Embedded Systems Project Report

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GitHub link: https://github.com/1kylecs/CPE-301_Final_Project.git

1. Project Description

1.1 Overview

This project implements a sonar-based object detection system capable of determining the distance to nearby obstacles. The system features multiple operational states—OFF, No Object Detected, and Object Detected—each represented using LEDs. A servo motor rotates the sonar sensor based on user input from an analog control knob. When an object is detected within a preset distance threshold, the system activates a buzzer and displays the measured distance on an LCD screen.

1.2 Functional Summary

- Rotates sonar sensor using a servo motor
- Measures distance using ultrasonic sensing
- Displays distance and angle on LCD depending on state
- Displays state changes and time to the Serial Monitor
- Indicates operational states using three LEDs
- Plays an audible alert when an object is detected
- Allows user control of servo angle through an analog knob
- Button to switch between OFF and Searching/Found states.
- Analog knob only moves servo when in OFF state, otherwise it is ignored.
- Sonar only runs in Scanning/Detected states

1.3 System States

OFF State:

- Blue LED on
- Servo rotates based on the potentiometer input
- Sonar is not performing measurements

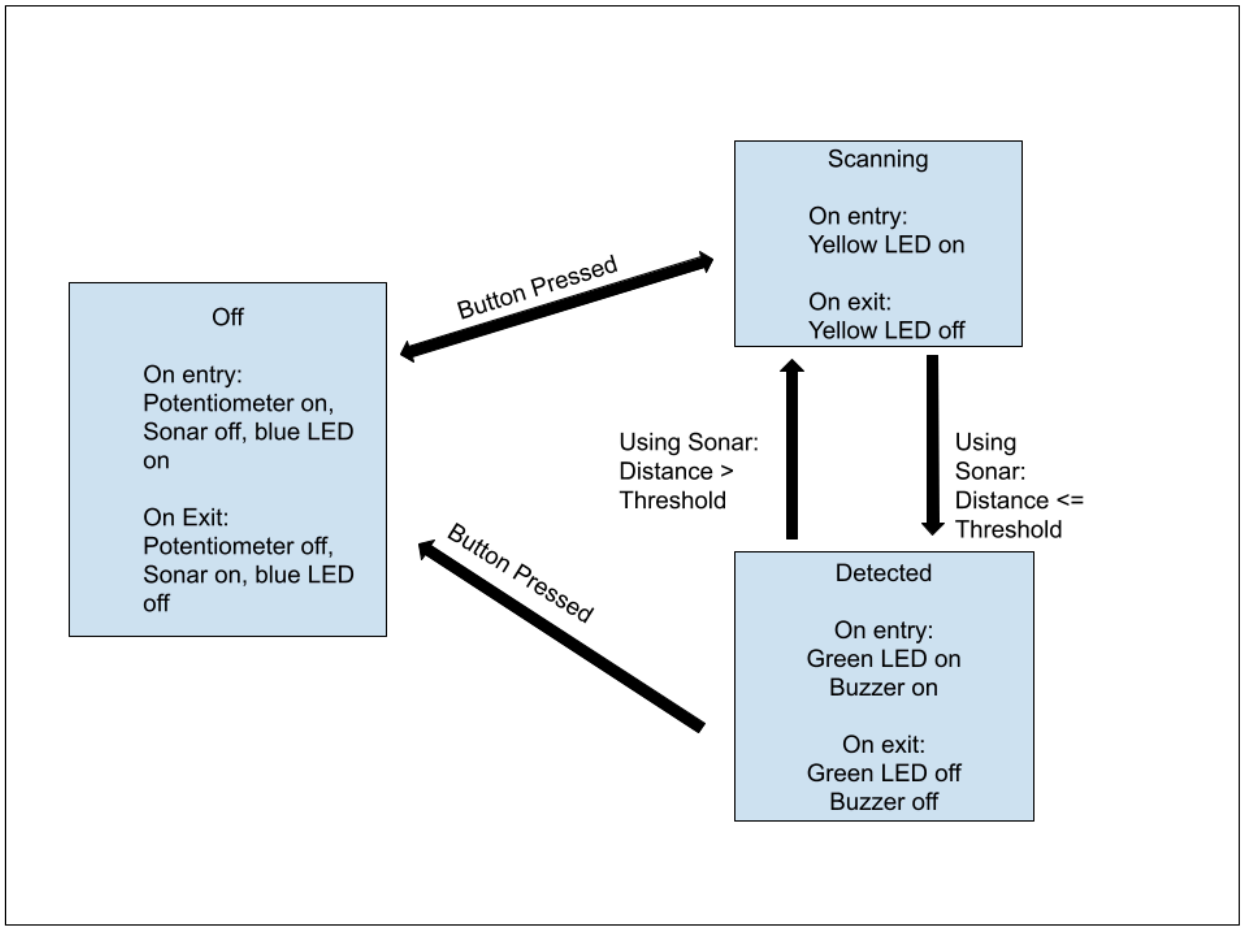
Scanning State:

