Soldier Status Monitoring Project

ECE 445 Design Review

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I. Introduction

As a soldier while it is important to know what is happening surrounding you, it is equally important to know what is happening internally. In the field a soldier needs to be at his best in order to assess and tackle difficult situations. Having a vital monitor would let the soldier know if he is at his best or not and what he can do to improve.

We chose this project because it involves sensors, wireless communication and power systems. Each of us has had theoretical knowledge on the subject but haven't had any practical experience. In addition to gaining practical experience this project also has an immediate practical application. When we complete our project hopefully a soldier out in the field would be able to use our vital monitoring harness to his benefit.

i. Goals

- Be able to gather heart rate and body temperature data reliably.
- Have the data transmitted to a central location where it can be stored and analyzed
- Be able to operate the sensors and transmitter reliably
- Have a power supply that can operate both transmitter and sensors efficiently.

ii. Functions

- LED display that will let the user know when he has reached a critical threshold in his vitals
- Wireless communication of the sensor data to a location at least 100 meters away
- Lightweight battery to supply power the soldier's device.

iii. Benefits

- The soldier will be able to see check his health
- Continuous monitoring of the soldiers vitals
- Remote monitoring of soldier's health to gain information on what is happening on the field
- Non-invasive monitoring of soldier

iv. Features

- A small and compact device that is comfortable to wear and not encumbersome
- real time analysis of the data gathered
- Battery lasts for at least 24 hours of use

II. Design

i. Block Diagrams

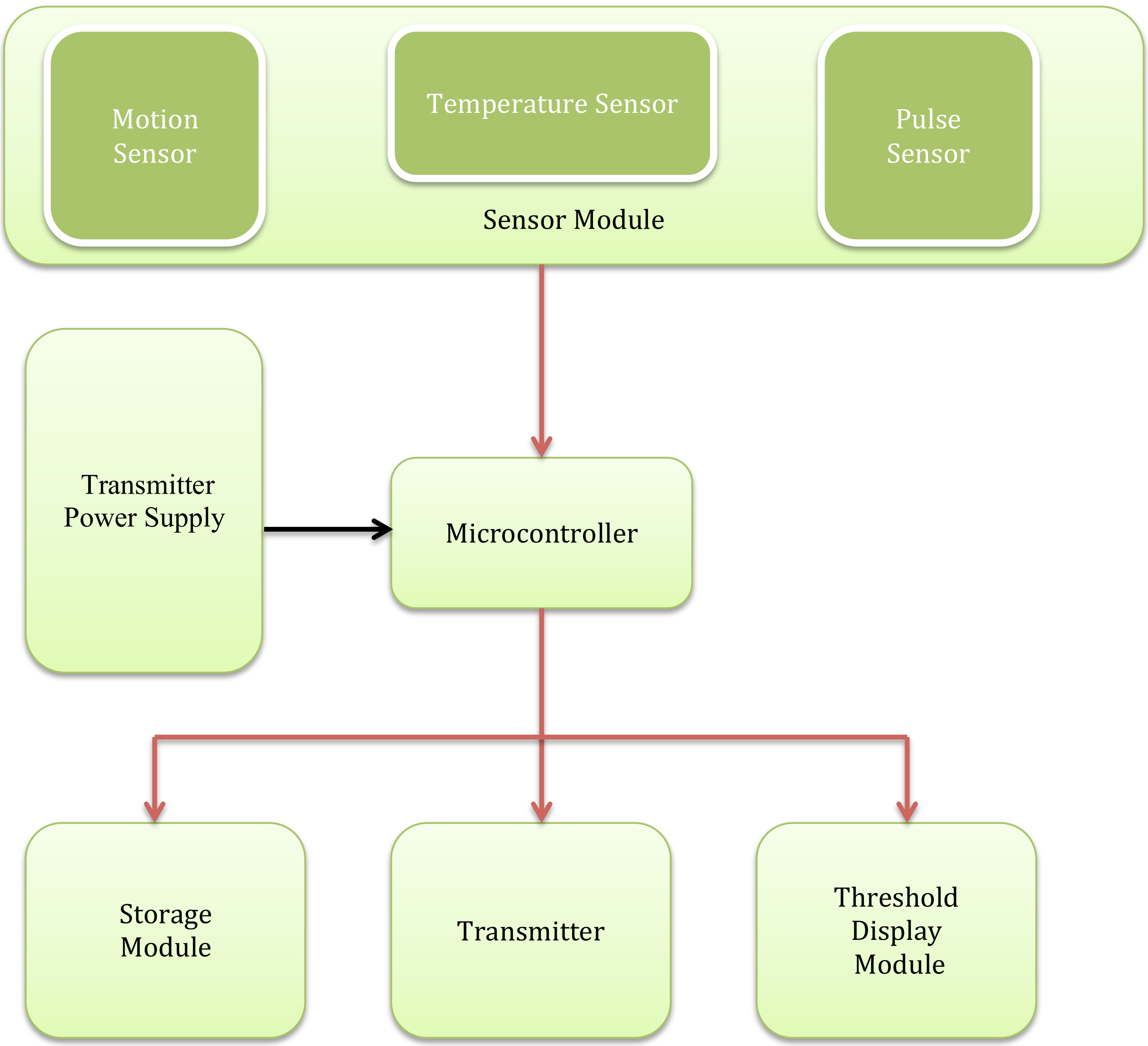


Fig 2.1 Transmitter Circuitry Block Diagram

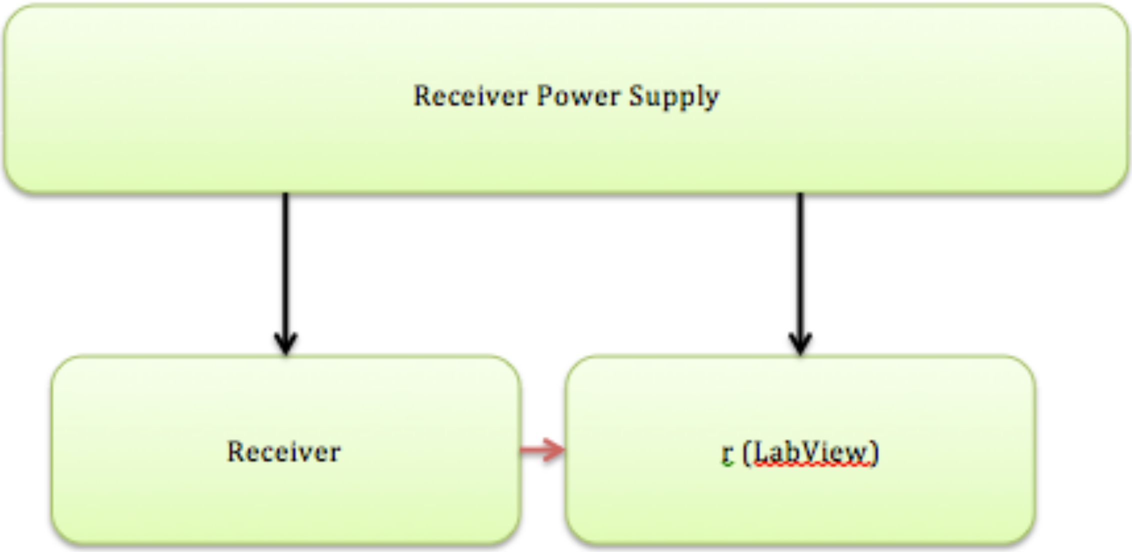


Figure 2.2: RECEIVER CIRCUITRY BLOCK DIAGRAM

ii. Block Descriptions

Sensor Module:

This module consists of three sensors that will monitor soldier body vitals. The sensors used are commercial off-the shelf sensors.

1. Skin Temperature Sensor:

We will make use of a non-contact temperature sensing infrared thermometer- **MLX90614** to measure body temperature. This sensor gives an average temperature of all objects in its Field of View. This is an I^2C device, which allows the sensor to output literal information with a 17bit resolution instead of giving a voltage reading.
Our second choice was the one-wire digital temperature sensor- **DS18B20**. While this sensor is also capable of outputting digital data of 9 to 12bit resolution, it measures ambient temperature around sensor and therefore produced poor body temperature readings when held near skin and was discarded for this project.

2. Pulse Sensor:

We will make use of the **Pulse Sensor Amped** to monitor heart rate data. It combines a simple optical heart rate sensor with amplification and noise cancellation circuitry. The device will be connected to the ear lobe and will acquire heart rate in beats per minute.

