Critical Design Review: A-TeChToP Seizure Watch

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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 will help monitor children with histories of seizures.

Mission Profile

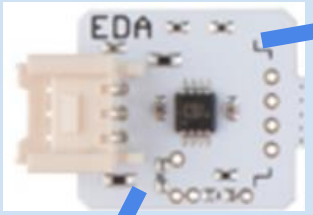
A-TeChToP's mission is to successfully monitor seizures for a child between the ages of 5 and 13 while playing on a playground for thirty minutes. The seizure device will be attached to the child's wrist and then the child will perform specific exercises and later play freely. Data will be sent continuously to a guardian-monitored computer and, if the child displays the symptoms of a seizure, the guardian will be warned.

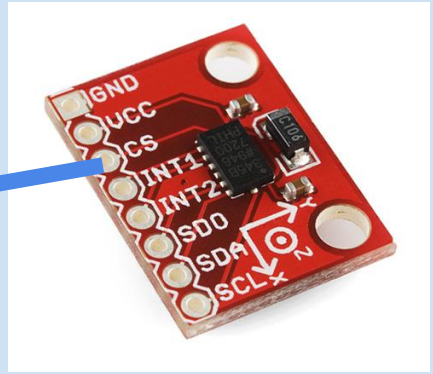
El Dorado Park, Long Beach

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

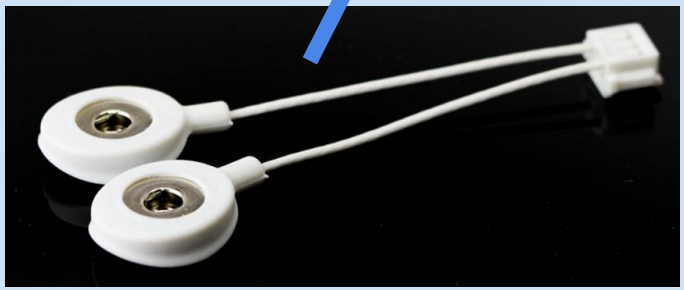
The Design

EDA Sensor





Accelerometer

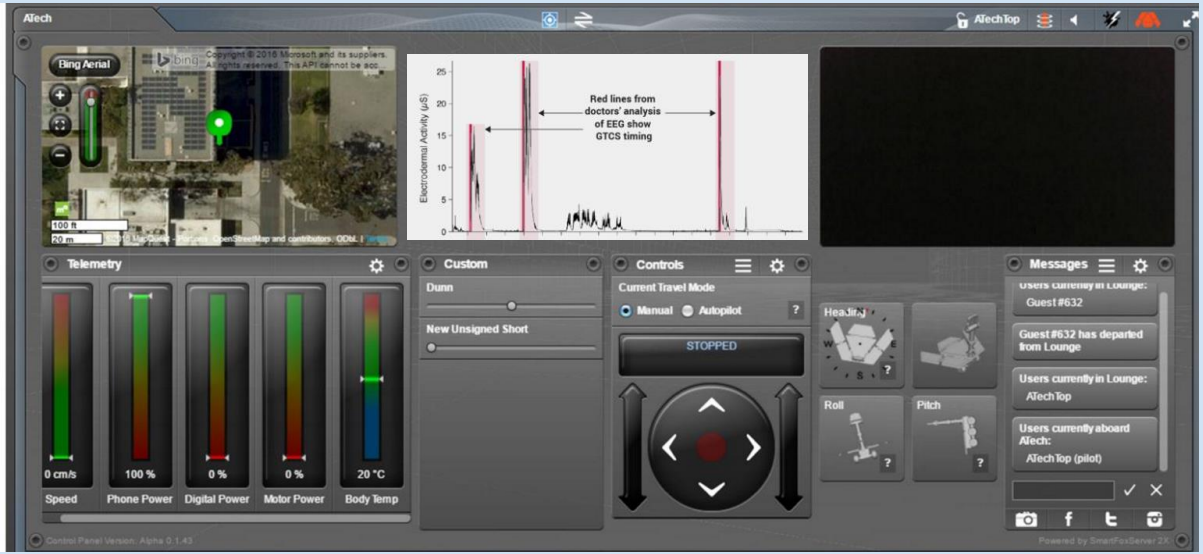


Electrodes

Controller and Bluetooth

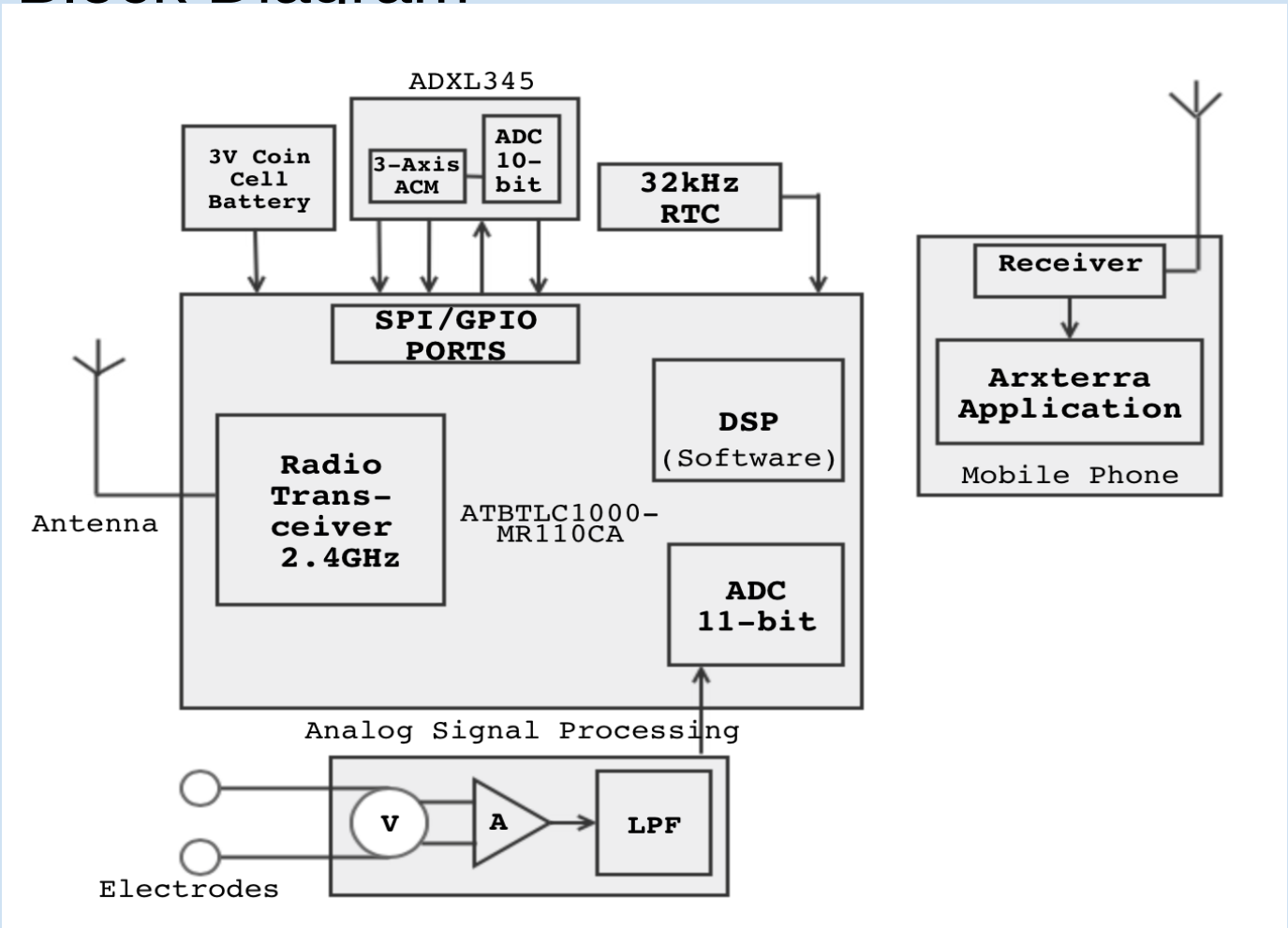
Project Features

- Combined Bluetooth and microprocessor on the SAMB11
- Extremely small
- Electrodermal activity sensor with reusable electrodes



- Combination of accelerometer and electrodermal activity sensor to detect seizures with the accuracy of an electroencephalogram [1]
- New graphical widget for displaying EDA signal

System Block Diagram



Outline of Experiments for Design Solutions

- The first experiment effectively tests and confirms the seizure detection capabilities of the combined use of an electrodermal activity sensor and accelerometer.
- The second experiment discusses the 3D printed materials that were considered in the watch band selection, the experiment confirms that the resulting watch straps design is best suited for the seizure watch.

Experiment 1 (In progress)

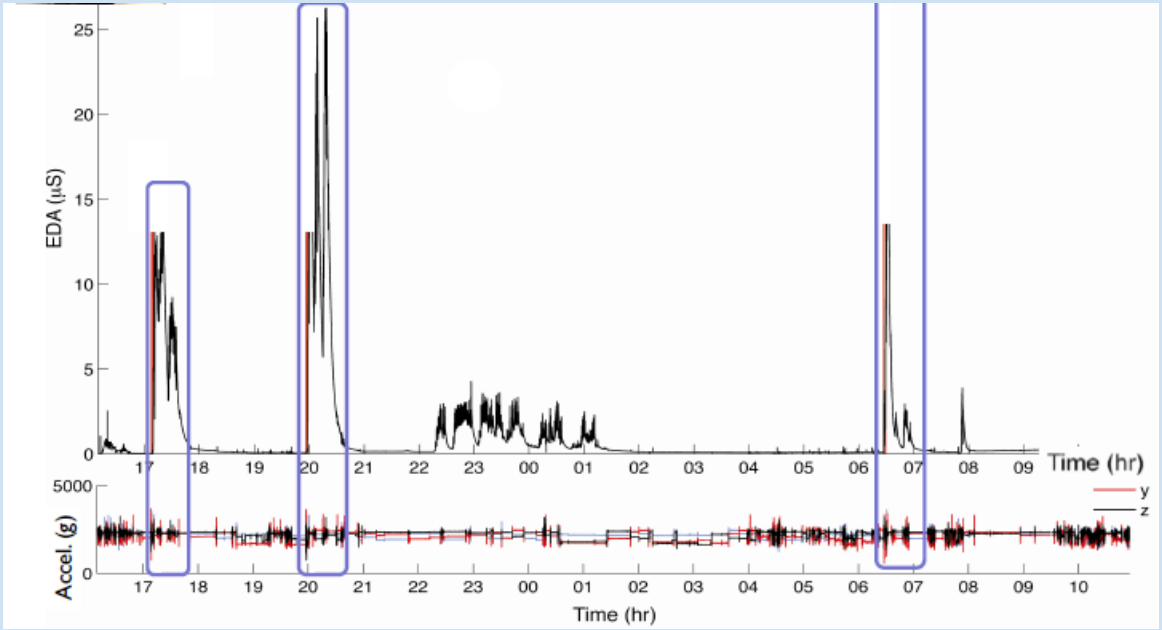


Fig. Graph shows the correlation between EDA and accel. data during seizure events [1]

