# BIO-Helmet

GROUP 3

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ADAM HOLLIFIELD – COMPUTER ENGINEER
MARK LE – ELECTRICAL ENGINEER

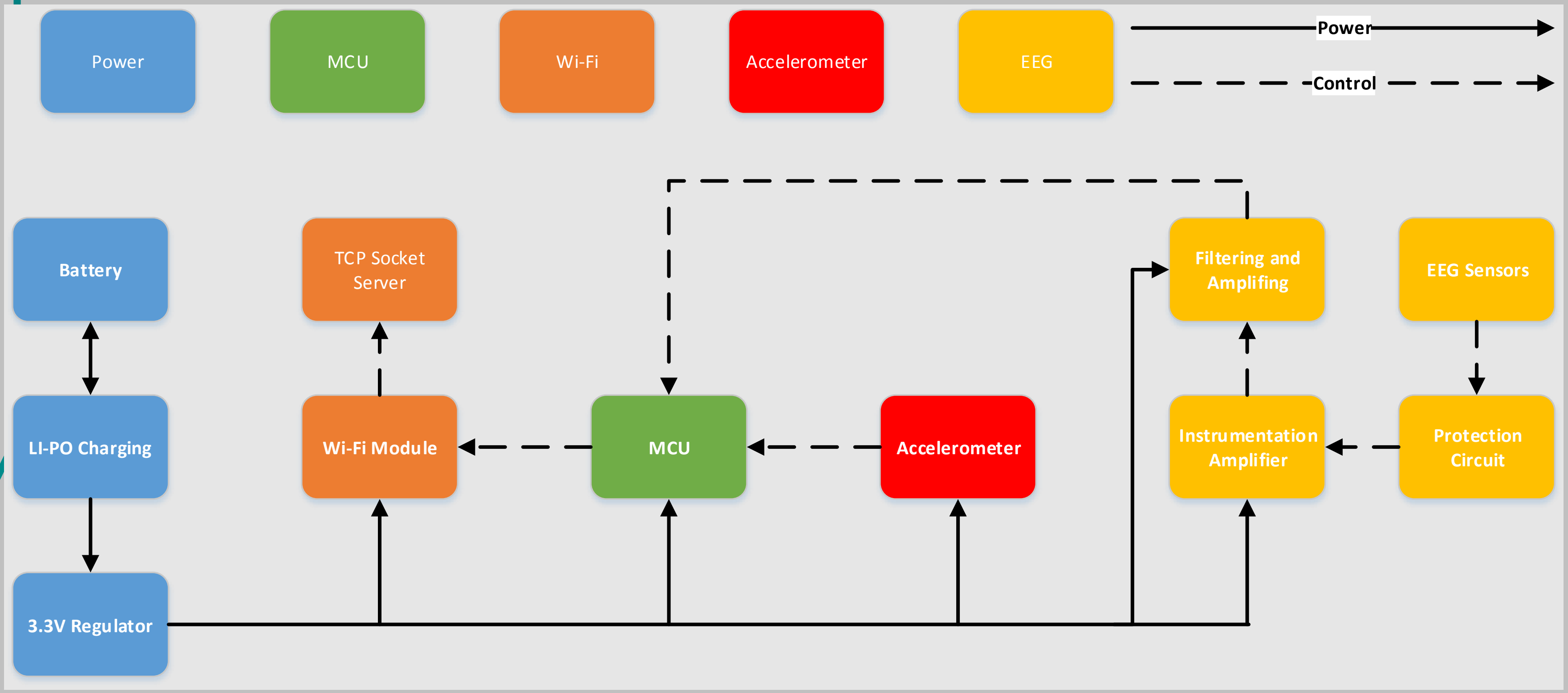
# Goals and Objectives

- Develop a better, more scientific approach to concussion identification
- Develop prototype model to protect athletes in contact sports
- Provide both impact data and brain wave data to a physician for faster concussion diagnosis and treatment
- Historical availability of brain wave and impact data
- Research and development of brain wave activity to concussion identification

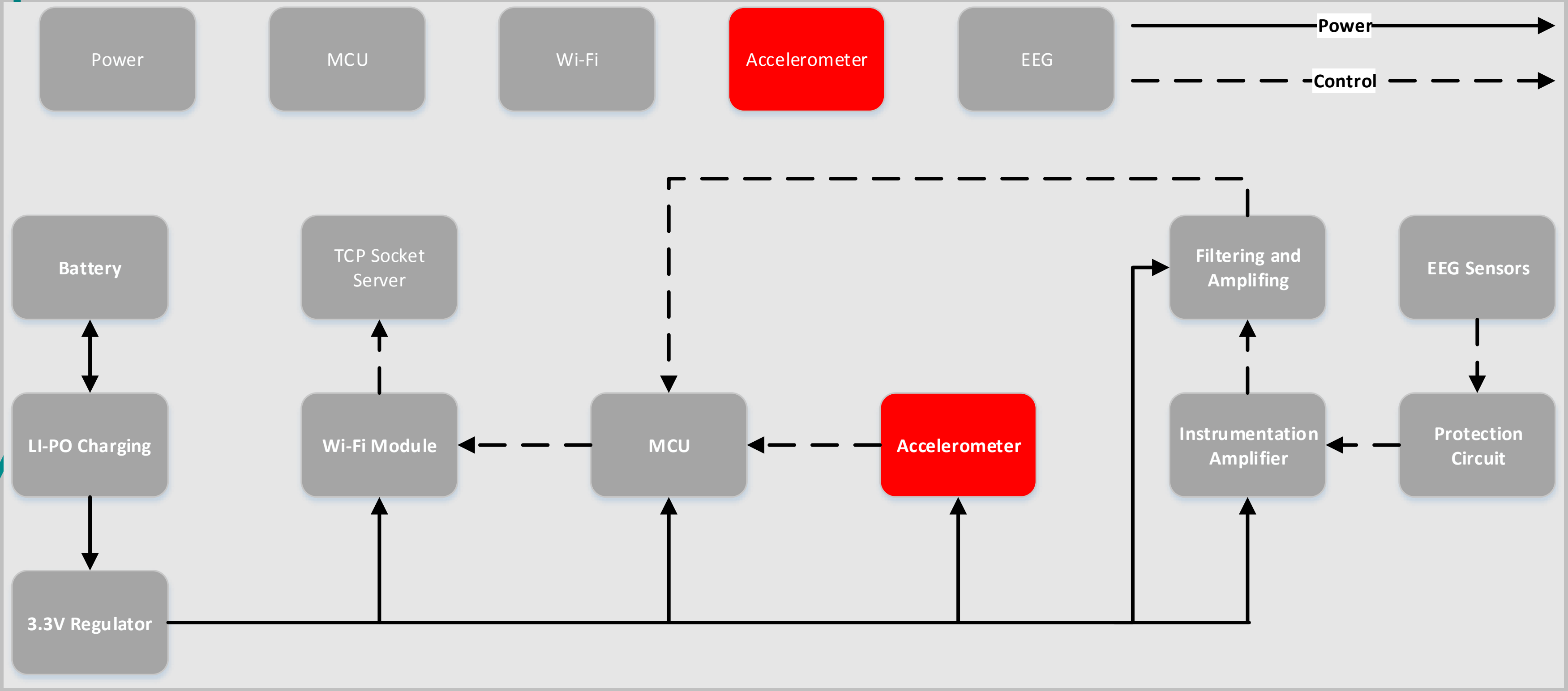
# Specifications and Requirements

| | |
|---|---|
| Hardware | • The microprocessor must be able to output accelerometer and EEG data in real time.<br>• The helmet must have a battery which lasts at least 2 hours.<br>• The accelerometers must be able to detect not only g-force but also the angle of impact.<br>• The EEG sensors must be able to provide valid EEG data from the surface of head without any invasive impacts to the user.<br>• All electronic devices must be able to withstand 100g impacts without losing reliability in data output.<br>• All electronic devices must be weather proofed for rain up to 0.30 inches per hour. |
| Software | • The local server must collect and process all sensor data (accelerometer and brain wave) received from the BIO-Helmet at a rate of three times per second.<br>• The local server must store all sensor data in a historical database for historical view and retrieval; three times per second for insertion and once per second for reading.<br>• Reporting software must be implemented which allows a user to view all sensor data in an easy to read graphical and/or tabular format; viewed as a single dataset obtained from the database.<br>• The reporting software must alert a user on the side line, with one popup message and a five last historical table, that a hard impact has occurred. |

# Hardware Block Diagram

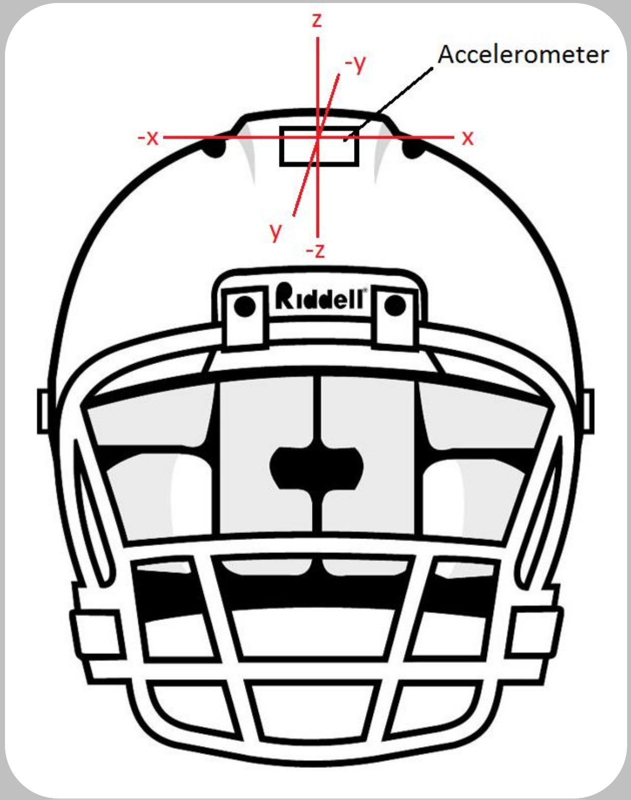


# Accelerometer



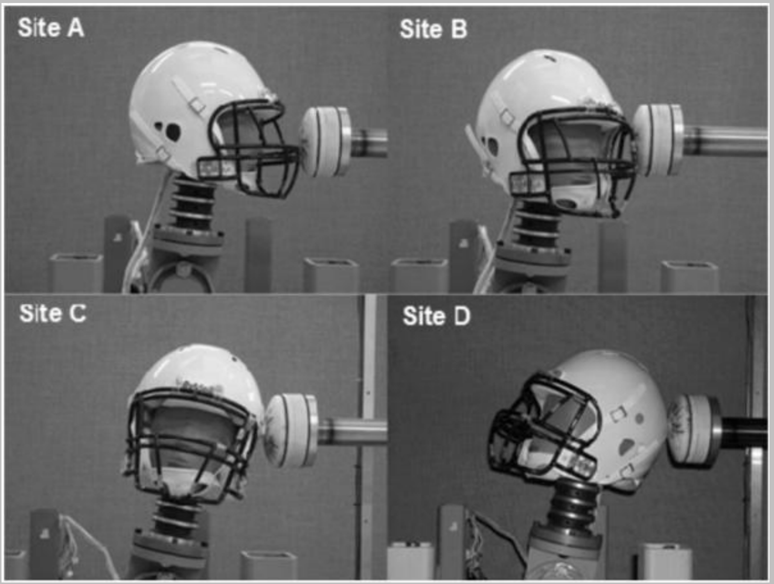
# ADXL377 Accelerometer

| Manufacturer | Analog Devices |
|---|---|
| Output | Analog |
| Number of Axes | 3-Axis |
| Range | -200 to +200 g |
| Sensitivity | 6.5 mV/g |
| Operating Voltage | 1.8 to 3.6 V |
| Supply Current | 300 uA |
| Dimensions | 3 x 3 x 1.45 mm |
| Shock Survival | 10,000 g |



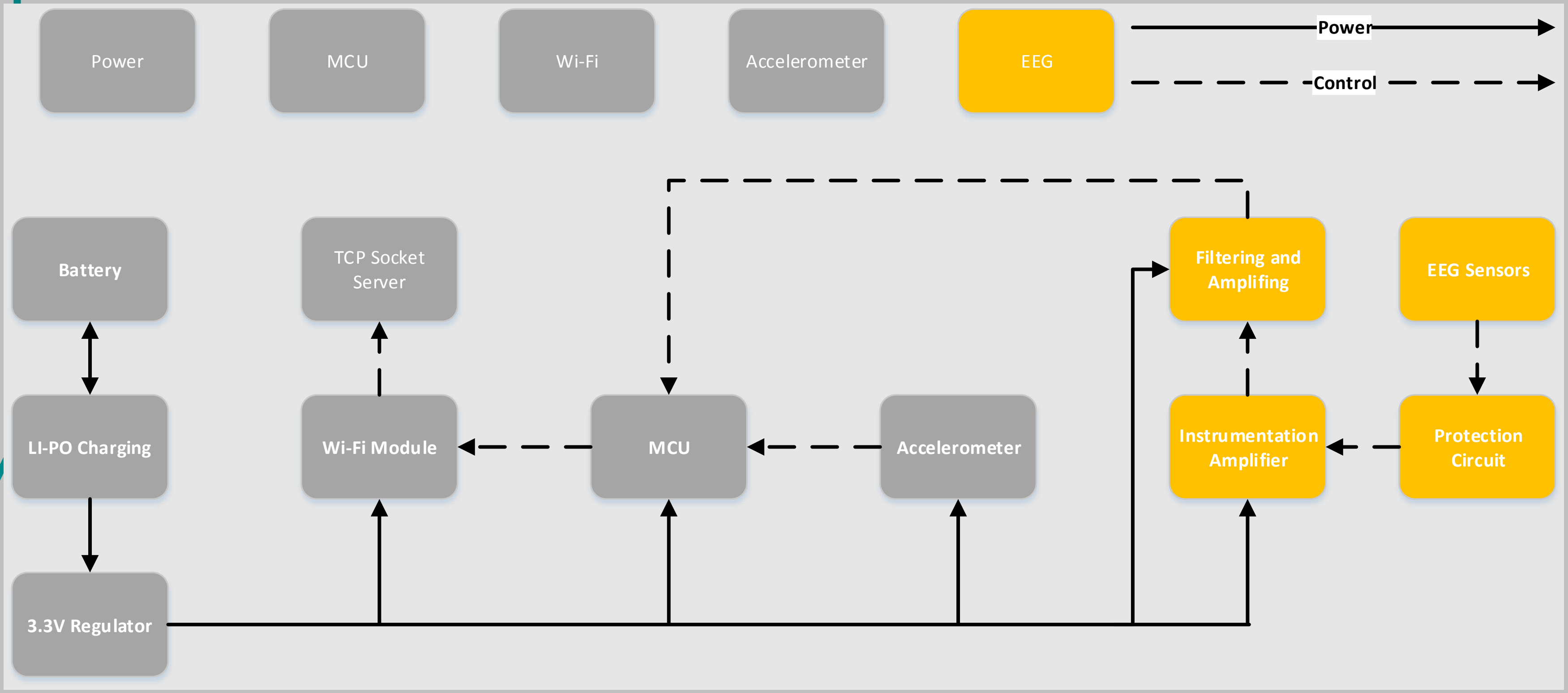
# ADXL377 Accelerometer

- Analog signal is easier to poll data from using our MCU
- Low power consumption
- 3 axes allow calculating direction of the impact
- Football impacts can measure greater than 100 g's
- Concussions can occur at as low as 10 g's



