Boston University
Electrical & Computer Engineering
EC463 Senior Design Project

Second Prototype Test Report

NeuroToys

by

Team 9
NeuroToys

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Materials and Setup

Our updated prototype for NeuroToys introduces a higher quality EEG, eye wink detection for directional control, and improved car hardware. The core hardware remains an ESP-WROOM-32 microcontroller, an L298N motor driver, and two 18650 lithium-ion batteries housed in a 2S holder, protected by a 32V 3A glass fuse. A personal computer and the Muse 2 EEG headset facilitate brainwave signal acquisition and processing. The Muse 2 headset wirelessly transmits real-time brain activity data to the computer via Bluetooth. A Python-based interface processes the signals, classifying both concentration levels for forward movement and eye winks for left and right turns. These commands are relayed to the ESP32 over Bluetooth, where preloaded C code executes the corresponding motor actions.

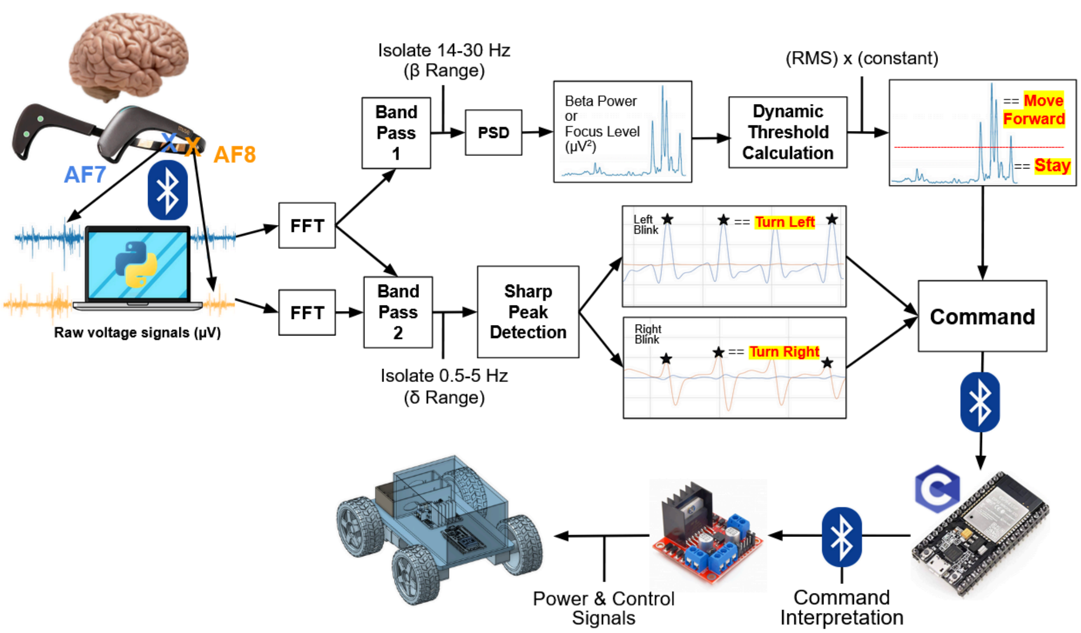


Figure 1: Second iteration of control flow diagram featuring Muse 2 EEG and blink detection

