Dwight Look College of
ENGINEERING
TEXAS A&M UNIVERSITY

Driver Drowsiness Detection System

Team: Dakota Mouton, Ali Imran, Coady Lewis

Problem: Driver Drowsiness

Driving fatigue has been a major cause of accidents on the road. Truck drivers are at a greater risk of driver fatigue because of the long hours spent driving.

Solution: DDDS

- Solution proposal: Our Driver Drowsiness Detection System will use a machine learning (ML) algorithm and electroencephalogram (EEG) device to determine a driver's level of fatigue and alert the driver to rest.

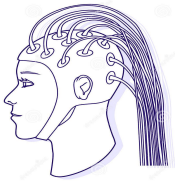
System Overview

EEG

- Filter out unwanted frequencies.
- Take in brain waves in microvolts and amplify them to volts.
- Send data to MCU

MCU

- Receive incoming signals from EEG
- Send data to computer running ML algorithm



Dakota

Simulator

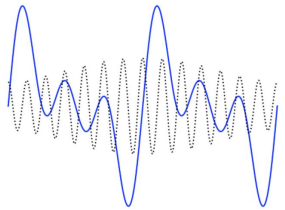
- Collect data
- Muse 2 EEG device

Signal Processor

- Perform live analysis of signals
- Process raw EEG signals

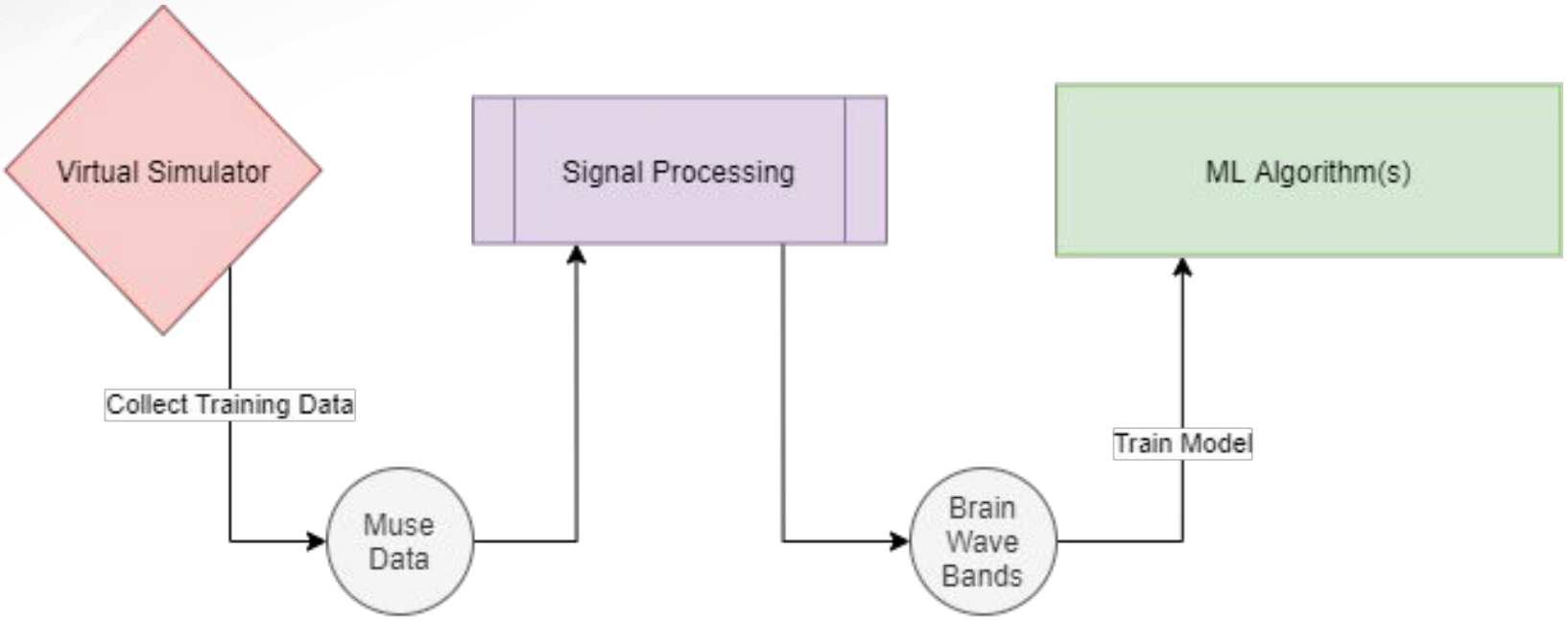
ML Algorithm

- Input processed EEG signals
- Output fatigue state of user



Team 2: Coady and Ali

Signal Processing -> ML Algorithm



Data Collection

Simulator:

- Steering wheel and pedals
- American Truck Simulator

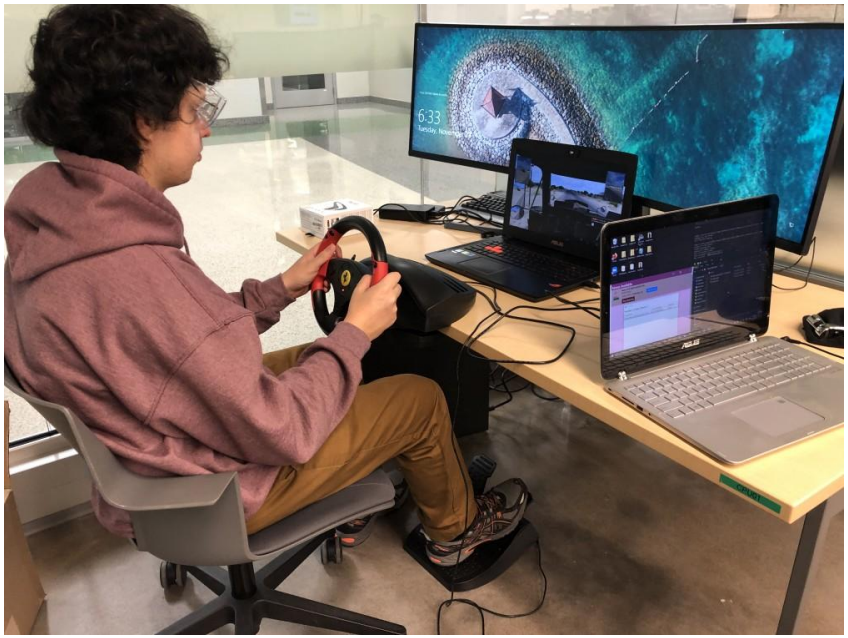
Data Collected (Muse + Simulator):

- 4 electrode EEG
- Ali: 8 hours awake/drowsy
- Ali/Coady: 4 hours awake/drowsy
    - 15 min/sample

Online Dataset:

- 40 electrode EEG
- ~4 hours awake/drowsy
    - 10 min/sample

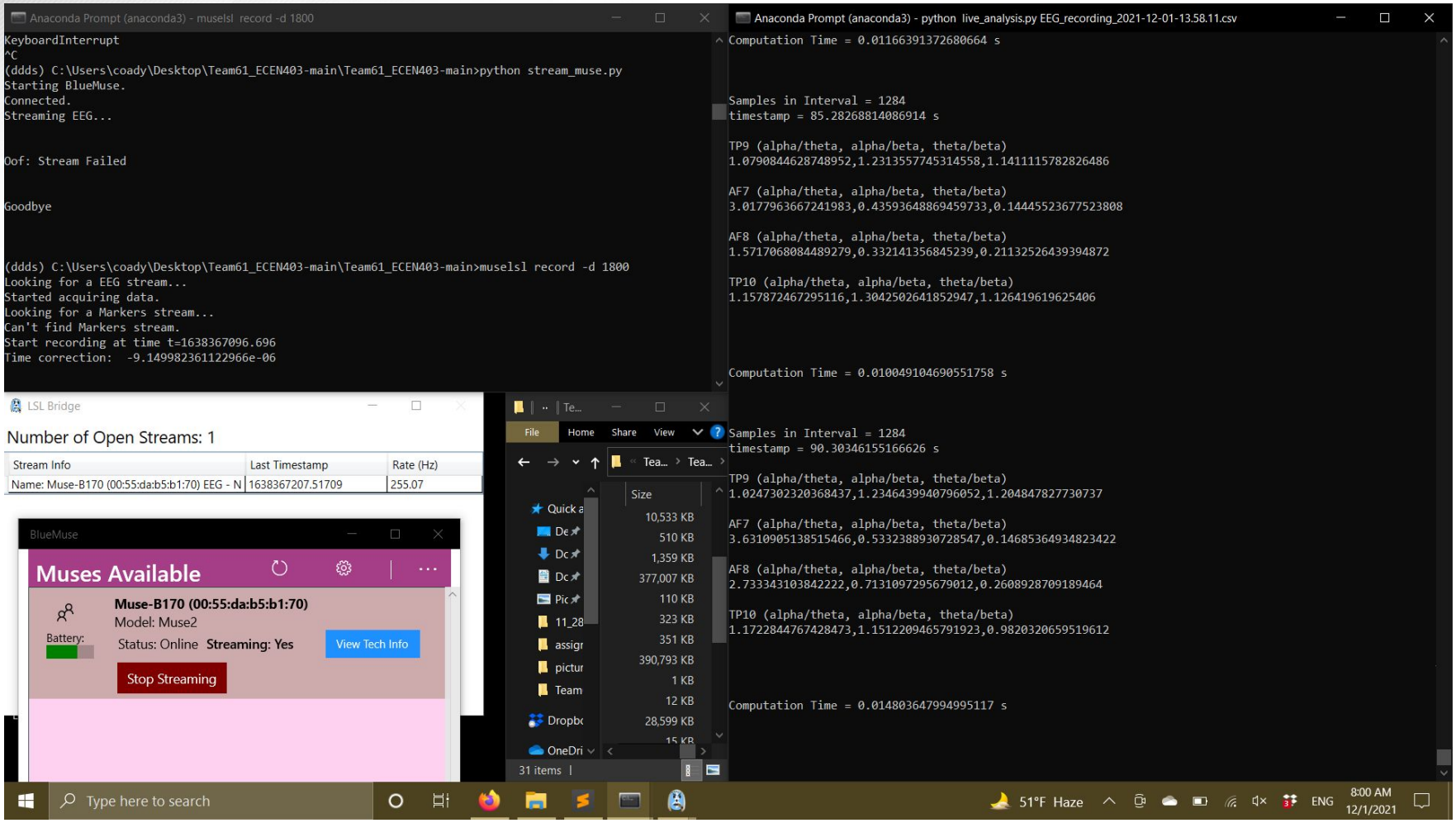
Data Collection



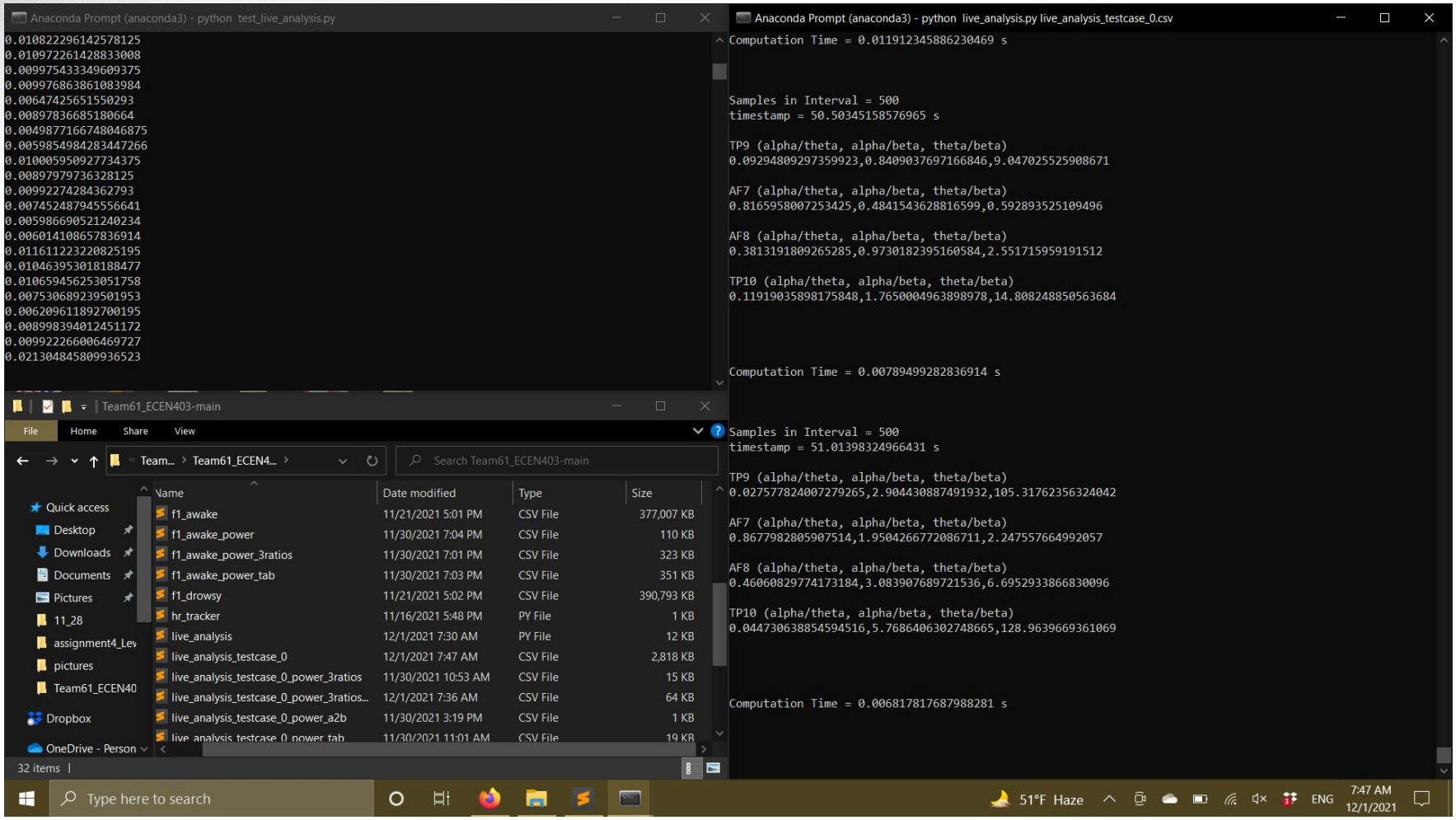
Signal Processing

- Real-time analysis program completed; Worked in demo
  - Computation time of <50 ms on a 5 second window at 256 Hz
  - Fast enough to run very short windows to increase response
    - Verified operation down to 0.5 second intervals at 1 kHz
    - Significantly better than validation plan spec of 10 seconds
    - Verified continuous operation for 40 min
- Added two more ratios to increase ML features
  - P_{Alpha}/P_{Theta}, P_{Alpha}/P_{Beta}, P_{Theta}/P_{Beta}
  - Experimented with regular power values, but got spikes.
- Using overlapped rectangular windows of 5s for training
  - wavelet transform yielded less accuracy from the ML
    - one test as low as 67%, compared to >80% STFT
  - Modified to handle up to 40 electrodes from online datasets