NFL Athlete Impact Points; reprinted with permission from National Library of Medicine

# EEG


Power
MCU
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Accelerometer
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TCP Socket Server
Filtering and Amplifing
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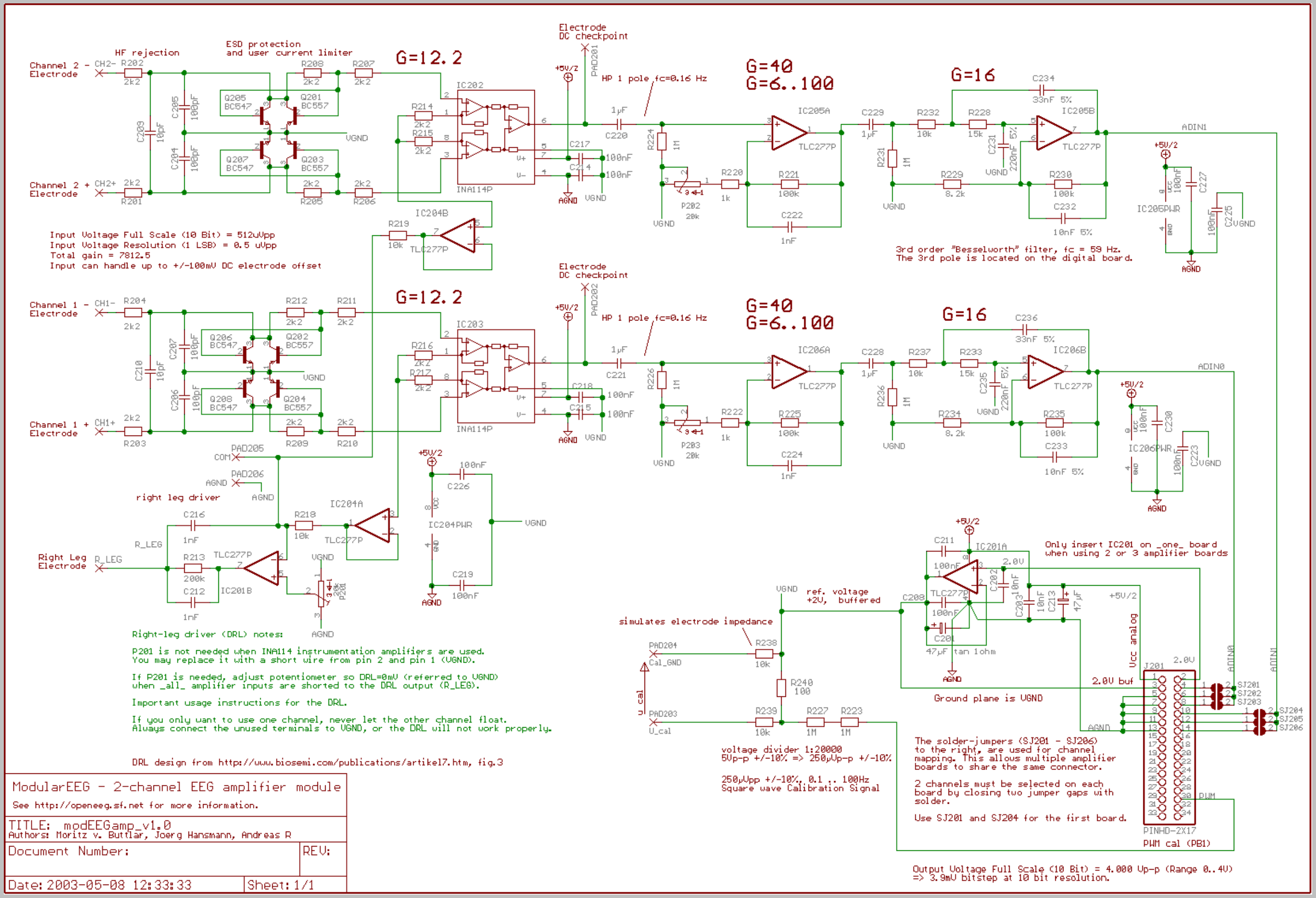
Accelerometer
Instrumentation Amplifier
Protection Circuit
3.3V Regulator

# EEG

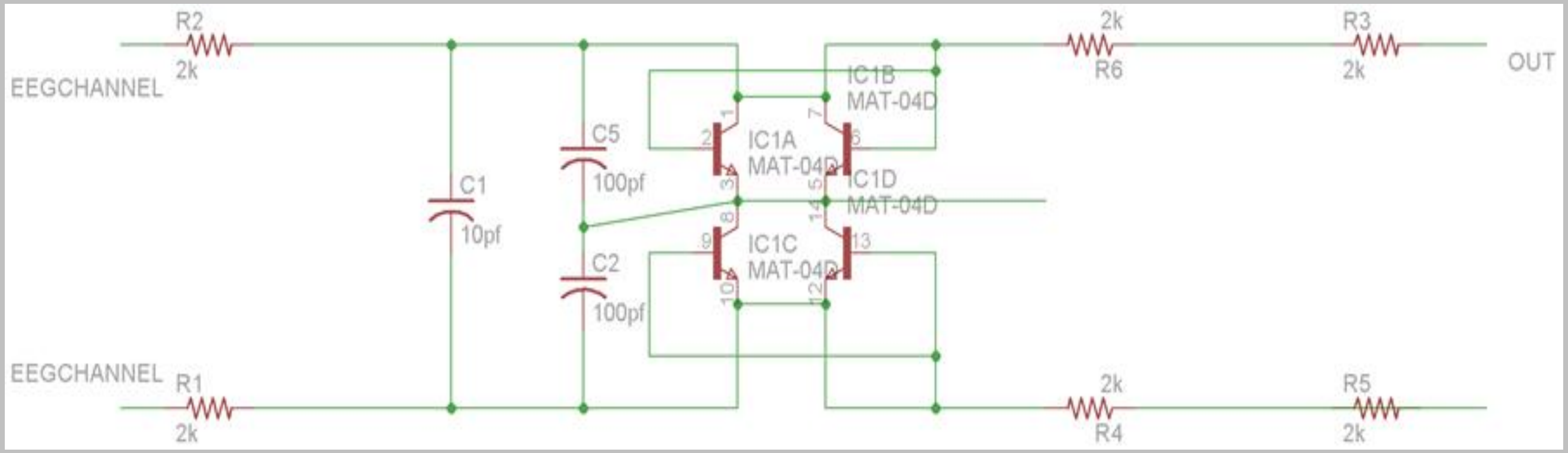



Reference Design; reprinted with permission from OpenEEG

# EEG

Protection Circuit

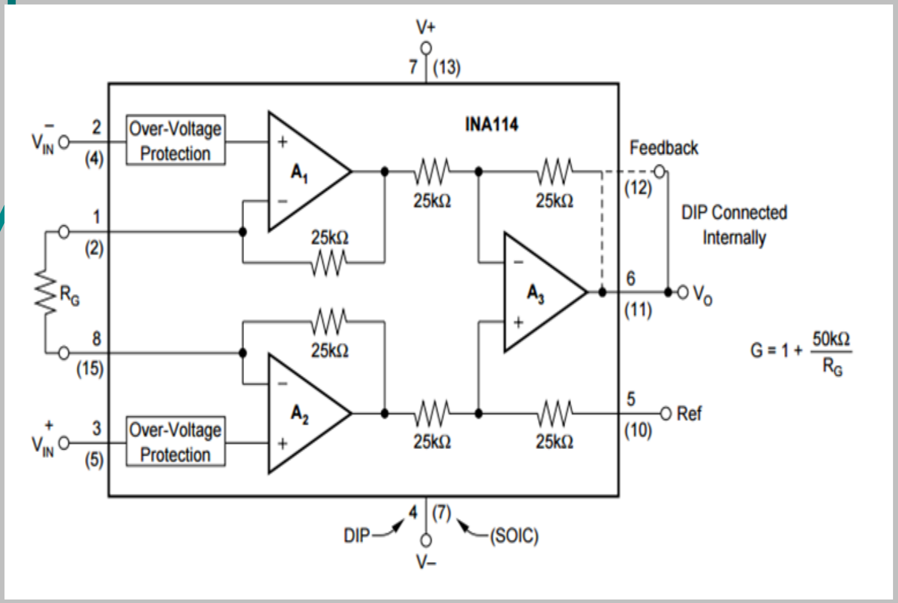
- Transistor Network, Capacitors and Resistors
- Circuits avoid the voltage ever going above 0.7 V
- Below 0.7 acts as open circuit
- From reference design



# EEG

Instrumentation Amplifier

- INA114AP Precision Amplifier provides first stage gain

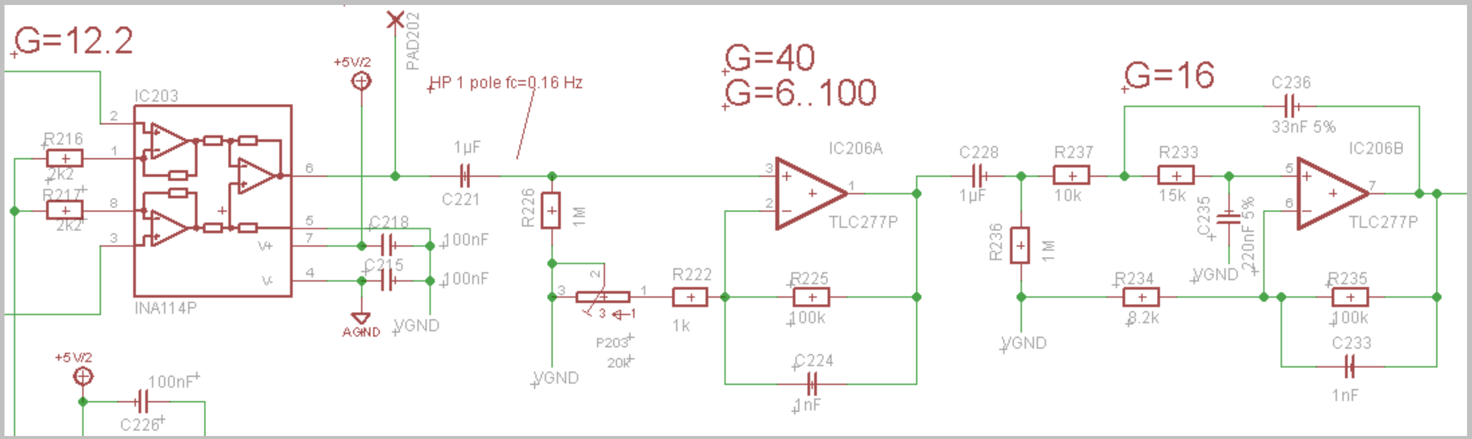



| Manufacturer | Bur-Brown |
|---|---|
| Output | Analog |
| CMMR | 115 dB |
| Range of Gain | 1-10000 |
| Max Offset Voltage | 50 uV |
| Operating Voltage | 2.25 to 18 V |
| Supply Current | 3.3 mA |
| Dimensions | 10.75x10.7x2.7 mm |

# EEG

Amplifier and Filter Stages

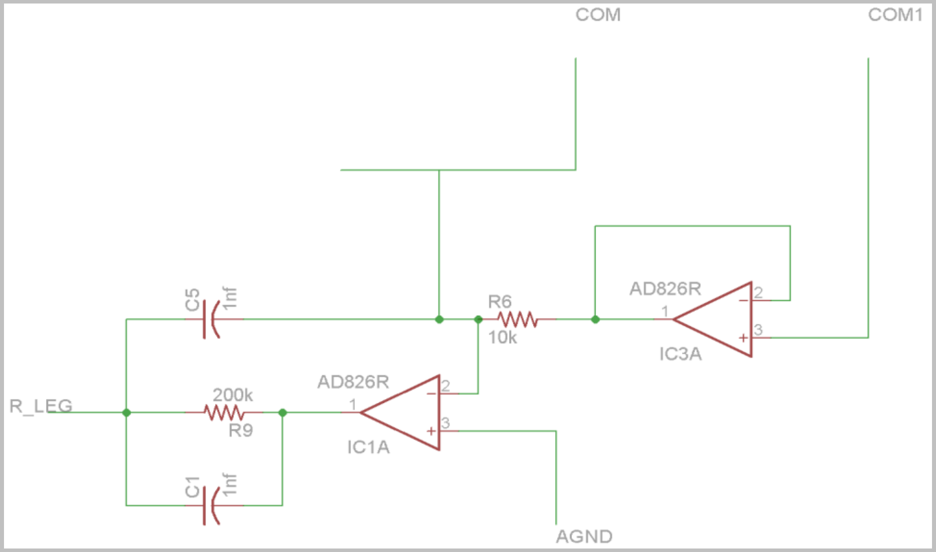
- Analog circuit will be processing the signal into its final form through three stages
- 1st Stage 12.2 gain, and 0.16 Hz cutoff frequency. Stage 2 gain of 40 and another HPF as in 1st Stage. Stage 3 has gain of 16 and a 3rd order LPF to remove larger frequencies (<100Hz)
- Using Precision Amplifiers TLC277 from TI



# EEG

DRL (Driver Right Leg)

