RADAR ON THE RACE

CASE SCHOOL OF ENGINEERING
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Problem Statement

The Cleveland Hearing and Speech Center (CHSC) holds an annual Cleveland Big Wheels Relay (CBWR) fundraiser. The CHSC lacks a system to measure and display participants' velocities during the race, displaying the racer's velocities would increase crowd engagement and hopefully their donations. While there are radar devices that exist and measure velocity, those devices are expensive and have a small screen to display the velocity, an example of this is radar guns used by the police. A device that is more affordable, measures and displays the velocity on a larger screen would improve audience engagement and increase the funds raised.

Background and Context

An affordable velocity measurement system that has public display capabilities is needed, existing radar solutions are expensive and limited to single-user displays. Our development builds upon three key precedents: the VSDCAR project, which proved HB100 module viability for accurate speed detection within 20 meters; Doppler Weather Radar systems, which provided valuable signal processing insights despite their industrial scale; and Kratzer's research on Low-Cost CW Radar Systems, which established crucial noise suppression and modular design principles.

Constraints and Standards

Constraints

HB100

- Module output amplitude ranges from 100μV-500μV.
- Device is very sensitive to electromagnetic interference and outputs a lot of noise.
- The device operates at 10.525GHz and cannot be adjusted.
- Device requires 5V power input.

ESP32

- There are 15 ADC pins available.
- the ADC accepts a range of 0-3.3V with 12bit resolution.
- The device's pins run on 3.3V.
- 4MBytes of memory available.
- ESP32 CPU runs at 160MHz.

Bluetooth®

- Bluetooth® can only connect to one other device at a time.
- Bluetooth® connection range is around 20m.

Standards

[1] *Radio Frequency Devices*, 47 CFR Part 15, FCC, Apr. 25, 1989. Accessed: Sep. 15, 2024. [Online]. Available: https://www.ecfr.gov/current/title-47/part-15

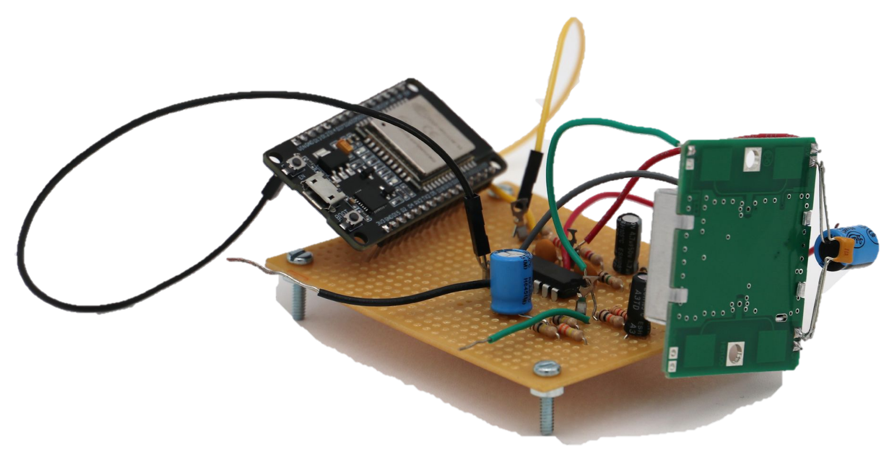
[2] *Core Specification 6.0*, Bluetooth®, Aug. 28, 2024. Accessed: Sep. 15, 2024. [Online]. Available: https://www.bluetooth.com/specifications/specs/core60-html/

