DOOR SENSOR FINAL REPORT

1.0 INTRODUCTION

1.1 Background

In Spring 2025, our final project for Engineering 11 was to design and prototype a practical engineering product. After brainstorming and evaluating multiple ideas, we decided to create a door sensor. The purpose of this device is to detect the opening of a door using a magnetic switch and to alert the user with a sound via a mini piezo buzzer. This simple, compact, and effective system enhances home security and accessibility, especially for individuals needing sound-based alerts.

2.0 DESIGN PROBLEM FORMULATION

2.1 Filling a Niche

While many commercial door sensors exist, many are expensive, bulky, or require Wi-Fi and smartphone integration. Our goal was to build a low-cost, battery-powered, stand-alone door sensor with audible feedback, suitable for dorms, homes, or tool sheds.

2.2 Market Surveying

We explored multiple concepts before settling on our final design. Below are our initial and alternative ideas:

1.

Tracking Bracelet: A sensor placed near the entrance would detect if the wearer crossed the threshold and trigger an alarm, alerting caretakers. This idea was appealing but limited to the quantity if there are too many people in a room.

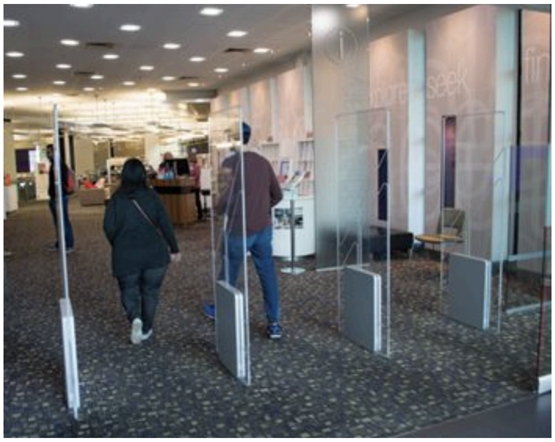
Price Estimate: $50

2.

Ring Camera System: It would notify users on their smartphones whenever someone exited a predefined boundary. While functional and modern, it required a Wi-Fi module, mobile app integration, and a camera—all of which were costly and time-consuming.

Price Estimate: $80

3.



RFID: RFID (Radio Frequency Identification) systems are commonly used in retail and library environments to detect tagged items as they pass through a sensor gate. In our context, a similar system could be used to detect when a person or pet (wearing an RFID tag) exits a space. The system uses passive or active RFID tags and a reader module near the door, but it becomes expensive when scaling up

Price Estimate: $60–$100 for a basic RFID reader and tag set

2.3 Performance Requirements

Function and Performance:

- Must cost under $200 to build
- Must fit within a 1.5x1x1 cm housing
- Must sound piezo buzzer when the door is opened
- Must run on a small battery (e.g., coin cell or AA)
- Must work for over 3 months without battery replacement

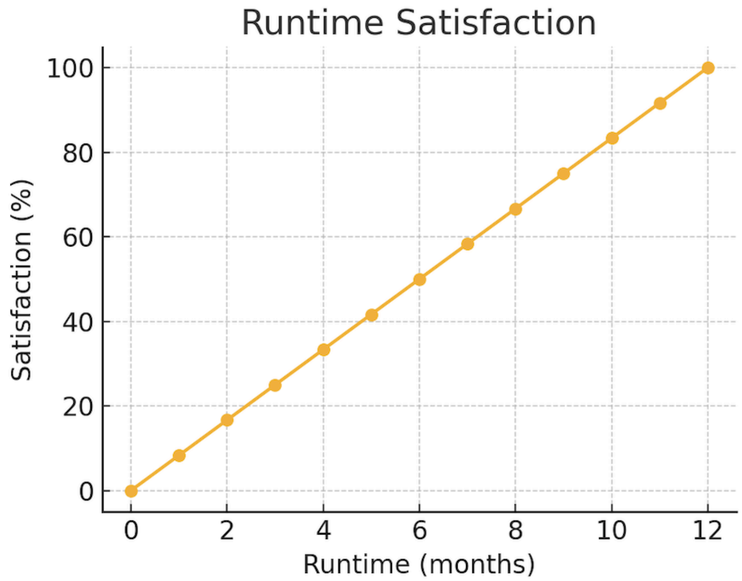
Operating Environment:
This device is designed for indoor residential use. It should operate within a temperature range of 32°F to 104°F (0°C to 40°C). It is not waterproof and must be kept dry. It should be mounted on a door frame away from direct sunlight or moisture.

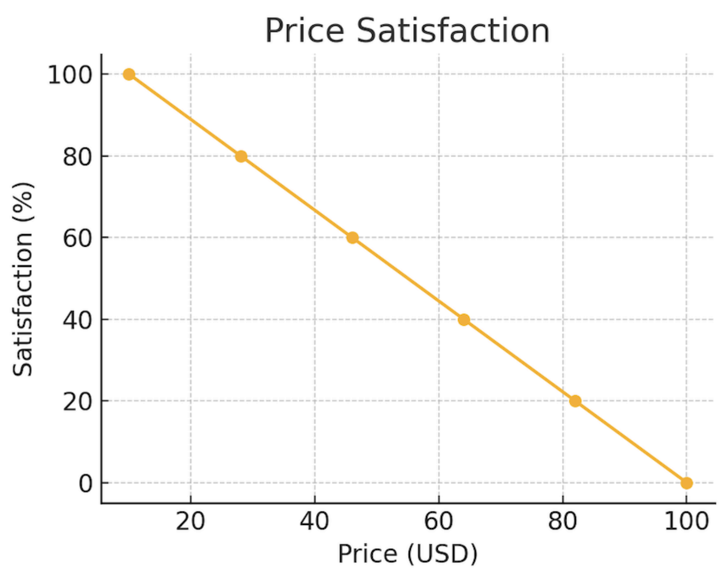
Life Expectancy:
The device is expected to last over 2 years with normal use. The reed switch and piezo buzzer have no moving parts and are rated for tens of thousands of cycles. Battery life will depend on usage and power-saving techniques but is estimated at 3–6 months before replacement.

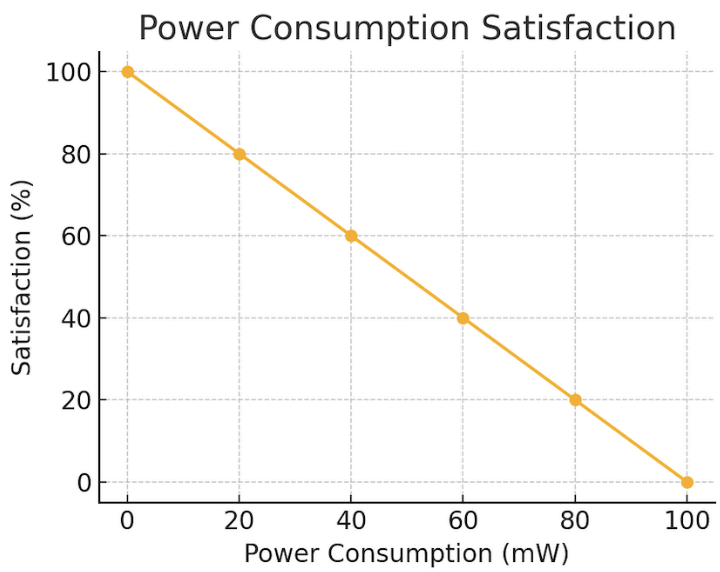
Repair, Disposal, and Maintenance:
This is a low-cost device intended for minimal maintenance. The battery should be replaced when depleted. If the device malfunctions, basic repairs like replacing the reed switch or piezo buzzer may be possible if soldering tools are available. Otherwise, the unit can be recycled or disposed of in accordance with electronic waste regulations. The plastic housing should be recycled if possible.

2.4 Customer Satisfaction Curves

To evaluate user satisfaction, we developed a set of curves illustrating how customer satisfaction varies with different performance factors. These include runtime (before battery change), price, and power consumption. Our goal was to ensure that our design choices align with the expectations and preferences of potential users.


Runtime Satisfaction
100
80
60
40
20
0
Satisfaction (%)
0
2
4
6
8
10
12
Runtime (months)


Price Satisfaction
100
80
60
40
20
0
Satisfaction (%)
20
40
60
80
100
Price (USD)



3.0 Project Engineering

3.1 Work Scope

The development of the door sensor project was completed over the course of 6 weeks. The scope of work included idea generation, component research, prototyping, testing, and documentation. A Gantt chart was used to plan and track progress throughout the phases of the project (see Appendix A). Team meetings were held weekly to share updates, troubleshoot issues, and assign tasks. Communication was maintained through group messaging and shared documents on Discord and Drive.