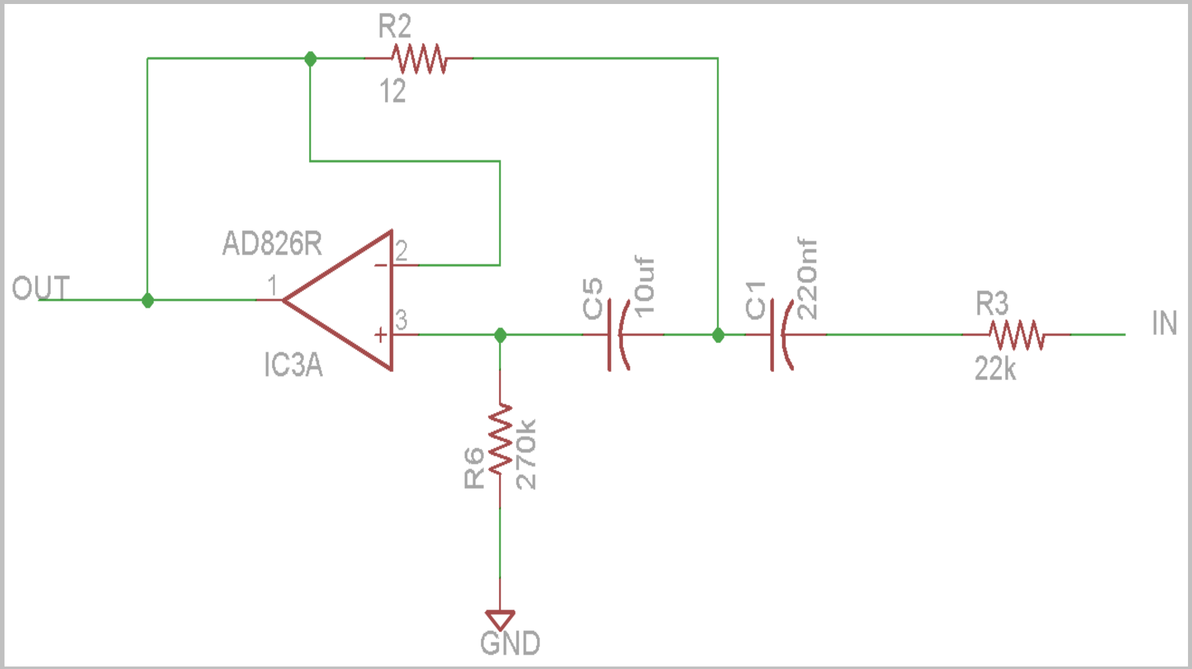
- First option to cancel the electromagnetic interference up from the body
- Must be connected to the right leg of the subject
- From reference design



# EEG

Notch Filter

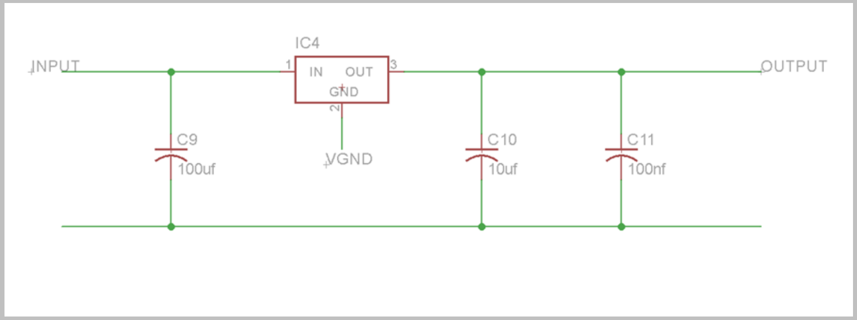
- Option to reject electromagnetic interference pick up by the human body 50/60 Hz
- Design from DIY EEG

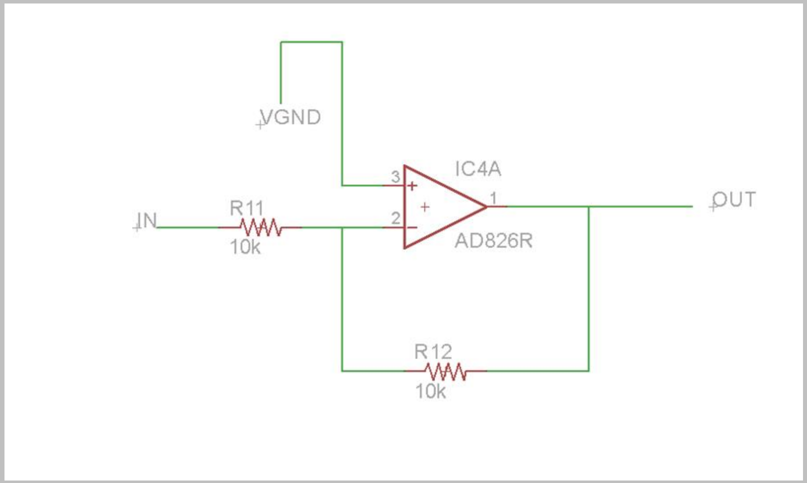


# EEG

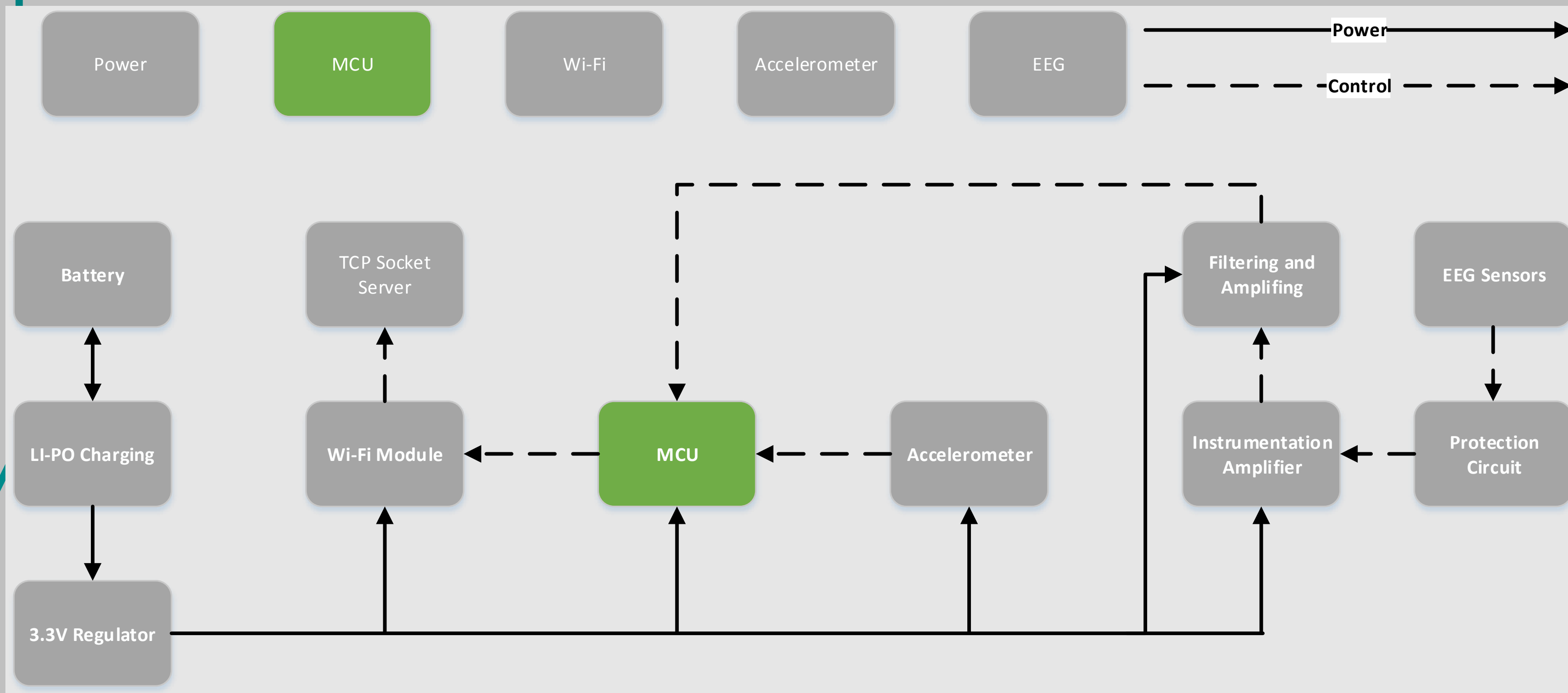
Other Considerations

- Voltage Regulator (depending on power supply from reference design)
- Voltage Inverter for input to the components of the design



# MCU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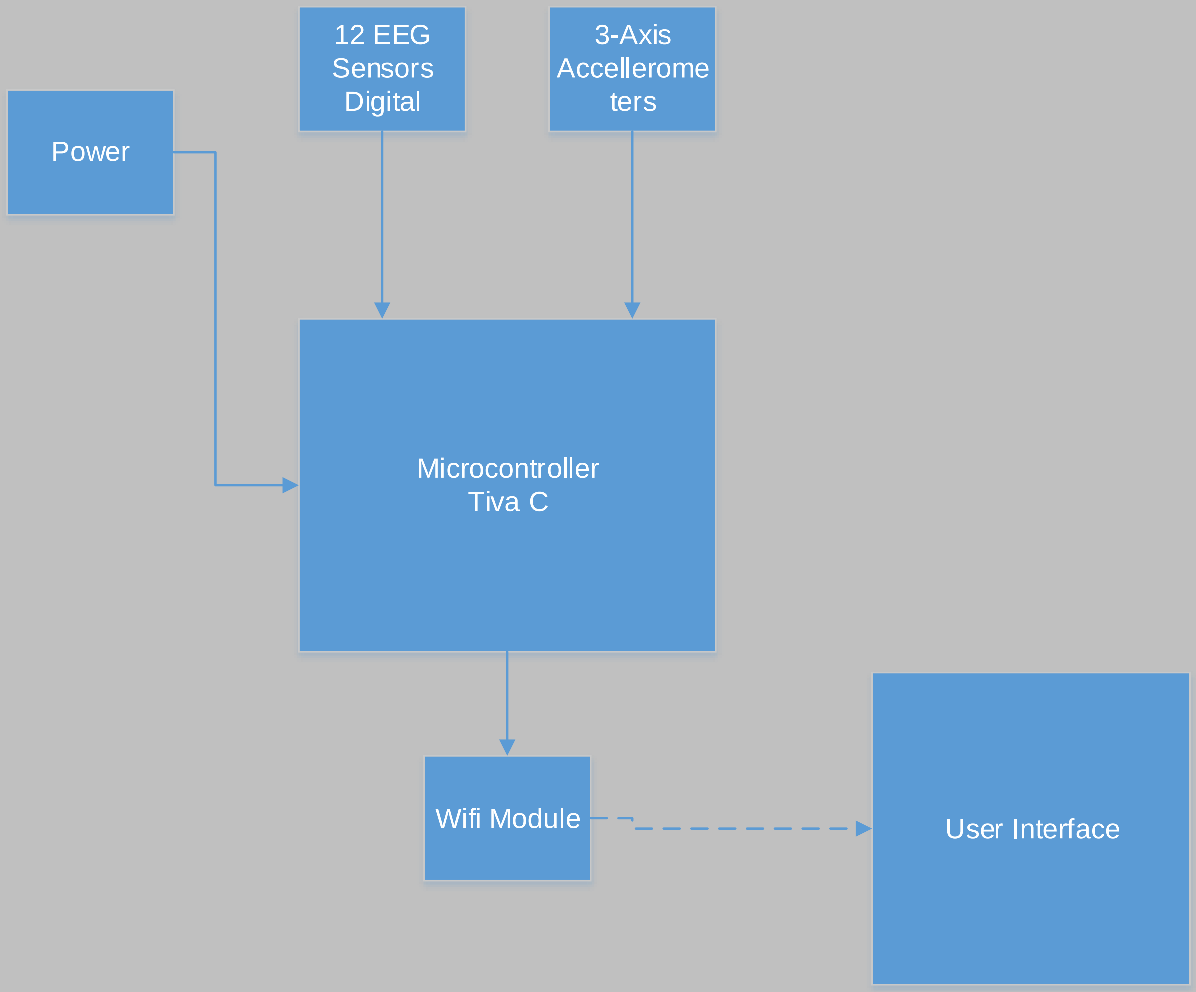
Wi-Fi Module
MCU
Accelerometer
Instrumentation Amplifier
Protection Circuit
3.3V Regulator

# MCU- Tiva C ARM Cortex

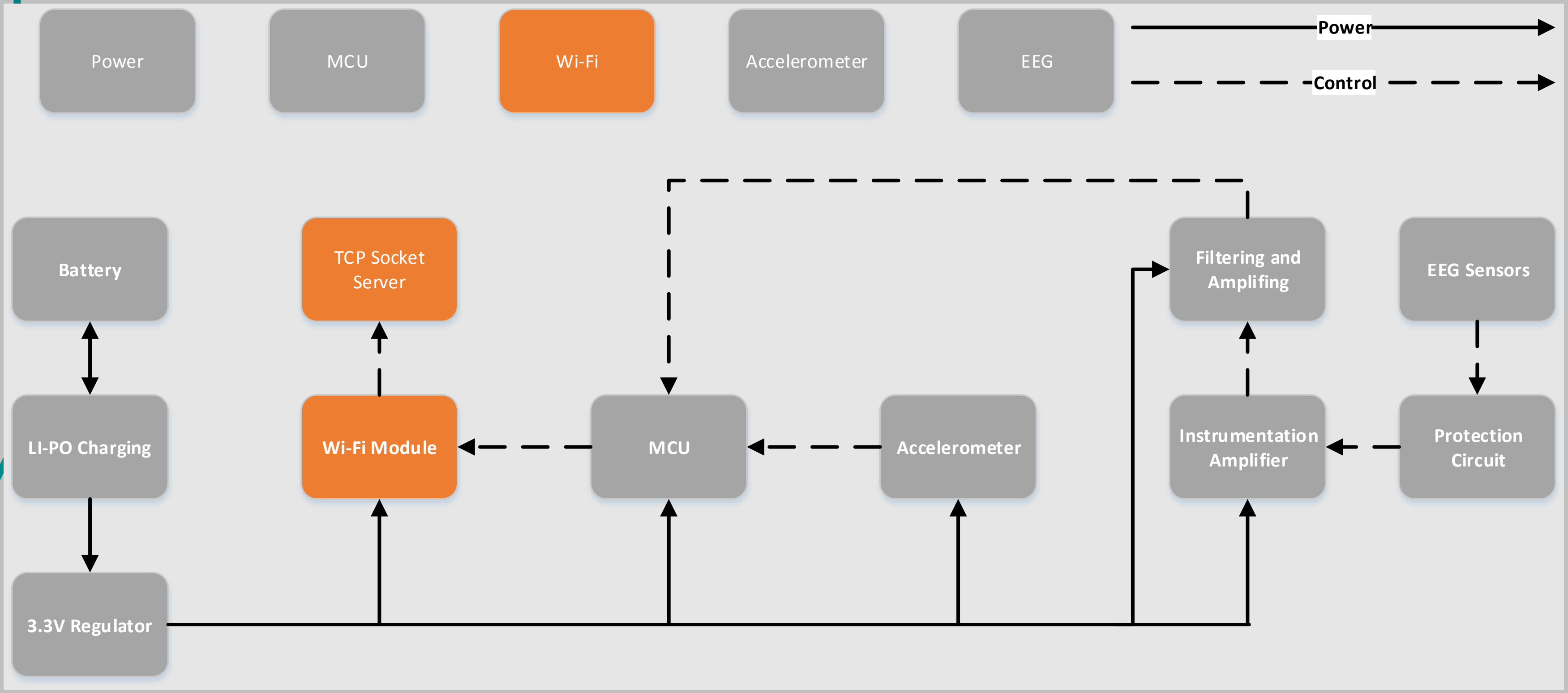
- We needed a microcontroller with the ability to processes and transmit data from multiple sensors wirelessly to a computer.
  - The Tiva C was designed for remote monitoring and motion control.