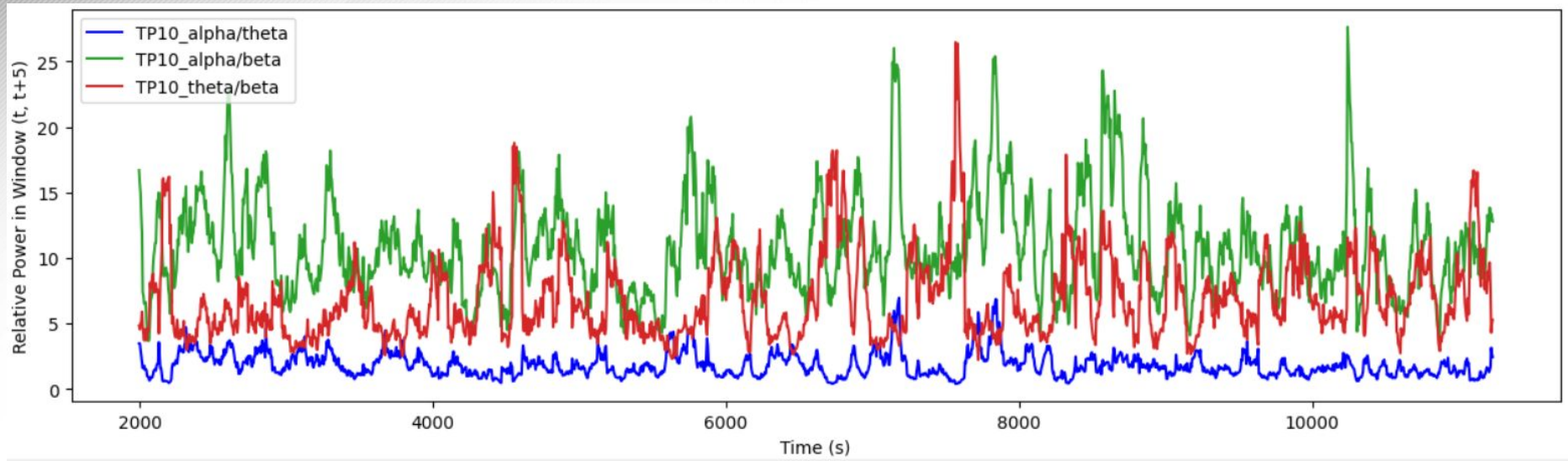
Signal Processing

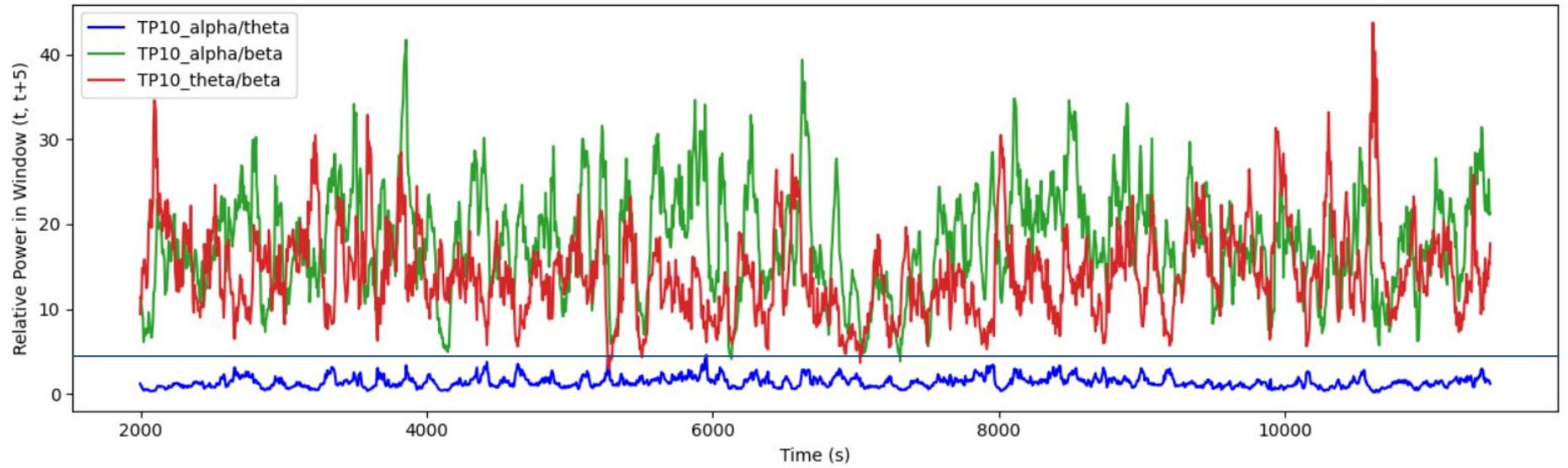


Signal Processing

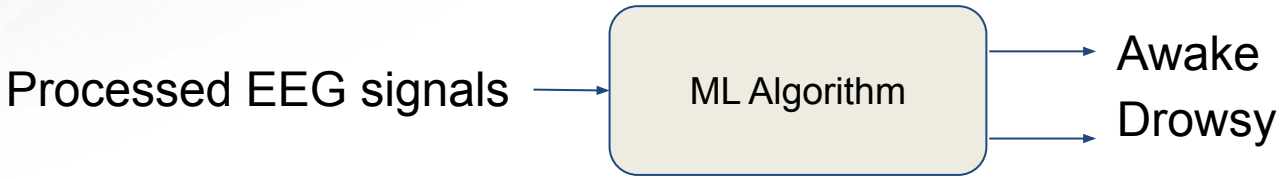


Signal Processing





Machine Learning



Models:

- Gaussian Naive Bayes
- Feedforward Neural Network
  - 4 layers: 1 input, 2 hidden, 1 output
- Kernel SVM
  - Radial basis function

ML Results

Accuracy:

- Target: 90%

	Dataset		
Model	8 Hours Ali	4 Hours Ali/Coady	Online Dataset
Naive Bayes	71.7	74.6	72.9
Neural Network	78.3	83.5	97.1
Kernel SVM	**83.5**	**85**	**97.3**

Neural Network:

```
[[2164  645]
 [ 401 3181]]
[0.80535914 0.8588013 ]
Total accuracy:  0.8353121665723426
```

Kernel SVM:

```
[[2245  618]
 [ 333 3195]]
[0.82521595 0.87045362]
Total accuracy:  0.8501883324862117
```

Prediction speed:

- Target: < 10 seconds on 30 seconds of data
- Neural Network: ~0.005 s (5 ms)
- Kernel SVM: ~0.05 s (50 ms)

