Critical Design Review: A-TeChToP Central Sensor Suite

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Project Objective

The project objective is to design and implement an affordable and wearable sensor suite (A-TeChToP) that allows for the safe and wireless real-time health monitoring of a child. A-TeChToP will notify guardians when the child's bio-signals have passed below or above healthy thresholds. The device must remove the need for standard encumbering medical equipment and minimize adult supervision.

This particular A-TeChToP device must help monitor children with histories of

Asthma Exacerbation

Osteogenesis Imperfecta

Arrhythmias

Frequent Fainting

Juvenile Idiopathic Arthritis

Frequent Fevers.

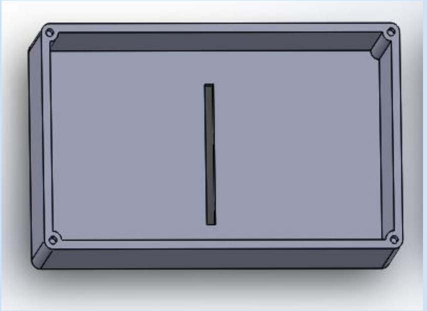
Mission Profile

A-TeChToP's mission is to successfully monitor the illnesses stated in the project objective for a child between the ages of 5 and 13 while playing on a playground for thirty minutes. The central sensor suite will be attached to the child's chest and then the child will perform specific exercises and later play freely. Data will be sent continuously to a guardian-monitored computer and, if the child displays the symptoms of an illness, the guardian will be warned.

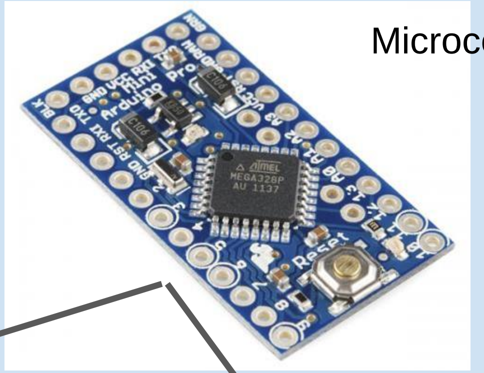
The device must be durable enough to withstand the small collisions and mild weather changes (light rain) associated with playground play.

