Using Magnetic Fields to Transfer Information:

RFID Automated Pet Door Project

Final Report

Team 10

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ENGI 2203: Engineering Design II

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April 16, 2025

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Chapter 1 – Introduction

1.1 Objectives

Traditional pet doors present several issues, including pests entering the home, heat loss due to cold air outdoors, and potential home invasion risks. Team 10 proposes an automated locking pet door that ensures only authorized pets may enter, maintains indoor temperature, and improves security.

1.1.1 Functional Objectives

The functional objectives are as follows:

- Install within a door, similar to existing flap pet doors.
- Restrict access to authorized pets only, ensuring selective entry and exit.
- Improve home security by implementing a locking mechanism.
- Increase energy efficiency with a door that fully seals when closed.
- Automate door operation using a microcontroller that detects pet presence.
- Enable a night-locking feature to prevent pet exits during nighttime hours.
- Alert the user of the pet's passage through the door through both visual and auditory system feedback.
- Connects to home power supply via electrical outlet.

1.1.2 Specifications

The technical specifications are as follows:

- The pet detection system operates within a 1-metre range on either side of the door.
- A magnetic coil is attached to the pet's collar and is detected by a Hall effect sensor in the door frame.
- LED indicators (green, orange, and red) reflect the detection system's operational state.
- A buzzer provides audio feedback when the pet is within 1 metre of the door.
- The door opens and closes vertically through a motorized mechanism.
- Night mode is triggered by low environmental light levels, detected via a photosensitive resistor.
- The system is connected to a power source via cable.

1.1.3 Sustainability

Project sustainability was addressed in both the design objectives and component selection. The pet door automates access to reduce unnecessary heating and cooling loss in the home, improving energy efficiency by ensuring the door remains fully closed when not in use. Additionally, the device uses relatively low-power components that minimize overall energy consumption.

1.1.4 Hazard Mitigation

Several potential hazards were considered throughout the development and implementation of the project. One concern was the risk of the door closing while a pet was still passing through. To mitigate this, the timer keeping the door open will reset if the pet continues to be detected. The possibility of unwanted animals entering the home was addressed by incorporating RFID-based access control, allowing only authorized pets to trigger the system. While the current prototype was tested under controlled indoor conditions, the team recognizes that real-world implementation may involve exposure to hazardous weather. Future improvements would include weatherproofing. Safety during development was also prioritized—proper soldering techniques and equipment handling were followed when working with circuit elements.

1.2 Methodology

The Methodology section is divided into Tools and Materials, Design Process, and Team Roles.

1.2.1 Tools and Materials

Each team member was provided a materials kit. The contents of one kit are listed in the following table.

Kit-Quantity	Part Number	Description
1	Resistor Kit (10 Each)	10Ω, 22Ω, 47Ω, 100Ω, 150Ω, 200Ω, 220Ω, 270Ω, 330Ω, 470Ω, 510Ω, 680Ω, 1KΩ, 2KΩ, 2.2KΩ, 3.3KΩ, 4.7KΩ, 5.1KΩ, 6.8KΩ, 10KΩ, 20KΩ, 47KΩ, 51KΩ, 68KΩ, 100KΩ, 220KΩ, 300KΩ, 470KΩ, 680KΩ, 1M
1	Capacitor Kit 1	Film (5 Each) 102, 152, 332, 472, 103, 333, 473, 104, 224, 474
1	Capacitor Kit 2	Aluminum (10 Each) 0u22, 0u47, 1u, 2u2, 4u7, 10u, 22u, 33u, 47u, 100u, 220u, 470u
5	C320C104J5R5TA7301	CAP CER 0.1UF 50V 5% RADIAL
2	R82DC3330AA60K	CAP FILM 0.33UF 63VDC 10% RADIAL
2	R82DC3470SH60J	CAP FILM 0.47UF 63VDC 5% RADIAL
1	ABRA-12	Breadboard-840 Tie Points
1	JW-1	Breadboard Wiring Kit
1	JW-2	Jumper Wire Strip M-F 20pc
2	1N4148	Signal Diode
1	3362P-1-103LF	TRIMMER 10K OHM 0.5W PC PIN

2	1N5819	Shottkey Diodes
1	Key-Pad	3X4 Numeric Keypad
7	HDR Pin	2.54 Pitch split long pin header pin
1	SPKM.10.8.A	10MM MINI 8 OHM SPEAKER
4	BC60ANP	Alligator Clip
1	Red	LED 3MM RED CLEAR
1	Green	LED 3MM GREEN CLEAR
1	Blue	LED 3MM BLUE CLEAR
1	Yellow	LED 3MM YELLOW CLEAR
1	White	LED 3MM WHITE CLEAR
1	GL5537	Photo Sensitive Resistor (CDs Cell)
1	MC7805CT-BP	IC 5V Regulator LDO 1A
1	MCP6281-E/P	Single Supply Op Amp
1	MCP6546-I/P	IC DIFF COMP
1	LMC555CN/NOPB	IC OSC SINGLE TIMER 3MHZ 8-DIP
1	TOL-08793	Needle Nose Pliers
1	TOL-08794	Diagonal Cutters
1	TOL-09146	1 Mini Phillips, 1- Mini slot
1	TOL-13114	Resistor Lead Bending tool
1	USB-AM51-01	Cable USB A male to Mini B male 1ft
1	NANO-V3	Nano Clone Mini WITH CABLE USB CH340 ATMEGA328PB
1	HC-SR04	Ultrasonic Distance Sensor
1	HC-SR501	PIR Motion Sensor
1	8189	Magnet
1	Tact Switch	Push Button Switch
1	MG 90S	Servo Motor Metal Gear
1	MPU-6500	6 Axis Gyro+Accellerometer
1	PAM8302	2.5W Audio Power Amp
1	AM2302	Humidity and Temperature Sensor
1	AH3572-P-B	Digital Switch Omni polar Switch Push-Pull Hall Effect TO-92
1	DRV5053CAQLPGM	Hall Effect Sensor Single Axis TO-92-3
1	CMA-4544PF-W	Electret Condenser Microphone
1	LM235Z	Temperature Sensor Analog, -40°C ~ 125°C 10mV/°K TO-92-3

Table 1: Kit Materials

The team was granted the following additional materials:

- 50g of Plastic for 3D Printing

- Cardboard Box
- Two-Layer 8cm x 10cm Printed Circuit Boards
- 1oz of Copper
- A 99.2% Iron Core, 3mm x 100mm
- 4m of 24 AWG Enamel Wire
- 4 Paper Clips
- Male Connectors for the Printed Circuit Board
- Glue for Plastic Materials as Needed
- 20 AWG Electrical Wire
- 2 8.2Ω, 2W Resistors

The team was granted access to the following hardware and software tools:

- Soldering Iron
- Power Supply
- Multimeter
- Oscilloscope
- Microchip Studio C/C++ IDE
- PuTTY serial output monitor

1.2.2 Design Process

The development of the automated pet door was completed in several consecutive phases: Preliminary Research, Door Prototyping, Circuitry and Programming, Door Construction and Final Assembly.