The final deliverables included:

- A working prototype of the door sensor
- CAD sketches of the housing
- A performance test report
- A finalized bill of materials

- Full project documentation including this report

3.2 Team Roles and Responsibilities

Each team member contributed to the design and execution of the project. While roles overlapped in certain areas, the responsibilities were distributed as follows:

- **Ryan Huynh**
  - Circuit design and breadboarding
  - Report writing and editing
  - 3D housing design and CAD modeling
- **Adrian Vinuya**
  - Final assembly and testing
  - Soldering and reed switch integration
  - Bill of materials organization
- **Arielah Arana**
  - Prototyping and debugging
  - 3D printing and enclosure assembly
  - Maintenance planning and cost estimation

The team collaborated closely to ensure all deadlines were met, with flexibility built into the schedule to allow for iterative improvements and troubleshooting.

4.0 Conceptual Design

4.1 Design Concept Alternatives

During the early stages of brainstorming, our team considered multiple designs to address the goal of detecting when a person or pet leaves a defined safe space. Below are the concepts we explored:

Concept 1 – Safe Space Alarm with Wearables

This concept involved using wearable trackers (bracelets or collars) for individuals or pets. A sensor placed near a doorway would detect when the wearer exited and trigger a central alarm.

Pros:

- Continuous monitoring
- Works for multiple users

Cons:

- Costly due to multiple devices
- Complex pairing and communication
- Requires power-hungry wireless modules

Concept 2 – Ring-Style Camera Monitoring System

This idea involved using a camera and software to detect motion or exits, then send smartphone notifications.

Pros:

- Visual confirmation
- Remote alert system

Cons:

- Requires internet connection
- Complex setup and privacy concerns
- Expensive (camera, Wi-Fi, app)

Concept 3 – Final Design: Door Sensor with Reed Switch and Piezo Buzzer

The final concept is a cost-effective and simplified solution. It consists of a magnetic reed switch, a piezo buzzer, and a CR2032 battery. When the door opens and the magnetic contact is broken, the reed switch closes the circuit, triggering the buzzer.

Pros:

- Very low cost
- Simple to build and reliable
- Low power consumption

Cons:

- No remote alert (local only)
- One-directional detection (door opens only)

4.2 Weighted Rating Matrix

We evaluated each concept using a weighted matrix to determine the most appropriate solution based on our key criteria:

Project	Aesthetic 10%	Cost-Effective 15%	Different from Market 10%	Functionality 25%	Potential to be done within time frame 20%	Environment friendly 10%	Durability 10%	Weighted Total
Camera Track	4 (0.4)	8 (1.2)	5 (0.5)	8 (2)	10 (2)	5 (0.5)	8 (0.8)	7.4
Band/Collar	8 (0.8)	8 (1.2)	5 (0.5)	8 (2)	6 (1.2)	3 (0.3)	8 (0.8)	6.8
Door Sensor	8 (0.8)	10 (1.5)	5 (0.5)	10 (2.5)	10 (2)	6 (0.6)	8 (0.8)	8.7

Based on the results of this matrix, we chose the reed switch door sensor design for its superior cost-efficiency, simplicity, and ease of implementation.

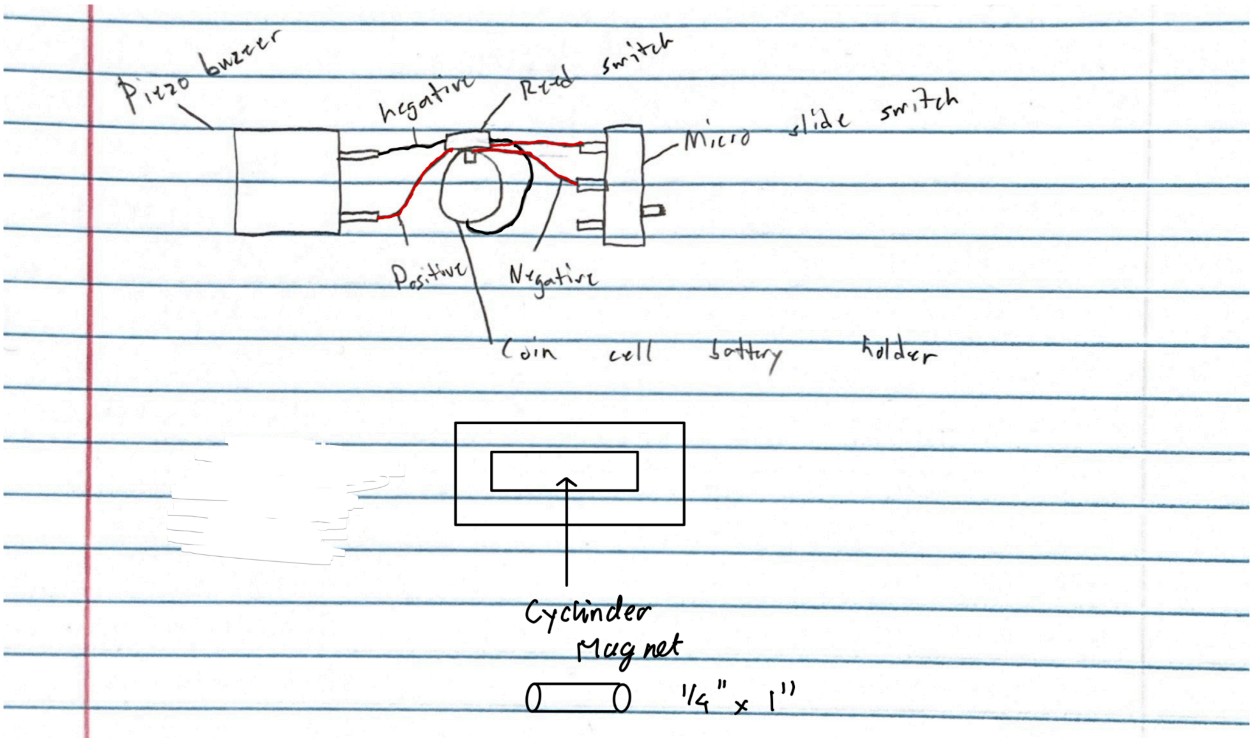
5.0 Configuration Design

5.1 Layout Sketch

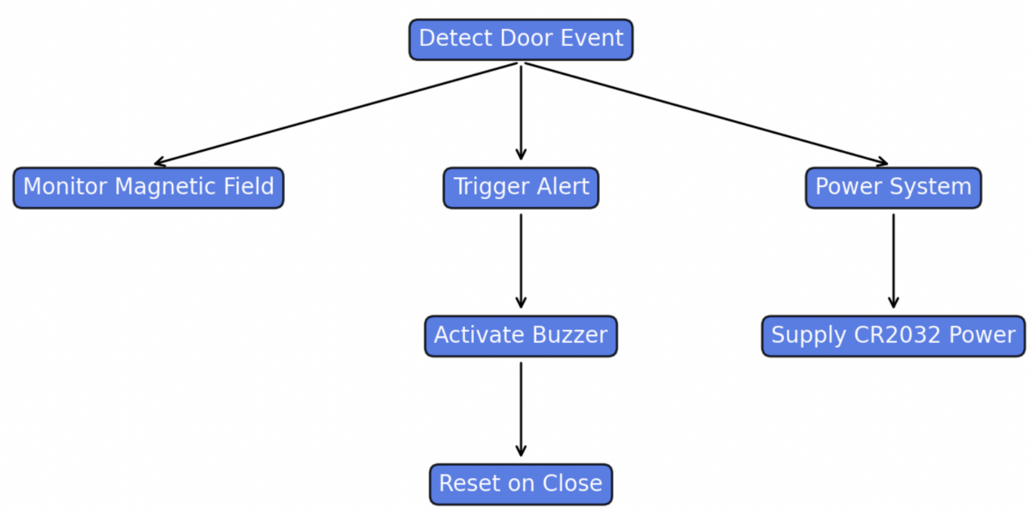
The door sensor consists of two housings:

- **Transmitter Housing**: Attached to the door frame, containing the reed switch, battery, piezo buzzer, and wiring.
- **Magnet Housing**: A small enclosure mounted on the door, aligned with the reed switch to maintain a closed circuit while the door is shut.