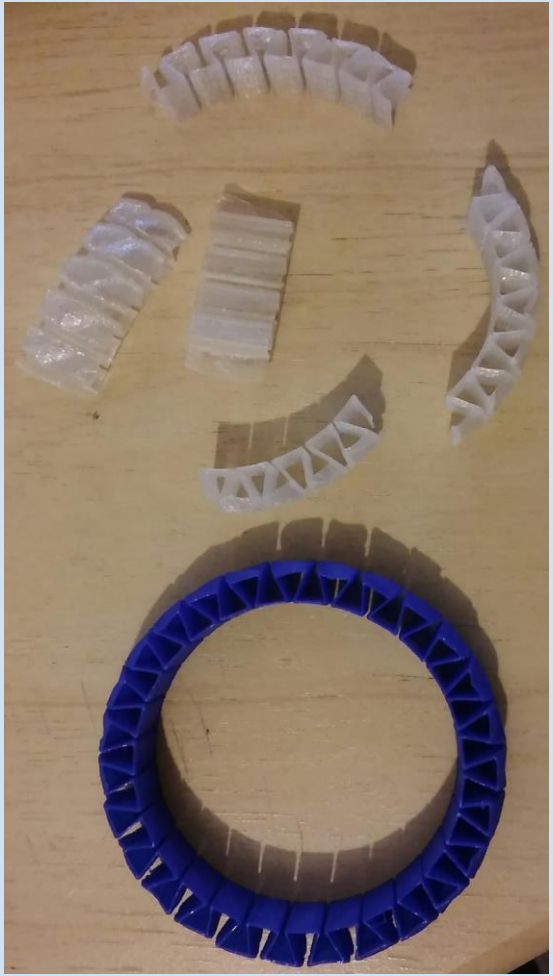
This experiment involves testing the output of the electrodermal activity sensor and the accelerometer on someone who is experiencing a seizure to confirm that both sensors respond as expected. This study [1] has shown that seizure detection is significantly more accurate with the combined use of an EDA and accelerometer. Experiment is to be completed once the EDA sensor is received.

Experiment 2

Arriving at the right design:

We tested different materials to determine the best one that provides flexibility, protection for electronic components, ease of use and coolness!

As a result, we decided not to 3D print the watch band and to have a thick walls for the housing.



Interface Matrix

Interface Definitions

Pin	Atmel BTLC1000-MR110CA Interface
1	Ground (connected to PCB Ground)
2	Clock Debug Pin interface
3	Data Debug Pin interface
4	GPIO/Default RXD
5	GPIO/Default TXD
6	PMU (connected to 3.3 V battery supply)
7	GPIO/Default CTS
8	GPIO/Default RTS
9	Ground (connected to PCB Ground)
10	Default SPI_SCK –Connected to ADXL345 SCLK Pin 14
11	Default SPI_MOSI -Connected to ADXL345 SDI Pin 13
12	Default SPI_SSN - Connected to ADXL345 CS Pin 7
13	Ground (connected to PCB Ground)
14	Default SPI_MISO -Connected to ADXL345 SDO Pin 12
15	GPIO/ADC
16	ADC: Output of EDA Circuitry (see explanation)
17	Chip Enable (tied to VDDIO or recommended 1.8V)
18	RTC (Positive Input) - Connected to 32kHz RTC
19	RTC Negative Input (must be left open)
20	Always on GPIO
21	GPIO/default Debug UART RxD
22	Power from Battery: 3.3 V
23	GPIO/default Debug UART TxD
24	Ground (connected to PCB Ground)
25	Ground Paddle

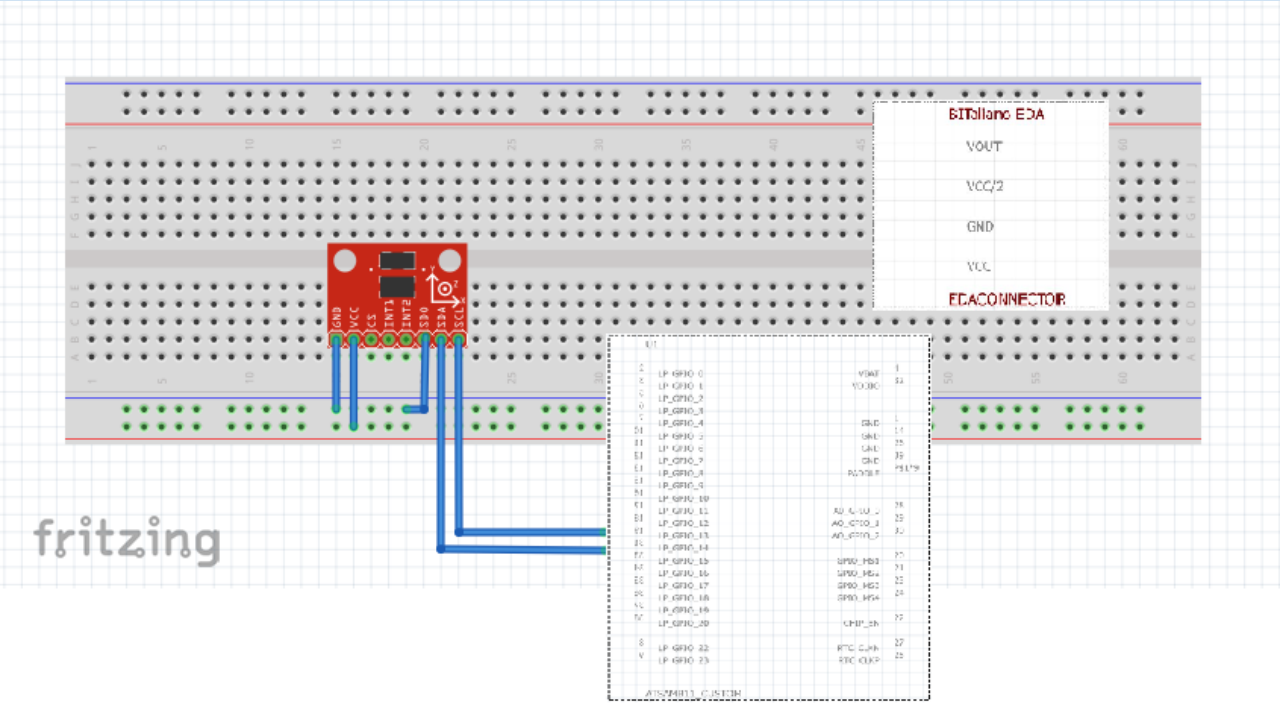
Pin	ADXL345 Interface
1	VDDIO - Connected to Power Supply
2	Ground (connected to PCB Ground)
3	Open
4	Ground (connected to PCB Ground)
5	Ground (connected to PCB Ground)
6	Vs - Connected to Power Supply
7	CS - connected to BTLC1000 SSN
8	INT1
9	INT2
10	NC - Left Open
11	Reserved - Left Open
12	SDO - Connected to BTLC1000 MISO
13	SDI - Connected to BTLC1000 MOSI
14	SCLK - Connected to BTLC1000 SCK

Wires, Cables, Connectors

The PCB board will be produced based on the interface matrix. The connections must be close to the SAMB11, in order to conserve space on the face of the device.

The wires connected to the electrodes must be routed down to the ventral side of the distal forearm from the watch face/pcb. The wires also must not be exposed or susceptible to movement, which would distort the electrodermal signal. This will require the manufacturing of a tube or line in the wristband, through which the wire can be wrapped around the wrist.

Fritzing Diagram



Fritzing diagram is in progress do to the custom parts which need to be finished.

