



# Driver Drowsiness Detection System

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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



Dakota

## MCU

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

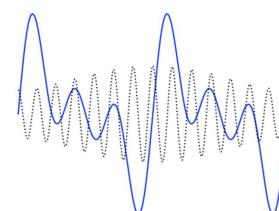


## Simulator

- Collect data
- Muse 2 EEG device

## Signal Processor

- Perform live analysis of signals
- Process raw EEG signals



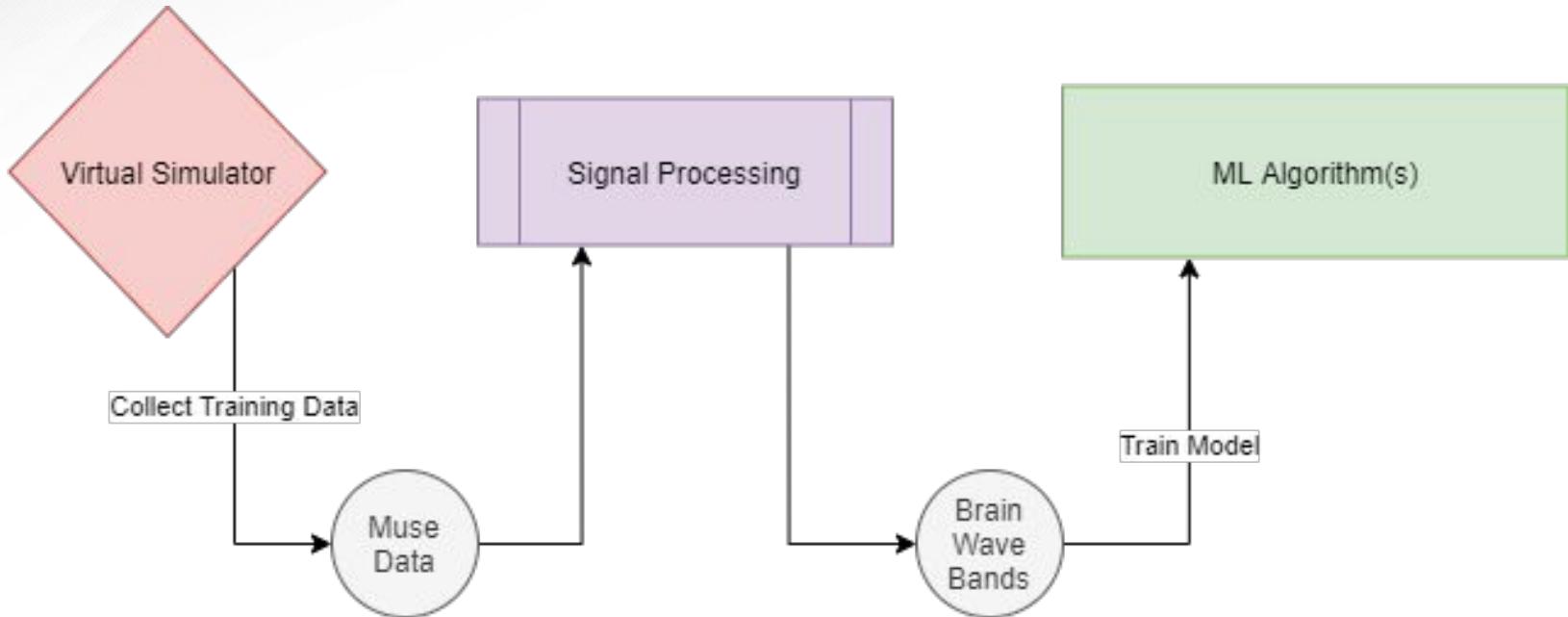
## ML Algorithm

- 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
  - $P_{\text{Alpha}}/P_{\text{Theta}}$ ,  $P_{\text{Alpha}}/P_{\text{Beta}}$ ,  $P_{\text{Theta}}/P_{\text{Beta}}$
  - 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

Anaconda Prompt (anaconda3) - muselsl record -d 1800

```

KeyboardInterrupt
^C
(ddds) C:\Users\coady\Desktop\Team61_ECEN403-main\Team61_ECEN403-main>python stream_muse.py
Starting BlueMuse.
Connected.
Streaming EEG...

Oof: Stream Failed

Goodbye

(ddds) C:\Users\coady\Desktop\Team61_ECEN403-main\Team61_ECEN403-main>muselsl record -d 1800
Looking for a EEG stream...
Started acquiring data.
Looking for a Markers stream...
Can't find Markers stream.
Start recording at time t=1638367096.696
Time correction: -9.149982361122966e-06
  
