Final Report: Introduction
Vital Signs Monitor
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Abstract:
The Vital Signs Monitor will be an effective way of monitoring multiple signals from the patient, at home or in the clinic/hospital, through a single, simple device apparatus that wirelessly transmits data to a mobile tablet for processing and ease of use. Currently, there is no such singularly wireless device that acquires this multitude of signals including blood glucose level, blood oxygen level, blood pressure, core body temperature, ECG, EMG, motion detector (for falls), respiration/heart rate, and patient’s weight. For this project, we will combine as many of these data collection devices as we can for ease of access, safety, and portability to provide for patients with little to no clinical expertise as well as providing clinicians benefits from this system by monitoring their patients in an effective manner. Our end goal is for this Vital Signs Monitor to be an inexpensive yet powerful solution for our potential customer’s uses.
2. Introduction:

2.1 Background:
Professor Enderle has been a member of the UConn Electrical Engineering department. Among his many research projects, he currently focuses on the innervation of eye and ear muscle systems. Through his research he aims to define an accurate and comprehensive model for simulating eye movements. A well respected professor, and researcher in the biomedical engineering field, his work continues to contribute to the rising interest and success of Biomedical engineering.

Alongside his numerous research projects, Professor Enderle has been working on this Vital Signs monitor for several years. His aims are to provide nonmedical personnel with the ability to obtain a great array of commonly needed signals that the body provides. This comprehensive point of view can then be sent to a doctor and used to keep track of a patient’s health in a manner that does not require constant supervision. Another benefit to this method is that the patient can also continue on their day, eliminating the need for an expensive visit to the doctors, as well as capturing a more accurate glimpse into the body during the daily life of a patient. Finally the presence of automated sensors reduces the need for in-home nurses, and hopefully will lower the costs of obtaining all the important measurements for anyone who needs them.

2.2 Purpose:
Many patients cannot spend the money or the time needed to obtain all of the data for such an extensive set of observations. Also, current monitors are bulky and contain many wires, which both cause hazard to the patient and people using them. Our design is going to be mobile therefore size and weight must be accounted for. These limits the patient’s accessibility to such care, and in many cases, the availability of up to date and accurate information on demand on the part of the doctor can result in many mistakes and faulty diagnoses of a patient.

On the other side of the health problem, during rehabilitation and recuperation, if the proper care is not observed, there may be issues that can return the patient to a state of illness. This device would introduce the concept of minimal upkeep and observation on the doctor’s part to ensure the proper actions are taking place. The Vital Sign Monitor will provide consolidated, continuous, and archived reports of the patient’s health status for the use of the patient, nurses, physicians, and any future caretaker. This allows the patient’s history of vital signs to be analyzed as the patient progresses through certain health conditions, rehabilitation or just normal life. Each vital sign is important in monitoring the patient’s health as well as the ability to call for aid if needed.

2.3 Previous Work:
In this project we will be picking up on a decade of work left by various professors and students. Most recently, the undergraduate Tom Capuano has revamped the entire project by reprogramming the circuit board, and finalizing the ECG function. The existing device is broken into three parts; the controller, the devices, and the Bluetooth program. The circuit board controller is programmed in C, and takes all of the inputs and selects the channels to send via Bluetooth to the computer. Each of the individual devices has their own output signal, and upon measuring, sends the data to the controller. The computer, upon receiving the Bluetooth signal takes the data and uses Bluetooth to analyze the signal.
2.3.1 Products:
Currently, there are other products existing in the market under the multiple sensor, vital sign monitor device. None of these current devices contain as many sensors as we are implementing or the usage of how this device is going to work. Devices like the Creative Medical® PC-900 monitoring system only records non-invasive blood pressure, pulse oxygen saturation, pulse rate, ECG, and temperature with the display on a standalone device while other vital sign monitors can only record one parameter or set of data. Other devices such as the Multi-Parameter Vital Signs Monitor (CareTaker™) by David W. Gerdt require disposable apparatuses but can transmit Bluetooth signals to other devices.

What sets our product apart from these other devices is that our Vital Sign monitor includes many more vital sign parameters, that other devices don’t have, including: ECG, temperature, heart rate, respiration rate, heart and lung sounds, blood oxygen level, and patient weight. With all of these parameters being converted into electrical signals, the data can be transmitted wirelessly to a tablet such as the Microsoft Surface for filtering, analysis, and display for the patient, which many of these preexisting products are incapable of. Lastly, other multi-parameter vital sign monitor devices can be expensive, into the thousands of dollars range, which we will try to minimize as outlined in further sections.

2.3.2 Patent Search Results:
There was only one patent (US20120022348) that fit the description of a multi-parameter vital sign monitor device.

2.4 Report Map
In subsequent sections, we will show how this device will function starting with the design of the main device strap around the patient’s torso. From there, we will show how each sensor will collect the different types of data necessary for our goals and how the device will sort the data inputs. Lastly, we will provide insight to further enhancement of the device and other implementation of how the Vital Sign monitor will better the lives of patients and doctors.
3 Project Design
3.1 Introduction

3.1.1 Chest Strap

The chest strap is intended to be a comfortable, adjustable strap with 4 open leads. The sensors are intended to use pins to align and connect to the 4 leads in order to sit in position and collect data. The 4 leads will correspond to the voltage source, 5 volts, a clock line and a data line, both needed for I2C communication, and a ground. Each of the sensors will be designed to draw a small amount of power for their continuous operation while waiting for a data request, and then only turn on the bulk of their collection instruments when the data is requested, and then turn off after the data has been sent.

3.1.2 Control box

The master controller will have three separate sections behind the theory of operation. The first and most prominent division will be the master controller for the I2C communication protocol. This will be responsible for collecting and maintaining all the relevant data signals in its local memory. The second division will be the emergency data portion. Since one limitation of I2C is that a slave device cannot organize its own sending of data, any information that is time sensitive cannot be dependent on the I2C Bus. So the fall detector and the ECG will both be handled on the control box itself. That way, if any dangerous situations occur, the master control unit will be able to allocate resources as needed. This might mean triggering an auditory alarm, or sending an email to a doctor, or using the Bluetooth connection to a phone to trigger an emergency call. The third section of the master control unit will be the Bluetooth communication antenna. Since this is where all of the data from sensors will be kept, this is also the location responsible for sending the data to a computer running LabVIEW. The battery and power source for all sensors will also originate from here.

3.1.3 Body Temperature Biosensor

The body temperature biosensor will require the least amount of power of the biosensors and will take a reading of the patient’s body temperature from inside their armpit upon request from the master controller. If a patient or caretaker commands the LabVIEW program to measure the patient’s body temperature, current will run through the thin film RTD (Resistance Temperature Detector) and based on the voltage drop across the element the LabVIEW program will make calculations and output the patient’s measured body temperature. The circuit construction of the body temperature biosensor ensures the least amount of error by eliminating lead wire noise using a 4-wire Wheatstone bridge.