(1) Preliminary Research
   a. Studied existing pet doors and automated entry systems
   b. Studied RFID technology circuit integration and functionality
   c. Used information to proceed with component selection and system design

(2) Door Prototyping
   a. Created rough sketches of a functioning door mechanism
   b. Made adjustments as per material constraints and additional feedback

(3) Circuitry and Programming
   a. Built Hall effect sensor/magnetic coil circuit
   b. Assessed coil detection using an oscilloscope
   c. Built motion sensor and buzzer circuits
   d. Wrote and tested code for motion sensor and buzzer

(4) Door Construction
   a. Built physical door mechanism and installed motor
   b. Wrote code for motor rotation
   c. Made hardware and code adjustments as per door mechanism performance

(5) Final Assembly

    a. Integrated door mechanism, motion sensor, buzzer, and RFID modules
    b. Validated communication between modules through functional testing to ensure smooth operation and expected feedback

A logbook was kept by each team member to record meeting minutes and project progress, brainstorm ideas, sketch prototypes, assess results, and take relevant lecture notes.

1.2.3 Team Roles

Roles were assigned based on individual strengths and prior experience. All members contributed to system development, with specific responsibilities outlined as follows:

(1) Daniel Navarro DeGiorgio
  a. Programmed and calibrated pet proximity detection system
  b. Assembled all modules into final product
  c. Contributed to project documentation

(2) Sophia Zykova
  a. Prototyped, constructed, and programmed door mechanism
  b. Assembled Hall effect sensor/coil circuit
  c. Contributed to project documentation

(3) Rhys Brown
  a. Programmed both curfew and alert systems
  b. Assembled all modules into final product
  c. Contributed to project documentation

(4) Brianna Farrell
  a. Prototyped door mechanism
  b. Assisted in Hall effect sensor/coil circuit assembly
  c. Contributed to project documentation

Chapter 2 – System Architecture

2.1 Module Interface

The automated pet door is composed of four interconnected primary modules: Proximity Detection, Door Mechanism, Alert System, and Curfew Enforcement. Each module performs a distinct function while contributing to the overall operation of the system.

(1) Proximity Detection

The detection system identifies the presence of the pet when it is within a 1-metre radius of the pet door via ultrasonic motion sensor and Hall effect sensor. If the pet is detected, it will send a signal to the microcontroller, which will initiate the door mechanism program.

(2) Door Mechanism

The function of the door depends on two conditions, the presence of the pet and the environmental light level. The door will raise vertically when the pet is nearby and lower when the pet has passed through. The door will open only if it is daytime; otherwise, it will remain closed.

(3) Alert System

The alert system activates a buzzer sound that notifies the owner when the pet is actively passing through the door. It additionally buzzes when the pet is detected within the ultrasonic sensor's range. The system acts as a bidirectional doorbell.

(4) Curfew Enforcement

The curfew feature inhibits the door from opening in a dim environment (night) to ensure that the pet remains safely indoors. A photoresistor sends a signal corresponding with the current light intensity to the microcontroller. The microcontroller then instructs the door mechanism to remain closed when it is night.

2.2 Electronic System

The electronic system consists of various components interfaced with the ATmega328PB microcontroller to enable sensing, triggering, and feedback. The hardware components of the system are listed as follows:

- HC-SR04 ultrasonic motion sensor
- LEDs (orange, green, red)
- Push buttons
- MG 90S servo motor
- ATmega328PB microcontroller
- SPKM.10.8.A speaker
- PAM8302A amplifier
- GL5537 photosensitive resistor

- Hall effect sensor (DRV5053CAQLPGM)
- Breadboard
- Wires

2.3 Program Architecture

The overall system logic was structured to ensure reliable decision-making based on sensor inputs. The following flowchart outlines the main control flow executed by the microcontroller.

