of the crutch; or when the accelerometer reports the crutch at 0 degrees angle with respect to the ground, i.e. the crutch is lying on the ground. The ALARM_SYS state can be deactivated by the user picking up the crutch and the accelerometer reporting an upright crutch position or if the user deactivates the state using a push button.
Figure 3 shows the state diagram for the system operation of the Smart Crutch.

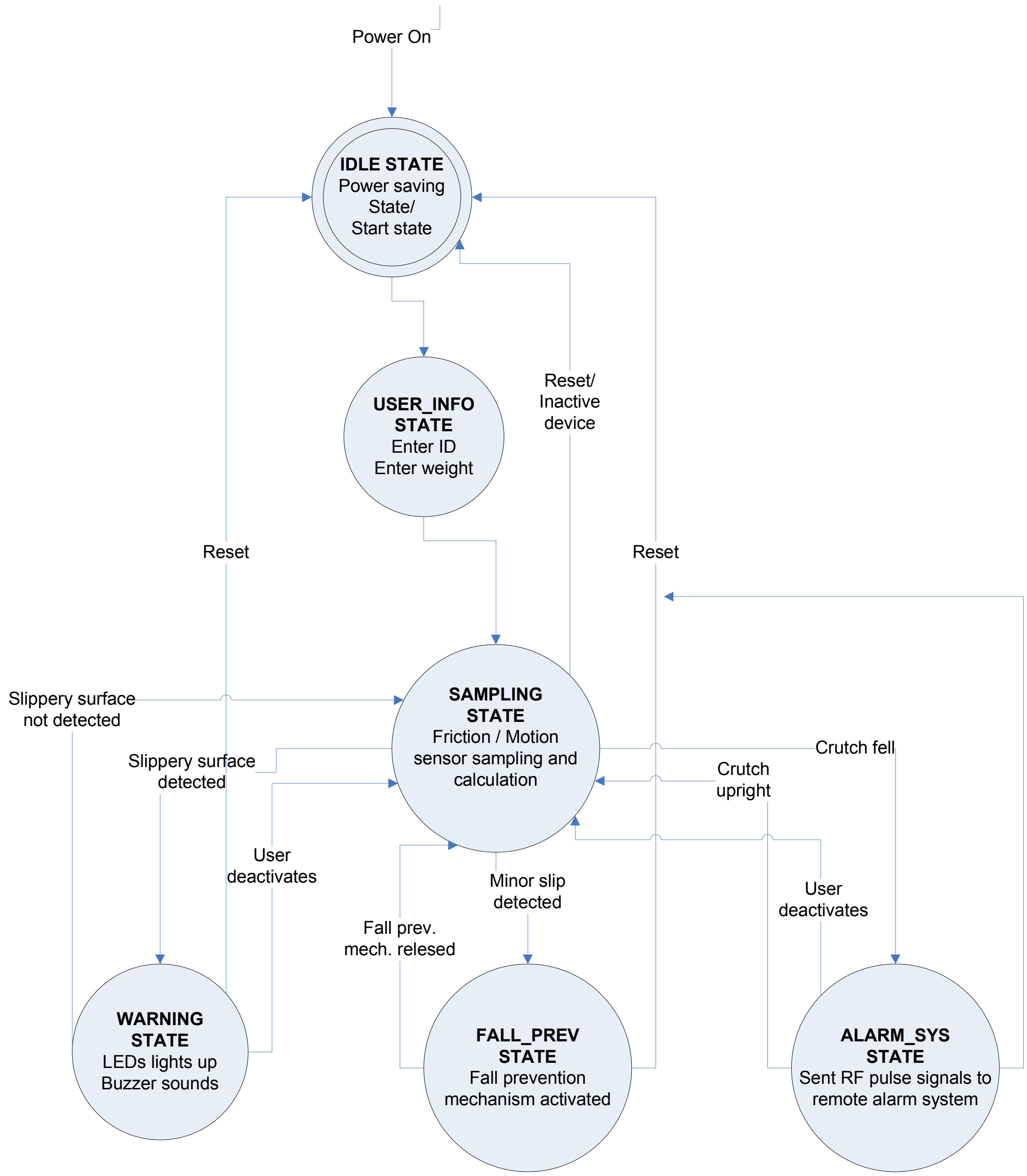

Figure 3: State diagram for Smart Crutch operation

3.3 Mechanical components

The three main mechanical components of the Smart Crutch includes friction sensor, the fall prevention mechanism and the accelerometer. The friction sensor is made up of a rotating wheel controlled by a high torque motor that barely touches the ground. The accelerometer is 3g tri-axis accelerometer located on the main controller board. Lastly, the fall prevention mechanism consists of two stabilizer bars held by a hook and release automatically using a motor. The mechanism is manually reset by the user using a pulley mechanism.

3.4 Electrical components

The electrical component of the Smart Crutch includes a 6V acid battery, the microcontroller unit and the microcontroller unit board. The microcontroller has ADC inputs for sampling analog signals coming from the sensor and several digital I/O connections for controlling or reading logic signals going into or going out of the LCD, the pushbuttons, and BJT logic switches. The MCU board has the main circuitry components such as the accelerometer chip, the LCD module, the pushbuttons, the ISP programming port and the BJT logic switches.

3.5 Other Considerations

The following subsections discuss other design considerations for the Smart Crutch.

3.5.1 Noise Considerations

During system operation, the Smart Crutch will be tested for possible noisy components. EMI will also be taken into account when making electrical connects between the electrical components.

The following lists possible approaches to minimize noise:
1. Shield motors to minimize noise produced during system operation.
2. Insulate all wirings and electrical connections between electrical components.
3. Carefully layout electrical connections between components in the MCU board to avoid possible EMI.
4. Follow FCC regulations pertaining to radiation limits that apply to ASK transmitters [2] to minimize interference with other RF devices.

3.5.2 Environmental Considerations

During system operation, the Smart Crutch is designed to address two main environmental concerns for the user: the noise generated by the system and the amount of radiation the user is exposed to. For the noise generated by the system, noise considerations for the design have been formulated (see above section, 3.5.1). For the safety of the user, FCC and IEEE regulations needs to be followed pertaining to safety standards of human exposure to radio frequency [3], [4].

The Smart Crutch is a module based system with components that can easily be replaced. The following table lists some components of the Smart Crutch and potential decommissioning procedure followed.

Component	Decommissioning suggestions
Rubber pads	Recyclable
Aluminum structure and mechanical components	Recyclable
MCU board	Circuit components can be unsoldered and reused or recycled
Friction sensor’s motor	Repaired (e.g. rewired) then reused

Table 1: Components of the Smart Crutch and possible decommissioning procedure

4 User Interface

The user interface provides the main interaction between the user and the system. The user interface consists of 5 pushbuttons which includes up, down, forward, backward, enter and reset pushbuttons for user input, a 2x16 LCD for the display and LEDs and buzzer for notification.

The following table summarizes the functionality of the pushbuttons and the LCD display for every system state.

STATE	User Input	User Input Function	Display
IDLE	Reset	Reset system	ASA Concepts logo
USER_INFO	Up	Increase numeral	-Display identification number or user weight as inputted by the user -Show message that remote alarm system is disabled/enabled
	Down	Decrease numeral	
	Forward	Go to the next new numeral input	
	Backward	Erase previous numeral input	
	Enter	- Enter user information - Disable remote alarm system	
SAMPLING	Reset	Reset system	Display sampling message
WARNING	Reset	Reset system	Display warning message
	Forward	Deactivate warning system	

ALARM_SYS	Reset	Reset system	Display alarm system message
	Forward	Deactivate remote alarm system	
FALL_PREV	n/a	n/a	Display fall prevention mechanism deployed message

Table 2: User interface operation

5 Microcontroller Unit Board

The MCU board will include the whole system circuitry including the microcontroller, LCD interface, user interface buttons, the 5V regulator power circuitry and the battery package, the accelerometer and RF transmitter, warning system circuitry (BJT switches), and the ISP interface for programming the prototype board through the development board STK500. We will hand solder the parts together on a protoboard. The desired layout for the initial design is shown in the following diagram.

