Dwight Look College of ENGINEERING
TEXAS A&M UNIVERSITY

ECEN 404 Final Presentation
Team 61: Driver Drowsiness Detection

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Sponsor: John Lusher
TA: Max Lesser

Problem Overview

<u>Problem</u>:
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.

<u>Solution</u>:
The Driver Drowsiness Detection project uses signal processing methods and a machine learning (ML) algorithm to classify a subject as either awake or drowsy with a Muse 2 EEG. Additionally, a custom EEG device was developed for future implementations.

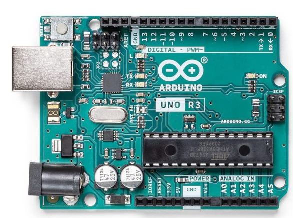
Project Diagram

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

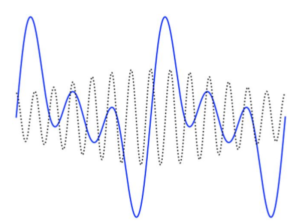
- Collect data
- Muse 2 EEG device

Signal Processor

- Perform live analysis of signals
- Process raw EEG signals

ML Model

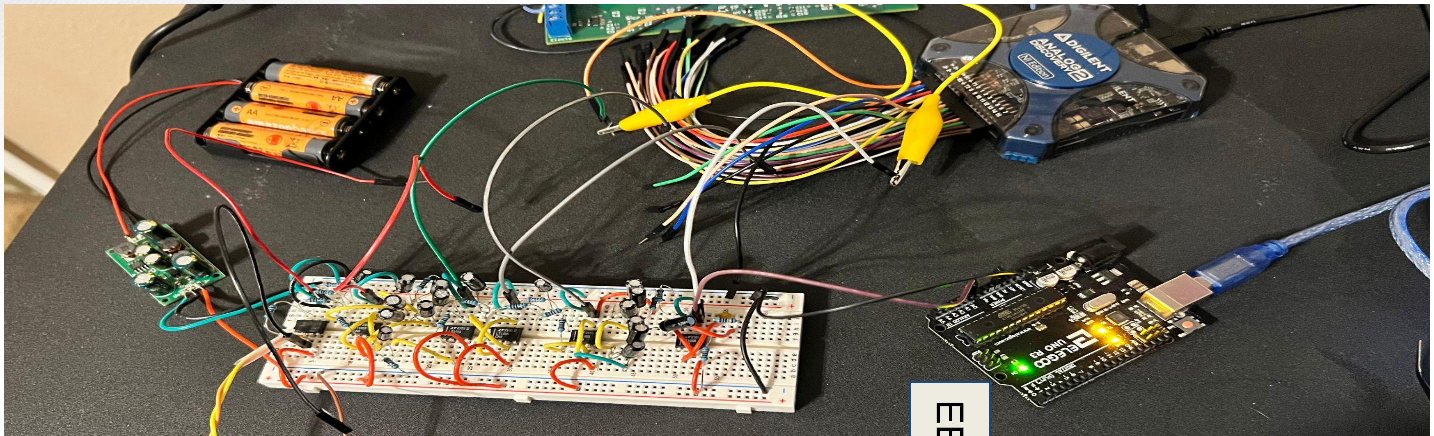
- Input processed EEG signals
- Output fatigue state of user