3. Motion Sensor:

We will make use of the triple axis accelerometer- **ADXL335.** Placed vertical so that z-axis is always aligned with forward motion of soldier, the sensor will output the acceleration of the soldier.

MLX90614:
INPUT: Voltage of 3.3V powered through a Lithium Polymer battery via the Mega Pro board.
OUTPUT: SDA is digital 20 and SCL is digital 21 on Mega Pro board. A 4.7 KΩ resistor needs to be connected from SDA to 3.3V, and another one from SCL to 3.3V. The sensor is capable of giving digital output with a 0.02 degree resolution. Our code for ATmega2560 will read temperature in Celsius and Fahrenheit.

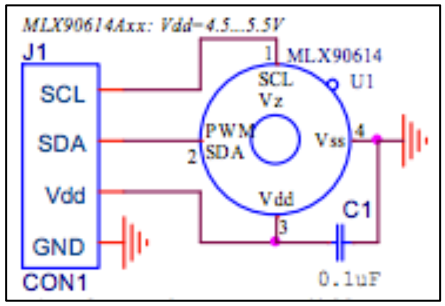


Fig 2.3 IR thermometer schematic **(REF-1)**

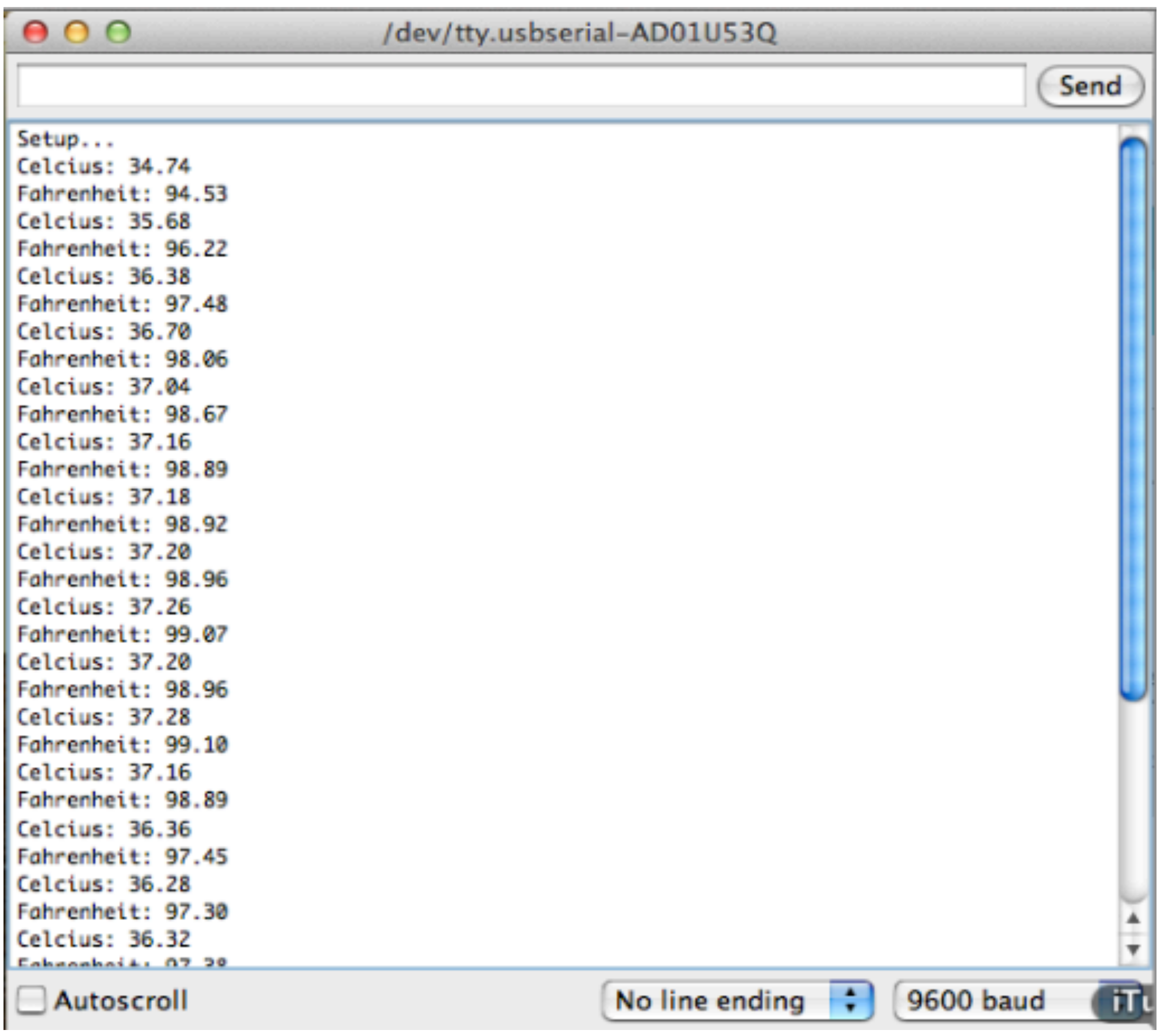


Fig 2.4 Experimental IR sensor real-time data

Pulse Sensor Amped:
INPUT: Voltage of 3.3V applied through a Lithium Polymer battery via the Mega Pro board. Also apply low voltage of 3.3V to Aref pin of Mega Pro board.
OUTPUT: Sensor output pin connected to Analog Pin 0 on Mega Pro board.

Below are the schematics for the Pulse Sensor Amped.

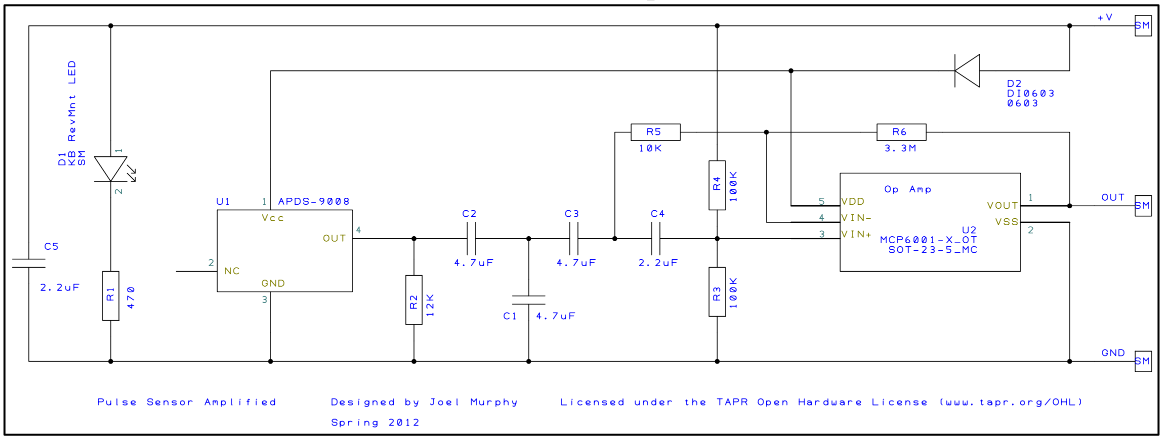


Fig 2.5 Pulse Sensor Amped **(REF-2)**

We connected our sensor to a 3.3v dc supply and analog data pin to an oscilloscope. The first two figures below show pulse spikes at regular intervals corresponding to regular heart beats. Our goal is to find successive moments of instantaneous heart beat and measure the time between, called the Inter Beat Interval (IBI). The BPM is derived every beat from an average of the previous 10 IBI times**.**

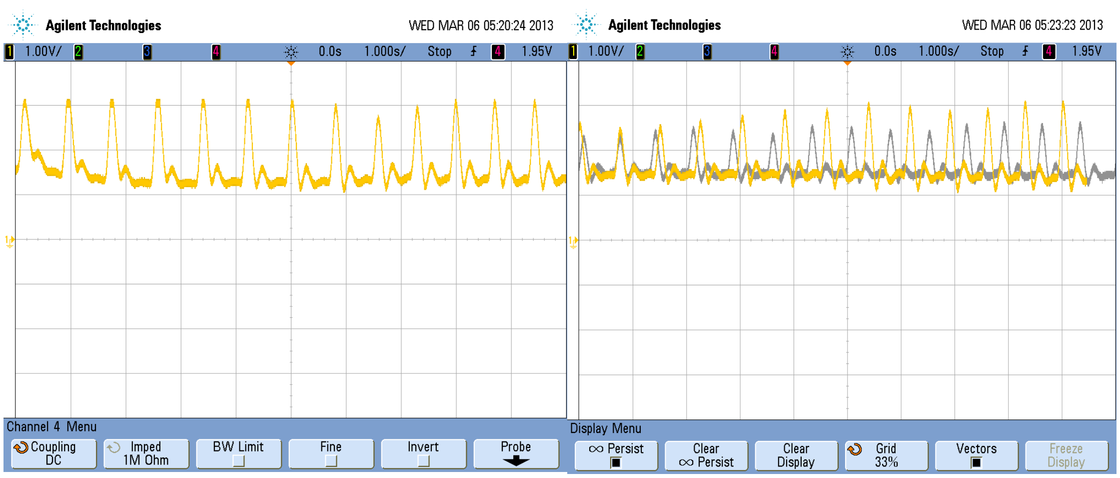


Fig 2.6 Pulse Sensor Amped simulating Heart Rate.

