Rep-Counter for Weightlifting

ECE 445 - Design Review

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1 Introduction

1.1 Motivation

Losing track of repetitions is a common problem with weightlifters. The problem arises when all the attention is focused towards achieving correct form and not towards the number of reps that have been completed. This project plans to solve this problem, as well as eliminate the notepad and paper most serious weightlifters use to track their repetitions and the weights.

1.2 Objectives

The goal of the project is to develop a portable electronic device that will count the number of reps for a weightlifter, determine the number of correct and incorrect reps and the log the workout data for future reference. Currently there are mobile applications for smartphones that calculate the number of reps for certain exercises. However, these applications are not able to differentiate between a correct and an incorrect rep. Moreover, these applications are not very accurate and record false positives for a rep-count.
This device will allow the user to choose from a set of a few given of the most common exercises (squats, bench press, etc.). The workout data will be stored and an interface to the computer will be developed to import the data into an Microsoft Excel file.

1.3 Benefits

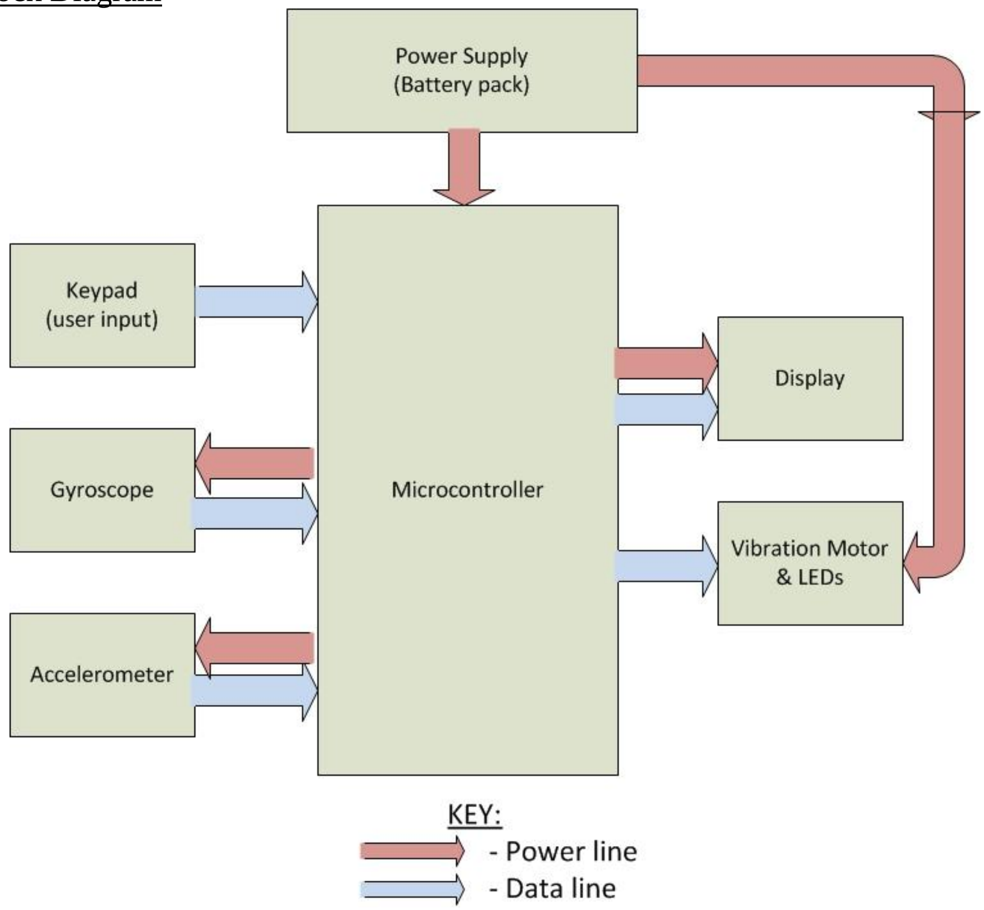
- Accurately keeps track of the lifters workout data by logging the reps, weight and sets
- Provides a library of the most common exercises to choose from
- Keeps track of good form and notifies the user if bad form is implemented
- Interfaces with the computer to export workout data from the device into an Excel document

1.3 Features

- Good form is maintained by monitoring 5 degrees of freedom of movement by means of an accelerometer and a gyroscope
- Uploads workout data to track progress on an organized spreadsheet
- User notified when desired number of repetitions is achieved via vibration and light
- User notified of bad form via vibration and light
- Streamlined interface to save the number of reps and the weight used using minimal push buttons: up, down, select, back/menu and power

2 Block Descriptions

2.1 Block Diagram



2.2 Power Supply

The power supply is consists of three 3-volt lithium ion batteries connected in series which will supply a nominal voltage of 9 volts. The negative terminal will be grounded and the positive terminal will be connected to the V_{in} port of the microcontroller. The microcontroller itself contains a voltage regulator that will output 3.3 volts. This will be used to power the accelerometer and the gyroscope. To power the other components we will use an external 3.3 volt regulator. We chose this because the microcontroller safely accepts a range of voltages between 7 and 12 volts and can output 3.3 volts to power the accelerometer and the gyroscope. We did not want the vibration motor to draw too much current from the microcontroller, so we will power it with the voltage regulator. The lithium ion batteries was selected over 6 AAA batteries that would provide the same output voltage, mainly because of its significantly greater energy density and because of more charge/discharge cycles.