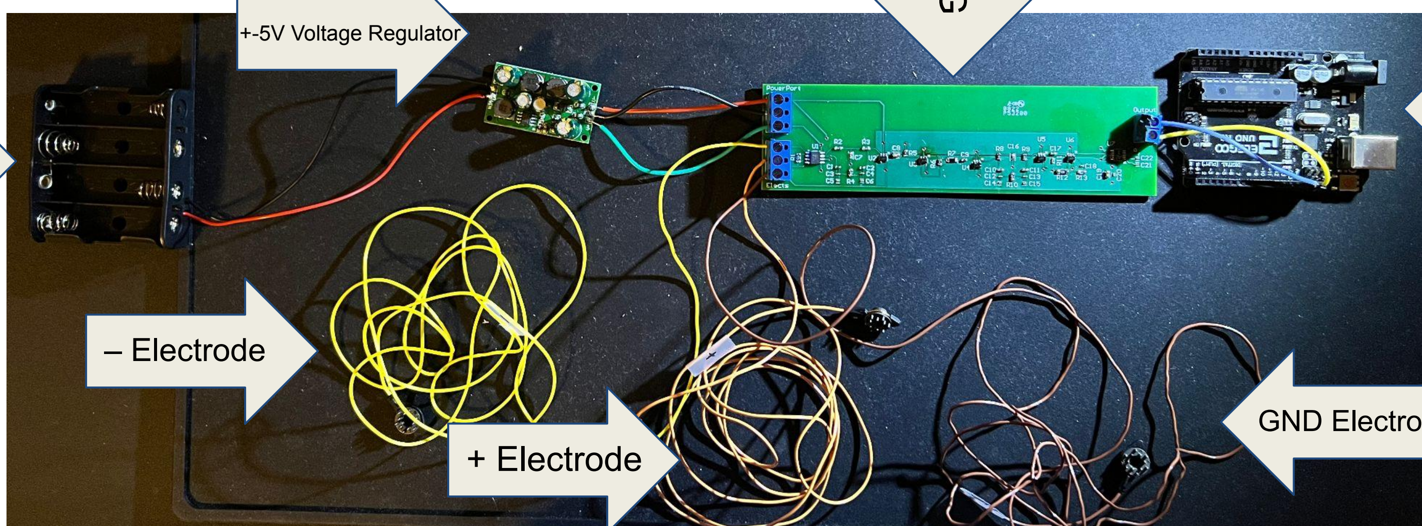


Team 2: Coady and Ali

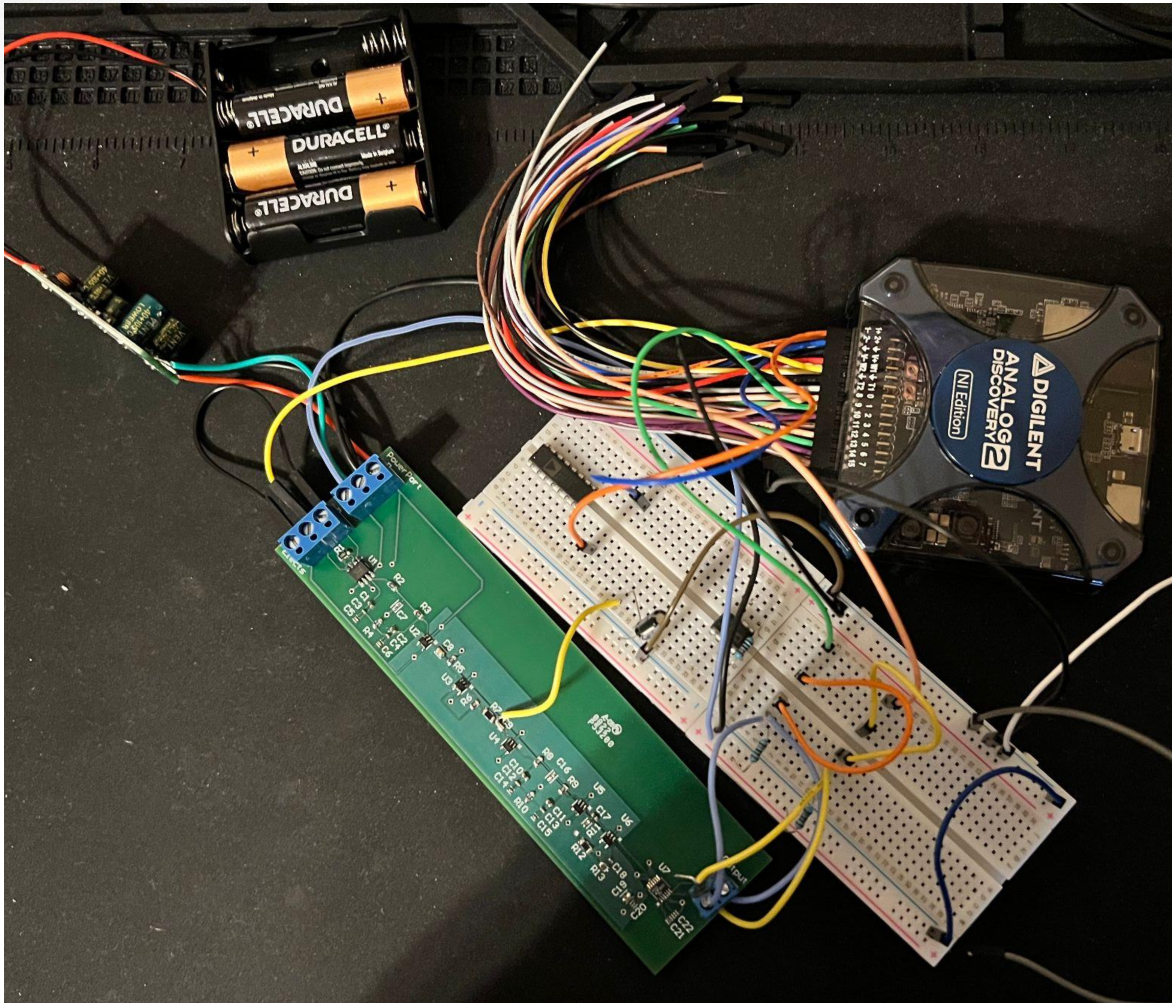
Project Photos

Project Photos: EEG





EEG Final System



EEG System Accomplishments

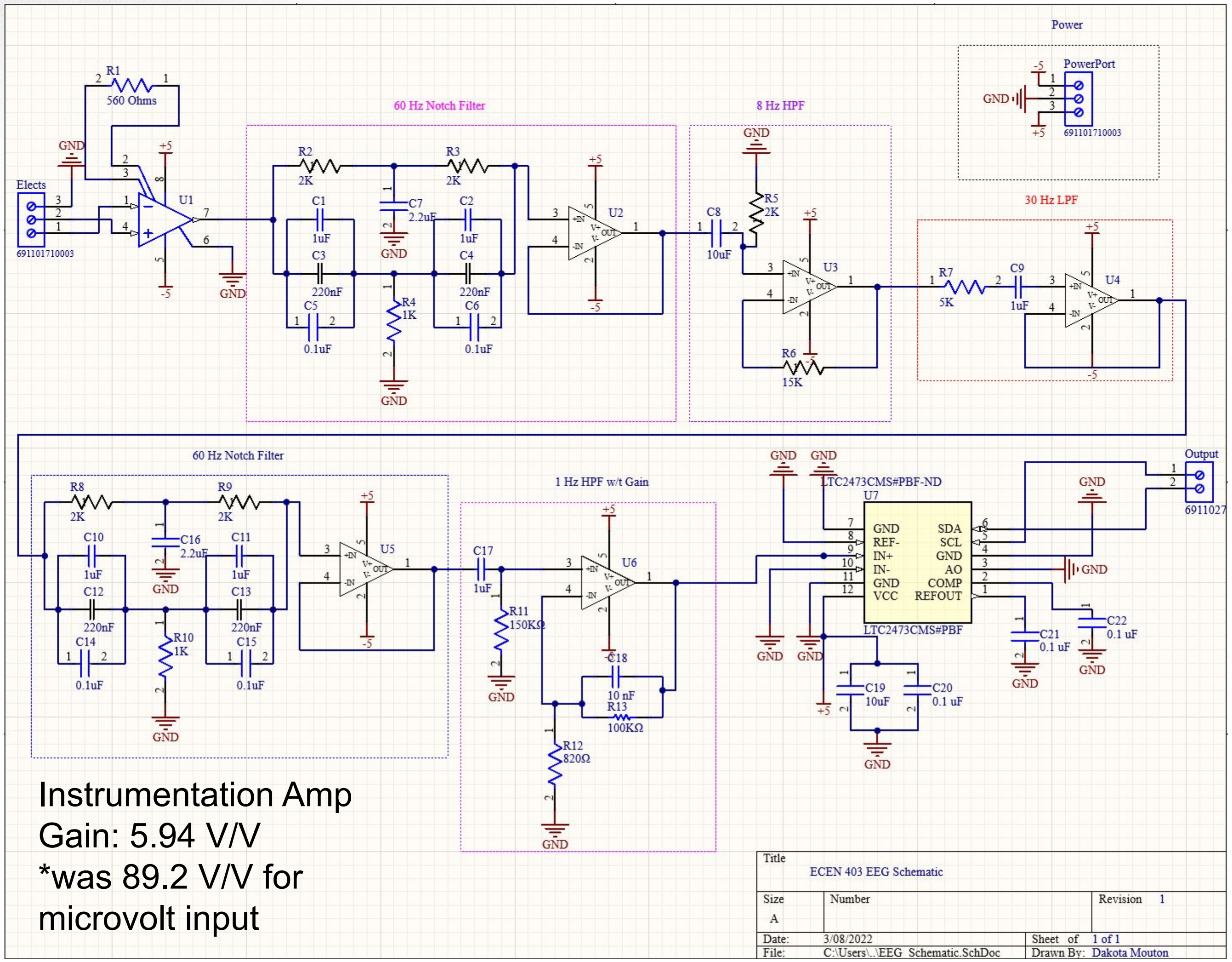
Specification	Details	Result
Designed Simulated Circuit for Initial Testing	Developing a series of Highpass, Lowpass and Notch filters to clean noise from signal	Pass
Breadboarding Prototype	Amplify millivolt signal to volts for more accurate visualization	Pass
PCB Design	Create EEG as a PCB for final product	Pass
Establish Serial Communication with MCU	Using I2C bus to send analog voltages to the MCU for processing, then sends to excel sheet	Pass

Hardware System Results

Specification:	Details:	Results:
Input Voltage = 148 mV - 812 mV amplified up to 1.25 V	Max voltage rating desired is 1.25 V from the amplifier IC.	Pass*; Input = 200 mV (differential), Output = 1.24 V
Circuit Vcc Regulated to +-5V	Take 6V input and hold at +-5V for powering circuit	Pass; Vcc+ = 5V, Vcc- = -5V
EEG Filtering Below 8 Hz	Reducing noise for signal processing by removing spikes in frequency band	Pass
EEG Filtering Above 32 Hz	Reducing noise for signal processing by removing spikes in frequency band	Pass
EEG Filtering at 60 Hz	Reducing powerline interference and large spike at 60 Hz	Pass

*The ADC output goes close to zero whenever a frequency outside our range is put through the system.