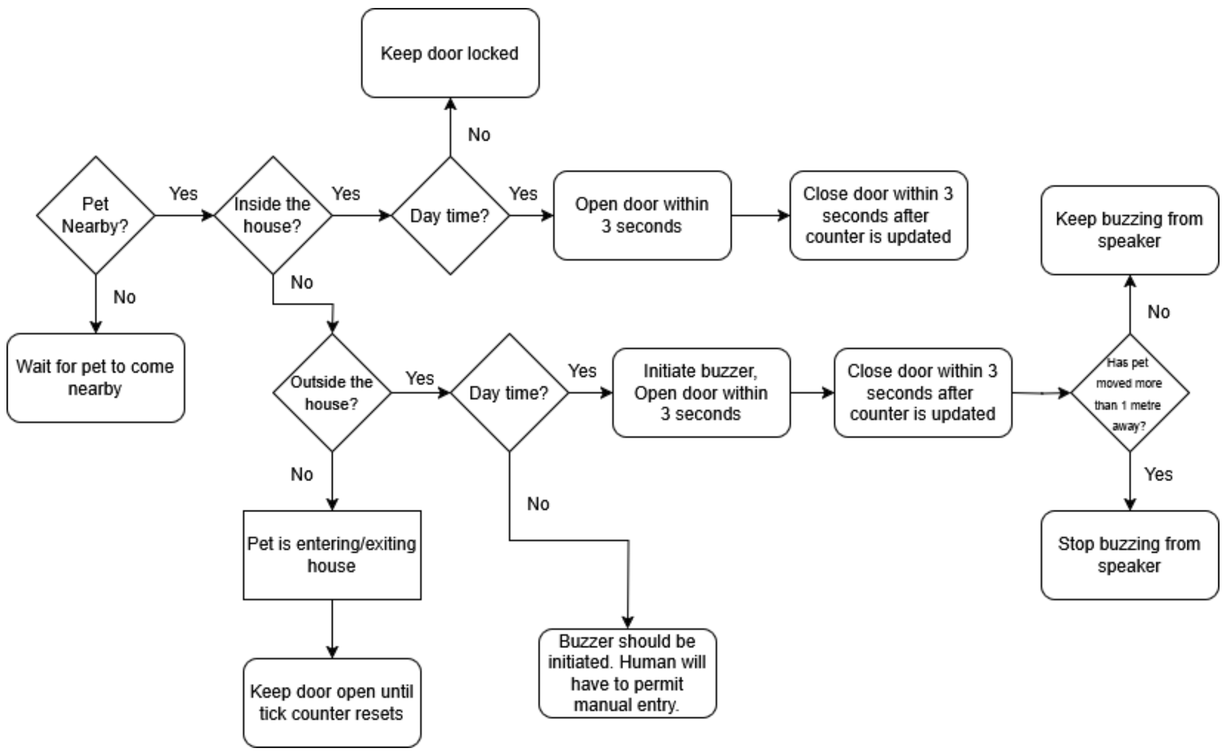

Figure 1: Microcontroller Logic Flowchart

Chapter 3 – Detailed Design

3.1 Electronics Design

The following images document the development and testing of the RFID detection circuit, which was designed to identify a pet's presence using a magnetic coil and a Hall effect sensor. The circuit aimed to produce a detectable voltage change when the magnetic field from the coil was brought near the sensor. Oscilloscope waveforms were captured during testing to observe sensor response. The Hall effect sensor did not register any consistent output when exposed to the coil's magnetic field, indicating a failure in detection.