```

Anaconda Prompt (anaconda3) - python live\_analysis.py EEG\_recording\_2021-12-01-13.58.11.csv

```

Computation Time = 0.01166391372680664 s

Samples in Interval = 1284
timestamp = 85.28268814086914 s

TP9 (alpha/theta, alpha/beta, theta/beta)
1.0790844628748952,1.2313557745314558,1.1411115782826486

AF7 (alpha/theta, alpha/beta, theta/beta)
3.0177963667241983,0.43593648869459733,0.14445523677523808

AF8 (alpha/theta, alpha/beta, theta/beta)
1.5717068084489279,0.332141356845239,0.21132526439394872

TP10 (alpha/theta, alpha/beta, theta/beta)
1.157872467295116,1.3042502641852947,1.126419619625406

Computation Time = 0.010049104690551758 s
  
```

LSL Bridge

Number of Open Streams: 1

Stream Info	Last Timestamp	Rate (Hz)
Name: Muse-B170 (00:55:da:b5:b1:70) EEG - N	1638367207.51709	255.07

BlueMuse

Muses Available

- Muse-B170 (00:55:da:b5:b1:70)  
Model: Muse2  
Status: Online Streaming: Yes [View Tech Info](#)

Stop Streaming

Type here to search

File Home Share View ? Samples in Interval = 1284 timestamp = 90.30346155166626 s

Size

- TP9 (alpha/theta, alpha/beta, theta/beta)  
1.0247302320368437,1.2346439940796052,1.204847827730737
- AF7 (alpha/theta, alpha/beta, theta/beta)  
3.6310905138515466,0.5332388930728547,0.14685364934823422
- AF8 (alpha/theta, alpha/beta, theta/beta)  
2.733343103842222,0.7131097295679012,0.2608928709189464
- TP10 (alpha/theta, alpha/beta, theta/beta)  
1.1722844767428473,1.1512209465791923,0.9820320659519612