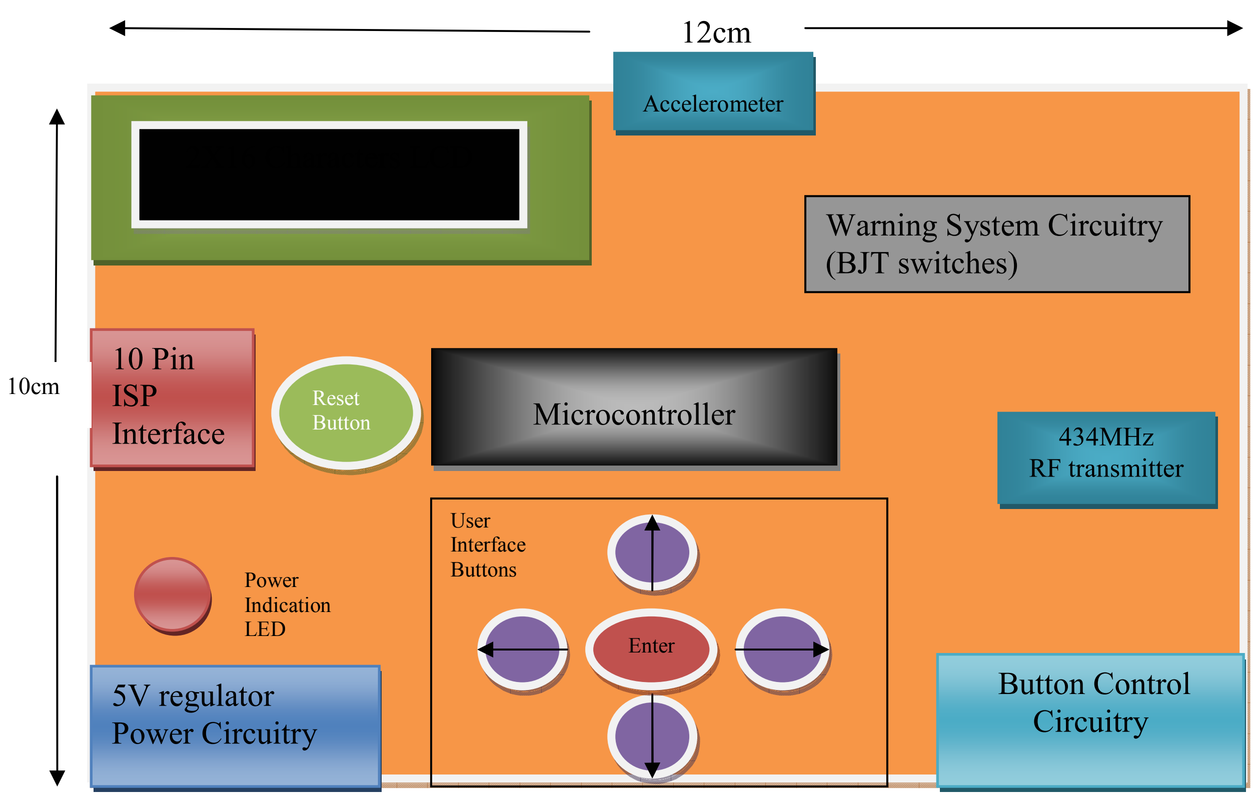

Figure 4: The MCU board layout diagram

The following subsection will discuss some of the hardware blocks with more details. In the end, we will list the overall pin assignment for the microcontroller.

5.1 Voltage regulator power circuitry

To power on the whole system including the MCU board and all the other sensors and motors, we will use a 6 volts battery package. It will go through a 5 volts regulator to power on all the circuit components. For the regulator, we will use a three terminal 5V regulator which can sustain up to 1A of current. The regulator is necessary for our project because we expect that the major current draw will come from the friction sensor, which draws 200mA in maximum from the experiment. In addition, the power circuitry will include a switch which allows the user to turn on and off the system and also a power indication LED to indicate if the system is powered on.

5.2 User interface circuitry

The user interface circuitry consists of the logic switches for LEDs and buzzers, the user pushbutton circuitry and the LCD display circuitry.

5.2.1 2x16 Character LCD

We use a 2 line X 16 characters black and white LCD display for our project. The LCD has 8 data bits for character writing and 3 control bits. All of them are connected to the specified IO pin of the microcontroller. 3 control bits are RS(Register select), R/W(Read or Write), and E(IO enable). The LCD needed a 5V voltage source and it is powered by the 5V regulator circuitry.

5.2.2 LED (BJT logic switch) circuitry

The LEDs are implemented for the system debug purpose for the programmer as well as the warning message for the user. The circuitry uses a NPN transistor to switch on and off the LED. The schematic is shown below.

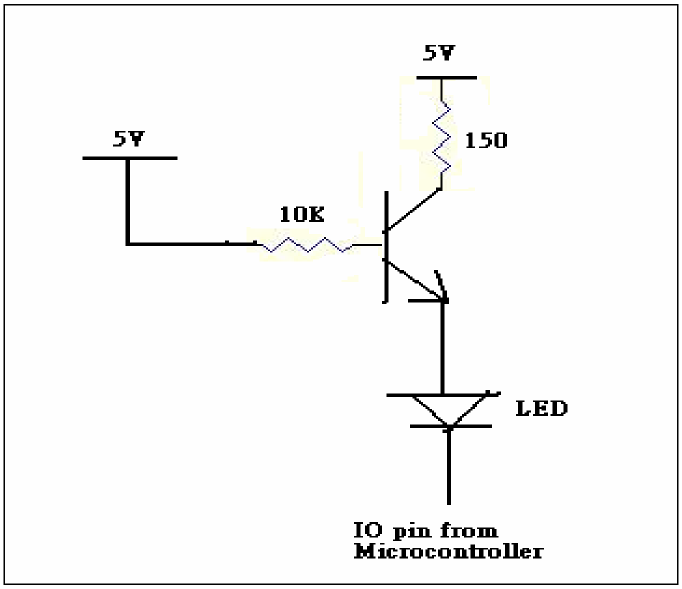

Figure 5: LED logic switch circuitry

From the schematic we can see that a logic low signal from the IO pin will turn on the LED and a logic high signal will turn if off.

5.2.3 User Button Control circuitry

From the prototype board layout, the system has 5 user buttons. We construct a button detection interrupt by using a NAND gate logic IC. Thus, when any five of the buttons is pressed, the NAND gate logic IC will produce a logic one output which is connected to a dedicated interrupt pin in the microcontroller. Once the system receives a button interrupt, the system will go through the button interrupt service routine which will check which button is pressed. Instead of connecting 5 individual buttons to 5 IO pins of microcontroller, we connect these five buttons to a 5 to 3 encoder IC. The three encoder outputs will connect to 3 IO pins of the microcontroller. By doing this we are able to save 2 IO pins of the microcontroller for other design purpose. The overall circuitry is shown in the following figure.