El Dorado Park, Long Beach

The Design



Case



Microcontroller

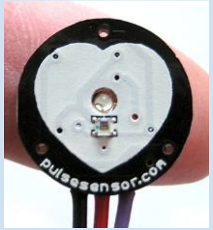
Sensors

Blood Oximeter

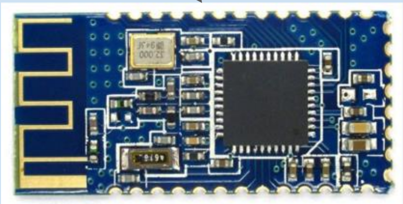
Temperature Sensor

ECG

Accelerometer



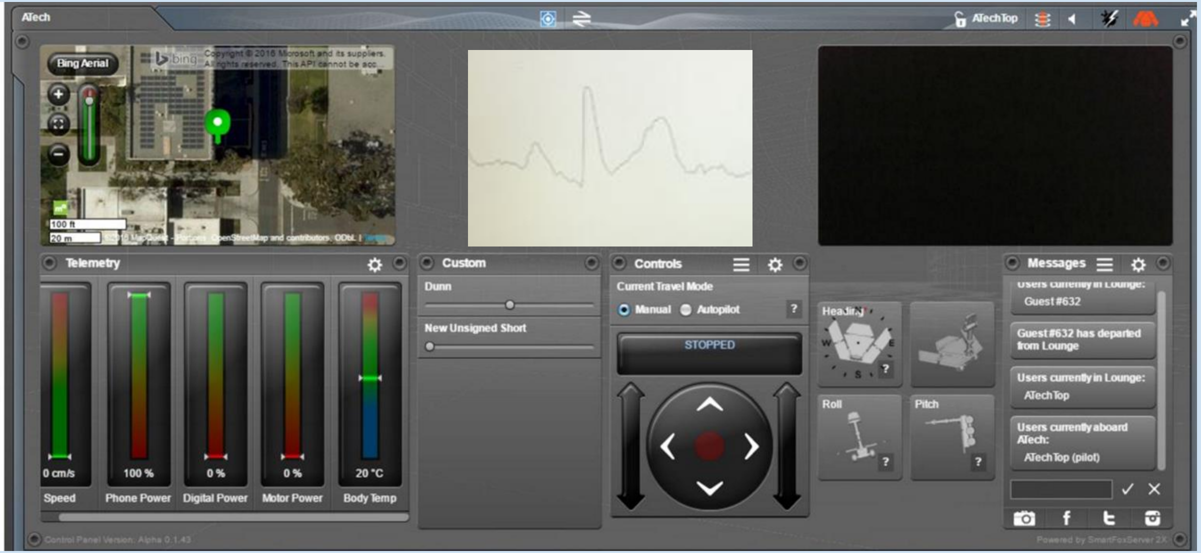
Pulse Sensor



Bluetooth

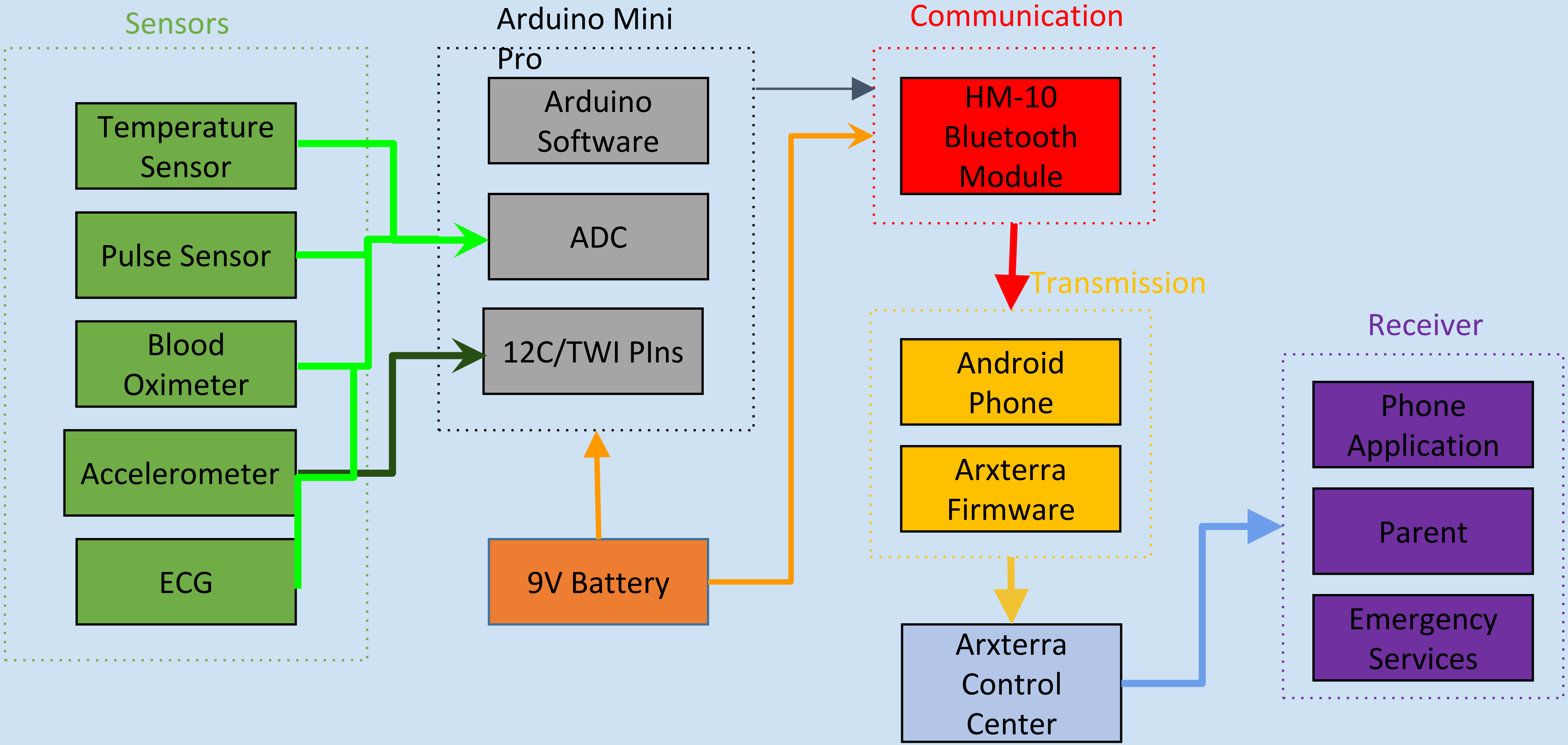
Project Features

- Five unique sensors: ECG, Blood Oximeter, Temperature Sensor, Accelerometer, and Pulse Sensor
- Designed the ECG circuit (Clearer signal than the off the shelf sensor)



- New graphical widget for displaying ECG signal
- Special harness design to work with sensors
- Arduino Pro Mini to decrease size

System Block Diagram

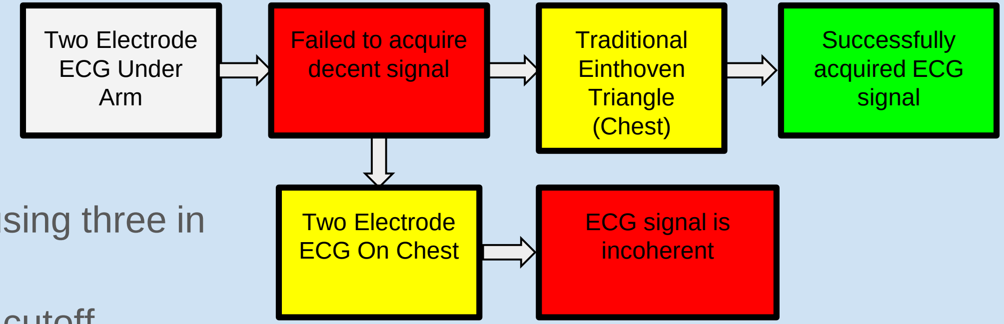


Outline of Experiments for Design Solutions

- ECG:
  - Test electrode placement underneath the arms, validating if only two electrodes rather than three could be used reliably.
  - Consider the most reliable scenario where three electrodes are used, noting that Einthoven's Triangle configuration is necessary.
  - Check the effectiveness of analog filters, starting with simple low pass and high pass filters.
  - Tweak the resistor and capacitor values in the filters and observe the effects upon the ECG signal output in terms of peaks and troughs.
  - Acknowledge the need of additional analog filtering, thus adding to a notch filter for muscle artifact removal.
- Blood Oximeter:
  - Construct a housing to test measuring Red LED and IR LED light intensity after passing through a thin section of skin, a finger.
  - Once light intensities are measured, use the calculation 100*((log(LEDred)/log(LEDir))) to calculate blood oxygen levels in percentage.
  - Test this same method using a custom made ear clip to pass light through an ear, compare the results to those of the finger.
- GY-521:
  - Consult the help of online libraries available for download to begin understanding the sensor.
  - Develop custom code for the purpose of tracking the child's upright orientation for certain periods of time.
  - Test different threshold values and different amounts of time to determine what the most effective combination is for ensuring the child has not been injured in falling.

ECG Experiment Solutions

The ECG circuit took multiple trials in terms of placement and filtering in order to meet the project requirements.



- Electrodes eventually had to be placed using three in an Einthoven triangle.
- Initial low pass and high pass filters with cutoff frequencies of 3Hz and 50Hz were insufficient.
- Low pass and high pass filters were adjusted to have cutoff frequencies 0.16Hz and 36Hz.
- A notch filter was also added in order to remove muscle artifacts at 50Hz.
- Digital filtering will also be implemented once the signal is passed through the MCU to remove baseline shift caused by movement from the child.