The heart signal from our pulse sensor is an analog fluctuation in voltage, by measuring the reflected light from the skin. More light and signal goes up, less light the opposite. If the amount of light incident on the sensor remains constant, the signal value will remain close to midpoint of ADC range. This is illustrated in the next two simulations under constant ambient light and then in dark room with no ambient light. We can notice that the signal output is constant.

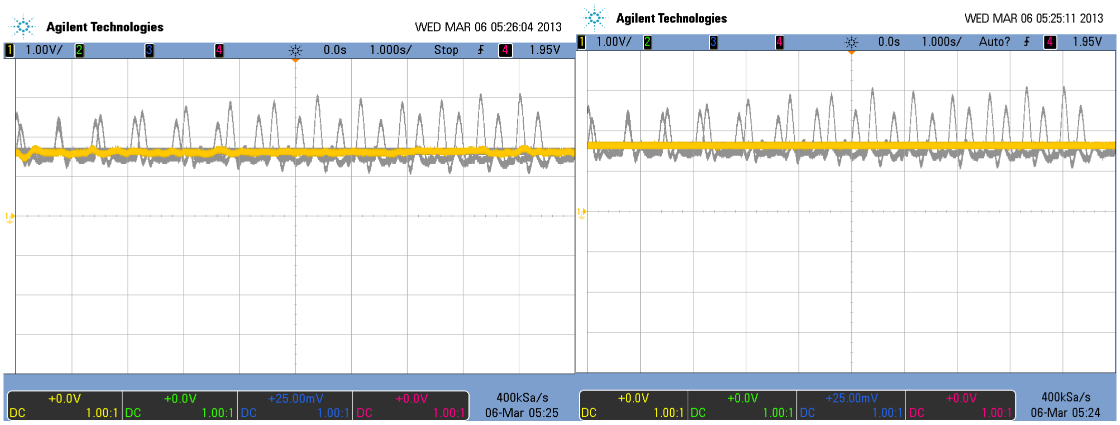


Fig 2.7 Pulse Sensor Amped signal testing at constant Light and No Light.

Triple Axis Accelerometer Breakout- ADXL 335
INPUT: Input voltage can be between 1.8V to 3.7VDC. We will apply 3.3V through a Lithium Polymer battery via the Mega Pro board.
OUTPUT: Accelerometer outputs analog voltage depending on sensed value in each axis. Connect the outputs of X, Y, Z connectors to the Mega Pro 1, 2, 3 Analog pins.

Accelerometer Breakout board schematics:

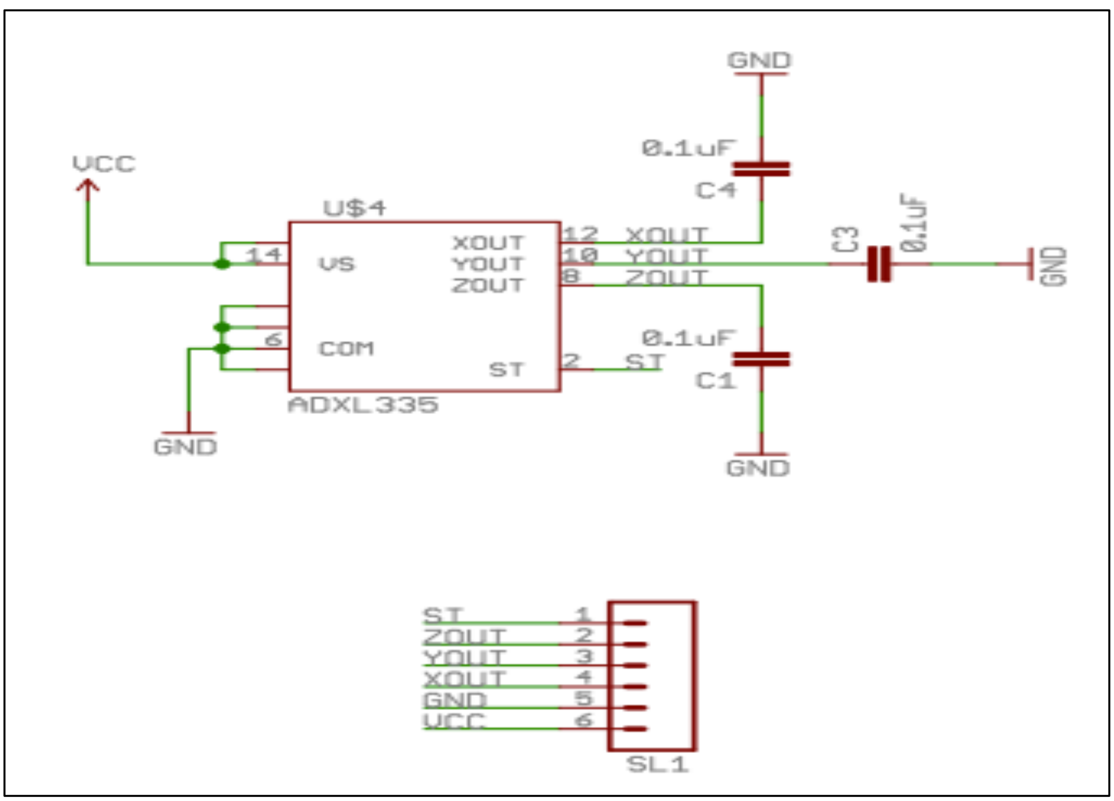
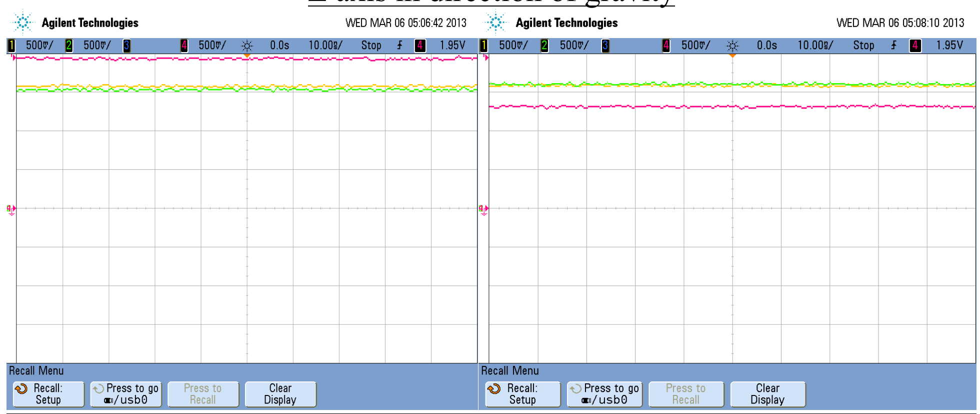


Fig 2.8 Triple Axis Accelerometer Breakout Schematic **(REF-3)**

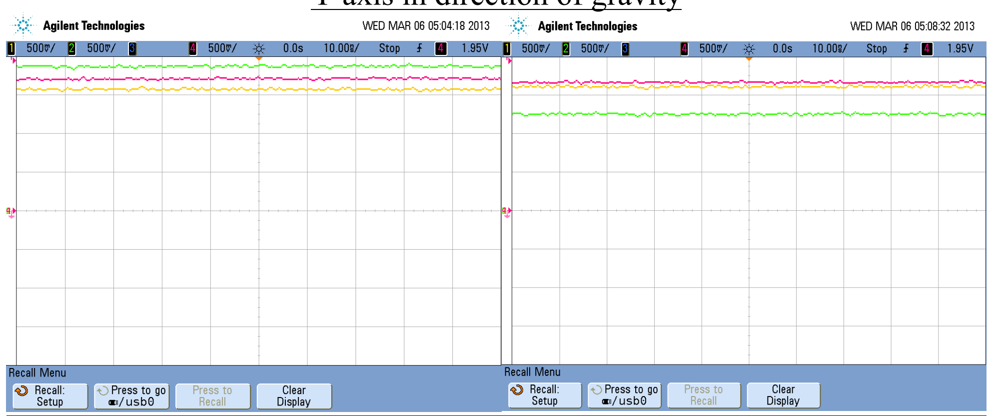
We powered the accelerometer through a 3.3v dc supply and connected the analog outputs of each axis from the sensor to an oscilloscope. In the simulations below: **Yellow=X-axis; Green=Y-axis; Magenta=Z-axis.** Reading the ADXL335 datasheet we see that on 3.3V power, we should expect an axis to read 1.65V when it has zero acceleration, and the voltage should typically change by 330 mV per G of acceleration.

