A-TeChToP

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Seizure Watch
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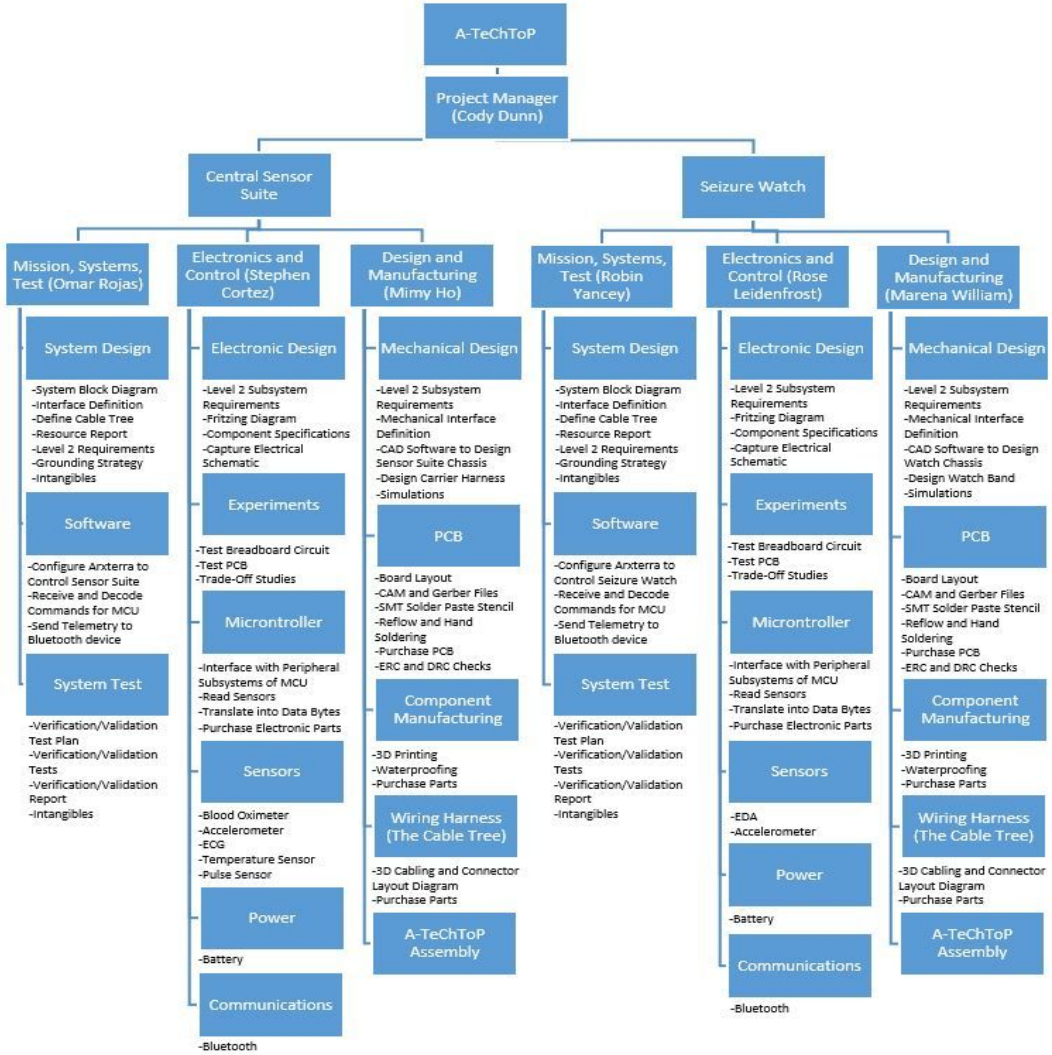
WBS

Two major branches for the subgroups (Central Sensor Suite and Seizure Watch)

The subgroups are quite similar in their system and subsystem level tasks



Program Objective

- Design and implement a wearable sensor suite (A-TeChToP) that allows for the safe and wireless real-time health monitoring of a child between the ages of 5 and 13
- Notify guardians and nearby onlookers when the child's bio-signals have passed below or above certain thresholds.

The device will help monitor children with histories of

-Asthma Exacerbation -Frequent Fainting -Osteogenesis Imperfecta

-Juvenile Idiopathic Arthritis -Arrhythmias -Frequent Fevers

-Seizures.

Mission Profile

- Used by strapping children with the chest and wrist sensor portions of the device which will then interface with a phone also on the child’s body
- Data from the sensors will be sent to a monitored PC or smartphone
- Demonstrated by attaching the device to a subject between the ages of 5 and 13
- The child will exercise and play on an outdoor playground for one hour as the team monitors his/her bio-signals
- A sensor will be removed to demonstrate the alarm system.

Program/Project Level 1 Requirements

1. The wearable body network must be completed by May 4, 2016, the last day of instruction for E400D in the CSULB Spring 2016 Semester [1].
2. The cost must be limited to $700 [1].
3. The complete body network shall meet ASTM F 963-11 safety requirements [2].
4. The body area network shall be functional for transferring biometric information for a child with the height of at least 1.77 meters (96th percentile height for a 13 year old) [1] [3].

Level 1 Requirements (Continued)

5. “From a full charge, energy allocation and source must provide at least 30.2 minutes of continuous monitoring and data transfer as according to the Center for Public Education’s polled average amount of time allocated to play in public schools” [1] [4].

6. Guardians and doctors shall have the ability to monitor a child’s biological signals wirelessly in real-time using the Arxterra control panel [1].

7. The device shall not hinder the child from completing the California FITNESSGRAM [5].

Level 1 Requirements (Continued)

8. The body network shall measure blood oxygen levels with the stability and accuracy to flag for asthma exacerbation [6].

9. The sensor suite shall measure the body temperature to determine when a fever has occurred [7].

10. Body orientation for the child must distinguish when the child has fallen due to illness from when he/she is upright [8].

Level 1 Requirements (Continued)

11. The device shall accurately measure electrodermal activity such that the detection of grand mal seizures will match that of a traditional electroencephalogram [9].

12. The device shall measure the QRS complex, P wave, and T wave of heart signals with high enough resolution to detect arrhythmias such as supraventricular tachycardia and premature atrial contraction [10] [11].

13. An alarm shall alert the parent and people nearby when one of the child's biological signals has dropped into a dangerous range [12].

Central Sensor Suite

Second Level Requirements

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. [1]
2. Android phone and Bluetooth device will not exceed SAR regulation of 1.6W/kg as stated by the FCC [2]
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). [3]

   Source: http://wonderopolis.org/wonder/how-many-times-does-your-heart-beat-in-a-lifetime/
4. The sensors, sensor suite, and android phone shall withstand forces (such as a child falling) of at least 20 Newtons. [4]

Second Level Requirements cont….

1. 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. [5]
2. An alert must be sent to the parent whenever vital sign measurements read as “unsafe” (as defined by settings in the Arxterra app).
3. Physiological signals must be clearly presented and updated in real-time on the Arxterra control center.
4. A temperature sensor shall be used to keep track of the child’s body temperature
5. Blood oxygen levels of the child shall be measured through a blood oximeter
6. An accelerometer shall be used to monitor body orientation of the child
7. A pulse sensor shall be used to monitor the pulse rate of the child
8. The heart activity of the child shall be measured through an electrocardiogram
9. Purchases cannot be made for sensors which need to be manufactured before shipping in order to meet deadline requirements.

Second Level Requirements cont….

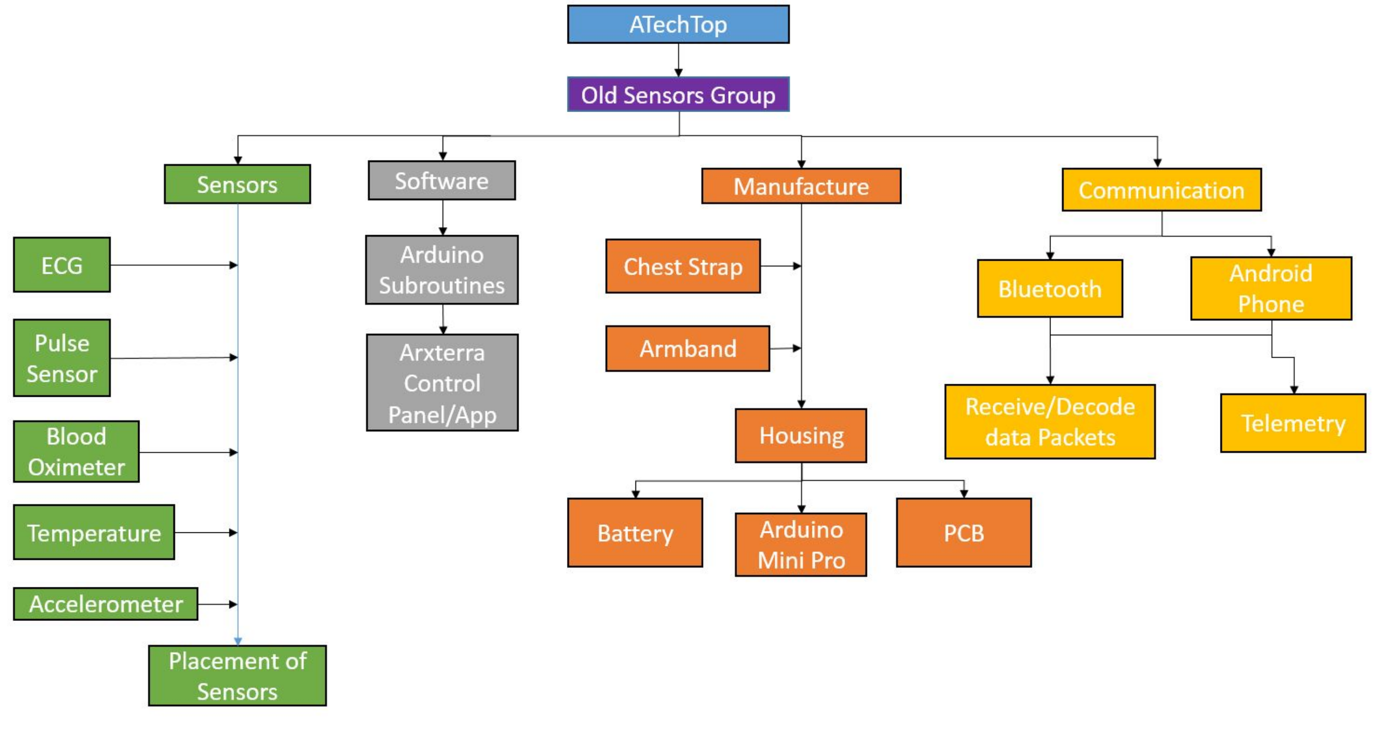
1. In order for project to stay within budget and meet deadline requirements, no purchase may be made for items outside of the United States.
2. To avoid harming the child, device will not reach a temperature greater than 113°F. [6]
3. The wearable device will avoid using materials that can lead to skin irritants caused by an allergic reaction [7]