Computation Time = 0.014803647994995117 s

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# Signal Processing

```
0.01082296142578125
0.010972261428833008
0.009975433349609375
0.009976863861083984
0.00647425651550293
0.00897836685180664
0.0049877166748046875
0.0059854984283447266
0.010005950927734375
0.00897979736328125
0.00992274284362793
0.007452487945556641
0.005986690521240234
0.006014108657836914
0.011611223220825195
0.010463953018188477
0.010659456253051758
0.007530689239501953
0.006209611892700195
0.008998394012451172
0.009922266006469727
0.021304845809936523

Anaconda Prompt (anaconda3) - python test_live_analysis.py
Computation Time = 0.011912345886230469 s

Samples in Interval = 500
timestamp = 50.50345158576965 s

TP9 (alpha/theta, alpha/beta, theta/beta)
0.09294809297359923, 0.8409037697166846, 9.047025525908671

AF7 (alpha/theta, alpha/beta, theta/beta)
0.8165958007253425, 0.4841543628816599, 0.592893525109496

AF8 (alpha/theta, alpha/beta, theta/beta)
0.3813191809265285, 0.9730182395160584, 2.551715959191512

TP10 (alpha/theta, alpha/beta, theta/beta)
0.11919035898175848, 1.765004963898978, 14.808248850563684