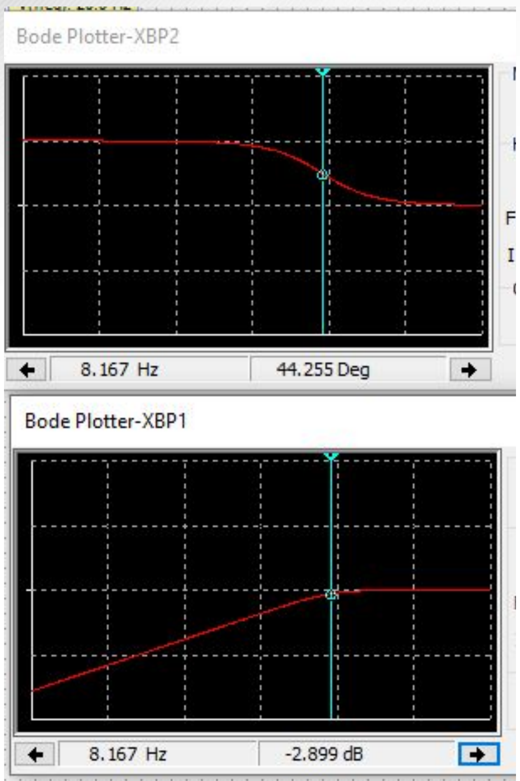
EEG Circuit Design



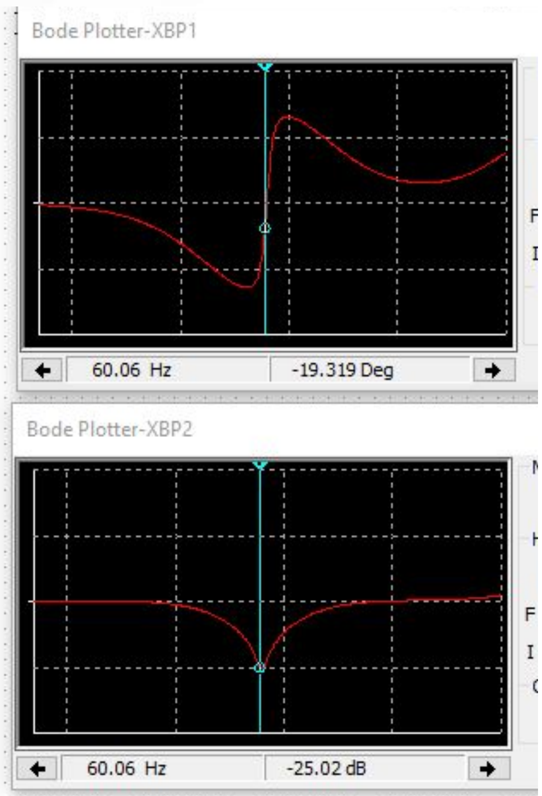
Instrumentation Amp
Gain: 5.94 V/V
*was 89.2 V/V for
microvolt input