Design Innovation

- Different Point of View: How would nature do it?
  - Wait for the child to fall and a passerby would hopefully notice
    - Can add an alarming system from the phone that draws attention to the child
    - Can measure whether the child is stationary and the child's orientation
- Attribute Listing
  - Material (Comfort)
    - Neoprene
  - Position
    - Chest, Arm
- Forced Relationship
  - Components will be held in a small "vault" for safety and decreased wiring

http://www.desiquintans.com/articles/noungenerator.php

Systems/Subsystem Design: PBS



Subsystem Design: Trade-Off Studies (Accelerometer)

ADXL335 [1]:

- Analog
- ±3g accuracy range (only)
- 3 DoF (3-Axis X, Y, Z)
- 16mm x 18mm x 3mm (roughly, slightly smaller actual)
- 1.8V to 3.6V range only, no power regulator

MMA8452Q [2]:

- Digital
- ±2g, ±4g, ±8g accuracy ranges (Programmable)
- 3 DoF (3-Axis X, Y, Z)
- 12-bit resolution (programmable to 8-bit)
- 16mm x 17mm x 3mm (roughly, slightly smaller actual)
- 1.95V to 3.6V range only, no power regulator

Final Decision: GY-521 MPU6050 [5]

ADXL345 [3]:

- Digital
- ±2g, ±4g, ±8g, ±16g accuracy ranges (Programmable)
- 3 DoF (3-Axis X, Y, Z)
- 13-bit resolution (programmable to 10-bit as well)
- 16mm x 20mm x 3mm (roughly, slightly smaller actual)
- 2V to 3.6V range only, no power regulator
- GitHub contains available libraries

GY-521 (MPU6050 Series) [4]:

- Digital
- Accelerometer and Gyroscope combination board (improved orientation accuracy)
- ±2g, ±4g, ±8g, ±16g accuracy ranges (Programmable)
- 6 DoF (3-Axis X, Y, Z)
- 16-bit resolution (programable)
- 16mm x 17mm x 3mm (roughly, slightly smaller actual)
- 2.3v to 6V range (possible damage to device around 6V however)

Subsystem Design: Trade-Off Studies (Temperature)

LM34 [6]:

- ±1˚F accuracy
- 5V to 30V operation range
- -45˚C to 150˚C
- Not moisture resistant
- About 5mm x 4mm (transistor size)

DS18B20 [7]:

- ±1˚F
- 3V to 5.5V operation range
- -55˚C to 125˚C
- Moisture resistant
- About 5mm x 4mm (transistor size)
- Utilizes only one wire to communicate
- 9 to 12-bit programmable resolution

TMP36 [8]:

- ±2˚F
- 2.7V to 5V operation range
- -40˚C to 125˚C
- Not moisture resistant
- About 5mm x 4mm (transistor size)

Final Decision: DS18B20

Subsystem Design: Trade-Off Studies (Pulse Sensor)

Pulse Sensor Amped (SEN-11574) [9]:

- Small, potentially concealable
- Can be applied to multiple surfaces (ear lobe and finger) with 24” cable
- 3V or 5V (from Arduino) operation voltages
- Comes with a clipper for attachments
- Arduino IDE compatible and libraries available for use

AD8232 Single Lead Heart Rate Monitor [10]:

- About 90mm x 75mm, which is not an ideal size for subtlety
- Placement would be located in center, main unit with wires expanding out
- 3.3V operating voltage (only)
- Capable of monitoring both ECG and heart pulse
- Arduino IDE compatible with existing libraries

Final Decision:

Considering that there was a limited pool of pulse sensors available to purchase on their own, the Pulse Sensor Amped was chosen for this sensor. This decision was made considering the versatility of this sensor due to its small electrode surface area. Also, since the ear lobe and finger are not ideal locations for this sensor, it has been considered to measure the pulse of the wearer by attaching the electrode directly to their chest, just outside of the main unit of the device. This positioning is presumed to emit a strong enough electrical pulse for the sensor to simply detect a signal and relay it to the Bluetooth device. This method will optimize device size and concealment while still performing the necessary functions.

Subsystem Design: Trade-Off Studies (Blood Oximeter)

TSL235R Light-to-Frequency Sensor [11]:

- 2.7V and above voltage operation range (includes desired 5V)
- 4mm x 4mm large, within expected size range
- $2.95 from SparkFun

Final Decision:

The decision for this sensor is straight forward considering that there are no reasonable commercially available pulse oximeters for the group to purchase. Therefore, a custom made pulse oximeter is required to be made using the TSL235R Light-to-Frequency Sensor. This particular sensor is available at a very reasonable price and has existing tutorials for how to construct the actual oximeter sensor. This will save the project group valuable time and funding as well as create room for customization.

Subsystem Design: Trade-Off Studies (ECG)

The selection process for this sensor did not require any comparisons between devices since the ECG of the child wearing the sensor suite will be obtained by a custom made filtering circuit receiving signals from specially positioned electrodes. These electrodes, in order to reduce visibility, will be placed on the torso of the child in a configuration that will promote comfort and accuracy. Position testing is necessary in order to reduce the external noise from the surrounding muscles and only measure the desired ECG signal. However, the customized filtering circuit will be designed with both a high pass filter and a low pass filter in order to remove large electromyography signals and small internal noise respectively.

Final Decision:

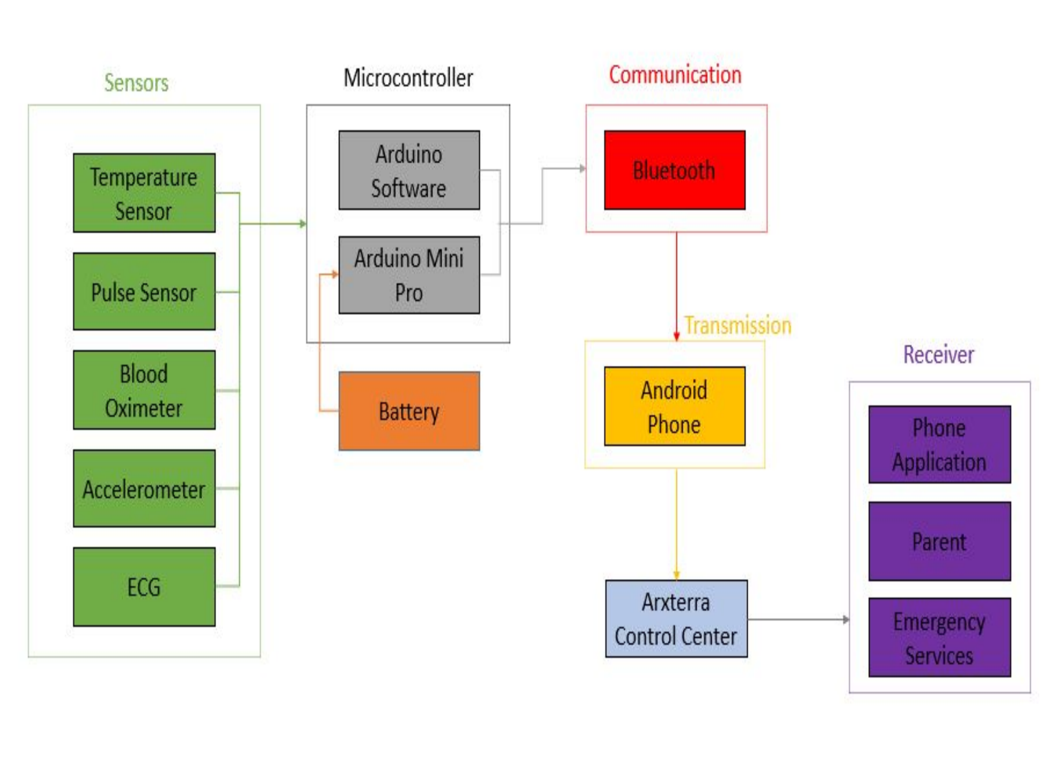
The ECG circuit design that will be used for the A-TeChToP Sensor Suite can be found at the following link [12]:

This design will be used as a reference for the group's final implementation of the ECG sensor. Once ideal electrode positions that can be used for the standard of the device are found, the capacitor and resistor values necessary for the particular filters will be chosen. The overall cost of this sensor along with its circuit does not seem like it should exceed $25.00.

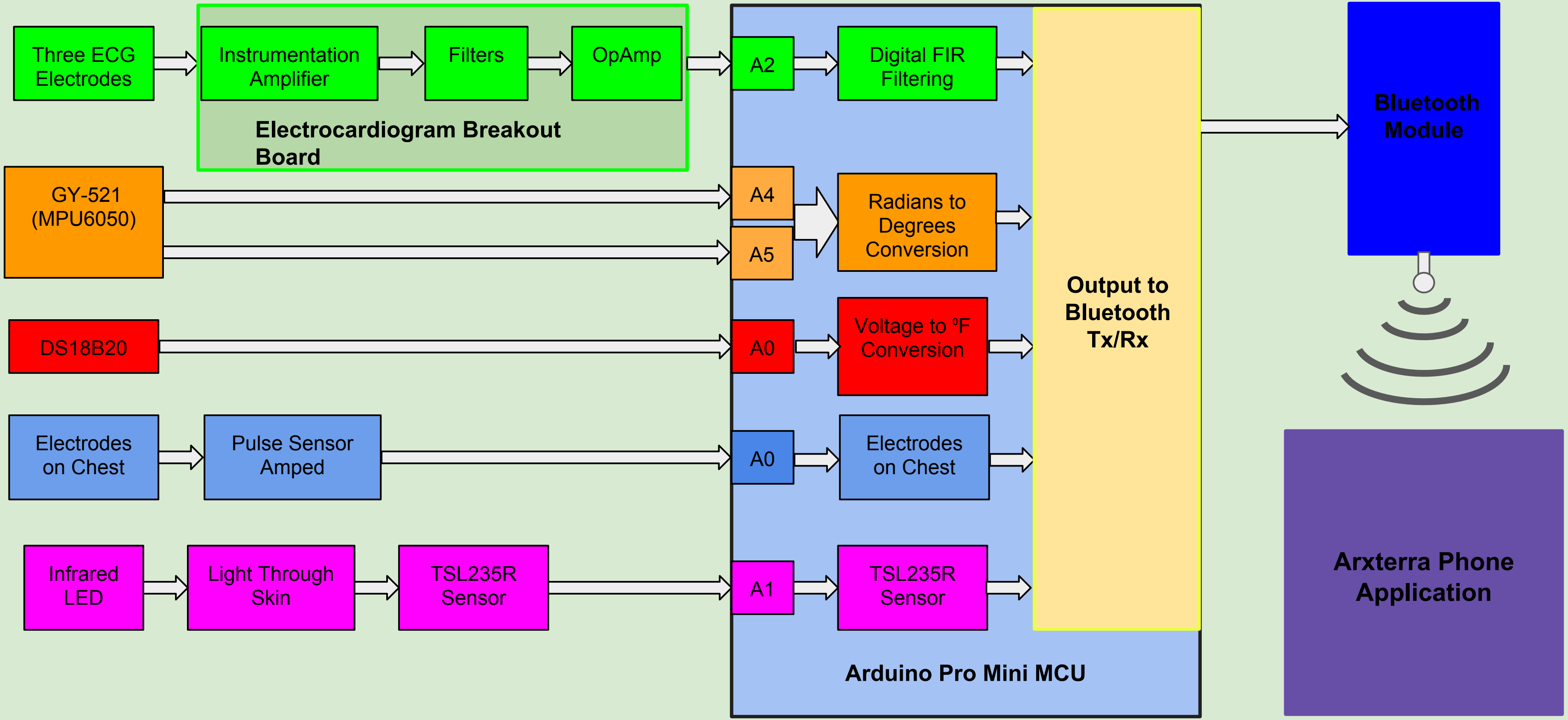
Systems/Subsystem Design: Electronic System Design (Interface definition)