3.1.4 Blood Oxygen Biosensor

The pulse oximeter will clip directly to the chest strap, but will have a smaller clip containing a photo sensor and two LED’s to clip onto the ear. The cord will be long enough so that this will not hamper the subject’s range of motion. The master controller will request data from the sensor which will then briefly turn on the lights long enough to get an absorbance. Then the absorbances will be sent to the LabVIEW program and the ratio of oxygenated to de-oxygenated blood will be calculated to obtain the blood oxygen content.
3.1.5 Fall Detection Biosensor

The fall detection biosensor will have the capability to detect when a patient is actively falling, fallen, and unresponsive. Based on this data, an alarm function will provide assistance to the patient in the event of an emergency. In order to prevent false alarms, the patient will be alerted with an auditory message commanding them to tap once on the fall detection biosensor if they need emergency caretakers or tap twice if they have not suffered any life threatening injuries. In addition, the fall detection biosensor will have the ability to automatically contact emergency caretakers in the event that the accelerometer indicates no movement following a fall or if the patient takes too long to respond to the auditory command. The fall detection biosensor probably has the most ability to be improved because of its ability to sense a fall before the patient has hit the ground. Possible future improvements could include a preemptive action being triggered based on a fall being detected which somehow increases the safety of the patient before they hit the ground. At the very least, the fall detection biosensor allows the quickest possible assessment of the patient’s status and emergency contact.

3.1.6 Stethoscope Biosensor

The stethoscope we have chosen to use is the electronic stethoscope developed by Chad Lyons. His product would be the perfect match for our design due to its low cost, and ease of use. In our design we plan to have a clip similar to all other sensors that won’t be part of the master control (and that don’t need an alarm functionality) and use it primarily for respiration rate. The microchip behind this will filter the raw sound signal, and attempt to count the pauses in breathing to calculate respiration rate. This data will then be sent to the master controller. In addition to digitally counting the respiration rate, we will include the ability to directly plug headphones into the clip sensor in order to take the analog sound and play it through the headphones for anyone who may need to listen in. This would minimize the need to remove the stethoscope repeatedly if needed to visit the doctor, increasing the longevity of a single sensor. Due to issues raised by Dr. Lyons however, the use of a single stethoscope will be limited by the adhesion properties of the patch, and thus the sensor clip will come built in with the ability to quickly swap out the patches as needed.

3.1.7 ECG Sensor

The ECG biosensor will utilize either a 2 lead system or a custom lead system which will require further research. The 2 lead system is less accurate, however it is capable of being placed on the chest strap without any additional wires. The lead system will plug into the analog front end of the Texas Instruments ADS1298R ECG chip which will amplify and filter the signal. This signal will then be sent to LabVIEW on the Microsoft Surface for the patient and caretakers to view and analyze. Additional programming in LabVIEW will warn the patient if their ECG shows any obvious abnormalities and output their heart rate.

3.1.8 Heart/Respiration Rate

Heart rate is an important vital sign of all patients, if the rate is 0 beats per minute the patient is technically dead. This vital sign can be calculated using multiple sensors including the pulse oximeter, ECG sensor, or stethoscope. In our optimal design, we chose to use the pulse oximeter and ECG sensor in conjunction as they were the easiest to program in LabVIEW and can be displayed as a single number changing over time, just as it does in a real hospital setting.
Respiration rate is a little more difficult to compute and might require additional sensors in the monitoring of this vital sign. We found a solution around this by placing a stethoscope on the back of the patient as this is how physicians monitor their patient’s respiration rate.

3.1.9 Weight Biosensor

Patient’s weight is an important aspect to their overall health, as obesity can cause serious health concerns. Their weight will be monitored through a separate apparatus from the overall device but will still communicate via Bluetooth to the user-interface. Not only will this data be displayed to the user but it will log this data day to day or whenever the patient weighs them. Bluetooth enabled scales already exist in the market, which we will use.

3.1.10 Blood Pressure Biosensor

Blood pressure is another majorly important aspect to the vitals of any patient as any sudden drop in blood pressure can mean heart failure and cause death. In order to monitor this signal, a blood pressure cuff is required to be worn on the arm which will periodically take data and transmit it via Bluetooth.

3.1.11 LabVIEW Programming

National Instruments: LabVIEW programming software is an important aspect to this device. Without this software, data analysis of these signals, transmitted via Bluetooth, would be near impossible to program/code and display to the user would be difficult if coded in other means. LabVIEW has fantastic, easy user display, as well as superior data analysis collection and processing. Bluetooth sub-programs in LabVIEW aid in this process of data collection which is a huge advantage to the device in the sense that the patient can be mobile and not have to worry about carrying their base station on person and the main program will handle the data being transmitted. Also, LabVIEW has multiple functions in analyzing many types of data from waveforms to arrays and clusters which can be manipulated to display to the user of what their Vital Signs are. The main LabVIEW program will also need some direct user input to connect to which Bluetooth device is being used. Lastly, the viewer will see Fig 1 as the front panel when the Vital Sign monitor is collecting data.
Figure 1: Front panel of main LabVIEW program that the user will see. Displayed Vital Signs from left to right, top to bottom, are: body temperature, blood oxygen level as a percentage, heart rate, respiration rate, systolic blood pressure, weight, diastolic blood pressure, ECG signal, stethoscope sound capability, and a stop button to stop the program from running. Fall detection will not be displayed however will trigger an alarm when tripped. The user will enter in which device that comes up and the data from the Bluetooth transmitter will be displayed.
3.2 Optimal Design

3.2.1 Objective

Our group’s interpretation of how best to organize this project suggests that the simplest design is the best. As any engineer should know, the less complicated something is, the less things that can break. We have decided that the best way to organize the vital signs monitor is to minimize the number of components to the bare minimum. This means that each sensor will be a part of a whole as opposed to being individual devices sharing only proximity. For a device that intends to provide a comprehensive look into the human body, we can do an optimal job of this by minimizing the sensors and stripping them of their luxuries. This way we can get rid of one Bluetooth module for each sensor, as well as remove the need to replace/charge several batteries. By separating everything, we can work backwards from the “the whole is greater than the sum of its parts” philosophy, and make each part an individually smaller portion that sums to the original whole.

The chest strap will be sweat resistant, elastic, soft, breathable material on the side closest to the body. On the other side, facing away from the patient however, there will be a few “rails” of open electrically conductive strips running parallel to each other throughout the length of the strap. There will be another soft elastic thin secondary layer designed to cover and protect the user, and these open wires from each other. The purpose of these striped wires will be to provide a ground, a power source, and a data channel. Connecting to each of these wires will be a box to which the chest strap originates. This box will be worn such that it will lie between the scapulae, and not impede any daily function of the user. This box will provide power and ground along two of the three parallel stripes. The third will be a data wire used to communicate between sensors and the main strap computer. This box will then take all of the data (communicated via a wired connection), consolidate it into a signal, and communicate via a Bluetooth chip to whatever base station or enabled device of one's choosing. The rails will provide power, and a means of communicating to the chest strap box, which will carry the brunt of the data processing load.