Physical Breadboard

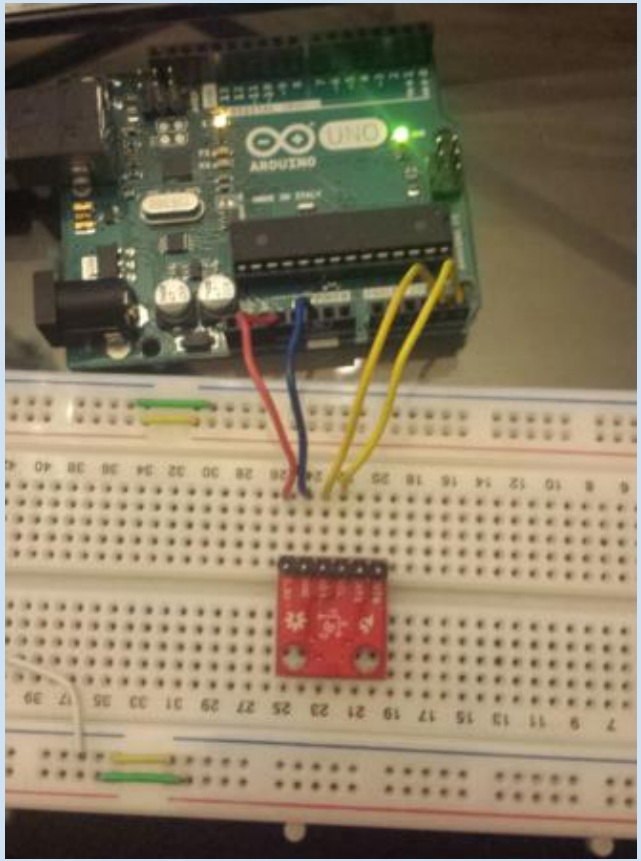
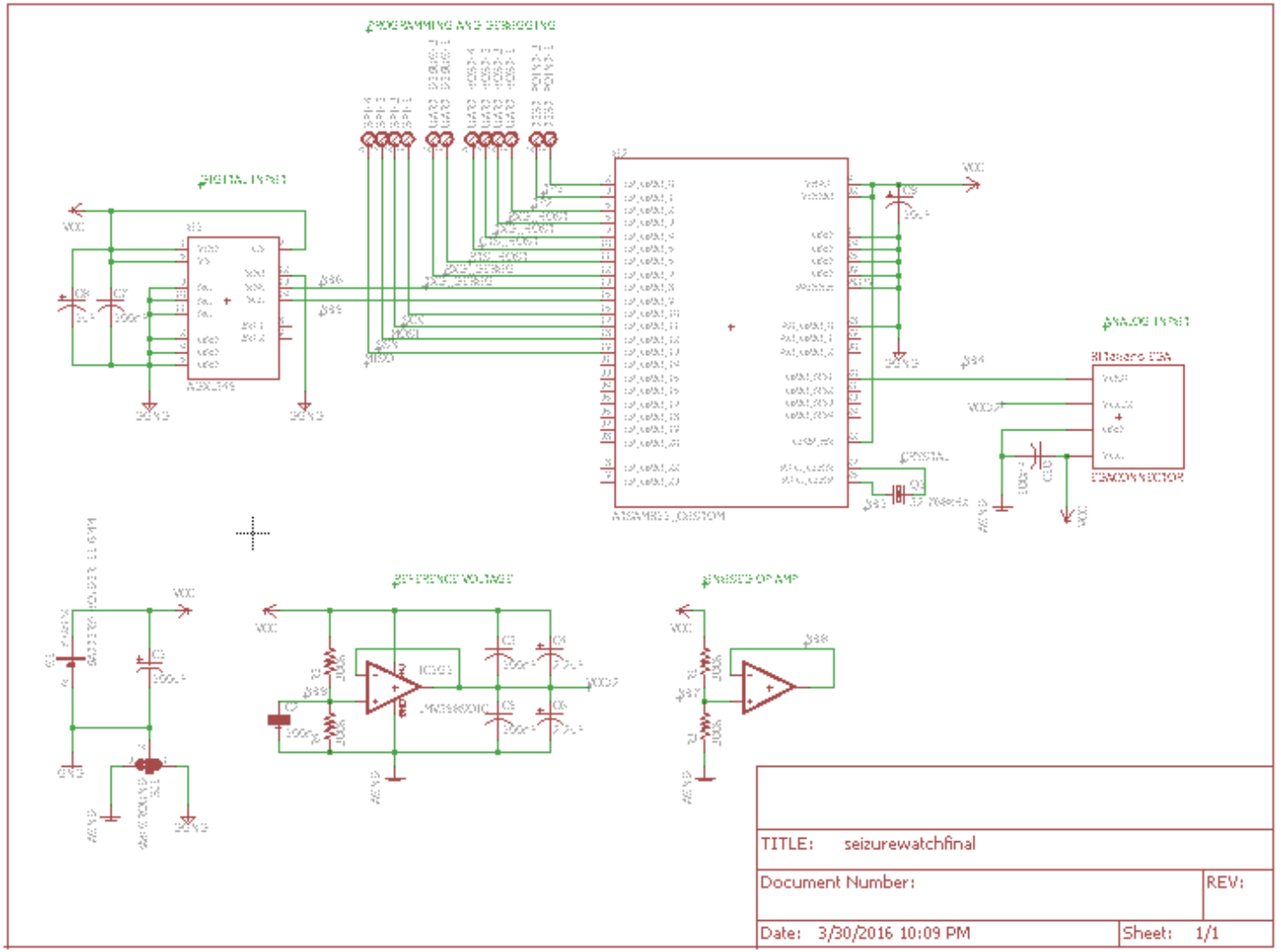


Image shows the breakout board from sparkfun which is connected with an Arduino Uno to test the functionality of the ADXL345. This board is connected over I2C and runs off of the 3.3V output of the arduino. The EDA sensor is to be integrated and tested as well.

Schematic


TITLE: seizurewatchfinal
Document Number:
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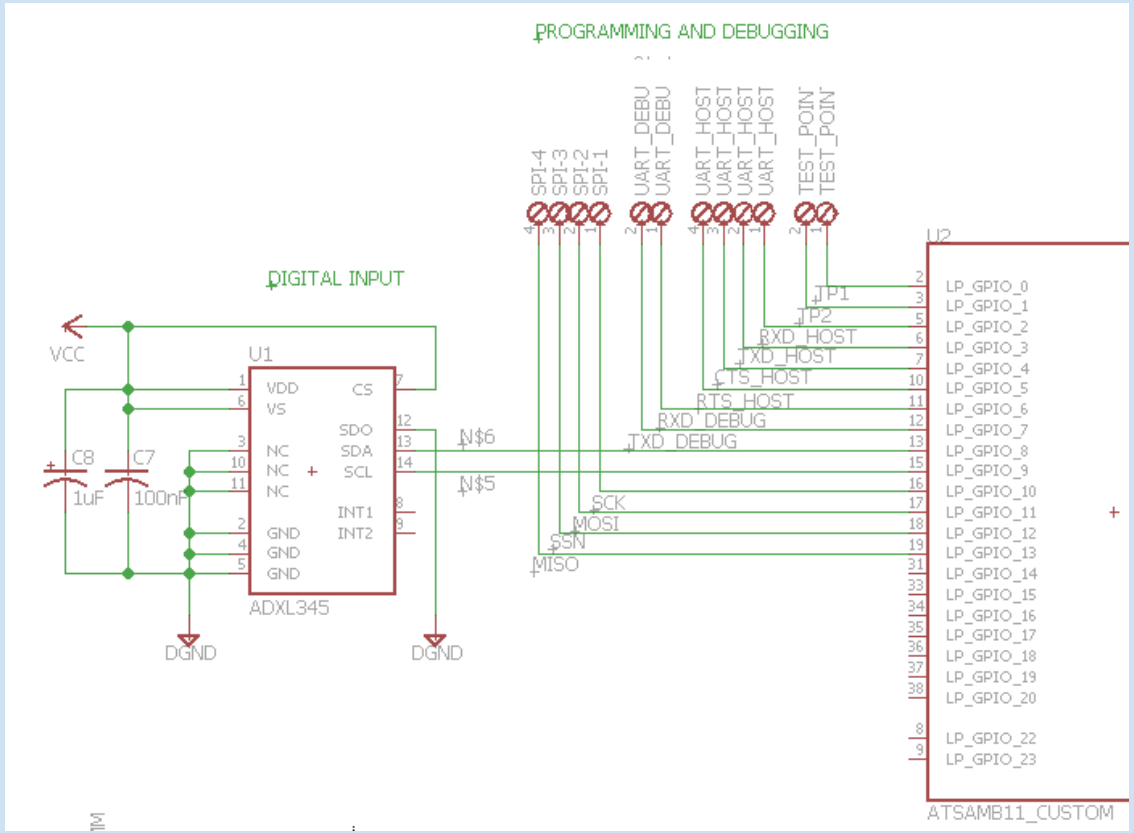
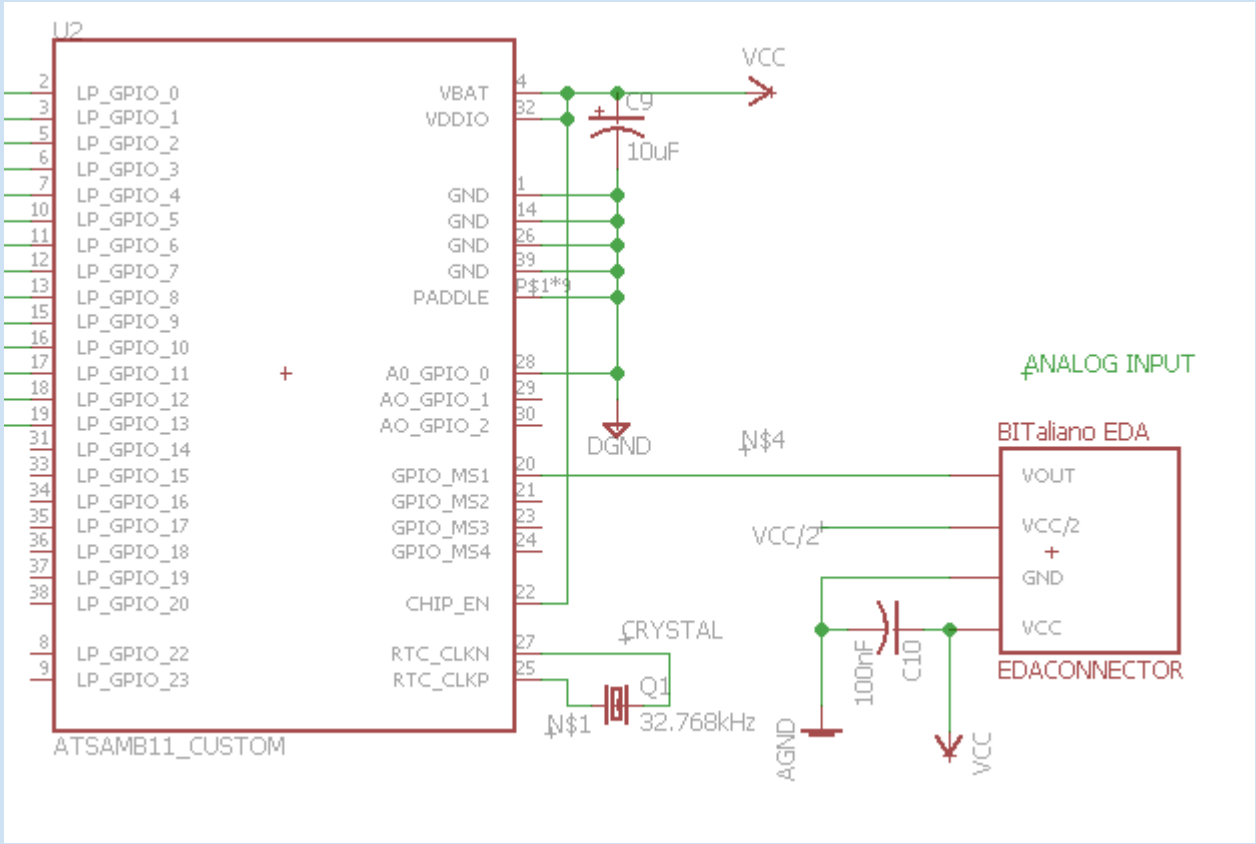
Date: 3/30/2016 10:09 PM
Sheet: 1/1