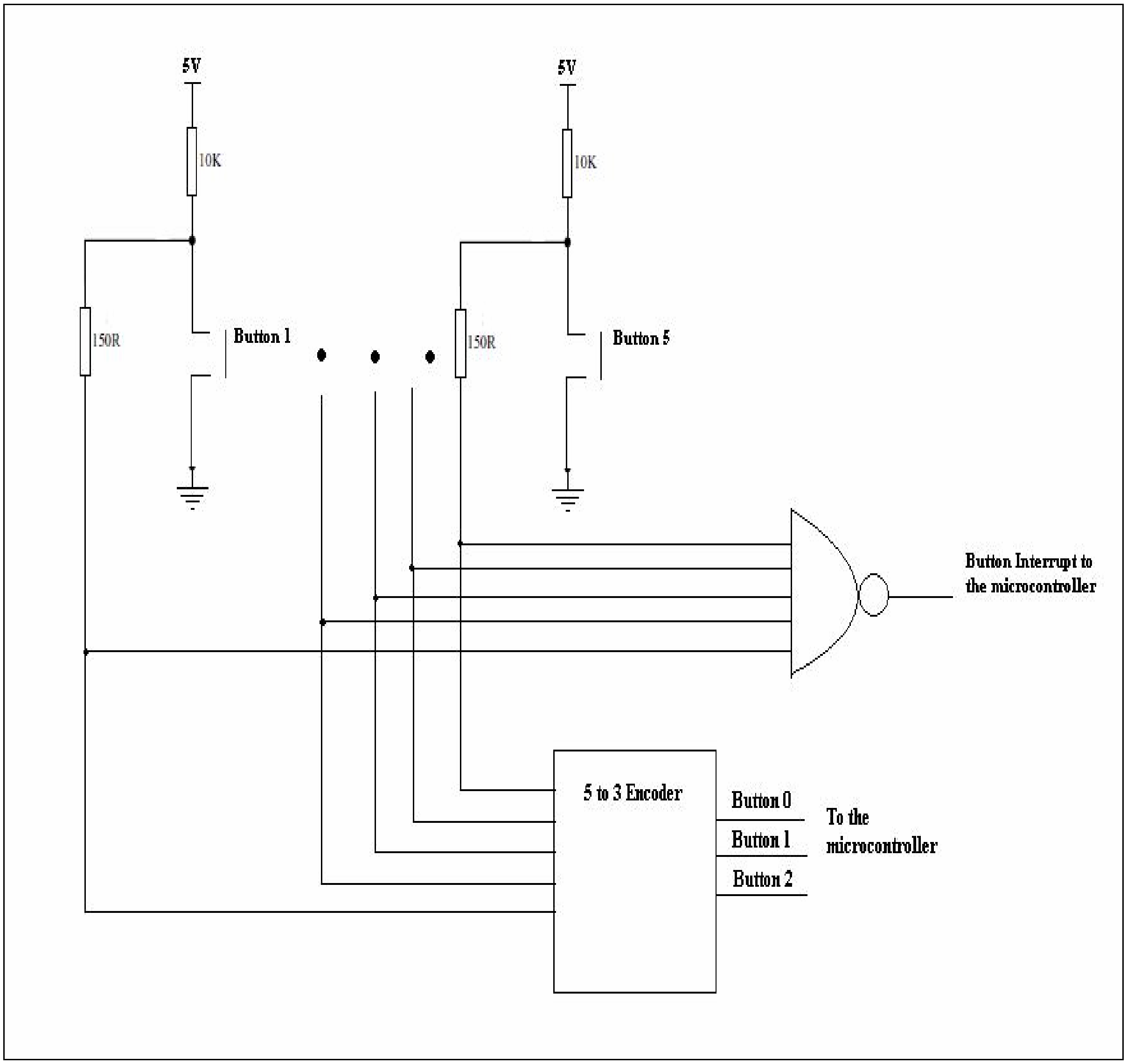

Figure 6: Button Control Schematic

5.3 Microcontroller unit ports

The microcontroller unit samples the analog signals coming from the friction sensor and accelerometer and calculates the possibility of slipping. Our microcontroller of choice is the Atmel ATMega16A which has 4 ports: Ports A, B, C and D.

For our A/D conversion, the ATMega16A documentation provides the following equation:

$$ADC = \frac{Vin \bullet 1024}{Vref} \qquad \text{eq. 1}$$

where, Vin is the analog voltage input to the MCU, Vref is the Aref external voltage (set as 4.8V) provided to the MCU and ADC is the final digital output obtained by the MCU. Also, according to the microcontroller's device datasheet, each port has certain pins that are dedicated for special purpose. For example, IO pins in port A can be used for A/D signal conversion. Some pins in Port B are dedicated for ISP programming but they can be used as IO pins once the programming job is done. Some pins in port D can be used for the system interrupt [5]. Therefore, based on the pin description of the microcontroller datasheet, we have made the following arrangement for all the IO pins and it is shown in the following table. Note that pins noted with N/E are not used in the current design stage.

Port A	**Pin Description**	**Port B**	**Pin Description**
A0	Friction Sensor enable	**B0**	Button 0
A1	Accelerometer X input	**B1**	Button 1
A2	Accelerometer Y input	**B2**	Button 2
A3	N/E	**B3**	Prevention Mechanism Enable
A4	N/E	**B4**	LCD control RS
A5	N/E	**B5**	LCD control RW
A6	N/E	**B6**	LCD control E
A7	N/E	**B7**	LED 0
Port C	**Pin Description**	**Port D**	**Pin Description**
C0	LCD Data 0	**D0**	LED 1
C1	LCD Data 1	**D1**	LED 2
C2	LCD Data 2	**D2**	Push button Interrupt
C3	LCD Data 3	**D3**	Friction sensor Interrupt
C4	LCD Data 4	**D4**	RF transmitter data
C5	LCD Data 5	**D5**	Buzzer warning system
C6	LCD Data 6	**D6**	N/E
C7	LCD Data 7	**D7**	N/E

Table 3: MCU pin assignments

5.4 ISP programming

The ISP interface is used for programming the microcontroller on the prototype board. There are four major signals: MISO(Master In Slave Out), MOSI(Master Out Slave In), SCK(Shift Clock), and RST(Reset). All four signals will be wired to connect to the dedicated pins of the microcontroller based on the device datasheet. We will build a 10 pin header to connect these programming signals to our development board STK500. The pin assignment for the 10 pin header is shown below.

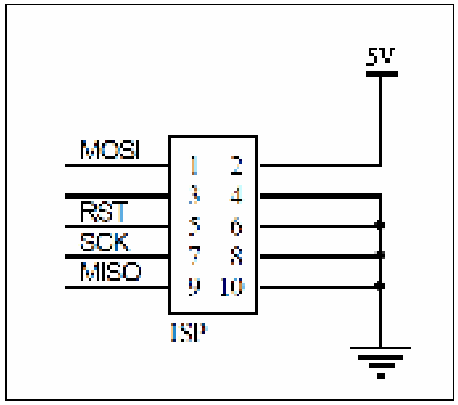

Figure 7: ISP header pin assignment

6 Friction Sensor

Friction sensor is a newly designed active sensor to detect the coefficient of friction of the ground using a motor. The friction sensor is not a sensor that can be picked up from a shelf. It was designed by our team and serves the microcontroller with a very close approximation of the coefficient of friction of the ground.

6.1 Mechanical description

To detect the coefficient of friction, a small motor that constantly rotates a small wheel that barely touches the ground provides the source of coefficient of friction between the ground and the crutch. The torque applied to the motor from the ground is proportional to the current drawn by the motor from the battery. By placing a resistor on the way of the input to the motor, the voltage across the resistor is measured. The varying electrical signal from the motor is fed to the microcontroller unit for interpretation.

In order to achieve the true value of the friction, the wheel has to be suspended from the crutch in a way that the force applied by the user to the crutch does not affect the torque applied due to friction. In order to achieve the goal, the motor is placed under a cylindrical shaft inside the lower pipe of the crutch down to the bottom of the rubber pad. The cylindrical shaft is then suspended by a spring with a very low spring constant. The spring is placed around a male fitting that is inside a female fitting. The ends of the two fittings limit the spring from over expanding. The other end of the spring fitting is attached to the body of the pipe using a bolt and a nut. Figure 8 bellow shows the details of the installation of the motor/wheel system.

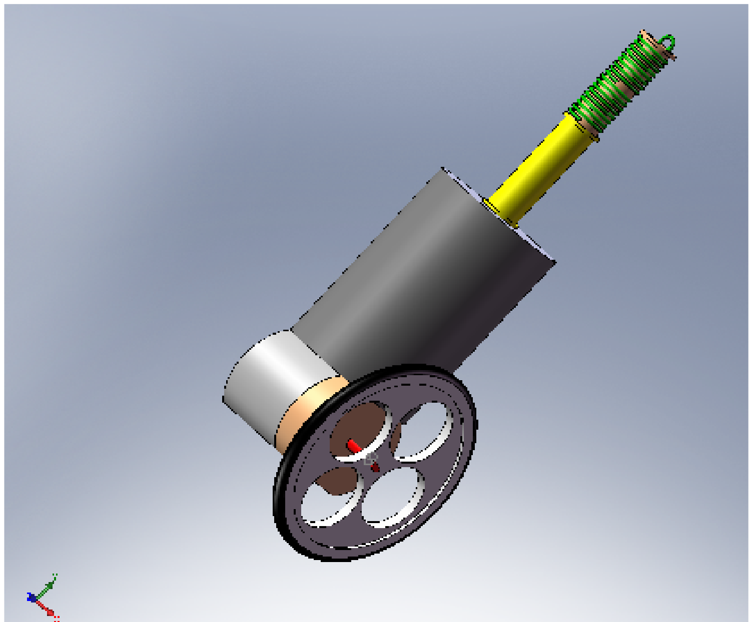

Figure 8: Structure of the Friction Sensor

The rubber pad goes around the bottom of the pipe and there exists a cut out on it which lets the wheel to stick out of the crutch and at the same time be connected to the motor inside the pipe. The same size and shape cut-out is on the pipe itself which provides enough space for the motor to move up and down inside the pipe. Figure 9 shows the shape of the pipe and the rubber pad under the crutch.