| | |
|---|---|
| Pin and Package | 64LQFP |
| CPU | ARM Cortex-M4 |
| Flash | 256 KB |
| SRAM | 32 KB |
| Max Speed | 80 MHz |
| Motion PWM Outputs | 16 |
| QEI | 2 |
| GPIOs | 43 |
| Operating Temperature Range | -40 degrees C to 105 degrees C |
| OTG | Yes |
| SSI/SPI | 4 |
| I2C | 4 |
| UART | 8 |
| ADC Channels | 12 |
| ADC Resolution | 12 Bits |
| CAN MAC | 2 |
| SysTick | Yes |

# Tiva C MCU Block Diagram



# Wi-Fi Module



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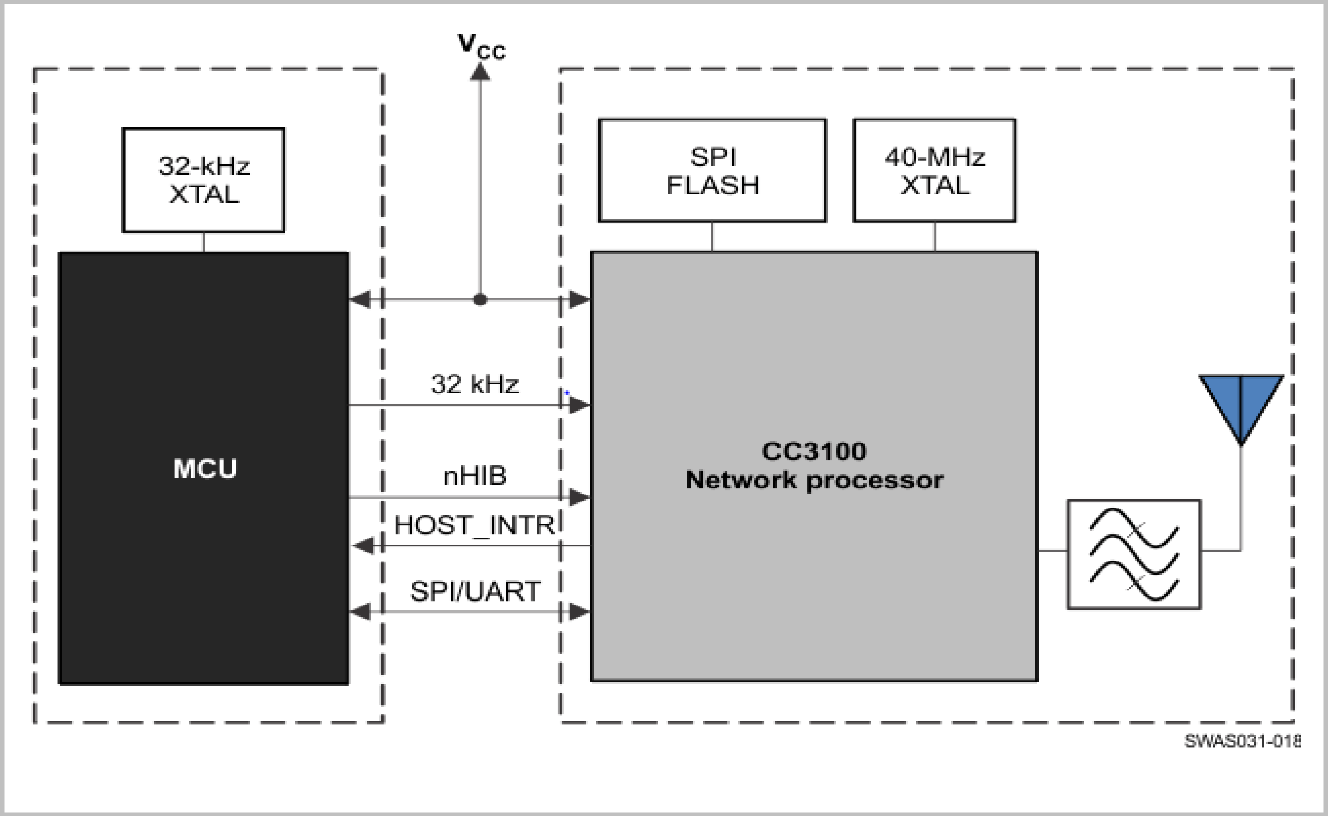
3.3V Regulator

# Wi-Fi Module- CC3100

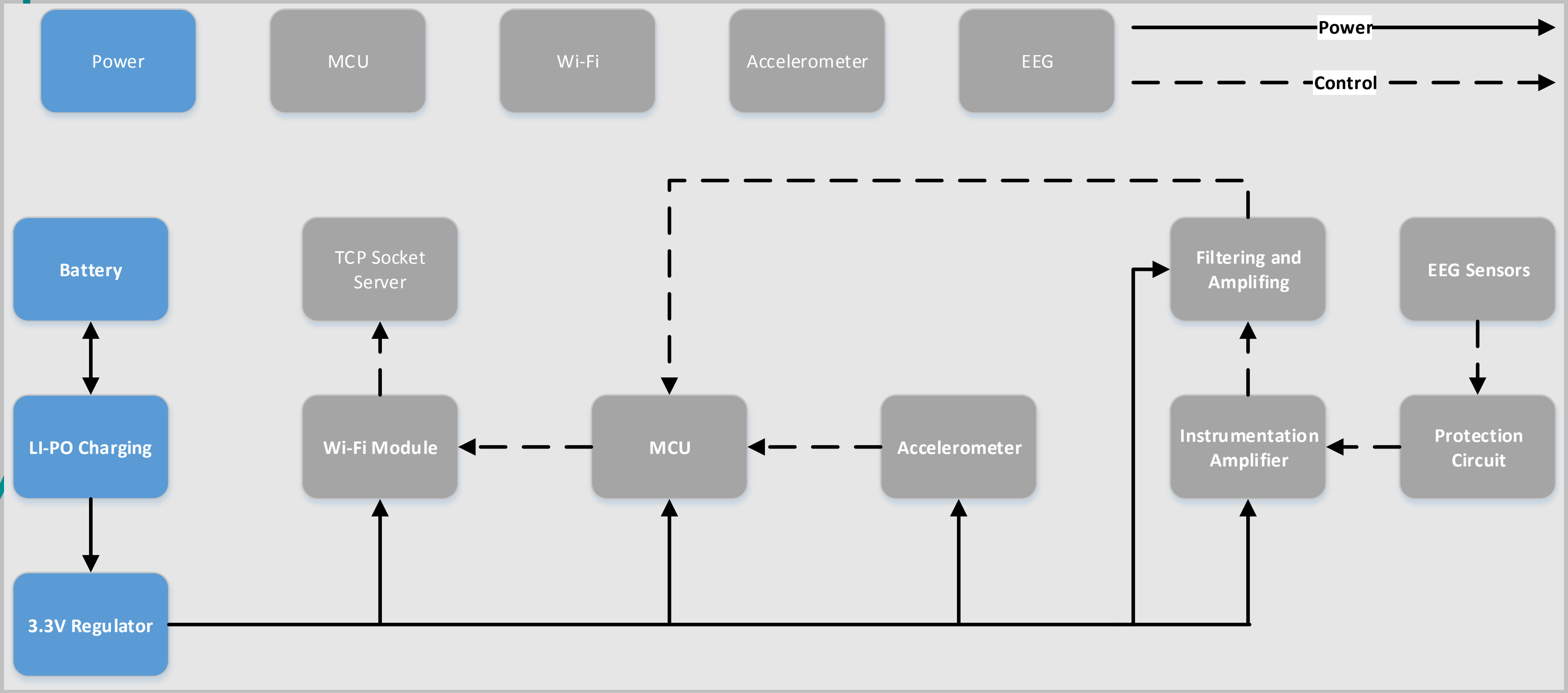
- We needed a Wi-Fi module that will use minimal power while being able to send real time signals in both the 2.4 and 5GHz band
  - The CC3100 is a Wi-Fi module designed for low-power wireless transmissions with high levels of data transfers
  - It is made for the 802.11 b/g/n radio, baseband, and medium access control capabilities
- Chosen for compatibility with TI microprocessors

# Wi-Fi Module- CC3100




TI CC3100; reprinted with permission from Texas Instruments

# Power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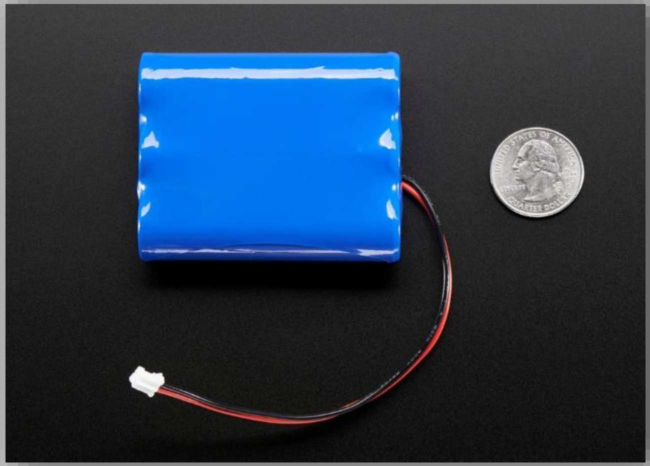
# PKCELL ICR18650 Lithium Ion Battery

- High energy density
- Capacity is enough to last a full football game
- Included protection circuitry
- Requires special charging circuit
- Durable



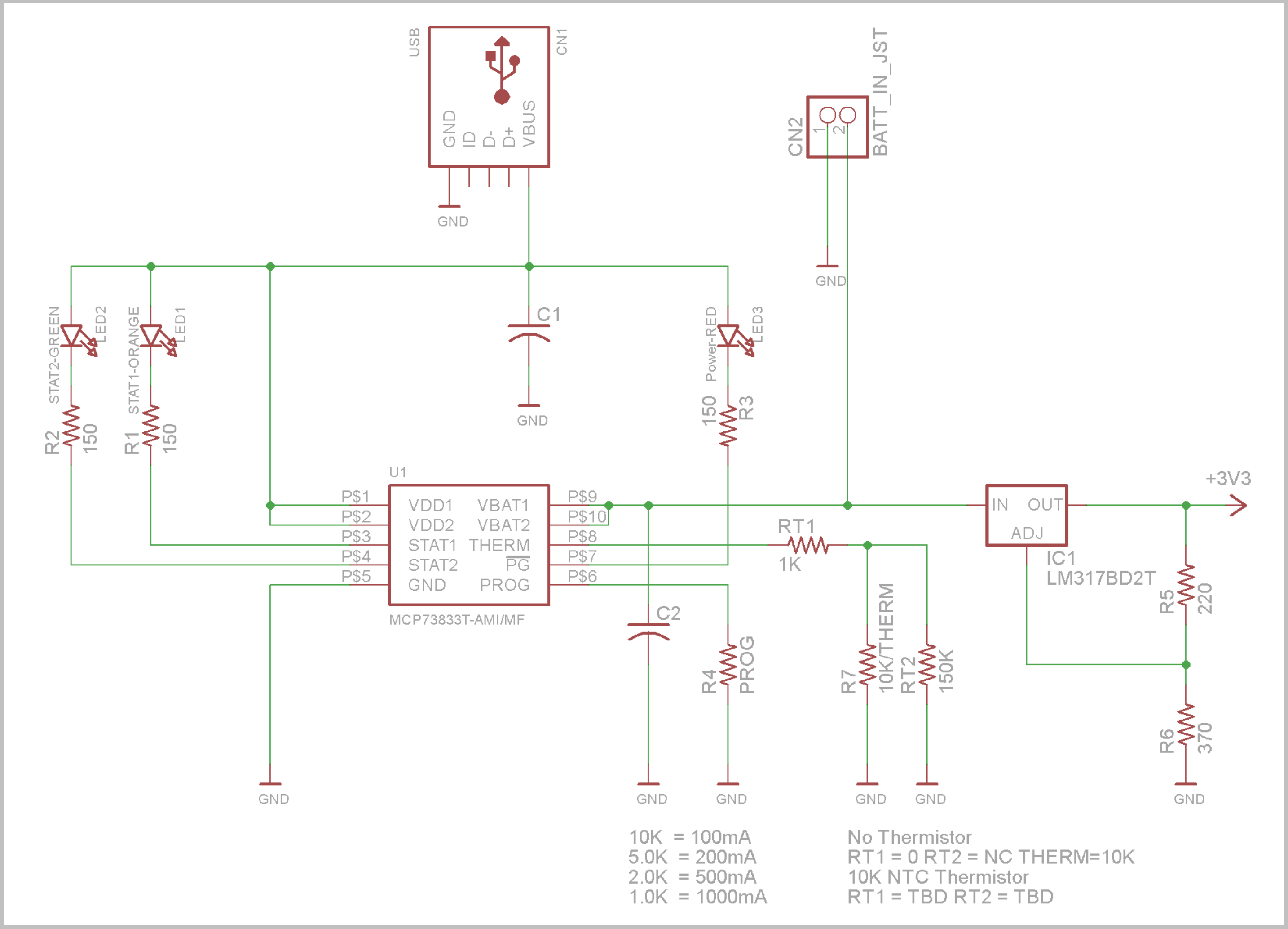
ICR18650 Size Comparison

| Item | Characteristic |
|---|---|
| Nominal Capacity | 6600 mAh |
| Nominal Voltage | 3.7 Volts |
| Charging cut-off voltage | 4.7 Volts |
| Discharging cut-off voltage | 3.0 Volts |
| Max Charging Rate | 3 Amps |
| Max Discharge Rate | 6 Amps |