After we determined that we could not use the microcontroller to power the vibration motor, we needed to determine if we could power it straight from the battery or use a voltage regulator. The vibration motor draws a maximum of 74 mA and needs 1.3 volts to operate. If we connected the battery straight to the motor, the following would result:

$$R = \frac{V}{I} = \frac{7.1}{0.074} = 95.6 \approx 100\ \Omega \qquad P = V \times I = 0.52\ W$$

The power dissipated in this case is too high because we are using a quarter watt-resistors. If we instead use a voltage regulator that outputs 3.3 volts, the following would result:

$$R = \frac{2}{0.074} = 27.02 \approx 30\ \Omega \qquad P = .148\ W$$

Here we see that we are only required to use a 30 Ω resistor, which results in a safer amount of power dissipated.

Please refer to the power budget table in section 2.2.1 for a more detailed analysis of power consumption of the system.

2.2.1 Power Budget

Part	Voltage (V)	Min Current (mA)	Max Current (mA)	Min Power (mW)	Max Power (mW)	%age Part is On	Average Current (mA)	Average Power (mW)
Accelerometer	3.3	0.003	0.4	0.0099	1.32	65%	0.26105	0.861465
Arduino Mega	8.4	1	200	8.4	1680	100%	200	1680
Buck Converter	8.4	0.15	7.5	1.26	63	20%	1.62	13.608
Display	3.3	17.5	18.5	57.75	61.05	100%	18.5	61.05
Gyroscope	3.3	6.8	0.005	22.44	0.0165	65%	2.38325	7.864725
LEDs	5	0	12	0	60	20%	2.4	12
Switch Resistors	3.3	0	1.32	0	4.356	20%	0.264	0.8712
Vibration Motor	1.3	0	74	0	96.2	20%	14.8	19.24
Total		25.453	313.725	89.8599	1965.9		240.228	1795.495

2.3 Microcontroller

The microcontroller we are using is the Arduino Mega 2560. This microcontroller operates at 5 volts, while accepting anywhere between 7 and 12 volts. It includes an internal voltage regulator that outputs 3.3 volts, which will be used to power the accelerometer and the gyroscope. It has 54 digital input/output pins, and 16 analog input pins. The accelerometer and the gyroscope will be connected to the analog pins, while the LEDs, vibration motor, LCD screen, and the input buttons will be connected to the digital I/O pins. The user will select which lift he or she wishes to perform, how many sets of the lift they will do, and how many reps are in each set. Data from the sensors will be processed, and the microcontroller will keep track of both correct and incorrect reps. The determination as to what constitutes a correct or incorrect rep will be based on comparing the sensor data to known requirements for the lift. The user will be notified with the LEDs and the vibration motor of both incorrect reps and when the preset number of reps has been performed. The microcontroller will also allow for a small delay before the accelerometer and the gyroscope begin taking data so as to let the lifter get into position. The LEDs and vibration motor will notify the user when they can begin. The Arduino Mega contains 256 KB of flash memory, along with 8 KB of SRAM and 4 KB of EEPROM. This memory will hold both the program and the data we store from the workout. We will store what kind of lift was performed, what weight it was at, how many sets were performed, how many correct reps were performed, and how many incorrect reps were performed. The main reason we chose this microcontroller was because of its combination of a large memory and many digital I/O pins. The microcontroller we initially selected did not have enough memory to store both our program and the data we would acquire, and it did not have enough pins to add external memory. Additionally, this microcontroller has a USB port built in, which will make data transfer much easier.

2.4 Accelerometer

The accelerometer will be a 3-axis analog accelerometer with a selectable sensitivity of either ±1.5g or ±6g sensitivity. Included on the chip is a 0-g detect feature and a sleep pin. The 0-g detect will output a high signal when the accelerometer experiences no acceleration in any direction. The sleep pin is internally pulled low to default to a low-power mode. This pin will be controlled by an I/O pin from the micro controller and will be used in conjunction with the other outputs to provide accurate data. The accelerometer itself is packaged on a carrier board, which is powered with an input voltage of between 2.2 and 3.6 volts. We will be powering it with the 3.3 volt output of our microcontroller. The acceleration data from the accelerometer will not drift an appreciable amount. However, we do want to utilize the accelerometer to provide data on the tilt angle. To do this we will utilize a complementary filter, which will make use of data from the gyroscope as well. The filter will be implemented with our microcontroller. More information on this is given with the gyroscope description. The main reasons we chose this accelerometer are its small size, ease of use, and the fact that it is already packaged on a board.

2.5 Gyroscope

The gyroscope will be a 2-axis analog gyroscope with a selectable range of either ±100°/s or ±400°/s. The two axes will be pitch and yaw, which are rotation about the X and Z axes. Also included on the chip is a power-down pin for use in low-power applications. We will not be utilizing this, and will be shorting it to ground. The gyroscope itself is packaged onto a carrier board that is powered with an input voltage of between 2.7 and 3.6 volts. We will be powering it with the 3.3 volt output of our microcontroller. The reasons we chose this gyroscope are the same as the accelerometer: its small size, ease of use, and the carrier board.