- Yellow LED ON
- Servo locked and not moving
- Sonar actively measures distance
- LCD displays measured distance

Detected State:

- Green LED ON
- Servo locked and not moving
- Buzzer activated
- LCD displays measured distance

State Diagram:



2. Component Details

For each component below, describe its function, electrical specifications, and how it is used in your project. Add photos or screenshots where required.

2.1 Microcontroller

- AtMega 2560

- Runs the program and controls all other components
- Data sheet: https://ww1.microchip.com/downloads/en/devicedoc/atmel-2549-8-bit-avr-microcontroller-atmega640-1280-1281-2560-2561_datasheet.pdf

2.2 Ultrasonic Sonar Sensor

- HC-SR04

- Function: emits ultrasonic pulses & measures echo time
- Distance measurement range & operating voltage
- Data sheet:

  https://www.digikey.com/htmldatasheets/production/1979760/0/0/1/hc-sr04.html?gclsrc=aw.ds&gad_source=1&gad_campaignid=120565755&gclid=Cj0KCQiAuvTJBhCwARIsAL6DemjIoICr6CIVuZdKDqUiTnNBjuSyeBc1X65Peg1wqB5dT_QaFGJbQkIaAisdEALw_wcB

2.3 Servo Motor

- SG90 Servo Motor
- Rotates the sonar position
- Used to aim sonar based on the potentiometer input
- Connected to a 100 microfarad capacitor
- Data Sheet:

  http://www.ee.ic.ac.uk/pcheung/teaching/DE1_EE/stores/sg90_datasheet.pdf

2.4 LEDs (3-state indicators)

- Blue LED for OFF
- Yellow for Nothing Detected
- Green for Object Detected
- Using 330 ohm resistors

2.5 Buzzer

- Active buzzer
- Alarm indication when an object is detected
- Connected to 200 ohm resistor
- Data sheet:

  https://www.electronicoscaldas.com/datasheet/LTE12-Series.pdf?srsltid=AfmBOorYeDaG3i6MZMoazjAfRysbdtX79Lk0SI8hWPB5rLtr7Wy9ylVh

2.6 LCD Display

- 16x2 I2C
- Displays distance, angles, and state info
- Data sheet: https://www.vishay.com/docs/37484/lcd016n002bcfhet.pdf

2.7 Analog Knob (Potentiometer)

- There are 2, one to control LCD contrast and one to control servo angle
- Voltage divider behavior
- Range: 0–5V → 0–1023 ADC reading
- Data sheet (different but very similar 10k potentiometer w/ same pins):

  https://components101.com/sites/default/files/component_datasheet/potentiometer%20datasheet.pdf

2.8 Power Supply

- Uses 9V battery
- Provides power for the servo
- Data sheet: https://www.handsontec.com/dataspecs/mb102-ps.pdf

