# Boston University
# Electrical & Computer Engineering
## EC463 Senior Design Project

# Final Project Test Report

NeuroToys

by

Team 9
NeuroToys


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## **Materials and Setup**

Our finalized system design for NeuroToys integrates a high quality EEG, wink detection for rotational control, and an improved user interface. 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, after which firmware written in C executes the corresponding motor actions.

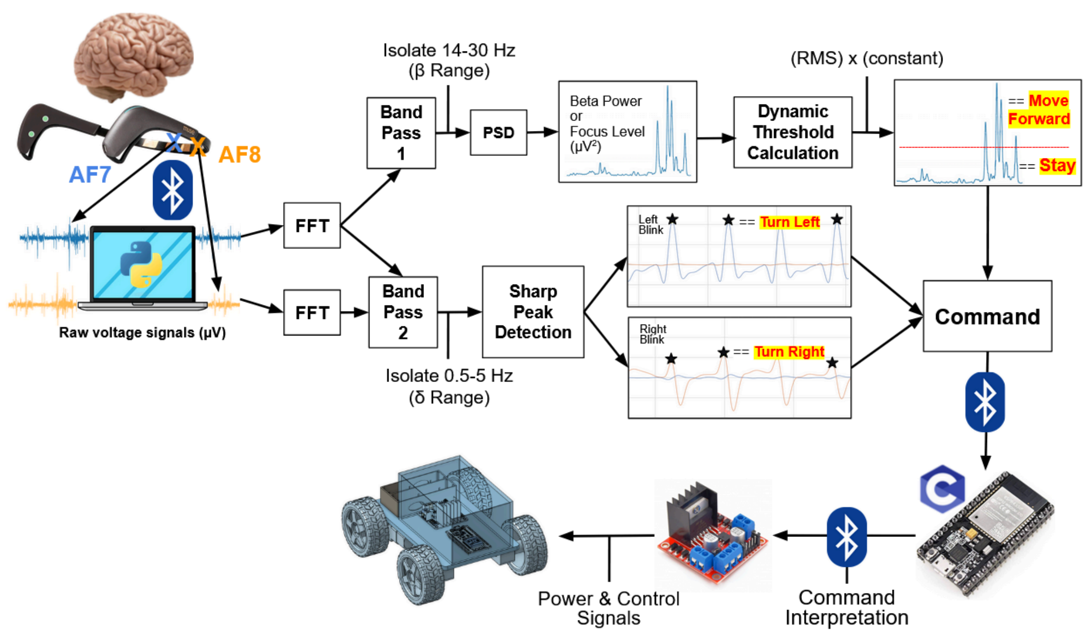


*Figure 1: Final iteration of control flow diagram featuring Muse 2 EEG and wink detection*

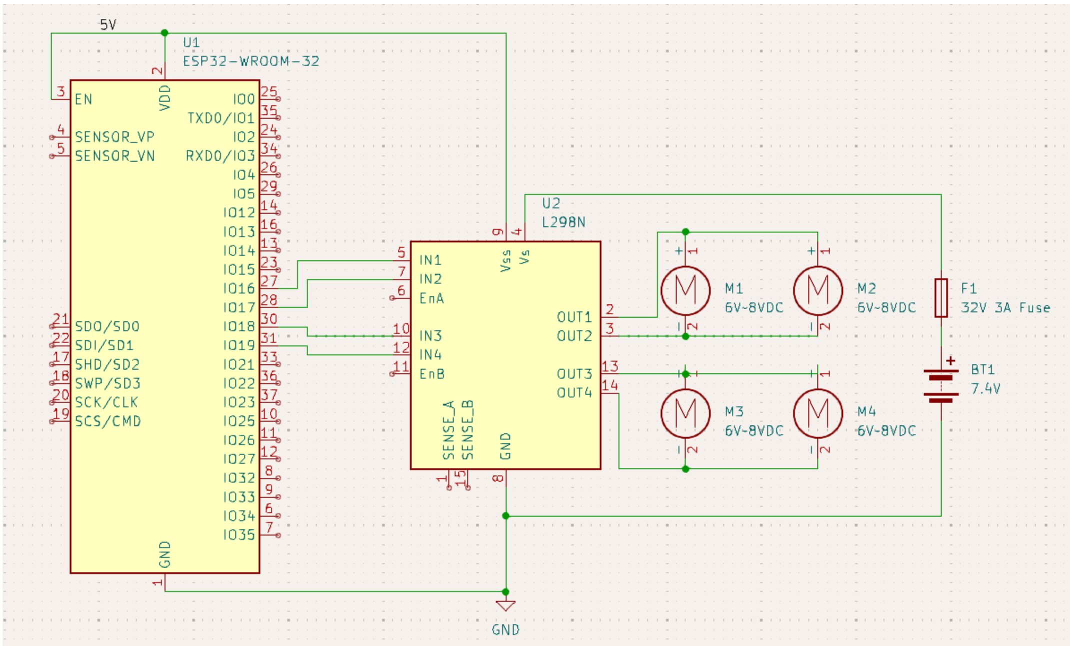


*Figure 2: RC car circuit diagram including pinouts and fuse*

## **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 $\mu V^2$), 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.

Additionally, we have experimented with implementing a reverse mode, toggling forward and backwards at threshold concentration levels via blinking both eyes simultaneously. However, our tests have determined that this feature makes controlling the device substantially more difficult than necessary. This will not be present in our final product.

Our testing procedure is intended to characterize the end-user experience and overall remote control efficacy for our product. The car should travel consistently and with minimal deviations towards an envisioned location. The system should also be capable of use with a multitude of users with little to no loss in performance.

## Testing Procedure

1. User sits comfortably in front of the path with the EEG headset on and calibrated.
2. Begin the trial. The user completes one full loop around the designated path using mental focus (beta band) to move forward and eye blinks (gamma band from AF7/AF8) to steer.
3. After completing the full loop, repeat the path in reverse direction with the same controls.
4. A second team member observes and records any deviations from the path (veering off course, incorrect turns, unresponsive commands).
5. Repeat the above steps for three distinct users.

## Results

*Table 1: Remote control car trial results*

| User 1 - Gabriela | # Path deviation incidents | # Rotation deviations | Task performed successfully (Y/N) |
|---|---|---|---|
| Forward | 0 | 4 | Y |
| Reverse | 1 | 2 | Y |

| User 2 - Mete | # Path deviation incidents | # Rotation deviations | Task performed successfully (Y/N) |
|---|---|---|---|
| Forward | 0 | 4 | Y |
| Reverse | 0 | 3 | Y |

| User 3 - Adam | # Path deviation incidents | # Rotation deviations | Task performed successfully (Y/N) |
|---|---|---|---|
| Forward | 0 | 3 | Y |
| Reverse | 1 | 2 | Y |

Table 1 shows that our project successfully interprets user intent for remote control of our car, maintaining performance within an acceptable range of deviations. The system exhibits no discernible bias across different users, which is a highly important consideration for future commercialization opportunities. Combined with an improved GUI for an enhanced user experience and more intuitive control feedback, NeuroToys demonstrates itself as a reliable, low-cost, and user-friendly system capable of accurately translating brain signals into real-time robotic control.