The complementary filter utilizes data from both the accelerometer and the gyroscope to produce an accurate angle measurement. The data from the accelerometer can give us what is known as the static tilt angle as shown in equation 1. a_x and a_y are the values we get from the accelerometer.

$$\theta_a = \arctan\left(\frac{x}{a_y}\right) \tag{1}$$

The gyroscope will output values corresponding to the angular velocity. We can integrate this to obtain the dynamic tilt angle by using equation 2. ω_x is the angular velocity read from the gyroscope, while ω_{x0} is the steady state value given by the gyroscope. S is the sensitivity of the gyroscope, and ΔT is the time interval that we sample at.

$$\theta_g = \theta_g + (\omega_X - \omega_{XO}) * S\Delta T \quad (2)$$

We will then filter our two angles values and sum them according to equation 3. β is a constant between 0 and 1 that acts as the filter. β acts as a high pass filter for the gyroscope data. This allows the high frequency component of the gyroscope to pass through, which is what we want because the gyroscope measures the dynamic tilt angle. The 1-β term acts as a low pass filter, allowing the low frequency component of the accelerometer to pass through. Low frequency data is needed because the accelerometer measures the static tilt angle.

$$\theta = \theta'_g + \theta'_a = \beta * \theta_s + (1 - \beta) * \theta_a \quad (3)$$

In equation 4 we show how we calculate the time constant of the filter. This can serve as a reference for calibrating the filter. If the movement is faster than the time constant, the data from the gyroscope is more important. If the movement is slower than the time constant, the data from the accelerometer is more important. After testing our components we will be able to determine an appropriate value for β.

$$\tau = \frac{\beta * \Delta T}{1 - \beta} \quad (4)$$

The complementary filter will easily be able to be implemented with our microcontroller. This is an advantage because we will not have to take up more space or consume more power using physical components.

2.6 Keypad (user input)

User input will consist of five switches. The power button will be a single pole, single throw, normally open toggle switch. The other four input buttons will be single pole, single throw, normally open momentary switches. The power switch will be connected in series with the battery. When the switch is closed, the battery will be connected to the microcontroller, the vibration motor, and the LCD screen. This button is a toggle switch, so once it is pushed it will remain closed until we push it again. The other four input buttons will be connected to four digital inputs. The inputs will be pulled high when the switches are open. When the switches are closed, the digital inputs will read low because current will flow to ground instead of the microcontroller. The microcontroller will recognize when the input reads low and respond with the appropriate action. We will debounce the digital input pins by writing a subroutine into the microcontroller. The reason for choosing the specific switches was simply that they fit our mechanical requirements. We needed a normally open toggle switch for the power button and normally open momentary switch for the input buttons. A large amount of switches are rated high enough for our design, so that was not of as much concern.

2.7 LEDs & Vibration Motor

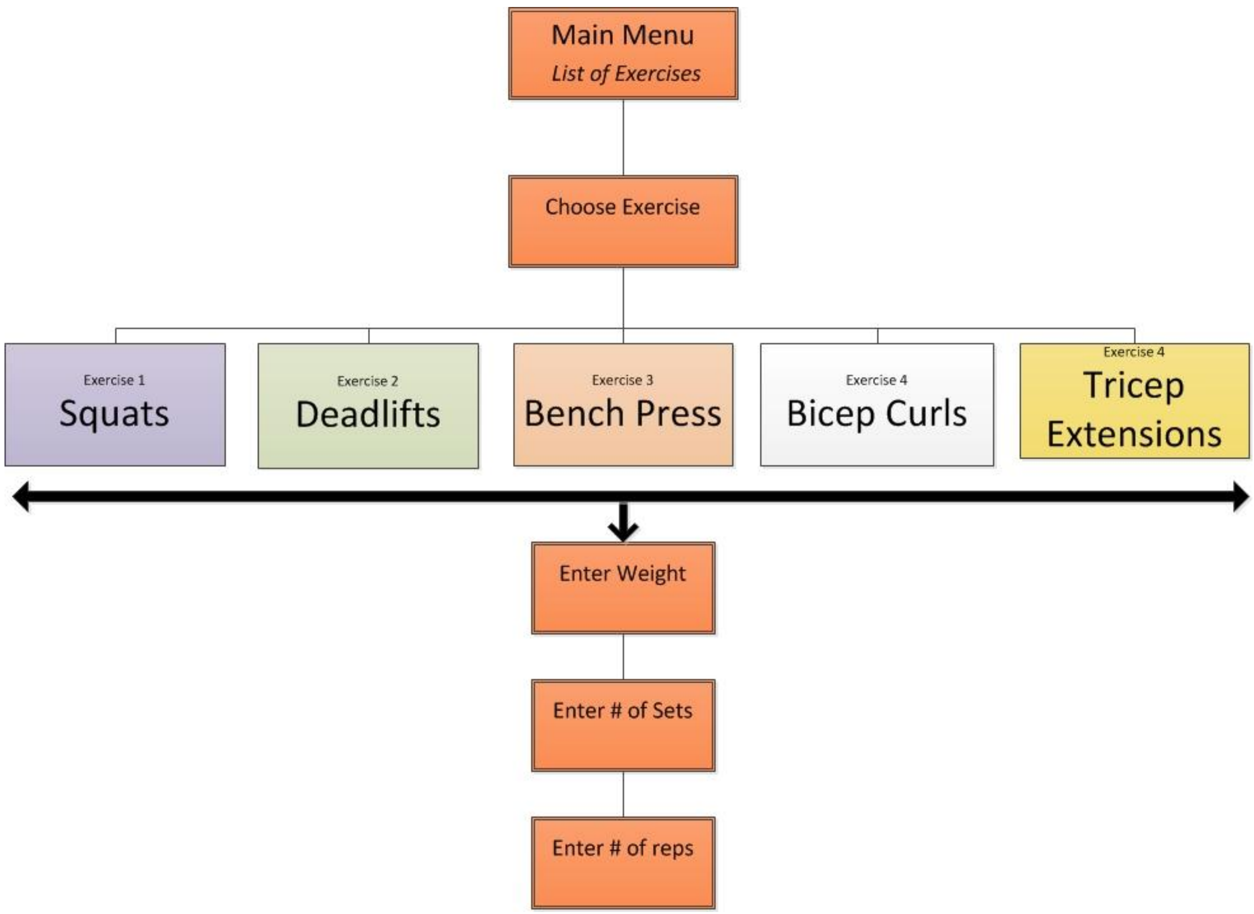
The LEDs and the vibration motor will notify the user of when to begin lifting, if an incorrect rep has been performed, and when the preset number of correct reps has been performed. There will be two LEDs driven by digital output pins of the microcontroller. The vibration motor will be powered by a 3.3 volt output from an external voltage regulator. We will use an NPN transistor to regulate the current flow through the motor. When one of the digital outputs to the LEDs is high the transistor will be switched on, allowing current to flow through the motor. We will utilize two different color LEDs to indicate different things to the user. When an incorrect rep has been performed and identified, a yellow LED will be pulsed once, along with the vibration motor. When the preset number of reps has been performed, a red LED and the vibration motor will be pulsed three times. Additionally, after the user has selected their lift, selected the number of reps, hit the start button, and the small time delay to allow the user to get into position has passed, the red LED and the vibration motor will be pulsed three times to indicate they can now begin the lift. The only decision in choosing the LEDs was the color. The main reason for choosing the specific vibration motor was its small size.