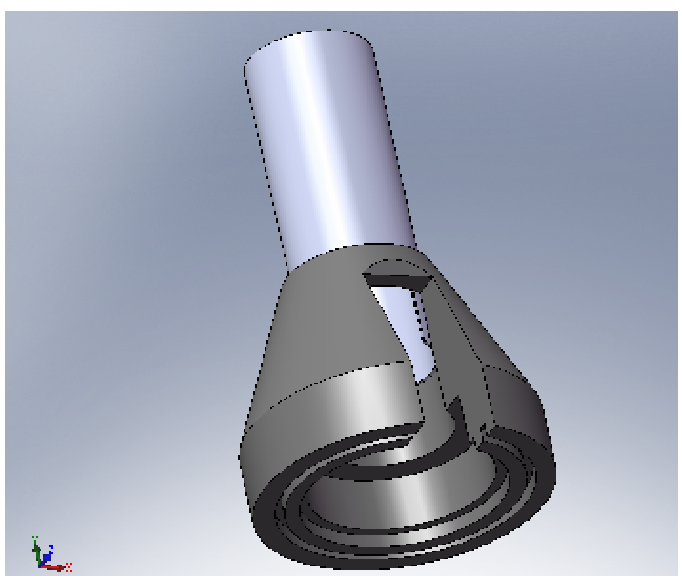

Figure 9: Rubber Pad and Pipe Cut Outs

In order to eliminate the force exerted by the ground to the wheel, a bearing system is needed around the shaft inside the pipe. The bearing makes the shaft move up and down smoothly.

Due to the cost of customized bearing and limitation of time, the second alternative was picked which is a rounded rubber disk. The rubber disk is placed under the motor and it is level to the wheel parallel to the ground by an overall crutch angle of 30 degrees. Using the crutch with a 30 degree angle from the user's body, the rubber pad pushes the whole motor/wheel system up to a point that the wheel is only touching the ground. Therefore, there is no extra force exerted by the ground to the wheel. The robber disk is the same material as the robber pad under the crutch which gives the pad its full surface area to handle the weight of the user and prevent the user from slipping. Figure 10 provides an overview of the bottom of the pad.

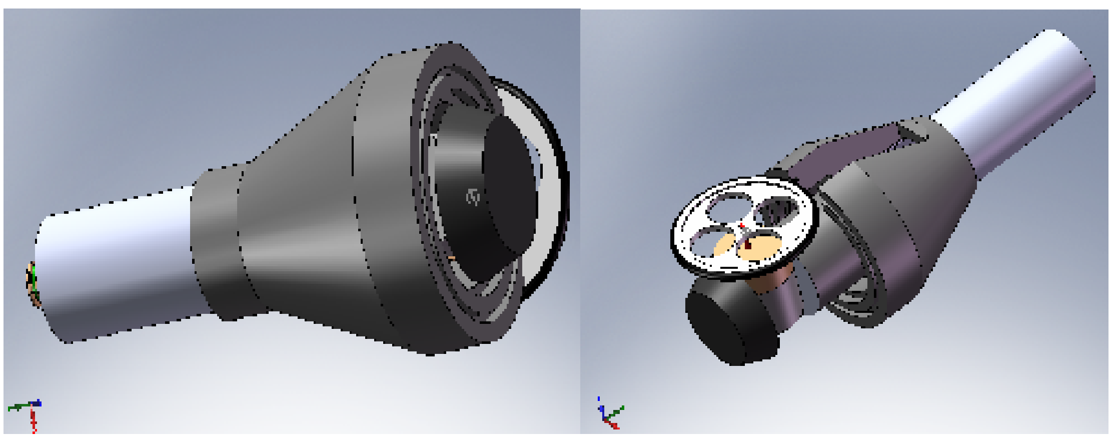

Figure 10: Rubber Pad and the Robber Disk Arrangement

When the crutch is lifted off the ground, the current drawn by the motor is minimal. In order to feed the microcontroller with the right information at the right time, having an activation switch under the rubber pad is required. The activation switch informs the microcontroller via interrupt that the crutch is on the ground. Figure 12 shows the exact placement of the activation switch at the bottom of the rubber pad under the crutch. The exact place of it was chosen in a way that most likely is the first point of the crutch touching the ground. The switch has a 45 degree angle to the bottom surface of the pad.

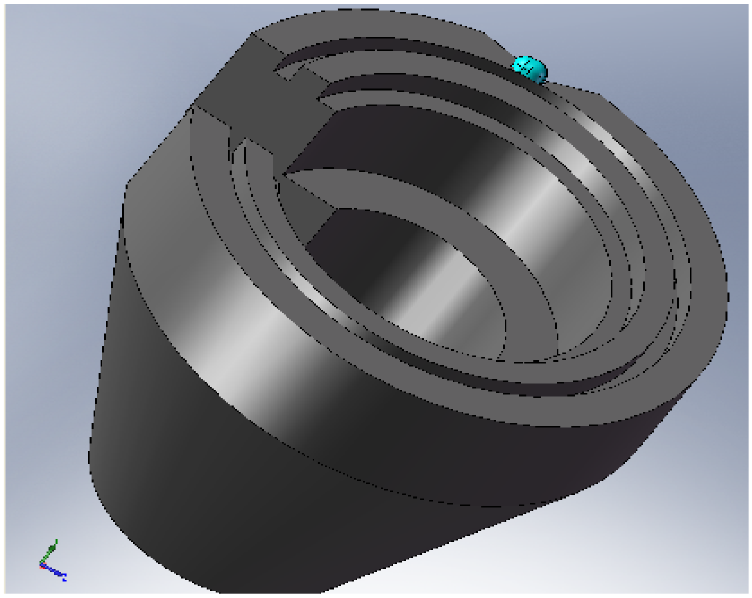

Figure 11: Activation Switch on Robber Pad

6.2 Electrical description

The motor is directly connected to the power supply and it spins with a constant speed of approximately 60 rpm. By spinning on different surfaces, the motor draws different amounts of current from the power supply, the variation of current found to be around 0.05 (A) to 0.15 (A) . There is a resistor on the way of the input to the motor by which a variation of voltage can be detected. Through experimentation, this resistance was chosen to be 15 (ohms). The voltage across the resistor is linearly proportional to the current drawn by the motor. The voltage variation was found to be between 0.55 (V) to 1.50 (V) for different surfaces.

In order to achieve a better signal to feed the microcontroller with, the voltage across the resistor gets filtered using a low pass filter, which helps reducing the noise of the signal. In addition, to have a better variation of voltage, the output signal from the filter gets amplified using a voltage amplifier of gain 2. This amplification serves the microcontroller with voltage range of approximately 1.10 (V) to 3 (V). The signal is connected to an analog to digital converter to the microcontroller where the signal is converted to its digital values for further calculations. Figure bellow shows the circuit diagram of this configuration (Figure 12).

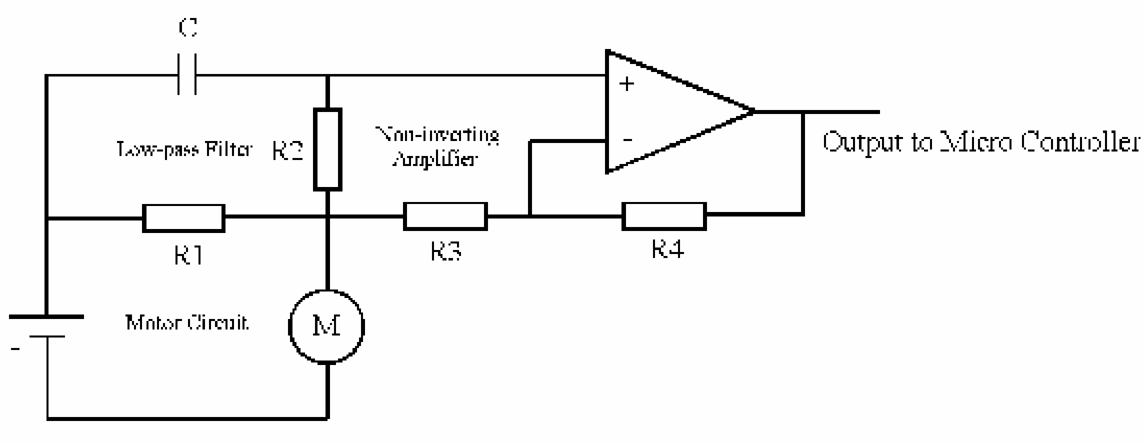

Figure 12: Circuit Diagram of the Motor Signal

6.3 System operation

The system was tested on different surfaces at the point of slip to find the relationship between the voltage across the resistor (the proportional value to the coefficient of frication of the ground) and the voltage out of the accelerometer (the proportional value to the angle of the crutch and the surface). The extremes of surfaces were also included in the data such as carpet which has an extremely high coefficient of friction and ice which has a very low coefficient of friction.