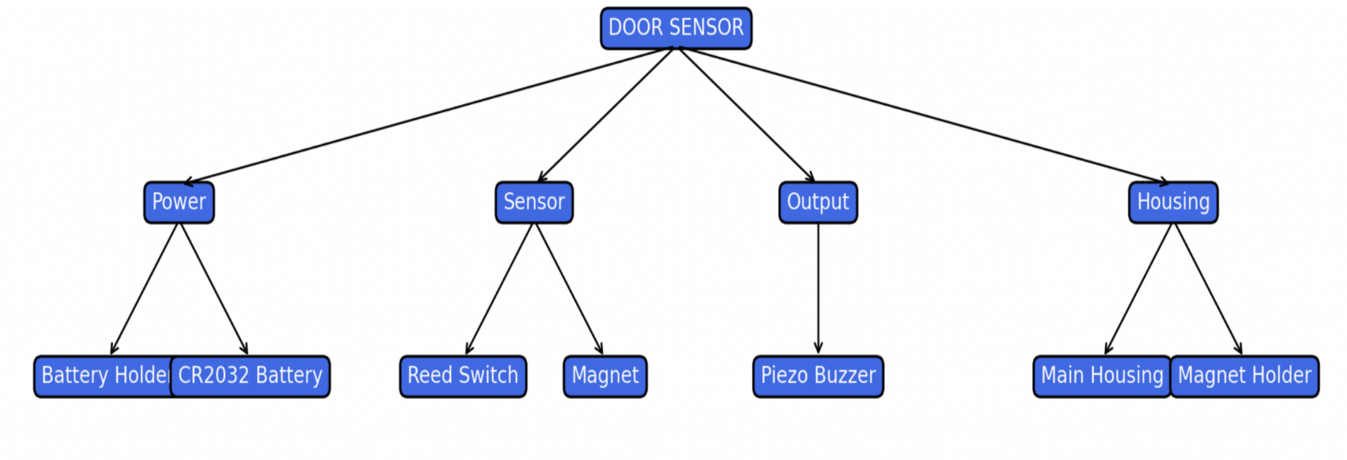
When the door opens, the magnet moves away from the reed switch, causing it to close the circuit and activate the buzzer. The device operates independently without requiring Wi-Fi or an external power source.



5.2 Functional Decomposition



5.3 Component Decomposition



6.0 Parametric Design

6.1 DFX

Design for Assembly

To ensure simplicity and reliability, the door sensor was designed using as few components as necessary. The assembly process was optimized for minimal tools, ease of alignment, and safe handling.

Design for Assembly Checklist:

- ✅ Minimal part count (magnet, reed switch, buzzer, battery, and housing)
- ✅ No soldering required if using jumper clips or pre-soldered components

- ✅ Snap-fit or screw-in housing for easy access
- ✅ Standard, low-cost components
- ✅ Compact modular design (sensor unit and magnet housing)
- ✅ Assembly instructions included
- ✅ Minimal tools required (small screwdriver or adhesive tape)

Key Features:

- The housing is made of two 3D-printed or plastic parts that align with door and frame edges.
- The reed switch and buzzer are pre-positioned and require minimal wiring.
- A coin cell battery snaps into a holder, eliminating the need for power cables.

Design for Function (DFF)

The door sensor is engineered to be energy-efficient, responsive, and durable for indoor residential use.

Design for Function Checklist:

- ✅ Strong plastic housing for durability
- ✅ Low power consumption for long battery life (~6 months on CR2032)
- ✅ Reed switch for fast, passive sensing
- ✅ Loud mini piezo buzzer (~85 dB) for clear alerts
- ✅ Safe, low-voltage operation (3V)
- ✅ Compact size for discreet installation
- ✅ Simple wiring minimizes failure points

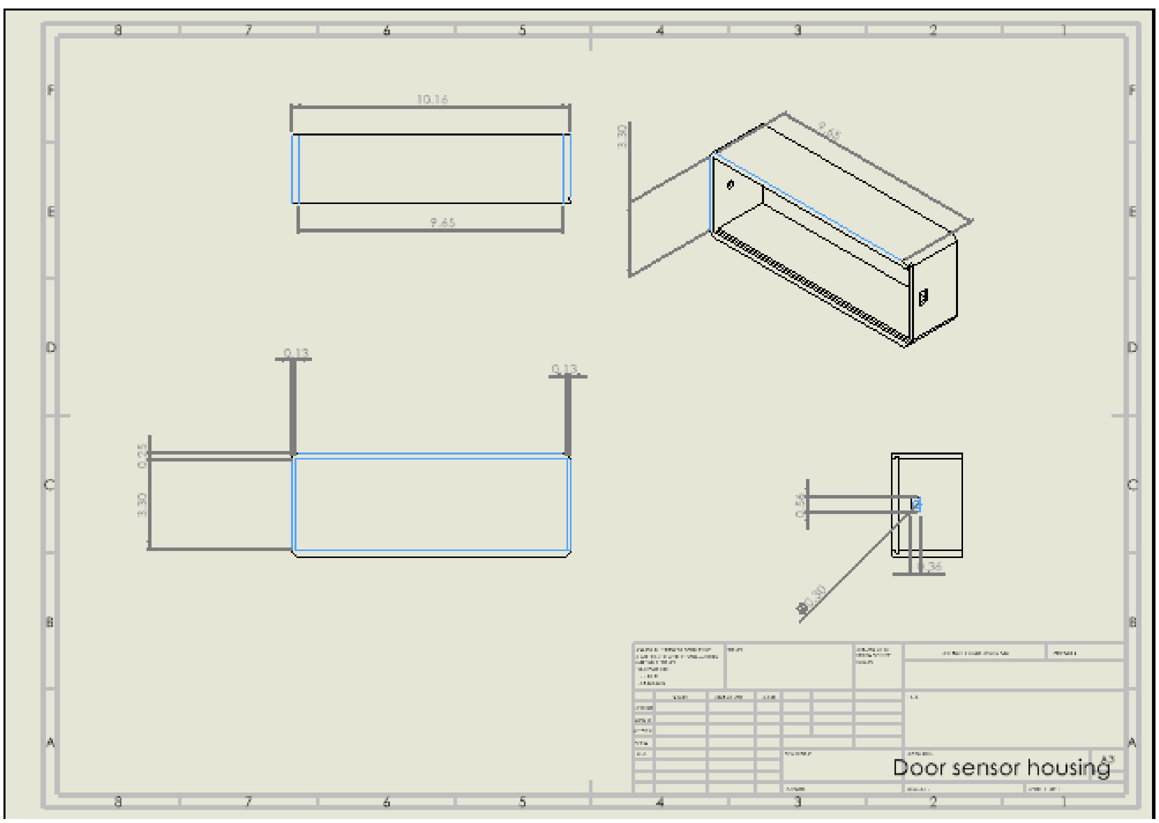
- ✅ Reliable magnetic alignment system
- ✅ Easy access for battery replacement

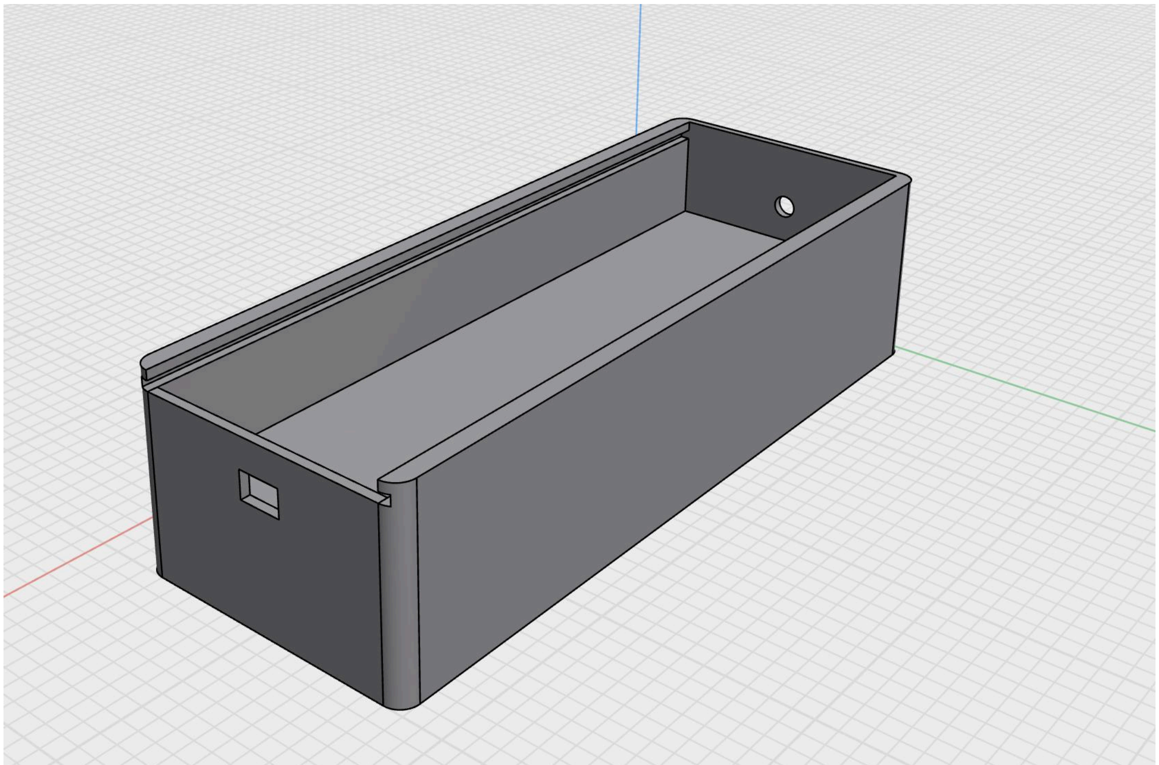
Functional Performance Goals:

- Must alert immediately upon door opening
- Must reset automatically once door is closed
- Must operate reliably for over 1,000 cycles
- Must require no maintenance other than battery replacement

6.2 CAD & Assembly Drawing

Door Sensor Housing



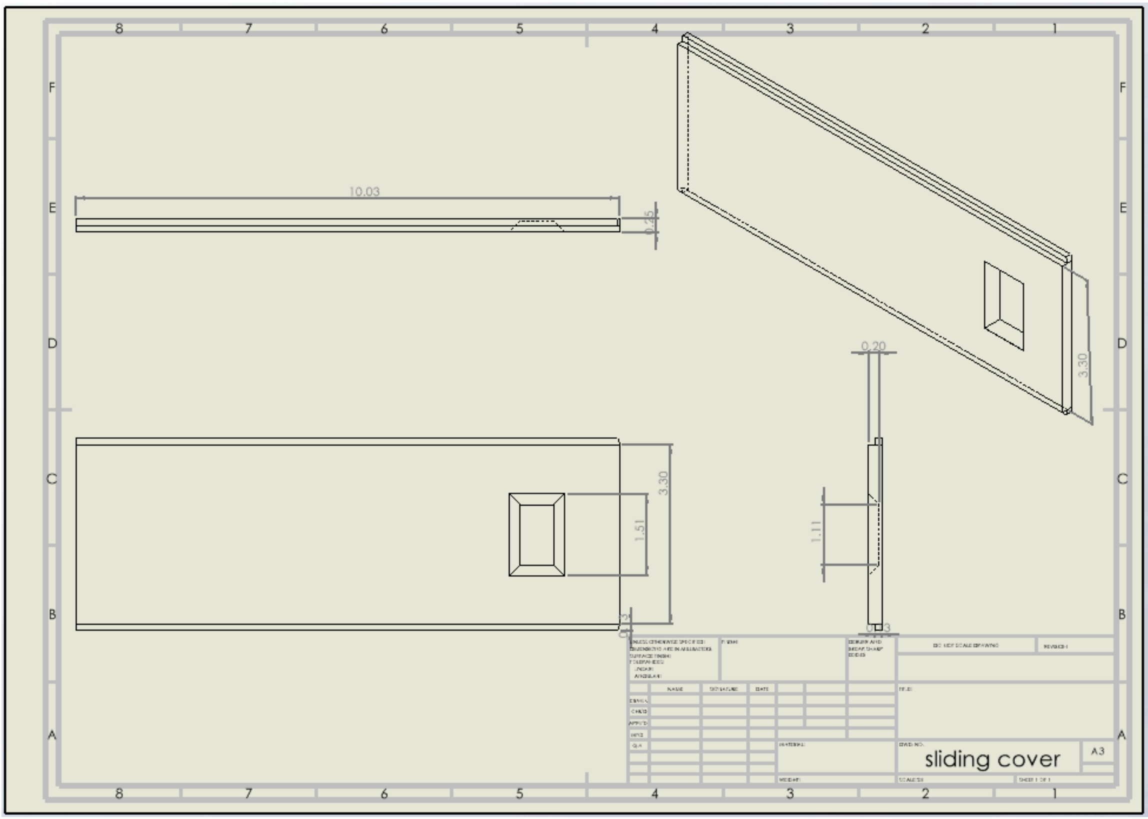


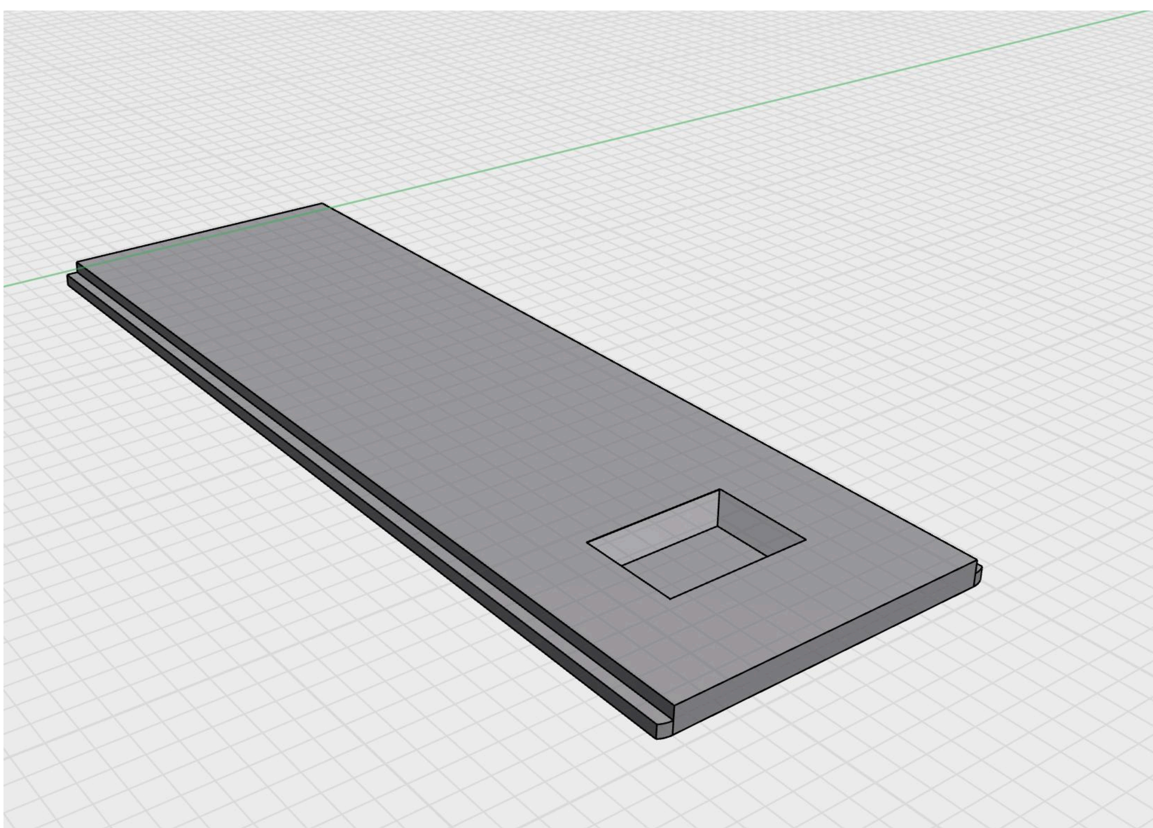
There are two cutouts in the housing design. The rectangular hole is for the on/off switch, allowing users to easily enable or disable the alarm system. The circular hole is positioned to align with the mini piezo buzzer, allowing the sound to pass clearly through the enclosure for effective audio alerts.

Additionally, there is a slot at the top designed for a sliding lid. This feature allows users to open the housing conveniently to replace the battery, perform maintenance, or upgrade components. It also supports easier disassembly for recycling at the end of the device's life cycle.

Inside the main housing, we securely place the reed switch, battery holder, and power switch, then solder the connections to complete the circuit.