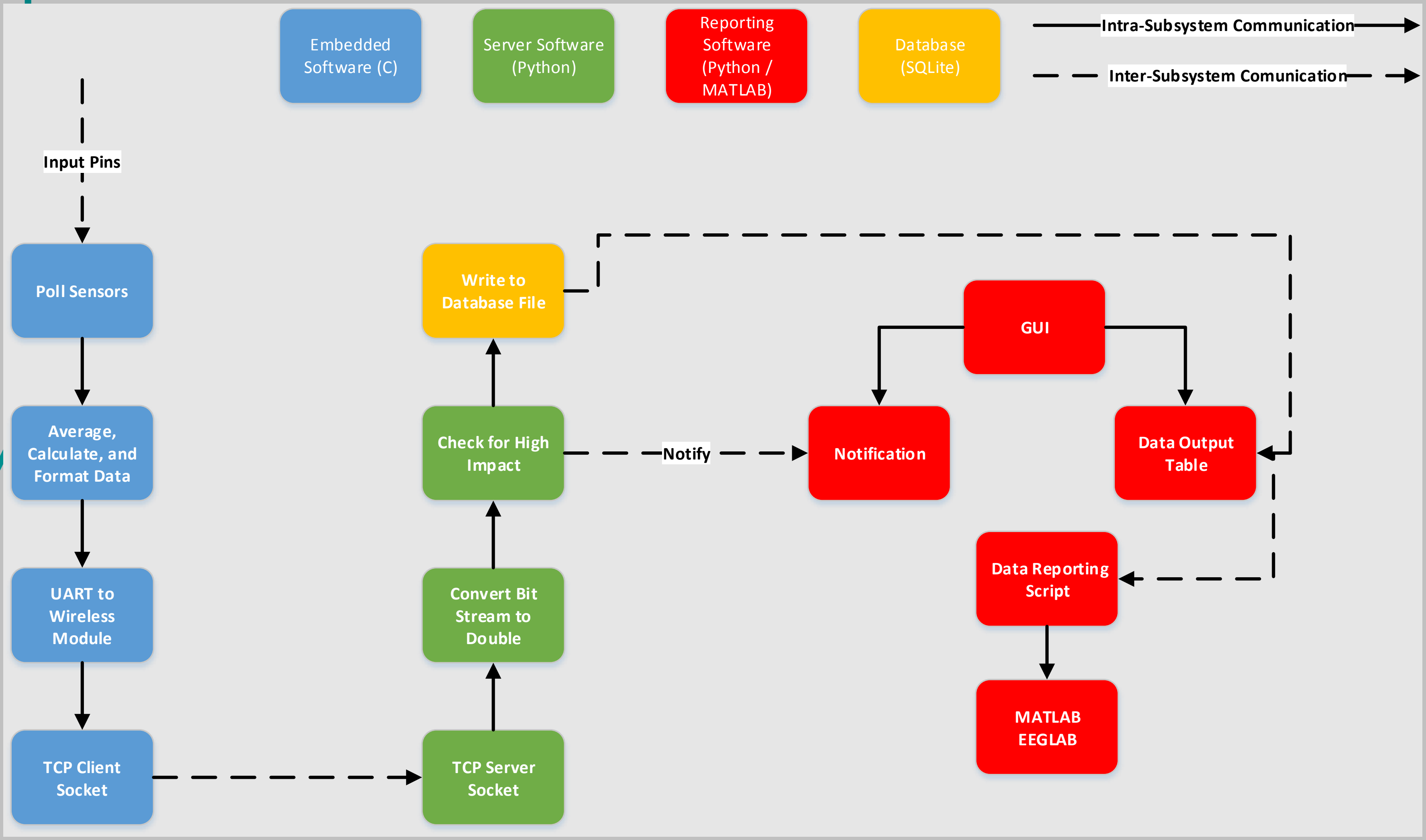
# Power / Charging Circuitry

- Based on  MCP73833 IC and Adafruit LiIon USB charger
- 1 amp charge current
- Can deliver up to 1.5 amps of power
- USB Mini-B connection can be connected to any USB wall charger
- LED status lights
  - RED – Power
  - ORANGE – Charging
  - GREEN – Fully Charged

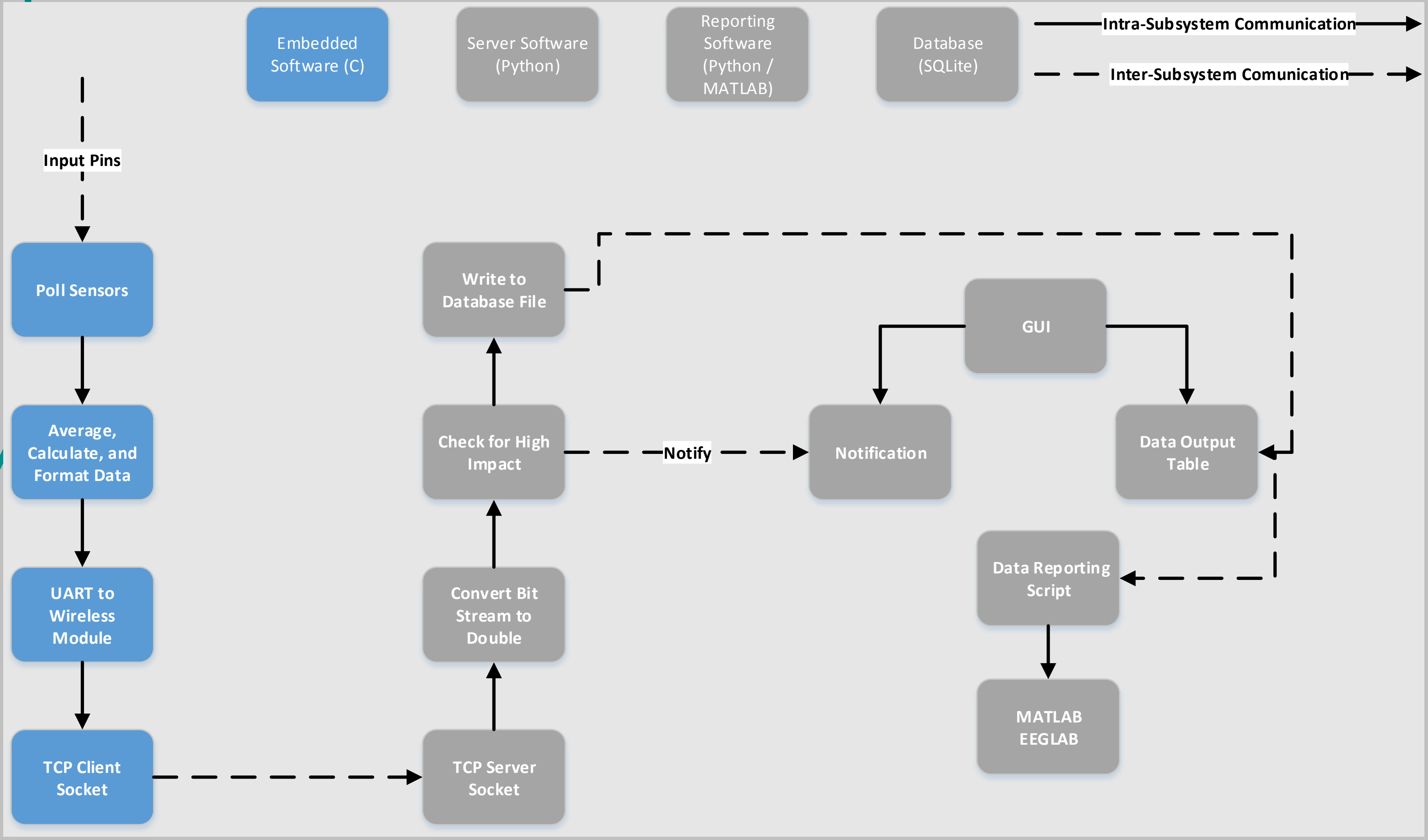
# Power Schematic



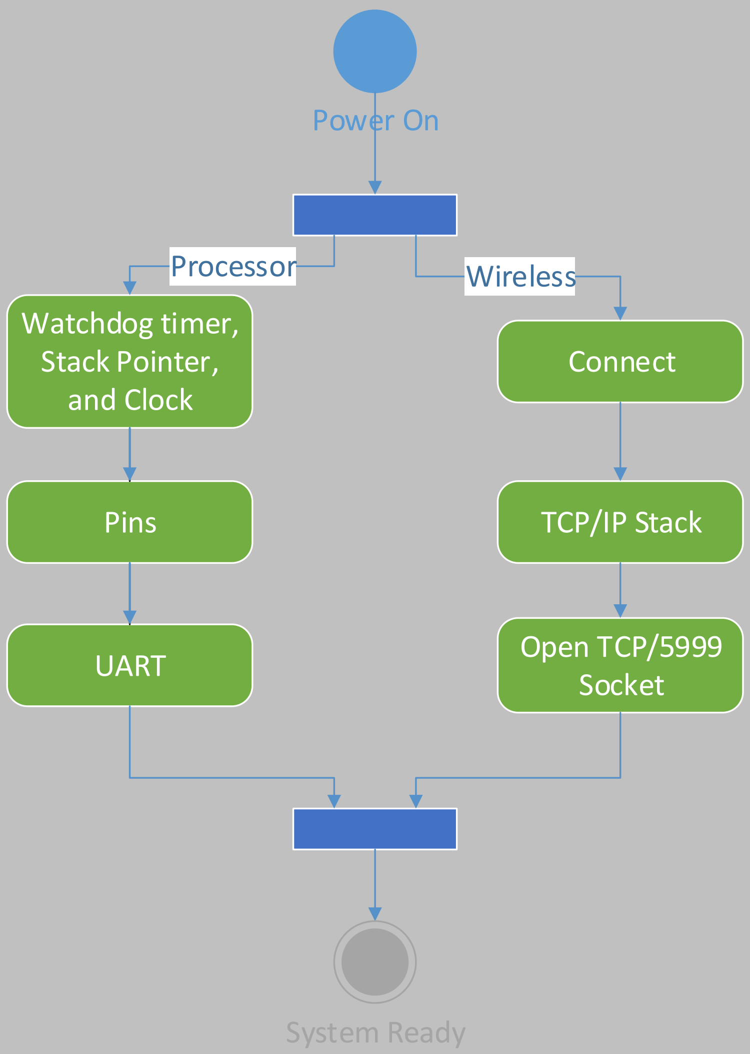
# Software Block Diagram



# Embedded Software



# Initializations




- Processor
  - Timer, clock, stack
  - I/O pins
  - UART
    - Debug
    - Wireless communication
- Wireless
  - Connect to UART
  - Configure TCP/IP Stack
  - Open TCP/5999 socket to local server

# Data Processing

- Accelerometer and EEG sensor input pins are polled three times per second
- Averaged over a one second period

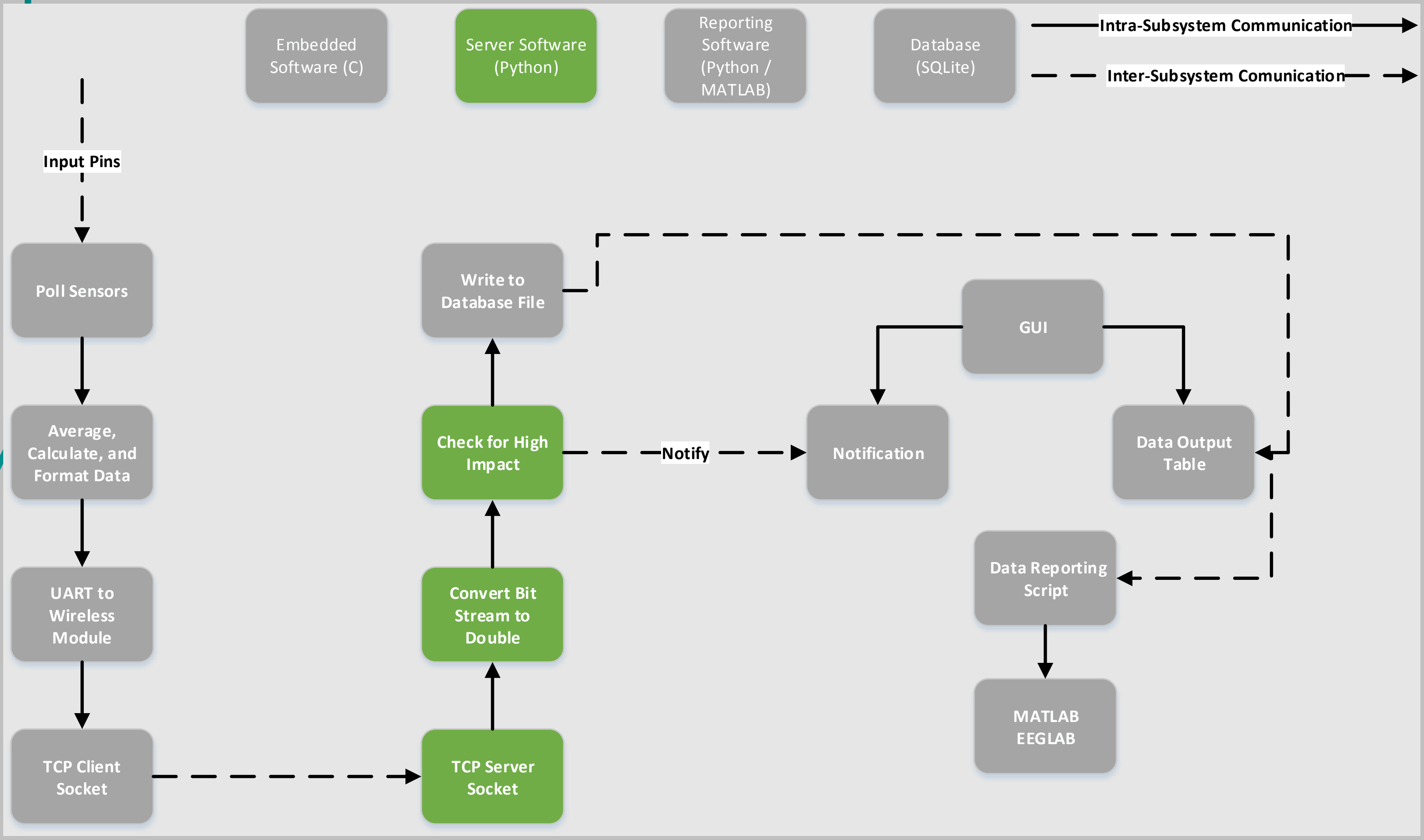
| Data | Type | Unit | Number | Calculations |
|---|---|---|---|---|
| Accelerometer | Double precision floating point | Meters per second | 3 per third second interval; X, Y, Z axes | Average over one second, convert m/s to g-force value, check for high impact threshold |
| EEG | Double precision floating point | Hertz | 5 per third second interval; Alpha, beta, gamma, delta, theta waves | Average over one second |