Data was recorded at the time of slip on different surfaces and for different user weights. Figure 13 shown bellow is a sampled graph of voltage output of the accelerometer versus the voltage output of the friction sensor at the angle of slip for an assumed weight of 70kg. As we can see the relationship is approximately linear which makes the experiment reliable.

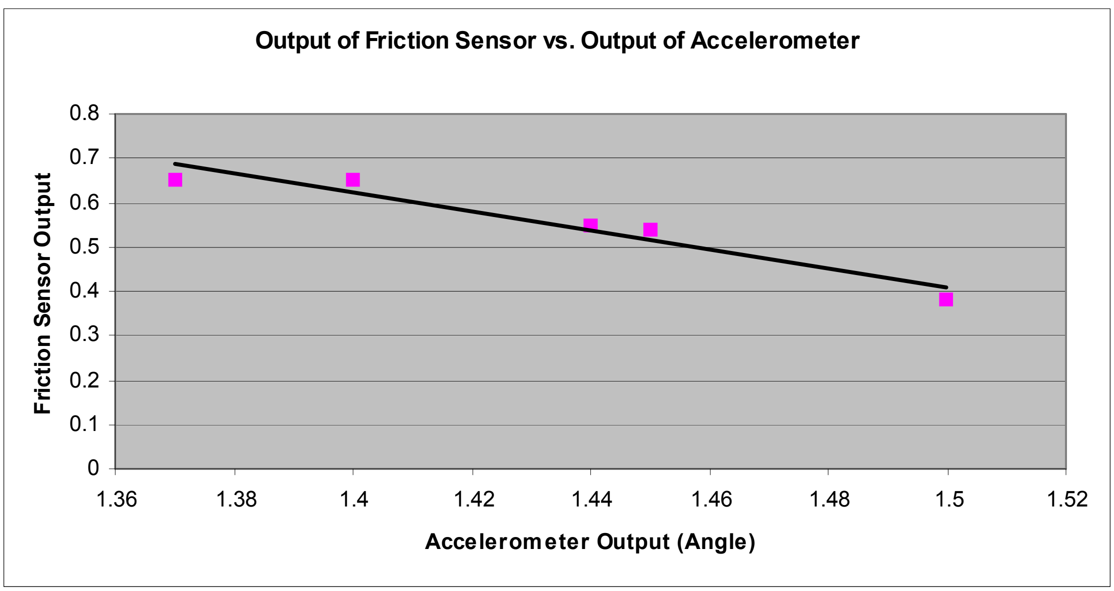

Figure 13: Output of Friction Sensor vs. Output of Accelerometer

The microcontroller samples the analog signal from the motor, converts it into digital value and calculates the average of the samples in a short period of time. Then it multiplies the value by half of the value of the weight which is given by the user. It then closely approximates the angle of slip by the line in Figure 14. The microcontroller then compares the value of the slip angle with the voltage out of the accelerometer. If the calculated value is more than the value from the accelerometer, it activates the preventing system to protect the user from falling.

Experiments have to be done in order to evaluate the warning stage of the crutch. In order to do that, sampling should be done at the point that the crutch is unstable and there exist a chance of slip but it is not in the merge of slipping. The micro controller then has to compare these values with every calculation as well to activate the buzzers and LEDs.

5 Motion Sensor

Our accelerometer of choice is the XL330K which will be used for detecting the tilting angle of the crutch with respect to the ground and the acceleration of the crutch during sudden movement. It will output different voltage values corresponding to a particular angle from around 0.5 to 2.5 voltage range. It can also detect 3-axis falling, but this part has to be tested later on to see how many axis are needed to detect a falling motion. The normal reference voltage is 1.673 V when the sensor is at 0 degrees with respect to the ground. In case of sudden motion, i.e. a motion having acceleration greater than 1g, the XL330K accelerometer will send a voltage pulse of greater than 2.0 volts. Those voltages will be sent to microcontroller for further angle or impact analysis.

The accelerometer is going to be implemented above the controller box and parallel to the crutch handler. It detects X and Y axis motion of the crutch. The implementation is shown in Figure 14.

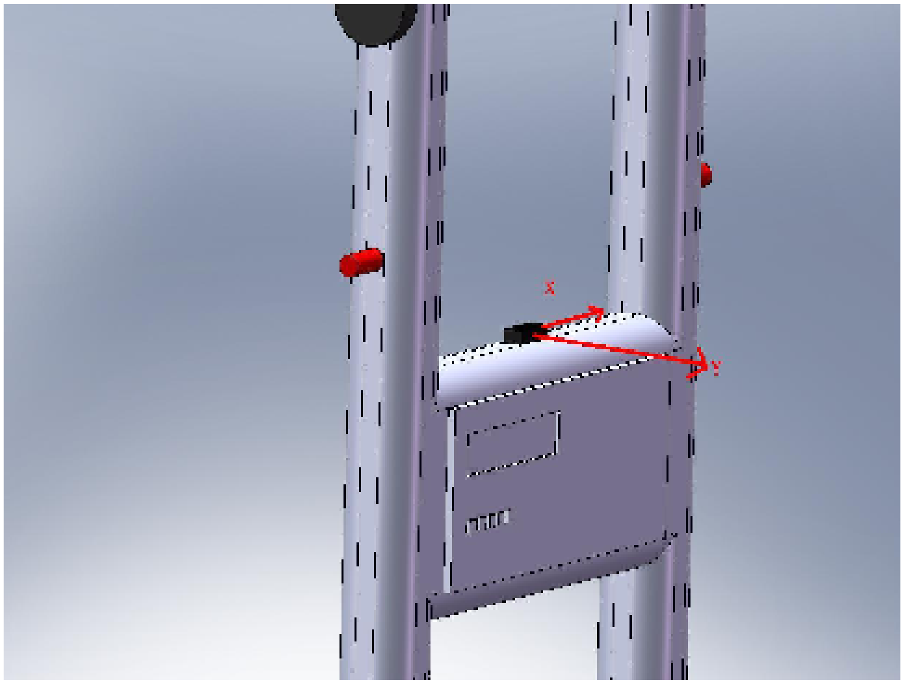

Figure 14: Accelerometer orientation

The X axis angle corresponds to the forward and backward tilting motion of the crutch. The angle detected must be in the range of -90 to 90 degrees. The Y axis angle corresponds to the sideward tilting motion of the crutch. The angle detected must be in the range of -30 to 60 degrees. Figures 15a and 15b shows the X and Y axis angles of the crutch with respect to the ground respectively.

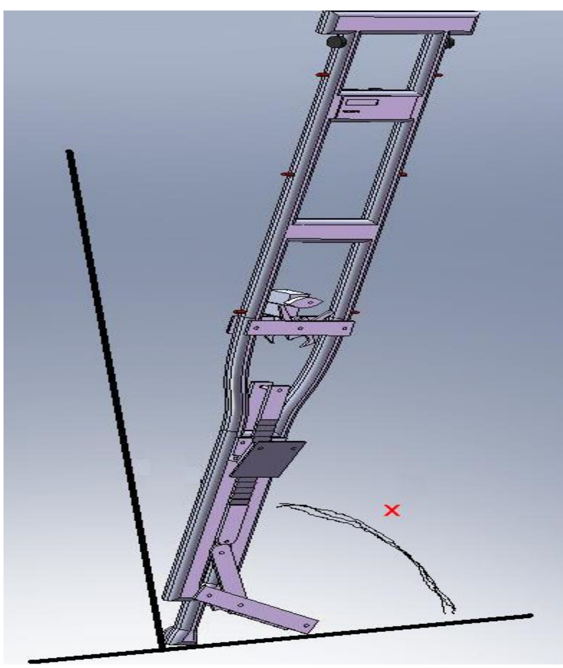

Figure 15a: X axis angle of crutch

Figure 15b: Y axis angle of crutch

6 Remote Alarm System

The emergency alarm system is activated when the microcontroller detects a sudden fall of crutches, i.e. >1g motion or an X and Y axis angle detection that the crutch is lying closely parallel to the ground. This feature can also be disabled by the user after the system power up.