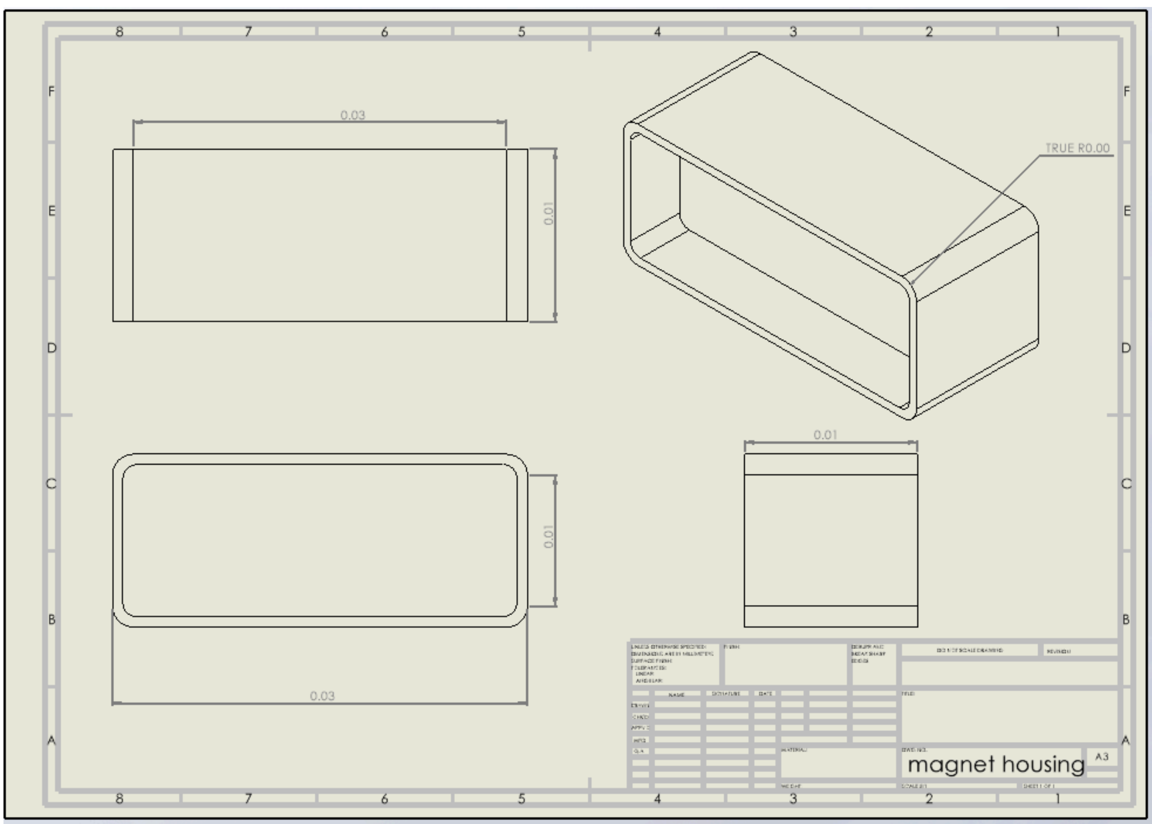
Sliding cover

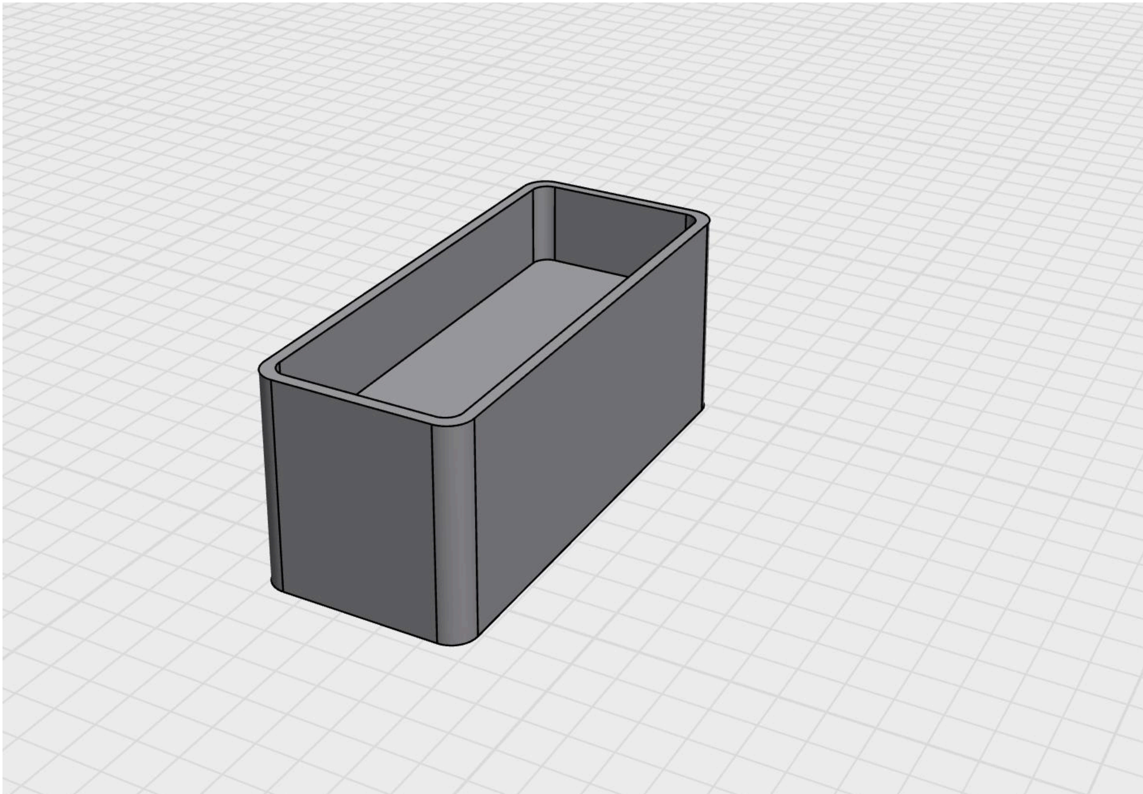




This is the sliding lid for the main housing. We designed a chambered cutout to provide users with a convenient grip area, making it easy to slide the lid open or closed. Additionally, the rails were precisely cut and fitted to ensure the lid aligns securely with the housing, forming a tight seal that helps prevent water and dirt from entering and damaging the internal components.