Project requirements were mostly met, excluding the proper implementation of baseline digital filtering in order to allow for accurate ECG readings during movement.

This filtering is intended to be properly added to the system shortly.

Blood Oximeter Experiment Solutions

Considering that there was little documentation about making the blood oximeter, multiple trials were necessary in order to determine where blood oxygen levels would be calculated easiest and most accurately.

- A small styrofoam housing was made in order to allow subjects to place their finger inside and test the intensity of the light passing through.
- The TSL235R was compared to a simple photodiode in terms of accuracy and ease of use when detecting light intensity.
- The photodiode was determined most effective and thus will proceed with trials with the ear.
- A makeshift earclip will be used to measure blood oxygen levels from the ear with the intention of designing a proper clip later on.
- Once the oxygen percentages are verified, the code and earclip will be implemented into the project.
- Not only does this device meet the design requirements, but it serves as a pulse meter as well, allowing some downsizing of the overall physical project.

GY-521 Experiment Solutions

This device was straight forward, using an existing library of Arduino IDE code to communicate with the device.

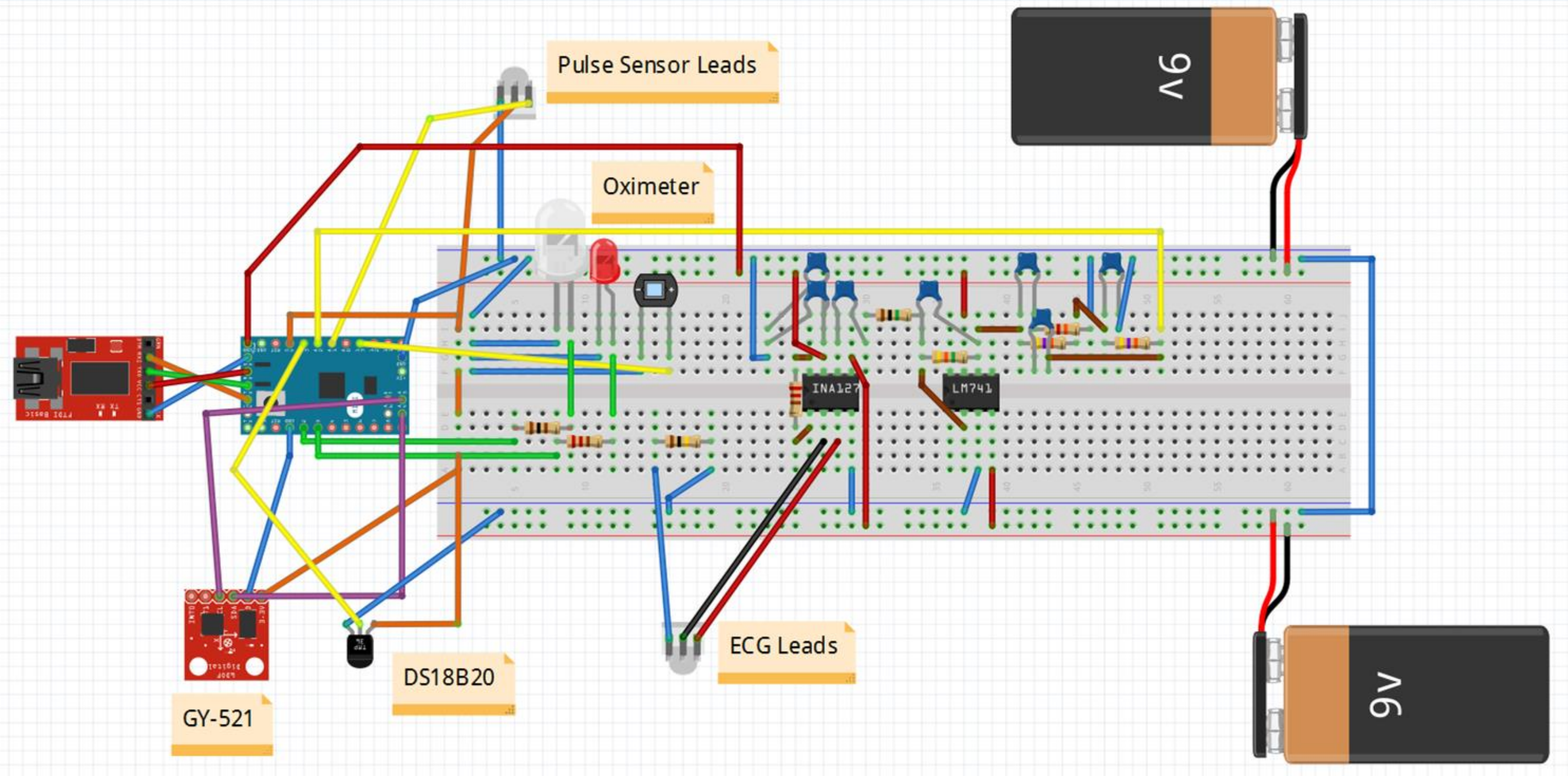
- The code was downloaded and tested, seeing how the module responded.
- Basic values in radians were able to be seen on the Serial Monitor, meaning that some simple conversions were left.
- The radians were converted into degrees.
- In order to incorporate some safety measures that will be intended for the final product of the project, threshold values were set for the GY-521 in order to monitor if the orientation was in an undesirable position for too long.
- This experimentation has allowed this device to meet all of its expected design requirements.