EEG System Simulation

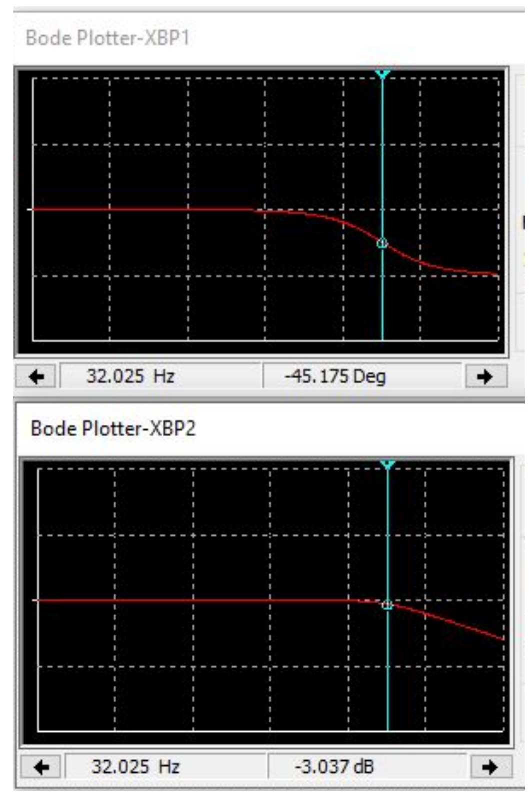
8 Hz HPF



60 Hz Notch Filter

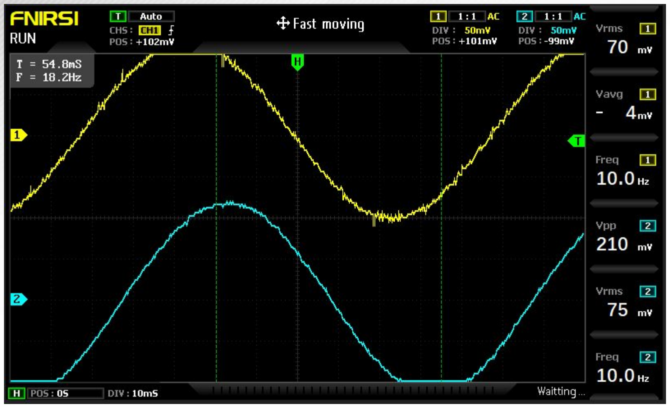


32 Hz LPF

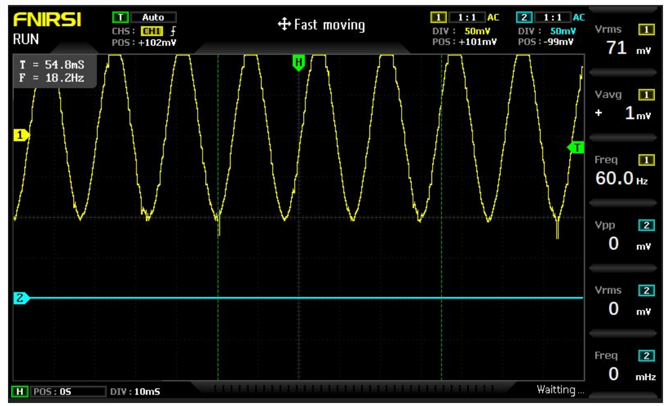


EEG System PCB Results

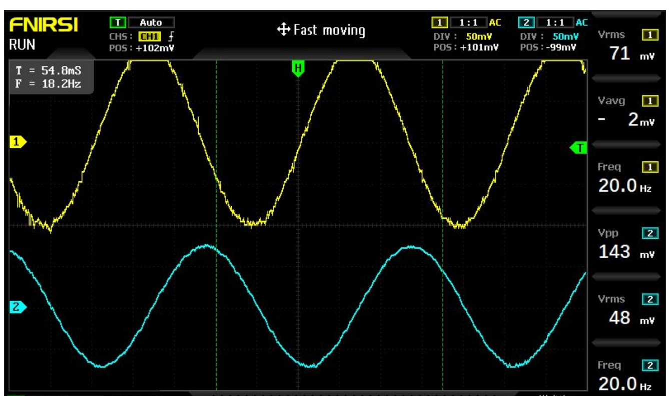
Yellow: Input signal
Blue: Output on U6
*before going into ADC



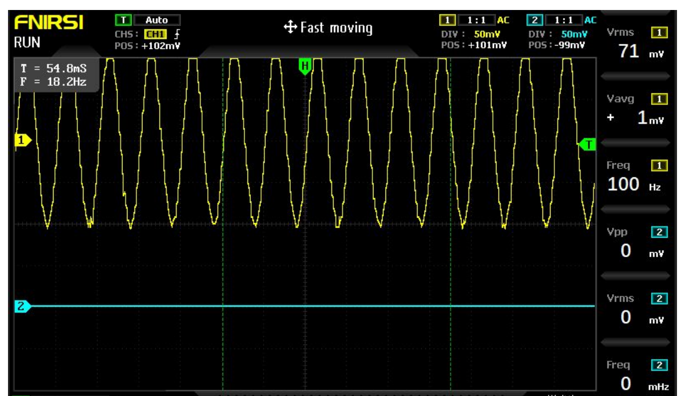
100mV, 10 Hz input



100mV, 60 Hz input



100mV, 20 Hz input



100mV, 100 Hz input

PCB IC Measured Voltages

*input is 160 mV AC, 20 Hz from AD2	AC RMS
U1 Postivie Input:	113 mV
U1 Output:	672 mV
U2 Input:	412 mV
U2 Output:	413 mV
U3 Input:	361 mV
U3 Output:	362 mV
U4 Input:	360 mV
U4 Output:	362 mV
U5 Input:	230 mV
U5 Output:	231 mV
U6 Input:	232 mV
U6 Output:	809 mV
ADC Input:	809 mV
SDA Line:	3.76 V
SCL Line:	3.76 V
Refout	1.25 V
Comp	1.87 V
*Replaced R12 with 5K and R13 with 13K and has R1 at 10K	

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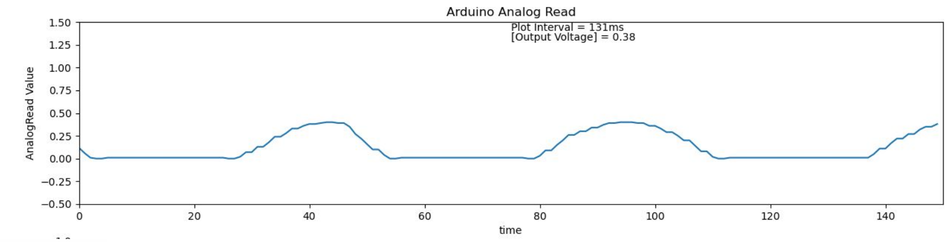
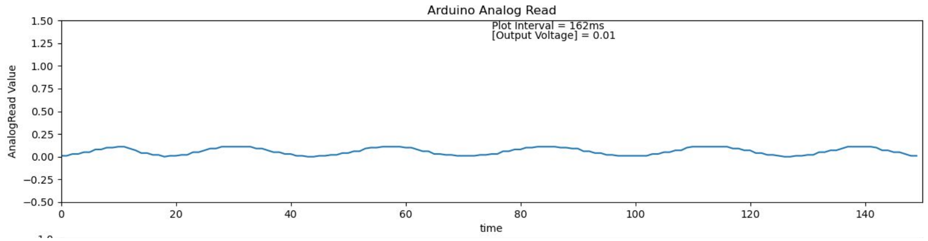
EEG Computer Interface Results

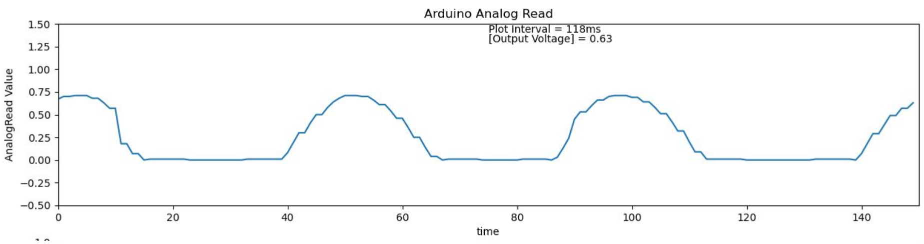
50 mV, 20 Hz



100 mV, 50 Hz



100 mV, 20 Hz



EEG System Cost

2 Electrode EEG

*Plus $33 for PCB manufacturing, therefore total price is $131.16. Compared to the Muse device priced around $250-$300 for 4 electrode device.