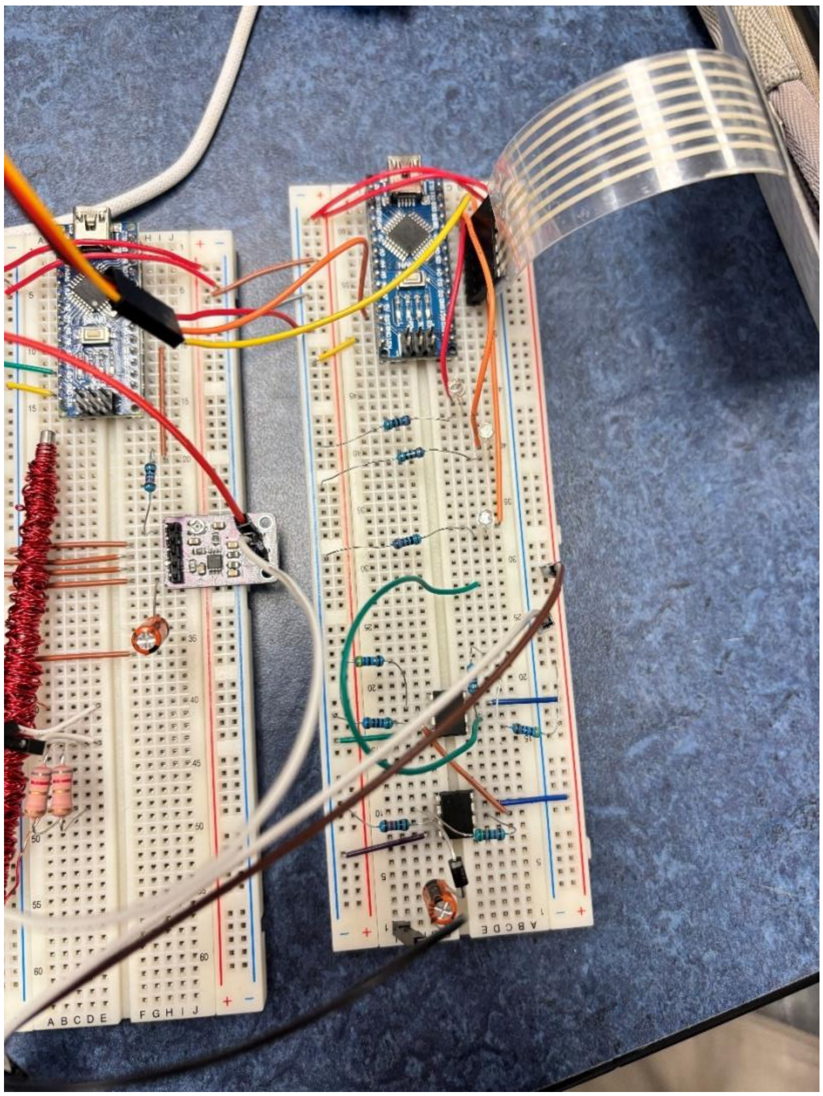

Figure 2: RFID Hall Effect Sensor/Coil Circuit

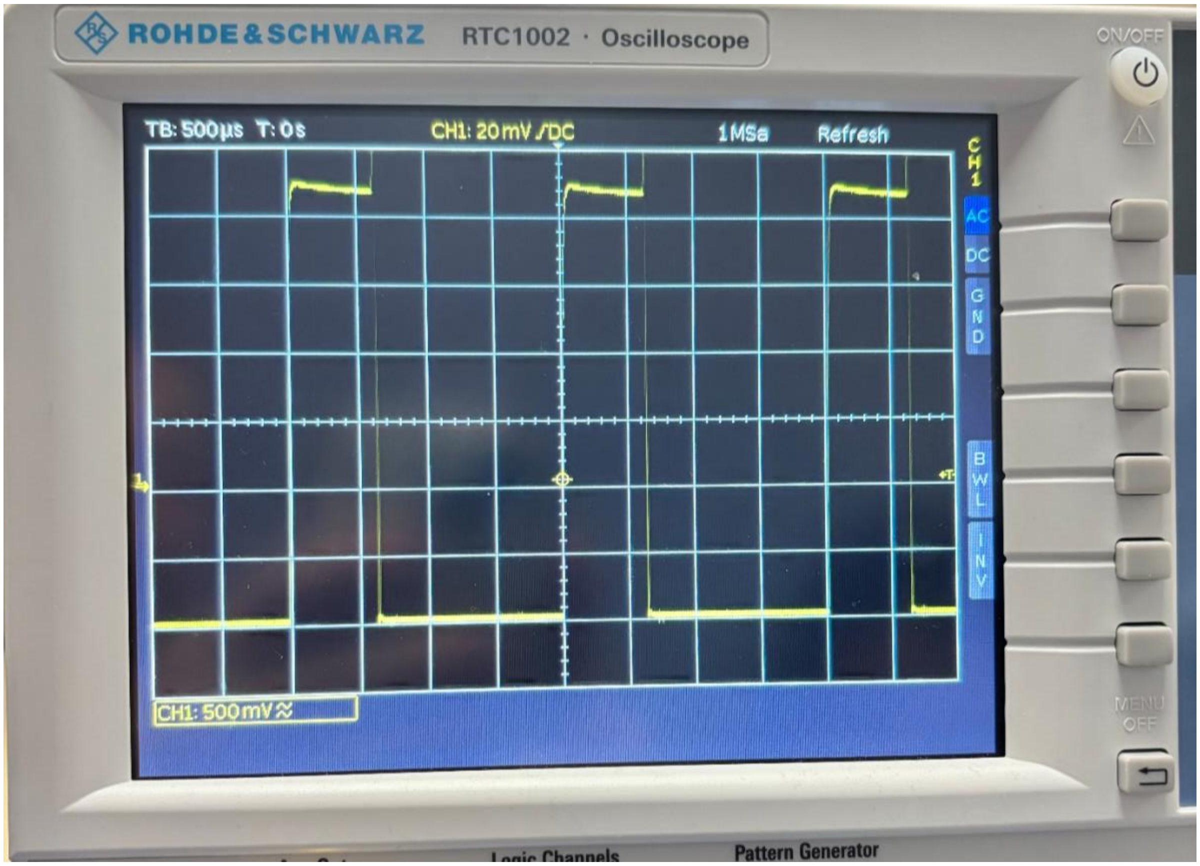

Figure 3: Oscilloscope Square Waveforms

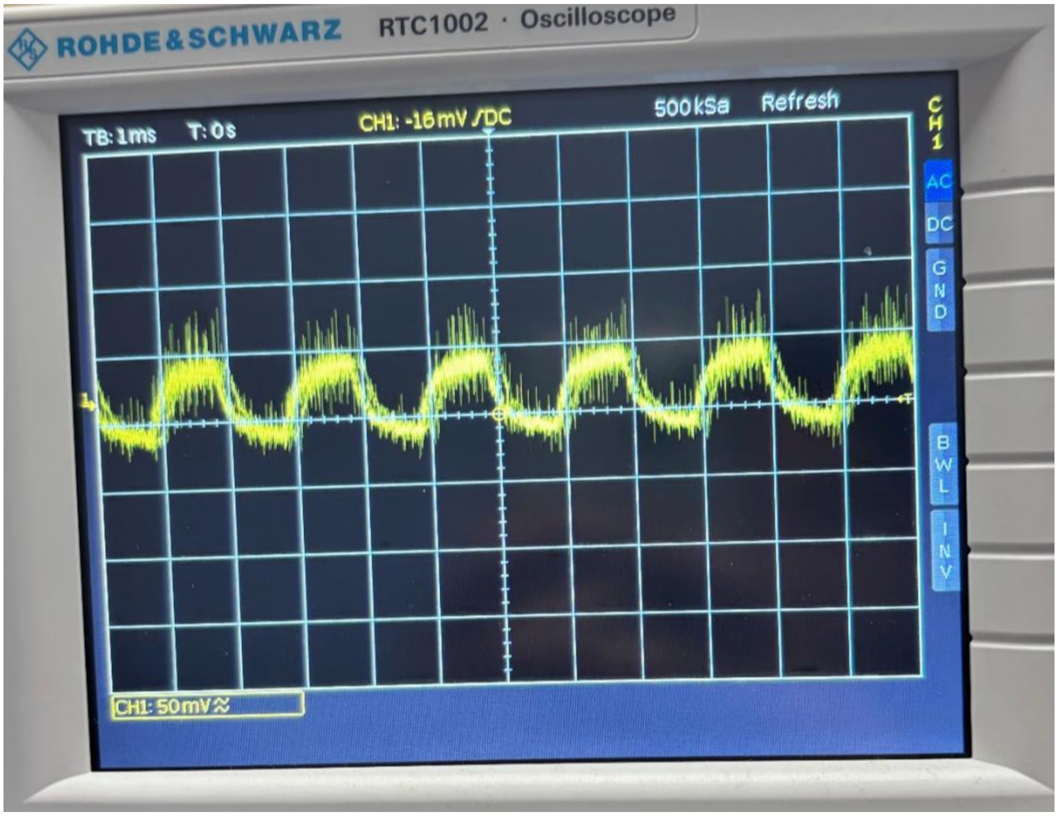

Figure 4: Oscilloscope Waveforms (Noisy)

To enable reliable testing of the door mechanism during development, a simplified button-operated control circuit was implemented. This circuit allowed manual actuation of the motor using a push-button input connected to the microcontroller.