The alarm consists of two 434MHz RF transmitters, one 434MHz RF receivers, a couple of LED diodes and a buzzer for emergency notification. Two RF transmitters are mounted on two crutches respectively with the data input pin connected to one of IO pins of the microcontroller. When crutches fall, the microcontroller will send out a series of pulse signal to the RF transmitter. The RF transmitter will then send out the pulse to the RF receiver and thus buzzers and LEDS will be turned on and off based on the pulse. The schematic for the emergency system is shown below.

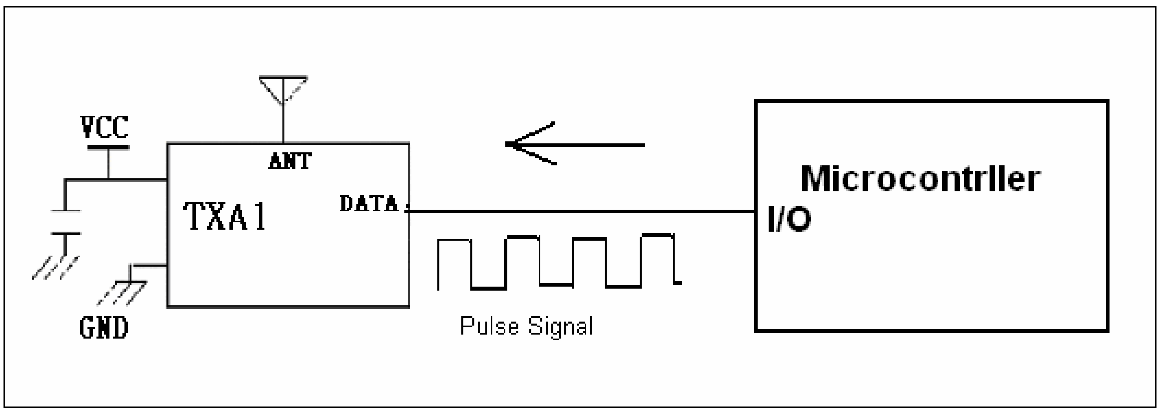

Figure 16: The transmitter schematic

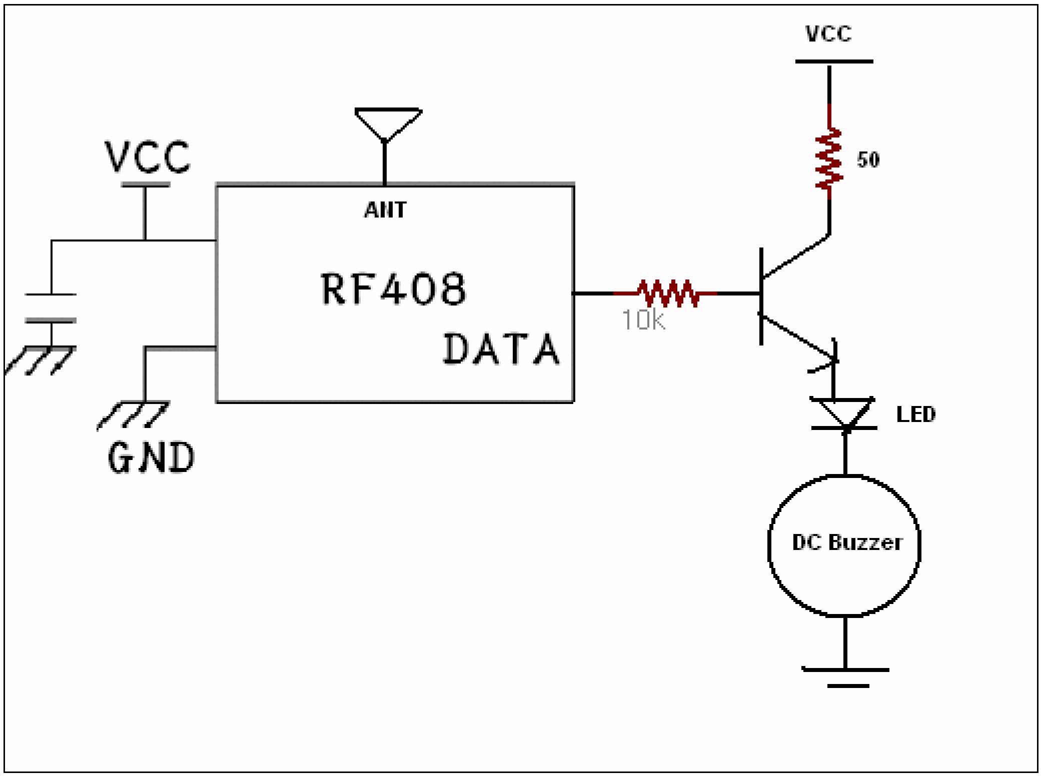

Figure 17: The Emergency Alarm System schematic

Both transmitter and receiver are powered by 5V power source. The transmitter will share the same power source with the MCU board. The alarm system with RF receiver will be powered by a 5V battery package.

7 Fall prevention mechanism

The fall prevention mechanism (FPM) is a new addition to the standard crutch that provides the user increased stability after the crutch has gone through an area of low friction. To accomplish this, whenever the microcontroller determines a low friction has been detected the FPM will be activated. It consists of one motor, pivoting bars, sliders, unidirectional gears, springs, and a grabbing mechanism.

7.2 Mechanical design

7.2.1 Dual parallel two bar and slider mechanism and spring

This mechanism is mounted on the lower region of the crutch, the pivot is placed 2"(need exact measurements) above the plastic joint leaving the pivot 7" above the ground. The main pivoting bar is a straight 1"wide x 7"long x "1/8"thick 5000 series aluminum flat bar with the fixed joint ½" up, then the secondary joint 4 ½" up. The secondary joint connects the main pivoting bar to the slider. This bar is 1"wide x 3"long x 1/8"thick 5000 series aluminum flat bar with two joints ½” from the ends. The end jointed to the slider is rounded to a half circle 1” in diameter. The slider is a 0.9”wide x 1/16”thick x 3”long 5000 series aluminum hollow round bar with two 5/16” holes drilled through the horizontal centerline each ½” from the ends. This slider fits snugly into the center pipe of the crutch. Figure 17 shows the dual parallel slider bar mechanism when it’s deployed.

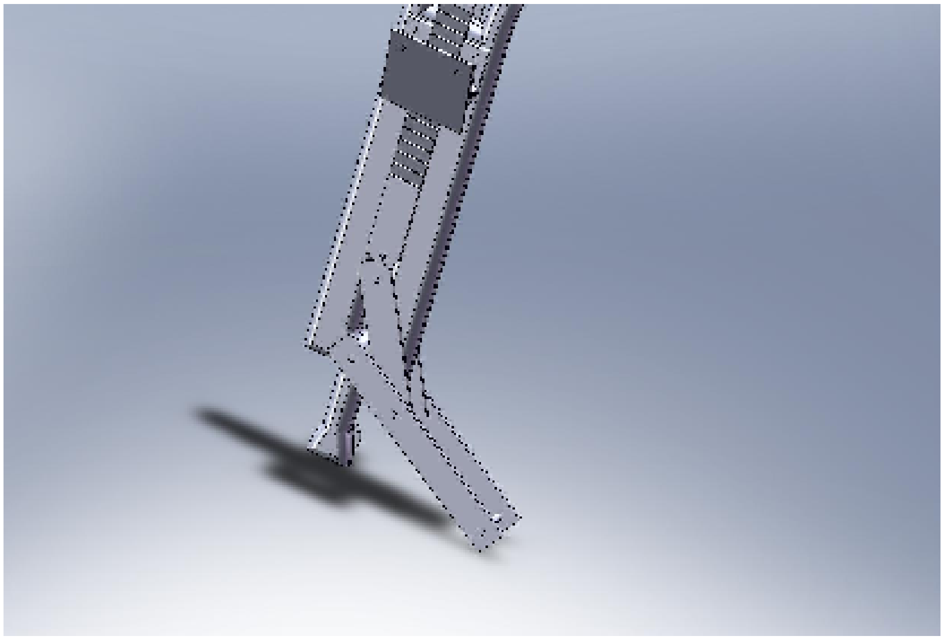

Figure 18: Dual parallel bar slider mechanism

Each joint is 5/16”, and ultimately we would like to use steel rivets for the joints to allow a sleeker design, with lighter weight, and lower cost. However right now we are using zinc plated steel bolts, galvanized steel washers and zinc plated steel nut with nylon threading all 5/16” diameter. The main pivoting joint has a bolt length of 3”, the slider joint uses a bolt 2 ½” long, and the middle joint has a 3/4” long bolt.