2.8 LCD Screen

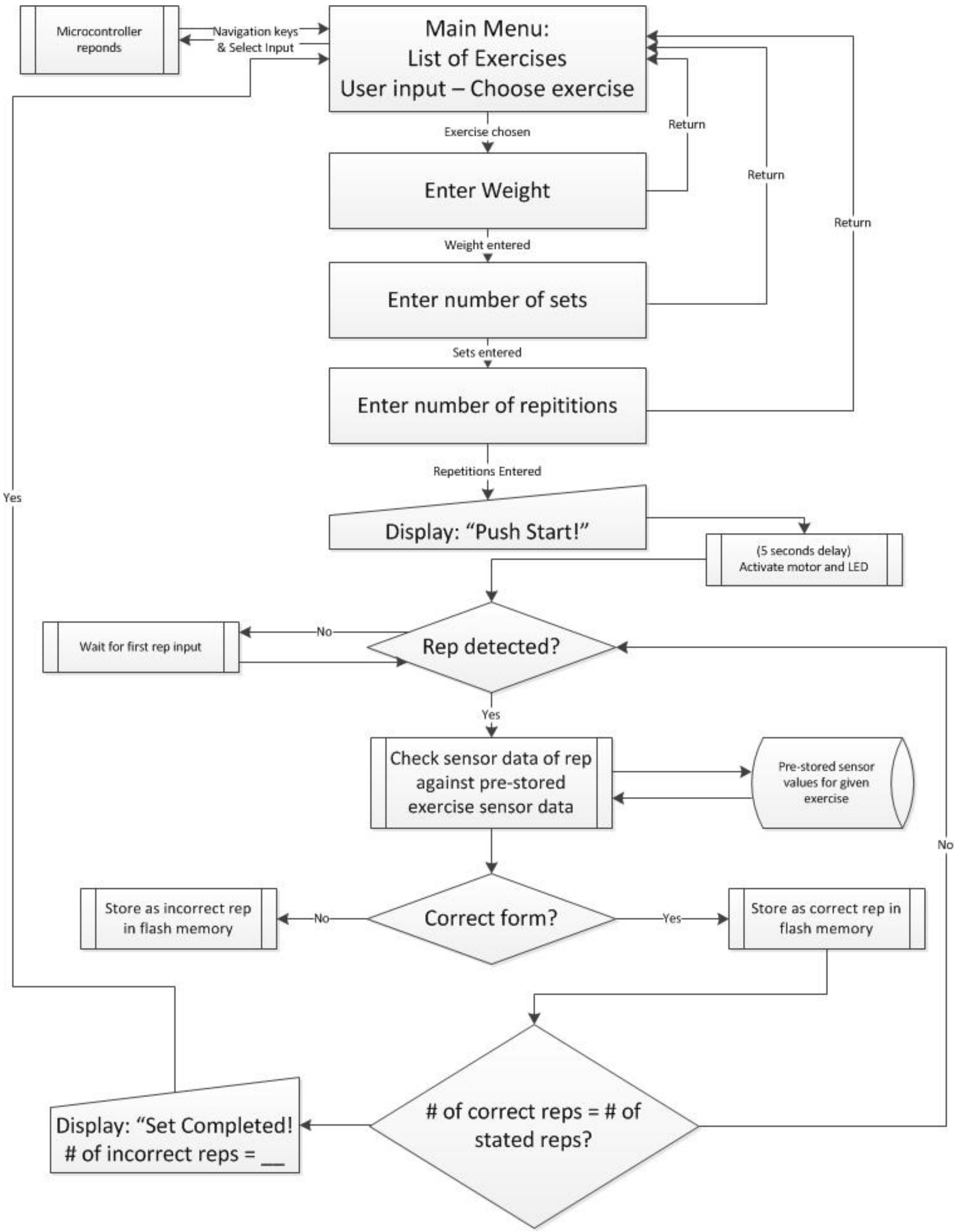
The LCD will output text information to the user. It will show two lines of sixteen black characters against a white background. The display will be used to display menu options. The controller and driver will be powered from the external voltage regulator. The backlight will also be powered from the voltage regulator, but will also be connected in series with a 10 kΩ variable resistor. This resistor is used to control the contrast of the backlight. The R'/W signal will be pulled high because we will always be writing to the LCD. The register select signal will come from a digital output of the microcontroller. This signal is used for various functions of the display. Pins DB4 through DB7 will come from digital outputs of the microcontroller, and will be used to display different characters on the screen. We are utilizing a library that will allow us to implement our display with only the four input pins. We chose this LCD screen for a variety of reasons. The most important ones are that it can be powered with a 3.3 volt input, and it's small size fits in with the physical scope of our project. Additionally, it can utilize a library to allow us to easily display text.