Arduino Mini Pro	Accelerometer	Temepratrure 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							

Systems/Subsystem Design: Electronic System Design (sys block diagram)



Systems/Subsystem Design: Software Design



Systems/Subsystem Design: Mechanical Design

The central sensor suit design shall contain 2 different parts:

1. The armband for an android phone
2. The harness including a chest strap with 3D printed case placed horizontally in the front and a single shoulder strap

Design and Unique Task

Task: Harness design

- The strap will be used by soft neoprene fabric.
- Velcro will be placed on the right side of of the horizontal strap for adjustable purpose
- Wiring will be placed on the left side of the horizontal strap to connect from the Arduino Pro Mini and PCB to the sensor
- Sensor placements:

  <u>Figure 1</u>: the ECG electrodes is placed on the underside of the upper arm of a child

  <u>Figure 2</u>:
  - the temperature sensor is placed on a chest area
  - the accelerometer and gyroscope is placed in front of a chest
  - the pulse sensor is placed near the chest
  - the blood oximeter is placed on a earlobe

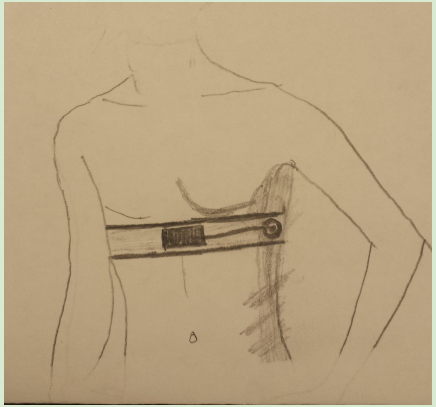


Figure 1

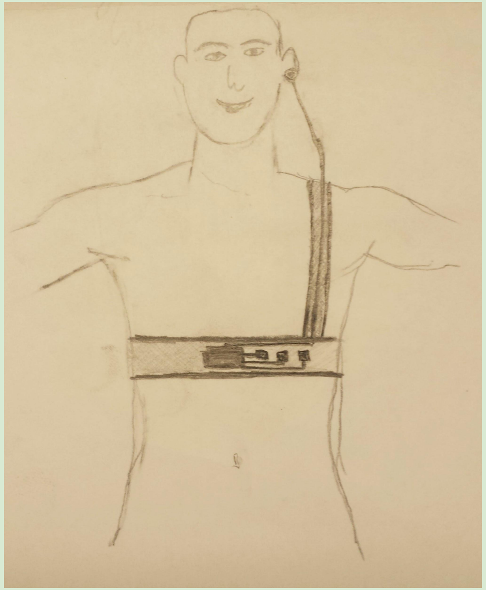


Figure 2

Design and Unique Task

Task: Design 3D printed case

Size: 101.6mm x 57.2mm x 38.1mm
(4in x 2.25in x 1.5in)

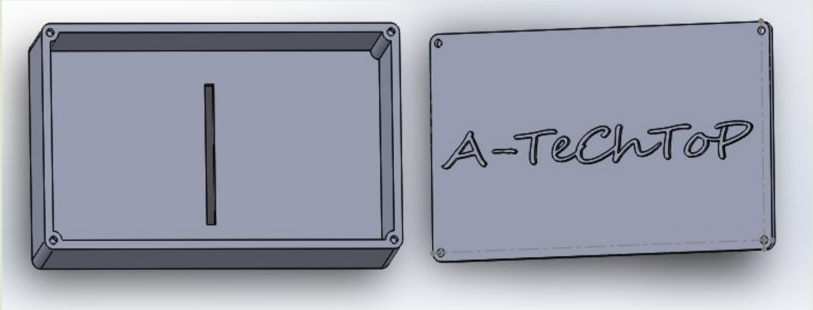
Components:

- Arduino Pro Mini: 33mm x 18mm
- Accelerometer (GY-521 MPU6050): 16mm x 17mm x 3mm
- Bluetooth (HC-06 Bluetooth Module): 27mm x 13mm x 10mm
- PCB: 80mm x 50mm
- Power Supply: 44.5 mm in length and 10.5 mm in diameter.

Material: PLA

Screws size: #2 x 1/2 in. Flat Head Phillips with 0.086in in diameter

* **Note:** Trying to reduce the thickness of the case to about 1 in



Project Status

- Finalizing designs of the chest strap and armband
- Order sensors and test/verify
- PCB design and manufacturing
- Working on displaying data from sensors onto the Arxterra App
- Working on subroutines that will deal with the alarm as well as interpret the data from the sensors
- Create tests to verify the device

Project Schedule: Sys/SubSys Level Tasks

Engineer	Task	Description	Due Date
Manufacturing	3D Render	Create a 3D render of the harness, armband, and casing	3D render due by March 2nd
	Harness	After renders, complete the construction	Harness construction due: March 16th
	Armband	After renders, complete the construction	Armband construction due: March 16th
	Casing	After renders, complete the construction	Casing construction due: March 16th
	PCB Layout	After PCB design is finalized, construct the PCB	PCB construction due by: April 4th
	Assembly	After construction has been completed for the harness, armband, PCB, and casing assemble everything	Total assembly due by: April 4th

Engineer	Task	Description	Due Date
Electronics	Sensors	-Purchase the sensor -test the sensor -implement the sensor	Purchase by: Feb 27th Implement Sensor: March 22nd
	ECG	- Gather the materials needed for the circuit - Test the circuit - Implement the sensor	Purchase by: Feb 27th Construct/Test ECG circuit: March 15th Implement Sensor: March 22nd
	PCB Design	Design the PCB to allow the incorporation of all the sensors. Verify after PCB construction	PCB design due by: March 12th Verified by: April 4th
	Battery	Select a battery	Decision of battery selection: March 2nd
	Software	Write subroutines to interpret/collect data from the sensors. Write subroutines for alarm	Subroutines due by: April 8th

Engineer	Task	Description	Due Date
System	Software	-Configure Arxterra control panel/ App -Code for Bluetooth telemetry -Code for receiving and decoding data packets	Configuration of Arxterra due by: March 15th Bluetooth telemetry due by: March 22nd Date packets subroutines due by: March 29th
	Testing	-Design test for ATechTop requirement verification and validation	Verification in three phases: 1st phase due by April 12 2nd phase due by April 27th 3rd phase due by May 4th
	Intangibles	-Verify there are no more intangibles in the product	Final verification due by: April 12th

Cost Report					
Resource	Expected Cost ($)	Measured Cost ($)	Uncertainty (%)	Margin ($)	
GY-521 MPU6050	6	N/A	10	2	
Arduino Pro Mini 328	10	N/A	10	3	
DS18B20	5	N/A	5	1	
Pulse Sensor Amped	25	N/A	5	5	
TSL235R	3	N/A	5	1	
ECG circuit	20	N/A	10	5	
HM-10 Bluetooth	5	N/A	10	2	
Wiring	10	N/A	5	3	
PCB	25	N/A	10	5	
Chest Strap	20	N/A	10	5	
3D printed case	0	N/A	5	0	
Armband	10	N/A	10	3	
Battery	20	N/A	10	5	
Project Allocation ($)					700
Total Margin ($)					40
Total Expected Cost ($)					159
Contingency ($)					581

Mass Report					
Resource	Expected Weight (g)	Measured Weight (g)	Uncertainty (%)	Margin (g)	
GY-521 MPU6050	5	N/A	5	1	
Arduino Pro Mini 328	2	N/A	5	1	
DS18B20	1	N/A	5	0.5	
Pulse Sensor Amped	4	N/A	5	1	
TSL235R	1	N/A	5	0.5	
ECG circuit	5	N/A	15	2	
HM-10 Bluetooth	1	N/A	10	0.5	
Wiring	5	N/A	5	2	
PCB	5	N/A	10	2	
Chest Strap	160	N/A	10	15	
3D printed case	10	N/A	10	3	
Armband	30	N/A	10	5	
Battery	102	N/A	5	20	
Project Allocation (g)					1800
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	N/A	3	1	
Arduino Pro Mini 328	150	N/A	5	50	
DS18B20	1.5	N/A	3	1	
Pulse Sensor Amped	4	N/A	5	3	
TSL235R	3	N/A	2	1	
ECG circuit	20	N/A	5	5	
HM-10 Bluetooth	20	N/A	5	5	
Project Allocation (mA)					1500
Total Margin (mA)					66
Total Expected Current (mA)					202.4
Contingency (mA)					1363.6

Seizure Watch

Requirements: System/Subsystem **ELECTRONICS**

1. **The sensor shall measure the exosomatic EDA (skin conductance) by injecting a constant current of less than 10 uA/Cm^2 into the two electrodes and measuring the potential difference between the two.**

   1.1. This is the recommended current limit for these types of devices because it minimizes the risk of damaging the sweat glands [9] [2].

   1.1.1. With the typical range of skin conductance of about 0.1uS to 15uS, the applied voltage should stay below 10uA·(1/15uS)=0.66V.

2. **Two silver coated dry disc electrodes (Ag/AgCl) with a contact area of about 1.0 cm^2, shall be used for measurement.**

   2.1. These electrodes are hypoallergenic, durable, replaceable, and easily snapped onto or off of the wristband [12].

   2.2. This is the size and type of electrodes which have been recommended by literature for EDA measurement [3].

   2.3. The signals produced with the use of electrically conductive fabrics and interconnects has been shown to be far less correlated with that of FDA approved devices [2].

   2.4. Measurements of EDA signals taken using Ag/AgCl electrodes are highly accurate and most widely used because they minimize the development of bias potentials and polarization [16] [15].

3. **The Atmel BTLC1000-MR110CA shall be used for the microprocessor.**

   3.1. The ATBTLC1000-MR110AC has 2 A/D pins which are required to receive and digitize analog inputs from the EDA sensor [27].

   3.2. The module is ultra low-power and comes with built in Bluetooth SMART (BLE 4.1), with and integrated transceiver, modem, MAC, PA, TR Switch and Power Management Unit [27].

   3.3. The device has dimensions of 12.7 x 20.152 x 2.0874 mm, which will leave enough room the other sensors, battery, and clock to be held on the face of the device PCB [27].

4. **The microprocessor shall be connected to a 32.768 real time clock, which is able to drive a 6pF load at a desired frequency, and has a maximum signal of 1.2 volts.**

   4.1. This allows the user to interpret data sample information transmitted via Bluetooth [6].

   4.2. In order to comply with BLE specifications the frequency of the clock must be within +/- 500ppm [27].

   4.3. the RTC signal must be able to drive the 6 pF internal capacitance of the positive clock input used for a potential oscillator.