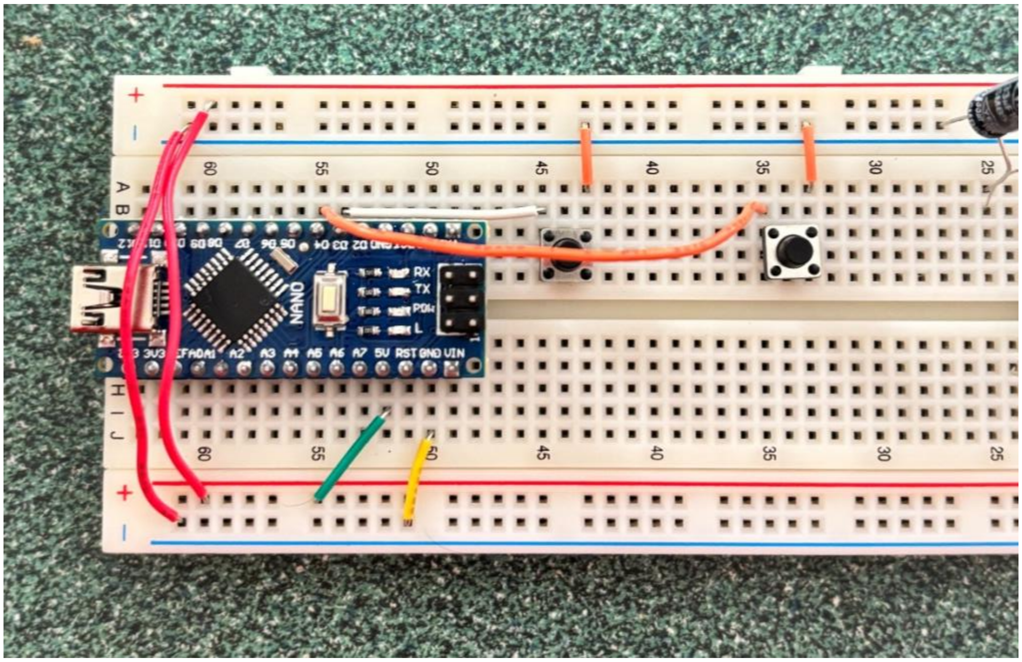

Figure 5: Button-Operated Door Mechanism Circuit

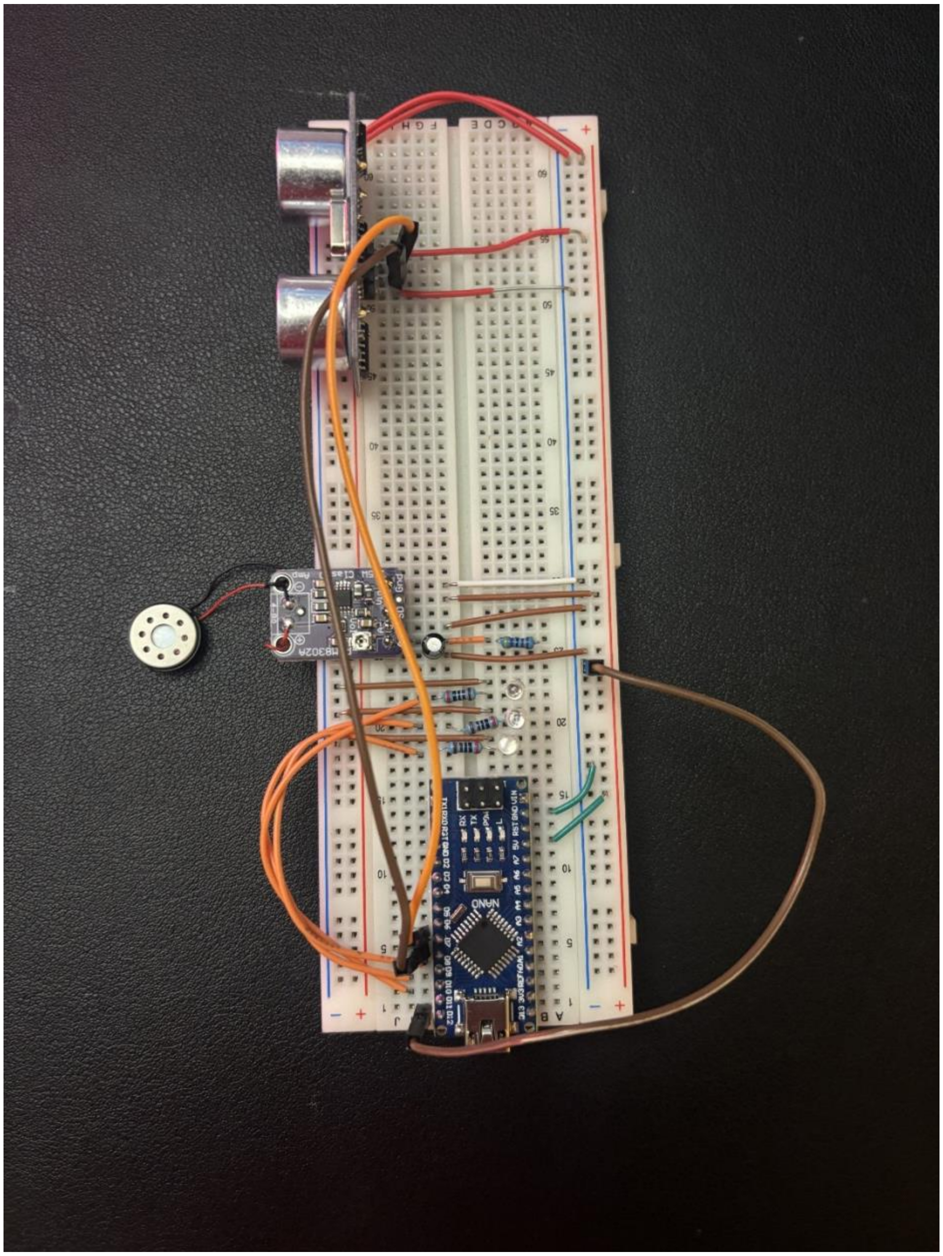

Figure 6: Proximity Detection and Buzzer Circuit

3.2 Software Verification

The software modules were divided into three submodule interfaces:

(1) Proximity Detection: The proximity detection module was used to detect the pet as it comes near the door. The HC-SR04 ultrasonic sensor was utilized due to its capability of accurately detecting objects up to a 40-metre distance within a certain field of view. The code used to configure the proximity detection utilized the following functions:

- **`ISR (TIMER1_OVF_vect)`**: used to handle the overflow condition for long echoes.
- **`ISR (TIMER1_CAPT_vect)`**: used to handle the echo signal detection.
- **`ISR (TIMER1_COMPA_vect)`**: used to stop the trigger pulse after 10 microseconds.
- **`ISR (TIMER1_COMPB_vect)`**: used when the counter reaches the count in compare register B (10 microseconds). The interrupts get disabled, and then it is returned to idle.
- **`void Trigger(void)`**: used to trigger the ultrasonic sensor.
- **`unsigned int CalculateDistance(void)`**: used to calculate the distance based on the echo pulse duration.
- **`uint16_t readADCValue(void)`**: used to read and return the analog value from the analog-to-digital convertor.
- **`void setupPWMOutput(void)`**: used to configure a PWM output on a speaker pin using Timer1 in CTC mode.
- **`void playToneFrequency(uint16_t frequency)`**: used to set the PWM frequency to generate a tone on the speaker.
- **`void stopToneOutput(void)`**: used to stop the tone by disabling the PWM toglge mode.
- **`void setupTimerInterrupt(void)`**: used to configure Timer0 to trigger an interrupt roughly every 100 milliseconds.
- **`ISR (TIMER0_COMPA_vect)`**: used to interrupt the service routine that sets a flag (timerFlag) when the timer matches.