2.9 Real Time Clock

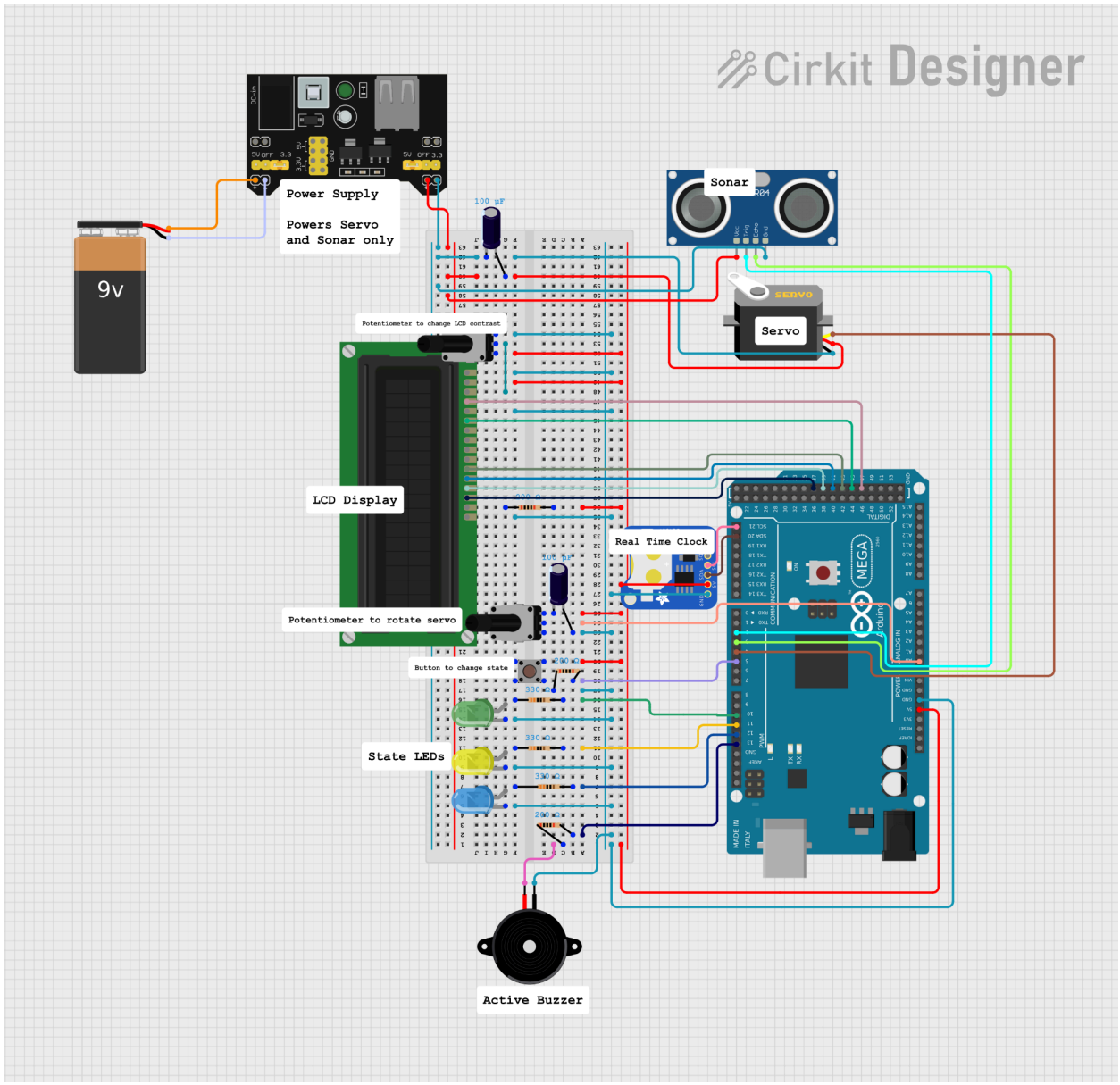
- DS1307 RTC Module V03
- Provides access to RTClib to post real-time data in the serial monitor
- Data sheet: https://www.analog.com/media/en/technical-documentation/data-sheets/ds1307.pdf

2.10 Button

- Toggles between OFF and SCAN states
- Enables/disables the ability to move the servo motor's angle
- Data sheet: https://www.arduino.cc/documents/datasheets/Button.pdf

3. Circuit Diagram and Images

3.1 Circuit Diagram


Cirkit Designer
Power Supply
Powers Servo and Sonar only
9v
100 µF
Sonar
Servo
Potentiometer to change LCD contrast
LCD Display
Real Time Clock
Potentiometer to rotate servo
Button to change state
State LEDs
330
Active Buzzer