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.**

   5.1. Measurement of the magnitude of body acceleration is necessary to detect and correct external interferences of the EDA signal [20] [12].

   4.2. The use of sampling frequencies over 20 Hz or amplitude measurement over +/-2g, has not been shown to give any significant increase in detection accuracy [21].

   4.3. Seizure related accelerations can occur in all three dimensions.

   4.4. A sampling frequency of 32 Hz is used by commercially sold devices (cited below), such as Empatica E3 [22].

   4.5. Use of an accelerometer is a low-cost and accurate method of measuring movement [23].

Requirements: System/Subsystem **SIGNAL PROCESSING**

1. **The analog signal shall be sampled with a resolution of 11 or 12 bits.**

   6.1. Within the small range of the conductance (about 0.1uS to 15uS), it should be able to detect amplitude changes at the nano-Siemen level, in order to distinguish between different activities.

   6.1.1. For example, using 11 bits we have conductance increments of 14.95uS/(2^11) =7nS.

   6.1.2. It would be inefficient to use a higher resolution 12 due to energy constraints.

2. **The EDA sensor value shall be sampled at a rate of 4 Hz.**

   7.1. The bandwidth of the signal is between about 1 and 2 Hz [14] [11] [13].

   a. Using Shannon's sampling theorem, the sampling frequency must be at least twice the highest frequency in the signal to avoid aliasing. The Nyquist rate is $2*f_{max}$=4 Hz.

   7.2. This sampling rate is used by most of the current commercially sold devices for EDA measurement (eg. Empatica, Moodimetric, ect.), as well as current research studies (see all works cited).

3. **EDA signal samples shall be band pass filtered between 0.5 and 2.5 Hz.**

   8.1. Given that the highest frequencies in the actual EDA signal are about 2 Hz, and frequencies, that do not fall within this range are due to motion artifacts and electrical noise [2] [4] [11].

4. **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.**

   9.1. Motion and temperature can easily influence a person's electrodermal and cardiovascular signals [1] [11].

   9.2. Almost all of the EDA devices sold commercially and developed for research purposes have required this to factor out many false alarms that would otherwise occur (see all works cited).

   9.2. Although EDA shows increased amplitude for both GTCS and CPS seizures, combined measurement of acceleration and EDA can greatly improve the performance of detection of seizures with motor activity and movement patterns, such as generalized tonic-clonic seizures (GTCS) [22] [23].

5. **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.**

   10.1. When monitoring throughout the day there is a lot of non-seizure data, pre-processing data will save computational time and workload, since most of the activity caused by the convulsions indicating a seizure occur above 2 Hz [23].

   10.2. When the net acceleration of movement of movement is below a certain threshold it can be disregarded as non-seizure movement [23].

   10.3. Multiple stages of feature extraction, and comparison with a threshold, will factor out most artifacts and insignificant data, which would cause false alarms [19] [23].

Requirements: System/Subsystem **COMMUNICATIONS**

1. **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.**

11.1. This will allow for more than 7 sensor nodes to be connected, at one time [5].

11.2. BLE uses less energy than Bluetooth, so that this device can run without recharge for as long as possible [17].

11.2.1. This is ideal and standard for wearable health care devices because it requires less than 1 mW to communicate to devices up to 30 meters away [5] [17].

11.2.1.1. Compared to classic Bluetooth, BLE uses 0.01-0.5 W and less than 15mA vs. the standard 1 W with less than 30mA [7].

11.2.1.2. The shorter distance range is acceptable for this application.

11.2.2. Compared to classic Bluetooth, BLE takes 3ms to send vs. the standard 100ms.

11.3. The MAC layer protocol implemented system will allow for devices to be moved into or out of the local network of sensors, without an interruption of the communication [5] [7].

11.4. ZigBee protocol was designed with built in security as a top priority, using a master network to keep a list of authenticated devices, who have joined through association, and only responding to those devices [8].

Requirements: System/Subsystem **POWER**

1. **The wristband shall contain a rechargeable lithium coin cell battery, embedded within the device.**

   12.1. This is important, so that the child does not have to continuously replace batteries, every time it runs out.

   12.2. If it is completely embedded, it will be better protected [10].

   12.3. Lithium batteries have a high enough operating voltage, optimal charge-discharge characteristic, are lighter, less rigid, and enclosed in a pouch [18].

   12.4. A coin cell battery has enough power to supply the very low voltage requirements of the components, which would allow the device to be both small and light, as required.

2. **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.**

   13.1. When the microprocessor/Bluetooth module is powered by a 3.6 V power source, the module consumes a maximum current of 4.0 mA, and the sensors only draw about 20uA [10].

      13.1.1 Back of the envelope calculation: Capacity = Amps·Hours(required), so Capacity= [20uA+4mA+(about 5uA accelerometer)]·(# hours desired by customer)

         13.1.1.1. Based on at least 5 research studies cited below, a 3.3-3.7 Volt battery with 1100mAh, will power the device for at least 9 hours (but probably much longer). The above calculation will be used to check the capacity requirement of the battery, once the sensors have been confirmed.

Requirements: System/Subsystem **MECHANICS**

1. **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.**

   14.1. Use of this location as a recording site has been shown in numerous studies to be highly correlated to the traditionally used palmar read recordings [2] [3] [4].

   14.2. Placement of the device on the the fingers would also impede the user's fine motor actions [4].

2. **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.**

   15.1. Since the child may be playing on a playground structure, it is likely that they will hit their hand on the equipment, fall, or have a seizure related fall, at some point [24].

3. **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.**

   16.1. These are the dimensions and mass of at least one typical fitness watch [26].

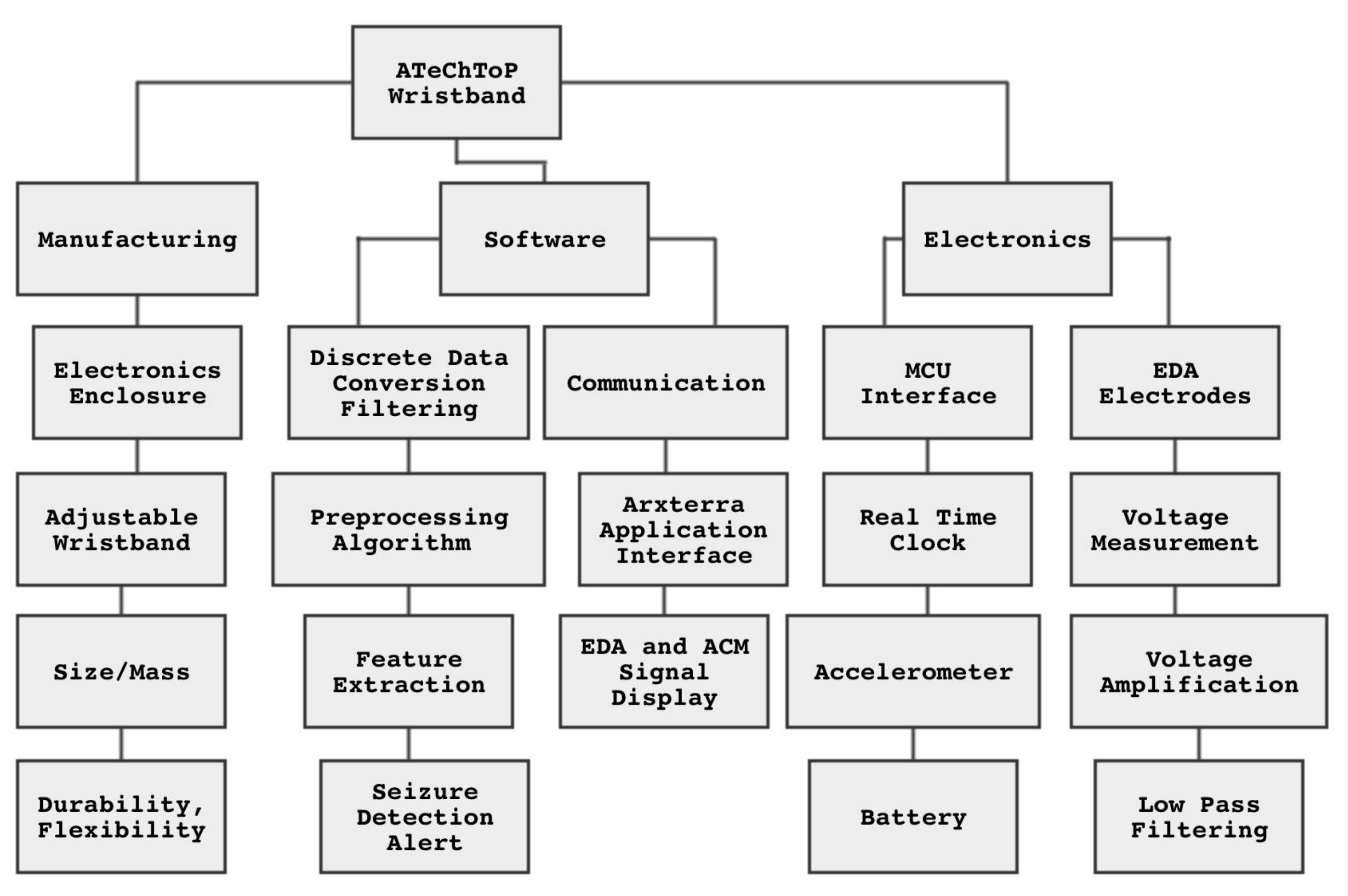
4. **The circumference of the wristband shall be adjustable for wrist sizes within +/- 30 mm from 161 mm.**

   17.1. The average circumference of the wrist of a 13-year-old boy is about 161 mm, while the average for an 8-year-old girl is 138 mm [25].