3 Figures & Schematics

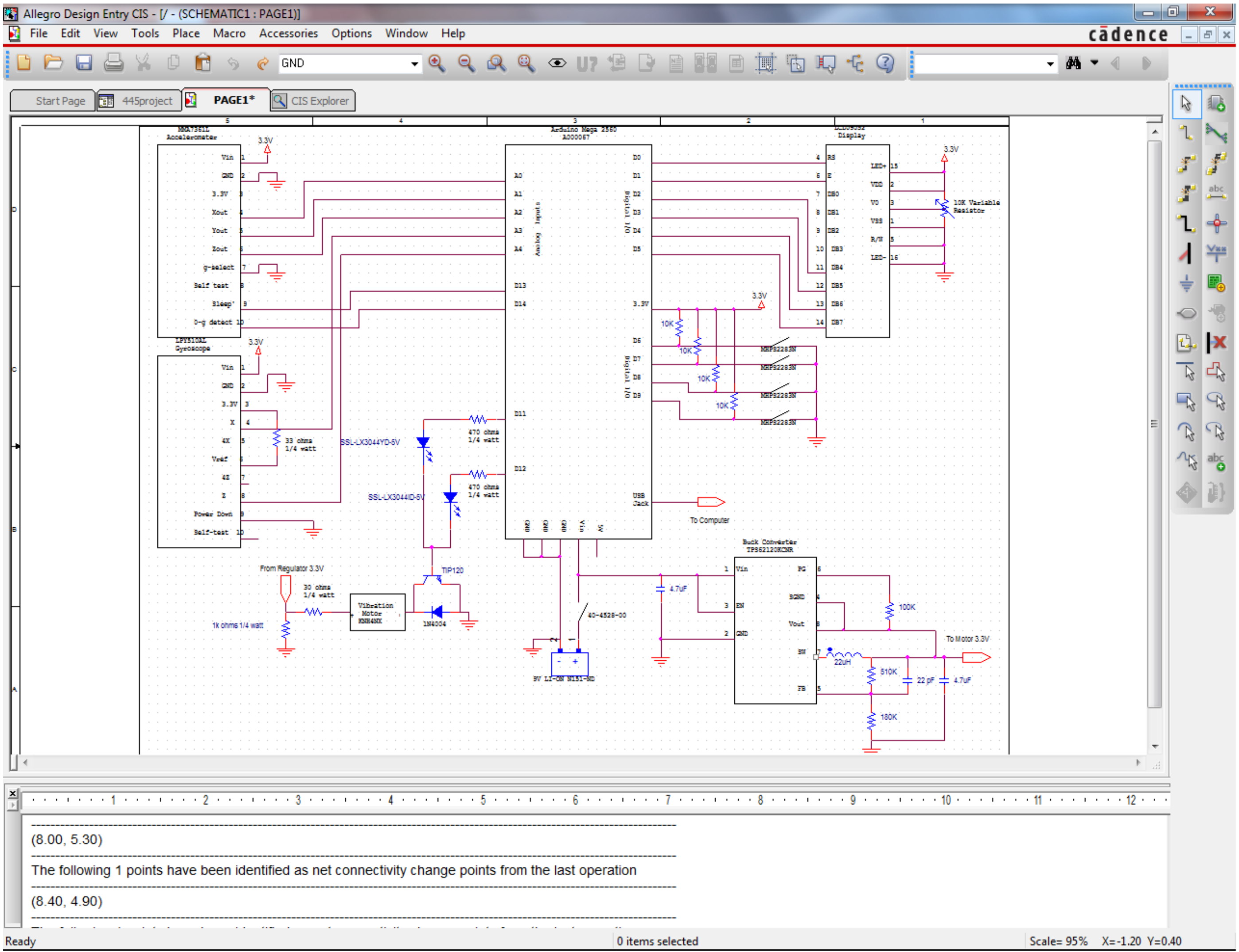
3.1 Main Menu Layout



3.2 System Flowchart



3.3 System Schematic



4 Performance Requirements

The end goal of this project is to develop a device that counts the number of reps for a weightlifter, records the number of correct and incorrect reps and stores all this information for future access. Listed below are some of the performance requirements for the system as a whole. For more specific requirements related to each separate module of the system, please refer to the 'Verification & Tolerance' section of this report.

- should be able to accurately detect reps and differentiate between good and bad form
- must be able to last at-least 3 hours under full charge from the 9-volt battery
- should be able to store workout data of at-least 3-workout sessions
- UI should be very user-friendly and the system should be easy to navigate

5 Verification & Tolerance

5.1 Testing & Verification

The following table clearly explains how each module is expected to operate. The table also lists the verification procedures that will be implemented.