Computation Time = 0.00789499282836914 s

Anaconda Prompt (anaconda3) - python live_analysis.py live_analysis_testcase_0.csv
Computation Time = 0.006817817687988281 s

Samples in Interval = 500
timestamp = 51.01398324966431 s

TP9 (alpha/theta, alpha/beta, theta/beta)
0.027577824007279265, 2.904430887491932, 105.31762356324042

AF7 (alpha/theta, alpha/beta, theta/beta)
0.8677982805907514, 1.9504266772086711, 2.247557664992057

AF8 (alpha/theta, alpha/beta, theta/beta)
0.46060829774173184, 3.083907689721536, 6.6952933866830096

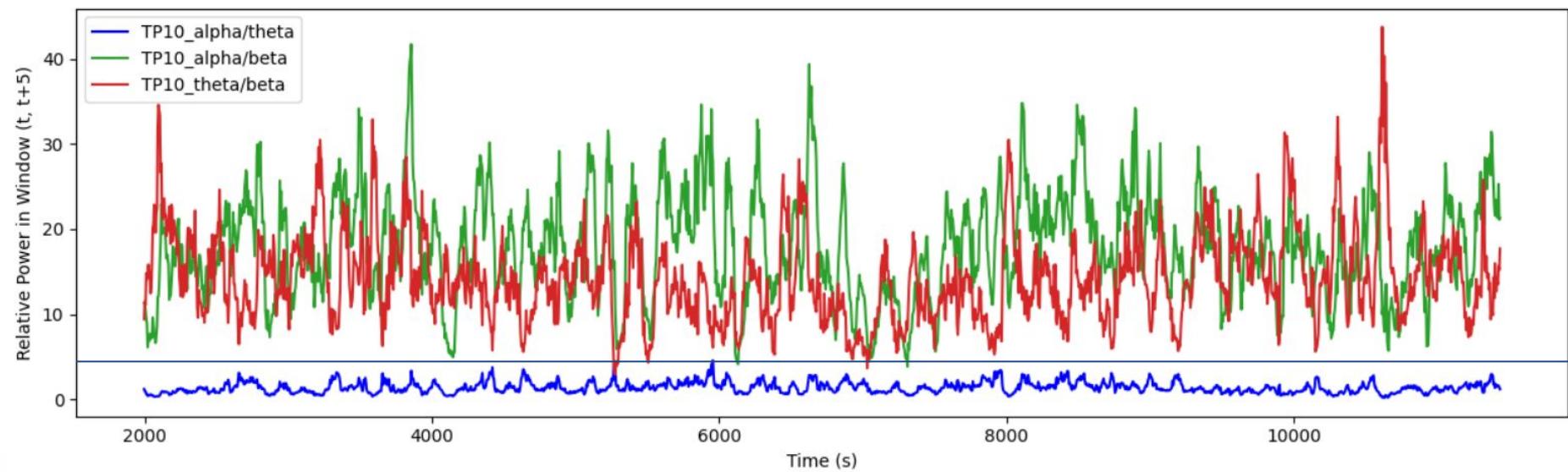
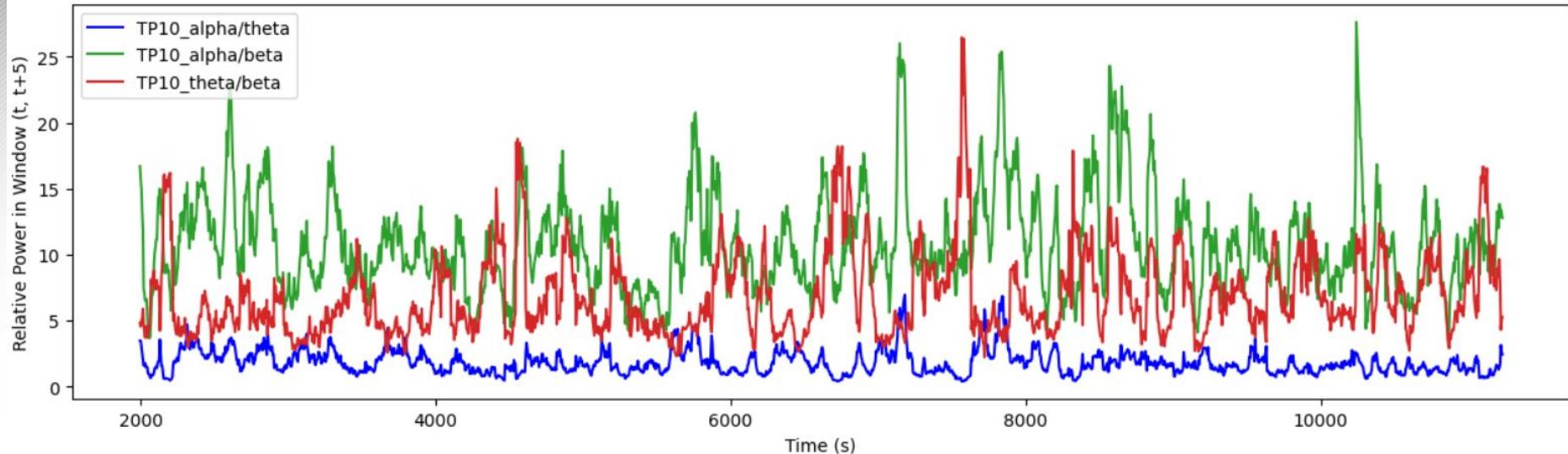
TP10 (alpha/theta, alpha/beta, theta/beta)
0.044730638854594516, 5.7686406302748665, 128.9639669361069

Computation Time = 0.006817817687988281 s

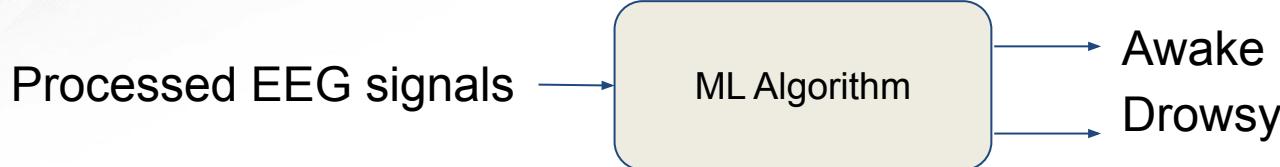
File Home Share View
Team61_ECEN403-main
Name Date modified Type Size
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f1_awake_power 11/30/2021 7:04 PM CSV File 110 KB
f1_awake_power_3ratios 11/30/2021 7:01 PM CSV File 323 KB
f1_awake_power_tab 11/30/2021 7:03 PM CSV File 351 KB
f1_drowsy 11/21/2021 5:02 PM CSV File 390,793 KB