(2) Door Mechanism and Alert System: utilized the MG 90S servo motor to power a pulley system which opens and closes the door. Push buttons were utilized in the demonstration to open and close the door, rather than RFID.

- **`void setupPWM()`**: used to configure Timer1 for 50Hz fast PWM (for servo control) with ICR1 setting the frequency.
- **`void setServoAngle(int16_t speed)`**: used to adjust servo position by modifying OCR1A, where speed offsets from a neutral position.
- **`void setupButtons()`**: used to set up pull-up resistors on two button pins (BUTTON_OPEN and BUTTON_CLOSE) for input.
- **`void doorOpen()`**: used to drive the servo clockwise (open), then stop.
- **`void doorClose()`**: used to drive the servo counterclockwise (close), then stop.

(3) Curfew Enforcement: utilized the GL5537 photosensitive resistor (PSR) to detect the ambient light levels in its surroundings to ensure that the door would not open at night when the light level would be low.
- **`void initADCSetup(void)`**: used to configure the ADC to use AVcc reference and photoresistor input pin, enabling the ADC with a prescaler of 128.
- **`uint16_T readADCValue(void)`**: used to read the analog-to-digital value of the light level detected by the photosensitive resistor.
- **`void setupTimerInterrupt(void)`**: used to set up **Timer0** to trigger an interrupt roughly every 100 milliseconds (CTC mode, prescaler 1024).
- **`ISR(TIMER0_COMPA_vect)`**: used to handle the interrupt handler that sets timerFlag when Timer0 matches OCR0A.

Each module had its own program files that were programmed and configurated for each module. In the end, at testing, the Arduino Nanos were all combined via their breadboards and worked unanimously.

Note: the test cases for the Door Mechanism and Alert System and Curfew Enforcement are mentioned further below in **3.3 Mechanical Design**.

Proximity Detection			
Function	**Quantifiable**	**Test Case**	**Outcome**
Detect the pet's distance	Distance should be detected between 1cm-100cm	The project box was utilized as a "mock pet" to ensure accuracy	Successful
LED-powered alert system	LEDs should light up based on defined cases	Red LED turns on for failure state Orange LED turns on for idle state Green LED turns on for success state	Successful
Buzzer-activated alert system	Short buzzing noise will be played upon detection of pet	Buzz should be played for 0.5 seconds	Successful

Table #2: Proximity Detection Testing Procedure

3.3 Mechanical Design

The door mechanism operates using a DC motor attached to a rotating arm, which is connected to the door via a cable. As the motor rotates, the arm lifts or lowers the door by pulling on the cable, enabling vertical motion. The door itself is mounted on a set of fixed tracks to ensure guided and stable movement. The structure—including the door, frame, and motor arm—is constructed from cardboard, chosen for its ease of prototyping and lightweight properties. The following images illustrate the assembled mechanism and its key components in detail.