3.2 Final Circuit Images

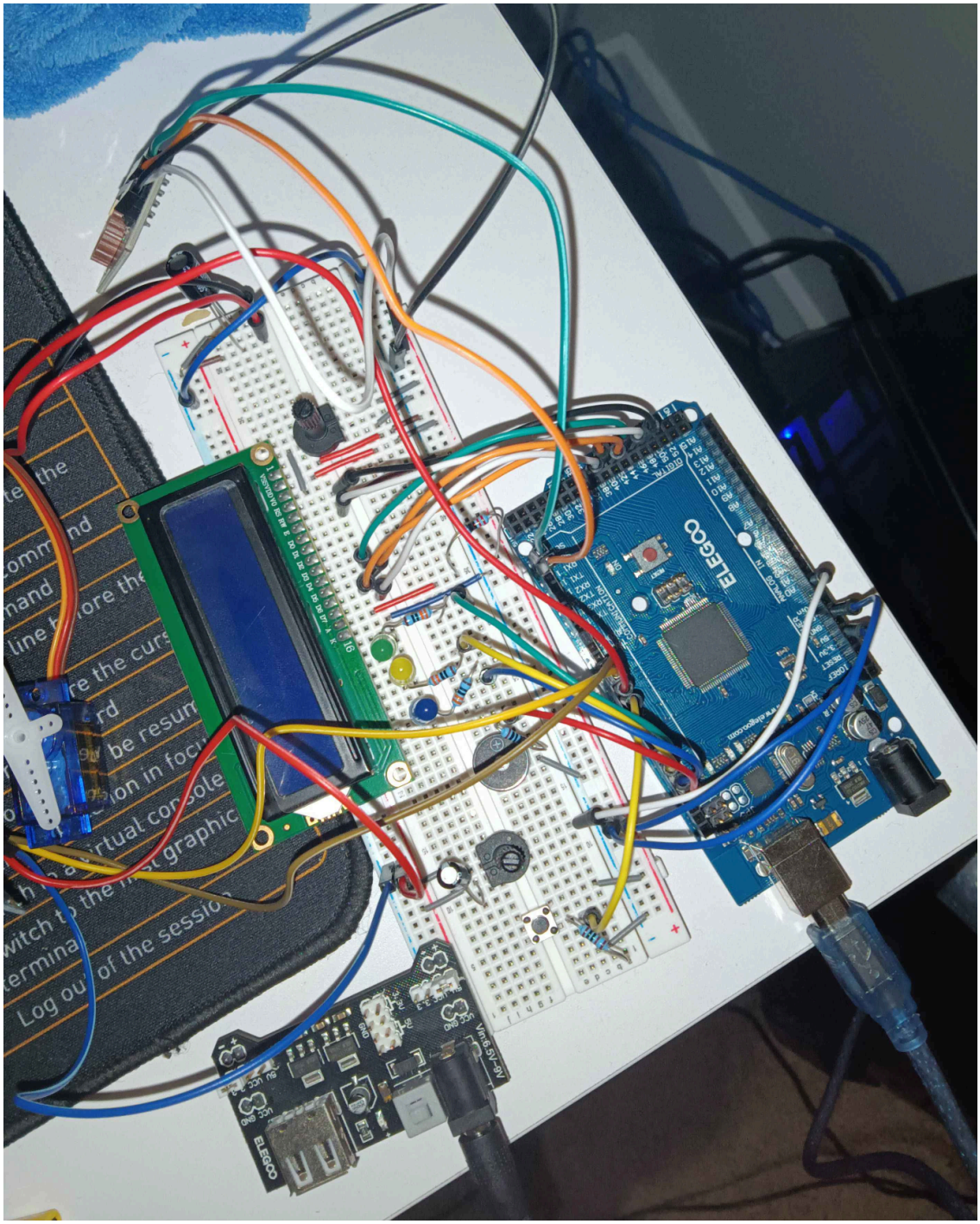


Figure 1: One angle of the final circuit, when turned off

