Targeted Audio for Those Suffering Hearing Loss

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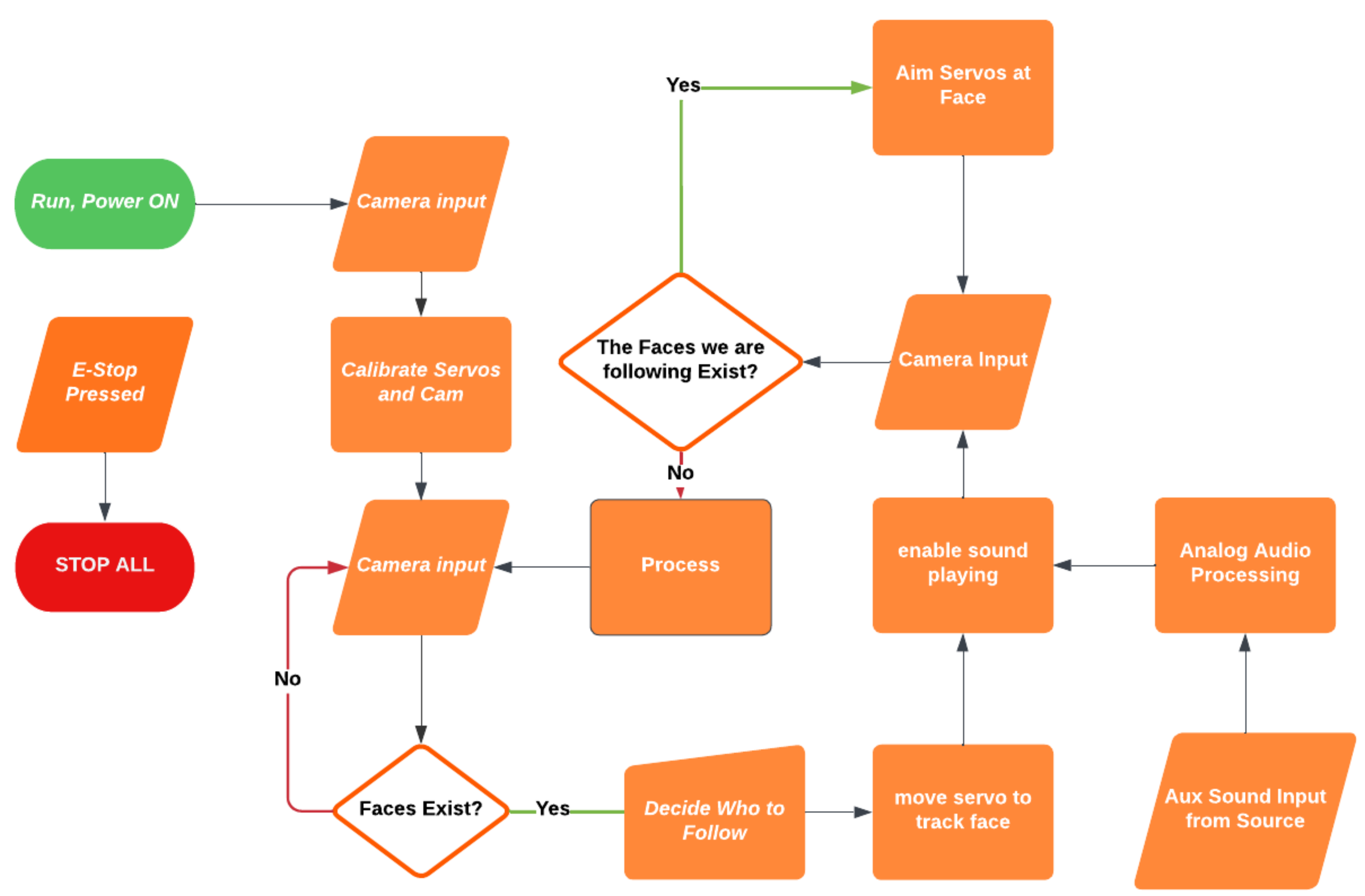
Team 5