Therefore to test the sensor accuracy, the sensor was allowed to sit stable so that at a time only one axis would point in the direction of acceleration due to gravity and thus we see one signal is roughly ±330mV of the other two axes that are stable at 1.6V(0acceleration)

<u>Z axis in direction of gravity</u>



<u>Y axis in direction of gravity</u>



<u>X axis in direction of gravity</u>

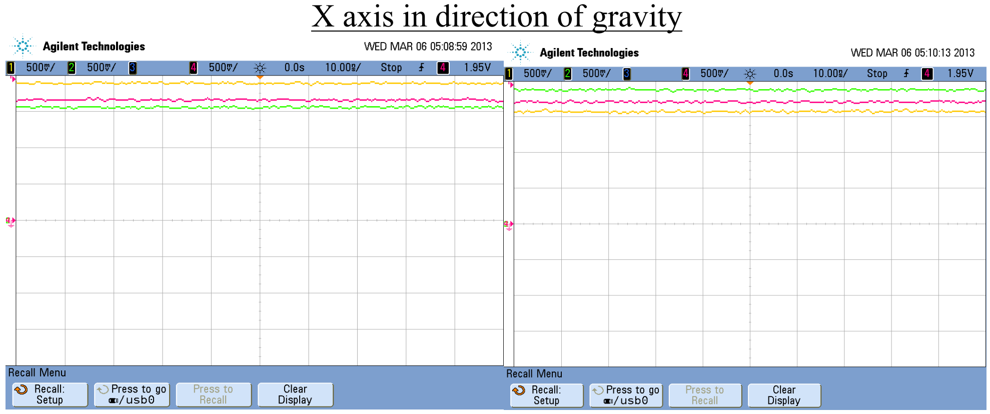
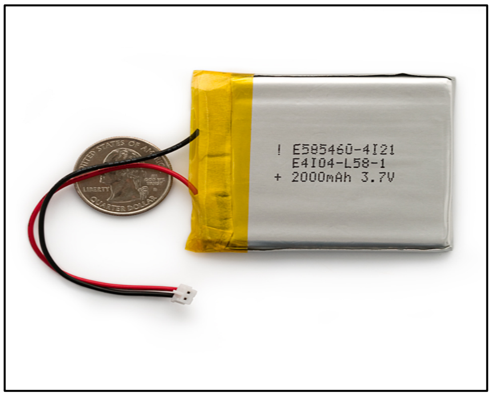


Fig 2.9 Accelerometer Output Checking for all-axis



Transmitter Power Supply Module:
This module needs to be able to power the sensors, the microcontroller, the transmitter, and the display modules. We will make use of a **2000mAh Lithium Polymer battery**. It is a very slim, extremely lightweight battery that outputs a nominal 3.7V at 2000mAh. Since our microcontroller and other sensors are running at 3.3V, this choice of battery is most suitable for fulfilling project goals of device being lightweight as well as a runtime of 24hours.

Features:
- Excellent long-term self-discharge rates (<8% per month)
- 2C continuous discharge
- Weight: 36g
- The battery includes built-in protection against over voltage, over current, and minimum voltage.

USB LiPoly Charger - Single Cell

We will also incorporate a Lithium Polymer Battery Charger circuitry into our device so that we can charge the battery through the device and not have to remove it for separate charging. Charging circuit allows 3.7V LiPo cells to charge at a rate of 500mA or 100mA per hour. The board has miniUSB input port along with status LED and other connections. The SYS-OUT connectors allow connection of charging circuit directly to our project.

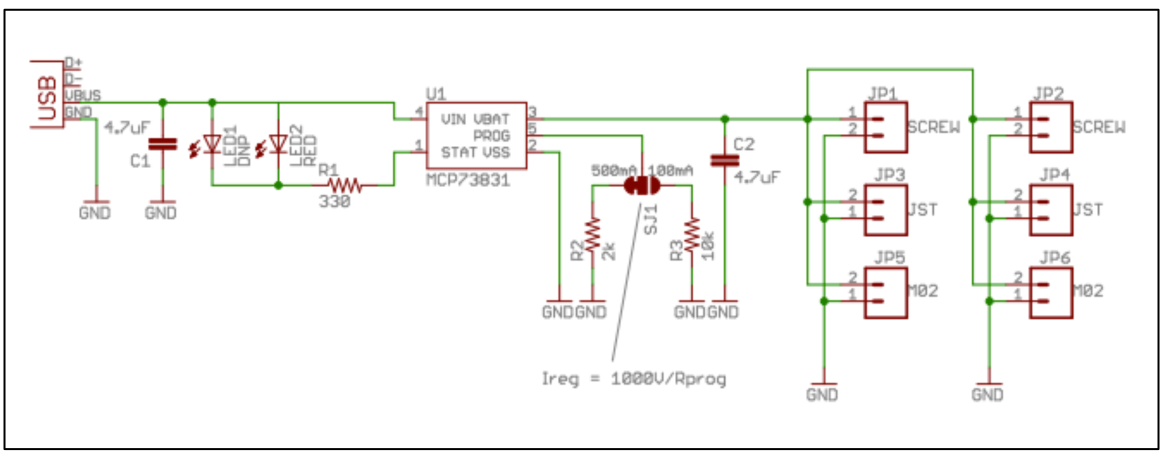


Fig 2.10 USB LiPoly Charger Schematic**(REF-4)**

Microcontroller:

We are using an Arduino compatible microcontroller board: **The Mega Pro.** Functions of the microcontroller is receiving data from sensors, packaging them and providing it to the transmitter for wireless communication. The arduino microcontroller will do an analysis on the vitals to see if they pass critical thresholds for each sensor and accordingly indicate on threshold display module.

Features of Mega Pro 3.3v

- ATmega2560 running a version of stk500v2 bootloader at 8MHz resonator
- Low-voltage board needs no interfacing circuitry to popular 3.3V devices
- USB connection off board
- 3.3V regulator, 500mA max
- Over current protected
- Reverse polarity protected
- Power select switch acts as on/off switch