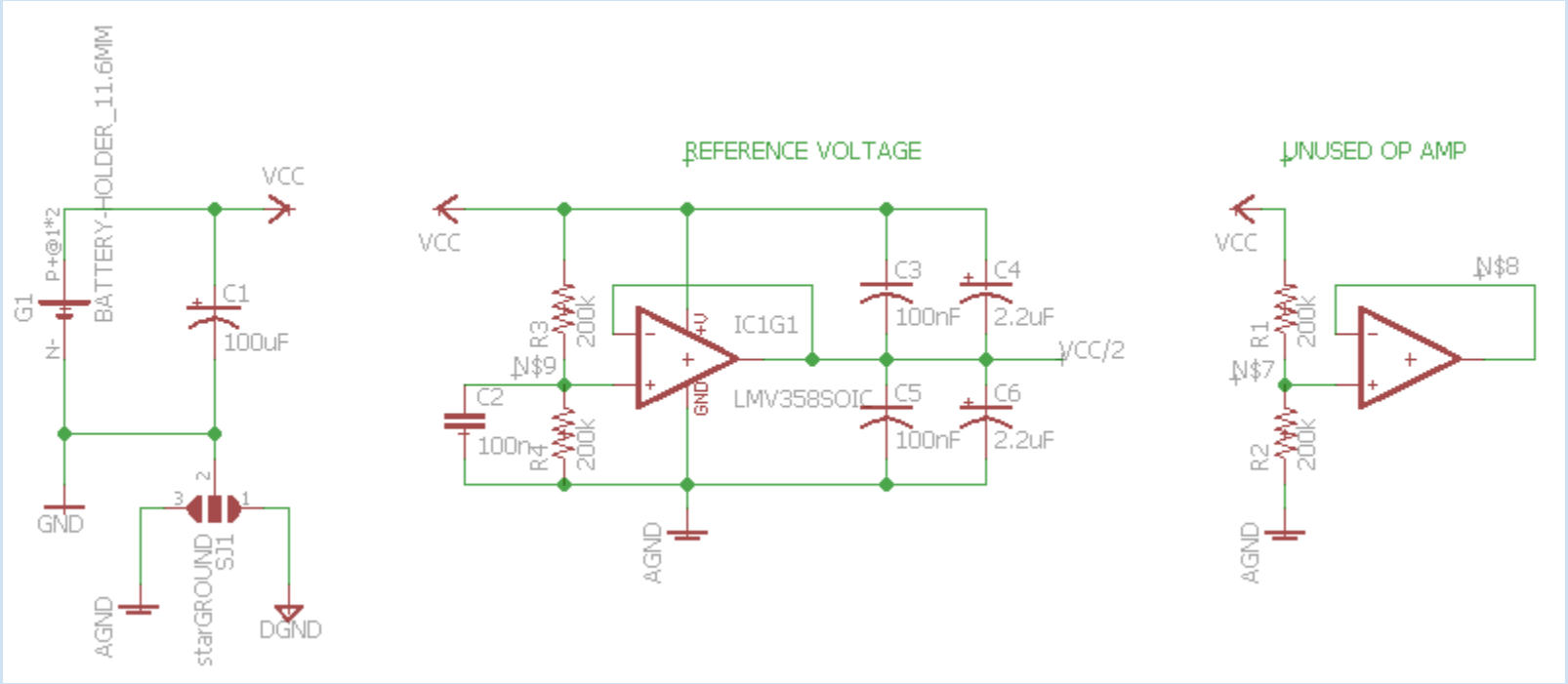
Schematic (Zoomed in)



Schematic (Zoomed in)

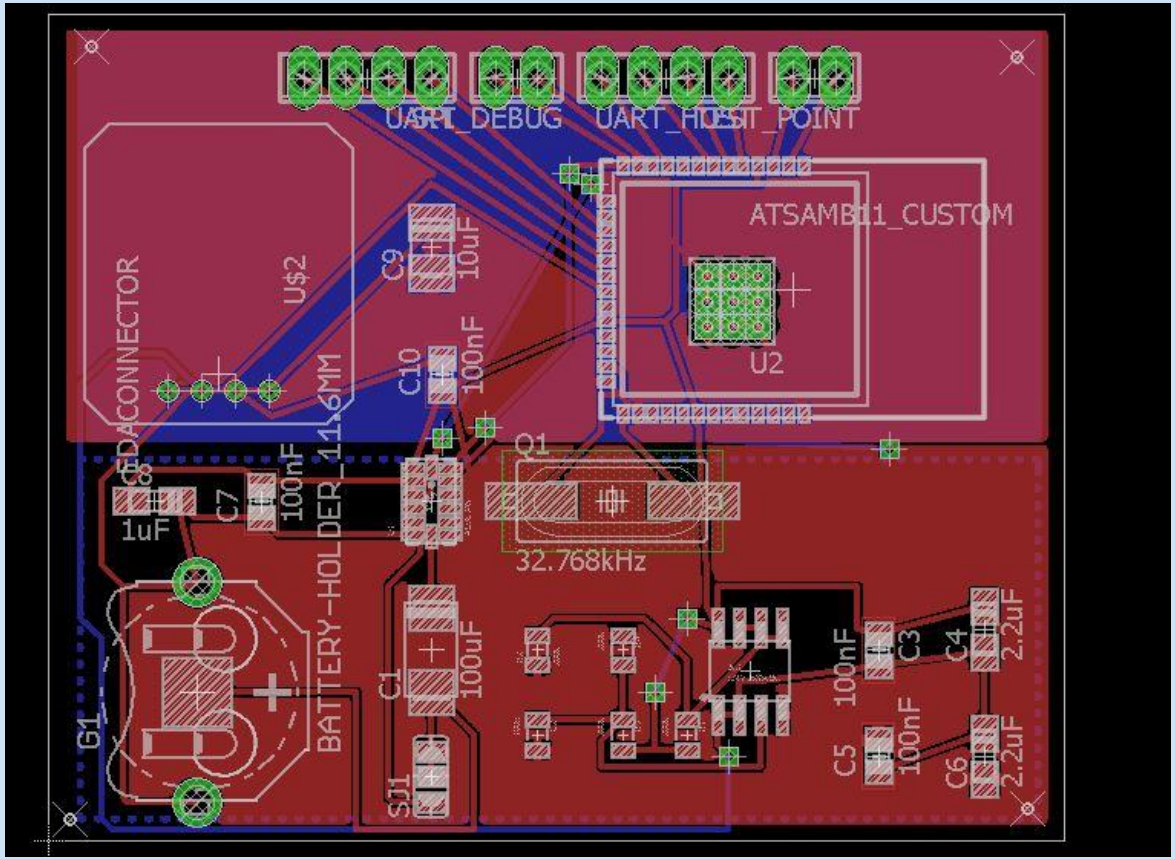


Schematic (Zoomed in)



PCB Layout

The PCB layout is still in progress.

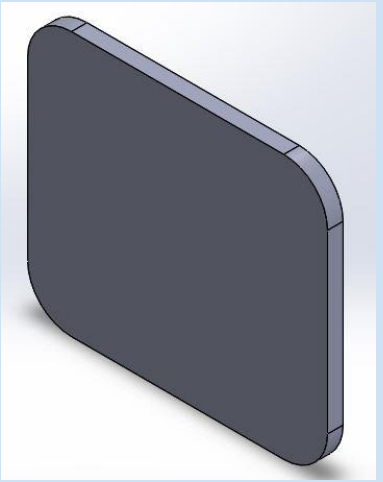


SolidWorks 3D Model

-The 3D SolidWorks model consist of the housing and its lid. The lid is attached to the housing with 4 micro screws one at each side.

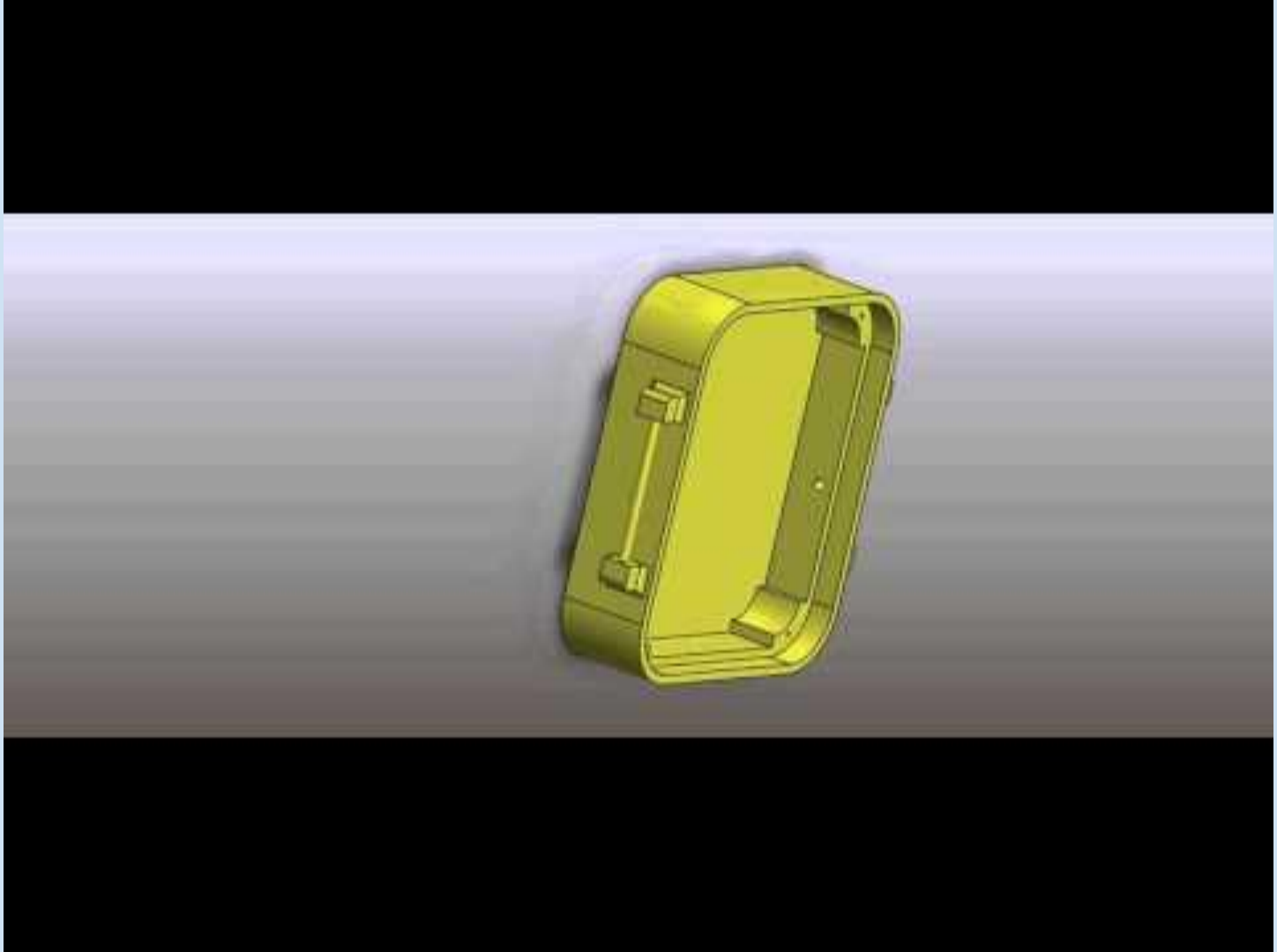
- The watch band(strap) will be attached to the housing through two lugs(one at each side).