Interface Matrix

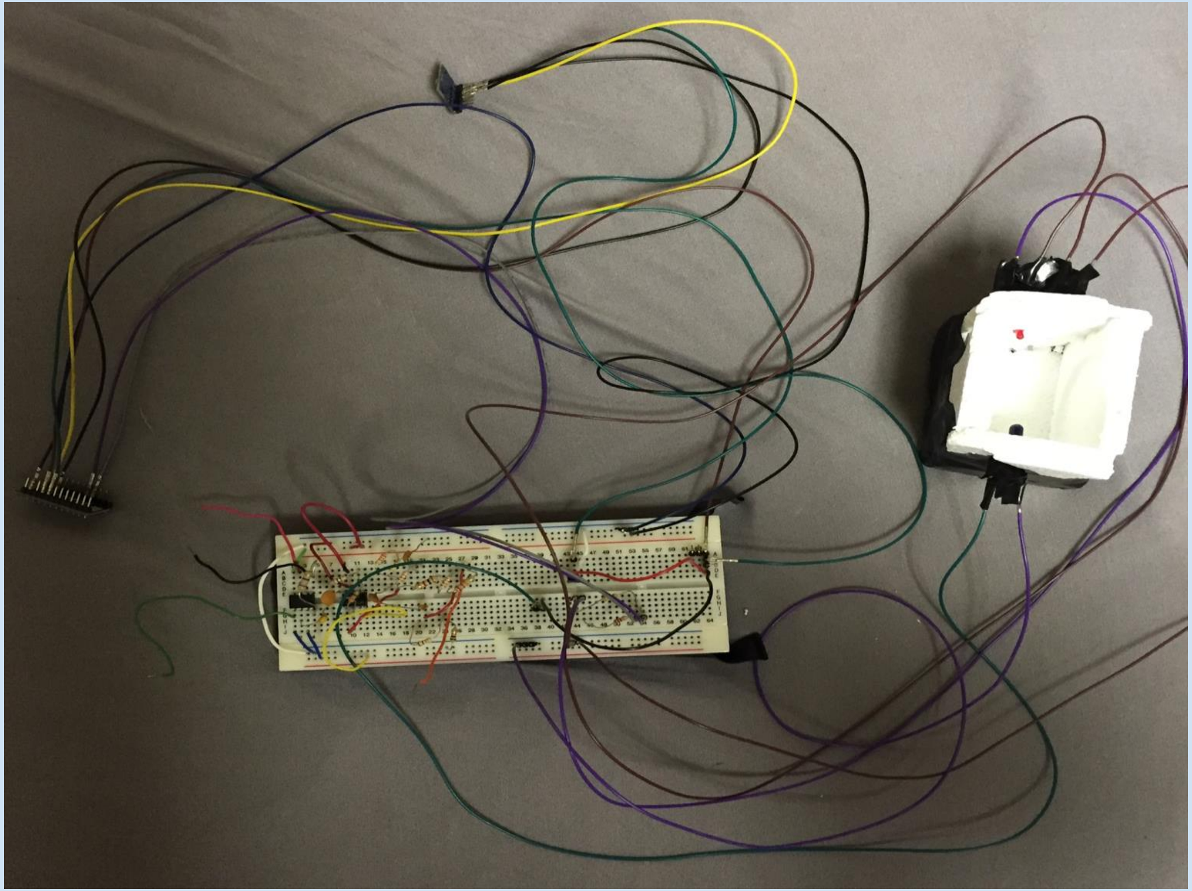
Arduino Mini Pro	Accelerometer	Temeprature Sensor	Pulse Sensor	Blood Oximeter	Power Supply	Bluetooth Module	ECG
RAW							
VCC	VCC	VCC	VCC	VCC	VCC	VCC	VCC
GND	GND	GND	GND	GND	GND	GND	GND
GND							
RX						RX	
TX						TX	
A0							
A1				Input			
A2							Input
A4	SCL						
A5	SDA						
A6			Input				
A7		Input					
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							