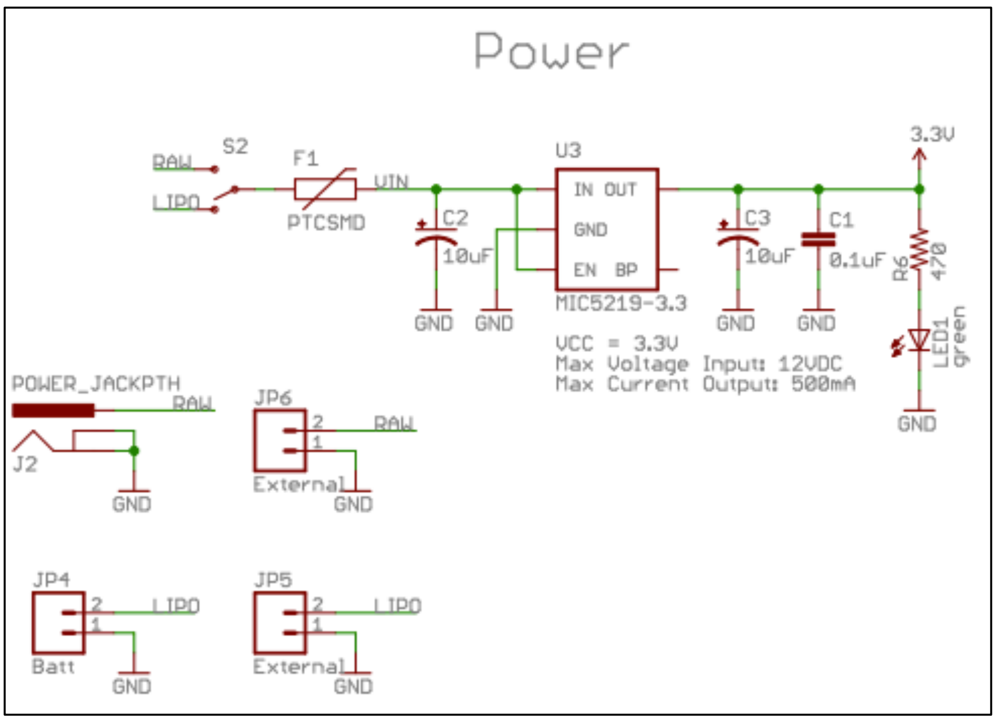


Fig 2.11 Power Schematics for Mega Pro 3.3v**(REF-5)**

Mega Pro Pin Layout

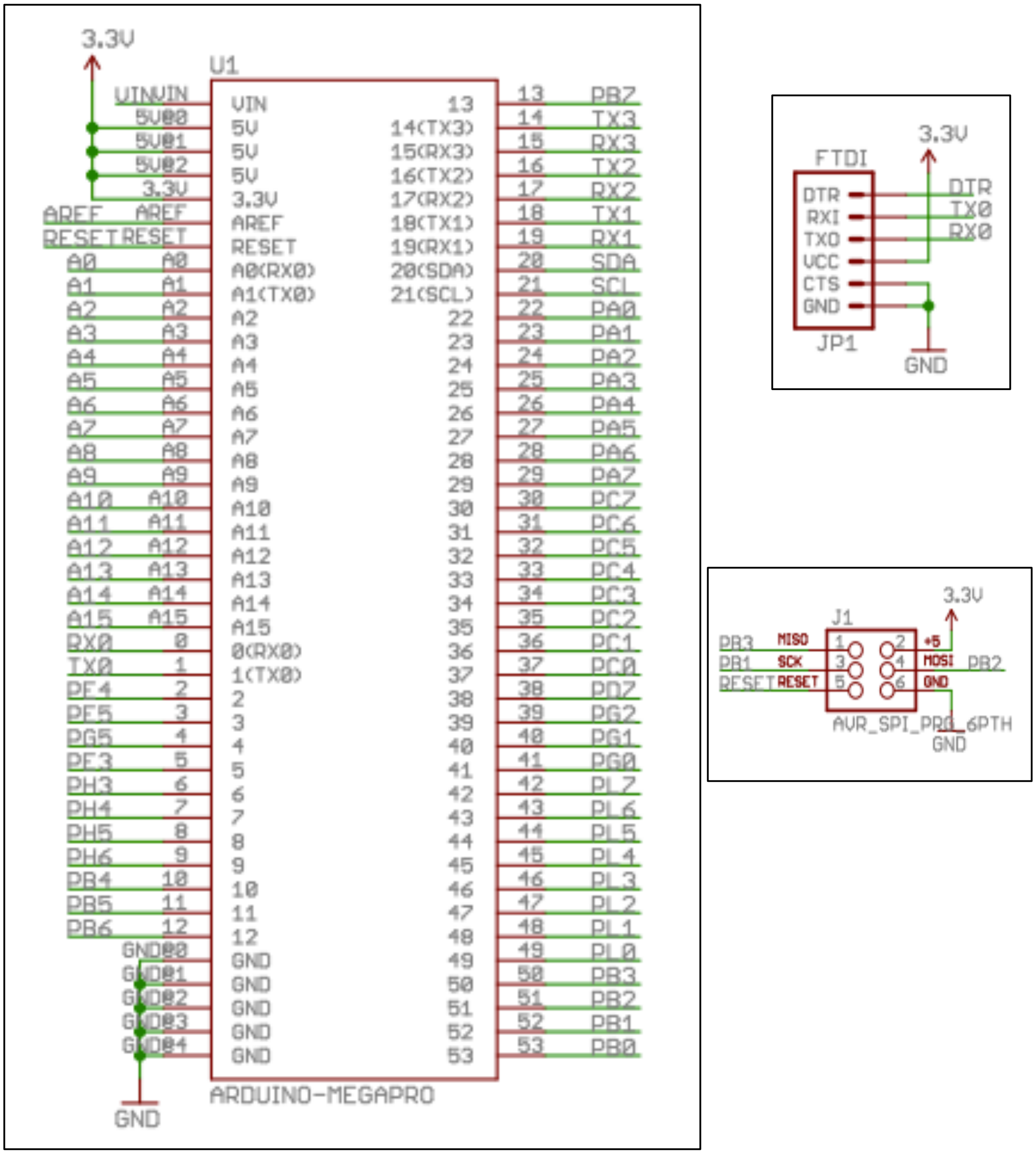
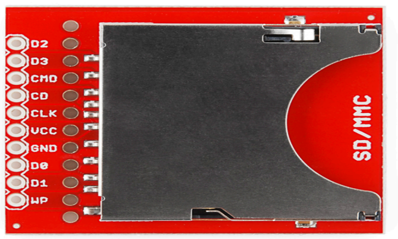


Fig. 2.12 Mega Pro pin layout**(REF-6)**



Storage Module:
This module is responsible for storing all the data acquired from the sensors. We are incorporating a breakout board for SD-MMC cards with The Mega Pro board. The microcontroller will store the packaged data from all sensors into the SD card just before transmitting to base station via the transmitter.