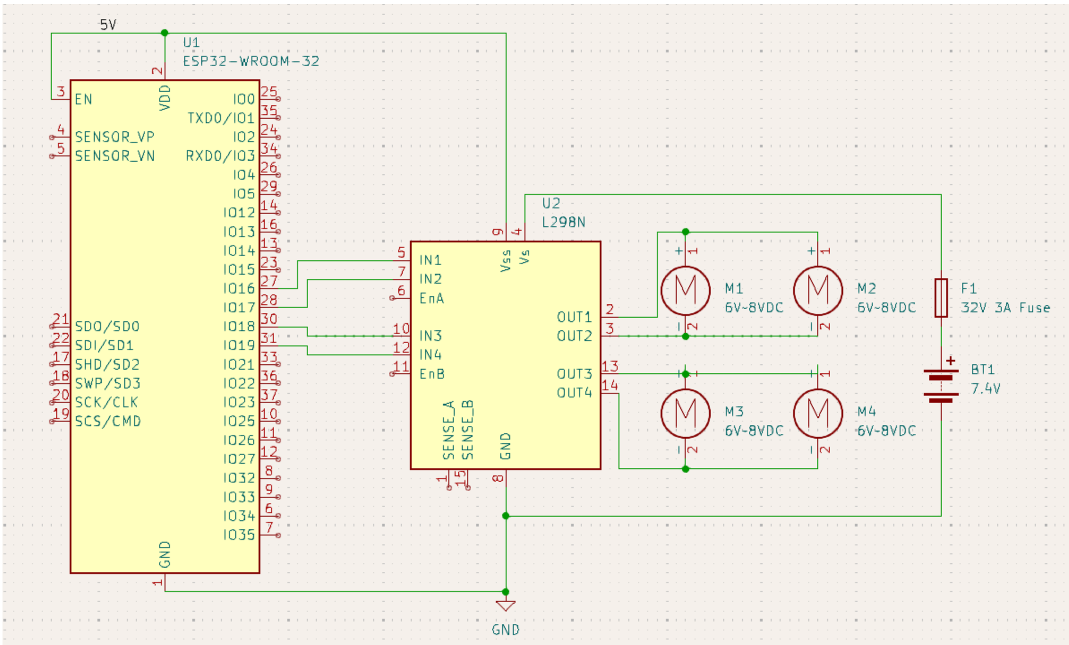


Figure 2: RC car circuit diagram including pinouts and fuse

Measurements Taken

There are three primary components to our system: the Muse 2 EEG headpiece, a computer which runs the Python interface, and the ESP32 in the RC car. The headpiece transmits raw brain voltage data (µV). The Python interface processes this signal by performing a Fourier Transform on the AF7 electrode (on the left side of the forehead – chosen arbitrarily, as they both pick up the same electrical activity of the prefrontal cortex) to isolate the beta frequency band from the EEG data, which is associated with focus. The beta power is then calculated (expressed in μV^2), representing the user's focus level. A threshold is established to determine whether a command should be sent to the ESP32, which then controls the forward movement of the toy car. A similar signal processing technique is used for right and left control, where the AF7 and AF8 electrodes on both sides of the forehead go through a band pass filter separately to isolate the gamma frequency band from the raw EEG data. Gamma is a lower frequency range (0.5 - 5 Hz), allowing for isolation of corneoretinal motion (eye-blink) detection instead of fast neural activity.

Peak detection algorithms are then used to classify between right and left eye blinks (AF8 vs. AF7 peaks), which in turn send the right and left turn commands to the car.

To test the efficiency of our prototype, these focus levels were measured and plotted, as well as a visual discernment of whether the toy moved once the user was intentionally focusing. Similarly, blinking signals were measured separately for each eye.