Introduction

Hearing loss is a rare type of injury in that it has no cure and no natural regenerative ability – that is, hearing loss is permanent. Those who have been subjected to loud noises (veterans, musicians, concertgoers, older people, etc) therefore cannot hear as well as the general population, and prefer audio systems to run louder than most. Our solution allows those with hearing loss to hear an audio system at a boosted volume without an intrusive hearing aid and without bothering others in the room. We implement a system that uses facial recognition to broadcast a directional "sound beam" [1] straight at an individual in the room who needs a boost in volume.

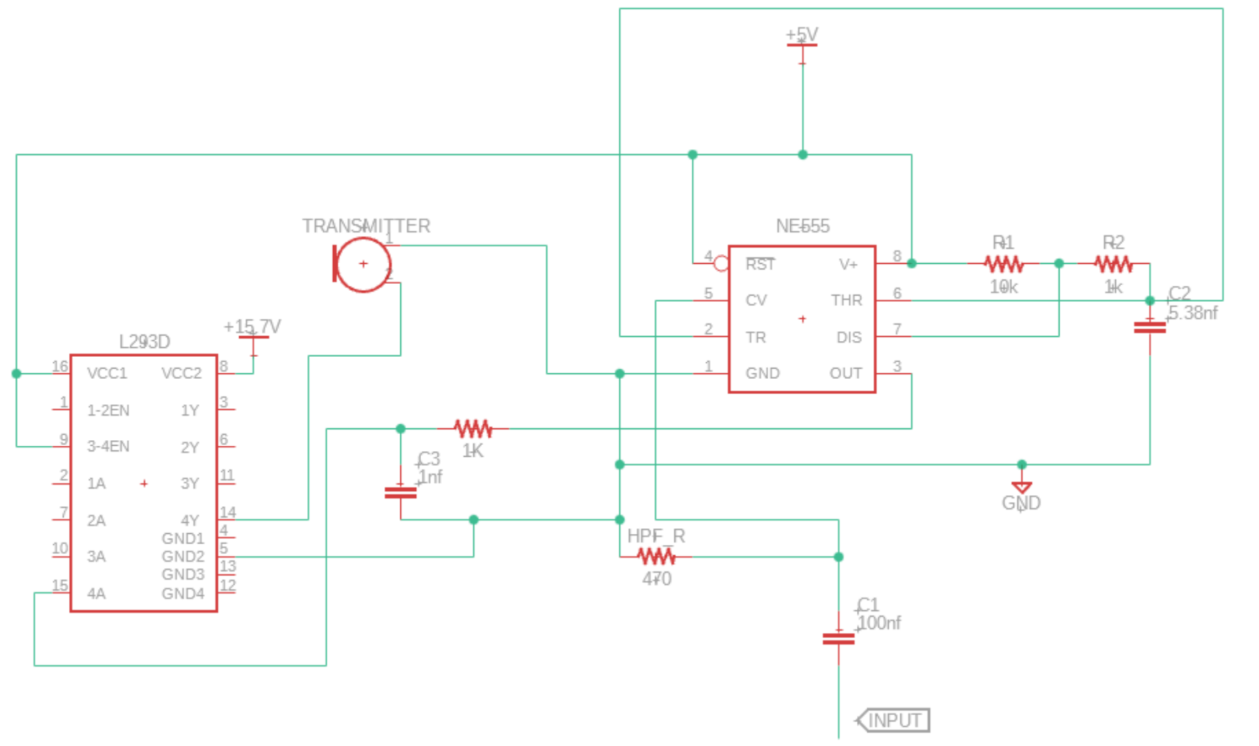


Objective

- Modulate audio signal into a Pulse-Width Modulated (PWM) signal carried around 40 KHz
- Keep track of more than one face in a live image frame using a Raspberry Pi
- Drive servos to aim speaker array at the desired face
- Provide appropriate power sources for every element of the system from a standard US power outlet

Project Implementation – Circuitry

The task of producing an audible, directional audio signal is one of analog circuitry design. This system is in two phases. The circuitry must first modulate an audio signal into a pulse width modulated ultrasonic carrier signal, in which the duty cycle increases with the input voltage. Next, it must amplify this signal to be sent to the speakers.