-The housing will be 3D printed from PLA and the band is made of nylon with plastic buckle.



Lid

Band only

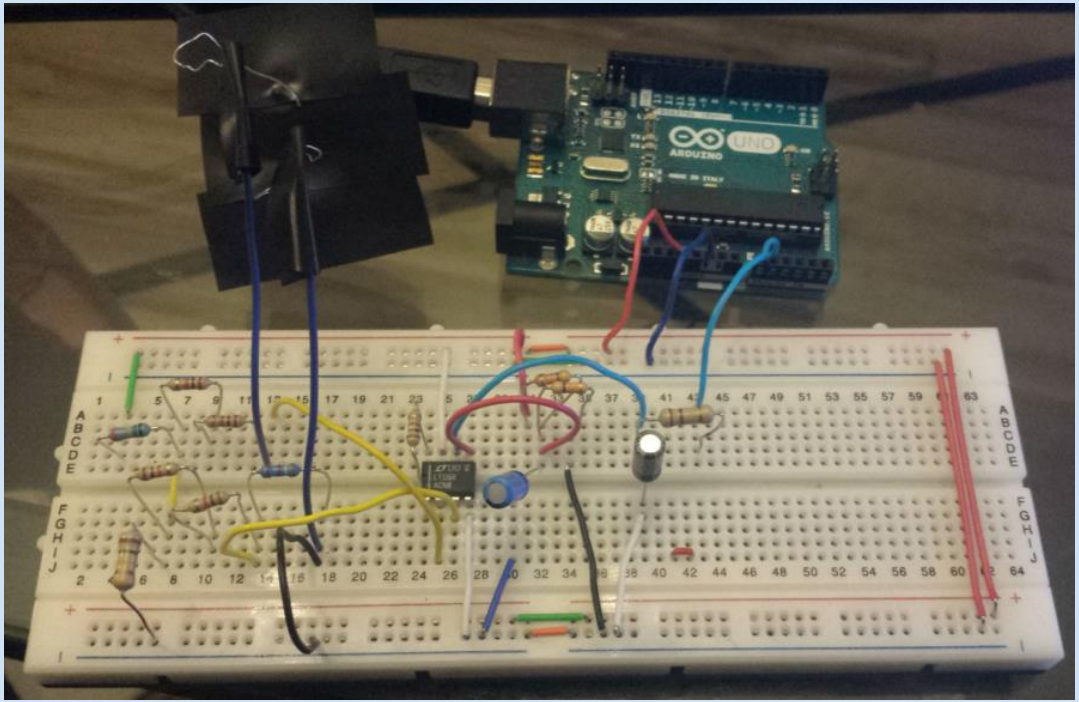


Prototype/Production Parts

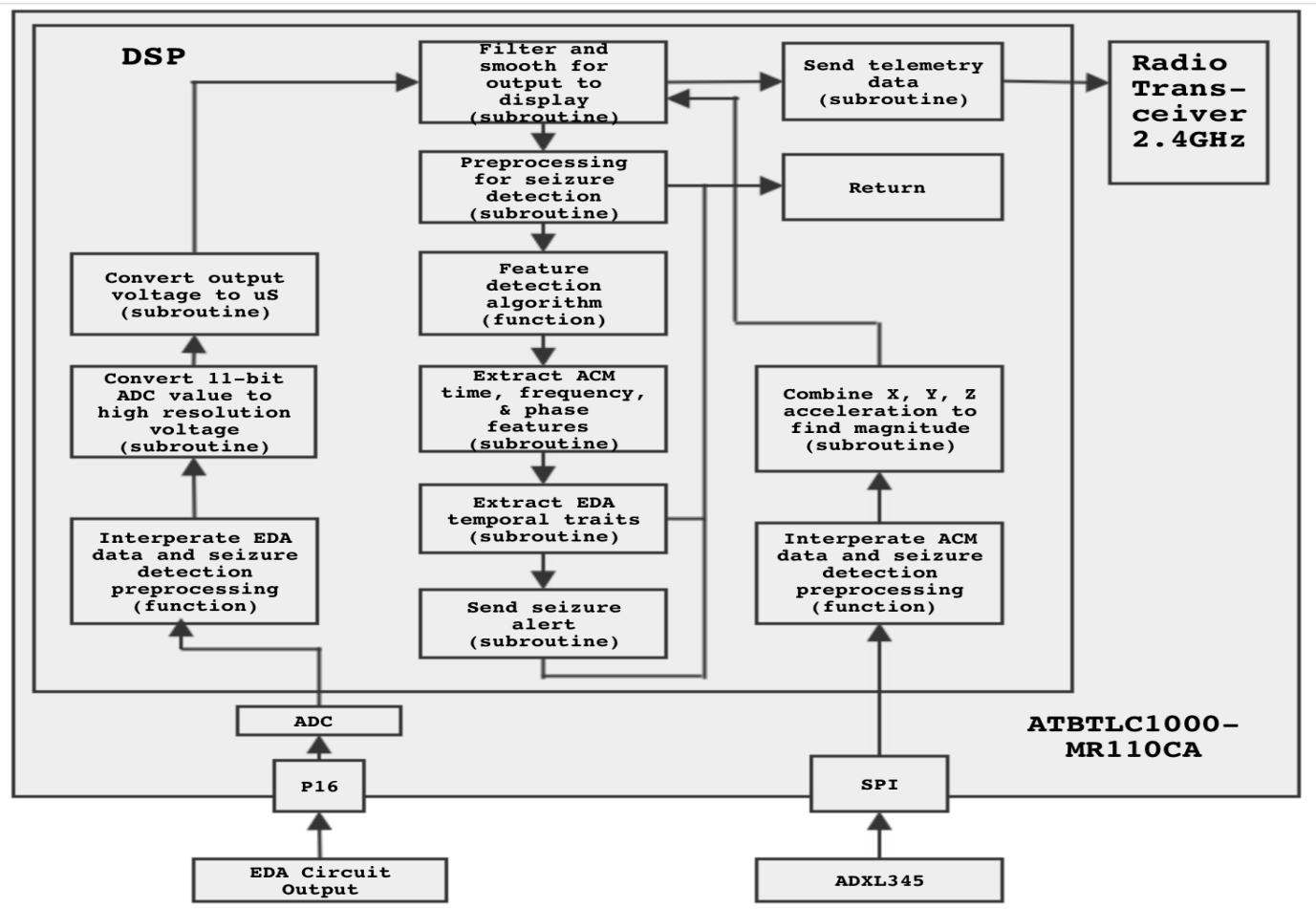
Rapid prototype of EDA circuit

The EDA circuit was adapted from [2] using a LT1168 instrumentation amplifier with the analog output connected to an arduino uno to easily view the output of the circuit.

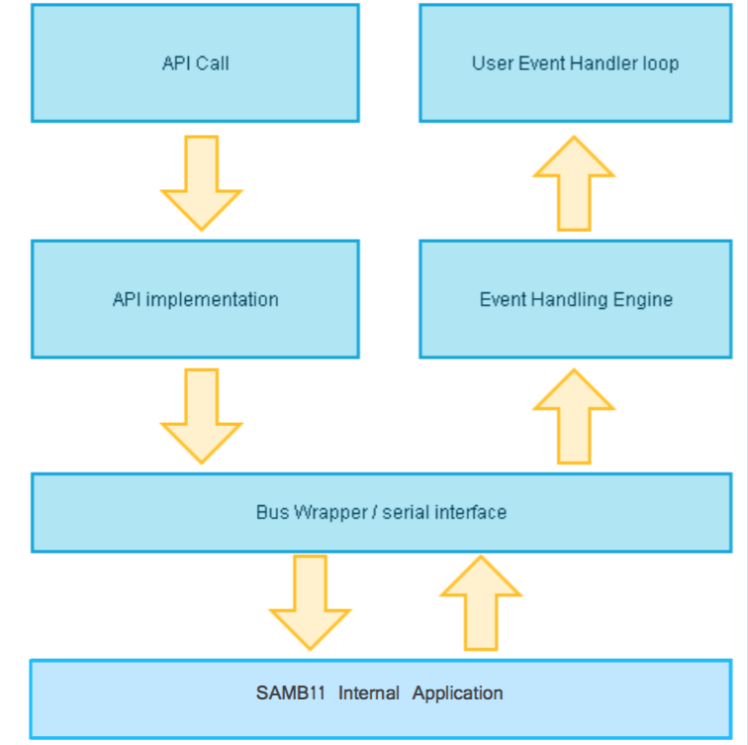
Result - There was a high amount of noise and distortion in the resulting signal and it was decided by the group to use a standalone EDA sensor instead.