# Data Packaging and Sending

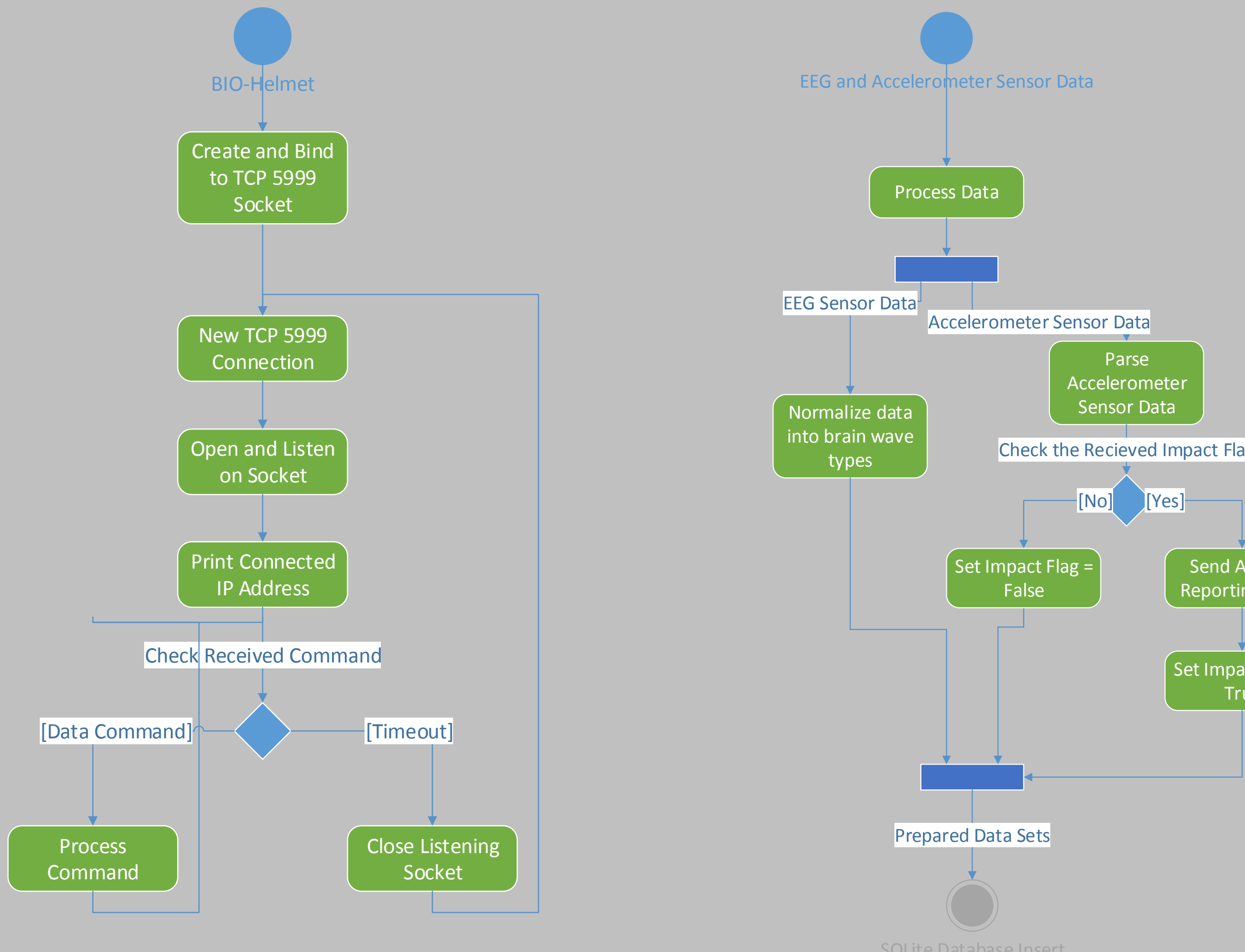
- Comma separated string is built and written to the MCU to wireless communication UART once every second
- Wireless module
  - Packs received data string into TCP packet
  - Sent over TCP port 5999 to local server for reporting and analysis

| Helmet ID | X-axis (m/s) | Y-axis (m/s) | Z-axis (m/s) | G-force (g's) | High Impact (Bool) | Alpha (Hertz) | Beta (Hertz) | Gamm a (Hertz) | Delta (Hertz) | Theta (Hertz) |
|---|---|---|---|---|---|---|---|---|---|---|

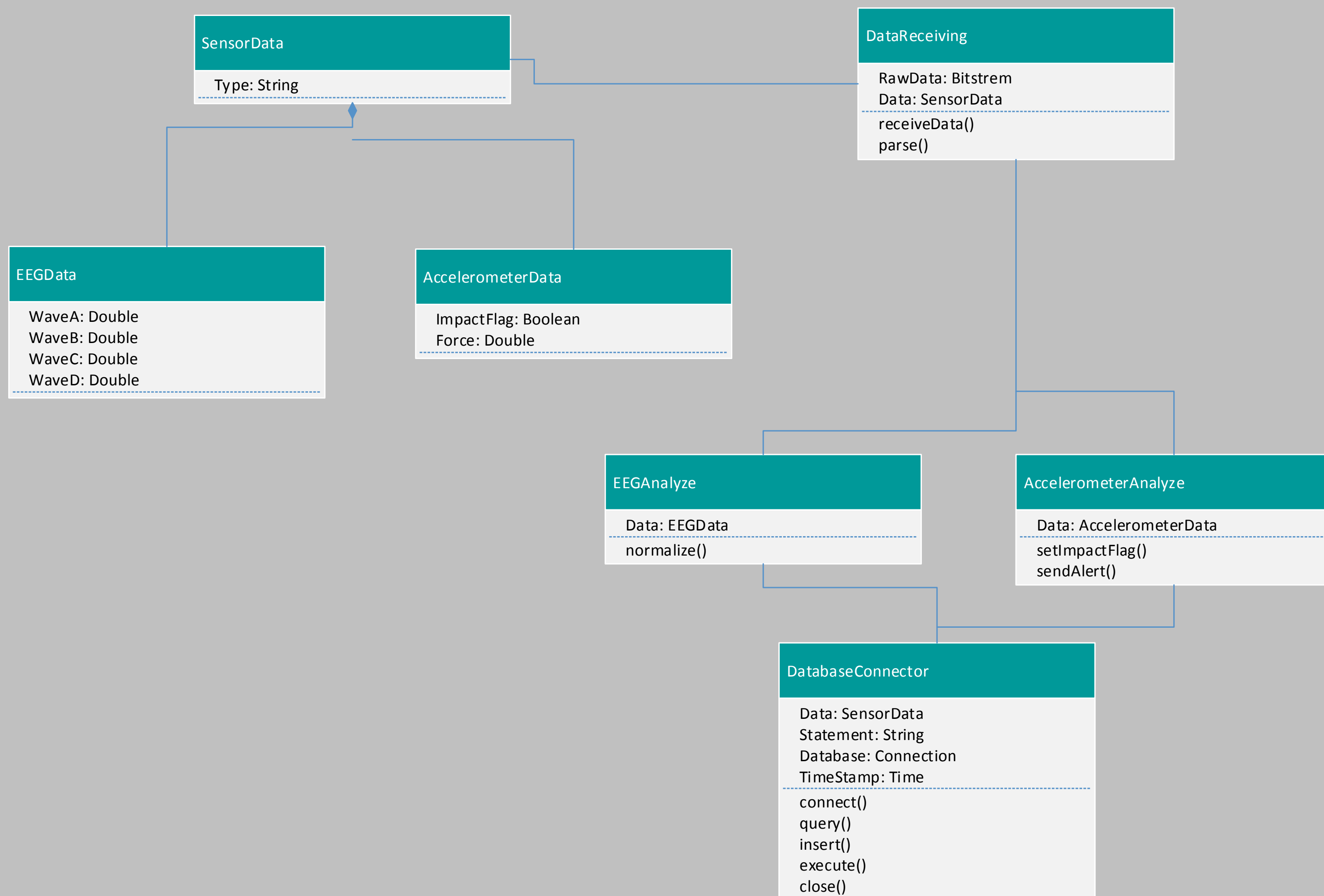
# Server Software



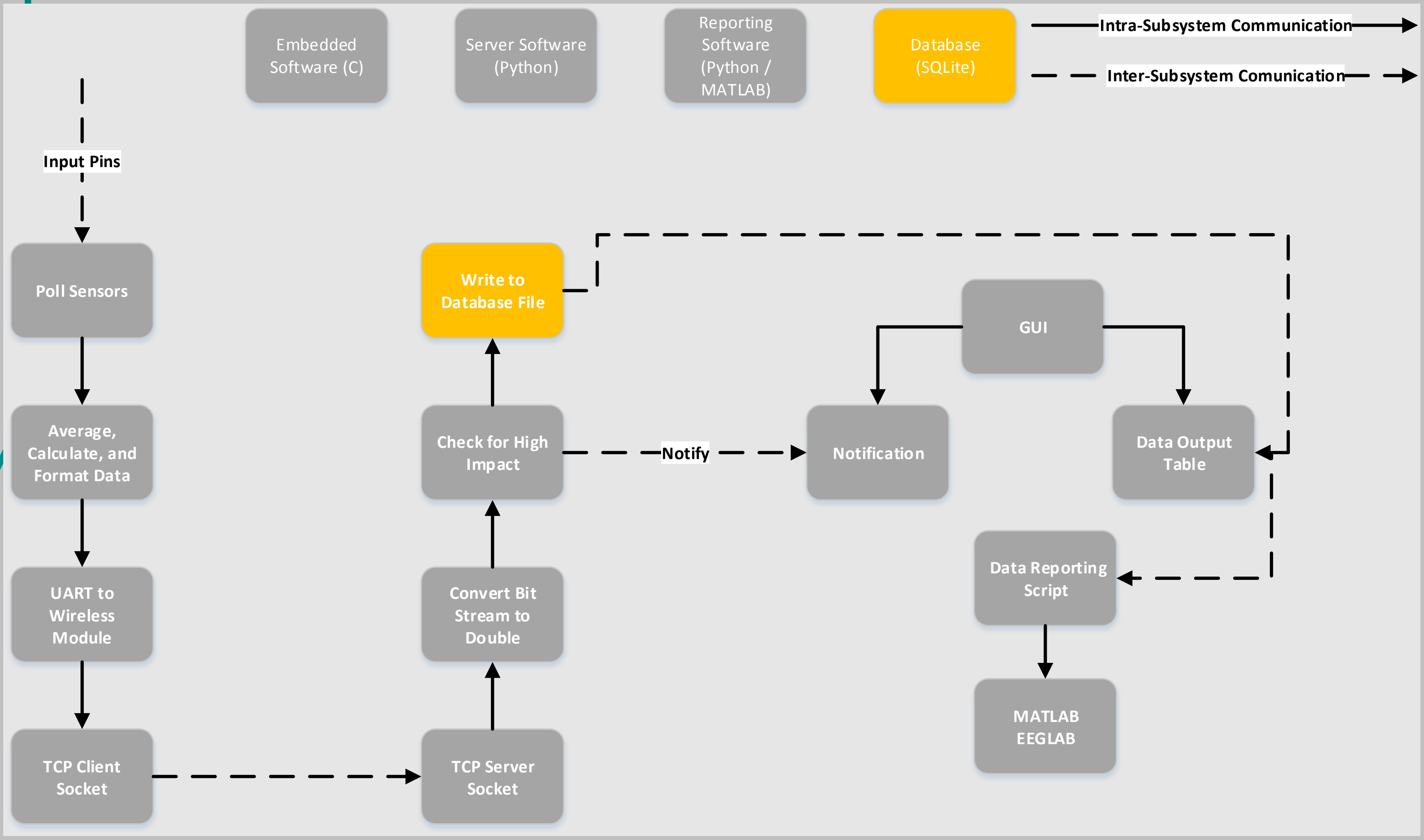
# Data Receiving Script Activity Diagram



# Data Receiving Script Class Diagram



# Database


Embedded Software (C)
Server Software (Python)
Reporting Software (Python / MATLAB)
Database (SQLite)
Intra-Subsystem Communication
Inter-Subsystem Comunication
Input Pins
Poll Sensors
Average, Calculate, and Format Data
UART to Wireless Module
TCP Client Socket
TCP Server Socket
Convert Bit Stream to Double
Check for High Impact
Write to Database File
Notify
Notification
GUI
Data Output Table
Data Reporting Script
MATLAB EEGLAB

# Database Structure

- SQLite based database
  - Stored in a single .db file
  - Cross platform
  - No installation necessary