hr_tracker 11/16/2021 5:48 PM PY File 1 KB
live_analysis 12/1/2021 7:30 AM PY File 12 KB
live_analysis testcase_0 12/1/2021 7:47 AM CSV File 2,818 KB
live_analysis testcase_0_power_3ratios 11/30/2021 10:53 AM CSV File 15 KB
live_analysis testcase_0_power_3ratios... 12/1/2021 7:36 AM CSV File 64 KB
live_analysis testcase_0_power_a2b 11/30/2021 3:19 PM CSV File 1 KB
live_analysis testcase_0_noPower_tab 11/30/2021 11:01 AM CSV File 19 KB

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```

# Signal Processing



# Machine Learning



## Models:

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

# ML Results

## Accuracy:

- Target: 90%

	<u>Dataset</u>		
<u>Model</u>	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	<b>83.5</b>	<b>85</b>	<b>97.3</b>

## 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)



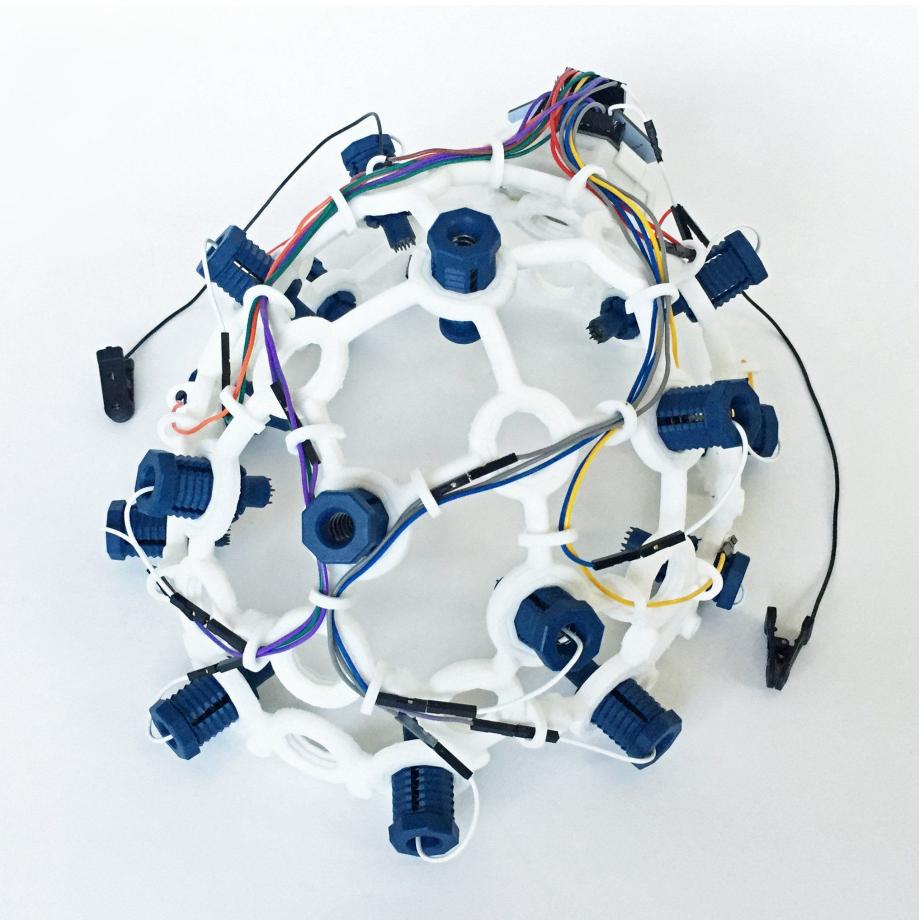
# EEG Subsystem

## Power System

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

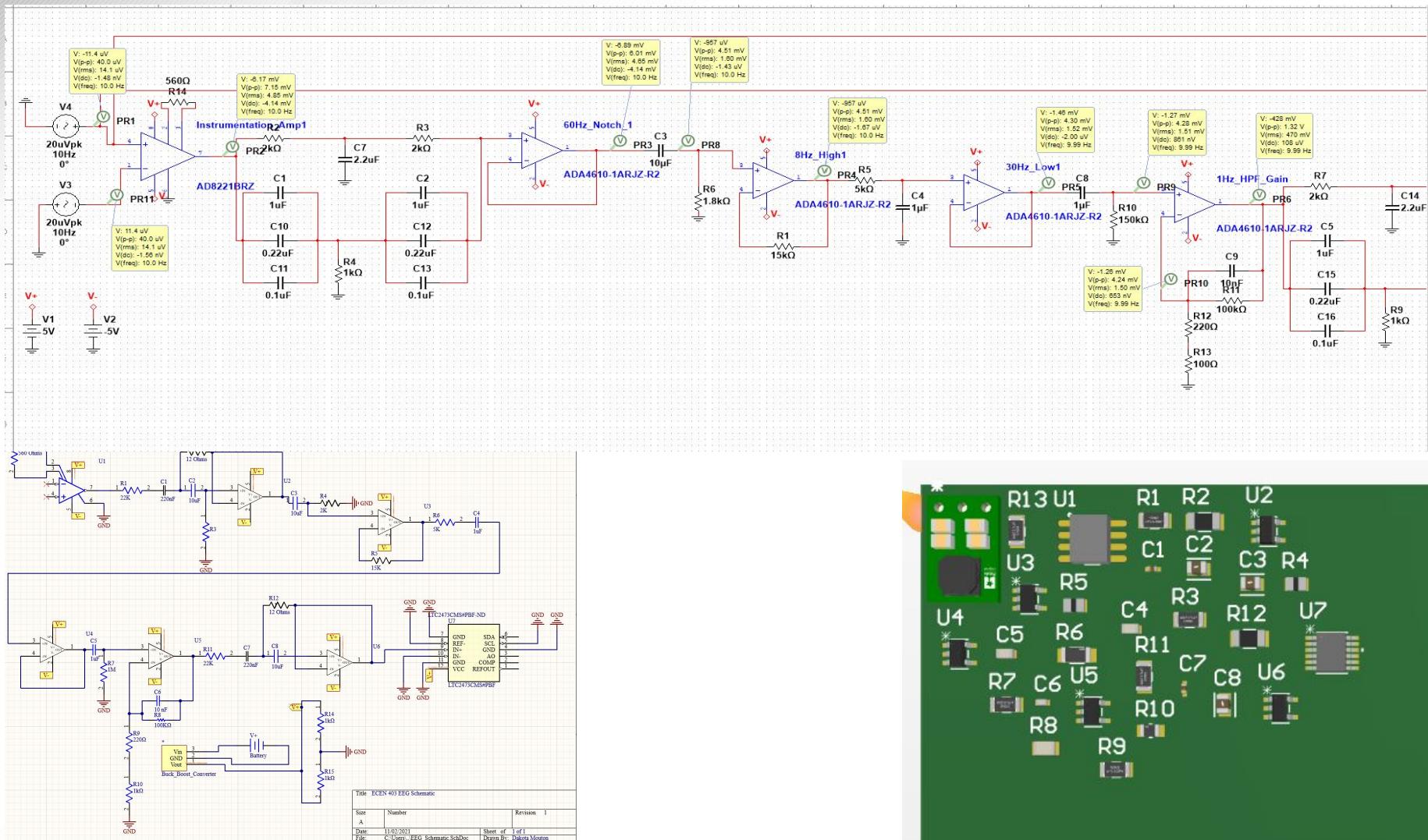
## Main Components

- 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
60	5.85	4.14		63.096	-3.486	56	0.136