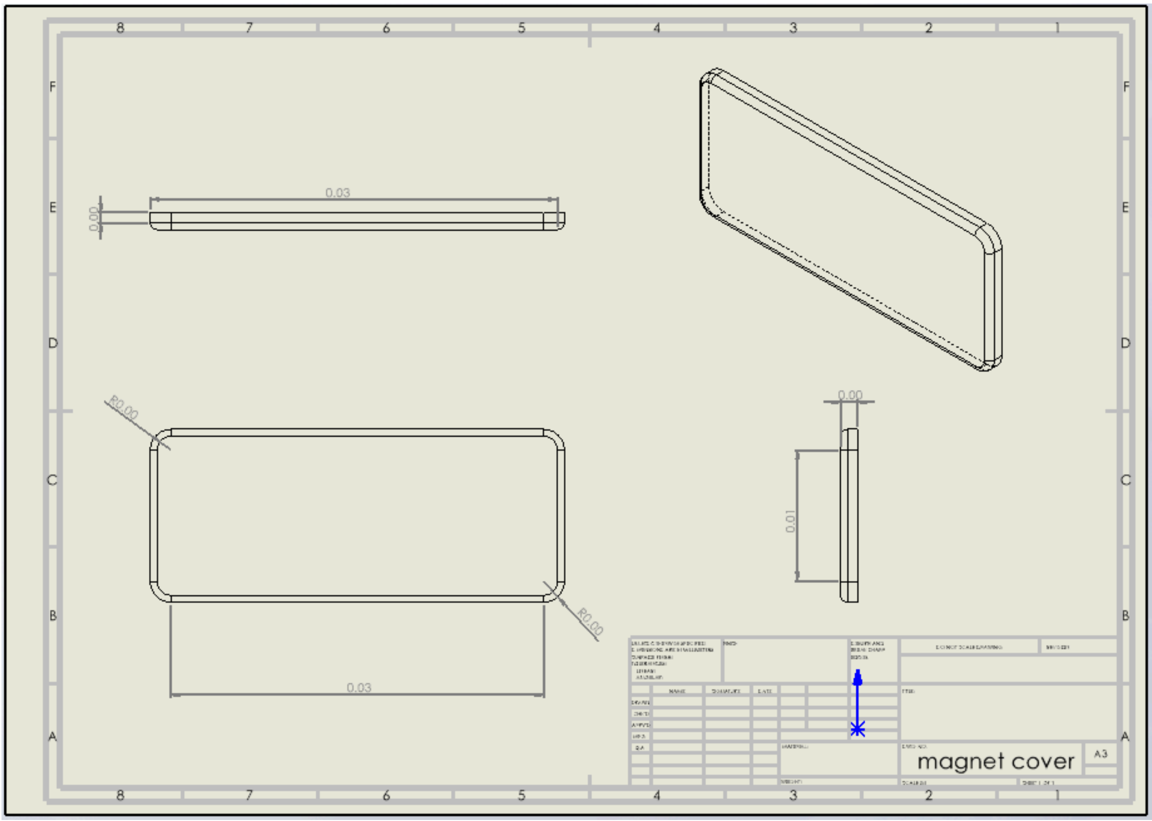
Magnet Housing

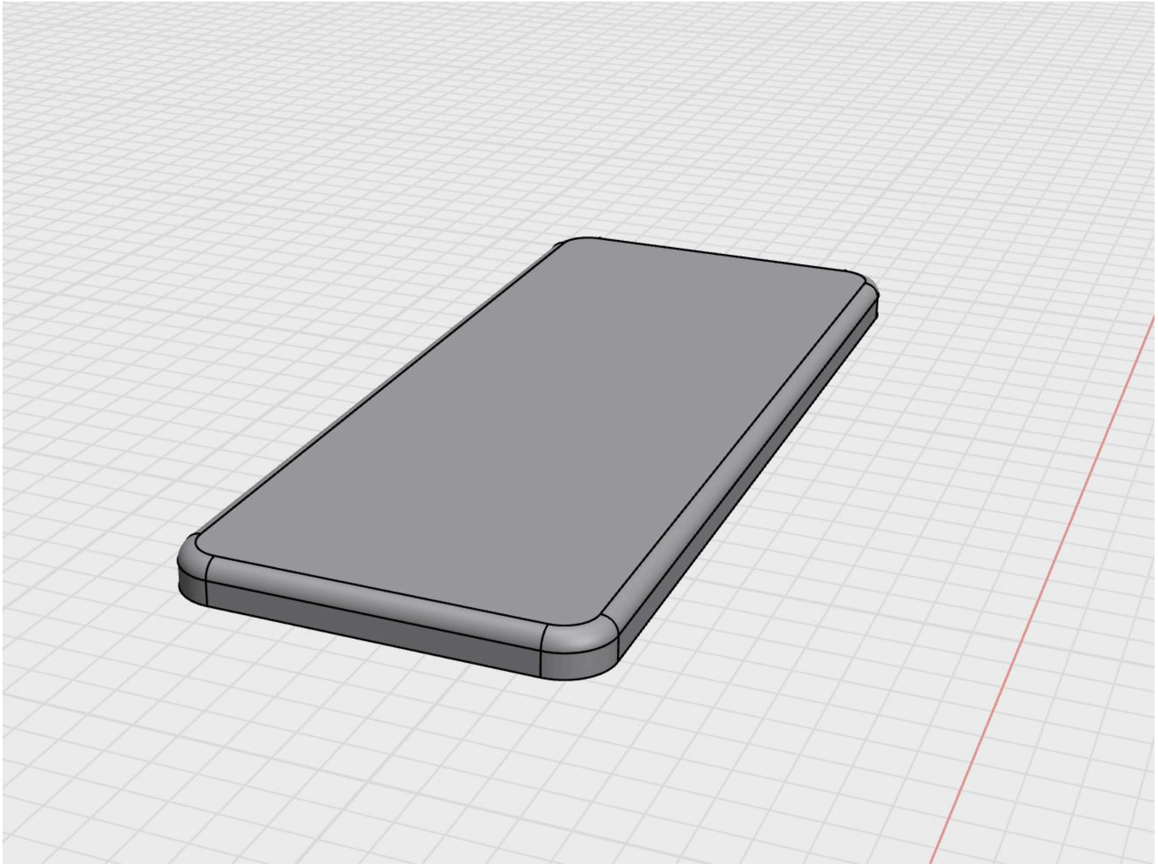




This is the magnet holder, designed to be mounted on the door frame, positioned close to the main housing. The main housing, which contains the electronics, is mounted on the moving part of the door. When the door is closed, the magnet aligns with the reed switch in the main housing to maintain the circuit's inactive state. Opening the door causes the magnet to move away, triggering the alarm.

Magnet cover





The magnet cover serves to protect the magnet from physical damage and environmental exposure while also providing a clean, aesthetically pleasing appearance.

7.0 Engineering Analysis

7.1 Power Consumption and Battery Life

The door sensor is powered by a CR2032 coin cell battery (3V, ~220 mAh). The circuit consists of a reed switch (passive), a mini piezo buzzer, and minimal wiring. Most of the time, the device draws virtually no current due to the open reed switch. Current only flows when the door is opened and the circuit is triggered.

Assumptions:

- Reed switch: passive (0 mA)
- Piezo buzzer: draws ~15 mA when active
- Buzz duration: ~2 seconds per activation
- Door opens ~20 times per day

$$\text{Daily buzzer runtime} = 20 \times 2 \text{ seconds} = 40 \text{ seconds}$$

$$\text{Average daily consumption} = \frac{15\,\text{mA} \times 40\,\text{s}}{86400\,\text{s/day}} \simeq 0.007\ \text{mA}$$

Add estimated idle leakage current: ~0.05 mA
Total average current draw ≈ 0.057 mA

Estimated Battery Life: ~5 to 6 months

7.2 Response Time

The reed switch closes almost instantaneously (~1 ms) when the magnet moves away. The piezo buzzer activates immediately upon switch closure. This ensures the alert is triggered as soon as the door opens, with near real-time feedback.

Conclusion:

- **Switch Response Time**: <1 ms
- **Audible Alert Delay**: <10 ms
- System responsiveness is excellent for the intended use.

7.3 Sound Output

The mini piezo buzzer emits sound in the range of 80–90 dB, sufficient to alert someone in a small room or hallway. This level was chosen to be noticeable but not irritating.

7.4 Range and Alignment

The magnetic reed switch activates when the magnet is within approximately 10 mm. Careful alignment of the sensor housing and magnet enclosure ensures consistent triggering.

Key Notes:

- Misalignment beyond 10 mm may prevent activation.
- Neodymium magnets are preferred for stronger fields.

8.0 Engineering Analysis

8.1 Test 1 - Circuit Functionality

Objective: Verify that the reed switch properly triggers the piezo buzzer when the magnetic field is disrupted.

Clarification: The reed switch used in our circuit has three wires: one input wire, and two output wires (a short leg and a long leg). The short leg corresponds to a normally closed (NC) contact, while the long leg is the normally open (NO) contact.

Since we want the mini piezo buzzer to activate when no magnet is detected (i.e., when the door is open), we connect the long leg (NO contact) to the piezo buzzer. This ensures that when the magnet is present, the circuit is open and the buzzer is off. When the magnet moves away, the circuit closes through the NO contact, allowing current to flow and the buzzer to sound.

Procedure:

- Connected the reed switch, piezo buzzer, and CR2032 battery on a breadboard.

- Aligned a neodymium magnet with the reed switch.
- Moved the magnet away to simulate a door opening.

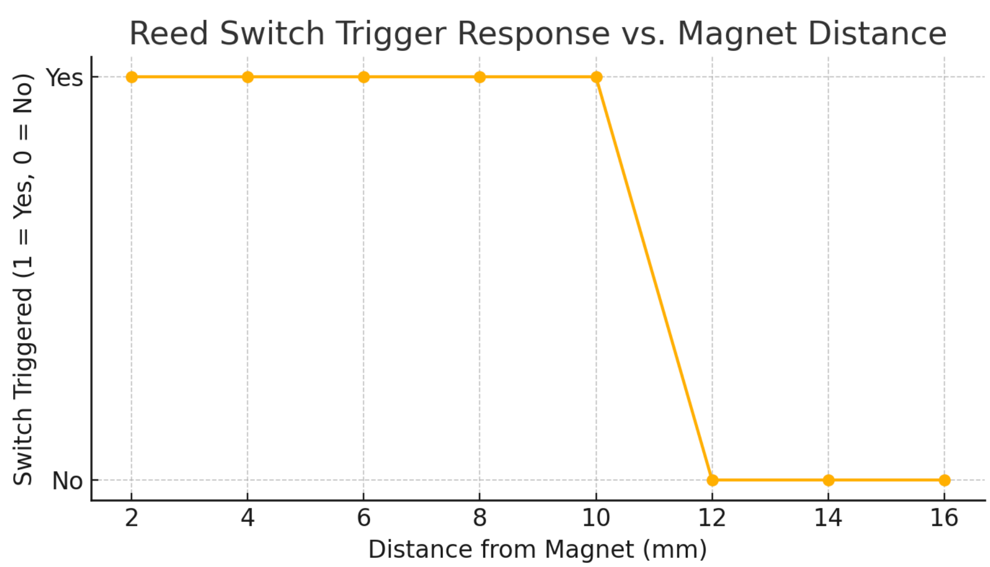
Result:
The buzzer activated immediately upon moving the magnet, confirming that the reed switch triggered correctly. The circuit returned to idle when the magnet was brought back. The response time was under 10 ms.

8.2 Test 2 - Alignment Sensitivity

Objective: Determine the maximum distance at which the reed switch responds to the magnet.

Procedure:

- Incrementally increased the distance between the magnet and the reed switch.
- Recorded the maximum gap at which the circuit still activated the buzzer.