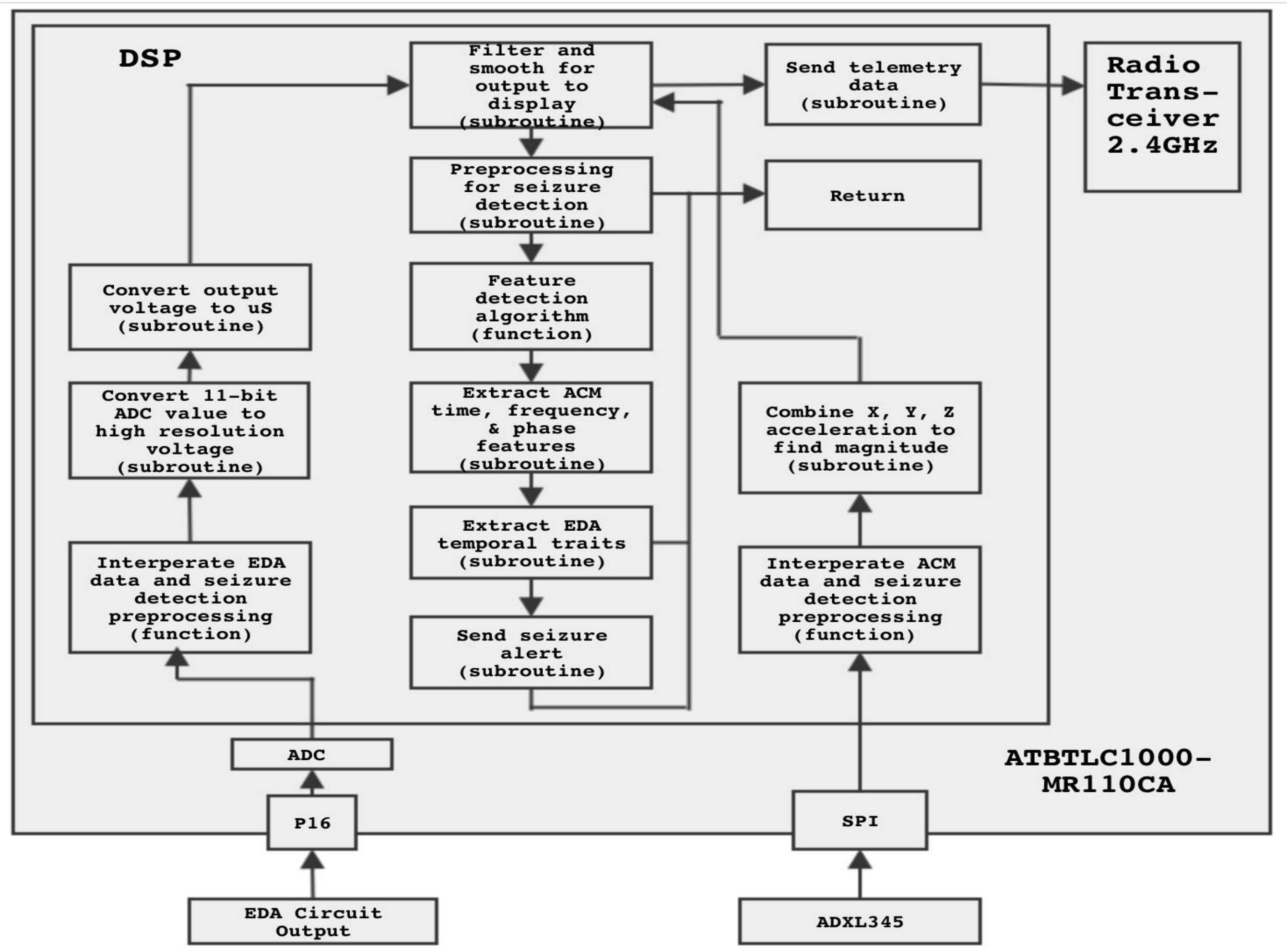
Design Innovation

- Using Duncker Mindset:
  - How can we not use EEG for seizures (target disease not solution)?:
    - Electrodermal activity (EDA) for skin conductivity
    - Accelerometer for rapid movements
- Brainstorming
  - How to decrease size?
    - Minimize microcontroller
    - Reduce the number of components
    - BTLC1000

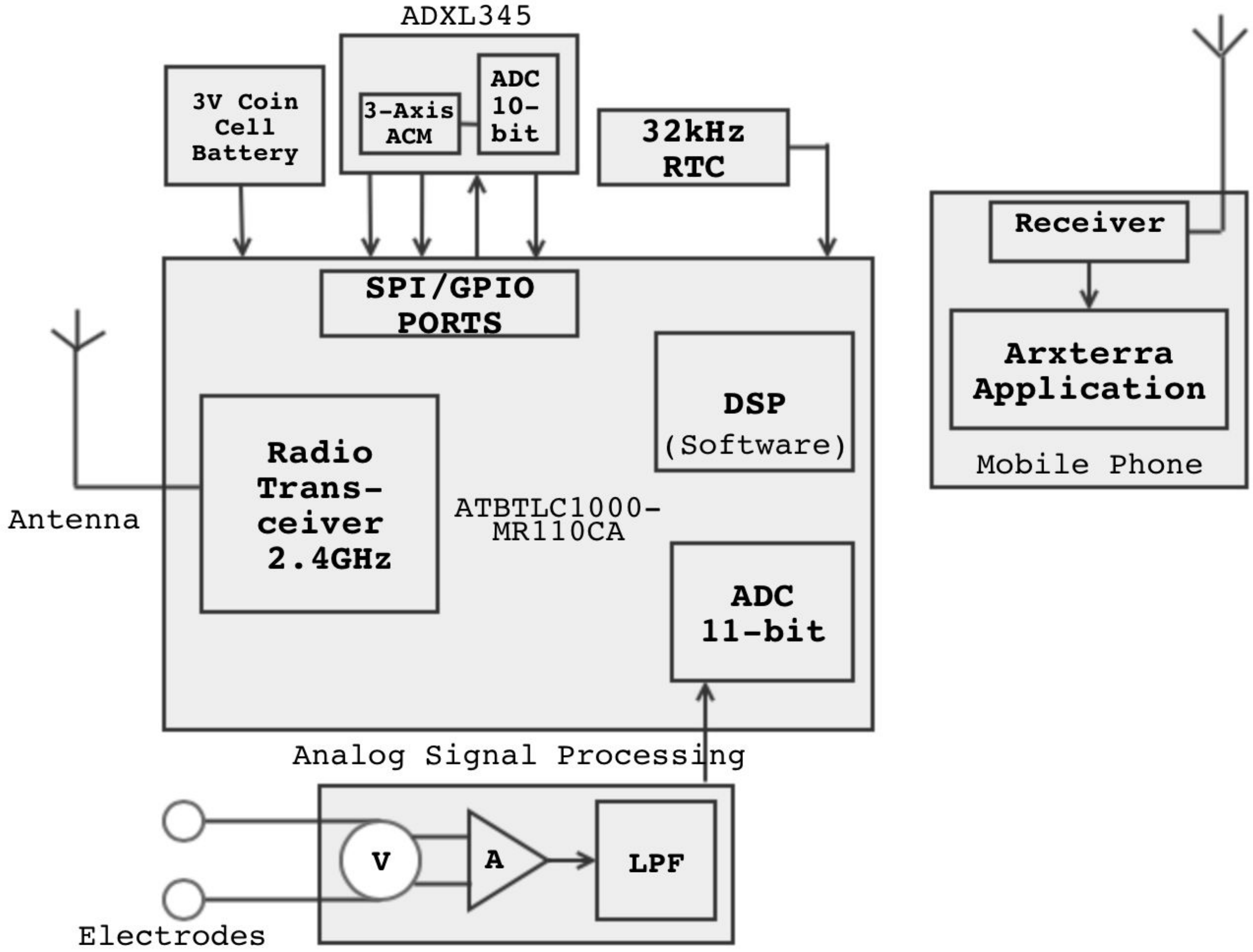
Systems/Subsystem Design: PBS



Systems/Subsystem Design: Software Design



Systems/Subsystem Design: Electronic System Design



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

Systems/Subsystem Design: Mechanical Design

- **Subsystem Requirements:**

1- The wristband while be designed to suit for a right-handed or left-handed child and it would be wore on the hand with less activities to allow clear non-noisy measurements and to permit the child to move freely.
2- The housing will be 3D printed from a material that provide protection for the electronics inside.
3- Initial draft of the wristwatch (see next slide).
4- To fit all sizes, the wristband strap will have an adjustable buckle.

- **PCB:**

The PCB will contain the EDA sensor, the accelerometer, clock and the Atmel ATBTLC1000 chip.

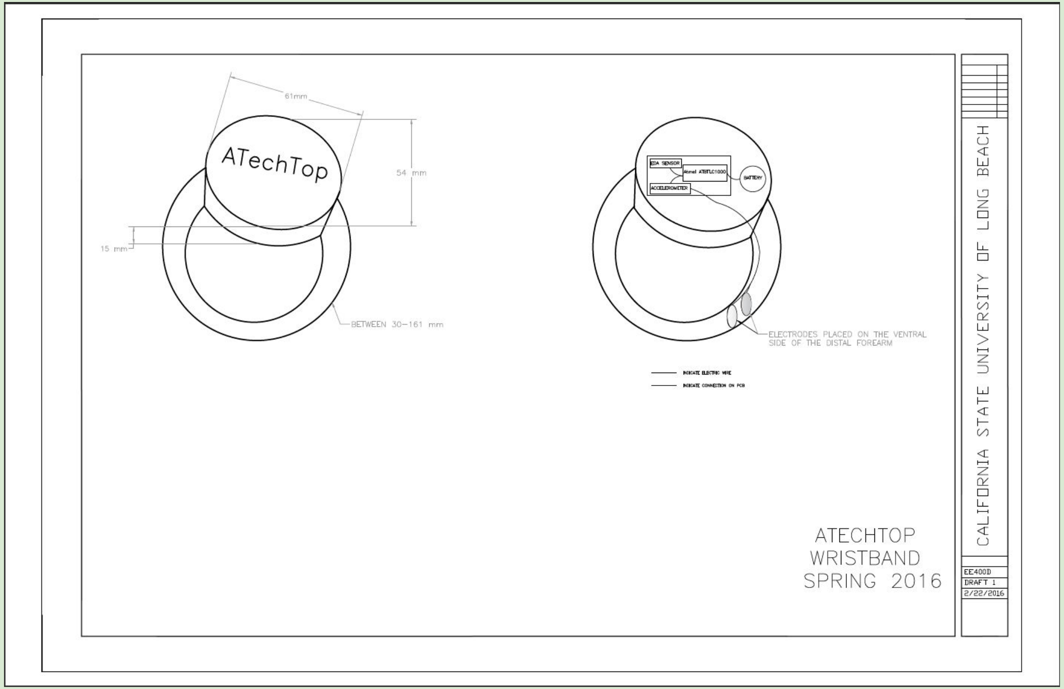
- **Component Manufacturing:**

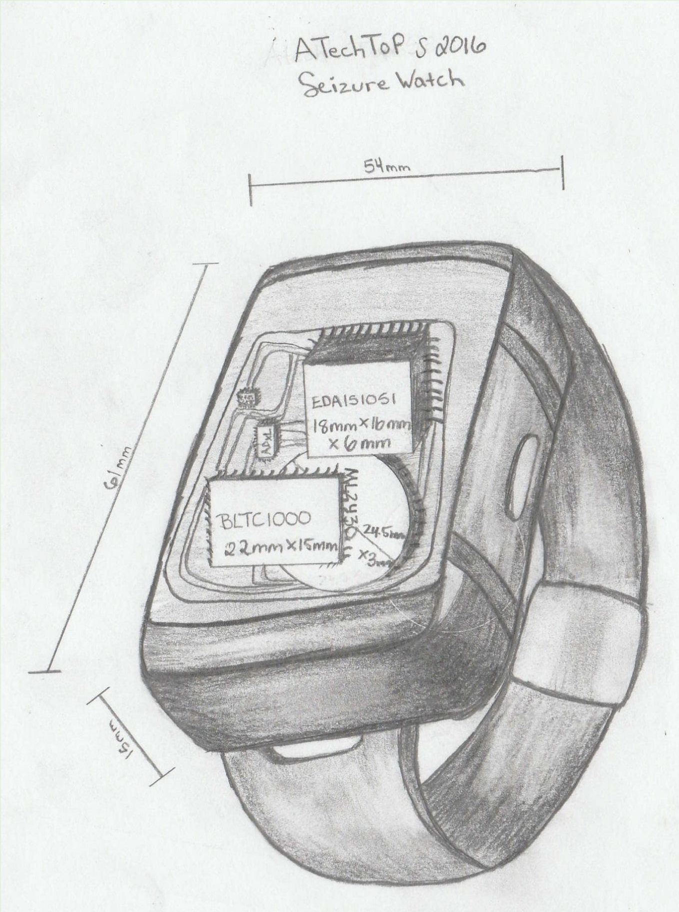
-3D Printing is to be done from PLA or ABS.
-The housing will be sprayed with silicon to add a water-resistive layer and the electrodes channels are to be sealed with silicon to prevent water/sweat getting to the PCB.