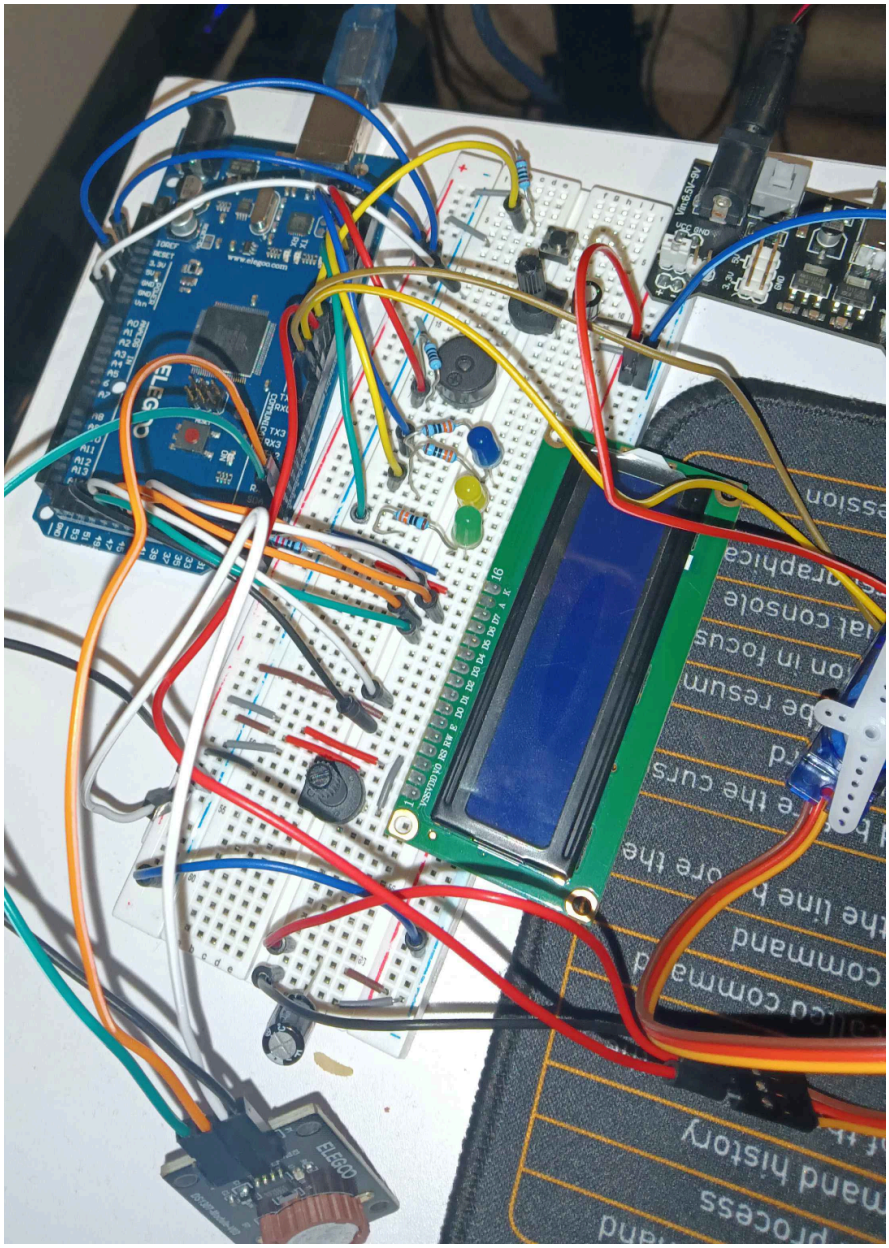


Figure 2: Another angle of the full circuit, powered off.