The sensors then will be used by clipping in between the two separate layers such that conducting pins will connect and provide power to each individual sensor (see Figure 2). A third pin will then be used to communicate the single channel of data to the box. Communicating multiple sources of data on a single wire can be accomplished using the I2C communication bus developed by Phillips. Either communication method is compatible with Arduino microcontrollers via existing API, however I2C is built into the existing library possibly making it easier to use. Each sensor will be programmed to handle its own input, translate it into a language communicable via this single wire, and then communicate to the main box on the chest strap back. This reliable method of data transfer will offer built in support for a variable amount of sensors (if two temperature sensors are needed for example) because each sensor will have its own unique serial number so the same type of data won’t confuse the microcontroller. The main box will then take each of the sensors data, and prepare it for interpretation by the existing circuitry. Ultimately the presence of three wires in the strap may or may not be necessary, dependent on whether we use this communication method or not. Since it is low power and low speed, the novelty of minimizing the expose wires will need to be addressed.

This system is efficient for several reasons. It will be cheaper to produce, lighter, user friendly, and customizable. It will be cheaper to produce because each sensor will be small, and lack complicated communication relay, or batteries. Due to the lack of batteries in each device,
the total weight of all sensors will be minimized, adding to the comfort of the user. The modular nature of each sensor means that replacement of faulty parts is simple. Either replaces the main battery, or a cheap sensor module, not both. Diagnosing such problems will be incredibly easy since either all parts are powered, or just one is not relaying data, or no data is being interpreted, but power is being sent to them. Troubleshooting will essentially be reduced to ensuring the proper contacts are maintained, and placing the sensors (which by attaching via clips, are variable in their placement) in the proper locations. From there, it would be easy to isolate which, if any, parts are not working. Since the wires run across the entirety of the strap, sensor position can be adjusted for any patient by clipping each of them wherever they may be optimally positioned on their body. Finally it is customizable by allowing doctors to purchase only specific sensors. Each one will be self-contained, and will be able to run independently of other sensors.

3.2.2 Subunits

3.2.2.1 Chest strap

We chose to use a strap similar to spandex because this lightweight breathable material is commonly used in similar applications, such as for holding existing sensors close to the body or binding splints along bodies for extended periods of time. This has a major benefit because there is existing proof that this will work well in a wide variety of patients. The strap will be embedded with 4 bare strips of flatwire. We chose flatwire because the open copper wire will provide a flexible and conductive pathway for signals and power to travel. There will be 4 pathways because there are two needed for power and ground respectively, while the two middle pathways will be for I2C Clock signal, and I2C Data Signal. I2C works by using the clock data to choreograph when each bit is sent from each sensor connected in parallel between the wires. The clock channel will also send an activation signal to the listening sensors. Since each sensor will not send data unless it is its “turn” we can use the activation as a trigger for a power save mode. Once the master requests that the sensor start sending data, the sensor can take a moment to begin drawing power, take measurements, send data and then stop and enter a low power state once the stop bits have been received. A limitation to I2C is that the data cannot be transmitted simultaneously from multiple sensors, however with a data transmission rate of around 100 kHz, and a relatively low volume of data, this is unlikely to be a problem. The strap will be connected at one end inside the master controller box, and the other end will loop through a hook on the other end of the box to be cinched, where a simple Velcro strap may be used to fasten it around the user at their comfort.

3.2.2.2 Master controller

The main controller box will use a more powerful microcontroller than any inside the sensors and will coordinate the communication from the sensors to the base station. This will involve programming revolving around two modes of communication. The main box will first take the I2C data received from all the sensors. This microcontroller will be the master responsible for taking and requesting data from the sensors and then send it to Bluetooth. Finally this controller must have some method of determining how many sensors are to be placed on the strap. This is so the serial data collection can occur enough times to cover each sensor. This might be implemented by LabVIEW or an interface on the box itself. Secondly, the master controller will then connect via Bluetooth to a device running LabVIEW. The VI will then read
the data streamed, and as needed process and analyze the raw data to display into the desired format. The VI is explained in the relevant section below.

The code included below for the master controller lays out the basic information collected by the I2C interface and describes the loop by which it will request data from each sensor and write the necessary information to memory.

```cpp
#include <Wire.h>
int numDevices; // each device has an identifier of 1,2,3 or something
// could use an array of device registers
int voltage;// taken from temp sensor
int infrared; // taken from oximeter
int red; // oximeter
// EKG signal?

void setup()
{
  Wire.begin(); // join i2c bus (address optional for master)
  Serial.begin(9600); // start serial for output
  // on button press Bluetooth pairing
  // on button2 press loop through all devices collecting data
}

void loop()
{
  Wire.requestFrom(2, 6); // request 6 bytes from slave device #2
  // The above statement will be replaced with collectData() when it is completed

  while(Wire.available()) // slave may send less than requested
  {
    char c = Wire.read(); // receive a byte as character
    Serial.print(c); // print the character (for testing only)
  }
detectFall(); // uses accelerometer to continuously check for falling
  // Will also call the EKG function as well

  delay(500); // this will perform all the above actionsevery half second. The delay can be customized
}
void alarm() // Call whenever ecg or Fall detection detects an alarm worthy event
{ // This is subject to change depending on the nature of the alarm
  void collectData()
  {
    for(int i = 0;i<numDevices;i++)
    {
      //ask for data from the device with the current identifier
      // if array is used for loop through the array to access the correct
      //"name" to refer to each sensor
    }
  }
  void detectFall()
  {
    // if.accelerometer input compare to falling range
    // { call alarm();
    // include buffer for false positives?
    
  }

  3.2.2.3 Temperature sensor
  This small device will clip on the chest strap and be placed in the armpit. This is the closest location for core body temperature that will be accessible to the chest strap. The inside of the clip will have three contacts for the power, ground and data transmission. This sensor will be the simplest to develop communication for. A resistance temperature detector (RTD) placed in
```
contact with the inside of the armpit will ensure constant contact and an accurate data reading. This thermistor will change in resistance as temperature changes. This change in resistance can be sensed by the microcontroller based on the voltage drop across the RTD, which can then interpret, and perform a simple calculation to convert the signal to degrees Celsius and degrees Fahrenheit. Alternatively the raw resistance data can be communicated and be calculated by LabVIEW. The size of the data needed to be transferred by this sensor is relatively small and should only take a small amount of bandwidth.