- **Wiring Harness (The cable tree):**

The housing include the PCB (EDA sensor, accelerometer, clock and Atmel ATBTLC1000 chip) and the battery. The electrodes are to be placed at the ventral side of the distal forearm (bottom of the wristband) and the wires are to be run on the inside side of the watch strip.

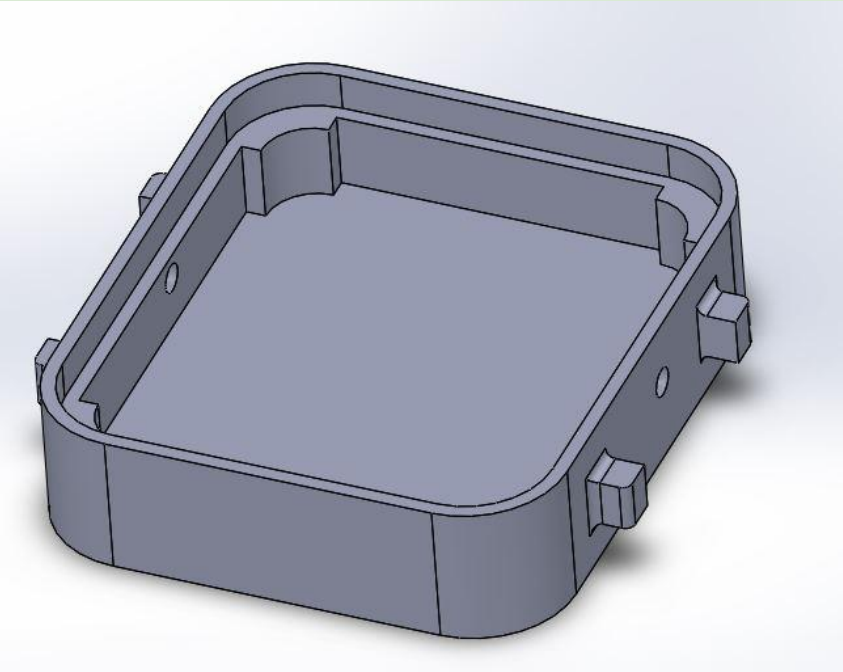
Initial Draft of the Wristwatch

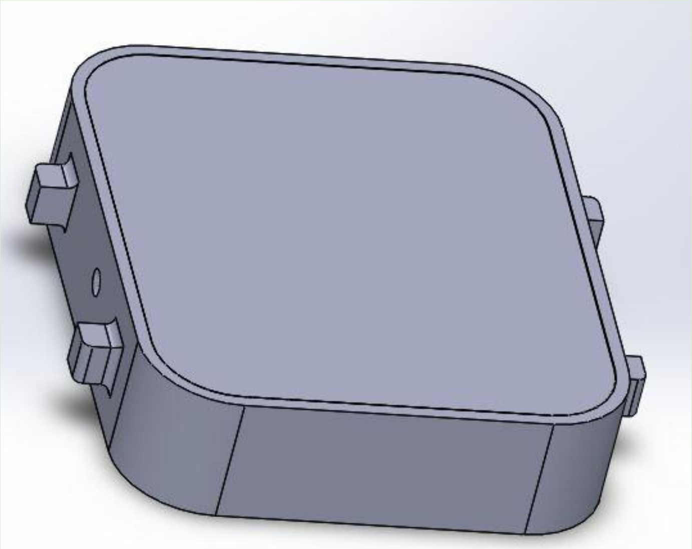


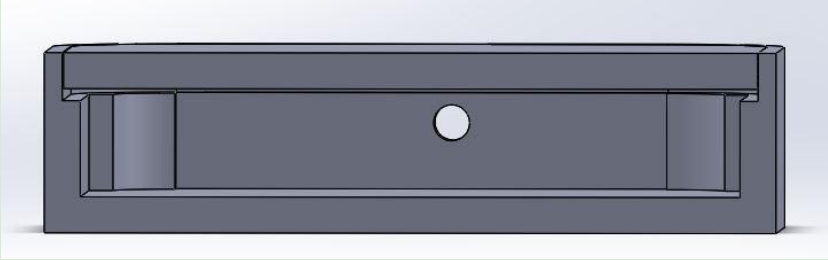


Sketch of preliminary mapping of the components within the watch

SolidWorks Design of the Wristwatch Housing



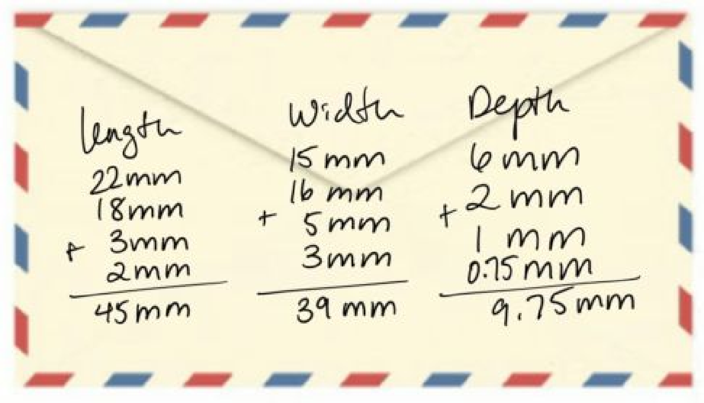




Design and Unique Task

Task: Construct a watch-like housing to encase seizure detection subsystem to be worn on the small child's wrist.
Design: Components (BTLC1000, EDA sensor, accelerometer, battery, MCU, clock) need to fit inside a watch casing with dimensions 54mm x 61mm x 15mm(Level 2 requirement).

BTLC1000	22mm x 15mm
ADXL345	3mm x 5mm x 1mm
EDA 151051	18mm x 16mm x 6mm
Bat. ML2430	24.5mm (dia) x 3mm
Clk. PCF85063TP	2mm x 3mm x .75mm



Include 1-2mm thickness for the PCB and 2-3mm for the casing. With proper placement the selected components will be integrated to satisfy the level 2 size requirement.

Rose Leidenfrost

Design and Unique Task

Task: Seizure watch must be able to process sensor data and transmit wireless signals through Bluetooth to the android phone.

Design: The BTLC1000 by Atmel is the MCU bluetooth module that will be integrated in the seizure watch in order to wirelessly transmit signal data. The BTLC1000 features industry standard Bluetooth low energy (BLE) technology and is the smallest commercially available chip of its kind[1]. Trade off study follows detailing the features of the BTLC1000 as applied to our seizure watch.

									External Requirement	
									RTC or Crystal	
Maunfacturer	Module	Cost	Ports [1]		Processor	I/O Supply Voltage (V)	Operating Temperature (°C)	Tranmission Current (mA)	Oscillation Frequency (kHz)	Vin (HIGH) (V)
Atmel Norway	BTLC1000-MR110CA	Free sample [2]	12 digital GPIO	2 Mixed signal GPIO	32-bit ARM Cortex-M0	-0.3 to 4.6	-40 to 85	3	32.768	0.7 to 1.2

[1] Each GPIO features a programmable 96kΩ pull up or pull down resistor
[2] Free sample of BTLC1000 obtained from Atmel and provided by Professor Gary Hill

The BTLC1000 has sufficient GPIO ports for the analog and digital input from the sensors. The lithium ion battery used in the SZ will provide enough voltage (as indicated by the supply voltage range) to the BTLC1000 as well as the other sensors and components. The bluetooth module does require an external RTC to be implemented with the listed specifications.

Rose Leidenfrost

Design and Unique Task

Task: Wrist device must be capable of detecting whether the patient is experiencing a convulsive seizure.

Design: The combined use of an EDA sensor and accelerometer on a wrist device is capable of convulsive seizure detection as described by Poh [2].
Raw signal data acquired by the two bio-signals will be filtered to reduce unnecessary signal data and associated noise. An algorithm will then implemented to determine if the two signals have indicated a seizure event [2].
Once a seizure is detected it will be transmitted through Bluetooth to the system to produce an alert on the Arxterra panel.

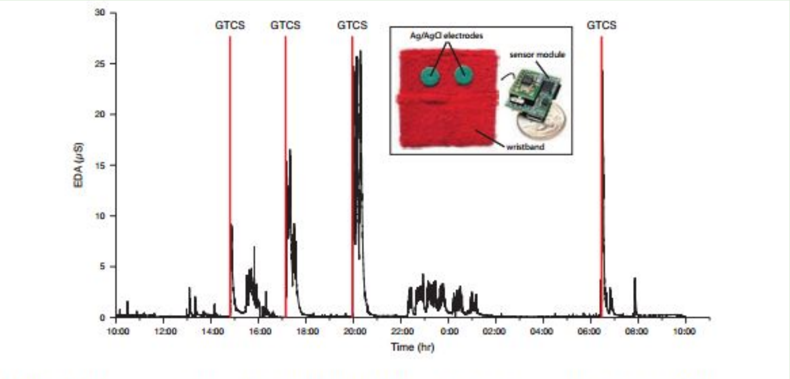


Figure 4-1: *Long-term electrodermal activity (EDA) recordings obtained from a wearable biosensor.*

[2]

Rose Leidenfrost

Design and Unique Task

Task: the wristwatch housing should withstand force that result from a hit or a fall down condition. The housing should also be waterresistave to protect the inside components from sweat while the child is exercising.

Design: Different material was examined to allow protection for the components inside the housing. NinjaFlex would have been the best choice but due to source limitation PLA or ABS would be used.