The main pivoting bar is placed on top of the secondary bar, giving the parallel width of the main pivoting bars to be 3” wide. The spring is a normally open ¾” diameter 8” long that can be compressed to 2”. It is fitted inside the middle bar of the crutch. It is fastened to the top part of the middle bar and pushes against the slider to provide force for movement. It has a normal k value close to 10 N/m. Figure 18 shows the dual parallel slider mechanism on its reset state.

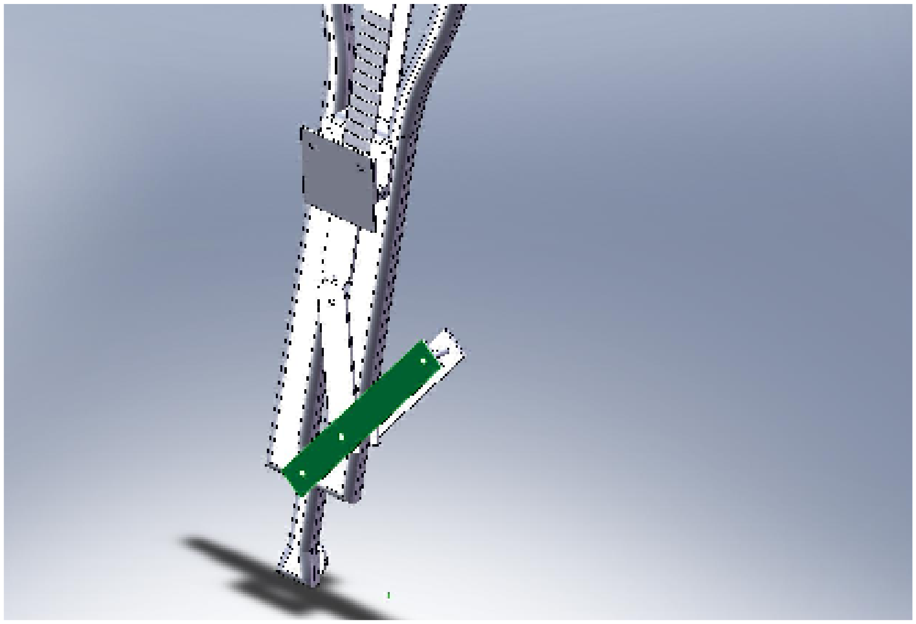

Figure 19: Dual parallel slider mechanism on reset state

7.2.2 One way gear and retracting mechanism

The one way gear is cut from 1"wide x 9"long x 1/8"thick 5000 series flat bar, it consists of 7 saw tooth shapes facing downwards starting 1" from the top. Each tooth is spaced ½" apart. The design allows for small stopping intervals and easy sliding in the forward direction. The bar is jointed to the slider from the dual-two-bar-and-slider mechanism and is what allows the slider to halt. What causes the saw tooth to catch is an aluminum plate that is angled across the surface of the gear. This plate is 2" wide x 3" long x 1/16" thick, it is secured onto a spring loaded device similar to that of a cloths-peg or a clipboard. This device allows the plate to apply consistent pressure on the gear so when a reverse motion happens the plate will catch on the saw teeth. There is a hole in the plate in which a rope is attached, it pulls against the device to allow the saw teeth to move in the reverse direction and go back to the starting position. This rope is connected on one enc to the plate on the other end to the top joint of the gear. In the middle of the rope is a pulley which allows the plate to first be released, then the gear to be pulled back. The force used to pull back the gear is supplied by the user. Figure 19 shows the slider bar being held by the one way gear while Figure 20 shows the slider bar released.

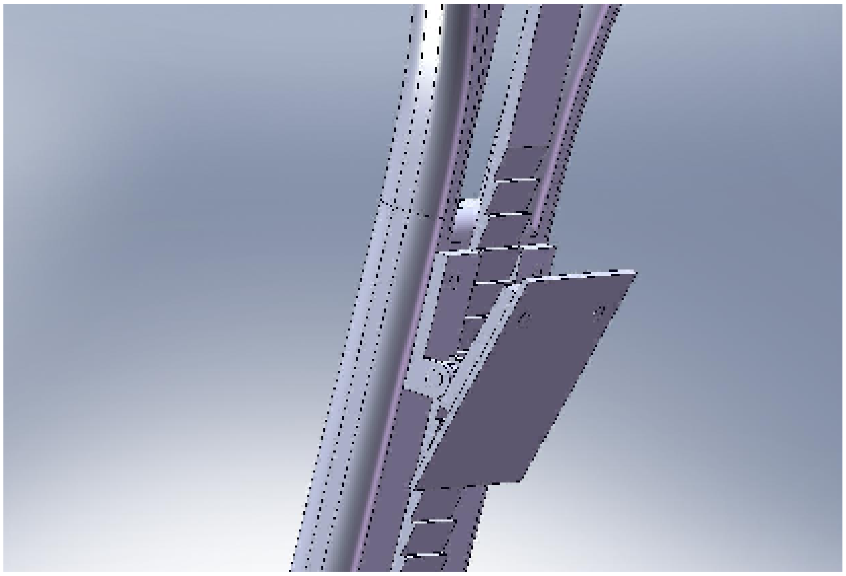

Figure 20: Slider bard held by one way gear mechanism

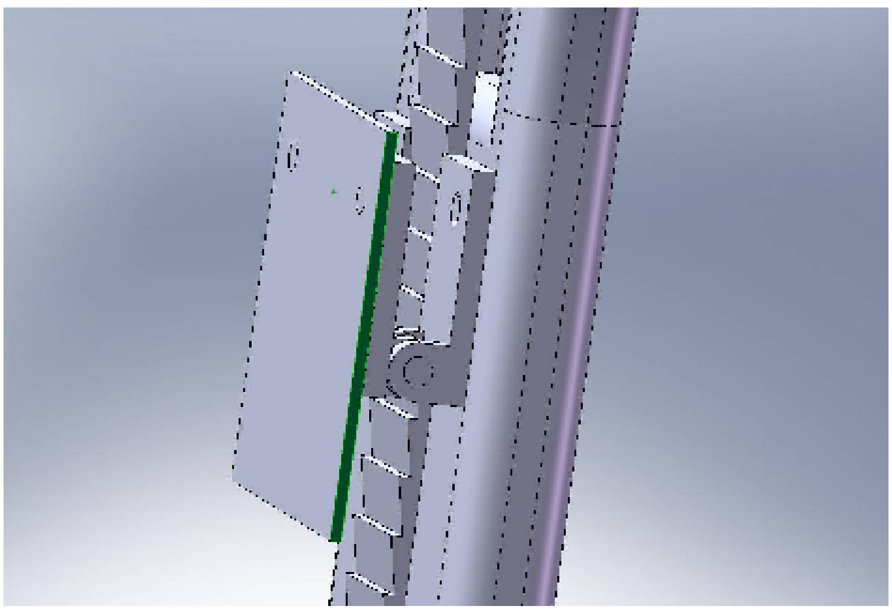

Figure 21: Slider bar released

7.2.3 Resetting and releasing mechanism

The resetting and releasing mechanism is based on that of a car door in which a bolt slides through the mechanism inside the door and then is secured until a force causes it to be released. It is simply to symmetrical plates cut to a shape like that of scissors. On the trapping end, the shape allows the bolt to push open the device, and has a hook like shape to trap the bolt once it has slid past. On the other end each plate's corner is held to the other plate via a small spring. This allows the plates to close after they have been opened. The centers of the plates are joined together and mounted onto an aluminum flat bar. This mechanism is placed in the centerline of the crutch 6” underneath the handle. Each plate is 1/16” thick 5000 series aluminum.

In between the plates is placed an egg shaped cam gear controlled by a motor(Figure 21), when the cam rotates the plates open and release the bar(Figure 22), when it rotates again the small spring closes the plates again.