Category	Part Number	Item Name	Location tc	Cost per Part	Quantity	Total Cost
Instrumention Amp	AD8221BRZ-R7CT-ND	AD8221BRZ-R7 Instrumentation Amp	https://ww	$10.90	1	$10.90
Single Op Amp	ADA4610-1ARJZ-R7	ADA4610-1ARJZ-R7 single op amp	https://ww	$2.81	5	$14.05
ADC	LTC2473CMS#PBF-ND	LTC2473CMS#PBF-ND ADC	https://ww	$4.55	1	$4.55
			Totals:	$18.26	7	$29.50
Capacitors	399-7848-1-ND-Cut Tape	C0603C105K9PAC7867 (1uf)	https://ww	$0.10	6	$0.60
	1276-2897-1-ND - Cut Ta	CL21A106KPFNNWE (10uf)	https://ww	$0.22	2	$0.44
	1276-1176-1-ND - Cut Ta	CL05B224KO5NNNC (220nf)	https://ww	$0.10	4	$0.40
	478-1114-1-ND - Cut Tap	0402YC103KAT2A (10nf)	https://ww	$0.10	1	$0.10
	1276-1043-1-ND	CL05A104KA5NNNC (0.1uF)	https://ww	$0.10	7	$0.70
	1276-1134-1-ND	CL10B225KP8NNNC (2.2uF)	https://ww	$0.12	2	$0.24
Resistors	RNCP0805FTD1K00CT-NE	RNCP0805FTD1K00 (1k)	https://ww	$0.10	2	$0.20
	RNCP0805FTD2K00CT-NE	RNCP0805FTD2K00 (2k)	https://ww	$0.10	5	$0.50
	RNCP0805FTD15K0CT-NE	RNCP0805FTD15K0 (15k)	https://ww	$0.10	1	$0.10
	YAG5090CT-ND	RT1206BRD075KL (5k)	https://ww	$0.65	2	$1.30
	A130442CT-ND	CRGP0603F150K (150k)	https://ww	$0.17	1	$0.17
	RMCF0805FT13K0CT-N	RMCF0805FT13K0 (13k)	https://w	$0.10	1	$0.10
	CRT1206-FZ-1002ELF	652-CRT1206FZ1002ELF (10k)	https://w	$0.30	1	$0.30
			totals:	$2.26	35	$5.15
Buck boost converter	5V Step-Up/Step-Down V	Buck boost converter	https://ww	$14.95	1	$14.95
Dry Electrodes	FRI-2140-1E	Package of 15 Disposable/Reusable Dry E	https://ww	$34.95	1	$34.95
Alkaline Batteries		Amazon Basics AA 1.5 Volt Performance A	https://ww	$5.49	1	$5.49
Battery Holder for 4 Batteries		LAMPVPATH (Pack of 2) 4 AA Battery Hold	https://ww	$5.99	1	$5.99
2 Output Pin Termina	732-2028-ND	6.91103E+11	https://ww	$0.71	1	$0.71
Power 3 Input termin	732-2027-ND	6.91102E+11	https://ww	$0.71	2	$1.42
			totals:	$62.80	7	$63.51
Grand Total:	$98.16					

Data Collection

Simulator:

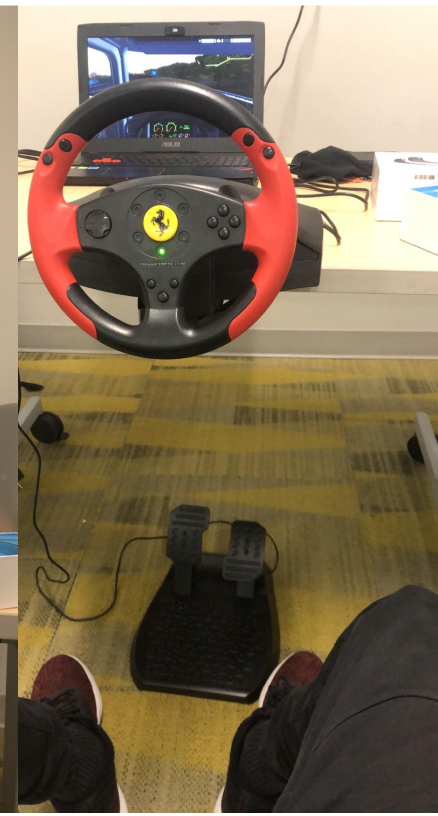
- Steering wheel and pedals
- American Truck Simulator

Data Collected (Muse + Simulator):

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

Labeling Method

- Focused on Extreme Cases
- 0 for awake, 1 for drowsy

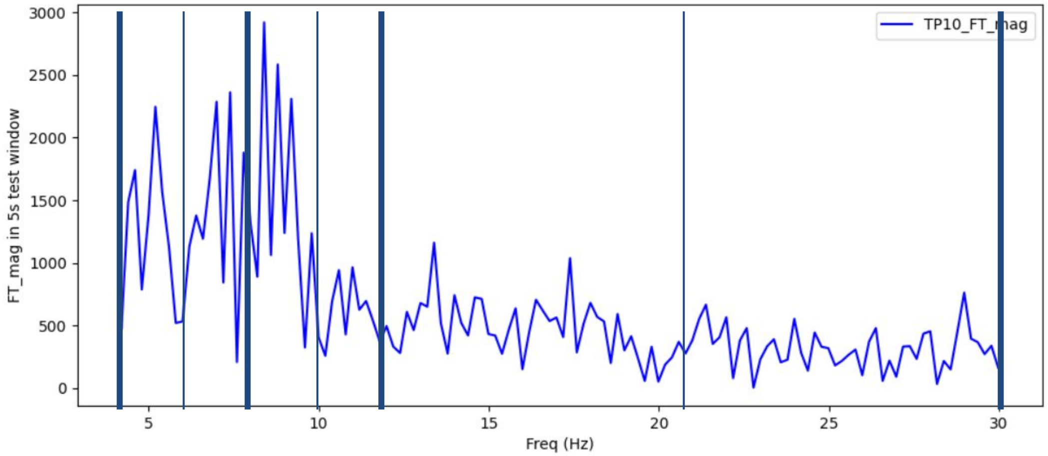


Signal Analysis Design

- EEG signals are erratic and highly variable.
- To get usable features, the final implementation uses an FFT on 5 second windows to calculate 15 ratio features from 6 bandlimited power values.
- The code handles a live LSL stream from the Muse to send processed values to the ML model in real time.
- Switched from single vectors to sequences
- In sequential mode, one sample is processed per update.