Team Introduction

From left to right:
- Tyler Myers (CpE)
- Ryan Catoe (EE)
- Ethan Gindlesperger (CpE)
- Cooper Sanders (EE & CpE)
- Warren Smith (EE)
- Ameen Mahmood (EE)

The modulation works by configuring a 555 timer to produce an astable PWM signal, and amplification is done using an L293ID IC, chosen for the desirable, high frequency response of its H-bridge design. The below equations are useful in configuring the 555.

Frequency equation:

$$f = \frac{1.44}{(R_1+2R_2)C}$$

Average Duty Cycle:

$$DC = \frac{R_1+R_2}{R_1+2R_2}\%$$

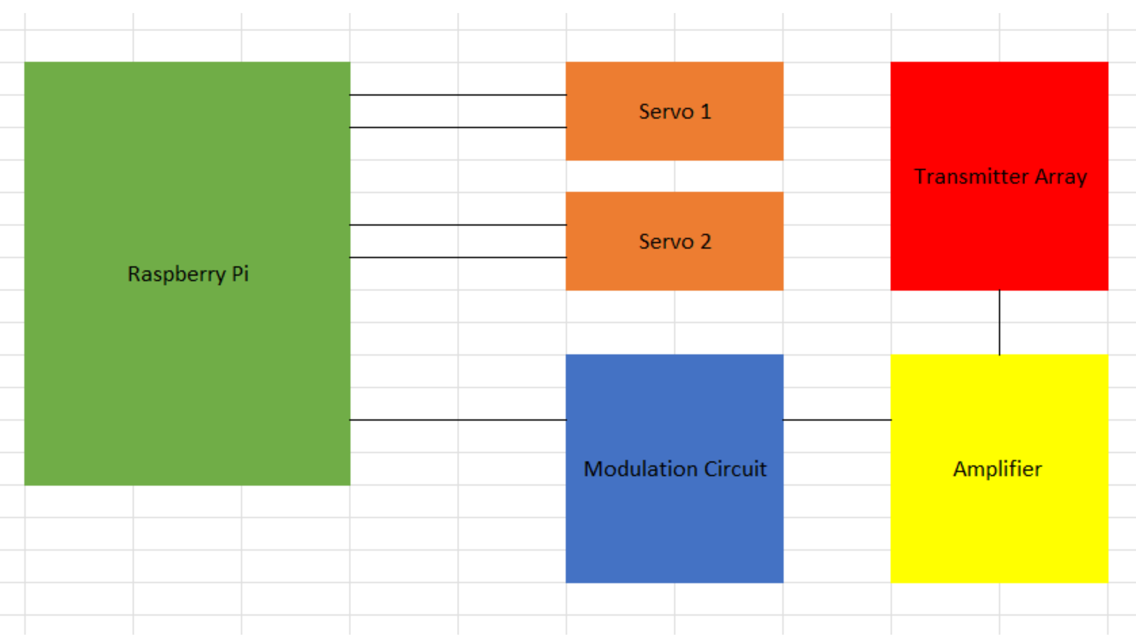
Project Implementation – Hardware

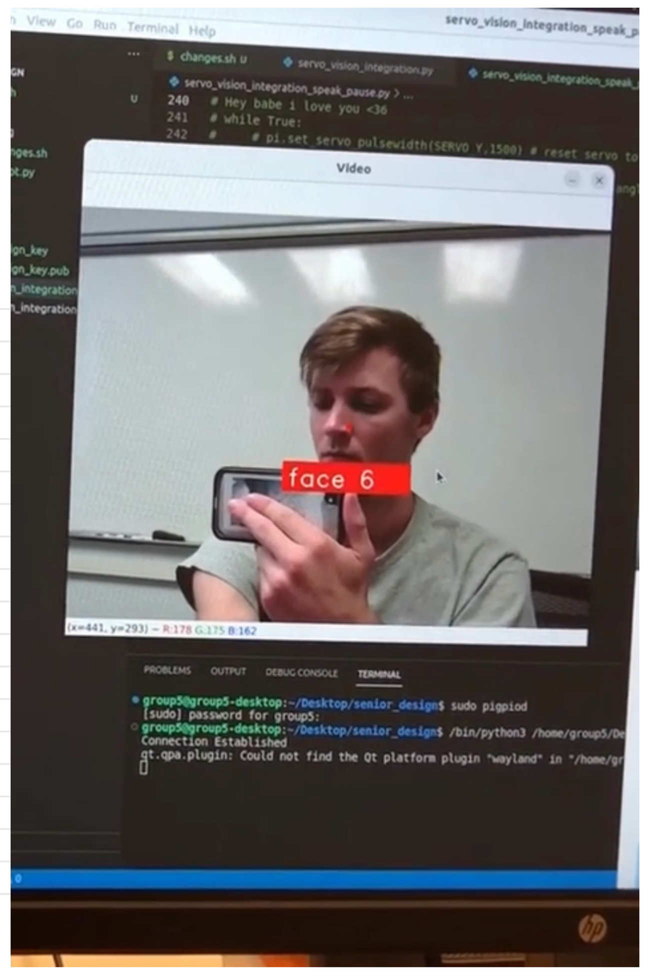
The hardware team is responsible for the development of a physical structure to support the system, which includes installing and powering servo motors that can be driven by the Raspberry Pi to aim the speakers. MG996R servos are chosen due to the torque characteristics at 5 V operation, and a 3D-printed structure is used to mount the camera and speakers onto the servos. For the speakers themselves, we use CT40-16 transmitters, chosen for the frequency response and operation voltage characteristics, which reach 40 KHz and 36 V_{rms}.

Project Implementation – Software

The software team is responsible for reading input from a camera using a Raspberry Pi, using that input to locate a desired face at which to aim a boosted audio signal, and then drive servo motors to aim the speakers at that face. To implement this, we use

- Ubuntu for the Raspberry Pi's Operating System
- Python for a general developing framework
- OpenCV for Facial Recognition
- PiGPIO for interfacing the servos