Requirement	Testing & Verification Procedure
Power Supply Unit: 1. The battery should be able to supply a nominal voltage of 9V (±1V) for approximately 3 hours. 2. The battery will be able to supply a nominal current rating of 143mA and a max. current rating of 321mA for a period of 3 hours. 3. The buck converter will be able to accept a nominal voltage of 9V (±1V) (Note: maximum acceptable range is 4.75V to 40V) 4. The buck converter will be able to output a voltage of 3.3V (±2.5%) and a maximum current output of 75mA.	**Test:** 1. The battery will be tested for 3 hours at maximum load (28Ω resistor based on maximum current and voltage). A DMM will be used to monitor the voltage across the battery and to measure the current drawn. Alternatively, for a more in depth analysis of the battery discharge rate, LabVIEW can be used to obtain a discharge graph for the 3 hours. 2. The buck converter will be supplied a 9V input using a bench DC power supply, and a load of 63Ω will be connected across its output. The current through the load will be monitored using a DMM over a period of 3 hours. Testing will be done to obtain the duration of the initial current draw of 74mA by the motor. A 44Ω load will be used to test the buck converter's ability to withstand this high current draw. The duration of this test will depend on the results obtained from the initial current draw test for the motor. **Positive Result:** 1. The battery is able to run the course of the test on one complete discharge cycle. 2. The current through the load stays within a 5% range of 52mA for the nominal current test; the current through the load stays within a 5% range of 74mA for the startup current test. **Negative Result:** 1. The battery is completely depleted before the stipulated time of 3 hours. 2. The current drops significantly over the period of 3 hours for either of the tests.
Accelerometer: 1. The sensor will function with an input ranging from 2.2V to 3.6V (with a nominal input of 3.3V and 0.5mA). 2. It will output a voltage ranging from 0V to 3.3V to indicate acceleration ranging from 1.5g to +1.5g (0g corresponding to a 1.65V output). The scale	**Test:** 1. A bench DC supply will be used to power the sensor with a 2.2V, 3.3V and 3.6V input. The test (mentioned below) will be performed at these 3 input voltages. At each of the above given voltages the differences in the output of the sensor will be measured. 2. The accelerometer will be jerked from left to

factor of the output will be 800mV/g (±7.5%). This applies to all 3 axes.	right (or top to bottom) over a variety of distances (max = 1.5m) and accelerations (max = $9.8m/s^2$). The same test is done on all 3 axes. For testing purposes, the output from the accelerometer will be analyzed using an oscilloscope or using NI-DAQ and LabVIEW. **Positive Result:** The accelerometer gives the readings that correspond to the correct axis on which it was jerked with a scale factor of 800mV/g (±7.5%). Faster jerks correspond to voltage responses closer to ±3.3V and slower jerks to 0V. **Negative Result:** The readings don't correspond to the right axis; relative changes in acceleration don't correspond to the right calibrated voltage; the sensor doesn't function with a scale factor 800mV/g (±7.5%).
Keypad (User-Input): 1. The push-buttons will open and close properly for all 3 scenarios of operation: momentary push, constant push and off. 2. The power switch will close when switched on and open when switched off.	**Test:** 1.The push-buttons will be pressed one at a time and a DMM will be used to check continuity. 2. The power switch will be toggled on and off and a DMM will be used to check continuity. **Positive Result:** The continuity check is positive when the respective buttons are pushed. **Negative Result:** The continuity check is negative when the respective buttons are pushed.
Gyroscope: 1. The sensor will function with an input ranging from 2.7V to 3.6V (with a nominal input of 3V). 2. It will output a voltage ranging from 0V to 3.3V to indicate the rate of change of angle ranging from 170 °/s to -170 °/s. The zero-rate level being 1.23V (not ratiometric to supply voltage). The scale factor of the device will be 10mV/ °/s (±10%).	**Test:** 1. A bench DC supply will be used to power the sensor with a 2.7V, 3.3V and 3.6V input. The test (mentioned below) will be performed at these 3 input voltages. At each of the above given voltages the differences in the output of the sensor will be measured. 2. The sensor will be rotated clockwise and counterclockwise along the pitch and yaw axes over a variety of angular rates (max = 170°/s). For testing purposes, the output from the gyroscope will be analyzed using an oscilloscope or using NI-DAQ and LabVIEW. **Positive Result:** The gyroscope gives the readings that correspond to the correct axis on which it was rotated with a scale factor of 10mV/ °/s (±10%); the sensor outputs a zero-rate level of 1.23V. **Negative Result:** The readings don't correspond to the right axis; relative changes in angular rates

	don't correspond to the expected voltage; the sensor doesn't function with a scale factor of 10mV/ °/s (±10%); the zero-rate level is not 1.23V.
Microcontroller: *1. Requirements related to interfacing with peripherals:* 1.1 The µC functions properly at voltages ranging from 8.25V to 9V with current draw not exceeding 200mA. 1.2 It's able to accept the voltage output from the accelerometer and convert it into g-force with a scale factor of 800mV/g (±7.5%) with a current input not exceeding 40mA. 1.3 It's able to accept the voltage output from the gyroscope and convert it into an angular rate with a scale factor of 10mV/ °/s (±10%) and with a current input not exceeding 40mA. 1.4 The µC will detect when the push buttons have been turned on and off (including the power button). It distinguishes each button with its respective functionality (power button, navigation buttons, select button and the menu button). 1.5 The µC will output characters onto the display by using only 4 data pins. 1.6 It lights up the LEDs when the program demands it to. 1.7 It will run the vibration motor by sending pulses that last for a second each; it will be able to send out a string of pulses for a maximum of 4 seconds (1 second pulses with 0.5 seconds delay); the maximum current drawn from the I/O pin won't exceed 40mA. *2. Requirements for higher level program:* 2.1 The µC is able to tell if a rep performed is either a correct or an incorrect one by crosschecking the real-time data with the existing database of parameters. 2.2 The vibration motor and LEDs are activated when a bad rep is detected (based on data from accelerometer and gyroscope) or when a set is completed.	**Test:** *1. Testing related to interfacing with peripherals:* 1.1 A bench DC supply will be used to power the sensor with a 8.25V, 8.5V and 9V input. The test (mentioned below) will be performed at these 3 input voltages. At each of these voltages the differences in the behavior (current and voltage ratings at I/O pins) of the system will be measured. 1.2 The same tests stated for the accelerometer will be performed here, however this time, the sensor will be talking to the µC. A test sketch will be developed for the Arduino to output the data received from the accelerometer in terms of g-force. 1.3 The same tests stated for the gyroscope will be performed here, however this time, the gyroscope will be talking to the µC. A test sketch will be developed for the Arduino to output the data received from the sensor in terms of angular rates measurements. 1.4 A custom arduino sketch will be developed just to signal to the programmer when the respective keypad buttons are turned on and off. 1.5 A test program will be developed to interface with the display alone; the program will output a variety of strings of characters and the display will be checked to see if the strings match; the display will also be examined to see if it flickers. 1.6 An arduino sketch will be developed to activate the LEDs at a variety of delays; the outputs on the I/O pins for the LEDs will be monitored using an oscilloscope. 1.7 A custom program will be written for the µC to test the vibration motor. The code will send pulses of high signals to the I/O pin for the vibration motor. The pulses will be 1 second long with delays 0.5 seconds; a maximum of 3 pulses will be sent to the digital output pin. This pin will be probed using an oscilloscope. *2. Testing for the higher level program:* 2.1 Incorrect reps (parameters of which will be determined after performing exercises with the system in place) will be performed and the output pins for the motor and the LEDs will be probed using an oscilloscope and a DMM. 2.2 The same test mentioned above is performed, except this time the vibration motor and LEDs are