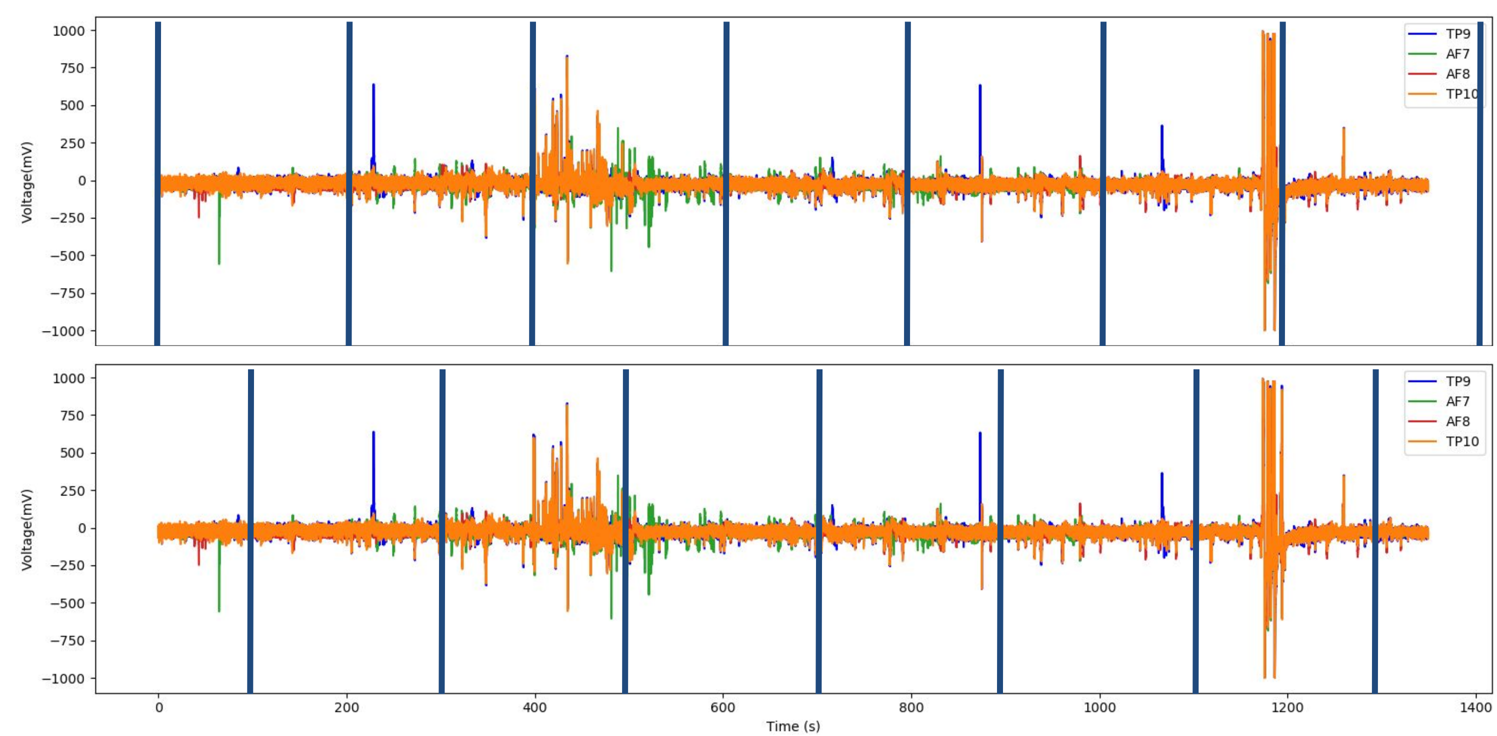
Signal Analysis Design

- Originally focused on 3 bands in 4-30 Hz.
- Doubling the number of bands gave repeatable accuracy increases of 9-10%.
- This strategy requires significantly more data.
- Selective density increases.



- Randomized data augmentation was tried, but it didn't yield good results.
- A different data augmentation method was settled on.

Signal Analysis Design



- This is how offsetting the windows generates many times more data points without losing the sequential structure.

ML Model Design

Naive Bayes | Kernel SVM | Neural Network

↓

Kernel SVM

↓

Recurrent Neural Network (RNN)

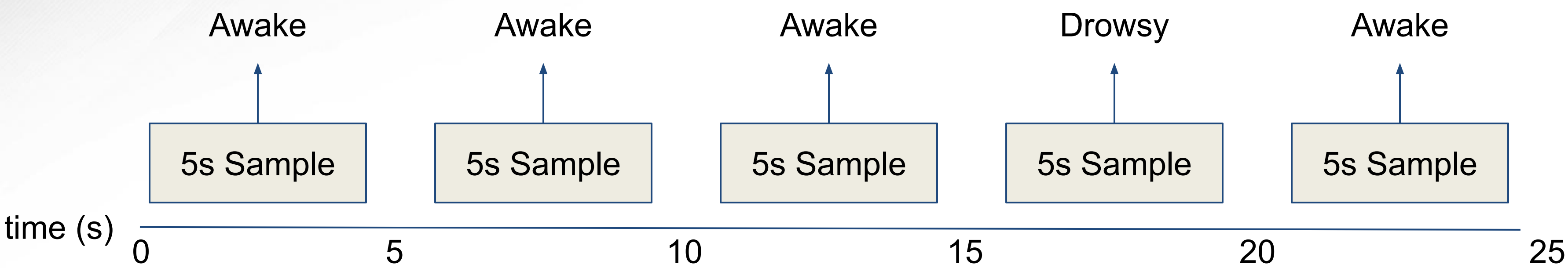
- time dependencies

↓

Recurrent Convolutional Neural Network (RCNN)

- both time and spatial dependencies

Recurrency


Awake
Awake
Awake
Drowsy
Awake
5s Sample
5s Sample
5s Sample
5s Sample
5s Sample
time (s)
0
5
10
15
20
25