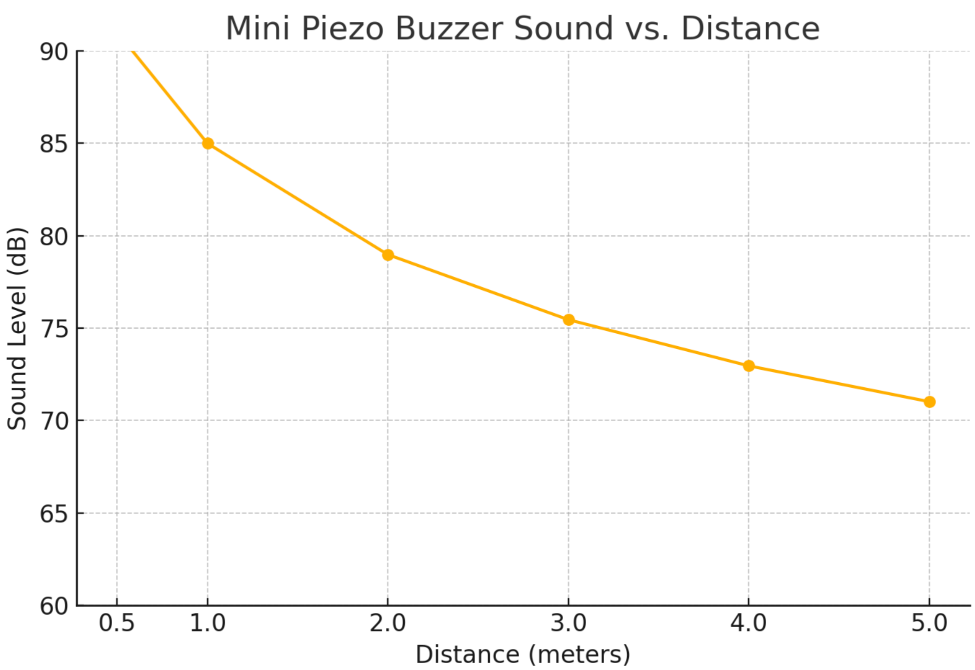
Result:
The reed switch consistently triggered at a distance up to ~10 mm. Beyond that, activation became unreliable. Alignment is critical for consistent functionality.

8.3 Test 3 - Sound Audibility

Objective: Evaluate the loudness of the buzzer in a typical indoor environment.

Procedure:

- Activated the buzzer in a quiet room.
- Used a sound level meter to measure the decibel output at 1 meter.



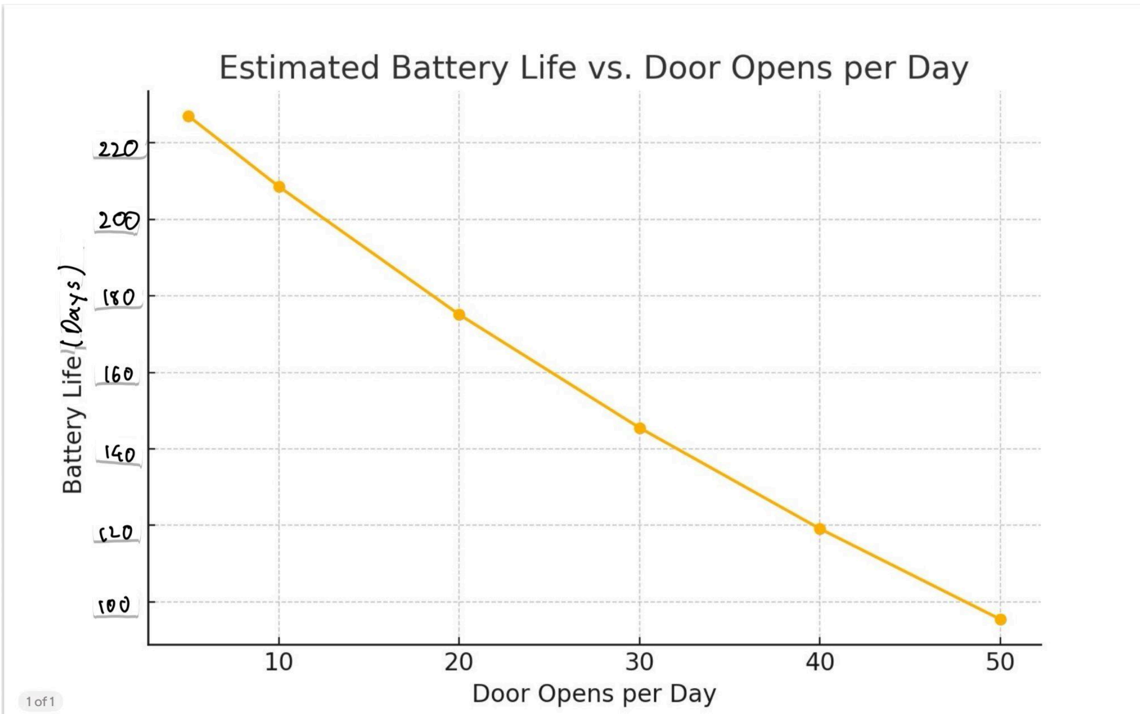
Result:
The buzzer produced ~85 dB, sufficient to alert someone in the same room or adjacent hallway.

8.4 Test 4 - Battery Life

Objective: Estimate battery longevity under realistic usage conditions.

Assumptions:

- 20 door openings per day
- 2-second buzzer activation per event
- 0.057 mA average current draw (as calculated in Section 7)



Result:
Theoretical runtime is ~5–6 months per CR2032 battery. A long-duration real-world test is in progress to verify this projection.

8.5 Conclusion and Recommendations

Conclusion

Through iterative prototyping and testing, our team successfully developed a compact, low-cost, and energy-efficient door sensor. The device performs reliably using a magnetic reed switch and piezo buzzer to alert users when a door is opened. Key test results demonstrated:

- Immediate response (<10 ms) upon magnetic disruption

- Audible buzzer output around 85 dB, effective for indoor alerts
- Reliable activation within a 10 mm magnet range
- Projected battery life of approximately 5–6 months using a CR2032 coin cell

The overall system met its core performance goals and user-centered design criteria, including ease of use, modular construction, and minimal maintenance.

Recommendations

For future improvement and scaling, we recommend:

1. **Adding Wireless Capabilities**
   Integrating a low-power wireless module (e.g., BLE or LoRa) could enable remote notifications to smartphones or smart home hubs.

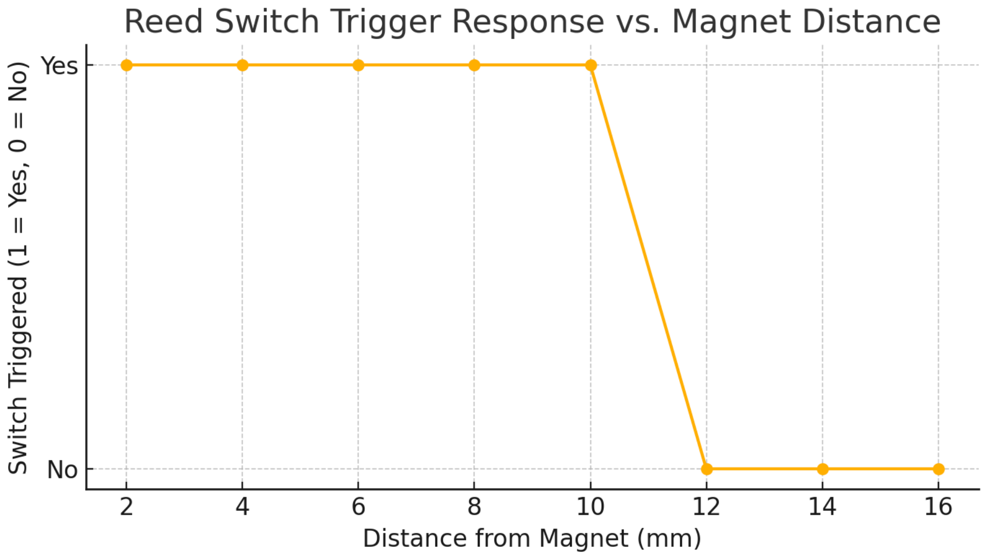
2. **Weatherproofing the Housing**
   Sealing the housing with gaskets or silicone would allow for outdoor or semi-outdoor use.