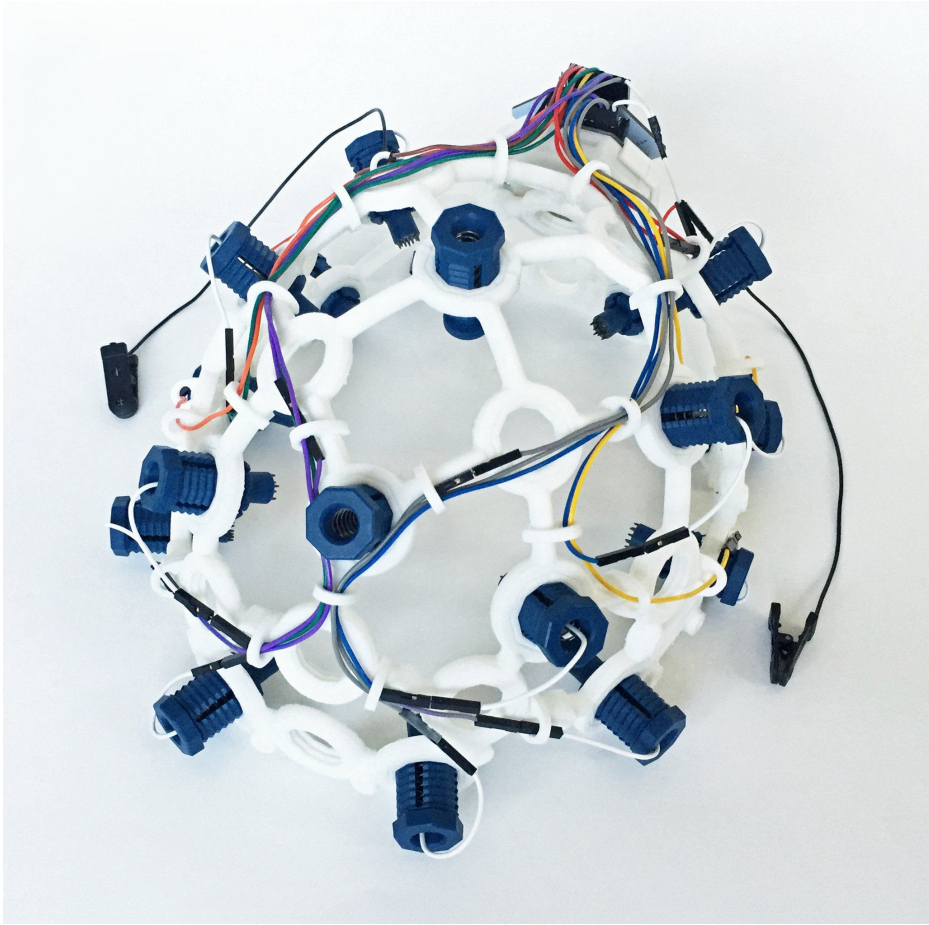
EEG Subsystem

Power System

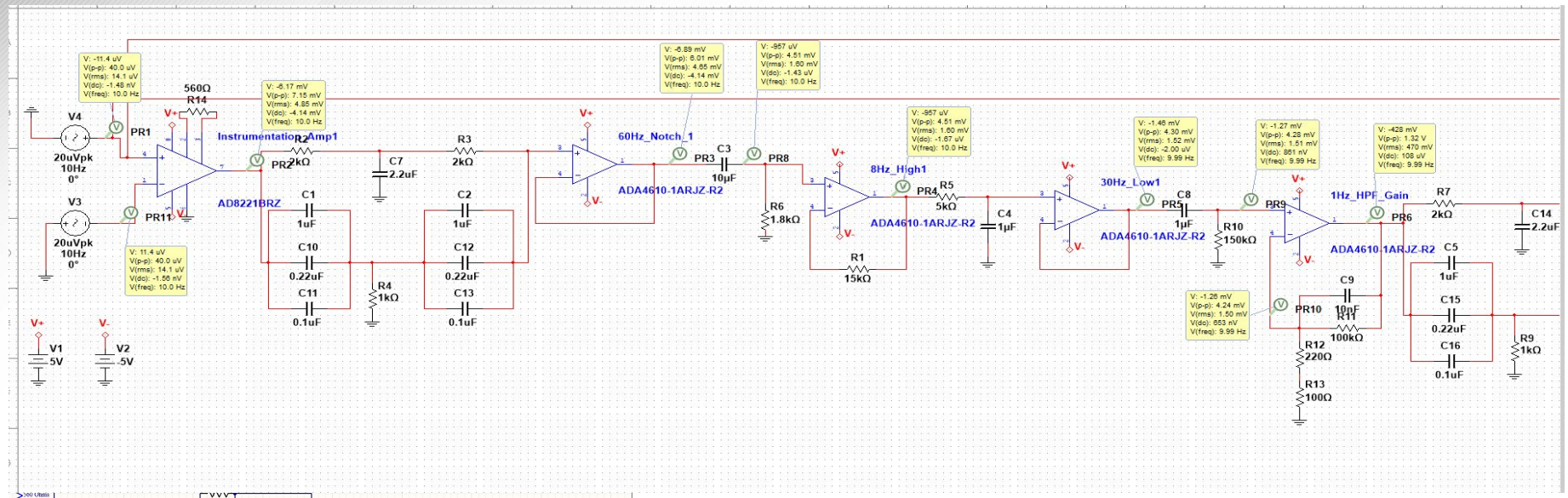
- 4 AA Batteries (6V total)
- Buck-boost convertor
- Use +-5V for components