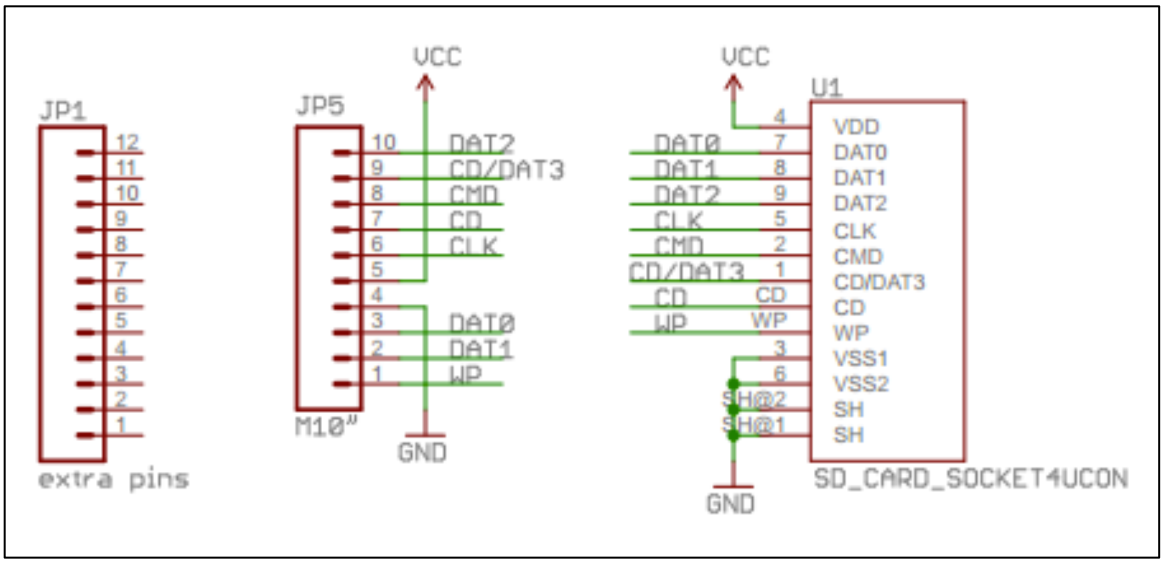


Fig 2.13 Breakout Board for SD-MMC Cards Schematic**(REF-7)**

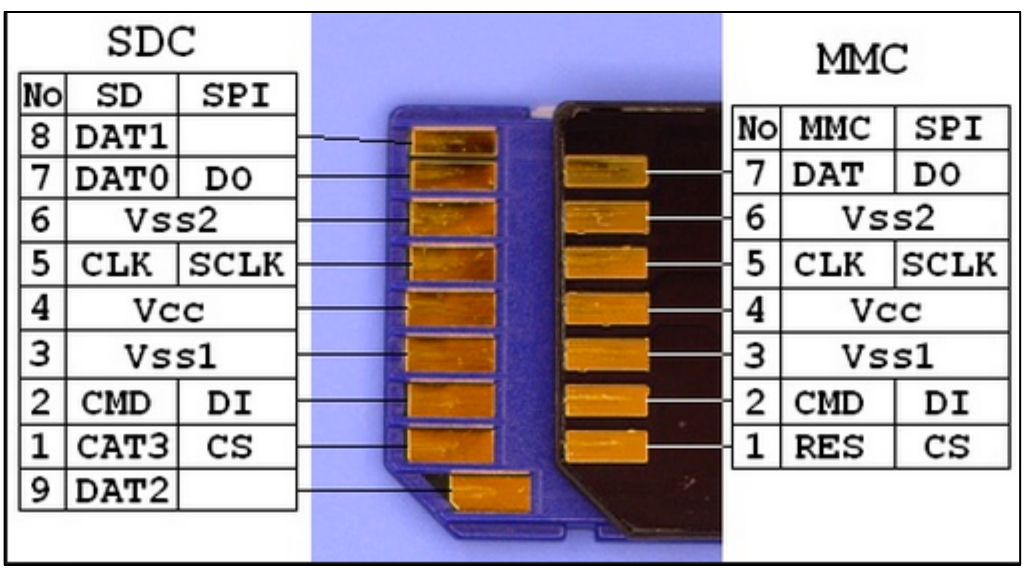


Fig 2.14: Pin-Outs for SD/MMC cards

Threshold Display Module:
This display module will be present on the soldier to indicate important information. We will make use of three different colored LEDs to indicate body vitals crossing a pre-set threshold value or if the battery does not have sufficient charge. The LEDs are controlled by the microcontroller which is responsible for checking if input data from sensors and battery monitoring has crossed threshold values

LED COLOR	Function
RED	Indicates when pulse rate crosses 180bpm
GREEN	Indicates body temperature crossing 100^{o}F
BLUE	Indicates when battery voltage falls below 3V

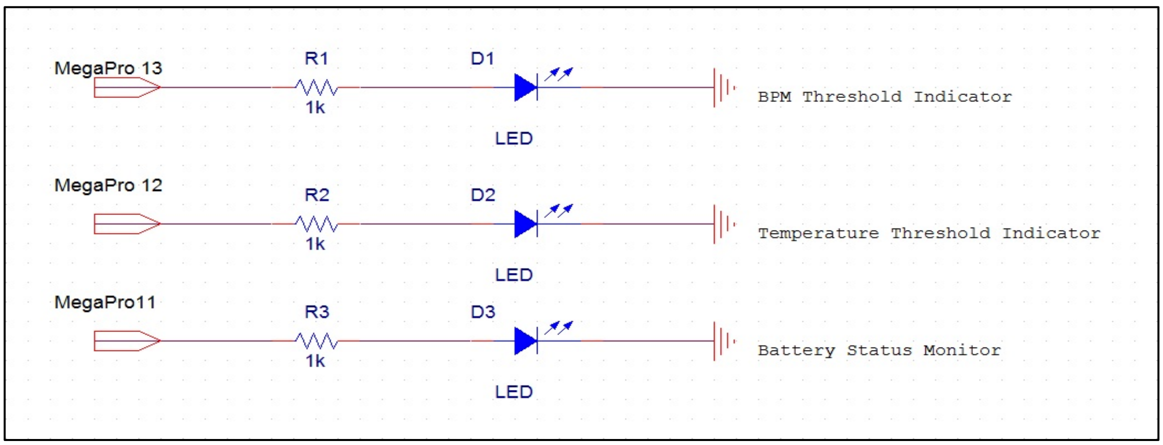


Fig 2.15 Mega pro to Display circuit

Receiver Power Supply:
This power supply will be a wall power supply and probably be connected to a computer.

Computer Display:
We will make use of a computer running LabView to further analyze the data received and display a continuous monitoring of body vitals.

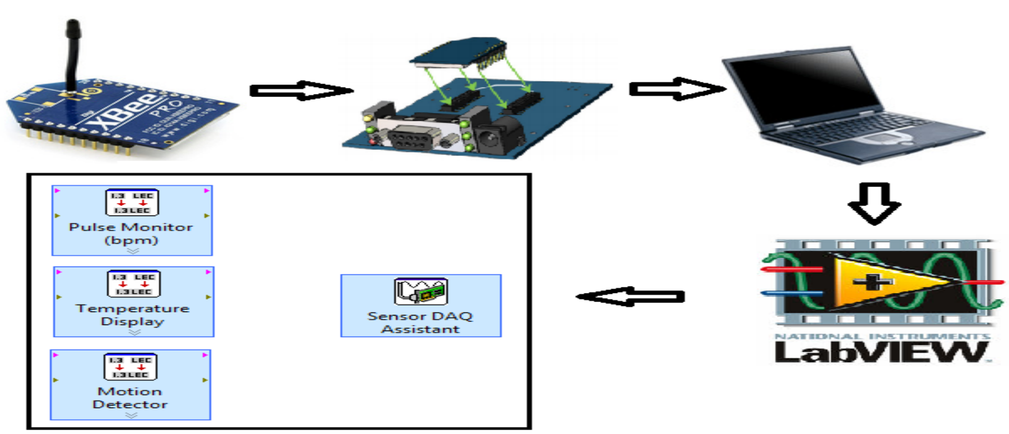


Fig 2.16 Receiver module to Labview

Transreceiver (XBee Pro 60mW Wire Antenna - Series 1 (802.15.4))

XBee-PRO products are engineered to meet IEEE 802.15.4 standards and support the unique needs of low-cost, low-power wireless sensor networks. IEEE 802. 15.4 standard offers the fundamental lower network layers The modules require minimal power and provide reliable delivery of data between devices. The modules operate within the ISM 2.4 GHz frequency band and are pin-for-pin compatible with each other. One Xbee will be attached to the microcontroller packaging the data for transmission to be received at the computer side. See Figure ###. The computer Xbee module will be powered by the computer itself using a ftdi to read and power the Xbee module. The microcontroller Xbee power will be supplied by the battery and will be connected to the microcontroller as shown in Figure 2.17