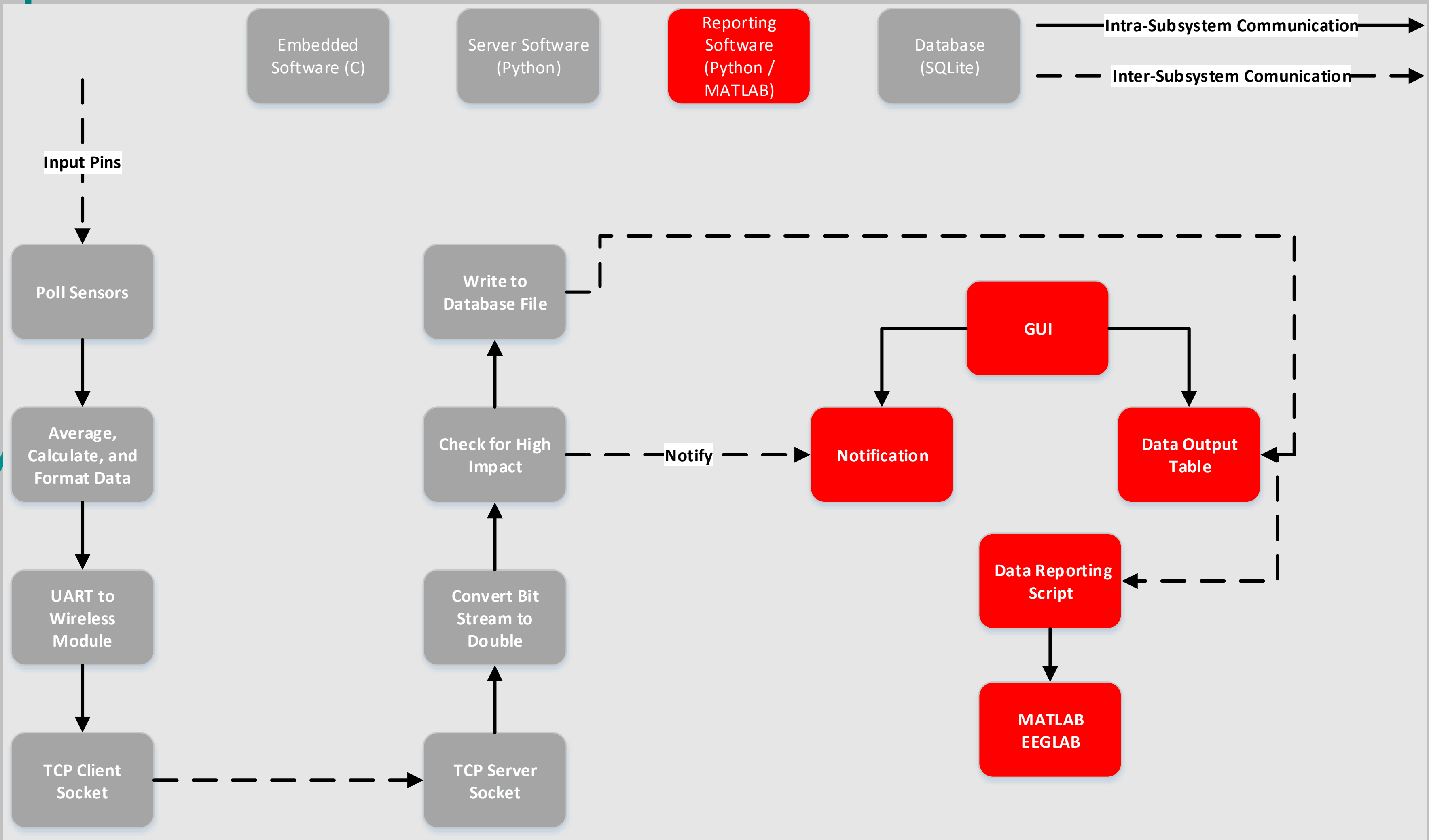
BIO-Helmet

| Accelerometer |
| --- |
| Time: TEXT |
| Force: REAL |
| HighImpact: BOOLEAN |

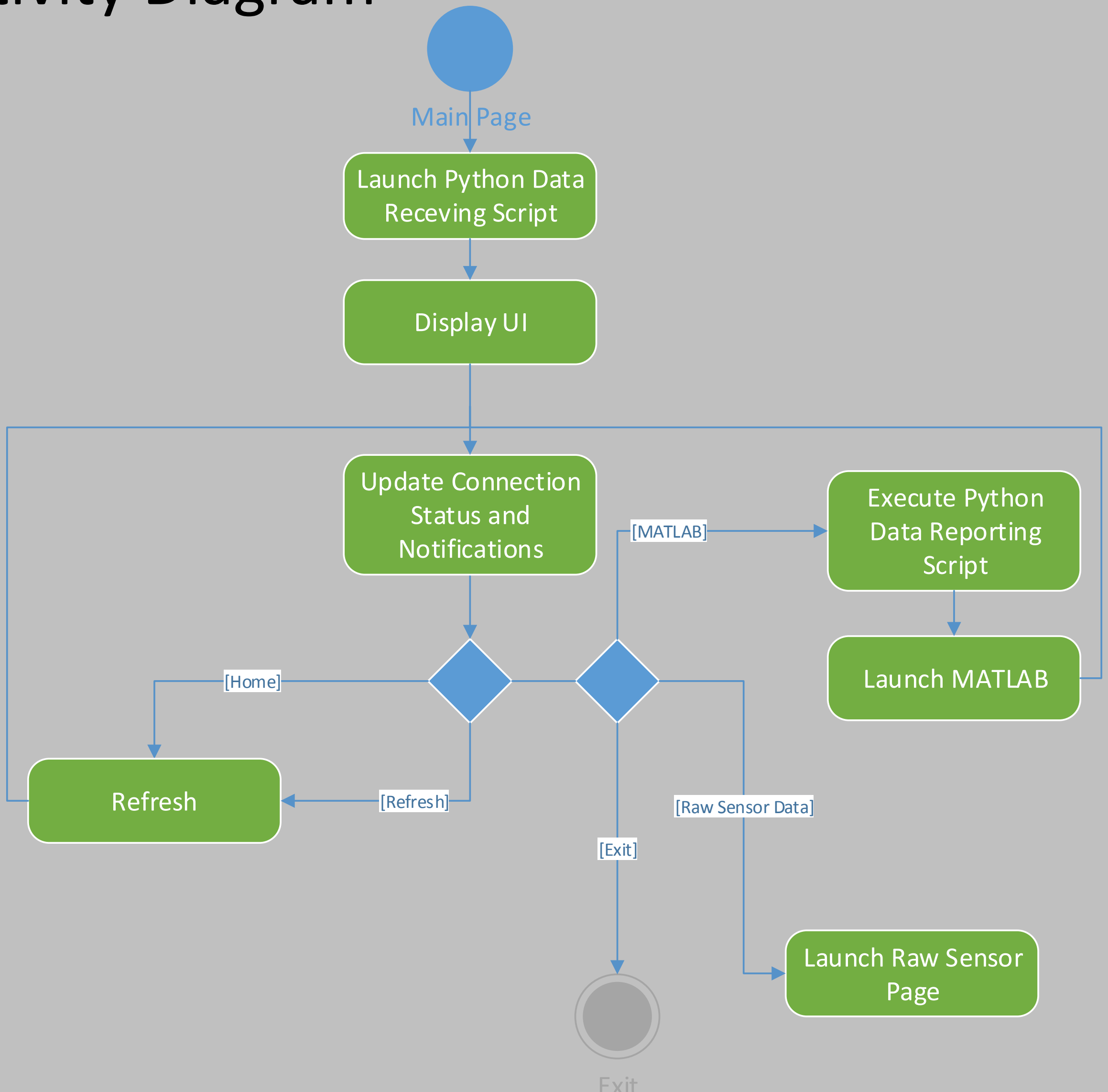
| EEG |
| --- |
| Time:TEXT |
| Alpha: REAL |
| Beta: REAL |
| Delta: REAL |
| Gamma: REAL |
| Theta: REAL |

- Time stored in format: YYYY-MM-DD HH:MM:SS

# Reporting Software

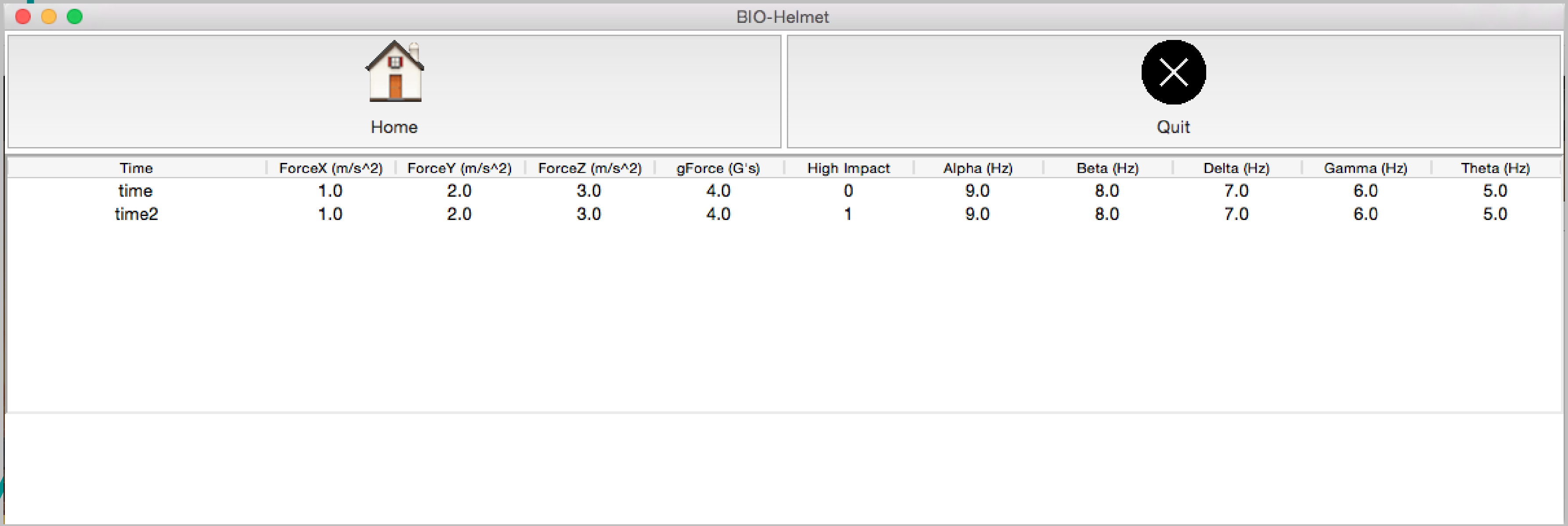


# GUI Activity Diagram



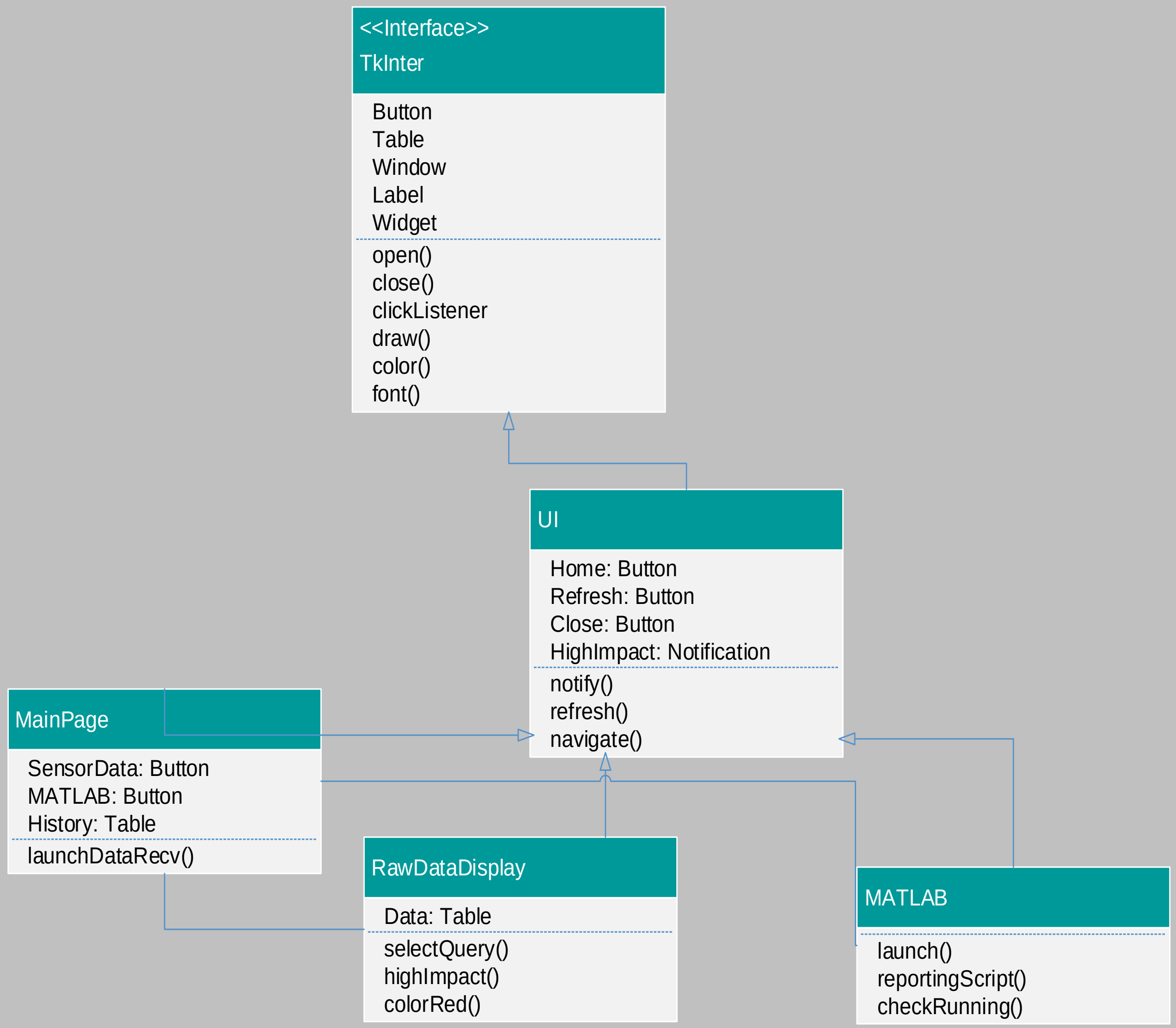
# GUI Home Page

# GUI Raw Sensor Data Page



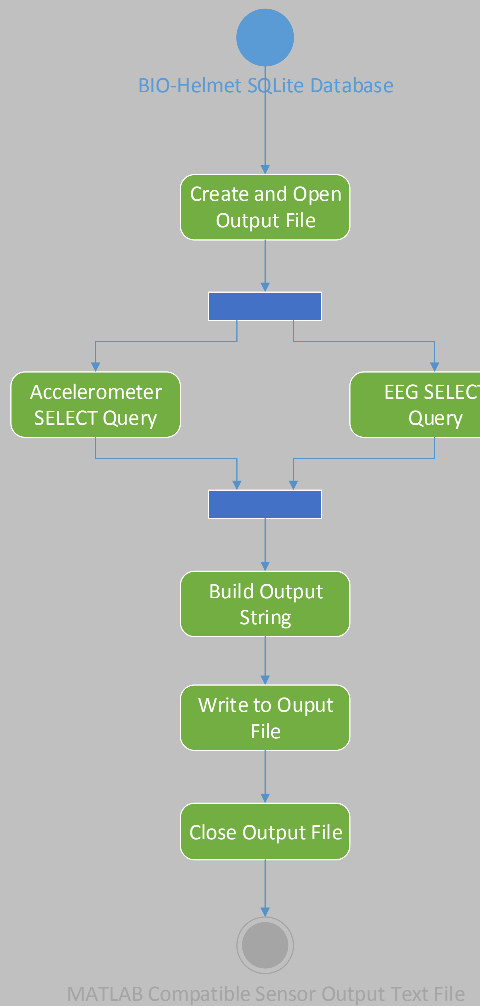

| Time | ForceX (m/s^2) | ForceY (m/s^2) | ForceZ (m/s^2) | gForce (G's) | High Impact | Alpha (Hz) | Beta (Hz) | Delta (Hz) | Gamma (Hz) | Theta (Hz) |
|---|---|---|---|---|---|---|---|---|---|---|
| time | 1.0 | 2.0 | 3.0 | 4.0 | 0 | 9.0 | 8.0 | 7.0 | 6.0 | 5.0 |
| time2 | 1.0 | 2.0 | 3.0 | 4.0 | 1 | 9.0 | 8.0 | 7.0 | 6.0 | 5.0 |