Testing Procedure

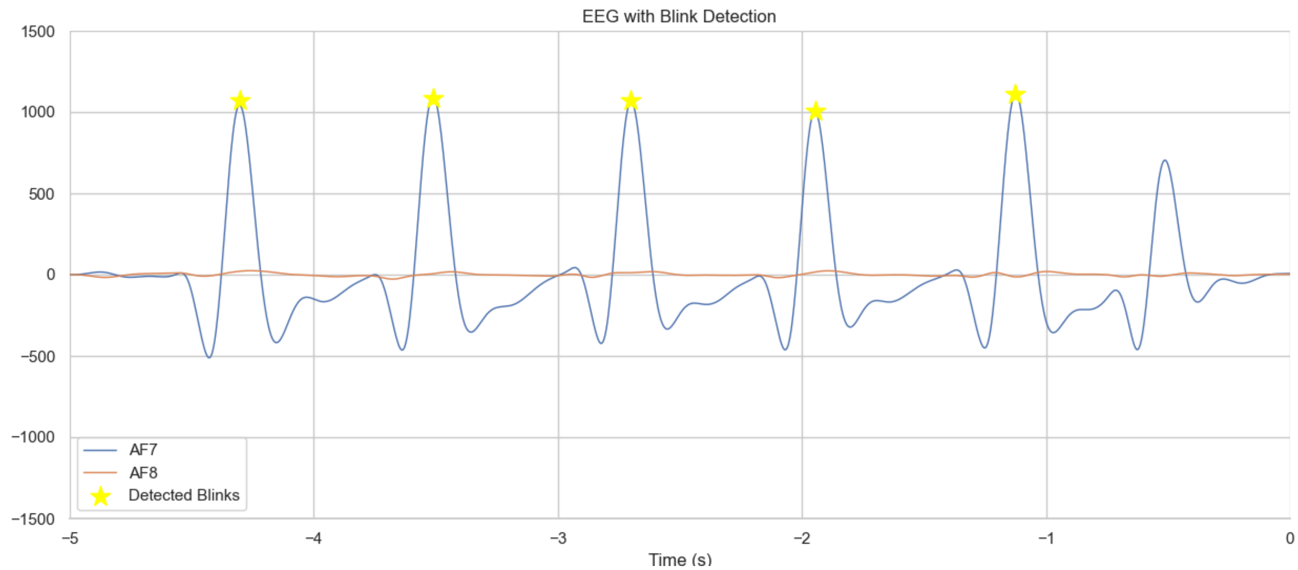
Blinking

1. Member 1 wears the headset
2. Member 2 starts a 1 minute timer
3. Member 1 should attempt to blink their right eye for 10 seconds at a frequency of one blink per second, repeat with the left eye, and take a 5 second break. These times are announced by Member 2 at the start and each switch.
4. Member 2 marks down errors as they occur at the start of each interval.
5. Right and Left eye blink detections command the car to turn in the direction