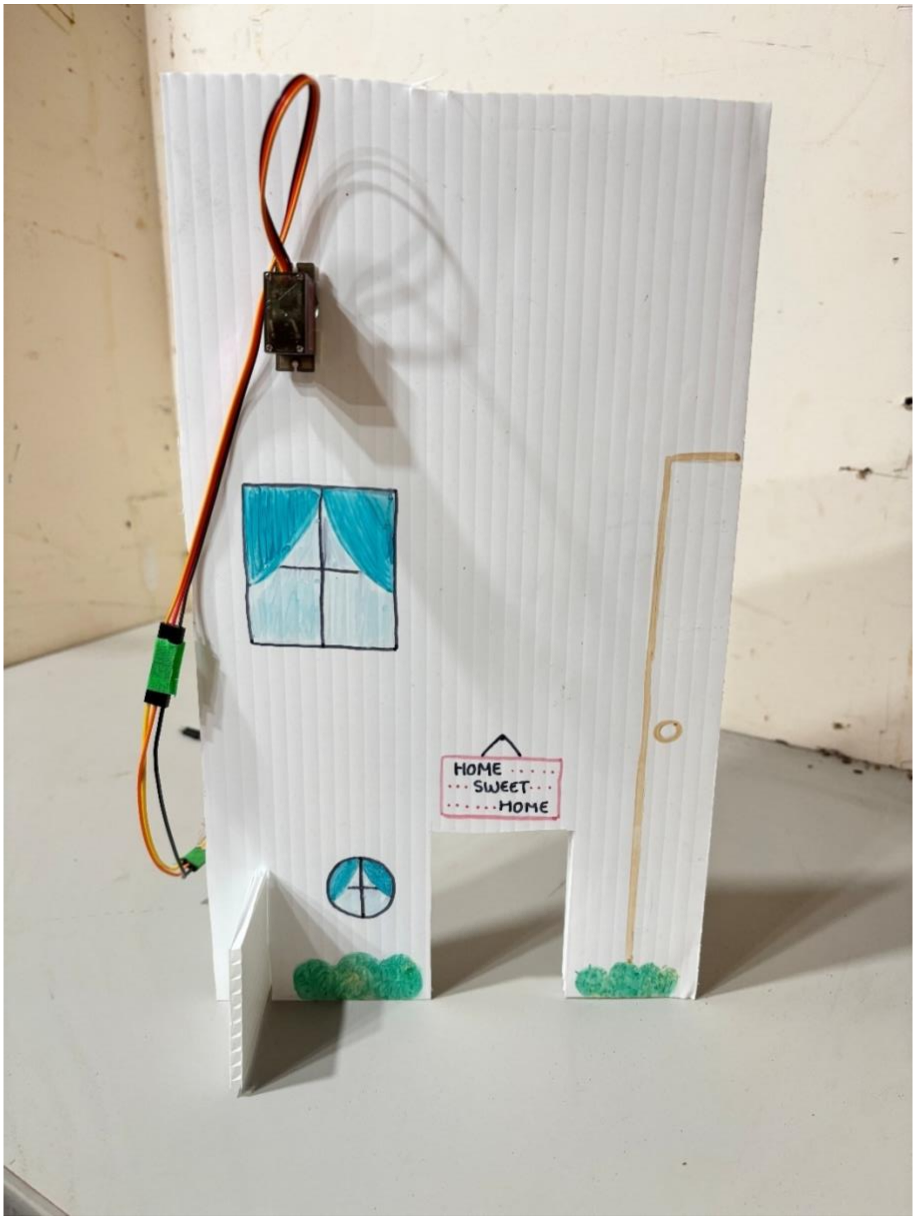

Figure 7: Front of Door; Home Exterior

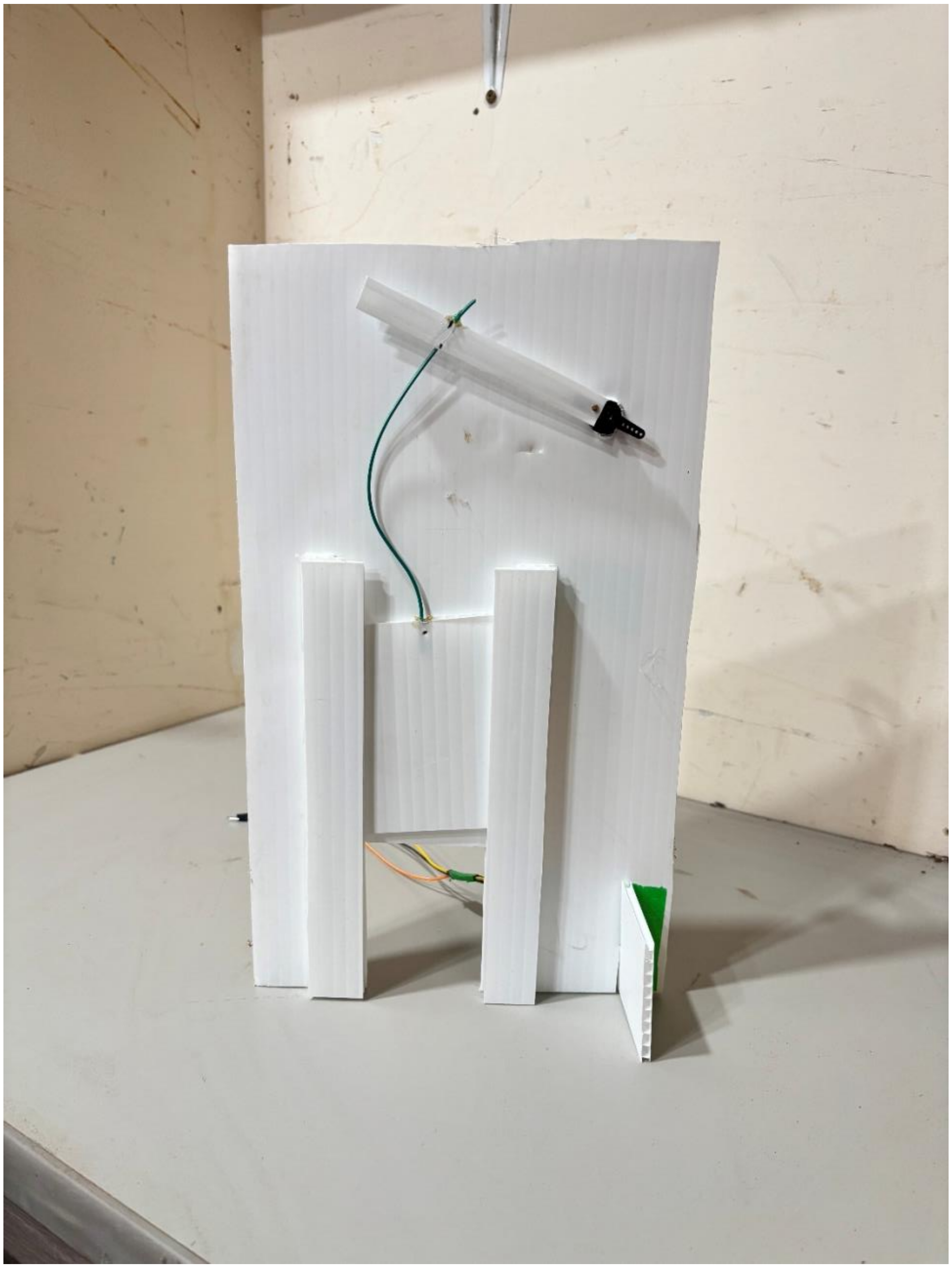

Figure 8: Back of Door in "Open" State

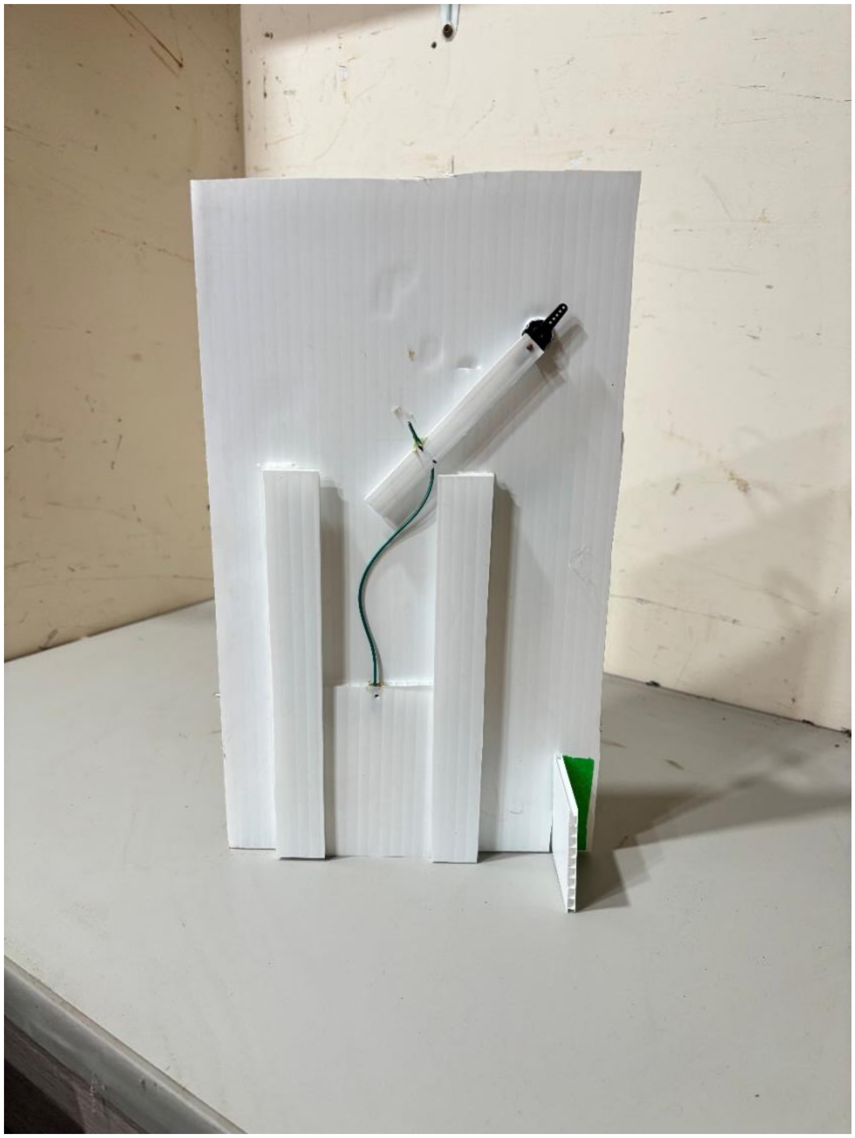

Figure 9: Back of Door in "Closed" State

For demonstration purposes, data from the motion sensor does not trigger the door. The door is user-operated with buttons.

The test procedure for the module is as follows:

(1) The user presses the open button (PD3).
(2) The servo rotates counterclockwise for 450ms to open the door.
(3) The user presses the close button (PD4).
(4) The servo rotates clockwise for 650ms to close the door.

Function	Quantifiable	Unit Test	Outcome
Open/close mechanism	Door will remain open and remain close as expected.	Door will remain open until instructed to close. Door will remain closed until instructed to open. Pressing the door open button while the door is open will keep the door open.	Successful
Alert system	Speaker will buzz when door is open.	Speaker will buzz for the entire duration in which the door is open and cease once the door has closed.	Unsuccessful; speaker did not buzz in accordance with detection system.

Table 3: Mechanical System Testing Procedure

The curfew enforcement module uses the GL5537 photosensitive resistor (PSR) to detect the ambient light levels in its surroundings to ensure that the door would not open at night when the light level would be low.

The testing procedure during the demonstration is outlined below:

(1) Ensure that the door opens and closes normally.
(2) Cover the photosensitive resistor with a finger to simulate nighttime.
(3) Check whether the door opens when the photosensitive resistor is covered.
(4) Uncover photosensitive resistor and open door.
(5) Cover the photosensitive resistor and check whether the door closes.

Function	Quantifiable	Unit Test	Outcome
Low light detection	The photosensitive resistor will detect changes in light from the bright ambient state to dark, covered state	Cover the photosensitive resistor with hand and ensure the door remains locked, or if open, door closes	Successful

Table 4: Curfew System Testing Procedure

Chapter 4 – System Performance

4.1 Performance Summary

The demonstration was assessed using three criteria: usefulness, innovation, and feasibility. Each criterion was assigned a score based on a predefined rubric. The following table summarizes the scores awarded for each criterion.

Criteria	Score
Usefulness (/5)	4
Innovation (/5)	3
Feasibility (/5)	3.5
Total (/15)	10.5

Table 5: Demonstration Grade by Criteria and Total Grade

4.2 Achievements in Objectives and Specifications

The door's mechanical operation functioned reliably during the demonstration, though it was controlled via manual button input rather than the intended sensor-based automation. The motion detection system operated correctly and triggered the LED indicators, successfully delivering visual feedback. The buzzer failed to activate during the demonstration, and as a result, the pet door did not include an audio alert feature as previously outlined in the objectives.