Trade-off study for 3D printing materials. [1], [2], [3],[4], [5],[6] *

	PLA	ABS	NinjaFlex
Temperature	65^{o}C	Up to 105^{o}C	Up to 120^{o}C
Flexibility	Not flexible	Moderate flexibility	Highly elastic (silicon like)
Strength/breakpoint	67 lbs	67 lbs	72 lbs
Water Resistance	Yes	Yes	Water and oil resistant
Density	1.25 g/cm3	1.03 to 1.38 g/cm3	1.2 g/cm3
Cost (estimate)	24.80 $/Kg	30.13 $/Kg	86.6 $/Kg
Availability	Available(more than one source)	Available (Division manager)	Not available by Maker Society or division manager/searching for sources

*Source reference in purple

Project Status

- Currently working on writing detailed explanations of software functions, to effectively detect seizures with minimal false alarms
- Finalizing cabling strategy, and efficient analog signal processing design for EDA electrode measurement input to MCU ADC
- Writing commands to send telemetry to Arxterra from Atmel Studio
- Buying the last few components for the design (Clock, battery)
- Designing wristband manufacturing, and PCB layout
- Testing wristband electronics on breadboard

Project Schedule: Sys/SubSys Level Tasks

Missions, Systems, and Test (Robin Yancey)	01/20/16	03/23/16	46d	56%
System Design	01/20/16	03/23/16	46d	77%
Level 2 Requirements	02/03/16	02/24/16	16d	94%
Resource Report	02/17/16	02/23/16	5d	1
Define System Resources & Make Data Sheets	02/17/16	02/18/16	2d	100%
Check That Parts meet all System\Subsystem requirements (listed+unlisted)	02/21/16	02/22/16	2d	100%
Discuss Parts to be Purchased with Subsystems	02/23/16	02/23/16	1d	100%
Find Missing Data Sheet Information Based on Choices	02/23/16	02/23/16	1d	100%
Interface Defintion	02/22/16	03/23/16	23d	83%
System Block Diagram	02/24/16	02/25/16	2d	100%
Define Cable Tree	02/23/16	03/04/16	9d	58%
Design Necessary Cable connections to Connect Interface Definitions	02/23/16	02/25/16	3d	30%
Design Circuit for EDA Meausrment	02/25/16	03/04/16	7d	70%
Grounding Strategy	01/20/16	02/24/16	26d	90%
Intangibles	01/20/16	02/24/16	26d	50%
Software	02/24/16	03/09/16	11d	20%
Configure Arxterra to Detect Seizures	02/24/16	03/02/16	6d	20%
DSP algorithms for MCU Software Program	02/24/16	03/02/16	6d	20%
Send Telemetry to Bluetooth Device	02/24/16	03/09/16	11d	20%

Electronics and Control (Rose Leidenfrost)	02/10/16	03/16/16	26d	21%
Electronic Design	02/10/16	03/11/16	23d	16%
Level 3 Subsystem Requirements	02/17/16	02/19/16	3d	80%
Component Definitions	02/10/16	02/24/16	11d	10%
Fritzing Diagram	03/03/16	03/04/16	2d	0%
Using interface definitions, and cable tree from the system engineer, use computer software to make a visual diagram of breadboard	03/03/16	03/04/16	2d	0%
Capture Electrical Schematic	03/05/16	03/11/16	6d	0%
Using interface definitions from the system engineer and cable tree, use computer software to make a visual diagram of the wristband system	03/05/16	03/11/16	6d	0%
Experiments	02/10/16	03/16/16	26d	47%
Test PCB	03/16/16	03/16/16	1d	0%
Trade-Off Studies	02/10/16	02/23/16	10d	80%
Test Breadboard Circuit	03/02/16	03/09/16	6d	0%
Microcontroller	03/02/16	03/09/16	6d	5%
Interface with Peripheral Subsystems of MCU	03/02/16	03/09/16	6d	0%
Read Sensors	03/02/16	03/04/16	3d	10%
Write code to collect data from ACM and ADC sensors	03/02/16	03/04/16	3d	10%
Translate into Data Bytes	03/02/16	03/04/16	3d	10%
write code for math algorithm	03/02/16	03/04/16	3d	10%
Communications	02/10/16	03/09/16	21d	0%

Design and Manufacturing (Marena William)	02/10/16	05/04/16	61d	11%
Mechanical Design	02/10/16	03/09/16	21d	44%
Level 3 Subsystem Requirements	02/10/16	02/26/16	13d	80%
Design Watch Band	02/17/16	02/19/16	3d	85%
Mechanical Interface Definition	02/29/16	03/04/16	5d	32%
Figure out how the electronics will stay safe and enclosed in the wristband.	02/29/16	02/29/16	1d	10%
Figure out how to put the wire through the bottom of the wristband from the electrodes to the PCB	02/29/16	03/04/16	5d	10%
Figure out how to have an adjustable strap with two watch faces	02/29/16	03/04/16	5d	10%
Figure out how the make the enclosure openable to charge or replace the battery.	02/29/16	03/04/16	5d	80%
CAD Software to Design Watch Chassis	02/17/16	02/24/16	6d	0%
Simulations	03/02/16	03/09/16	6d	0%
PCB	02/24/16	03/23/16	21d	0%
Board Layout	02/24/16	03/02/16	6d	0%
CAM and Gerber Files	03/02/16	03/09/16	6d	0%
SMT Solder Paste Stencil	03/09/16	03/16/16	6d	0%
Reflow and Hand Soldering	03/09/16	03/16/16	6d	0%
Purchase PCB	02/29/16	03/04/16	5d	0%
Find a good place to purchase PCB	02/29/16	03/04/16	5d	0%
ERC and DRC Checks	03/16/16	03/23/16	6d	0%

System Resource Reports

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

System Resource Reports

Wristband Power Report

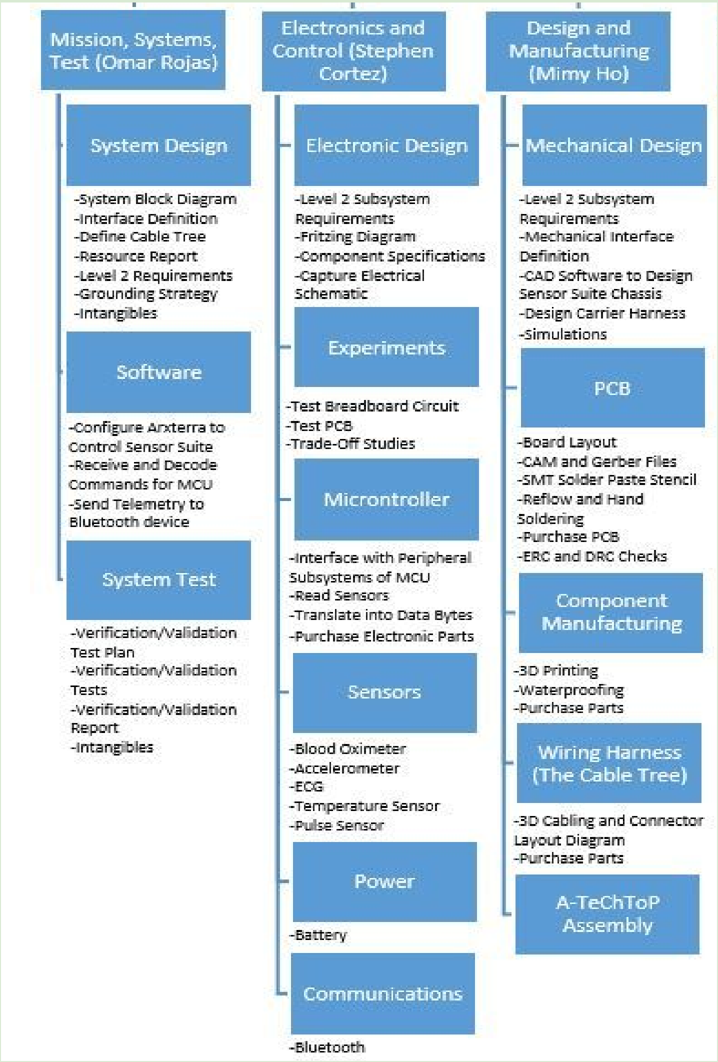
Resource	Expected Current Draw (mA)	Measured Current Draw (mA)	Uncertainty (%)	Margin (±mA)	
Accelerometer (ADXL345)	0.02		10%	0.00	
MCU+Blutetooth Module	4.50		10%	0.45	
Electrodes, Resisters, Skin	0.02		10%	0.00	
RTC	0.00		5%	0.00	
LTC6081 (x3)	0.99		3%	0.00	
Project Allocation					250
Total Margin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

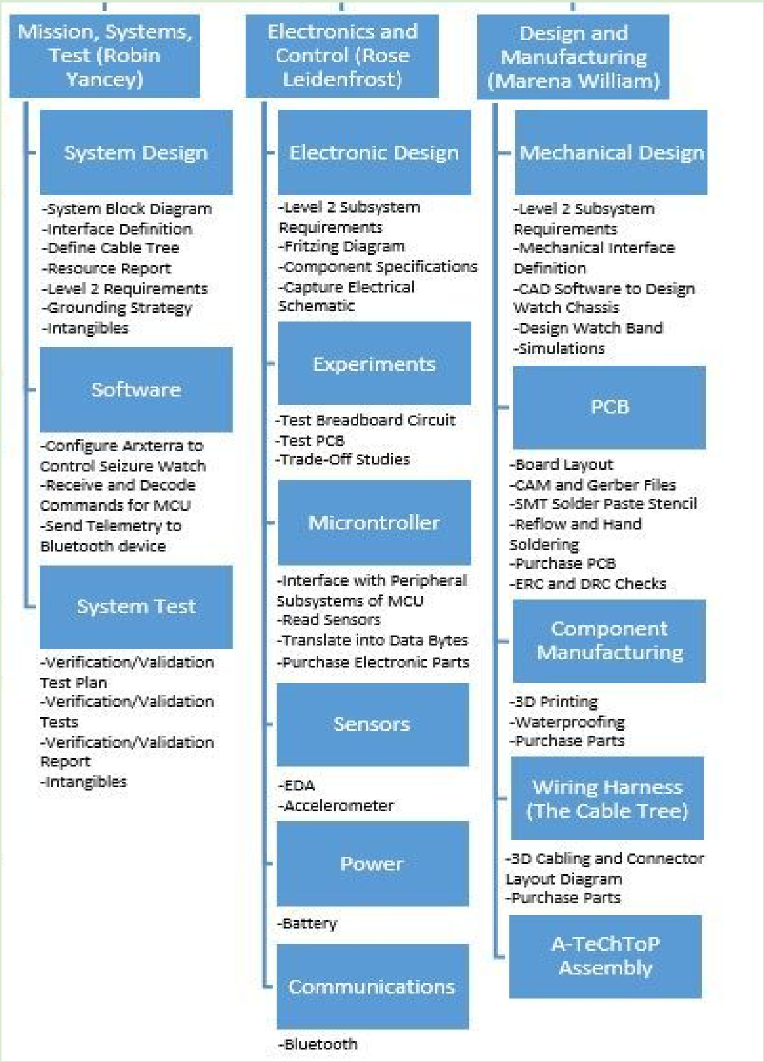
System Resource Reports

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

WBS


Mission, Systems, Test (Omar Rojas)
System Design
-System Block Diagram
-Interface Definition
-Define Cable Tree
-Resource Report
-Level 2 Requirements
-Grounding Strategy
-Intangibles
Software
-Configure Arxterra to Control Sensor Suite
-Receive and Decode Commands for MCU
-Send Telemetry to Bluetooth device
System Test
-Verification/Validation Test Plan
-Verification/Validation Tests
-Verification/Validation Report
-Intangibles
Electronics and Control (Stephen Cortez)
Electronic Design
-Level 2 Subsystem Requirements
-Fritzing Diagram
-Component Specifications
-Capture Electrical Schematic
Experiments
-Test Breadboard Circuit
-Test PCB
-Trade-Off Studies
Microntroller
-Interface with Peripheral Subsystems of MCU
-Read Sensors
-Translate into Data Bytes
-Purchase Electronic Parts
Sensors
-Blood Oximeter
-Accelerometer
-ECG
-Temperature Sensor
-Pulse Sensor
Power
-Battery
Communications
-Bluetooth
Design and Manufacturing (Mimy Ho)
Mechanical Design
-Level 2 Subsystem Requirements
-Mechanical Interface Definition
-CAD Software to Design Sensor Suite Chassis
-Design Carrier Harness
-Simulations
PCB
-Board Layout
-CAM and Gerber Files
-SMT Solder Paste Stencil
-Reflow and Hand Soldering
-Purchase PCB
-ERC and DRC Checks
Component Manufacturing
-3D Printing
-Waterproofing
-Purchase Parts
Wiring Harness (The Cable Tree)
-3D Cabling and Connector Layout Diagram
-Purchase Parts
A-TeChToP Assembly