The temperature biosensor will use an OMEGA Thin Film RTD Element/Probe to record the patient’s body temperature. This product was selected because of its high ratio of surface area to volume, high surface conductivity, flat platinum resistance detector design, fast response time and low cost ($25-$75). This RTD complies with DIN 43760 and BS 1904 resistance and tolerance standards which requires platinum wires to have a temperature coefficient (α) of +0.00392 °C/Ω and a tolerance of .06% @ 0°C for class A RTD’s. The response time of the OMEGA Thin Film RTD is under a minute in air moving at 1 m/s. Our application of this device will be in still conditions under the armpit, suggesting that the response time may be even quicker. The expected patient body temperature resides well within the RTD temperature range which resides between -70°C (-95°F) and 500°C (930°F). The final resistance can be calculated for temperatures above 0°C by using the equation:

\[ R_t = R_0(1 + A_t + B_t * t^2) \]

where \( A = 3.90833 \times 10^{-3} \text{(C-1)} \), \( B = -5.7753 \times 10^{-7} \text{(C-2)} \), \( R_0 \) is the resistance at 0°C, and \( t \) is the temperature.

Thin film RTD elements work by placing platinum resistive material on a ceramic substrate and coating it in an epoxy or glass. The coating helps protect the platinum wire from shock, vibration, deformation, and strain. One disadvantage to thin films are they are less stable than wire wound or coiled RTD elements, however its form is beneficial to our chest strap design by making the biosensor less bulky without sacrificing the overall function of the RTD significantly.

The body temperature biosensor circuitry will consist of a 4-wire bridge to eliminate lead impedance which can create error in the temperature measurement. Figure 1 shows the RTD sensor circuit with RT representing the RTD resistance, RL and RL2 representing the resistance of the long wires, and R1-R3 representing the other resistances in the Wheatstone bridge. The RTD is distanced from the rest of the circuit to reduce heat exposure to the remainder of the circuit which may change other resistor values and create error.

![RTD Sensor Multisim Diagram](image-url)

**Figure 2:** RTD Sensor Multisim Diagram
The temperature sensor will be powered by an ATtiny4313 microprocessor, which has 4 kilobytes of on board memory, and support for the Arduino bootloader. This small chip can use one of its serial ports as to detect voltage. This voltage reading is then sent via I2C to the master controller, where upon connecting to the base station will convert it to a resistance and subsequently, a temperature reading. The will be used to calculate the temperature from voltage due to memory considerations because an early draft program that attempted to calculate the temperature on the sensor itself ended up being around 8 kilobytes. Outsourcing the math to the LabVIEW program proved to be a much better decision because the computer will typically have less size and power restrictions than the sensors themselves. In order to minimize the power consumption, the voltage divider will be connected to power via a digital switch. This will remain open until the data is requested from the master controller. At this point, the switch will momentarily close, the serial port will read the voltage out, and then the switch will open again. This ensures that there is no power wasted on continuously running a voltage divider. The code so far for the temperature sensor is included below. This is a combination of serial read statements, and the Wire library slave write functions:

```c
#include <Wire.h>
int analogPin = 0; // potentiometer wiper (middle terminal) connected to analog pin 3
// outside leads to ground and +5V
float Vout; // variable to store the output voltage
int ID = 2; // I2C address

void setup()
{
  Wire.begin(ID);
  // turn on power to the thermistor using a switch
  float Vout = takeVoltage();
  Wire.onRequest(requestEvent);
  Serial.begin(9600); // Setup serial
digitalWrite(13, HIGH); // Indicates that the program has initialized
}

void loop()
{
  //testbed
}

void requestEvent()
{
  char voltage = char(Vout);
  Wire.write(voltage); // Write the voltage value to the master
}

float takeVoltage()
{
  Vout = analogRead(analogPin); // Reads the Input PIN
  //delay(1000); //delay(1000);
}
```

The voltmeter represents the output data of the temperature biosensor which is then processed by LabVIEW. Using the output voltage, the program will process the data to find the final resistance of the RTD and evaluate the patient’s body temperature by comparing the final resistance to the initial resistance as seen in Figure 3.
Figure 3: Temperature Biosensor Programming
The simulated signal represents the signal sent from the body temperature biosensor. Once processed, the final output displays the user’s body temperature to the user on their Microsoft Surface tablet.

3.2.2.4 Blood Oxygen monitor

Figure 4: Absorbances of hemoglobin and saturated hemoglobin

Pulse oximetry is the measure of blood oxygen content using the optical properties of hemoglobin. Oxygenated hemoglobin absorbs infrared light and lets red light pass through, while deoxygenated hemoglobin displays the opposite properties. Pulse oximetry is thus accomplished by shining a red and an infrared light through a translucent part of the body (useful contact points for this are the finger, toes, the earlobe, and the tip of the ear). Opposite to this point is a light detector that detects the light that has passed through the thin section of the body. After the sensor detects this, a computer calculates the ratio of absorbed red to absorbed infrared light ratio.

Upon obtaining this ratio, the software can then consult a table of values, usually from reference, or calibration data, to determine the blood oxygen content ratio. There are two placements of sensors for detection, transmittance and reflectance. In transmittance, the sensor sits opposite to the light sources, and the absorbance is calculated dependent on the light that passed through the skin.
In reflectance, the sensor is placed on the same side as the light sources, and the light that is returned is used to obtain measurements. Since the two methods require two different theories behind operation, a decision needs to be made regarding whether transmitted or reflected data should be used. This will affect the calibration data needed to determine blood oxygen content.

This sensor will be designed differently from the others. Whereas the other sensors have the option of picking up singular point of data and sending it along the wire to the Bluetooth transmitter, this sensor will require more processing power, and depending on the kind of data sent, more memory on board. A blood oxygen monitor needs two different LEDs to shine through a thin portion of the patient’s skin, in this case, the earlobe. A detector then picks up the light that has shined through the patient and a ratio comparing the two absorbance’s must either be calculated on the sensor itself, or be sent to the controller, dependent on the limitations provided by the microchip on board, and the requirements of the I2C communication protocol. This is then plugged into a function, or compared to an absorbance curve based on standard data to determine the blood oxygen content in the blood. In this design, it would be sensible to place a sensor box on the patients back, and have a wire that contains the clip with two LED’s and the one photosensor snaking up under the shirt to the patients earlobe. This thin area of the body also serves as a good location for pulse oximetry compared to the finger, and has the added benefit of being very near the chest strap. A small cable no longer than 10 inches will be all that is needed to ensure that the signal can be obtained by the sensor wherever it is placed. The earlobe clip will need to have power going to both sides, with just a power and a ground wire for the lights, and a third wire for the photosensor. We will be using a light to frequency converter to subvert some of the calculation. Once that data is sent directly to the chip, the ratio and then blood oxygen content can hopefully be transmitted to the controller box.