Wires, Cables, Connectors

Fritzing Diagram

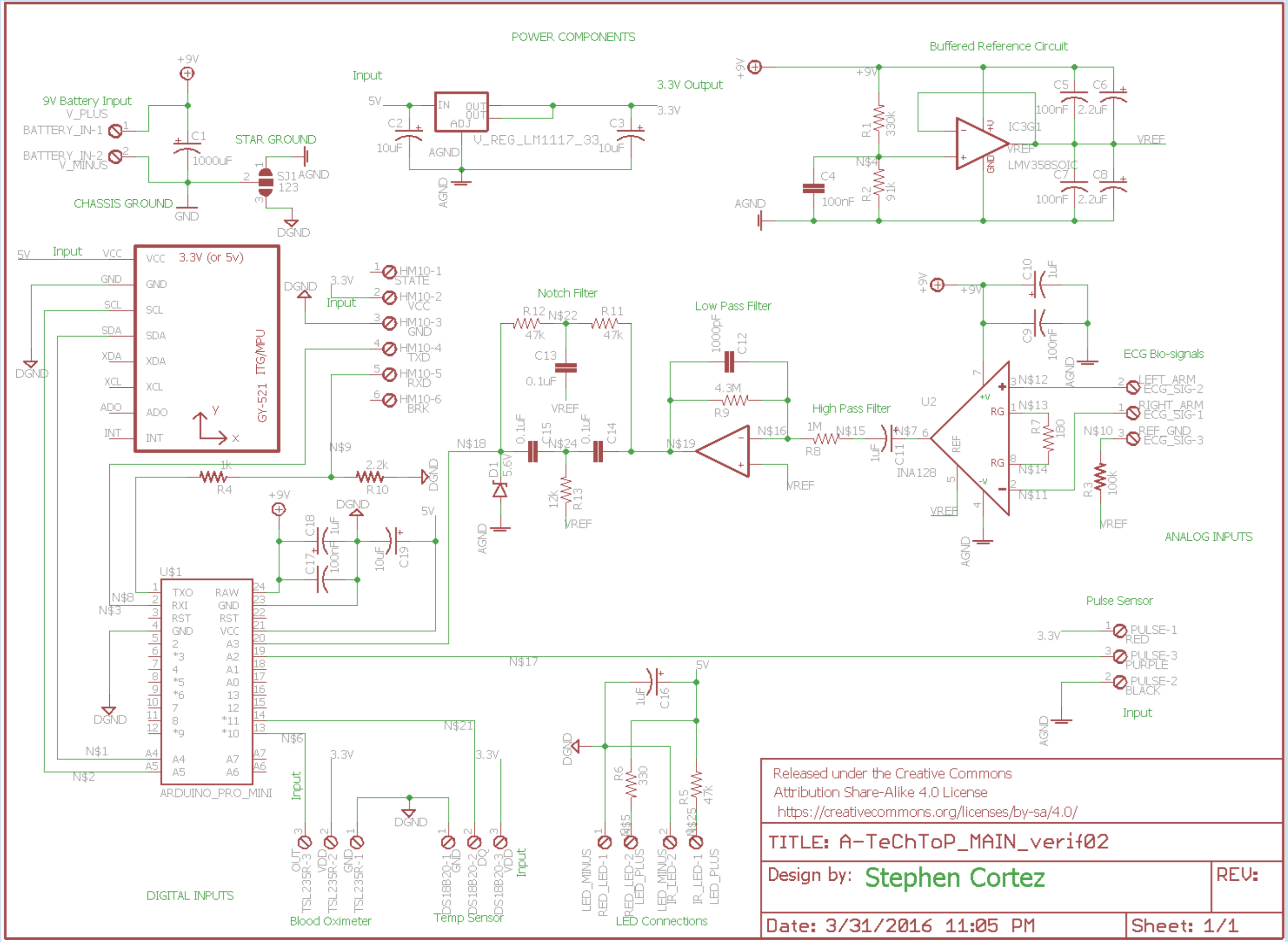


Physical Breadboard

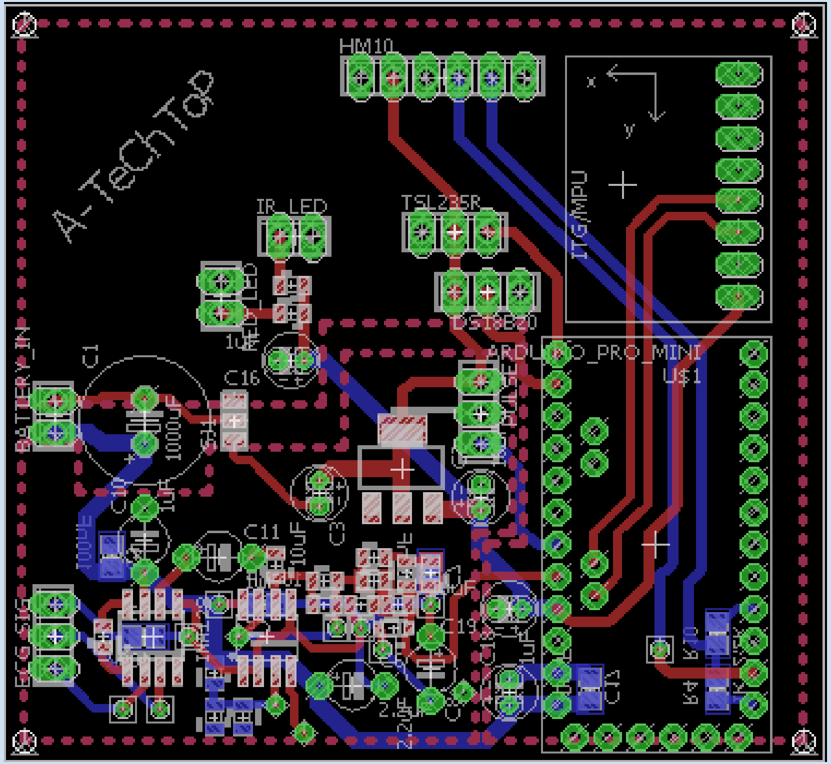


Schematic

Edited and Approved by: Jeff
(Electronics Division Manager)



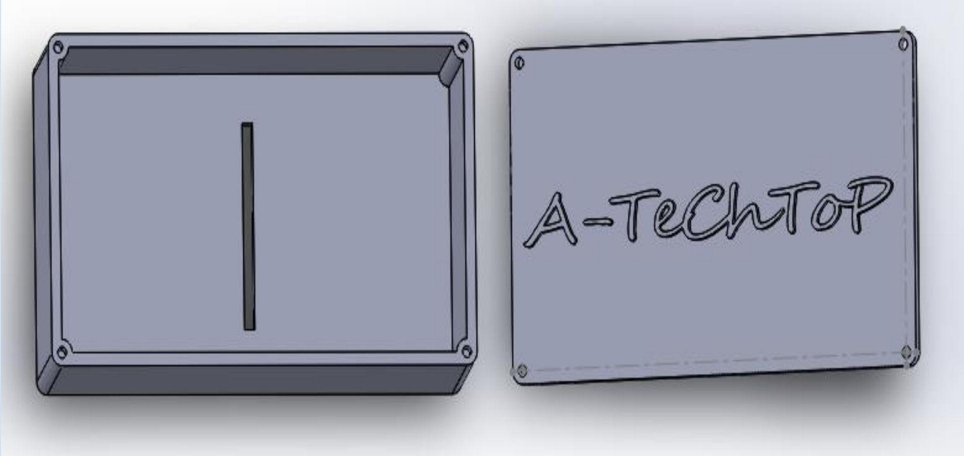
PCB Layout



Edited by: Chad (President) and Kevin (Manufacturing Division Manager)

- Size: 2.50 x 2.37 in
- AGND and DGND separate on the same layer of ground plane
  - AGND: LM358, INA128, LM1117, Pulse sensor
  - DGND: Arduino micro, HM10, GY-521, TSL235R, DS18B20
- Star connection is accomplished with SMD solder jumper SJ1.
- The board got approved by Manu. Div. Manager and is ready to be ordered.