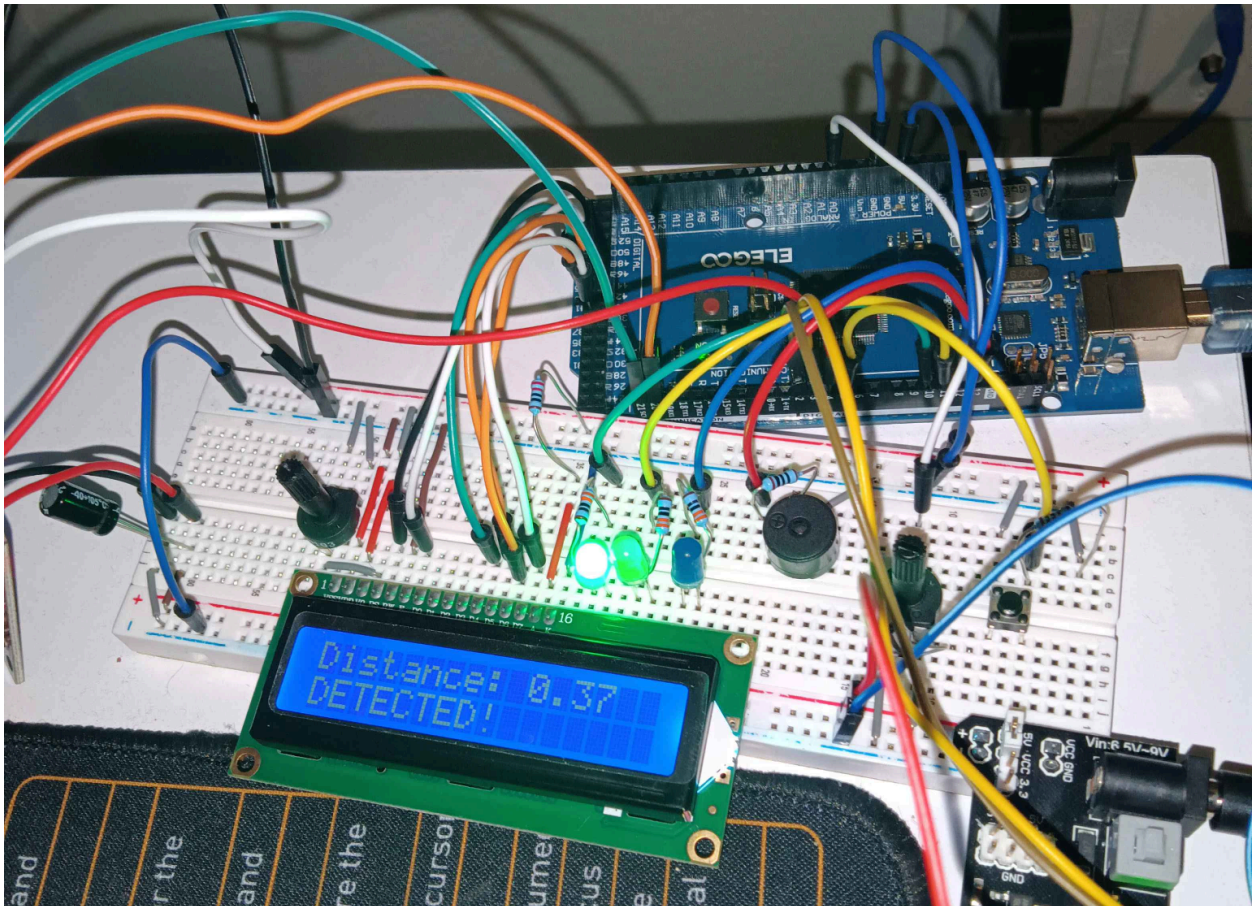


Figure 3: Circuit during DETECTED state, green LED on distance printed to LCD.