3.2.2.5 Fall Detector

In interest of keeping as many sensors as close to the chest strap as possible (to remove the hassle of peripheral devices), the fall detection biosensor will use a triple axis accelerometer attached to the chest strap to detect abnormal three dimensional motions. As opposed to extremities such as the arms or legs, the core of the patient’s body will only have a drastic change in motion and positioning during a fall. Extremities will have constant change in motion and positioning during daily activities. The triple axis accelerometer being placed on the chest strap allows the fall detector biosensor to evaluate the patient’s stability closer to their center of gravity which should allow for more accurately identifying when the patient falls. The data sent by the fall detection biosensor will be calibrated to prevent a false identification of a fall and allow proper evaluation of abnormal movements in the patient’s center of gravity. The triple
axis accelerometer detects proper acceleration, or acceleration relative to free fall, in all three axes of movement. After processing the data using a microchip to determine whether abnormal motion occurred, the output will be sent to the LabVIEW program which will indicate the patient’s stability as well as whether they have fallen. This biosensor will incorporate an alarm function in order to contact help during an emergency situation such as a fall or seizure.

In order to continuously monitor the patient to detect a fall at any point, the fall detection biosensor will need to draw a minimum amount of power continuously in order to power the accelerometer and microchip. Minimizing the energy consumed by the fall detection biosensor will ensure our goal of creating an efficient and environmentally responsible vital signs monitor. In order to meet these design requirements, the fall detection biosensor will use the ADXL345 triple axis accelerometer made by Sparkfun Electronics (Boulder, CO) seen in Figure 6.

In order to continuously monitor the patient to detect a fall at any point, the fall detection biosensor will need to draw a minimum amount of power continuously in order to power the accelerometer and microchip. Minimizing the energy consumed by the fall detection biosensor will ensure our goal of creating an efficient and environmentally responsible vital signs monitor. In order to meet these design requirements, the fall detection biosensor will use the ADXL345 triple axis accelerometer made by Sparkfun Electronics (Boulder, CO) seen in Figure 6.

Figure 6: Sparkfun Electronics ADXL345 Triple-Axis Accelerometer

This product is more attractive than our previous selection, the ADXL335, because it has a higher full sensing range, it is accessible through I2c digital interface, and it has a higher resolution. Having a resolution of 4mg/LSB allows the ADXL345 to measure inclination changes of less than 1.0 degrees. This allows the fall detection biosensor to sense when the patient has tilted past the point in which it is capable to maintain stability, indicating a fall. This knowledge could also lead to future developments in which some sort of precaution is activated after the tilt has reached the threshold but before the patient has completed their fall. Currently, it will alert caretakers as quick as possible by reporting an emergency as the fall is occurring. The ADXL345 measures up to 16g and outputs the data digitally formatted as a 16-bit twos complement. This generation includes the ability to measure tilt-sensing applications, dynamic acceleration resulting from motion or shock, and inclination changes. This information will upload into software on the Microsoft Surface which will determine whether the patient is upright, falling, or has fallen and is not getting back up. Having this ability allows us to possibly alert the patient with an auditory message or command after experiencing a fall and refraining to send a false alarm emergency contact until a determined time has passed without a response by
the patient manually or by the accelerometer’s detection of a lack of movement. Additional capabilities include activity and inactivity sensing to detect presence or lack of motion, the ability to detect if the acceleration on any axis exceeds a user-set level, free-fall sensing, tap sensing, a 32-level FIFO buffer which can be used to store data in order to minimize host processor intervention, and low power modes which enable intelligent motion-based power management with threshold sensing and active acceleration measurements at extremely low power dissipation. The tap sensing ability could be incorporated as the manual response from the patient after a fall. For example, the auditory message would command the patient to tap once to contact emergency caretakers or tap twice to indicate they have not suffered life threatening injuries.

One limitation includes the need for a lower voltage power supply to the accelerometer. If we assume the power line of the chest strap has a voltage of 5 V, there will need to be a voltage drop in the circuit to accommodate the accelerometer’s desired voltage range of 1.8–3.6VDC for optimal performance. Also, based on the previous design of the vital signs monitor, only one output of data from a biosensor can be received at a time. In order to have the fall detection biosensor constantly monitoring without using the data transmission line, the output of the biosensor must only transmit data in the case of a fall, rather than continuously occupying the line.

In order to calibrate the ADXL345 accelerometer, it is necessary to remove any biases from the readings. The following code will ensure the base values for the x and y axes are approximately zero and the z axis reads approximately 1g:

```c
void calibrateAccelerometer(){
    //Take a number of readings and average them
    //to calculate any bias the accelerometer may have.
    for (int i = 0; i < 32; i++) {
        accelerometer.getOutput(readings);
        a_x += (int16_t) readings[0];
        a_y += (int16_t) readings[1];
        a_z += (int16_t) readings[2];
    }
    //50Hz data rate.
    delay(20);// Arduino does things in milliseconds
    a_x /= 128;
    a_y /= 128;
    a_z /= 128;
    //At 4mg/LSB, 250 LSBs is 1g.
    a_xBias = a_x;
    a_yBias = a_y;
    a_zBias = (a_z - 250);
    a_x = 0;
    a_y = 0;
    a_z = 0;
}
```

During the calibration, the accelerometer must be on a stable surface and oriented in the resting position of how it will be placed on the chest strap. One discrepancy we have found for this product is the datasheet says the sensitivity is 4 mg/LSB, however the specifications says it is 3.9mg/LSB. If we are doing a proper calibration that produces significant error due to the 0.1
mg/LSB discrepancy then we would have to change the z axis bias. The z-axis bias would become 256 as opposed to 250.

3.2.2.6 Stethoscope Biosensor
The stethoscope biosensor will use the electronic sensor developed by Chad Lyons and have a headphone jack for local output. There will be no digitizing signal, it will just calculate the respiration rate on the sensor itself, and then send that information when requested. The stethoscope can be used on both sides of the body to listen to different areas, as physicians are able to detect different sounds from the front of the patient and their back. There are some drawbacks using a stethoscope including frequencies too low for humans to hear, artifacts being introduced through movement of the sensor, and in Chad’s design the adhesive hydrogel can’t be reapplied so the user will have to purchase multiple apparatuses with the hydrogel application. Once the data is transmitted to LabVIEW, the user has the option to play back the sounds transmitted from the device and in the programming this data will be used to calculate respiration rate as mentioned in section 3.2.2.8.