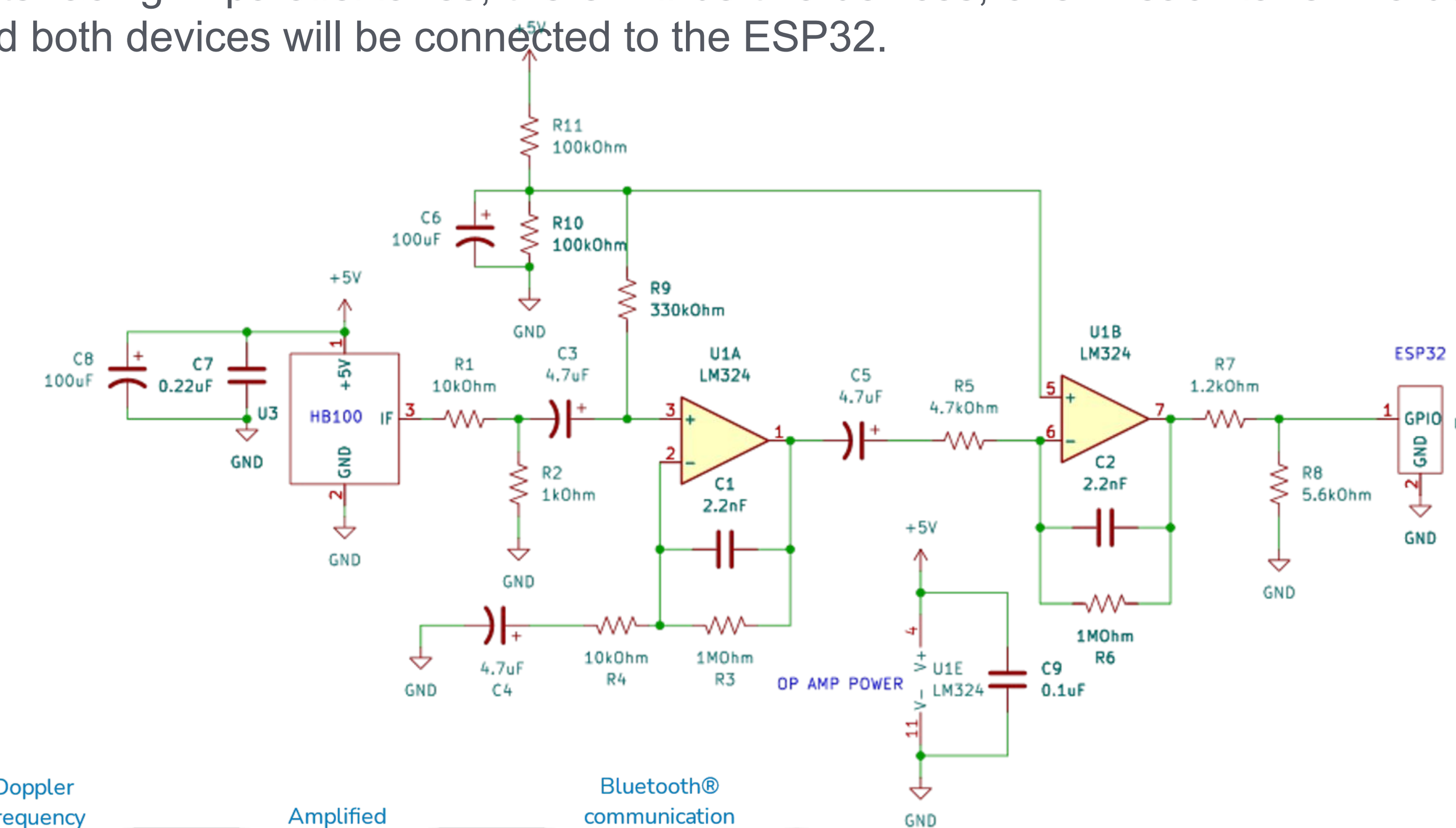
[3] *Programming Languages - C++*, ISO/IEC JTC1 SC22 WG21 N 3690, ISO, May 15, 2013. Accessed: Sep. 15, 2024. [Online]. Available: https://www.open-std.org/jtc1/sc22/wg21/docs/papers/2013/n3690.pdf

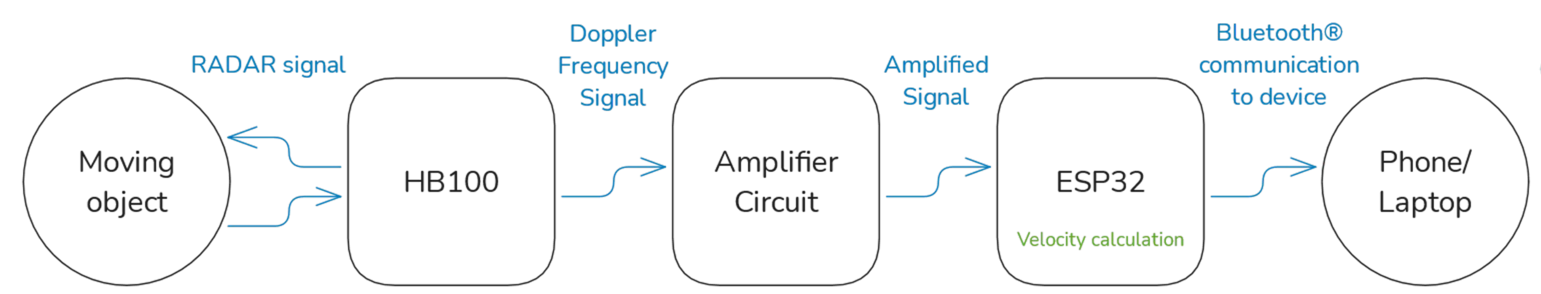
[4]"ESP32 Hardware Design Guidelines Release master Espressif Systems," 2024. Accessed: Sep. 15, 2024. [Online]. Available: https://docs.espressif.com/projects/esp-hardware-design-guidelines/en/latest/esp32/esp-hardware-design-guidelines-en-master-esp32.pdf