# GUI Class Diagram

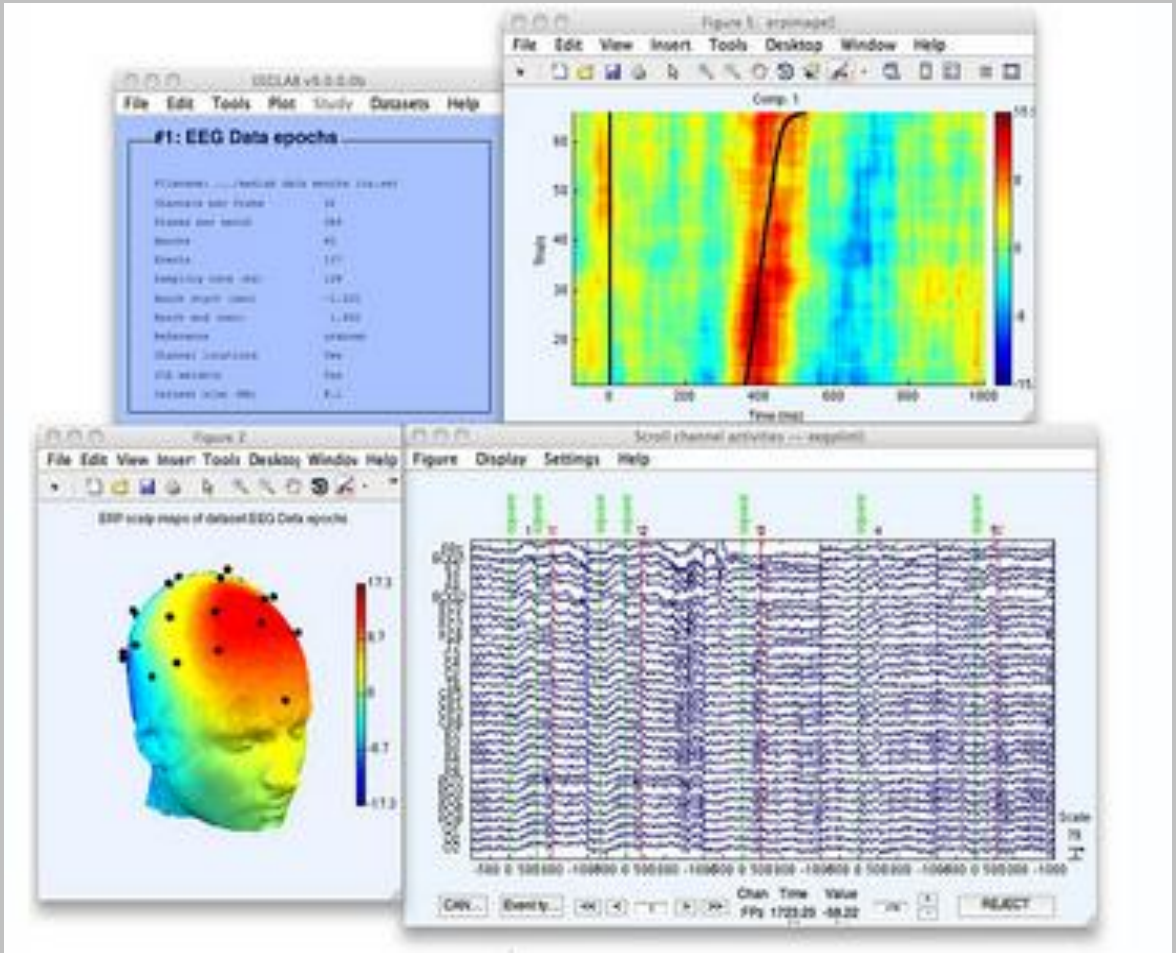


# Data Reporting Script

- Dumps SQLite database to a MATLAB compatible text file



# MATLAB EEGLAB




MATLAB EEGLAB; reprinted with permission from EEGLAB

# Design constraints (environmental, social, etc.)

- Economic and Time Constraints
  - Time and money, always seems short
- Environmental Constraint
  - Built out of materials that will greatly reduce possible damages both in research and development as well disposal of our product once it is obsolete
- Social Constraints
  - Loss of compensation due to injuries
- Political
  - Loss of privacy

# Hardware Related Standards

| | |
|---|---|
| IEEE 1625-2008 | IEEE Standard for Rechargeable Batteries for Multi-Cell Mobile Computing Devices |
| IEEE 1680.1-2009 | IEEE Standard for Environmental Assessment of Personal Computer Products, Including Notebook Personal Computers, Desktop Personal Computers, and Personal Computer Displays |
| IEEE 2010-2012 | IEEE Recommended Practice for Neurofeedback Systems |
| IEEE 1686-2013 | IEEE Standard for Intelligent Electronic Devices Cyber Security Capabilities |

# Software Related Standards

| | |
|---|---|
| BSR/IEEE 802.11ac-201x | • Wireless communication standard for WLAN<br>• All Wi-Fi products interoperable |
| ISO/IEC 14766:1997 | • Transmission Control Protocol<br>• Reliable data transfer on TCP/IP stack<br>• Standard communication protocol between devices |
| RS232 | • UART serial communication standard<br>• Used for debug interface<br>• Used for communication between MCU and Wi-Fi Module |
| PEP 8 | • Style guidelines for Python code<br>• BIO-Helmet server side code written in Python |
| PEP 249 | • Interaction of Python code and SQL based databases<br>• Server programs interact with SQLite database |

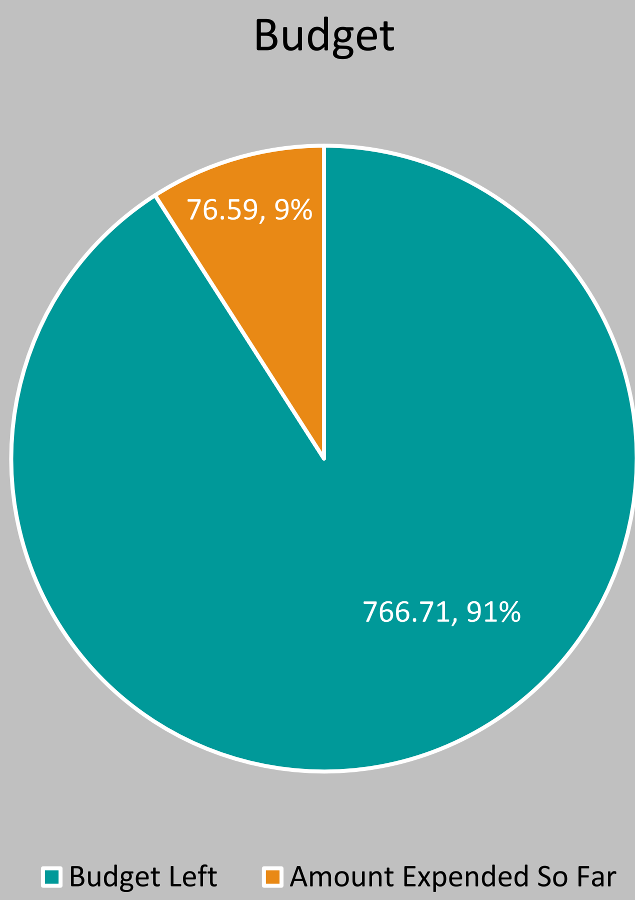
# Budget and Financing

- BOM
- Total Budget= $843.30

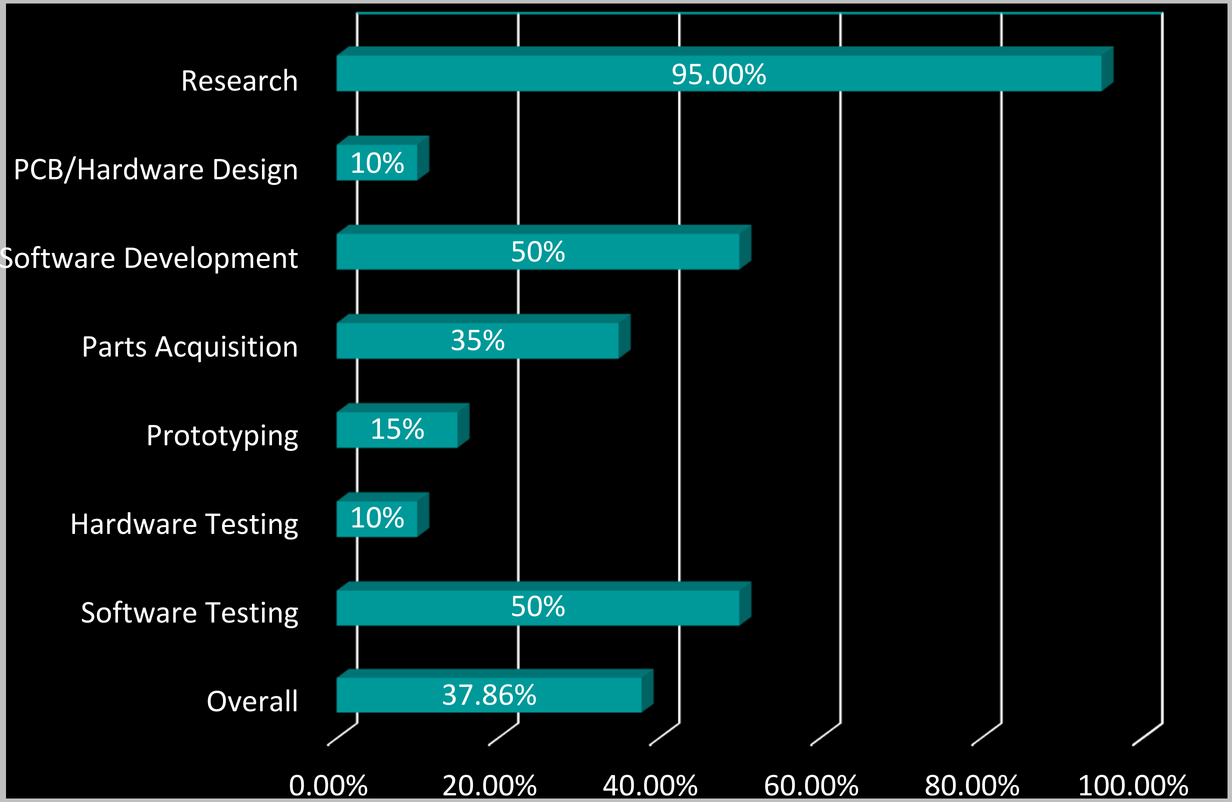
| Accelerometer Sensor | | | | |
|---|---|---|---|---|
| **Part** | Cost | Quantity | Total | Vendor |
| **ADXL377** | $11.49 | 1 | $11.49 | Analog Devices |
| **Capacitor SM** | $0.24 | 4 | $0.96 | Digi Key |
| **EEG Sensors** | | | | |
| **Part** | Cost | Quantity | Total | Vendor |
| **COM-10969** | $7.95 | 2 | $15.90 | SparkFun |
| **TL084cdr** | $0.50 | 4 | $2.00 | Texas Instruments |
| **INA114** | $11.59 | 4 | $46.36 | Texas Instruments |
| **PRT-00124 ROHS** | $6.95 | 3 | $20.85 | SparkFun |
| **709-1110-ND** | $53.98 | 1 | $53.98 | Digi Key |
| **511-L7805CV** | $0.48 | 1 | $0.48 | Mouser Electronics |
| **445-10G-48TP** | $85 | 1 | $85 | Jari Supply |
| **Wi-Fi Module** | | | | |
| **Part** | Cost | Quantity | Total | Vendor |
| **CC3100** | $14.07 | 1 | $14.07 | Texas Instruments |
| **Microprocessor** | | | | |
| **Part** | Cost | Quantity | Total | Vendor |
| **TM4C123GH6PI7** | $11.42 | 1 | $11.42 | Texas Instruments |
| **Power Supply** | | | | |
| **Part** | Cost | Quantity | Total | Vendor |
| **MCP73833** | $0.85 | 1 | $0.85 | Microchip |
| **Battery** | $29.50 | 1 | $29.50 | Adafruit |
| **LED** | $0.35 | 3 | $1.05 | Sparkfun |
| **Resistor SM** | $0.10 | 6 | $0.60 | Mouser |
| **Micro USB SM** | $1.50 | 1 | $1.50 | SparkFun |
| **JST SM** | $0.95 | 1 | $0.95 | SparkFun |
| **Capacitor SM** | $0.24 | 2 | $0.48 | Digi Key |
| **Misc /Software** | | | | |
| **Helmet** | $169.00 | 1 | $169.00 | |
| **MATLAB License** | $49.00 | 1 | $49.99 | |
| | Total Cost: | | $516.43 | |

# Budget and Finance

- Sponsorship by Boeing
- Cost of Development
- Unexpected Cost



# Current Project Progress



# Immediate plans for a successful completion

**April 29, 2015**
- Start ordering all parts

**May 15,2015**
- Start building prototype
- Start Programming

**June 15, 2015**
- Have all individual parts working properly

**June 16, 2015**
- Integration
- Work out any kinks

**July 20, 2015**
- Prepare for presentation

# Issues

- Hardware Design Issues
  - Changes from reference design
  - Efficiency
- GUI notification subsystem
  - Query database at set interval?
  - Communicate between Python scripts?
- MATLAB EEGLAB Text File format?
  - Accepts ASCII .txt
  - CSV, line separated?

# Questions?