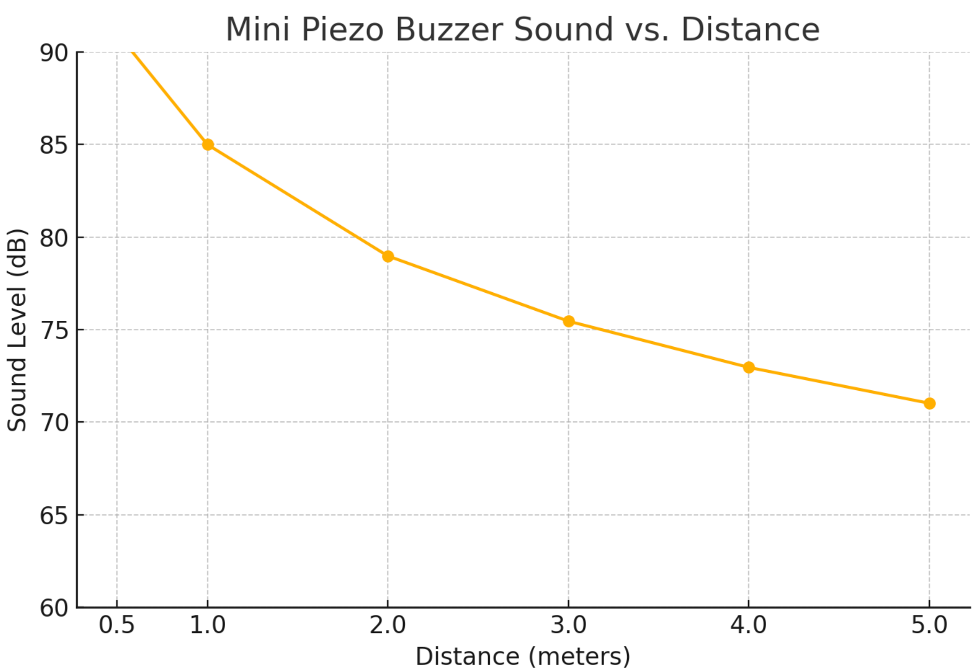
3. **PCB Integration**
   Replacing hand-wiring with a printed circuit board (PCB) would improve durability, consistency, and ease of assembly.

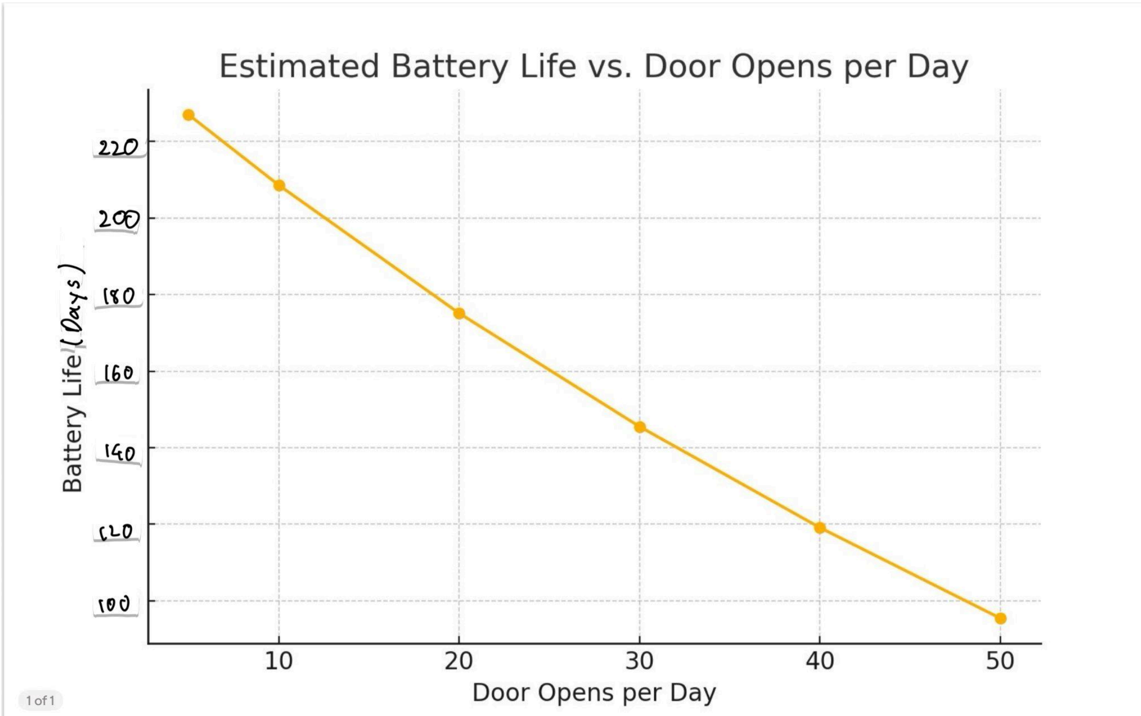
4. **User Interface Enhancement**
   Incorporating an LED indicator or adjustable buzzer tone could improve user interaction and accessibility.

5. **Modular Battery Design**
   Designing for AA or rechargeable battery packs could provide longer life or environmental benefits.

FINAL TEST DATA

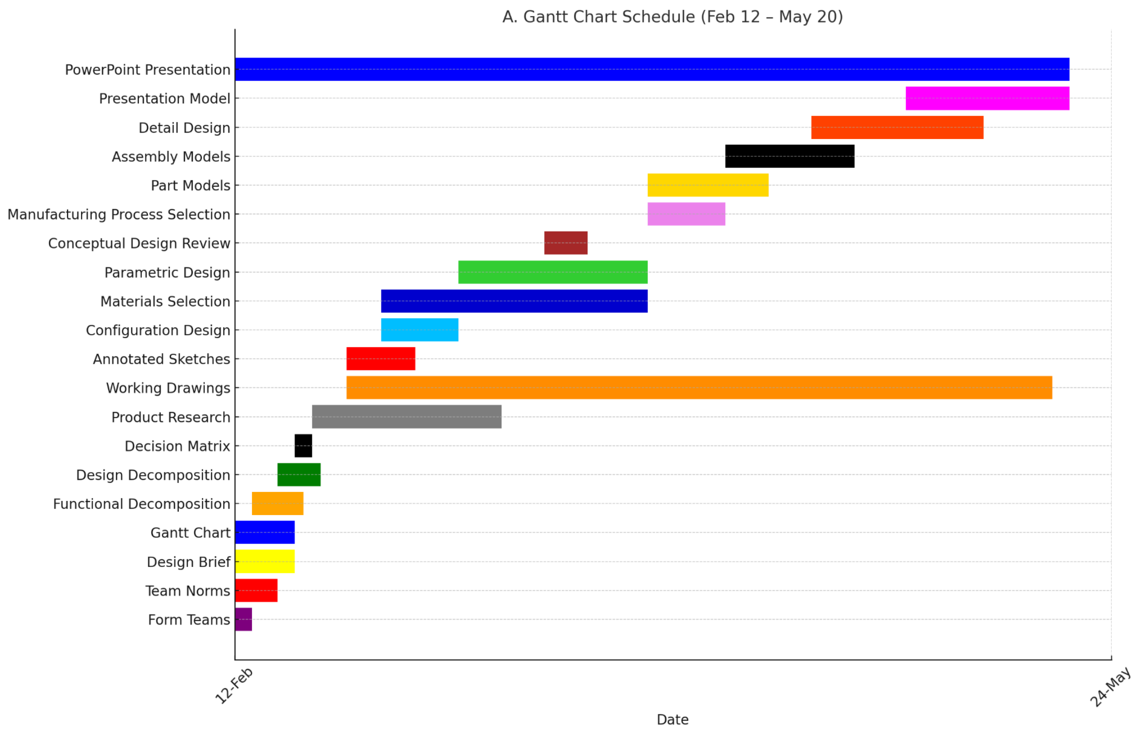

Reed Switch Trigger Response vs. Magnet Distance
Yes
No
Switch Triggered (1 = Yes, 0 = No)
2
4
6
8
10
12
14
16
Distance from Magnet (mm)


Mini Piezo Buzzer Sound vs. Distance
90
85
80
75
70
65
60
Sound Level (dB)
0.5
1.0
2.0
3.0
4.0
5.0
Distance (meters)


Estimated Battery Life vs. Door Opens per Day
Battery Life (Days)
220
200
180
160
140
120
100
10
20
30
40
50
Door Opens per Day
1 of 1

APPENDIX

A. Gantt Chart Schedule



B. Bill of Materials (BOM)

Component	Description	Quantity	Estimated Cost (USD)
Reed Switch	Magnetic door sensor	1	$1.60
Mini Piezo Buzzer	3V buzzer, 85 dB	1	$3.00
CR2032 Battery	3V coin cell	1	$1.00
Battery Holder	For CR2032	1	$0.60
SPDT Switch	Toggle on/off	1	$0.60

Neodymium Magnet	Small round magnet	1	$0.80
Plastic Housing	3D printed enclosure	1 set	$4.50
Jumper Wires/Solder	For connections	-	$0.40
Total			**~$12.50**

C. OPERATION

Instructions for Use

1. **Mount the Sensor:**
    - Attach the **main housing** (with reed switch and buzzer) to the **door** using adhesive or screws.
    - Align and mount the **magnet housing** on the **door frame**, directly across from the reed switch.
2. **Insert Battery:**
    - Slide open the top lid.
    - Insert a **CR2032 coin cell battery** into the holder with correct polarity.
    - Close the lid securely.
3. **Activate the Alarm:**
    - Use the **power switch** to turn the sensor **on**.
    - When the door opens (magnet moves away), the buzzer will sound.
4. **Turn Off the Alarm:**
    - Slide the switch to the **off** position to disable the buzzer.