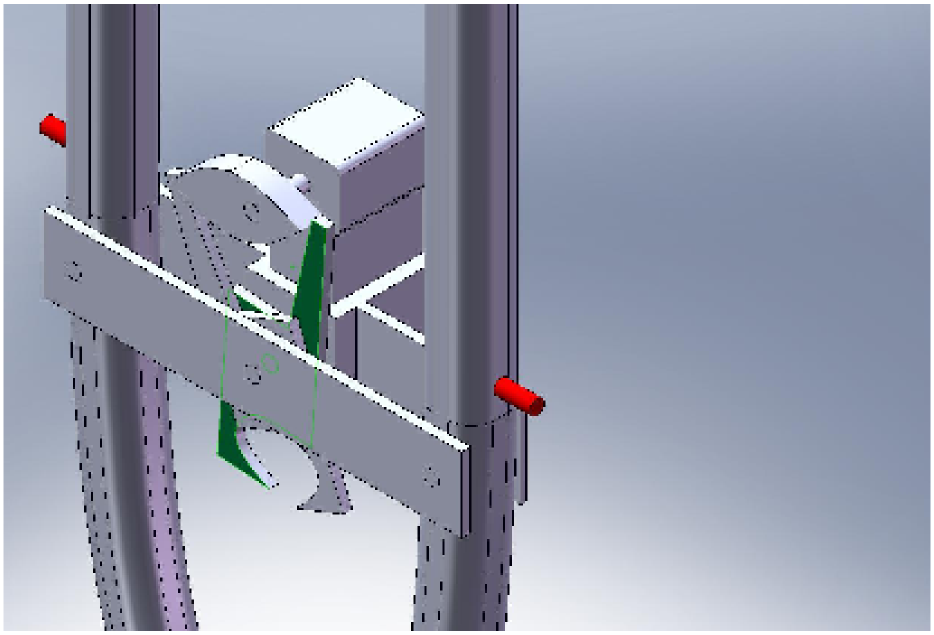

Figure 22: Egg shaped cam gear controlled by a motor

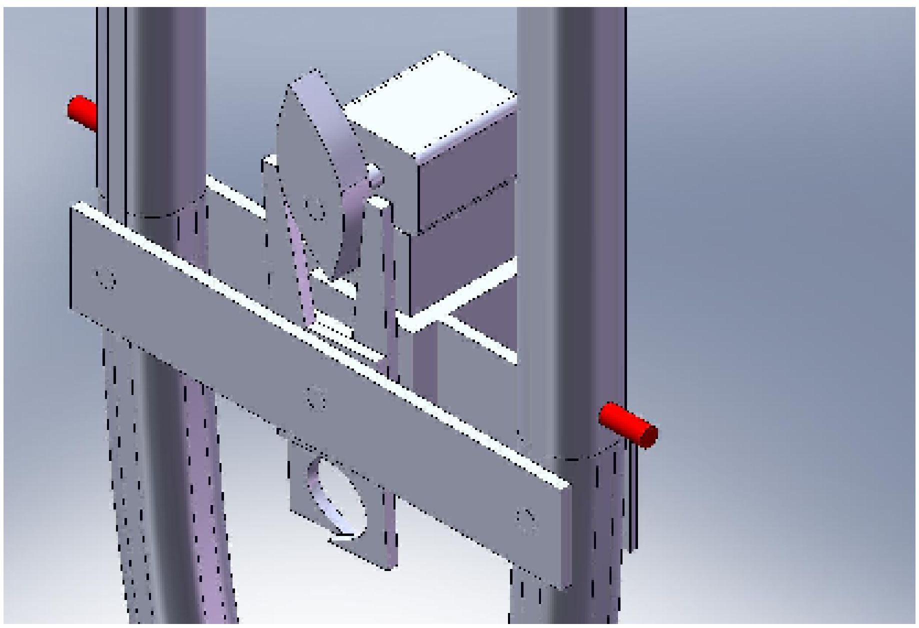

Figure 23: Rotated egg shaped cam gear

Figure 23 shows the release mechanism on its initial state wherein in its ready to release the slider bar it holds.

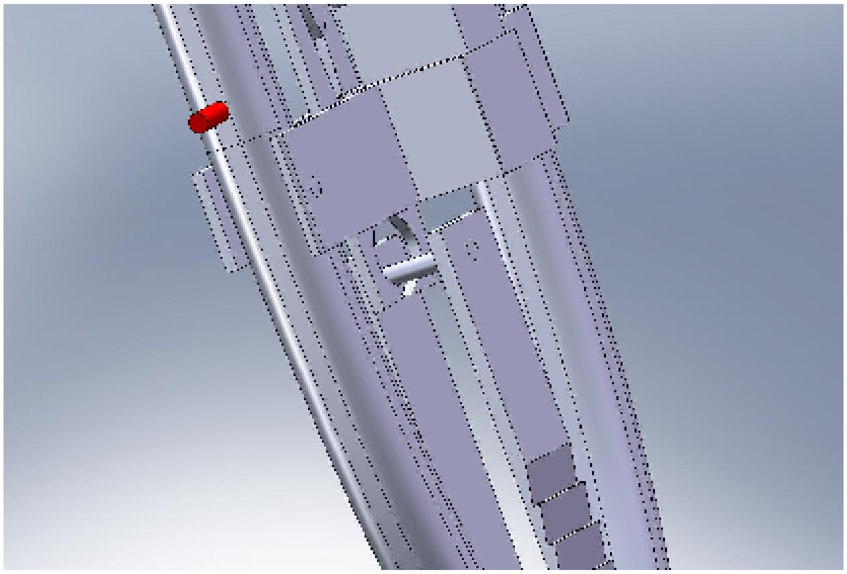

Figure 24: Release mechanism on its reset state

7.2 Electrical design

The motor is the only electronic component in this mechanism. It will have an angular velocity such that the bar can be released within 100-150ms. It will be the same motor as used in the friction sensor with high torque and low current value of maximum 150mA.

8 System test plan

To manufacture a reliable and useful product that will ultimately erase the safety concern for all the crutch users, Asa-Concepts design engineers have made two detailed lists of the system test plans. The first list applies to the individual part development stage which happens before the whole system integration. The second list applies to the whole system integration stage including the final product test plans.

Test plan for individual part development stage

1. The Friction Sensor: The friction sensor needs to predict the slip motion accurately based on the contact surface, user's weight, and the angular position of crutches. Our engineering team will conduct several tests in different contact surface, ranging from the most slippery one to the least slippery one. They will make sure the sensor measures the friction accurately and consistently through out different contact surfaces.
2. The Prevention Mechanism: When the prevention mechanism receives a slip detection message from the microcontroller, it needs to release the extra

mechanical support fast enough so that crutch users do not fall down. Our engineer team will verify the validity of this part by checking the response of prevention mechanism with different angular position and contact surfaces during the slip motion.

3. The alarm system and the motion sensor: the alarm should be off during the safe operation and on when it receives an emergency message. The motion sensor should be able to measure angular position of crutches accurately.

Test plan for the whole system integration stage

1. The prototype construction: The prototype construction will start once we finish testing all the individual part and verifying their interaction with the microcontroller development board. We will conduct a series of hardware test by probing the ICs to verify the correct functionality of the prototype circuitry. We will also do a current draw measurement on our power circuitry to calculate the battery life of Smart Crutches.
2. The weight endurance: We will test the weight endurance of crutches and the friction sensor by applying a large magnitude of forces and then put a maximum weight endurance label on crutches.
3. Normal crutch operation: Our engineering team will compare the user experience of using Smart Crutches and normal crutches. We will make sure the users do not feel much difference during the normal crutch operation. Our added features and extra supports should be positioned in adequate place and also with minimized size and weight so that users do not have troubles carrying our Smart Crutches.
4. User-friendly interface: Our engineering team will make sure Smart Crutches are easy to use with clear labeling on the user input buttons and also the understandable message on the LCD display. We will find some other people who are not involved in the development cycle and ask for their feedback on this.
5. Overall system response: Once we finish prototyping our Smart Crutches, we will conduct an overall system test including the accuracy of the slip motion detection, the validity of the prevention mechanism, and the proper response of the alarm system during the emergency.
6. The prototype protection guard: The prototype protection guard should be strong enough to protect all the electronic parts reside in the crutch during the falling motion. We will conduct this test by purposely dropping the crutch with different angular position to verify the expected result.
7. Minimal impact on surroundings: We should test the rubber pads and the other add-on mechanisms of the crutches so that it does not damage the floor when the user tries to walk with it. We should also choose a reliable power source so that a constant change of battery will not happen.

9 Conclusion

Design Specification for the Smart Crutch document finalizes the design details to manufacture a pair of user-friendly, reliable, and useful high tech crutches. ASA-Concepts engineering team has finished most of individual module designs and is now moving toward the final system integration and stage. A final goal of making the safest and easy-to-use crutches will challenge all the design engineers in ASA-Concepts. By carefully following the design methodology and test plans described in this document, ASA-Concepts is confident that Smart Crutches will bring a good news for all the disabled people in the end.

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