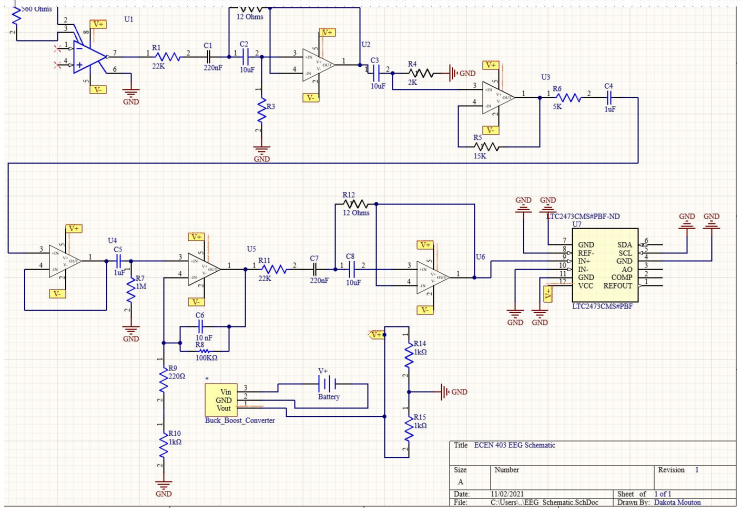
Main Components

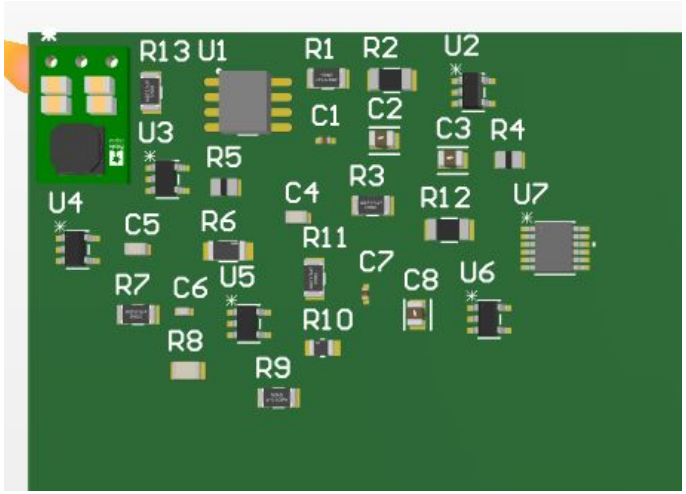
- AD8221 Instrumentation Amp
- 5 ADA4610 Op Amps
- 8 dry electrodes