<u>2.3</u> The µC interprets the keypad inputs correctly to determine state of program.	connected to the µC. <u>2.3</u> The user interface will be simulated by using a bench DC power unit to supply the data input ports with high and low signals (low corresponding to ON, since these button inputs will be active-low). A test sketch will be developed that will signal to the programmer which button was pressed. **Positive Result:** <u>1.1</u> There is a very little change in current and voltage ratings at I/O pins when operating at all 3 given voltages. <u>1.2</u> The resulting accelerometer data corresponds exactly to the g-force put in with a scale factor of 800mV/g (±7.5%). <u>1.3</u> The resulting gyroscope data corresponds exactly to the angular rate input with a scale factor of 10mV/ °/s (±10%). <u>1.4</u> The program correctly processes the keypad inputs (interprets the select button as the select button, interprets the menu button as the menu button and so on); the program is able to tell when each switch is on and when each switch is off. <u>1.5</u> The strings on the display match the test program's strings; the display doesn't demonstrate any flickering. <u>1.6</u> The output graph on the oscilloscope corresponds exactly with the program's duration of delay between activation signals. <u>1.7</u> The output on the oscilloscope corresponds exactly to the pulse width and delay commanded by the program. <u>2.1</u> The program recognizes an incorrect rep when an incorrect rep is performed. <u>2.2</u> The vibration motor and LEDs are activated when they are supposed to (as demanded by the program). <u>2.3</u> The program interprets each push-button correctly (what the button corresponds to: select, menu, etc.) **Negative Result:** <u>1.1</u> There is a significant change in current and voltage ratings (±20%) at the I/O pins when operating at the 3 given voltages. <u>1.2</u> The resulting accelerometer data doesn't correspond exactly to the g-force. In other words, the absolute error in scale factor is greater 7.5%. <u>1.3</u> The resulting gyroscope data doesn't correspond exactly to the input angular rate. In

	other words, the absolute error in scale factor is greater 10%. 1.4 The program incorrectly processes the keypad inputs (doesn't interpret the select button as the select button, doesn't interpret the menu button as the menu button and so on); the program is not able to tell when each switch is on and when each switch is off. 1.5 The strings on the display don't match the test program's strings; the display demonstrates flickering. 1.6 The output graph on the oscilloscope does not correspond with the program's duration of delay between activation signals. 1.7 The output on the oscilloscope does not correspond correctly to the pulse width and delay commanded by the program. 2.1 The program doesn't indicate an incorrect rep when an incorrect rep is performed. 2.2 The vibration motor and LEDs are not activated when they are supposed to (as demanded by the program). 2.3 The program does not interpret each push-button correctly (this includes false positives).
Display: 1. The display will function with an input ranging from 3.1V to 3.5V (with a nominal input of 3.3V). 2. The backlight of the display will light up properly at a nominal voltage of 3.3V (in-built resistor drops it down to 3V). 3. It will display numbers, letters and symbols correctly without any flickering or contrast defects.	**Test:** 1. A bench DC supply will be used to power the display with a 3.1V, 3.3V and 3.5V input. The test (mentioned below) will be performed at these 3 input voltages. At each of the above given voltages the differences in the quality of the display will be noted. 2. The backlight pin inputs (LED±) will be supplied a 3.3V input using a bench DC supply. 3. The display will be tested with the microcontroller connected to it. A custom sketch for the arduino will make the display output a variety of character strings and the display will be checked to see if the strings match; the display will also be examined for flickering and contrast defects. **Positive Result:** 1. The backlight of the display lights up with the 3.3V supply. 2. The characters are displayed clearly on the screen with no flickering or contrast defects; the strings match the strings coded into the microcontroller.

	Negative Result: <u>1.</u> The backlight of the display does not light up with the 3.3V supply or the backlight is very dim at this voltage. <u>2.</u> The characters are not displayed clearly on the screen; the display exhibits flickering and there are contrast defects; the strings don't match the strings coded into the microcontroller.
Vibration Motor & LEDs: <u>1.</u> The vibration motor will function properly at an input voltage of 3.3V (dropped to 1.3V for the motor). It will operate at a nominal current draw of 52mA and an initial start-up current draw of 74mA (duration of which will be determined during initial testing). The functionality of the motor wont deteriorate over a 30-minute period. <u>2.</u> The LEDs light up with a 2V supply (maximum of 2.5V) and nominal current of 30mA.	**Test:** *Note: An initial test will be conducted to determine the duration of the high initial current draw of the motor (of 74mA).* <u>1.</u> A bench DC supply will be used to power the motor with a 3.3V input. And a current limitation of 75mA. The test will be conducted for 30 minutes. The performance of the motor will be monitored over this period of time. <u>2.</u> The LEDs will be supplied a voltage of 2V using a bench DC power supply. A switch will be used to turn it on and off manually. **Positive Result:** <u>1.</u> The motor vibrates properly for 30 minutes without spinning off. <u>2.</u> The LEDs light up exactly when the switch is turned on; there is no significant change in brightness over the course of the test. **Negative Result:** <u>1.</u> The motor does not vibrate properly for 30 minutes; it spun off during the test. <u>2.</u> The LEDs don't light up exactly when the switch is turned on; there is a significant change in brightness over the course of the test.