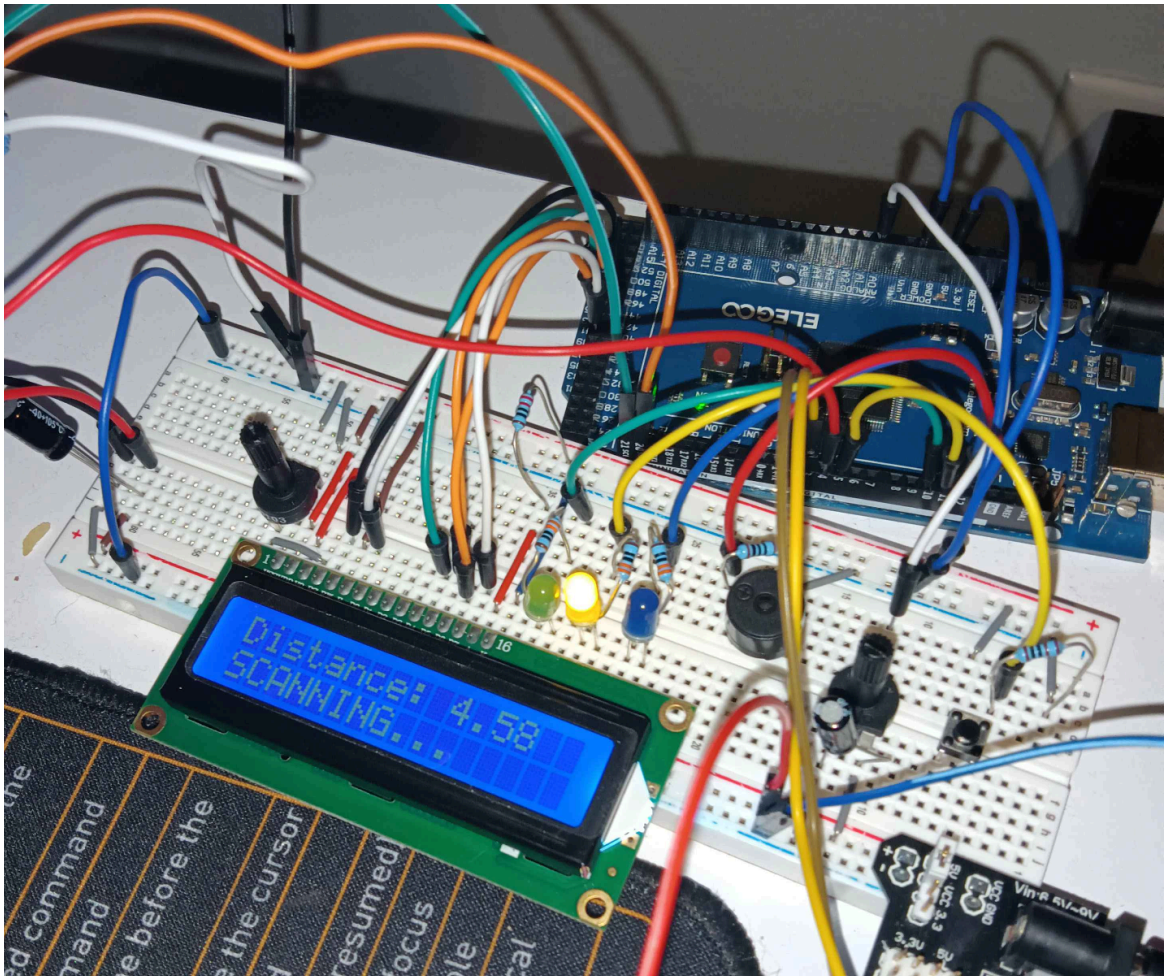


Figure 4: Circuit during SCANNING state, yellow LED on, measured distance printed to LCD.