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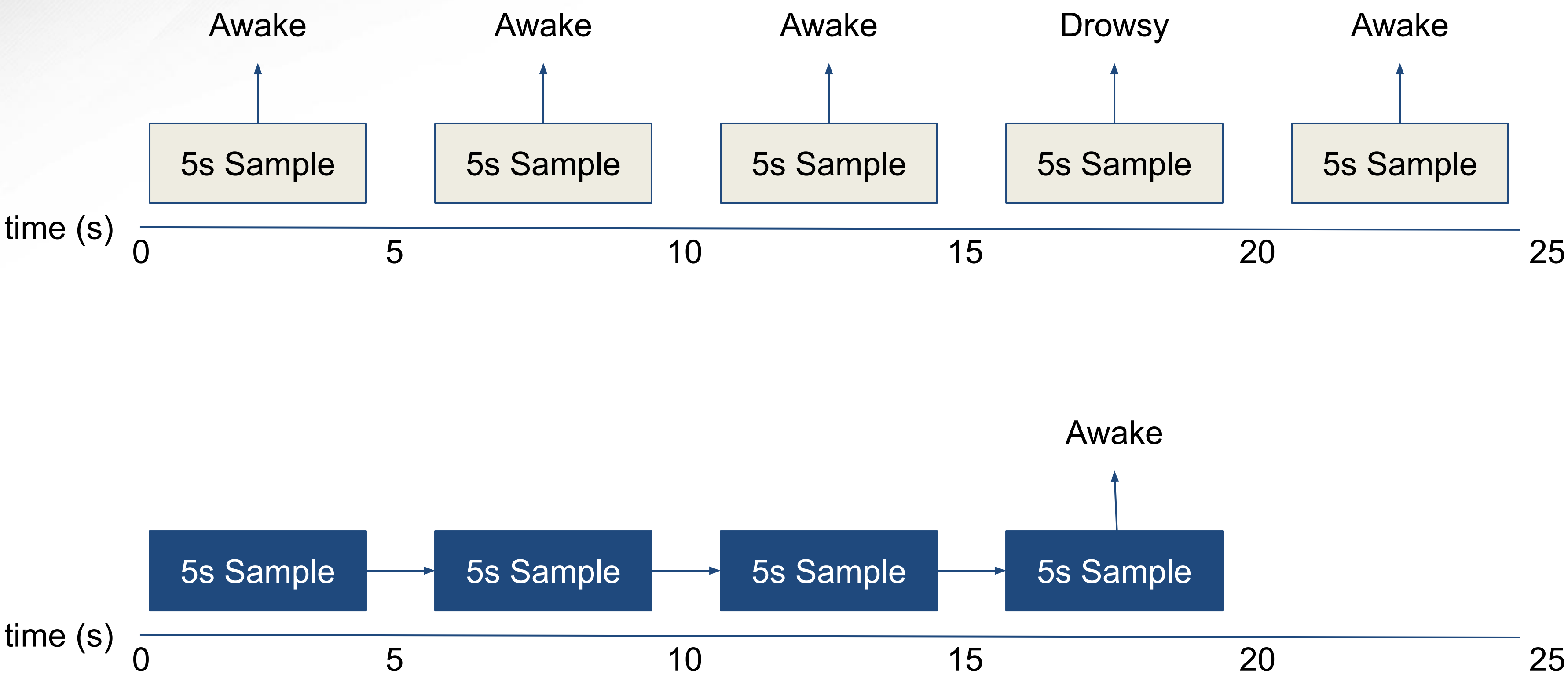
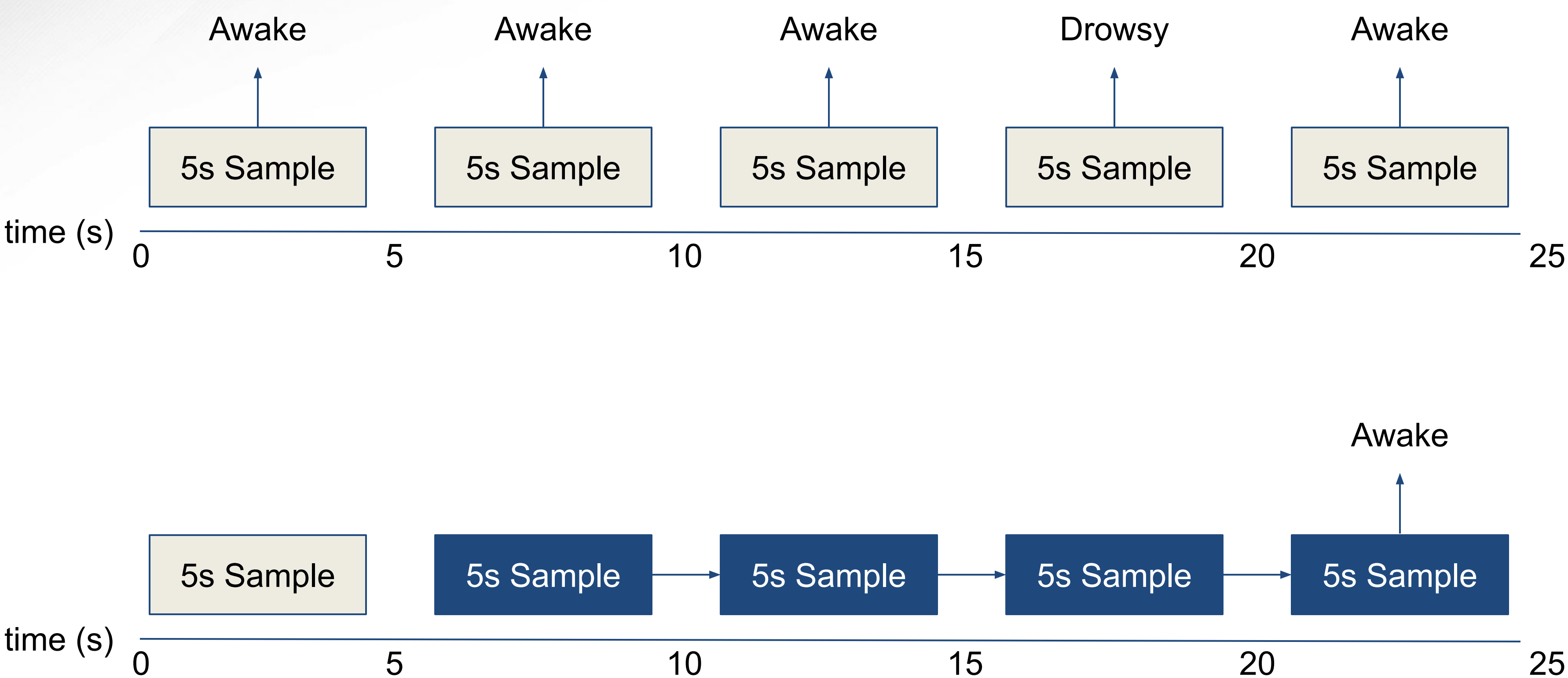
Recurrency



Sequence Length = 4

Recurrency



Sequence Length = 4

Convolution

Features per Electrode (15)

Electrodes (4)

TP9	f0	f1	f2	…	f13	f14
AF7	f0	f1	f2	…	f13	f14
AF8	f0	f1	f2	…	f13	f14
TP10	f0	f1	f2	…	f13	f14

Convolution

Features per Electrode (15)

Electrodes (4)

TP9	f0	f1	f2	…	f13	f14
AF7	f0	f1	f2	…	f13	f14
AF8	f0	f1	f2	…	f13	f14
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Convolution

Features per Electrode (15)

Electrodes (4)						
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Convolution

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Convolution

Features per Electrode (15)