6 Cost Analysis

6.1 Parts

Part Description	Model Number	Quantity	Price Per Unit($)	Total
100KΩ Resistor	ERD-S1TJ104V	1	0.01	0.01
10KΩ Pot Core Resistor	3352K-1-103LF	1	0.83	0.83
10KΩ Resistor	CF14JT10K	4	0.005	0.02
180KΩ Resistor	ERD-S1TJ184V	1	0.01	0.01
30Ω Resistor	CF14JT30R0	1	0.005	0.005
33Ω Resistor	CF14JT33R0	1	0.005	0.005
470Ω Resistor	CF14JT470R	2	0.005	0.01
510KΩ Resistor	ERD-S2TJ514V	1	0.06	0.06
Accelerometer	MMA7361L	1	11.95	11.95
Arduino Mega 2560	A000067	1	38.95	38.95
Battery (8.4V)	N151-ND	3	3.5	10.5
Battery Holder	708-1412-ND	3	1.64	4.92
BJT	TIP120	1	0.68	0.68
Buck Converter	TPS62120DCNR	1	2.8	2.8
Capacitor 22pF	ECC-NVS220JG	1	0.15	0.15
Capacitor 4.7uF	ECC-NVS047JG	1	0.18	0.18
Diode	1N4004	1	0.016	0.016
Gyroscope	LPY510AL	1	19.95	19.95
Inductor 22uH	TSL0808RA-220K1R7-PF	1	0.25	0.25
LCD Screen	LCD09052	1	14.95	14.95
LED Red	SSL-LX3044ID	1	0.63	0.63
LED Yellow	SSL-LX3044YD	1	0.66	0.66
Power Switch	40-4528-00	1	0.73	0.73
Push Button Switches	MHPS2283N	4	0.31	1.24
Vibration Motor	KHN4NX	1	4.7	4.7
Zener diode	1N5819	1	0.07	0.07
			Total:	107.54

6.2 Labor

Name	Rate (per hour)	Hours	Total	Multiplier (x2.5)
Andrew Mast	$40	200	$8,000	$20,000
Ben Rosborough	$40	200	$8,000	$20,000
M. Fahim Kadhi	$40	200	$8,000	$20,000
			Total:	**$60,000**

6.3 Grand Total

Entity	Total
Labor	$60,000
Parts	$107.54
Grand Total:	**$60,107.54**

7 Schedule

Week of	Tasks	Group Member(s)
Feb 6th	Introduction	Mast
	Block diagram and descriptions	Rosborough
	Verification process (description only)	Kadhi
	Cost and schedule	Mast
	Research microcontroller and communication module	Rosborough
	Research display unit and gyroscope	Kadhi
	Research accelerometer and vibrating motor	Mast
Feb 13th	Sign-up for design review	Rosborough
	Research filtering of sensors	Kadhi
	Research programming the communication module	Mast
Feb 20th	Design the circuit for design review	Rosborough
	Write down performance requirements and testing	Kadhi
	Write down module descriptions, update schedule and cost report	Mast
Feb 27th	Order parts	Rosborough
	Practice programming the Micro	Kadhi
	Get push buttons to interface with the Micro	Mast
	Address the issues related to Design Review	Rosborough
March 5th	Interface the Gyroscope with Micro	Kadhi
	Interface the Accelerometer with the Micro	Mast
	Program subroutines into micro for different exercises	Rosborough
	Start writing individual progress reports	All
March 12th	Finalize and submit individual progress report	All
	Design plastic casing for the whole unit	Kadhi
	Continue integrating accelerometer and gyro into system	Mast
	Test and debug code	Rosborough

March 19th	Spring break	X
March 26th	Mock-up demo	All
	Test and debug code	Kadhi
	Sign up for mock presentation	Mast
	Get Micro to interface with a PC	Rosborough
	Prepare for mock presentation	Kadhi
	Design user interface	Mast
April 2nd	Mock presentation	Rosborough
	Continue designing user interface	Kadhi
	Get plastic casing built	Mast
	Gather info for final report	Rosborough
	Test and debug code	Kadhi
April 9th	Address any issues related to the presentation	Mast
	Test and debug code	Rosborough
	Continue working on Final report	Kadhi
April 16th	Sign up for demo	Mast
	Sign up for presentation	Rosborough
	Final test with all components integrated into the unit	Kadhi
	Package the whole system with the armband	Mast
	Finish first draft of final report	Rosborough
April 23rd	Final demos and presentations	Kadhi
April 30th	Final demos and presentations (continued)	Mast
	Finalize and submit final report	Rosborough
May 3rd	CHECKOUT	

8 Ethical Considerations

The following are the codes that are concerned with this project:

Code 1. to accept responsibility in making decisions consistent with the safety, health and welfare of the public, and to disclose promptly factors that might endanger the public or the environment;

Code 9. to avoid injuring others, their property, reputation, or employment by false or malicious action;

This product needs to be safe for the user. Therefore all circuitry needs to be contained in such a manner that no sweat or moisture will be able to access the circuitry that could shock and harm the user.