3.2.2.7 ECG sensor
The ECG sensor will utilize either 2 lead electrodes or custom leads which may be possible with further research. 2 leads are possible but will not give as clear a waveform as ECGs with more leads. The leads will plug into an integrated analog front end of the Texas Instruments ADS1298R ECG chip. The ADS1298R chip packs 44 discrete which reduces the power consumption by 95% compared to a fully discrete design and the component count. The chip is available in eight-, six-, and four- channel versions which all provide 20 milliohm of resolution for respiration impedance. The chip consists of 8 analog-to-digital converters, 8 programmable gain amplifiers, and 8 active filters. This chip is beneficial to our design based on the low power consumption and its capabilities which include a portable electrocardiogram, integrated respiration impedance meter, and an analog front end. Potential problems include the leads, which in the following diagram show connecting leads at various places on the body. If we are able to modify this design in order to need only chest leads as inputs for this chip, this chip will enhance the simplicity of our ECG design and provide efficient ECG and respiration rate outputs. To build on this, assuming this chip is applicable to our design, the group can now work on a LabVIEW program to detect abnormalities in the ECG as well as an alert system. The following figure on the next page shows the block diagram overview of the ADS1298R chip and its hardware capabilities. Once transmitted to the LabVIEW program, the ECG will be displayed in real-time on a graph on the front panel as show in Figure 1, and be used to calculate the heart rate of the patient.
3.2.2.8 Heart and Respiration Rate

Heart rate will be monitored through the use of the ECG signal and the pulse oximeter. From the ECG signal, the distance between two subsequent peaks or period can be used to calculate the frequency or rate that the patient’s heart is beating. This will be used in conjunction with the pulse oximeter as blood flows through the veins of the patient underneath the sensor; it picks up on the movement of the hemoglobin and saturated hemoglobin which this movement can be used to calculate the frequency/rate of the blood flow which translates to the patient’s heart beats.

Respiration rate is a little trickier in that the lungs must be monitored or at least the air flow coming in through the trachea. If monitored through the trachea, this will require another wire and microphone which is undesirable as there is another ‘type’ of microphone already being used on this device, the stethoscope. When placed on a patient’s back, physicians get a rough idea of how often the patient is breathing by use of a stethoscope. However, through continuous use by a stationary stethoscope, the respiration rate will be monitored over a larger period of time as well as monitored in real time. The way that LabVIEW will calculate this data is by using a similar method to the heart rate, measuring the distance between two peaks. As a person breathe in, air fills up the alveoli of the lungs and produce sound as it rushes in which produces peak decibel values. These values should have repetitive nature as respiration is typically an involuntary action. By measuring the distance of peaks LabVIEW will display the respiration rate.
3.2.2.9 Weight sensor
As mentioned in the introduction, patient’s weight will be measured through an external Bluetooth enabled scale that is separate from the main Vital Sign Monitor device. The scale will still be in contact with the base station and have the data transmitted to the Microsoft Surface for analysis and display through LabVIEW. Each set of data taken from the scale will be paired with the date and sent to a separate file so the patient can monitor their weight over time.

3.2.2.10 Blood pressure cuff
Blood pressure contains 2 sets of data, diastolic and systolic (or minimum and maximum). This vital sign must be collected by constricting vessels in order to determine these minimum and maximum points, therefore a blood pressure cuff around the arm will be necessary to monitor this data. Since this cuff is around the arm, and away from the main device, it will need its own Bluetooth transmitter which Bluetooth enabled cuffs already exist in the market. The data sent from this cuff will be broken into the systolic and diastolic measurements needed for display to the patient.

3.2.2.11 LabVIEW Programming
As mentioned above in the introduction, LabVIEW is an important aspect to this project. The block diagram, as shown in Fig 8, shows a majority of the programming behind the front panel as shown in Figure 1.

![Block diagram of the main LabVIEW program.](image)

**Figure 8:** Block diagram of the main LabVIEW program, on the left hand side, is the data acquisition from the Bluetooth sensor(s), while all of the orange blocks are the various vital signs which will be wired once the data is sorted. The case statement is in case the patient/physician desires to listen to the stethoscope data.
3. Realistic Constraints and Standards

Engineering standards enable devices for universal use by any individual and enable different manufacturers to create products that work together. Standards for the vital sign monitor include: power supply in the form of batteries; biosensor devices adhering to existing standards in the medical field and IEEE standards; thin film temperature sensor adhering to US, German, and British standards which display Celsius and Fahrenheit; Withings scale displaying weight in kilograms, pounds, and stone-pounds; blood-pressure cuff displaying diastolic and systolic measurements; pulse rate in beats per minute. These standardized measurement systems and components will be implemented in the design of this vital sign monitor.

One of the most important constraints for this project is power consumption. Hopefully most of the sensors are relatively low in their power consumption, and the I2C protocol has some built-in ways to trigger a “power save” mode for sensors when they are not collecting data. However, for the pulse oximeter, a relatively high amount of energy needs to be provided for the light emittance, and then subsequent calculation of data. There is no way to tell whether or not it would be possible to supply a table of values for comparison. Ideally a function can be used to model the absorbance to oxygen content relationship, and a simple calculation will be all that is needed. As of the current stage, without more experience with the programming, it is difficult to tell whether or not the existing microchips will be able to handle the load of interpreting and calculating a ratio. If this is done on the sensor itself, this calculation may tax the microchip since we aim to use low power, low cost chips, (depending on the complexity). If due to the way I2C works, we need to send it already processed, then we might need to use a more powerful chip, in which case the concerns for the straps ability to provide power to all of the sensors still stands, and may even be cause for more concern. The design of the sensors to distribute their software amongst different outlets may work to our advantage since we have the option of performing some calculations in one of three places, either the onboard microchip on the sensor, or the controller box, or finally for the most intensive of tasks, we can send raw data to LabVIEW to interpret and organize for us. The largest obstacle for the blood oxygen content sensor is that at the very least, the frequency data needs to be compiled into a singular ratio before sent to a computer across Bluetooth because the existing Bluetooth program was not created to accept multiple points of data.

In order to continuously monitor the patient to detect a fall at any point, the fall detection biosensor will need to draw a minimum amount of power continuously in order to power the accelerometer and microchip. Minimizing the energy consumed by the fall detection biosensor will ensure our goal of creating an efficient and environmentally responsible vital signs monitor. Based on the previous design of the vital signs monitor, only one output of data from a biosensor can be received at a time. In order to have the fall detection biosensor constantly monitoring without using the data transmission line, there will be an additional wire so that the biosensor is directly connected so as to not continuously utilize the data transmission line. The Sparkfun Electronic’s ADXL345 Triple Axis Accelerometer needs the power supply to exist in the range of 1.8-3.6 VDC which creates the need to make a voltage drop from the chest strap Vcc power line if it is above the given voltage range. The ADXL345 accelerometer has a power management system which will only consume power when a user-set acceleration or degree of inclination occurs. This will ensure the least amount of power consumption as possible.