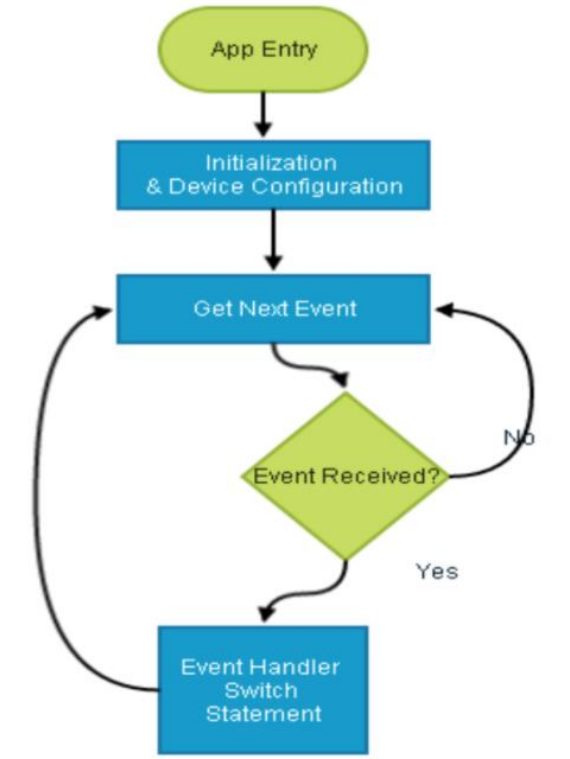
Software System Block Diagram



New Software: Atmel BTLC1000 Telemetry Subroutine

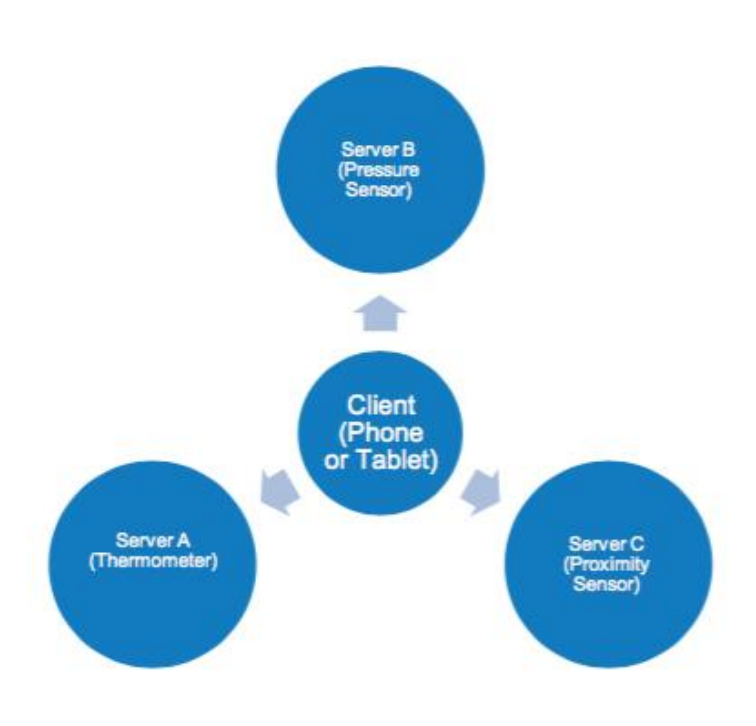


API Block Diagram [3]

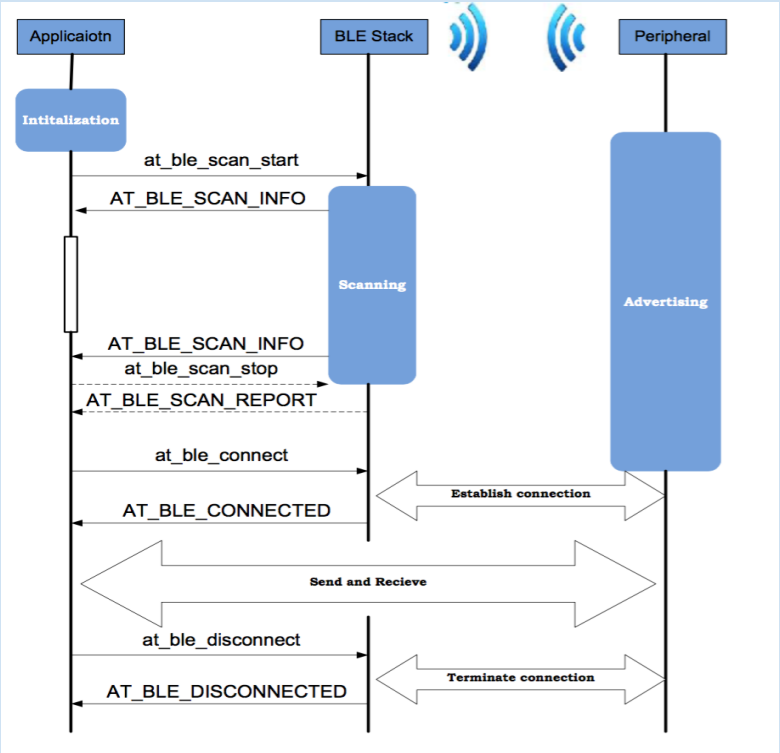


Event Handling Flow Chart [3]

New Software: Atmel BTLC1000 Telemetry Subroutine



Client Server Connection Example [3]



Sending/Receiving Communication Commands [3]

SAMB11 Software Modules

qs_i2c_slave_basic_use.c | Solution Explorer

qs_i2c_slave_basic_use.c | C:\Users\Roselaptop\Docur

```
struct i2c_slave_module i2c_slave_instance;
//! [dev_inst]

//! [initialize_i2c]
static void configure_i2c_slave(void)
{
    /* Initialize config structure and software module. */
    //! [init_conf]
    struct i2c_slave_config config_i2c_slave;
    i2c_slave_get_config_defaults(&config_i2c_slave);
    //! [init_conf]
    /* Change address and address_mode. */
    //! [conf_changes]
    config_i2c_slave.address = SLAVE_ADDRESS;
    config_i2c_slave.pin_number_pad0 = PIN_LP_GPIO_14;
    config_i2c_slave.pin_number_pad1 = PIN_LP_GPIO_15;
    config_i2c_slave.pinmux_sel_pad0 = MUX_LP_GPIO_14_MUX4_I2C1_SDA;
    config_i2c_slave.pinmux_sel_pad1 = MUX_LP_GPIO_15_MUX4_I2C1_SCL;
    //! [conf_changes]
    /* Initialize and enable device with config, and enable i2c. */
    //! [init_module]
    while(i2c_slave_init(&i2c_slave_instance, I2C1, &config_i2c_slave)
            != STATUS_OK);
    //! [init_module]
    //! [enable_module]
    i2c_enable(i2c_slave_instance.hw);
    //! [enable_module]
    //! [enable_interupt]
    i2c_slave_rx_interrupt(i2c_slave_instance.hw, true);
    i2c_slave_tx_interrupt(i2c_slave_instance.hw, true);
    //! [enable_interupt]
```

70 %

qs_adc_basic.c | asf.h | conf_board.h | Solution Explorer

qs_adc_basic.c | C:\Users\Roselaptop\Documents\Atmel S

```
//! [setup_enable]
}
//! [setup]

int main(void)
{
    system_clock_config(CLOCK_RESOURCE_XO_26_MHZ, CLOCK_FREQ_26_MHZ);

//! [setup_init]
    configure_adc();
//! [setup_init]

//! [main]

//! [get_res]
    uint16_t result;

    do {
        /* Wait for conversion to be done and read out result */
    } while (adc_read(CONF_ADC_INPUT_CH, &result) == STATUS_BUSY);
//! [get_res]

//! [inf_loop]
    while (1) {
        /* Infinite loop */
    }
//! [inf_loop]
//! [main]
}
```

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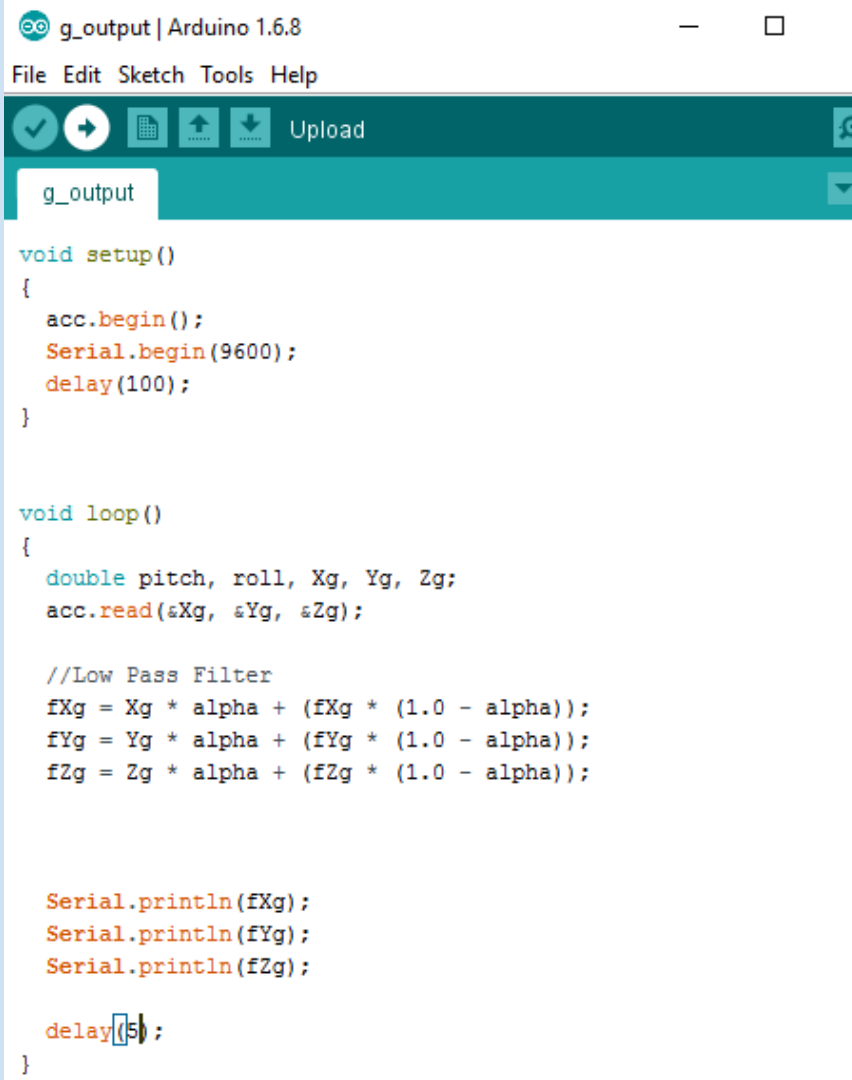
Subsystem Software Modules