Schematic & Pin Configuration

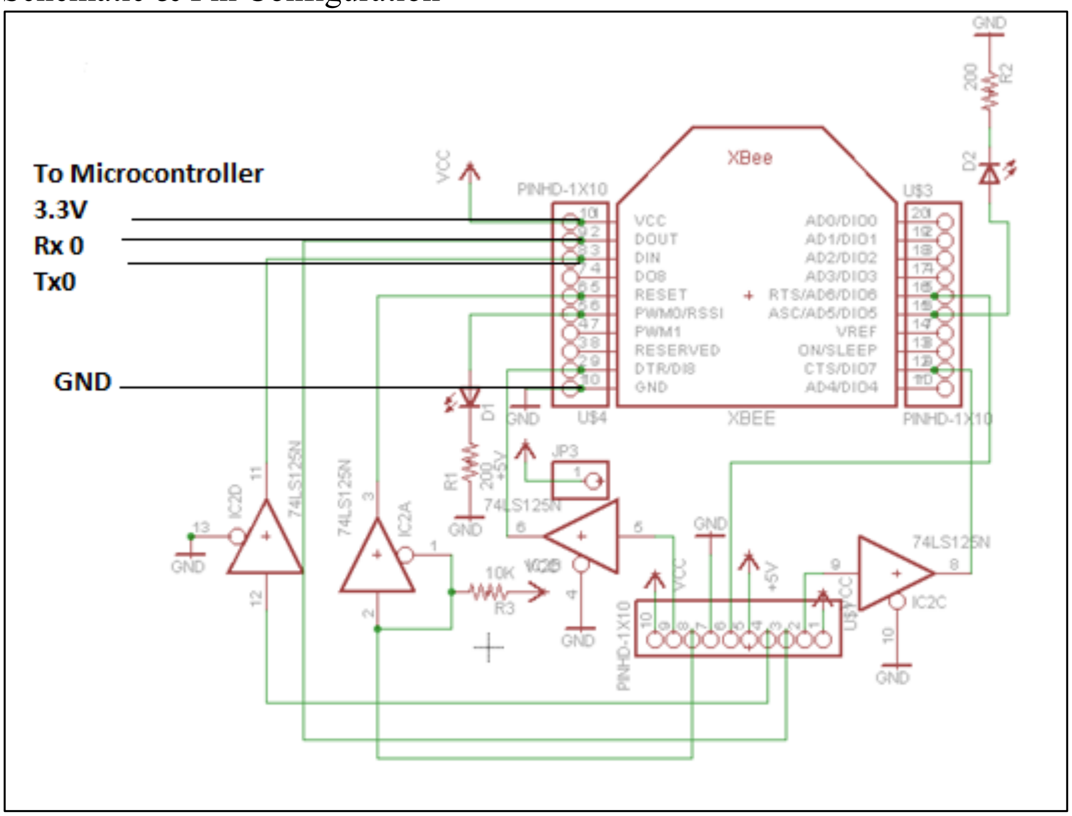


Fig 2.17 Xbee to Microcontroller Schematic**(REF-8)**

System Data Flow Diagram in a UART-interfaced environment

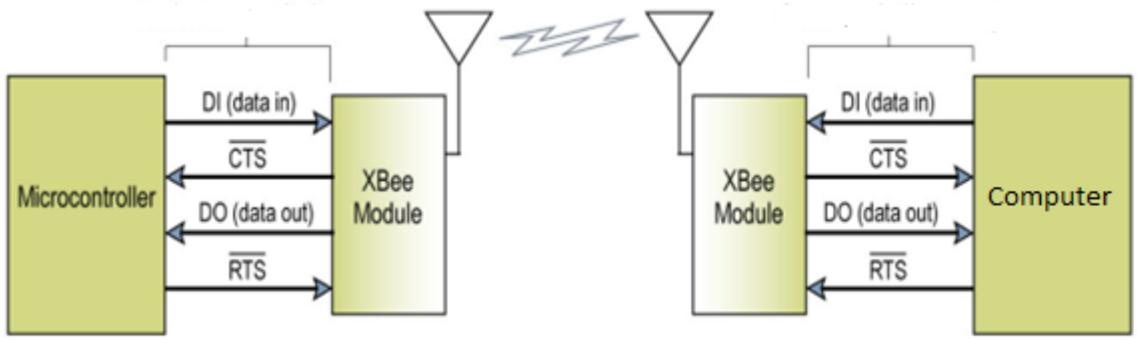


Figure 2.18 Xbee flow from Microcontroller to Computer **(REF-9)**

Overall Schematics of Device:

Our device focuses on the multiple functionalities of a microcontroller that enables A/D conversion and wireless communication from Xbee transreceiver module. Analog outputs generated from the sensors will go through a digital conversion through microcontroller. Then, the packaged data in SD card will travel wirelessly from a transmitter to a receiver. At the receiver end, we have a computer display that shows all the digital data that were transferred. The microcontroller also analyzes on the vitals if they exceed critical threshold values for each sensor and will be displayed at the received end as well. The sensors, microcontroller, transreceiver, and the display modules will be powered from the lithium ion polymer battery.

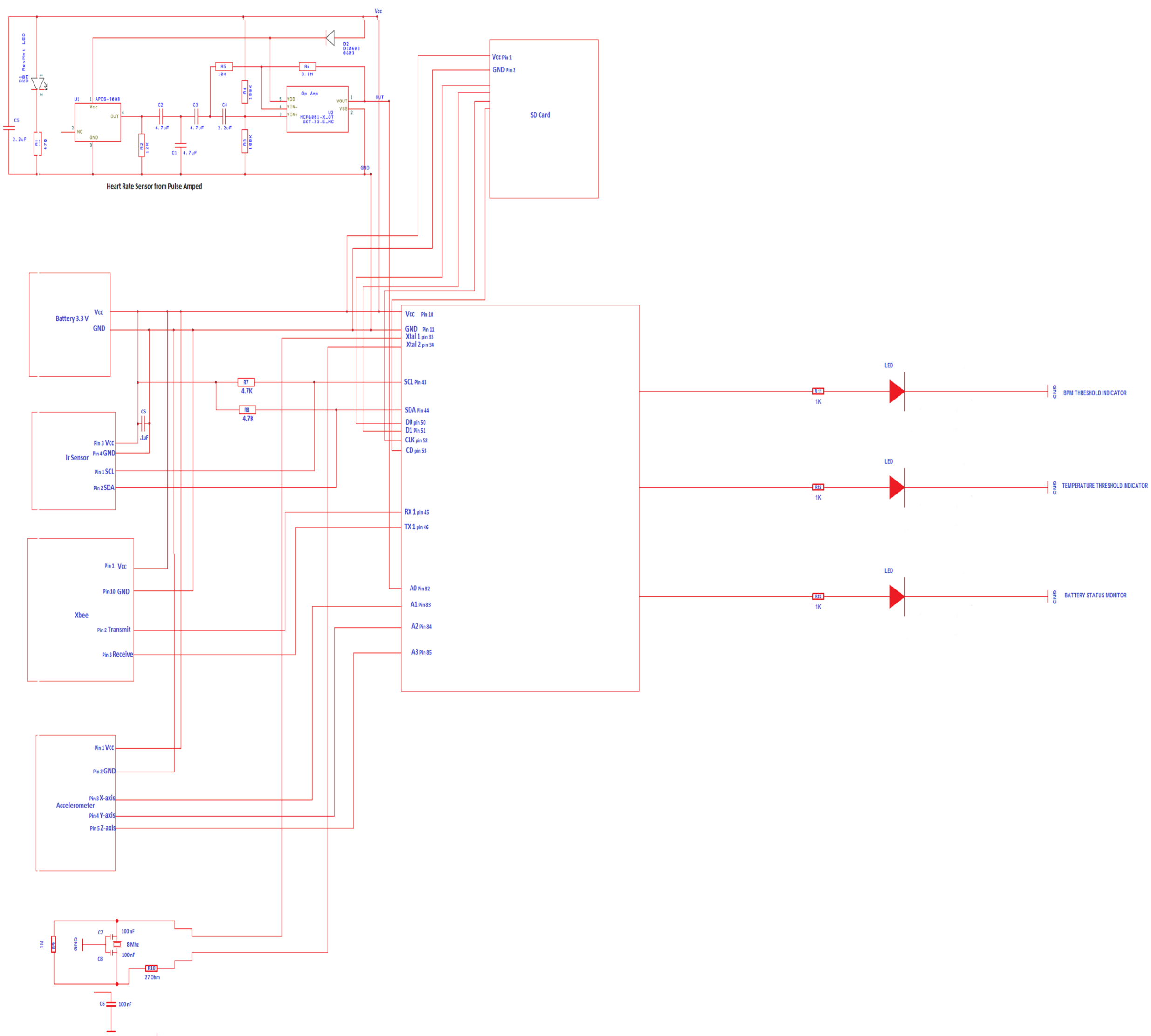


Fig 2.19: Overall Schematics of Device

IV. Requirements and Verification
i. Requirements and Verification Table

Block Title	Requirements	Verification
Heart Rate Sensor	1. “beats per minute” (bpm) to be (±)2% of actual heart bpm a. Displays peaks with constant time interval b. Maximum voltage should be 3.3V	1. Use calibrated off-the-shelf heart rate monitor to compare bpm a. Use oscilloscope to verify constant time interval between peaks b. Use oscilloscope to check voltage
Motion Sensor	1. It needs to generate analog output in x,y and z axis a. When stationary, x and y axis needs to output 1.6v and z axis 1.93v b. When moving, every 1g of acceleration corresponds to an additional 0.33v	1. Use oscilloscope to verify the outputs of x, y and z axis a. Use oscilloscope to check voltage at stationary b. Use oscilloscope to check voltage when moving by at least 1g
IR sensor	1. It needs to give out 2% of actual body temperature a. Data out from IR sensor gives us 17bits bit depth resolution	1. Use off-the-shelf thermometer to verify a. Use oscilloscope to check 17-bit resolution
Solder Vitals Supply	1. Battery should power microcontroller, sensors, and transmitter for 12 hours a. Battery maintains 3.0v to 3.3v for 12hours b. Battery should provide 2.15mA 2. Charging unit should provide constant voltage a. Charger circuit should convert down from 5v to 3.3v b. allows you to charge 3.7V LiPo cells at a rate of 100mA per hour.	1. Verify by powering microcontroller, sensors and transmitter for 12 hours a. Use multimeter to check voltage of battery b. Use multimeter to check current from charger circuit to the battery 2. Use multimeter to check voltage when charging a. . Use multimeter to check current when charging
Storage Module (SD card)	1. Stores packaged data from the sensors a. Stored data should be in hex and written to a text file	1. Write known data in text file to SD card a. Connect to a computer and check
Threshold Display Module	1. if (data received to microcontroller) is bigger (preset threshold value), LED blinks a. LED(red, pin13) blinks (Pulse) b. LED(green, pin12 blinks (Temperature) c. LED(blue, pin11) blinks (Battery)	1. Send data that would cause overflow a. Set pulse rate > 180bpm b. Body temperature > 100F c. Battery voltage < 3V
Microcontroller	1. Powered from the battery a. Microcontroller should be powered at 3.3v	1. Power LED lights up a. Use oscilloscope to check Vcc is 3.3v