The temperature biosensor includes a thin film RTD which requires several constraints in order to perform accurately and efficiently. Voltage above 100Vdc will destroy the thin film RTD element. The RTD element must be separated from the other circuit elements which may
increase in temperature to avoid self-heating error. The minimum and maximum temperature the RTD can measure are -70°C (-95°F) and 500°C (930°F) respectively. The RTD must also avoid internal heating due to excess power from a high lead current. If extra heat cannot be dissipated, heating caused by excitation current can raise the temperature of the sensing element above the ambient temperature causing error due to a change in resistance of the RTD. A 100 ohm RTD element has a recommended maximum operating current of 1mA.

The ECG biosensor will consist of 2 chest leads attached to the underside of the chest strap which plug into an analog input for the Texas Instruments ADS1298R ECG chip. The chest leads must be made out of non-allergenic materials and may require electrode gel to ensure proper conduction. The ADS1298R ECG chip has several realistic constraints. The operating temperature range is -40 degrees Celsius to 85 degrees Celsius. The momentary input current is 100 mA and the continuous input current is 10 mA. The digital input and output voltages range from -0.3 V to 0.3 V. The ECG chip resolution is 17 bits with the maximum 32kSPS data rate, 19 bits with a 16kSPS data rate, and 24 bits with data rates up to 8kSPS. The interface is SPI which may provide problems, however the chip will probably get connected to a microchip which will export information through I2C to transmit data to LabVIEW. The flexible power-down and standby modes will ensure limited power consumption.

A severe limitation on stethoscopes is that they yield poor analysis even by a trained professional, nevertheless they can be used to calculate respiration rate as desired in the vital sign monitor. Stethoscopes come in a variety of different products, from classical stethoscopes used by a physician to electronic stethoscopes converting physical audio signals to electronic signals for amplification and processing. Classical stethoscopes can’t be used due to an electrical signal and can’t detect subtle heart/lung irregularities while electronic stethoscopes generate electrical signals and detect many more defects but can be quite costly as the technology put into them are more advanced than other devices and are still bulky. Prices range from $125-600 for electronic stethoscopes, possibly lower. To get around these constraints, we found a stethoscope device that generates an electrical signal from sound, is small enough for patient use, excellent irregularity detection, and cost effective. This Stethoscope Receptacle, patented by Chad Lyons, will be used in this device with limitations on having to replace the device after use, and hydrogel adhesive being used which has to be applied for the device to attach to the patient’s skin.

An often seen constraint in patient weight is what type of measurement system they are using, US or SI. The scale that we implemented in this design provides display in both formats. Further constraints to scales, are weight limits as the Withings scale can load up to 300 pounds, and type of surface it can rest on, which the device comes with carpet feet attachments.
4. Safety Issues

Safety is always a primary concern when dealing with patients as they are already in a less than normal state and with our monitor, it will hopefully be used by a numerous amount of patients with varying states of health and/or disease ranging from cancer, heart disease, infection, trauma, and other medical uses. No device is perfectly safe as people manage to harm themselves accidentally in strange ways and we must account for these odd variables. We will try to minimize hazardous design as much as possible.

Devices that contain electrical elements always will pose a safety issue. Current should be limited around the strap with a low yet usable voltage. Each sensor must have an adequate power source (through the single wire) and contact with skin, so one safety issue is the contact with skin posing an electrocution problem and can be minimized by insulating material surrounding contacts (besides the skin) and the voltage leading to the sensors. Infrared radiation from the pulse oximeter is also a possibility which may have a harmful effect and will be noted to the patient. Coinciding with electricity and radiation, these elements can heat up therefore material that dissipates heat is desired to not burn patient’s skin.

Since each sensor will be removable via clip, there can be potentially small parts that can be hazardous to infants. There will be a warning label and possibly a case that can house each sensor is possible. Another mechanical issue is the clips in itself they can pinch and perhaps pierce patient’s skin.

Materials are important in design as they are in direct contact with skin and clothing. Safety hazards with the materials are scratching, skin irritation, allergic reaction, and immune response among others. Our device will be made out of material that will avoid all of these potential hazards as well as a sweat resistant, elastic, soft, breathable material on the side closest to the body and nothing abrasive to rip or tear through clothing that the patient will wear on the outside.

5. Impact of Engineering Solutions

This vital signs monitor will have the opportunity to become a solution to many global, economic, environmental, and societal problems which are prevalent today by providing an inexpensive way to monitor the heart using an ECG, respiration, blood pressure, body temperature, blood oxygen level, weight, and detect falls in the case of an emergency. The goal of this project is to make an efficient vital signs monitor that emphasizes on accuracy and economic accessibility. As health care remains a significant issue here in the United States and the rest of the world, an inexpensive vital signs monitor will enhance each individual’s ability to understand their health, improve their well-being, and collaborate with their caretakers through the quick and easy transmission of vital data in real time. Patients suffering from numerous different conditions will attain the ability to properly monitor themselves outside of a hospital or doctor’s office while simultaneously providing their caretakers with data to progress their health over time and in several different circumstances of daily life.

Providing an inexpensive vital signs monitor allows many members of society which struggle economically to assess their health at home and eliminates many unnecessary doctor or emergency room visits which can become extremely costly. This product improves the process of diagnosing conditions, doctor evaluations, self-evaluations, and examining health progress over time. With the ability to transfer information wirelessly from the biosensors on the patient’s body to LabVIEW on the Microsoft Surface for processing to any internet platform for the
viewing of the patient, their family, their doctors, and other caretakers the time it takes to
diagnose and assess a problem will be less than the patient’s time spent in the waiting room.

This project is capable of having a global effect due to its compatibility and portability. The Microsoft Surface will be available worldwide following its release date allowing our vital
signs monitor to be relevant all over the globe. With the global economy suffering,
revolutionizing basic vital signs monitoring with our relatively inexpensive device can result in
many people being provided with proper health care whom normally could not receive the proper
attention.

Our efficient vital signs monitor design stresses environmental responsibility through the
limited use of materials, elimination of waste by making each biosensor capable of clipping on
and off the base chest strap, and limited power usage due to our effective circuit designs in order
to use the absolute minimum amount of energy possible. Making each biosensor individual with
the clip-on system is an advantage for consumers and environmentalists as it reduces the waste in
the event of a sensor error or malfunction. If one biosensor malfunctions, instead of needing to
replace the entire chest strap, the patient need only replace the specific biosensor which no
longer works accurately.

6. Life-long Learning

This device will take advantage of a simple and modular design that will allow future
development to continue to add to the existing project with a simple hardware interface. This will
provide an easy template and route of thinking that makes it easy for future engineers to design
around our work without it presenting a major obstacle in functionality of the device. This is an
important skill to learn because we feel that starting to work on a project with existing progress
is frustrating because it requires new engineers with different ideas and experiences to conform
to existing limitations and blind spots. While we don't presume that our design doesn't have such
problems, we feel that the open ended format we have presented allows for the greatest amount
of expansion, considering that beyond offering a platform that provides power, and a means of
transmitting data, there are no restrictions or adjustments that need to be made to existing sensors
to make new sensors work alongside future developments, indeed the way we plan to implement
our one wire communication array is built on the assumption that there may need to be a variable
amount of sensors and future devices attached to the same product.