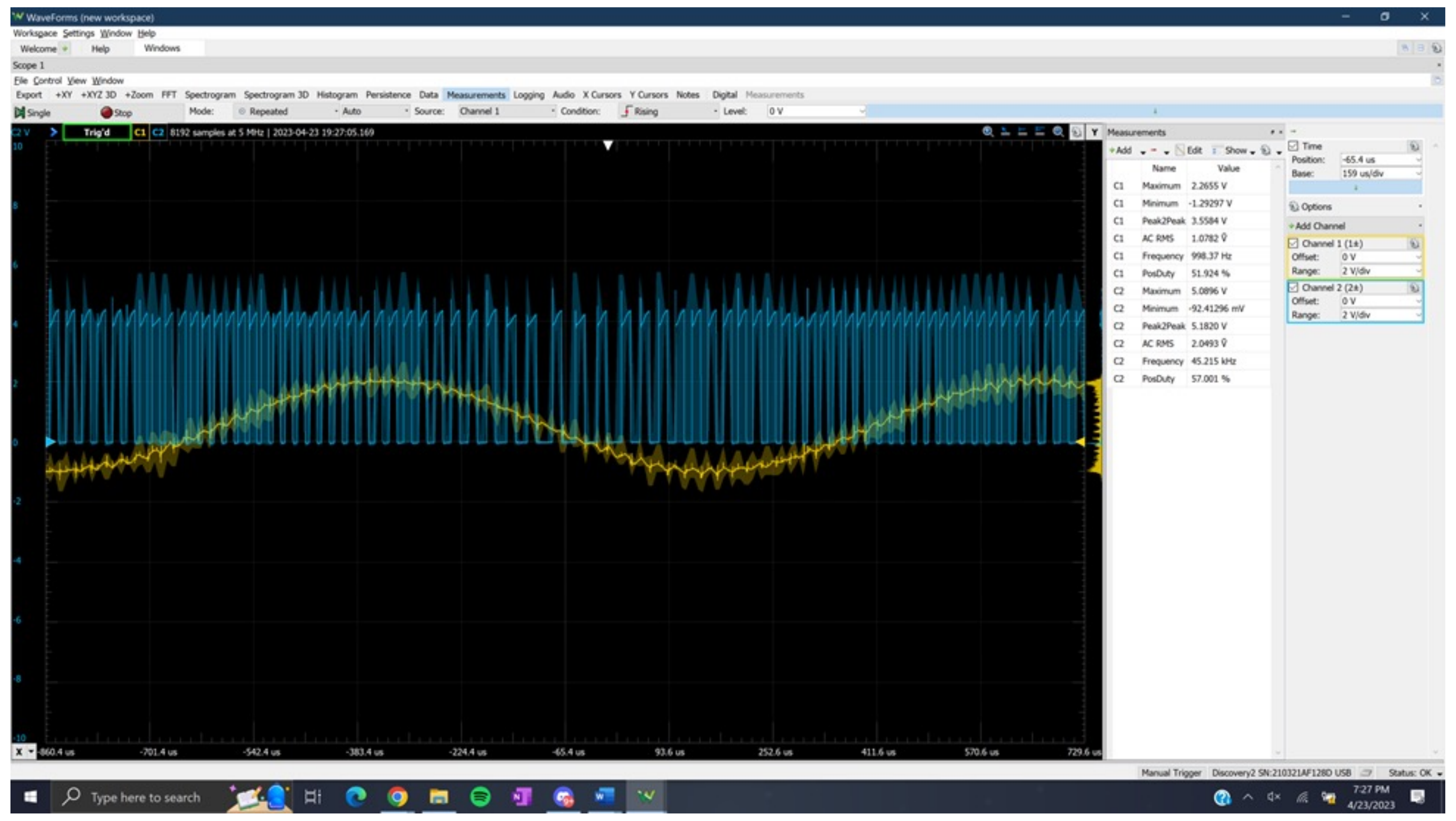


References

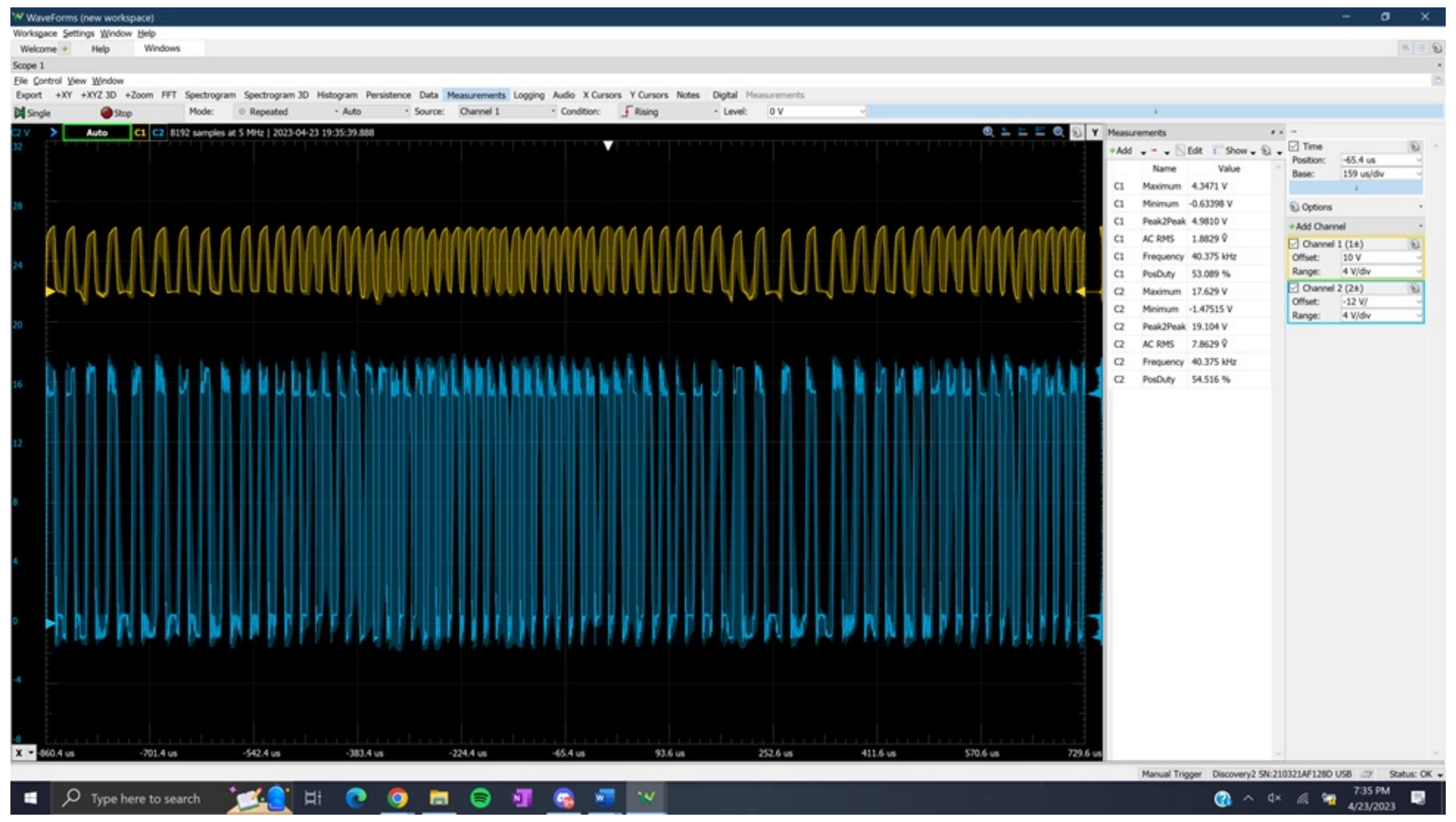
[1] K. Sjölander, B. Miller, A. Shrestha, S. N. Lee, J., Tuner, Á., Marse, J. H. Lee, M., Musick, C. Mydlarz, and J. Salamon. Short overview in parametric loudspeakers array technology and its implications in spatialization in electronic music. 2018.

Results

Individually observing different parts of the analog circuitry reveals in more detail the functionality of the system.



Here, the yellow plot measures a test, sinusoidal input audio signal to the modulation circuit, and the blue plot measures the results of the modulation. The effect of the input signal on the duty cycle is evident.



Next, the results of amplification are shown. The yellow plot measures a modulated signal going into the amplifier, and the blue plot measures the amplified signal. As can be seen in the vertical measurements shown, the amplifier produces a ~3.8x voltage increase in our configuration – enough to power the speakers.

Summary

We have a functional device that completes our set goal and follows the project planned flow chart. While there are improvements that could be made, this design is a fully functional proof of concept. If we were to take this to market, we would need some finer tuning and minor design changes, but our group has completed our project sufficiently.
Some future directions we could take the project with would include many different improvements, such as finer tuning of sound quality and volume enhancement. Also, researching and implementing battery array shapes for less acoustic scattering. A stronger computer for higher speed tracking would result in less jitter in camera movement, along with precise aiming.

Acknowledgements

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