- Writing software for the Samb11 has proven to be a very difficult task and will require significantly more time.
- Necessary software modules include
  - ADXL345 accelerometer data (SPI) processing code
    - Three axis data to determine orientation
  - Bitalino EDA sensor data (analog) processing code, using ADC of the Samb11
    - Noise reduction
    - Removal of artifacts

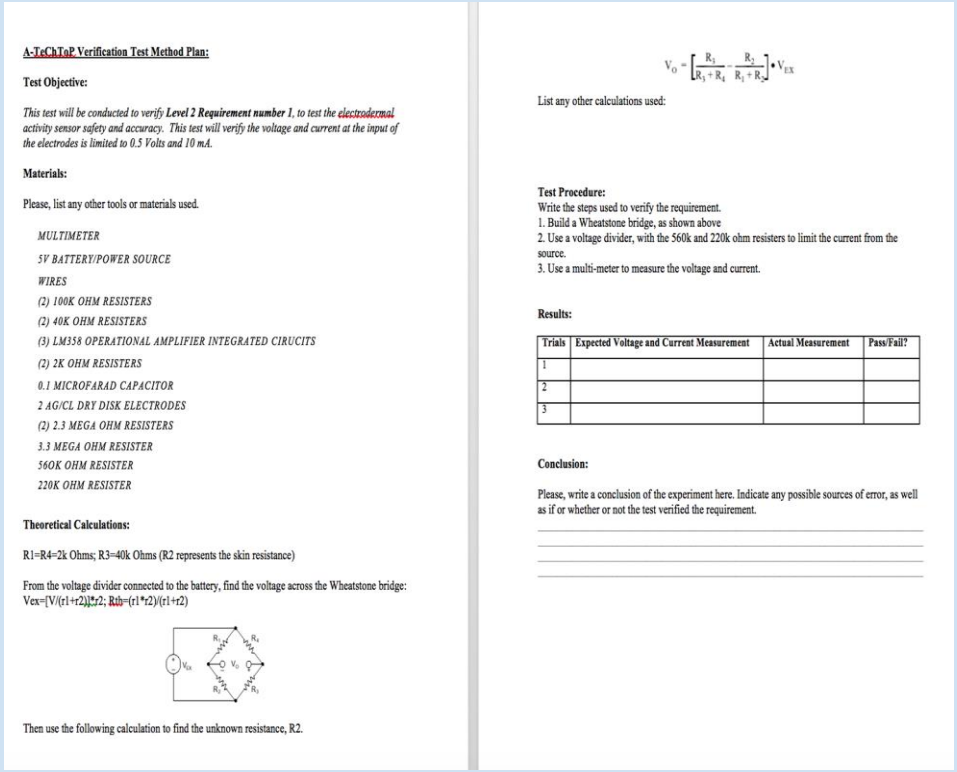


Strategy for Verification and Validation

Verification of electronics requirements such as number 3, 4, 5, 11, and 12 require a careful inspection of the data sheet prior to purchase. In most cases, this will also include breadboard testing, to ensure that these specifications are met.

Verification of signal processing requirements such as number 7 and 8 will be verified by analyzing the frequency distribution, to ensure that noise has been eliminated and the frequencies lie within the required bandwidth. Requirement number 6 will be verified by analyzing the precision of the output data points in the terminal window.

Manufacturing requirements such as dimensions and weight will require hand measurement of the final product parts.



A-TeChToP Verification Test Method Plan:

Test Objective:

This test will be conducted to verify ***Level 2 Requirement number 1****, to test the electrodermal activity sensor safety and accuracy. This test will verify the voltage and current at the input of the electrodes is limited to 0.5 Volts and 10 mA.*

Materials:

Please, list any other tools or materials used.

MULTIMETER
5V BATTERY/POWER SOURCE
WIRES
(2) 100K OHM RESISTERS
(2) 40K OHM RESISTERS
(3) LM358 OPERATIONAL AMPLIFIER INTEGRATED CIRUCITS
(2) 2K OHM RESISTERS
0.1 MICROFARAD CAPACITOR
2 AG/CL DRY DISK ELECTRODES
(2) 2.3 MEGA OHM RESISTERS
3.3 MEGA OHM RESISTER
560K OHM RESISTER
220K OHM RESISTER

Theoretical Calculations:

R1=R4=2k Ohms; R3=40k Ohms (R2 represents the skin resistance)

From the voltage divider connected to the battery, find the voltage across the Wheatstone bridge: Vex=[V/(r1+r2)]*r2; Rth=(r1*r2)/(r1+r2)

Then use the following calculation to find the unknown resistance, R2.

$$V_O = \left[\frac{R_3}{R_3+R_4} - \frac{R_2}{R_1+R_2}\right] \bullet V_{EX}$$

List any other calculations used:

Test Procedure:
Write the steps used to verify the requirement.
1. Build a Wheatstone bridge, as shown above
2. Use a voltage divider, with the 560k and 220k ohm resisters to limit the current from the source.
3. Use a multi-meter to measure the voltage and current.

Results:

Trials	Expected Voltage and Current Measurement	Actual Measurement	Pass/Fail?
1			
2			
3			

Conclusion:

Please, write a conclusion of the experiment here. Indicate any possible sources of error, as well as if or whether or not the test verified the requirement.

Example Test Plan (requirement number 1)

Verification and Validation Matrices

Requirement Number	"Shall" Statement	Verification Success Criteria	Verification Method (inspection, test, analysis, or demonstration):	Results	Pass/Fail
1	The sensor shall measure the exosomatic EDA (skin conductance) by injecting a constant current of less than 8 uA/Cm^2 into the two electrodes and measuring the potential difference between the two.	Measured current through the resister in series with the electrode is within +/- 10% of 8uA.	Test		
2	Two silver coated dry disc electrodes (Ag/AgCl) with a contact area of about 1.0 cm^2, shall be used for measurement.	The radii of the electrodes will be measured by hand and/or the data sheet will be checked to be within within +/- 20% of 1.0 cm^2 (before and after purchase).	Test		
3	The Atmel BTLC1000-MR110CA shall be used for the microprocessor.	The data sheet will be inspected before purchase to have name "Atmel BTLC1000-MR110CA", and other electronics will be chosen to be compatible with the MCU.	Inspection		
4	The microprocessor shall be connected to a 32.768 kHz real time clock, which is able to drive a 6pF load at a desired frequency, and has a maximum signal of 1.2 volts.	The data sheet for the clock will be inspected by the electronics engineer before purchase, to confirm indicated values, and clock will be breadboard tested for proper functionality.	Inspection/Test		

Verification and Validation Matrices (continued)

5	A 3-axis accelerometer with a sampling frequency of 32 Hz, 8-bit resolution, and a range of +/-2g shall be implemented to measure acceleration.	The data sheet for the clock will be inspected before purchase, and the device will be implemented with the indicated measures.	Inspection		
6	The analog signal shall be sampled with a resolution of 11 or 12 bits.	Precision of output data points will be analyzed, by viewing values in the terminal window.	Analysis		
7	The EDA sensor value shall be sampled at a rate of 4 Hz.	Computational methods will be used to analyze the bandwidth on the frequency spectrum, to be 2 Hz (fs/2).	Analysis		
8	EDA signal samples shall be band pass filtered between 0.5 and 2.5 Hz.	Computational methods will be used to analyze the bandwidth on the frequency spectrum to be between 0.5 and 2.5 Hz.	Analysis		
9	A machine algorithm shall be designed to detect the rhythmic patterns of a seizure and combine it with the data from the EDA sensor, and automatically send an alert if both indicate a seizure.	The algorithm will be tested on ambulatory skin conductance data, for accurate alert times (during the onset of a seizure).	Test		

Verification and Validation Matrices (continued)

10	The algorithm to detect seizures shall first pre-process intervals of samples for reduction, and then extract significant types of features from the ACM and EDA signals.	The computational processing time will be timed for a maximum delay of 3 seconds.	Test		
11	Bluetooth IEEE802.15.4 (ZigBee) version 4.0-4.1 physical layer protocol shall be used for communication with the Arduino and the Arxterra control panel.	The data sheet of the Bluetooth device will indicate BLE version 4.0-4.1.	Inspection		
12	The wristband shall contain a rechargeable lithium coin cell battery, embedded within the device.	The data sheet will specify the battery to be of type lithium, and the radius of the battery will be less than 3mm.	Inspection		
13	The battery shall have enough capacity to support the maximum current drawn from the microcontroller/Bluetooth LE module, and sensor circuit, for at least a few hours, without being recharged to allow enough time for the child to play.	The measured time of powered device will be at least 3 hours.	Test		

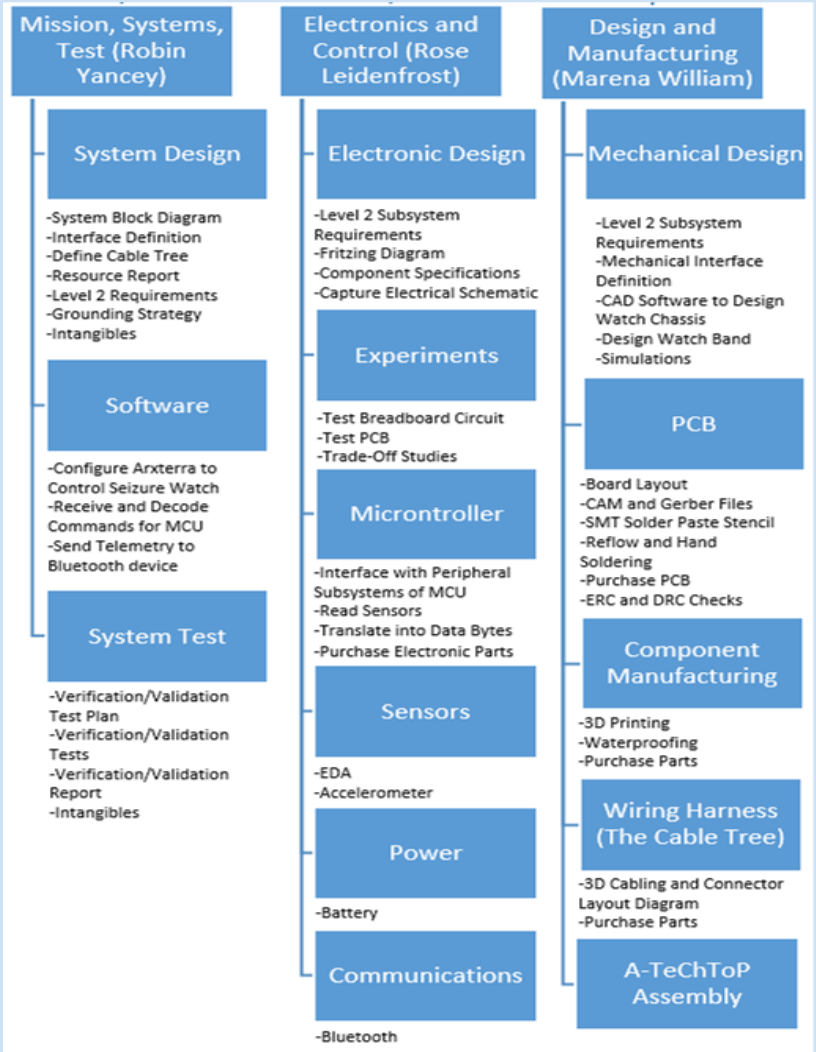
Verification and Validation Matrices (continued)