Mission, Systems, Test (Robin Yancey)
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-Design Watch Band
-Simulations
PCB
-Board Layout
-CAM and Gerber Files
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Component Manufacturing
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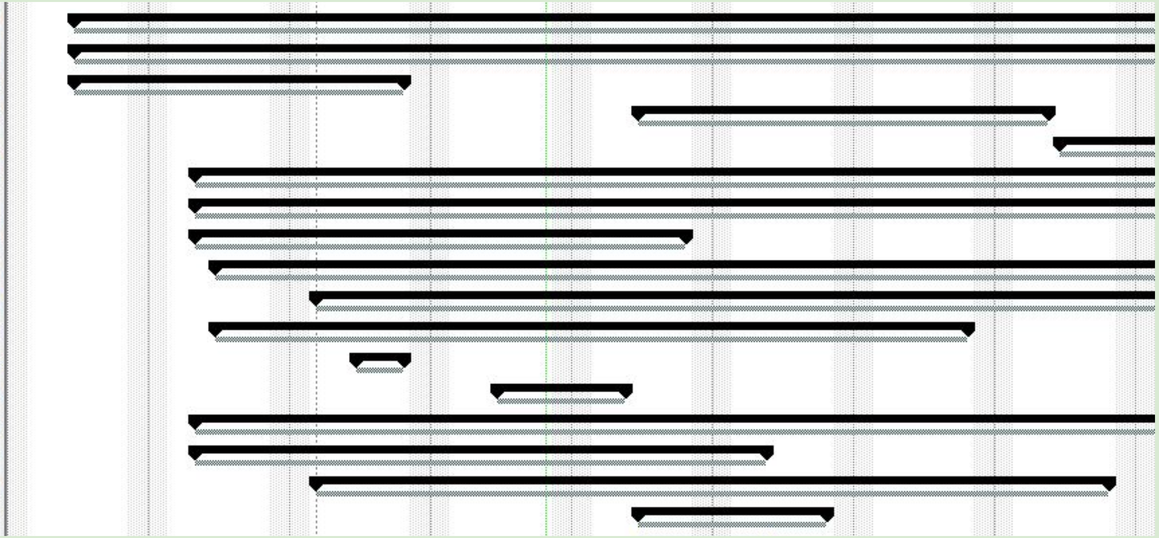
-Waterproofing
-Purchase Parts
Wiring Harness (The Cable Tree)
-3D Cabling and Connector Layout Diagram
-Purchase Parts
A-TeChToP Assembly

Project Schedule: Top Level Schedule

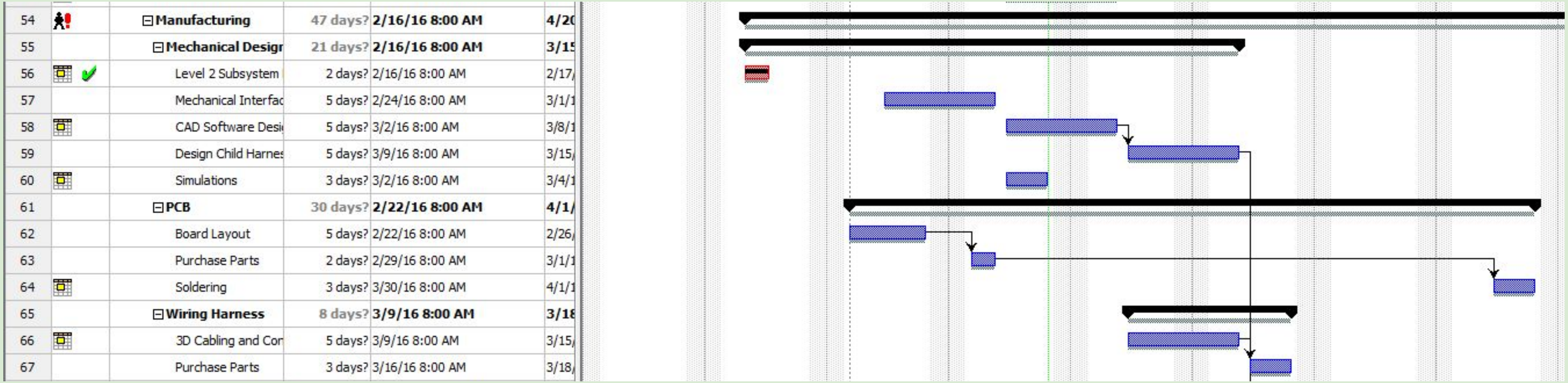
- The top level schedule follows the WBS blocks and then elaborates on the sub-tasks
- Both groups follow similar initial schedules which may be altered

11		⊟Repeated for Both Sen	61 days?	2/10/16 8:00 AM	5/4/
12		⊟Systems	61 days?	2/10/16 8:00 AM	5/4/
13		⊞System Design	13 days?	2/10/16 8:00 AM	2/26
20		⊞Software	15 days?	3/9/16 8:00 AM	3/29
24		⊞Systems Test	26 days?	3/30/16 7:00 AM	5/4/
29		⊟Subsystems	47 days?	2/16/16 8:00 AM	4/20
30		⊟Electronics	39 days?	2/16/16 8:00 AM	4/8/
31		⊞Design	19 days?	2/16/16 8:00 AM	3/11
36		⊞Experiments	36 days?	2/17/16 8:00 AM	4/6/
40		⊞Microcontroller	35 days?	2/22/16 8:00 AM	4/8/
45		⊞Sensors	28 days?	2/17/16 8:00 AM	3/25
49		⊞Power	3 days?	2/24/16 8:00 AM	2/26
52		⊞Commnications	5 days?	3/2/16 8:00 AM	3/8/
54		⊟Manufacturing	47 days?	2/16/16 8:00 AM	4/20
55		⊞Mechanical Desigr	21 days?	2/16/16 8:00 AM	3/15
61		⊞PCB	30 days?	2/22/16 8:00 AM	4/1/
65		⊟Wiring Harness	8 days?	3/9/16 8:00 AM	3/18



Project Schedule (Continued)

- The blocks from the WBS are then expanded upon in the schedule
- This helps determine the causality of the tasks
- Each member has their own tasks



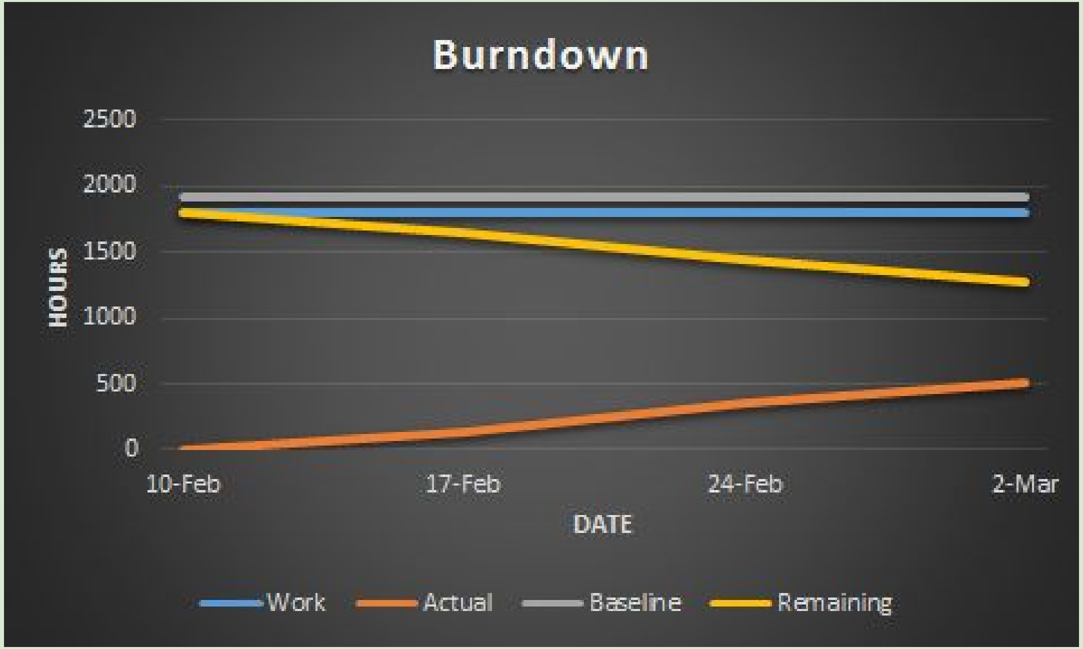
54		Manufacturing	47 days?	2/16/16 8:00 AM	4/20
55		Mechanical Design	21 days?	2/16/16 8:00 AM	3/15
56		Level 2 Subsystem	2 days?	2/16/16 8:00 AM	2/17/
57		Mechanical Interfac	5 days?	2/24/16 8:00 AM	3/1/1
58		CAD Software Desi	5 days?	3/2/16 8:00 AM	3/8/1
59		Design Child Harnes	5 days?	3/9/16 8:00 AM	3/15/
60		Simulations	3 days?	3/2/16 8:00 AM	3/4/1
61		PCB	30 days?	2/22/16 8:00 AM	4/1/
62		Board Layout	5 days?	2/22/16 8:00 AM	2/26/
63		Purchase Parts	2 days?	2/29/16 8:00 AM	3/1/1
64		Soldering	3 days?	3/30/16 8:00 AM	4/1/1
65		Wiring Harness	8 days?	3/9/16 8:00 AM	3/18
66		3D Cabling and Cor	5 days?	3/9/16 8:00 AM	3/15/
67		Purchase Parts	3 days?	3/16/16 8:00 AM	3/18/

Project Schedule: Burn Down and Project Percent Completion

The group has completed 28.8% of the project as measured in hours.

The project should pick up pace as parts arrive.

*The hours are doubled because of the two subgroups.



Total Cost

Project Allocation: $700

Total Margin: $66.01

Total Expected Cost: $332.87

Contingency: $433.14

Central Sensor Suite to be funded by department

Seizure Watch to be self-funded

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