	2. Microcontroller takes analog input from sensors and converts it to digital input a. The packed digital data will be stored in SD card before transmitting.	2. Use oscilloscope to display analog signals and manually calculate its digital conversion. a. Check the hexadecimal digital data in SD card to check if data is packaged properly.
Transmitter	1. Transmitter should be powered by the battery a. Transmitter requires 3.3v 2. Accurate data transmission over 100m a. When transmitting, a sinusoidal wave is outputted b. Transmitter requires 63mW (18dBm)	1. Use multimeter to check Vcc has a positive voltage a. Use multimeter to check Vcc pin is at 3.3v 2. Check receiving Xbee module if receiving data is same as transmitting data a. Use oscilloscope to check outputted wave is sinusoidal b. Use oscilloscope to check power required is 63mV
Receiver	1. Receiver should be powered by the computer a. Receiver requires 3.3v 2. Accurate data transmission over 100m a. When receiving, a sinusoidal wave is shown	1. Use multimeter to check Vcc has a positive voltage a. Use multimeter to check Vcc pin is at 3.3v 2. Check receiving Xbee module if receiving data is same as transmitting data a. Use oscilloscope to check outputted wave is sinusoidal
Computer Display	1. Displays received data in a graphical form	1. Use calibrated off-the-shelf monitor to show correct measurement

ii. Tolerance Analysis

The potential success of this project mainly rests on the wireless transmission of data of the soldier's heart rate, body temperature and stress level. Wireless signals travel through atmosphere meaning they are susceptible to any forms of interference. There are many factors affecting wireless transmission. These factors will make the wireless transmission difficult, which will cause critical errors while in usage. Thus, we will give our transmission component an extreme condition to ensure its functionality in any circumstance. First, most common interference is physical objects such as trees, buildings while the density of these objects determines whether or not RF can pass through them. We will first try to choose a place where there are a considerable amount of objects that might interfere the transmission. Second, another notable interference would be RF interference from another device. Most common wireless technologies use a RF range of 2.4GHz. The devices that share this channel will not only weaken the signals but also will cause noise. Thus, we will try to use devices that would share the same channel as our wireless transmission. This tolerance testing will be effective in that we also can consider any kinds of electrical interference as well. Lastly, weather condition affects wireless communication. For example, fog and rain make the signal hard to pass through in the atmosphere and lightning can cause electrical interference. Therefore, we will test our transmission under one of those extreme weather conditions. Overall, enabling a firm wireless transmission under these conditions will guarantee our success in the end.

IV. Cost Analysis

i. Labor

Member	$/hour	Hours/week	Total of hours	Subtotal($)
Sanghee Seo	40	20	320	12800
Santhosh Vairavan	40	20	320	12800
Yash Kulkarni	40	20	320	12800
Grand Total (x 2.5)				96000

ii. Parts

Vendor	Vendor Part #	Description	Quantity	Price	Total
Sparkfun	WRL-08742	XBee Pro 60mW Wire Antenna - Series 1 (802.15.4)	2	37.95	75.90
Sparkfun	WRL-11216	XBee Pro 60mW PCB Antenna - Series 1 (802.15.4)	1	37.95	37.95
Sparkfun	SEN-11574	Pulse Sensor Amped	3	24.95	74.85
Sparkfun	SEN-09269	Triple Axis Accelerometer Breakout - ADXL335	3	24.95	74.85
Sparkfun	SEN-11050	Temperature Sensor - Waterproof (DS18B20)	3	9.95	29.85
Sparkfun	BOB-11403	Breakout Board for SD-MMC Cards	2	9.95	19.90
Sparkfun	DEV-10744	Mega Pro 3.3V	2	44.95	89.90
Sparkfun	PRT-08483	Polymer Lithium Ion Battery - 2000mAh	2	16.95	33.90
Sparkfun	PRT-10161	USB LiPoly Charger - Single Cell	2	14.95	29.90
Sparkfun	PRT-09749	JST Right-Angle Connector - Through-Hole 2-Pin	2	0.95	1.90
Sparkfun	DEV-09873	FTDI Basic Breakout - 3.3V	2	14.95	29.90
Sparkfun	CAB-11301	USB Mini-B Cable - 6 Foot	2	3.95	7.90
Sparkfun	SEN-09570	Infrared Thermometer - MLX90614	3	19.95	59.85
					566.55

V. Schedule

Week	Yash Kulkarni	Sanghee Seo	Santhosh Vairavan
Feb. 4th	Work on Project Proposal	Work on Project Proposal	Work on Project Proposal
Feb. 11th	Order parts and sensors	Learn Eagle and pcb layout design	Learn Arduino microcontroller Programming
Feb. 17th	Receive parts and test Heart Rate Sensor to see if we are getting accurate data	Receive Parts and Test microcontroller to see if it is working.	Receive Parts build pcb for xbee kit to program with the computer
Feb. 25th	Work On Design Review. Prototype Sensors Heart Rate, with microcontroller	Work On Design Review. Make Microcontroller schematic for PCB	Work On Design Review. Test Xbee Transceiver to see it transmits data
Mar. 4th	Finish Prototyping and Test hardware Specifications with sensors and battery	Finish PCB schematic for microcontroller. Create PCB for ir temperature sensor and integrate it with microcontroller PCB	Start Programming microcontroller and xbee
Mar. 11st	Work on Individual Progress Report. Finalize PCB schematic with all components	Work on Individual Progress Report. Finalize PCB Schematic with all components	Work on Individual Progress Report. Finalize arduino code
Mar. 18th	Spring Break	Spring Break	Spring Break
Mar. 25th	Mock Up Demo. Create PCB	Mock Up Demo Design case for PCB	Mockup Demo Debug arduino Code
Apr. 1st	Solder PCB and components	Fabricate Case for PCB	Integrate Labview with Xbee module on the computer side
Apr. 8th	Debug and Test PCB	Debug and Test PCB	Debug and Test Labview Data
Apr. 15th	Verify All Requirements	Verify All Requirements	Verify All Requirements

Apr. 22nd	DEMO Finalize Finishing Touches	DEMO Finalize Finishing Touches	DEMO Finalize Finishing Touches
Apr. 29th	Final presentation, Final Demo, Finish Paper	Final presentation, final demo, finish paper	Final presentation, final demo, finish paper

VI. Code of Ethics

We, team25, are responsible for making decisions that focus on safety and well-being of the public. Along this project, we will maintain and broaden our understanding of recent technologies.
We will act professional to assist the members, seek for help and accept criticism to improve.
Our device will not harm any users in any ways following the code of ethics.
We recognize how important it is to follow the code of ethics.

VII. Reference

1. IR thermometer schematic : https://www.sparkfun.com/products/9570
2. Pulse Sensor Amped schematic : https://www.sparkfun.com/products/11574
3. Triple Axis Accelerometer Breakout schematic: https://www.sparkfun.com/products/9269
4. USB poly charger schematic: https://www.sparkfun.com/products/10161
5. Power for Mega Pro 3.3v Schematic: https://www.sparkfun.com/products/10744
6. Mega Pro 3.3v pin layout : https://www.sparkfun.com/products/10744
7. Breakout Board for SD-MMC Cards Schematic : https://www.sparkfun.com/products/11403
8. Xbee to Microcontroller Schematic : https://www.sparkfun.com/products/8742
9. Xbee flow from Microcontroller to Computer : https://www.sparkfun.com/products/8742