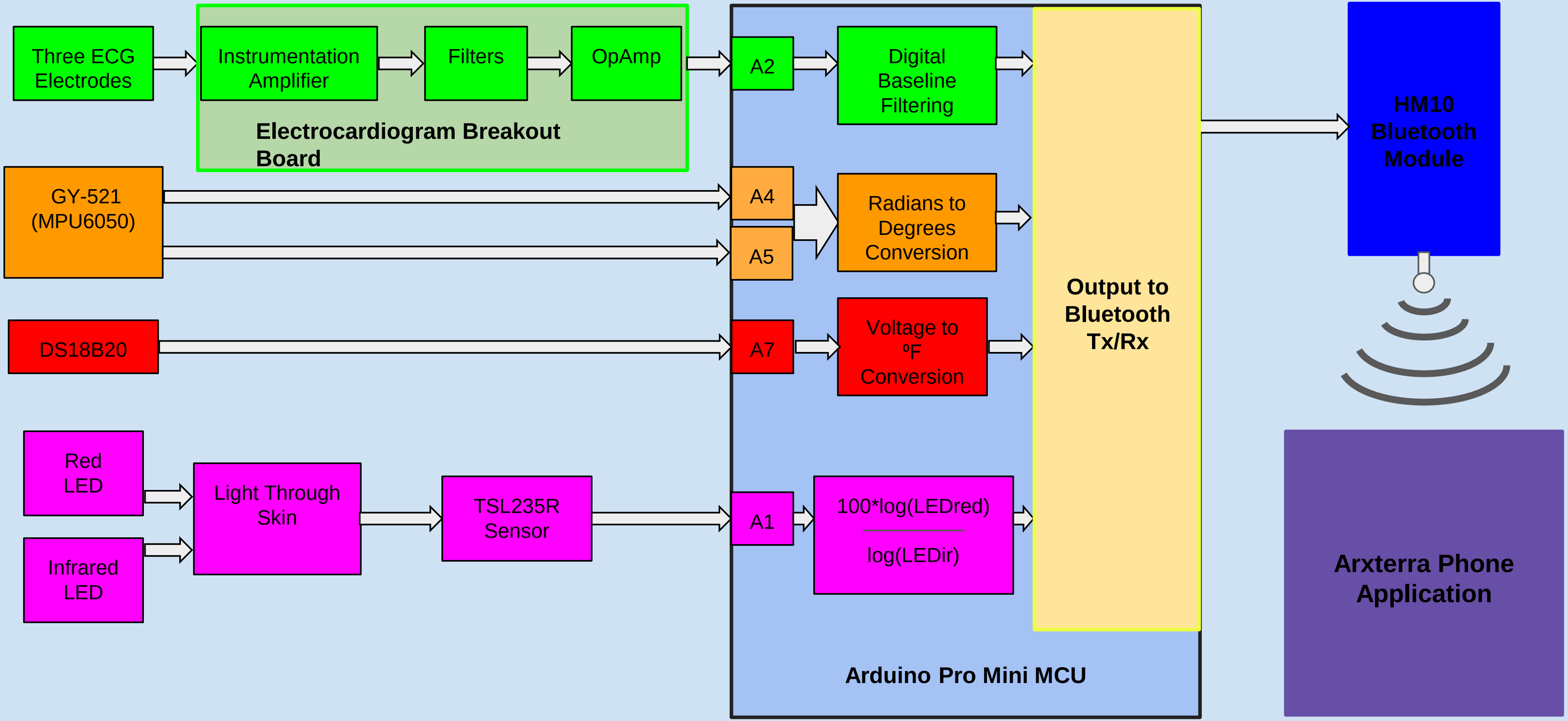
SolidWorks 3D Model



Dimension: 3.6 x 2.45 x 0.9 in

Prototype/Production Parts

Systems/Subsystem Design: Software Design



Arduino Software Modules

```
#if aTechTop

tempTime =tempMonitor(Wait, tempTime);
//Calling temperature sensor method

// accelTime = accel(Wait, accelTime);
//Calling the accelerometer method

pulseTime = pulseMonitor(Wait, pulseTime);
//Calling pulse sensor method

ECGTime = ECG(Wait, ECGTime);       //Calling
ECG code

bloodox = ECG(Wait, boTime);
//Calling blood oximeter code

#endif
```

Subsystem Software Modules

```
#include <Wire.h>
//#include "GY-521.h"
int ECG = 0;
int RedLED = 0;
int IRLED = 0;
int Oxygen = 0;
int Temp = 0;
float X_val;
float Y_val;
const int GY_521_addr=0x68; //Address of
Device
int16_t AcX,AcY,AcZ,Tmp,GyX,GyY,GyZ;

void setup() {
  // put your setup code here, to run once:
Serial.begin(9600);
Wire.begin();
pinMode(5, OUTPUT);
pinMode(6, OUTPUT);
digitalWrite(5, LOW);
digitalWrite(6, LOW);
Wire.beginTransmission(GY_521_addr);
Wire.write(0x6B); //Power Management Register
Wire.write(0); //Wake up GY-521
Wire.endTransmission(true);
}
```

```
void loop() {
  int ECG = analogRead(A1);
  digitalWrite(5, HIGH);
  delay(1000);
  RedLED = analogRead(A2);
  digitalWrite(5, LOW);
  delay(5);
  digitalWrite(6, HIGH);
  delay(1000);
  IRLED = analogRead(A2);
  digitalWrite(6, LOW);
  delay(5);
  int Temp = analogRead(A3);
```

```
  Wire.beginTransmission(GY_521_addr);
  Wire.write(0x3B); //Accelerometer Register
  Wire.endTransmission(false);
  Wire.requestFrom(GY_521_addr, 14, true);
  AcX = Wire.read()<<8|Wire.read();
  AcY = Wire.read()<<8|Wire.read();
  AcZ = Wire.read()<<8|Wire.read();
  Tmp = Wire.read()<<8|Wire.read();
  GyX = Wire.read()<<8|Wire.read();
  GyY = Wire.read()<<8|Wire.read();
  GyZ = Wire.read()<<8|Wire.read();
  X_val = AcX;
  Y_val = AcY;
  delay(500);
  Oxygen =
100*((log(1/RedLED))/(log(1/IRLED)));
  //Begin Printing Values:
  Serial.print("Oxygen %:");
  Serial.print("\t"); Serial.println(Oxygen);
  Serial.print("Temp:");
  Serial.print("\t"); Serial.println(Temp);
  Serial.print("GY-521:");
  Serial.print("\t"); Serial.print(X_val);
  Serial.print("\t"); Serial.println(Y_val);
  Serial.println();
}
```