Approach and Design Methodology

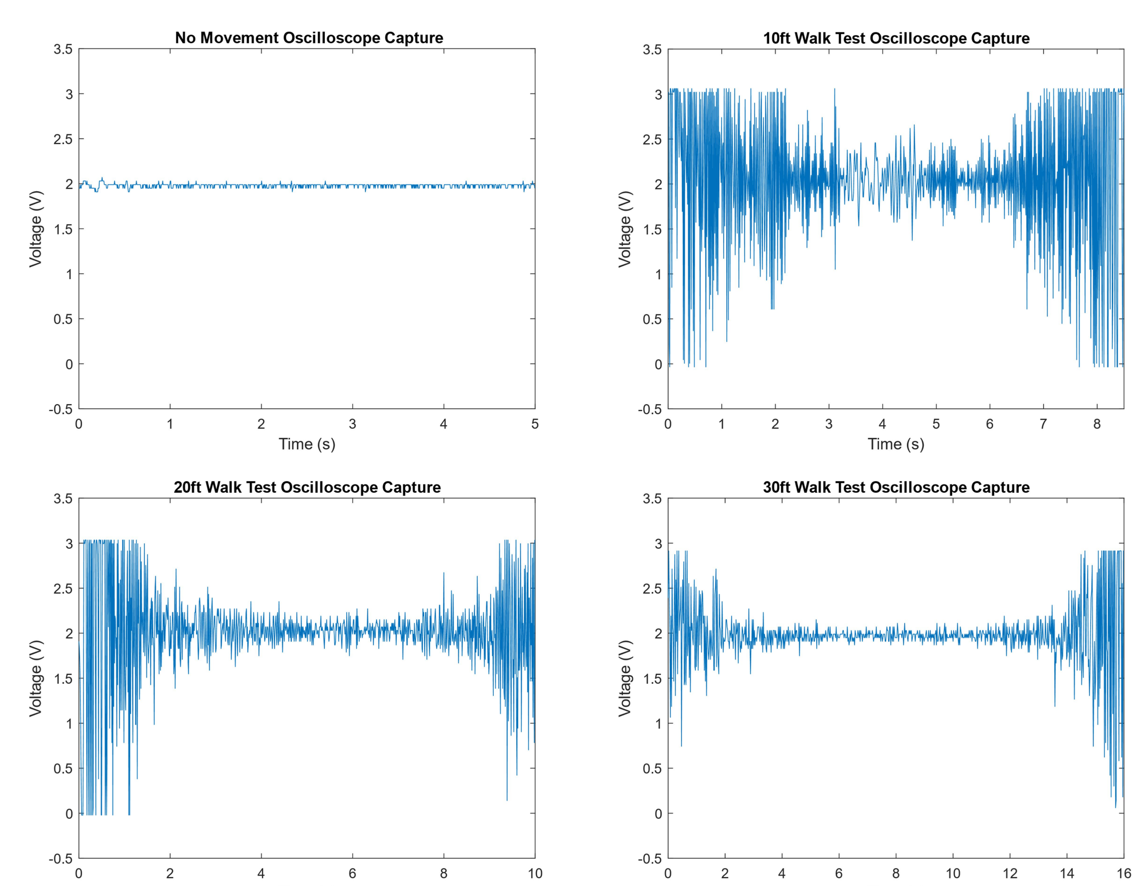
Originally our device was going to utilizes a HB100 doppler module, an operation amplifier circuit, an Arduino and an ESP32. We decided to remove the Arduino and only use the ESP 32 to reduce the cost and avoid overcomplicating the project. The HB100 continuously emits 10.525 GHz microwave signals and receives the reflections, the device compares the emitted signal to the received signal to determine the doppler frequency, which is the signal outputted from the HB100. Outputted signal is in the range of 100-500μV and passes through an operation amplifier circuit and voltage divider before it is sent to the ESP32 using an analog input pin. The ESP 32 calculated the velocity and shares the velocity via Bluetooth. Since the relay consists of two participants racing in parallel lanes, there will be two devices, one in each lane in-order to keep track of the competitors' speeds, and both devices will be connected to the ESP32.







Verification and Results



Test	Expected Speed (m/s)	Average Measured Speed (m/s)	Percent Error (%)
No Movement	0	1.2610	126.10
Walk 10ft away	1.016	4.2664	320.55
Walk 10ft towards	1.016	4.0818	301.76
Walk 20ft away	1.2192	4.1508	240.46
Walk 20ft towards	1.2192	4.0009	231.20
Walk 30ft away	1.3063	4.3094	232.71
Walk 30ft towards	1.3063	3.1800	159.39

Project Management

Emma:

- Signal processing
- Circuit assembly

Ishika:

- Bluetooth® code
- Signal Processing code

Isabella:

- Circuit testing
- Amplifier Design

Relevant Courses

Emma

ECSE 245	Circuits and amplifiers
ECSE 313	Digital signal processing, filters, Nyquist frequency
ECSE 309	Electromagnetic waves and devices

Isabella

ECSE 308	Signal processing, filters, Nyquist frequency.
ECSE 245	Circuits and amplifiers
ECSE 303	Microcontroller use, analog to digital conversion
ECSE 313	Digital signal processing, filters, Nyquist frequency

Ishika

ECSE 309	Electromagnetic waves and devices
ECSE 318	Circuits optimization, computer aided design
ECSE 303	Microcontroller use, analog to digital conversion
ECSE 315	Controllers, programmable logic
ECSE 210	Circuit analysis, analog design, noise analysis

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