Additionally, the RFID detection circuit was non-functional, as the Hall effect sensor failed to detect the magnetic coil. Separately, a logic error was identified in the initial conceptual design: the placement of the magnetic coil and Hall effect sensor was reversed, with the coil embedded in the door frame and the sensor intended for the pet's collar. In the correct configuration, the magnetic coil should be attached to the pet's collar, and the Hall effect sensor fixed to the door frame for proper detection.

Chapter 5 – Conclusion

The project successfully resulted in a functional prototype of an automated RFID pet door with additional features such as curfew enforcement, visual and audio alerts, and pet tracking logic. While the current design demonstrates full system functionality, future improvements include integrating the circuitry and door mechanism into a real-world enclosure, as the existing setup separates these elements and uses temporary materials like cardboard. Further optimization of the door mechanism and hardware selection could enhance efficiency and long-term durability. Additionally, the RFID subsystem requires refinement to reliably identify individual pets, as its current limitations present a potential security risk. Addressing logic inconsistencies and improving signal reliability will be key areas of focus in future iterations.

Dalhousie University
Faculty of Engineering
ENGI 2203 Engineering Design 2
Project Contribution Record

This contract is to be filled out once the work is completed. It must be attached with the midterm and final report. Write a one sentence description of the task that was accomplished by each group member and then fill in a percentage of each member's contribution toward the work documented (percentages must be rounded to the integer value and must add to 100%).

Group Member Statement of Contribution

1) Daniel Navarro Degiorgio — Proximity detector with buzzer module, Combination of all modules, and overall software management

% 25

2) Brianna Farrell — Hardware (RFID circuit), door mechanics (prototyping)

% 25

3) Rhys Brown — Curfew and alarm module

% 25

4) Sophia Zykova — hardware (sin wave) door mechonics (open/close) door design / constructing it together

% 25

I have read the descriptions and percentage scores shown above and am in agreement with the assessment.

Member 1: Daniel Navarro

Member 2: Brianna Farrell

Member 3: Rhys Brown

Member 4: Sophia Zykova

I understand that the impact of this contract is that it will be used to weigh the value of midterm and final report. Specifically, the original score S_i (graded on a percentage scale) will be applied a weight to establish the final score $S_{f,\ ind}$ for student *ind.* The final score is equal to:

$$S_{f,\ ind} = S_i - (W_{max} - W_{ind}) + (W_{max} - W_{min})/2$$

where W_{max} is the maximum individual contribution, W_{min} is the minimum individual contribution, and W_{ind} is the contribution of the individual student.

Date: April 16th, 2025