Strategy for Verification and Validation

Refer to PDF files showing the plans for verification and validation

Validation Matrices

Validation Product No	Activity	Objective	Method	Results	Pass/Fail
1	Customer will be able to interact with the completed device by May 4	The wearable body network must be completed by May 4, 2016, the last day of instruction for E400D in the CSULB Spring 2016 Semester	Test		
2	Customer will look through the receipts to verify the total amount spent	The cost must be limited to $700	Test		
3	Customer will inspect the body network	Body network shall be evaluated to make sure it meet the safety standards of ASTM F 963-11	Inspect		
4	Customer will test the range of the body network	Range of body network shall be tested	Demonstration		

Validation Product No	Activity	Objective	Method	Results	Pass/Fail
5	Customer will turn on the device and observe for 30 mins to see the device will remain functional during that time period	The device shall last 30.2 minutes when powered on	Test		
6	Customer will observe the Arxterra control panel to see the biological signals coming from the device	The biological signals shall appear on the Arxterra control panel	Inspect		
7	Customer will observe the device allowing free range of motion when worn	The device shall not hinder the motion of the child	Test		

Validation Product No	Activity	Objective	Method	Verification Method	Results	Pass/Fail
6	Purchases cannot be made for sensors which need to be manufactured before shipping in order to meet deadline requirements	Purchases of devices shall be made for complete sensors	No purchases will of incomplete devices will take place	Inspection		
7	In order for project to stay within budget and meet deadline requirements, no purchase may be made for items outside of the United States.	Purchases shall stay inside of the United States	No purchases will takes place outside of the United States	Inspection		

Validation Product No	Activity	Objective	Method	Results	Pass/Fail
8	Customer will observe the blood oximeter levels	Body network shall measure blood oxygen levels	Demonstration		
9	Customer will observe the temperature values	The sensor suite shall measure the body temperature	Demonstration		
10	Customer will observe the accelerometer values	Body orientation for the child shall be distinguished	Demonstration		
11	Customer will observe the ECG signals	The device shall measure ECG signals	Demonstration		
12	Customer will observe the alarm	An alarm shall alert when one of the child's biological signals has dropped into a dangerous range	Demostration		

Verification

Requirement No.	Paragraph	Shall Statement	Verification Success Criteria	Verification Method	Results	Pass/Fail
1	Bluetooth, IEEE 802.15.1 standard will be used as the wireless method of communication between the Arduino and Android phone due to its simplicity interacting with both the Android phone and the Arduino platform	IEEE Bluetooth standard shall be used	Bluetooth module will comply with this standard	Inspection		

Requirement No.	Paragraph	Shall Statement	Verification Success Criteria	Verification Method	Results	Pass/Fail
2	Android phone and Bluetooth device will not exceed SAR regulation of 1.6W/kg as stated by the FCC	Bluetooth shall not exceed SAR regulation of 1.6W/kg	Device will not exceed the SAR regulation	Inspection		
3	Transmission of signals through Bluetooth to Android phone and from Android phone to Arxterra control center shall have a minimal cumulative delay for immediate reaction time. Delay shall be least than a heartbeat (80 beats per min)	Signals shall have a minimum cumulative delay of no more than the time it takes for a heartbeat	Sensor values should update in the time it takes for a heartbeat to occur	Test		

Requirement No.	Paragraph	Shall Statement	Verification Success Criteria	Verification Method	Results	Pass/Fail
4	The sensors, sensor suite, and android phone shall withstand forces (such as a child falling) of at least 20 Newtons	Sensor suite shall withstand forces of at least 20 Newtons	Sensor suite will remain functional after withstanding 20 Newtons of force	Test		
5	Electrical components shall qualify as level two water resistance which is defined as “allows for contact with water such as washing hands or light rain	Sensor suite shall qualify as level two water resistance	Sensor suite will remain functional after light water contact	Test		
6	Purchases cannot be made for sensors which need to be manufactured before shipping in order to meet deadline requirements	Purchases of devices shall be made for complete sensors	No purchases will of incomplete devices will take place	Inspection		

Requirement No.	Paragraph	Shall Statement	Verification Success Criteria	Verification Method	Results	Pass/Fail
7	In order for project to stay within budget and meet deadline requirements, no purchase may be made for items outside of the United States.	Purchases shall stay inside of the United States	No purchases will takes place outside of the United States	Inspection		
8	To avoid harming the child, device will not reach a temperature greater than 113°F	Device shall not reach temperatures greater than 113°F	Device will remain cooler than 113°F when functioning	Test		
9	The wearable device will avoid using materials that can lead to skin irritants caused by an allergic reaction	Device will avoid materials that cause skin allergies as found on this website	Device will have no trace of any of the common materials that cause skin allergies	Test		

Work Breakdown Structure

- Two major branches for the groups (Central Sensor Suite and Seizure Watch)
- Each group member completes all their division tasks