Currently, we are all learning about the internal design of medical devices, as we
continue to design these components, we will move from modeling to making the actual device,
when we will run into a better idea of the software to hardware constraints. Since we intend to
make the sensors out of the smallest microchips we can program to keep them light, we might
run into memory issues that are currently unforeseen.
### 7 Budget and Timeline
### 7.1 Budget

<table>
<thead>
<tr>
<th>Device</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Microsoft Surface Pro</td>
<td>$999 (128GB) + $129 (thick cover)</td>
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<tr>
<td>Main strap</td>
<td>$170</td>
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<tr>
<td>Body temperature sensor</td>
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<td>Blood oxygen sensor</td>
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<td>Heart Rate Monitor</td>
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<td>Fall Detection Monitor</td>
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<td>Blood pressure Sensor</td>
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<td>Weight Sensor</td>
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<td>Respiration rate sensor</td>
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<td>Total Budget</td>
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## 7.2 Timeline

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<td>Mon 2/11/13</td>
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<td>Mon 4/1/13</td>
</tr>
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<tr>
<td>Stethoscope Arduino programming</td>
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<td>Pulse Arduino programming</td>
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<td>ECG Arduino programming</td>
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<td>Accelerometer Arduino programming</td>
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8 Team Members Contributions to the Project

8.1 Team Members

8.1.1 David Knoff

David Knoff’s contribution to the vital signs monitor focused on the body temperature biosensor, fall detection biosensor, and ECG biosensor. He designed the body temperature biosensor 4-wire RTD circuit and wrote the subvi LabVIEW program to process the body temperature in Celsius and Fahrenheit from the voltage drop across the RTD. He selected the Sparkfun Electronics ADXL345 triple-axis accelerometer for the fall detection biosensor and wrote the calibration program. He also designed the alarm feedback flowchart to detect a lack of balance and fall. Further programming and testing will be needed in the coming weeks and months to implement this feedback design. For the ECG biosensor he researched lead and electrode designs to fit the group’s design specifications while also providing the most accurate ECG waveform. He researched the Texas Instruments ADS1298R ECG chip which will make the biosensor design more efficient by reducing power consumption and board size by 95% each. The overall concept and design of the vital signs monitor including the chest strap, each biosensor, and programming was a result of constant collaboration between each member of the group to ensure compatibility, efficiency, and quality.

8.1.2 Maysarah Shahabuddin

Maysarah Shahabuddin’s contributions to this project have focused primarily on the sensor programming. His job began with the division of sensors, once it was decided that the scale and the blood pressure sensor would be adopted from existing Bluetooth enabled sensors, the rest of the vital signs were going to be mounted on the chest strap. His idea to connect all of the sensors via the I2C bus seemed to be the best compromise of economy and function. From there the three team members split up the sensors. Since I2C was by and large Maysarahs idea, the master controller programming was his responsibility. From there, the programming of any sensor that would use I2C via the wires on the strap fell under his jurisdiction. Up till now, his contributions have included making the functions that will allow the master controller to cycle through the sensors and request their data, as well as storing them until they are uploaded to the LabVIEW via Bluetooth. Then, in collaboration with David, who did the research on the hardware for the temperature sensor, they designed the temperature sensor from the bottom up, and Maysarah made an I2C compatible program that would output the temperature. In interest of minimizing the hardware, he then minimized the programming such that a smaller chip could be used. His current work involves finishing up the pulse oximeter. This pulse oximeter when done will be able to work standalone as a blood oxygen content monitor if such a need were ever to be developed. Alongside this development is the programming of a miniaturized program that would be dependent on the LabVIEW VI for its data interpretation.

8.1.3 Jacob Adams

Jacob Adams’ contributions to this project have focused primarily on the LabVIEW programming interface for the physician or at home user. His primary objective was to design a way for LabVIEW to acquire the information, extract the different sets of data for each sensor, and distribute each signal to be processed and displayed in an effective manner. Along with the LabVIEW coding, Jacob was in primary charge of the scale, stethoscope, Microsoft Surface, blood pressure cuff, and website while he contributed to the aid of Maysarah with the coding of
the microcontrollers in C++ programming language as well as the pulse oximeter. Up until now, Jacob has completed the extraction and distribution steps of the LabVIEW but still has to display the information in a concise manner that can be easily read by a patient with no medical knowledge whatsoever. Further work will be in testing how each of his main devices communicates with the tablet.

9 Conclusion

This vital signs monitor will provide an inexpensive way to monitor blood pressure, blood glucose level, heart rate, respiration rate, body temperature, blood oxygen level, heart and lung sounds through a stethoscope, weight and detect falls in the case of an emergency. With the majority of our biosensors efficiently designed to fit in a strap across the patient’s chest, this device is portable and has the ability to monitor vital signs comfortably in a variety of settings including during exercise, daily tasks, sleep, and many other activities. In the design of our vital signs monitor, we stress simplicity to accommodate the average consumer with little or no clinical experience and possible disabilities. The patient’s vital signs will be wirelessly transmitted via Bluetooth to a tablet, such as the Microsoft Surface, through a remote receiving and storing device. From the tablet, the patient’s vital signs can be transferred over the internet in order to be accessed by themselves and their doctors on several different platforms. Our vital signs monitor provides a unique, inexpensive and effective way for consumers to monitor themselves during daily activities and efficiently relay relevant medical information to their doctors.

Our design platform provides the opportunity for future developments through the addition of biosensors with relative ease. New, state of the art biosensors can be implemented into our vital signs monitor through simple design and programming at any point in the product’s lifetime.
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11 Acknowledgements

**Tom Capuano**

Tom Capuano has done work in professor Enderle’s lab making a Bluetooth EKG and temperature sensor that works with LabVIEW. Due to his prior success, we have used his knowledge, and with his permission, his VI for much of the inspiration behind our LabVIEW code. His suggestions for various hardware upgrades, and existing issues in the project has also shaped the direction we have gone in regards to many design decisions.

**Chad Lyons**

Chad Lyons has worked with Professor John Enderle in the past to develop a small, stethoscope patch. This patch has piqued our interest as we would like to use it as our stethoscope sensor.

**Dr. Faqir Jain**

Dr. Jain, of the electrical engineering faculty in UConn has developed a blood glucose sensor that can be implanted under the skin. His insight and experience on blood glucose detection proved useful when attempting to include this sensor into our project. Since no current sensors exist to fit our preferences, we had to abandon this venue. However, his advice and resources will not go unacknowledged.

**Dave Kaputa for his work and aid with the Vital Sign Monitor, past and present**

**Sarah Brittain**

**Dr. John Enderle**

**Dr. Gielo-Perczak**