30	5.85	4.14		60.06	-19.319	-25.02	1.57
30	5.85	4.14		60.06	-3.486	56	1.57
59	5.85	4.14		60.06	-19.319	-25.05	0.161

## 1Hz\_HPF

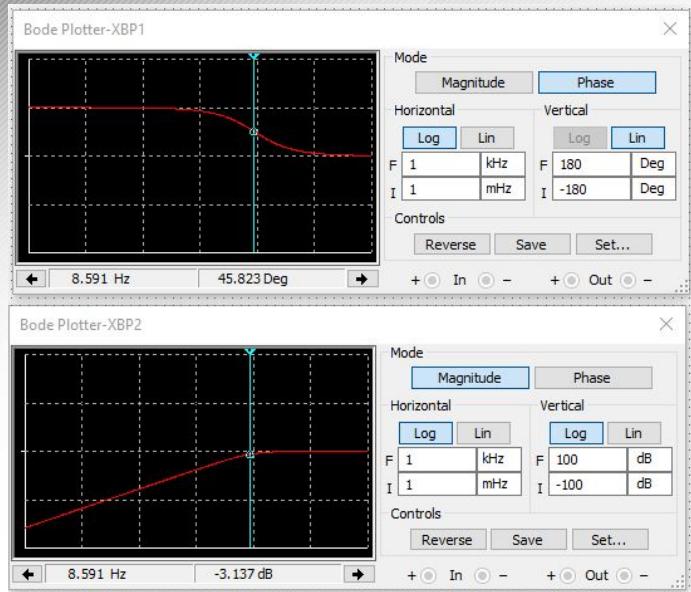
Input Frequency: (Hz)	Input Voltage: (mV)	RMS Voltage: (mV)	Cut-off Frequency: (Hz)	Phase shift: (Deg)	Magnitude: (dB)	Output Voltage: (mV, RMS)	Output Voltage: (mV, Pk)
1	5.85	4.14		0.975	45.378	46.467	863
1	10	7.07		1.026	44.656	13.96	1180
10	5.85	4.14		0.975	45.378	46.467	1200
10	10	7.07		1.026	44.656	13.69	1270

## Full EEG Circuit

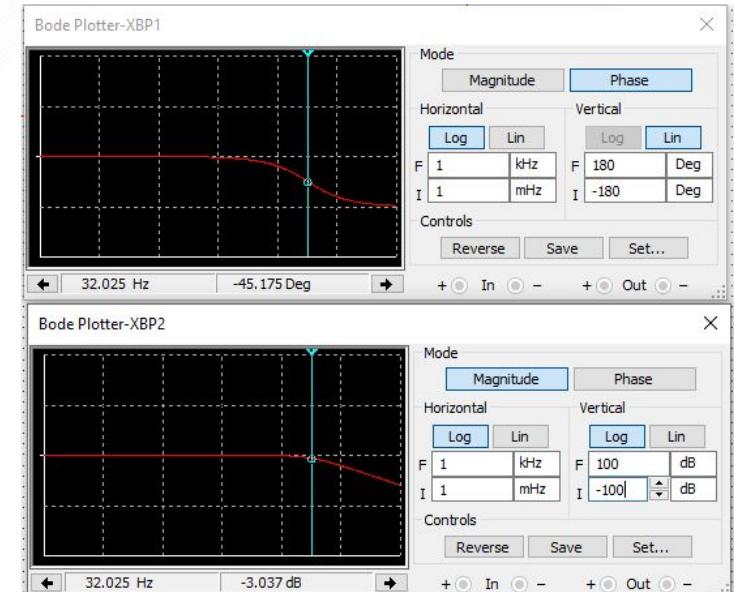
Input Frequency: (Hz)	Input Voltage: (mV)	RMS Voltage: (mV)	Cut-off Frequency: (Hz)	Phase shift: (Deg)	Magnitude: (dB)	Output Voltage: (mV, RMS)	Output Voltage: (mV, Pk)
10	0.02	0.0141		54.483	-203.193	29.532	396
30	0.02	0.0141		54.483	-203.193	29.532	99.3
75	0.02	0.0141		60.286	-155.308	29.532	9.35
100	0.02	0.0141		60.286	-155.308	29.532	15.4
300	0.02	0.0141		60.286	-155.308	28.248	23.1
1000	0.02	0.0141		60.286	-155.308	29.532	4.47
10	0.03	0.0212		60.286	-155.308	29.532	594
100	0.03	0.0212		60.286	-155.308	29.532	19.1

# EEG Subsystem: Test Results (Sims)

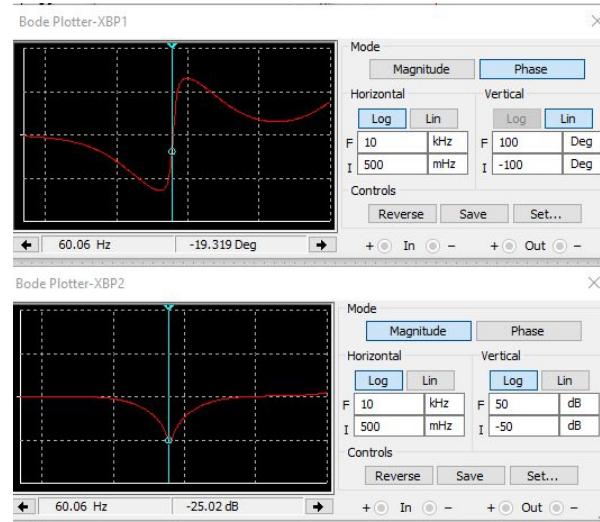