EEG Subsystem





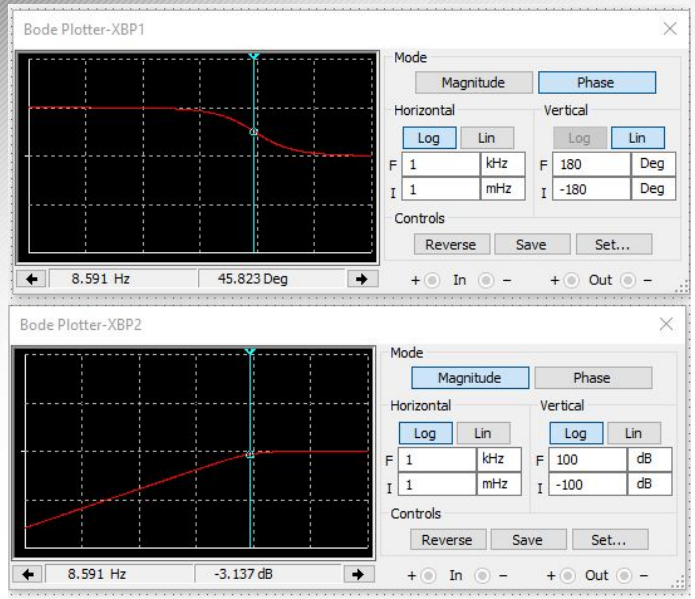


EEG Subsystem: Test Results

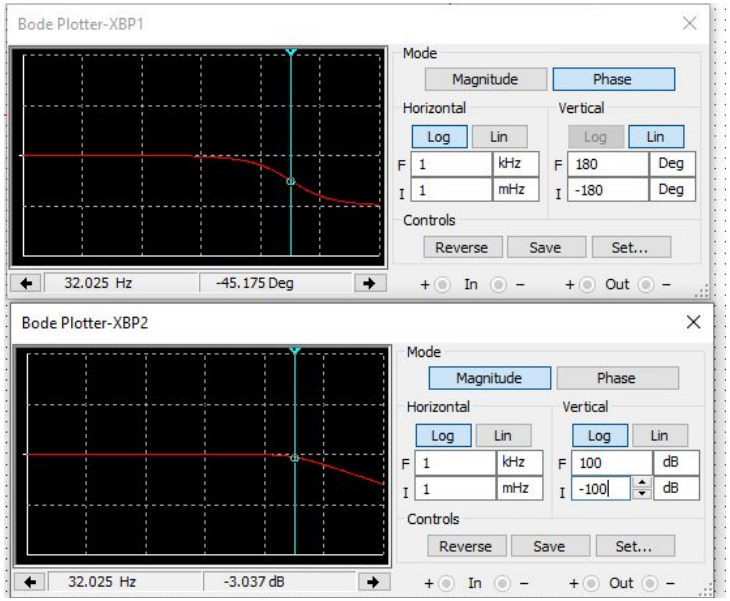
8Hz_HPF								
Input Frequency: (Hz)	Input Voltage: (mV)	RMS Voltage: (mV)	Cut-off Frequency: (Hz)	Phase shift: (Deg)	Magnitude: (dB)	Output Voltage: (mV, RMS)	Output Voltage: (mV, Pk)	
5	5.85	4.14	8.591	45.823	-3.127	2.04		
5	10	7.07	8.591	45.823	-3.137	3.49		
5	20	14.1	8.591	45.823	-3.127	6.98		
10	5.85	4.14	8.167	47.271	-3.369	3.1		
15	5.85	4.14	8.591	45.823	-3.137	3.57		
15	10	7.07	8.591	45.823	-3.137	6.1		
15	20	14.1	8.591	45.823	-3.137	12.2		
30Hz_LPF								
Input Frequency: (Hz)	Input Voltage: (mV)	RMS Voltage: (mV)	Cut-off Frequency: (Hz)	Phase shift: (Deg)	Magnitude: (dB)	Output Voltage: (mV, RMS)	Output Voltage: (mV, Pk)	
10	5.85	4.14	32.025	-45.175	-3.037	3.95		
10	10	7.07	32.025	-45.175	-3.037	6.74		
10	20	14.1	32.025	-45.175	-3.037	13.5		
40	5.85	4.14	32.025	-45.175	-3.037	2.57		
40	10	7.07	32.025	-45.175	-3.037	4.39		
40	20	14.1	32.025	-45.175	-3.037	8.79		
60Hz_Notch Filters								
Input Frequency: (Hz)	Input Voltage: (mV)	RMS Voltage: (mV)	Cut-off Frequency: (Hz)	Phase shift: (Deg)	Magnitude: (dB)	Output Voltage: (mV, RMS)	Output Voltage: (mV, Pk)	
60	5.85	4.14	60.06	-19.319	-25.02	0.136		*from bode plots
60	5.85	4.14	63.096	-3.486	56	0.136		*from network analyzer
30	5.85	4.14	60.06	-19.319	-25.02	1.57		*from bode plots
30	5.85	4.14	60.06	-3.486	56	1.57		*from network analyzer
59	5.85	4.14	60.06	-19.319	-25.05	0.161		*from bode plots
1Hz_HPF								
Input Frequency: (Hz)	Input Voltage: (mV)	RMS Voltage: (mV)	Cut-off Frequency: (Hz)	Phase shift: (Deg)	Magnitude: (dB)	Output Voltage: (mV, RMS)	Output Voltage: (mV, Pk)	
1	5.85	4.14	0.975	45.378	46.467	863		
1	10	7.07	1.026	44.656	13.96	1180		
10	5.85	4.14	0.975	45.378	46.467	1200		
10	10	7.07	1.026	44.656	13.69	1270		
Full EEG Circuit								
Input Frequency: (Hz)	Input Voltage: (mV)	RMS Voltage: (mV)	Cut-off Frequency: (Hz)	Phase shift: (Deg)	Magnitude: (dB)	Output Voltage: (mV, RMS)	Output Voltage: (mV, Pk)	
10	0.02	0.0141	54.483	-203.193	29.532	396	1120	
30	0.02	0.0141	54.483	-203.193	29.532	99.3	237	
75	0.02	0.0141	60.286	-155.308	29.532	9.35	6.91	
100	0.02	0.0141	60.286	-155.308	29.532	15.4	33.2	
300	0.02	0.0141	60.286	-155.308	28.248	23.1	63	
1000	0.02	0.0141	60.286	-155.308	29.532	4.47	10.5	
10	0.03	0.0212	60.286	-155.308	29.532	594	1670	
100	0.03	0.0212	60.286	-155.308	29.532	19.1	49.2	

EEG Subsystem: Test Results (Sims)