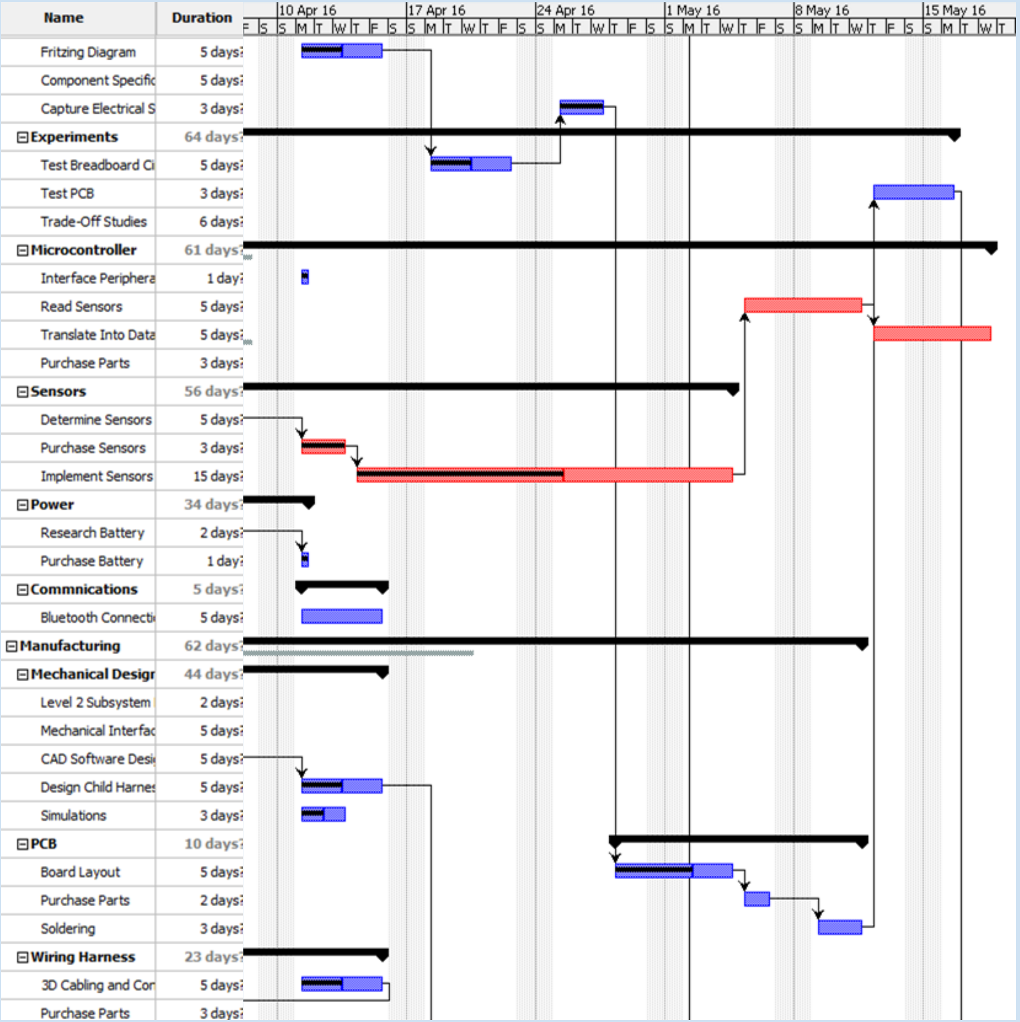
Mass Report					
Resource	Expected Weight (g)	Measured Weight (g)	Uncertainty (%)	Margin (g)	
GY-521 MPU6050	5	5	5	1	
Arduino Pro Mini 328	2	3	5	1	
DS18B20	1	2	5	0.5	
Pulse Sensor Amped	4	N/A	5	1	
TSL235R	1	2	5	0.5	
ECG circuit	5	4	15	2	
HM-10 Bluetooth	1	2	10	0.5	
Wiring	5	6	5	2	
PCB	5	N/A	10	2	
Chest Strap	160	173	10	15	
3D printed case	10	8	10	3	
Armband	30	N/A	10	5	
Battery	102	99	5	20	
Project Allocation (g)					1800
Actual Weight(g)					304
Total Margin (g)					53.5
Total Expected Weight (g)					331
Contingency (g)					1522.5

Power Report					
Resource	Expected Power (mA)	Measured Power (mA)	Uncertainty (%)	Margin (mA)	
GY-521 MPU6050	3.9	4.2	3	1	
Arduino Pro Mini 328	150	151	5	50	
DS18B20	1.5	1.7	3	1	
Pulse Sensor Amped	4	5	5	3	
TSL235R	3	4	2	1	
ECG circuit	20	23	5	5	
HM-10 Bluetooth	20	24	5	5	
Project Allocation (mA)					1500
Actual Power (mA)					212.9
Total Margin (mA)					66
Total Expected Current (mA)					202.4
Contingency (mA)					1363.6

Cost Report					
Resource	Expected Cost ($)	Measured Cost ($)	Uncertainty (%)	Margin ($)	
GY-521 MPU6050	6	3.35	10	2	
Arduino Pro Mini 328	10	10.75	10	3	
DS18B20	5	4.25	5	1	
Pulse Sensor Amped	25	24.95	5	5	
TSL235R	3	2.95	5	1	
ECG circuit	20	35.9	10	5	
HM-10 Bluetooth	5	16.99	10	2	
Eelctrodes	65	72	10	7	
Wiring	10	5	5	3	
PCB	25	N/A	10	5	
Chest Strap	20	30	10	5	
3D printed case	0	N/A	5	0	
Breakout Board	20	17.95	5	5	
Armband	10	N/A	10	3	
Medi-Trace Foam Gel	10	7.99	10	3	
Battery	20	18	10	5	
Project Allocation ($)					258.8
Total Margin ($)					55
Total Expected Cost ($)					254
Contingency ($)					59.8
Actual Cost					250.08

Updated Schedule

- Follows WBS
- Areas that slowed progress:
  - PCB
  - Arxterra Control Panel
  - ECG design
- Target areas to help speed up progress:
  - Assembly
  - Sensor integration
  - Testing



Burndown

- Blue: Baseline Hours
- Yellow: Actual Remaining Hours
- Red: Theoretical Remaining Hours if on Schedule
- Arxterra Control Panel and Manufacturing will be most time consuming at this point
- 59.6% of project complete