## 8 Hz High Pass Filter



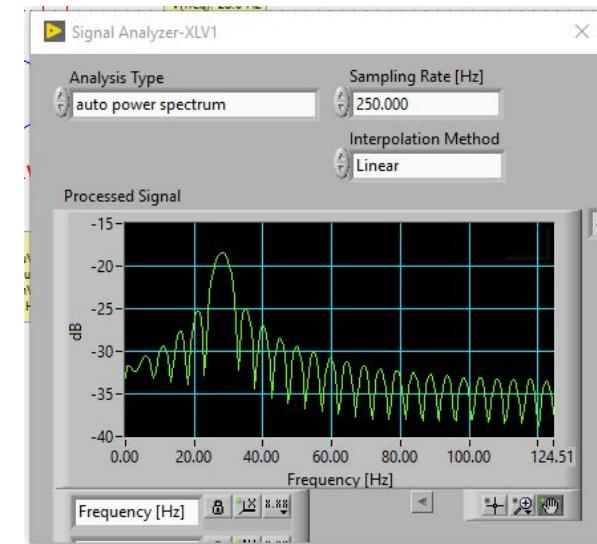
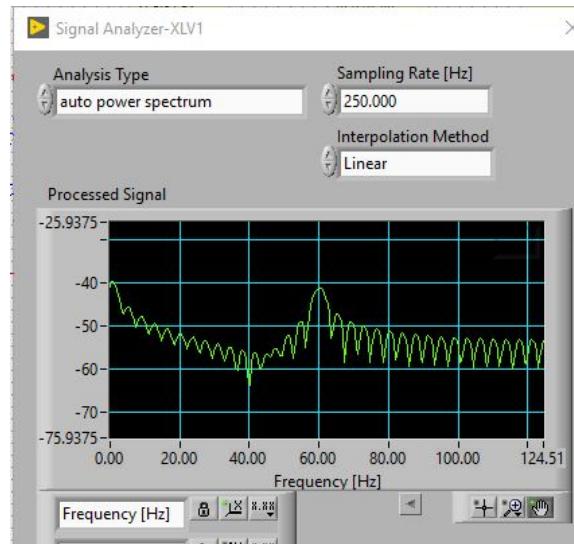
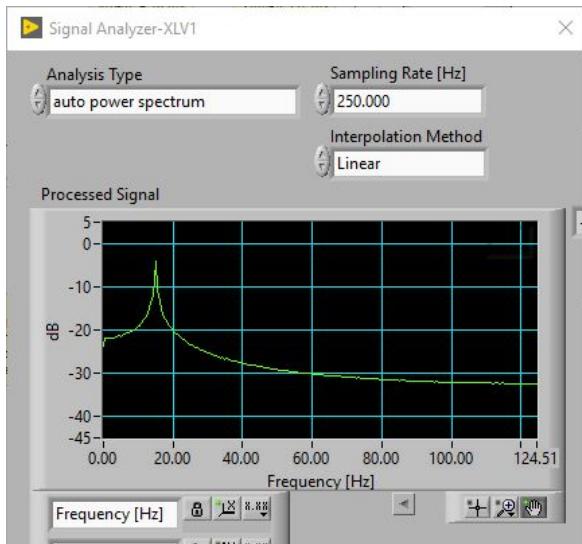
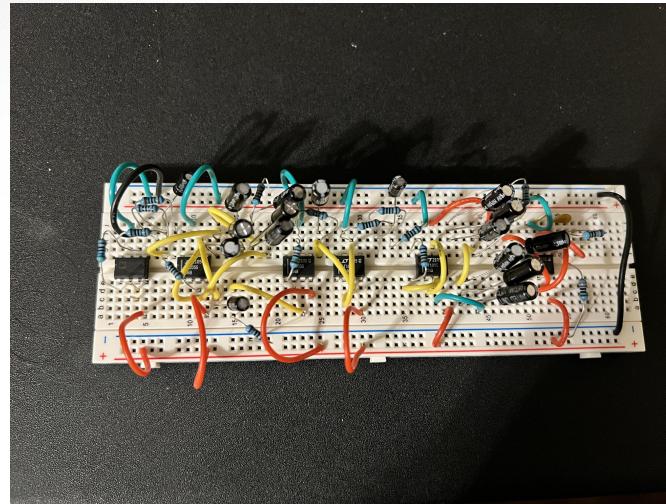
## 30 Hz Low Pass Filter



## 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	Green
Receive project details	9/3/21	All	Green
Talk with project sponsor	9/9/21	All	Green
Research	9/14/21	All	Green
ConOps Report	9/16/21	All	Green
Assign subsystems	9/21/21	All	Green
FSR Report	10/4/21	All	Green
ICD Report	10/4/21	All	Green
Decide best ML algorithm	10/8/21	Ali, Coady	Green
Test out Muse 2 device	10/12/21	Ali, Coady	Green
Create midterm presentation	10/12/21	All	Green
Get virtual simulator parts ordered	10/13/21	Ali, Coady	Green
<b>Midterm Presentation</b>	10/13/21	All	Green
Learn ML algorithm using basic tutorials and online datasets	10/17/21	Ali, Coady	Green
Create EEG filtering program	10/17/21	Ali, Coady	Green
Assemble virtual simulator rig	10/19/21	Ali, Coady	Green
Workout EEG Schematic in Altium for PCB	10/19/21	Dakota	Green
Finish Circuit Design of EEG	10/19/21	Dakota	Green
Collect training data from simulator	10/19/21	All	Green
Test filtering program off of collected data	10/20/21	Ali, Coady	Green
Get EEG device parts ordered	10/22/21	Dakota	Green
Have PCB Design Approved and Ready to Print	10/26/21	Dakota	Cyan
Create status update presentation	10/30/21	All	Green
<b>Status Update Presentation</b>	11/1/21	All	Green

Create ML algorithm off of collected data	11/2/21	Ali, Coady	Green
Connect EEG to Electrodes and Test	11/2/21	Dakota	Cyan
Validate and Troubleshoot EEG	11/2/21	Dakota	Cyan
Test ML algorithm with new simulator data	11/7/21	All	Green
Verify ML algorithm detection rate > 90%	11/14/21	Ali, Coady	Green
Finished Working EEG	11/23/21	Dakota	Red
Final validation checks for each subsystem	11/27/21	All	Green
Create final presentation	11/30/21	All	Green
<b>Final Presentation</b>	12/01/21	All	Green
Finish final report	12/4/21	All	Green
<b>Final Report</b>	12/5/21	All	Green

█ - 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: <ul style="list-style-type: none"> <li>• EEG data collection</li> <li>• Transfer and signal processing</li> <li>• Fatigue state output</li> </ul>	< 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