8 Hz High Pass Filter

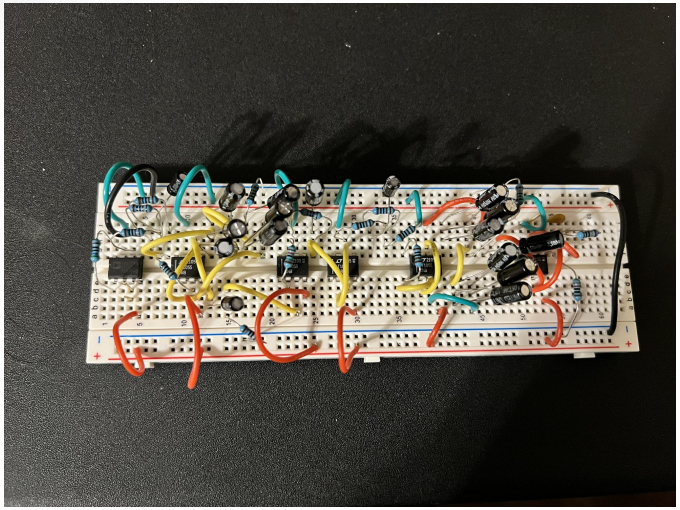


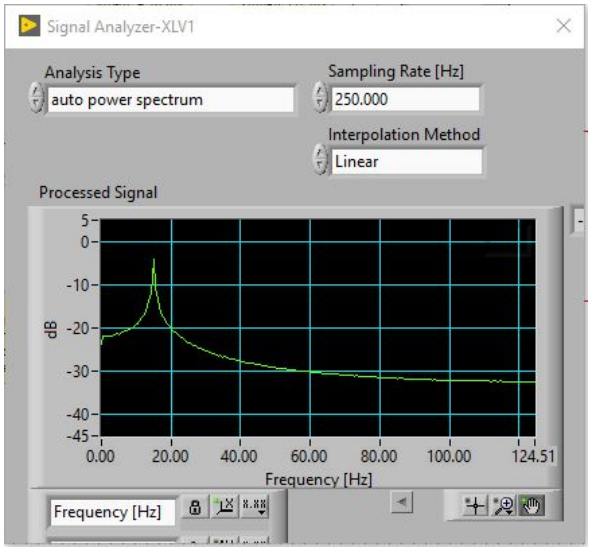
30 Hz Low Pass Filter

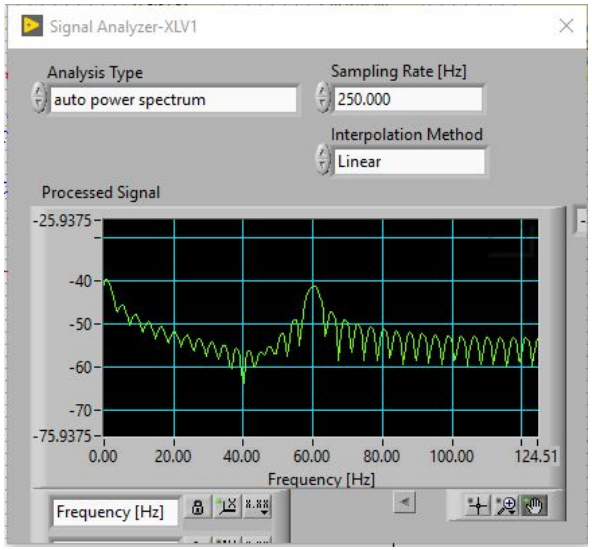


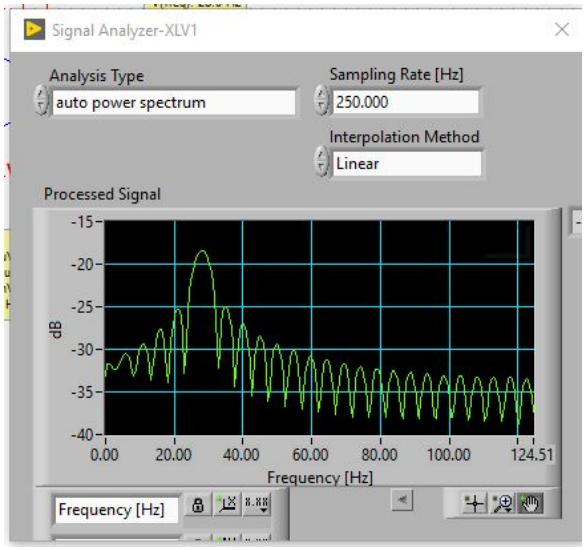
60 Hz Notch Filter

EEG Subsystem: Breadboard & Results









Execution Plan

Driver Drowsiness Detection System Schedule:

Work	End Date	Owner	Status
Create team	8/31/21	All	
Receive project details	9/3/21	All	
Talk with project sponsor	9/9/21	All	
Research	9/14/21	All	
ConOps Report	9/16/21	All	
Assign subsystems	9/21/21	All	
FSR Report	10/4/21	All	
ICD Report	10/4/21	All	
Decide best ML algorithm	10/8/21	Ali, Coady	
Test out Muse 2 device	10/12/21	Ali, Coady	
Create midterm presentation	10/12/21	All	
Get virtual simulator parts ordered	10/13/21	Ali, Coady	
Midterm Presentation	10/13/21	All	
Learn ML algorithm using basic tutorials and online datasets	10/17/21	Ali, Coady	
Create EEG filtering program	10/17/21	Ali, Coady	
Assemble virtual simulator rig	10/19/21	Ali, Coady	
Workout EEG Schematic in Altium for PCB	10/19/21	Dakota	
Finish Circuit Design of EEG	10/19/21	Dakota	
Collect training data from simulator	10/19/21	All	
Test filtering program off of collected data	10/20/21	Ali, Coady	
Get EEG device parts ordered	10/22/21	Dakota	
Have PCB Design Approved and Ready to Print	10/26/21	Dakota	
Create status update presentation	10/30/21	All	
Status Update Presentation	11/1/21	All	
Create ML algorithm off of collected data	11/2/21	Ali, Coady	
Connect EEG to Electrodes and Test	11/2/21	Dakota	
Validate and Troubleshoot EEG	11/2/21	Dakota	
Test ML algorithm with new simulator data	11/7/21	All	
Verify ML algorithm detection rate > 90%	11/14/21	Ali, Coady	
Finished Working EEG	11/23/21	Dakota	
Final validation checks for each subsystem	11/27/21	All	
Create final presentation	1130/21	All	
Final Presentation	12/01/21	All	
Finish final report	12/4/21	All	
Final Report	12/5/21	All	

- Completed
- On Schedule
- Behind

Validation plan

Driver Drowsiness Detection Validation Plan:

Task	Specification	Result	Owner
ML Algorithm drowsiness detection	>90% success rate		Ali, Coady
Performance of data collection and processing every interval: • EEG data collection • Transfer and signal processing • Fatigue state output	< 30 seconds < 10 seconds < 10 seconds < 10 seconds		All Dakota Sam Ali, Coady
EEG Filters below 8 Hz	f>=8 Hz	See screenshots	Dakota
EEG Filters Above 30 Hz	f<=30 Hz	See screenshots	Dakota
Gain from Instrumentation Amplifier close to 100	G = 80+	G = 1+49,400/Rg, Rg = 560 Ohms, G = 89.2	Dakota
Final voltage readings have amplified from microvolts to volts	0.148<V<0.81172 But V<1 Input 15 Hz, 30uV	Vrms = 0.148 V, Vpk = 0.417 V	Dakota
Final voltage readings have amplified from microvolts to volts (Max and Min Readings)	Max Input: 10 Hz, 30uV Min Input: 1000 Hz, 20 uV	Max: Vrms = 0.594 V, Vpk = 1.67 V Min: Vrms = 4.47 mV, Vpk = 10.5 mV	Dakota
System voltage input	6 V	Regulated to +-5V	All
Peak Power Consumption	2 W		All