14	For ergonomic purposes, the electrodermal activity sensor electrodes shall be placed on the ventral side of the distal forearm, of the non-dominant hand, so that the signal is far less susceptible to motion artifacts.	The manufacturing engineer will ensure the design of the watch allows for the indicated placement.	Demonstration		
15	All electronics and wiring shall be concealed and secured within a protective, durable casing, which will not break if the child falls or hits his/her arm on the device.	The device will stay fully intact and secure on the wrist during a child's typical "play-time" activities.	Test		
16	The face of the device shall not exceed 72g and 54 x 61 x 15 mm (the mass and dimensions of a typical fitness watch) in order for it to be inconspicuous and non-stigmatizing to wear on a daily basis, while not interfering with play activities.	The face of the watch will be hand-measured to be within +/- 10% of 72g and 54 x 61 x 15 mm.	Test		
17	The circumference of the wristband shall be adjustable for wrist sizes within +/- 30 mm from 161 mm.	The length of the wristband will be measured by hand to be within within +/- 30 mm from 161 mm.	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 Resource Report

Wristband Mass Report

Resource	Expected Weight (g)	Measured Weight (g)	Uncertainty (%)	Margin (±g)	
Battery, Holder	5.10		5%	0.26	
Accelerometer (ADXL345)	1.27		10%	0.13	
MCU+Blutetooth Module	1.00		20%	0.20	
Electrodes	2.52		5%	0.13	
RTC, RC, & ICs	1.00		10%	0.01	
3D Printing	40.00		50%	20.00	
PCB	3		30%	0.90	
Project Allocation					72
Total Margin					21.62
Total Expected Weight					53.89
Contingency					39.73

Power Resource Report

Wristband Power Report

Resource	Expected Current Draw (mA)	Measured Current Draw (mA)	Uncertainty (%)	Margin (±mA)	
Accelerometer (ADXL345)	0.02		10%	0.00	
MCU+Blutetooth Module	4.50		10%	0.45	
Electrodes, Resisters, Skin	0.02		10%	0.00	
RTC	0.00		5%	0.00	
LTC6081 (x3)	0.99		3%	0.00	
Project Allocation					250
Total Margin					0.46
Total Expected Current					5.53
Contingency					244.93

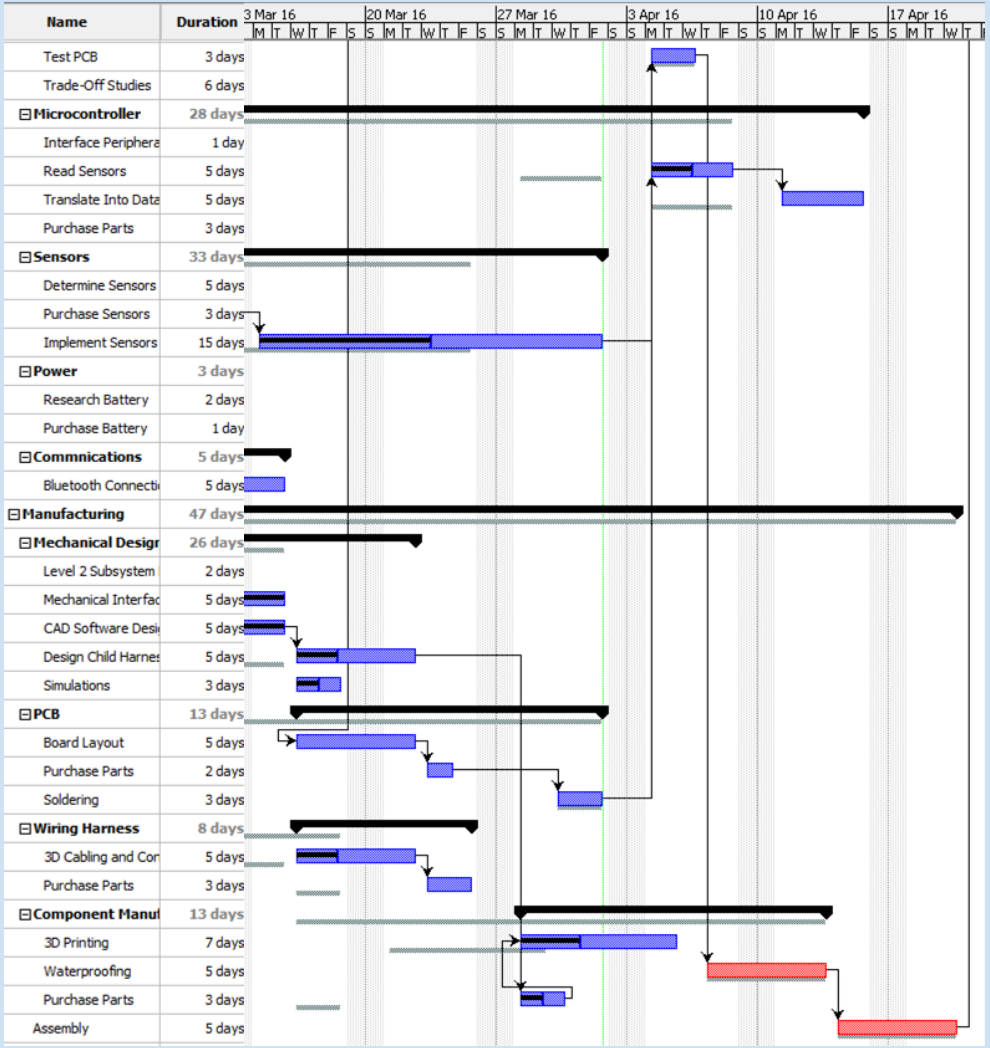
Budget Report

Wristband Cost Report

Resource	Expected ($)	Measured ($)	Uncertainty (%)	Margin (±$)	
Coin Cell Battery, Holder	6.90		5%	0.35	
Accelerometer (ADXL345)	17.50		5%	0.88	
MCU+Blutetooth	8.03		3%	0.24	
Reusable Electrode (x2)	47.95		0%	0.00	
32 kHz RTC	1.50		5%	0.08	
LTC6081 (x3)	12.66		0%	0.00	
Resisters, Capacitors	0		0%	0.00	
3D Printing	4.33		80%	3.46	
PCB	60		30%	18.00	
Project Allocation					350
Total Margin					23.01
Total Expected					158.87
Contingency					214.14

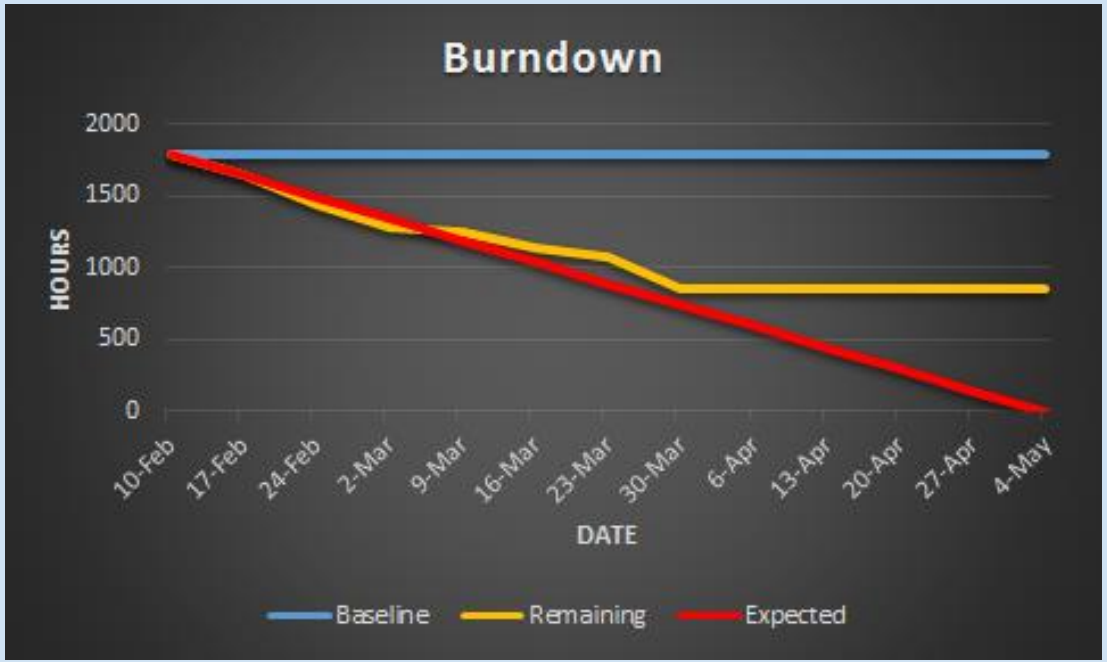
Updated Schedule

- Follows WBS
- Areas that slowed progress:
  - PCB
  - Coding of the SAMB11
  - EDA Sensor would not ship
- 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
- Currently working hard to catch up in some areas, but it seems as though tasks are being started but not finished
- 52.0% of project complete



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