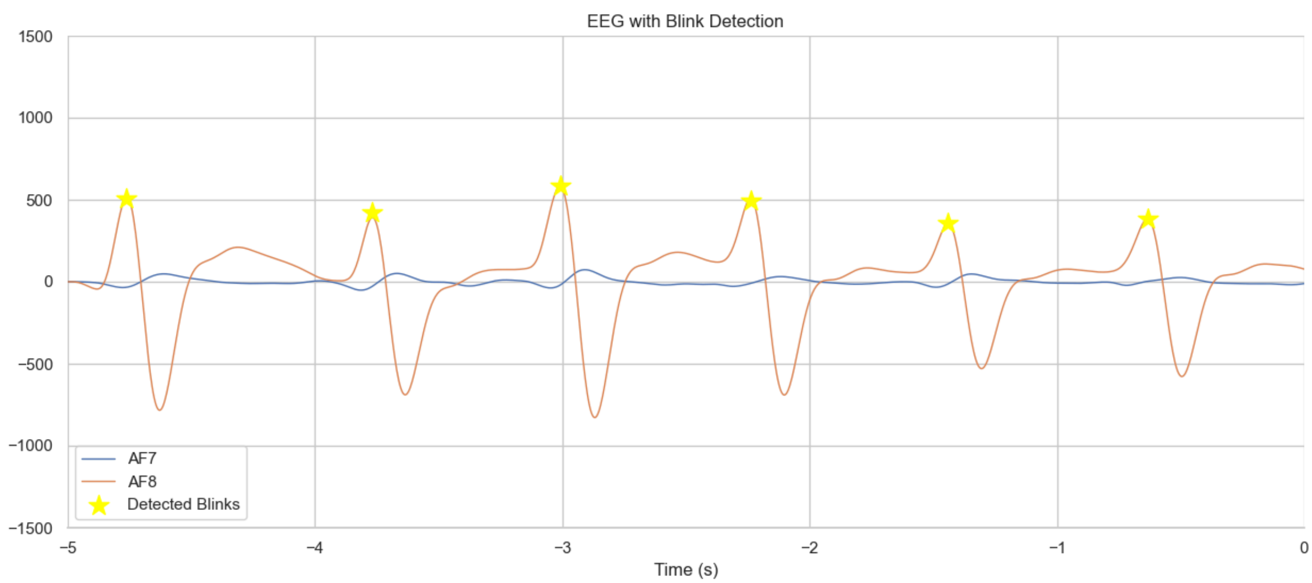
Focus

1. Member 1 wears the headset
2. Member 2 starts a 1 minute timer
3. Member 1 should attempt to focus and unfocus at 10 second intervals. These intervals are announced by Member 2 at the start and each switch.
4. Member 2 marks down errors as they occur at the start of each interval.
5. Forward movement of the toy is enabled at above the dynamic beta power (focus level) threshold, and disabled when below.

Results



(a)



(b)

Figure 3: Left (a) and right (b) eye blink detection results sampled over a 5 second interval

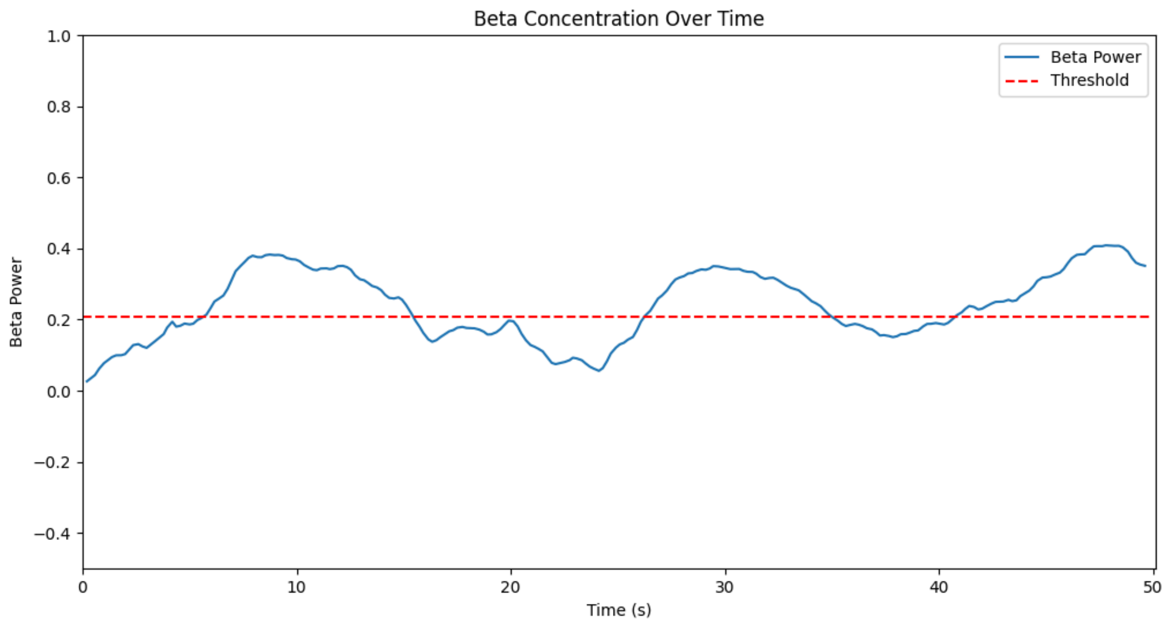


Figure 4: Beta power (focus) level resulting in forward motion while above threshold

Figure 3 shows evidence of successful detection and differentiation between voluntary eye winks. The data highlights distinct voltage peaks in EEG sensors AF7 and AF8, corresponding to left and right eye activity respectively, confirming the reliability of our classification algorithm. Figure 4 demonstrates that modifications to the EEG and code since our last tests have not compromised our ability to correctly classify focused and unfocused brain signals. In testing, both concentration and blink signals are interpreted simultaneously in real-time to facilitate forward movement and rotation in either direction.

From this evidence, we conclude that NeuroToys Prototype 2 has successfully implemented remote turning via left and right eye blinks. For our final prototype, we aim to refine our signal processing pipeline, develop a user-friendly UI, and improve the car design for the purposes of functionality and aesthetics.