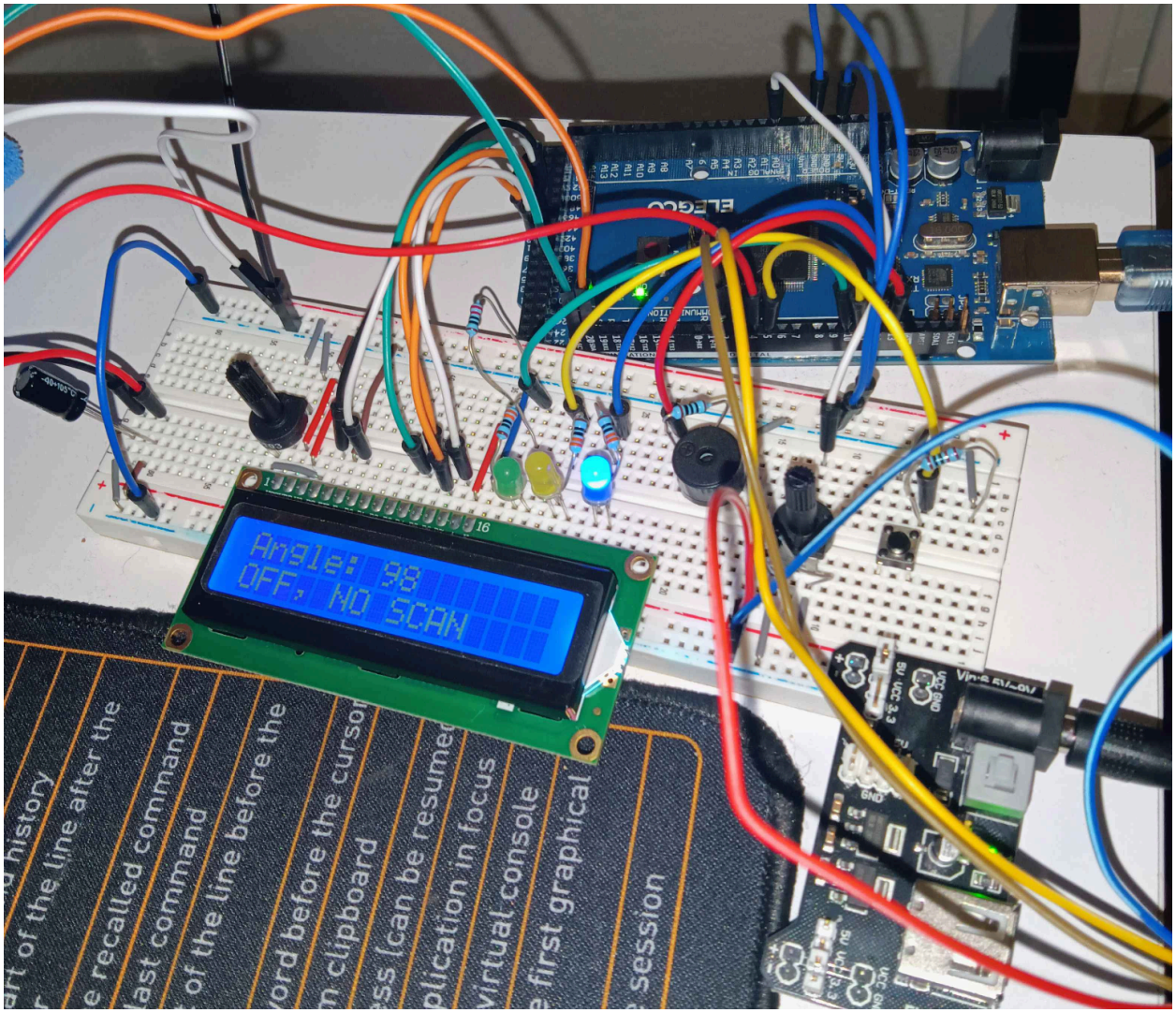


Figure 5: Circuit during OFF state, blue LED on,

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[00:17:58] Moved within 1ft of scanner, detected
[00:18:13] Moved outside 1ft, scanning
[00:18:18] Button pressed, turning sonar off, able to rotate servo
[00:18:26] Button clicked, transitioning into scan, locking servo
[00:19:03] Moved within 1ft of scanner, detected
[00:19:07] Moved outside 1ft, scanning
[00:19:10] Moved within 1ft of scanner, detected
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Figure 6: Example of Serial Monitor output and state change information.

3.3 Video Demonstration

https://www.youtube.com/shorts/9WKkbGqSulM

4. Environmental Report

This project was designed with consideration for environmental impact, safety, and responsible engineering practices. The following sections discuss the project's benefits and relevance from both an environmental and design perspective, using details from the implemented system.

Energy Efficiency

The system demonstrates efficient power usage by activating components only when necessary. The ultrasonic sonar operates exclusively in the *Scanning* and *Detected* states, remaining completely inactive during the *OFF* state to prevent unnecessary power draw. Similarly, the servo motor is only actively driven when the system is in the *OFF* state and the user adjusts the potentiometer; once scanning or detection begins, the servo is locked in position, eliminating continuous motor movement and reducing energy consumption. LEDs and the buzzer are state-dependent and are not powered continuously. This state-based control strategy minimizes wasted energy and ensures efficient use of the 9V battery power supply.

Design Safety

Safety was a key consideration in the circuit and system design. All LEDs are connected with appropriate current-limiting resistors (330 Ω), and the buzzer is protected with a 200 Ω resistor to prevent overcurrent conditions. Voltage levels are kept within safe operating limits for all components, with the microcontroller managing logic-level signals and isolating control from higher-current devices like the servo. The use of a decoupling capacitor on the servo helps reduce voltage spikes and electrical noise, improving system stability and preventing erratic behavior. Clear state definitions and predictable transitions also provide safe error recovery, ensuring the system defaults to a known, non-harmful state when powered on or turned off.

Affordability

The project uses low-cost, widely available components such as the ATmega 2560, HC-SR04 ultrasonic sensor, SG90 servo motor, standard LEDs, and a basic 16×2 I2C LCD. These components are commonly used in educational and hobbyist projects, making the system affordable while still maintaining reliability and functionality. By avoiding specialized or

proprietary hardware, the design remains cost-effective and accessible to students and entry-level engineers without sacrificing performance.

Sustainability

Sustainability is supported through the use of durable, reusable components that can be easily repaired or replaced individually rather than discarding the entire system. The modular nature of the design allows components such as the servo, sensor, or display to be swapped out if they fail. Efficient energy usage extends battery life, reducing waste from frequent battery replacement. Additionally, the project's straightforward wiring and reliance on standard components promote reuse in future projects, contributing to more responsible resource utilization.

Accessibility

The system is designed to be user-friendly and inclusive. Clear visual feedback is provided through three LEDs that indicate system state at a glance, while the LCD presents readable distance and state information. User interaction is simple and intuitive, relying on a single button and analog knobs rather than complex input methods. From a builder's perspective, the circuit uses common components and clear state logic, making it easy to assemble, understand, and operate for users with varying levels of experience in embedded systems.

Overall, this project balances functionality with responsible design choices, demonstrating how embedded systems can be energy-efficient, safe, affordable, sustainable, and accessible while still meeting technical objectives.