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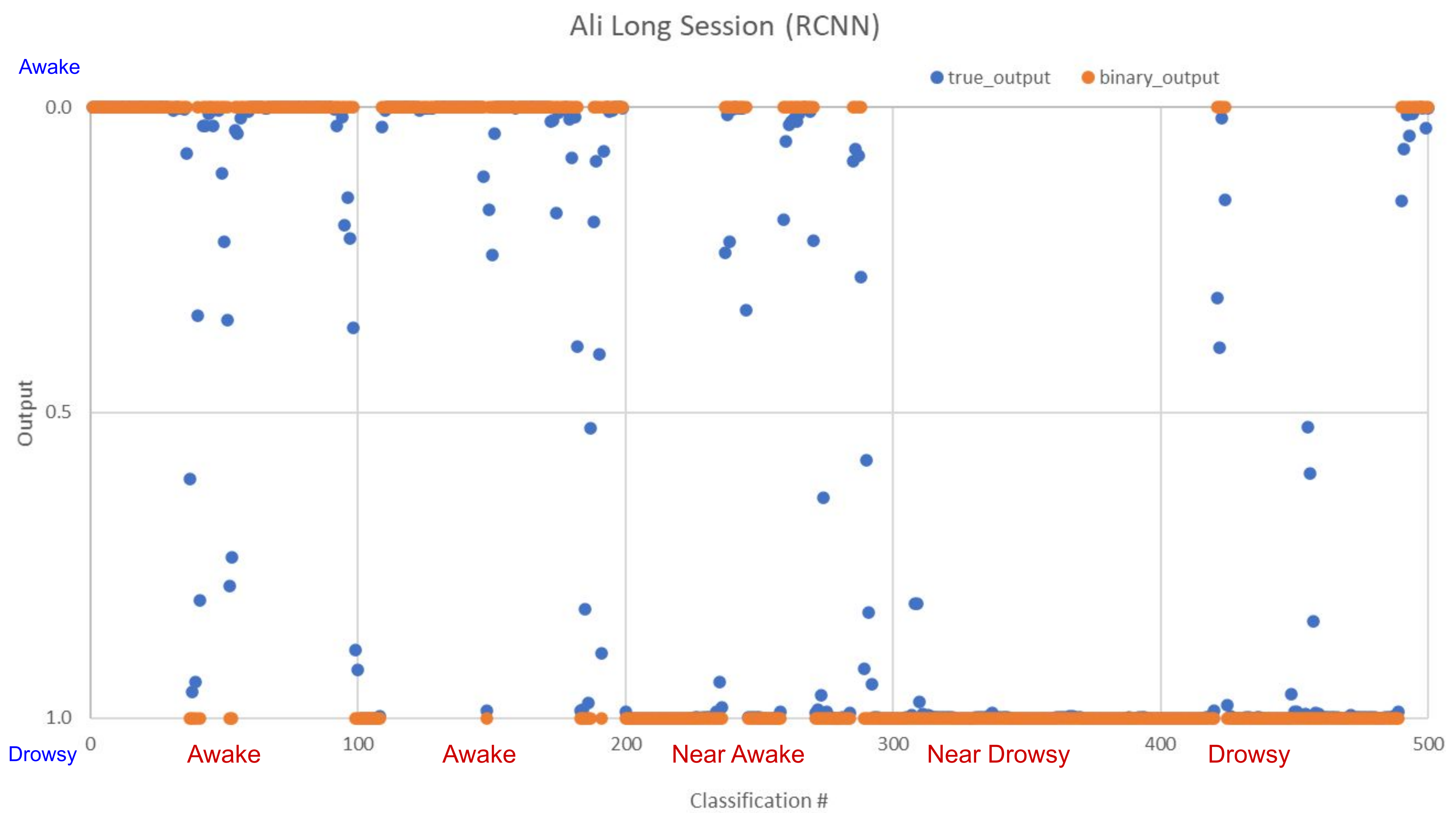
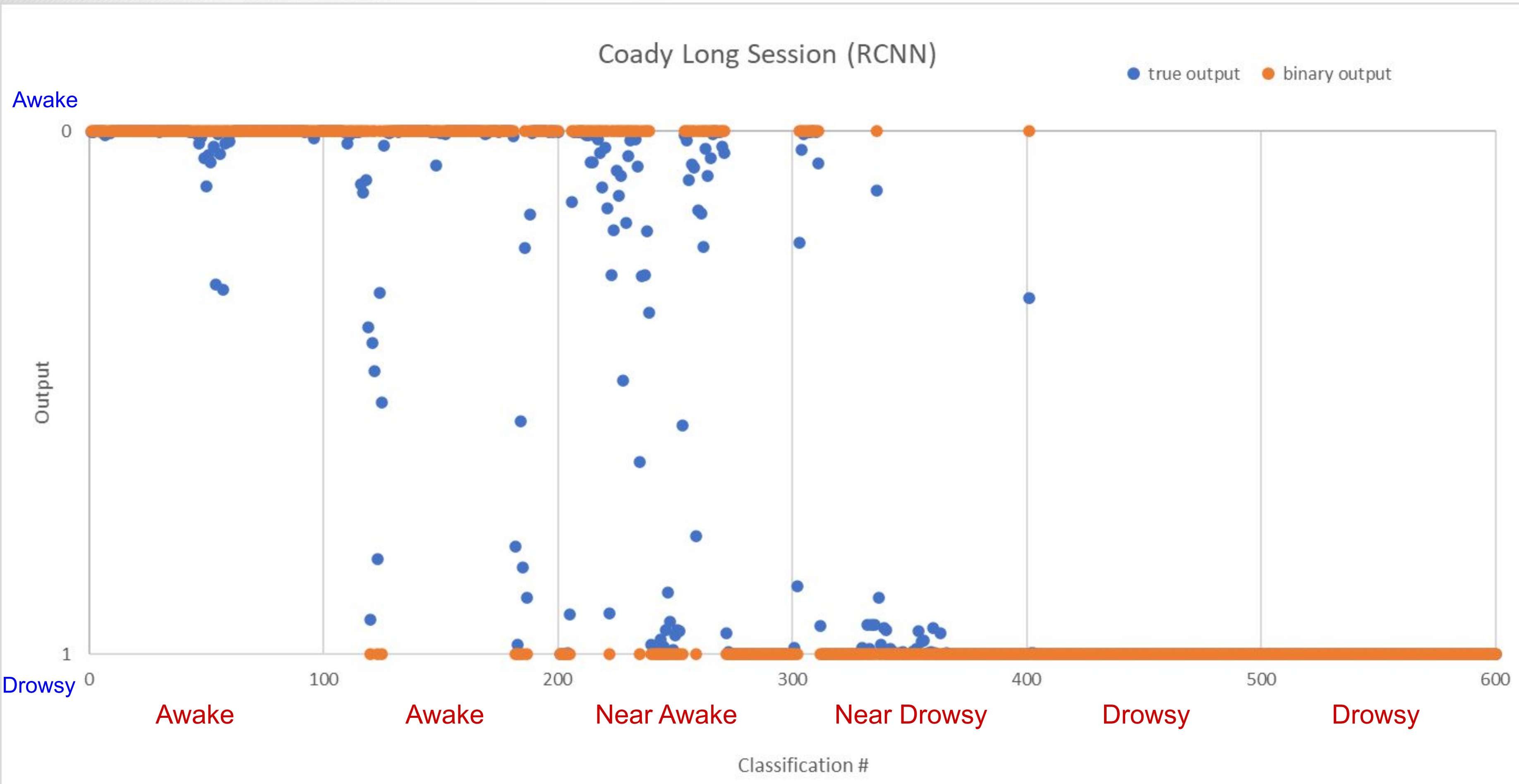
TP9	f0	f1	f2	…	f13	f14
AF7	f0	f1	f2	…	f13	f14
AF8	f0	f1	f2	…	f13	f14
TP10	f0	f1	f2	…	f13	f14

Long Session Output (Ali)



Long Session Output (Coady)



Accuracies (Long Sessions)

Total: 93.6%

Fully Awake: 92.3%
Fully Drowsy: 95%

False Positive: 7.7%
False Negative: 5%

Software System Results

- Full Awake/Full Drowsy Test
  - https://youtu.be/pWFG5qb1vY0

- Response to Stimulus Example
  - https://youtu.be/Y3JlhLka4Ks

Challenges for Future (Hardware)

PCB Footprint

- Reducing footprint of pcb to fit on a hat or wearable accessory for the driver

Electrode Interference

- Shielding input electrodes from electrical interference in the surrounding environment

More Electrodes

- Upscale the circuitry to use more electrodes for more accurate measurements
- Active right leg grounding vs passive grounding electrode

Challenges for Future (Software)

Sample Labeling Methods

- Individual rather than batch sample labeling

Data Volume and Subject Count

- Build a more robust and generalized model
- Will allow for more bands from signal processing

Simulation Realism

- Vehicle NVH

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Questions?