# Design Review 1

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**Itinerary:**

1. Introduction
    a. Attendance
        i. Meeting Leader: Allison Fleming
        ii. Meeting Minutes: Mary Rose Nelligan
2. Major Subsystems
    a. Feedback Subsystem
    b. Mechanical Subsystem
    c. Power Subsystem
    d. Obstacle Subsystem
3. Essential Connections of All Components
    a. Power Supplies
    b. Programming
4. Plan for Design Review 2
    a. Expected Problems
    b. Action Items
    c. Questions

## Major Subsystems

<u>Feedback Subsystem</u>

**LCD and 7 Segment Display:**

- Requires 3.3 V DC power supply (see Figure 1 below for power for subsystem)
- LCD has 10MHz internal clock
  - Requires 8 digital data lines and 4 or 5 digital control lines (SPI) to read and write to the display (12 lines total)
  - If need be, the display can operate on SPI mode, which requires only 5 pins total (SPI data in, data out, clock, select, and d/c)
- 7 segment will only use 1 (4 total digits) that will count scores in increments of 10
  - SPI connections needed: SDA, SCL, GND, +5V, VIO

**Audio:**

- Uses PC68-4 Dayton Audio Poly Cone Driver for the speaker that has a 4 ohm impedance
- Audio will be amplified with a 5.5 V digital amplifier connected to the ESP 32 and the speaker, as seen to the right

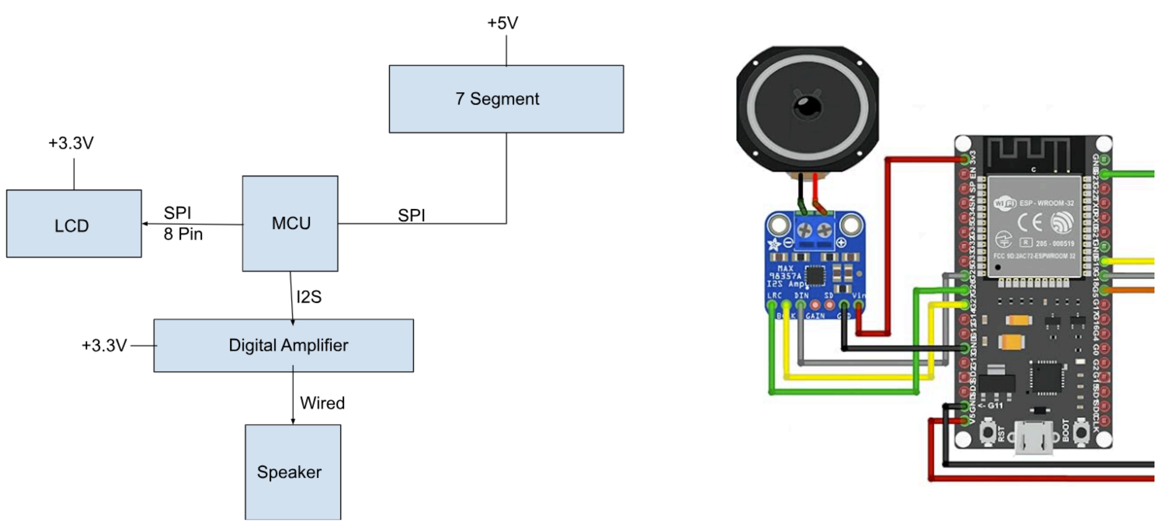



Figure 1: General Connections and Power for OLED, 7 Segment, and Audio System

**Lighting:**

- Will purchase APA102 1 meter programmable LED strip for lighting
- Requires 5V power to draw up to 60 mA of current
- Connections will be made with wires or jumper wires
- Uses a simplified SPI system that requires only two connections
- LEDs are communicated with in a data frame of 16 bits that control color and brightness
- LED strip is terminated with four colored wires to allow for power, ground, clock, and data communication
- Capacitor of 100 uF or 1000 uF needed between power and ground to act as a reservoir
- Libraries already exist with different potential colors and lighting combinations on GitHub

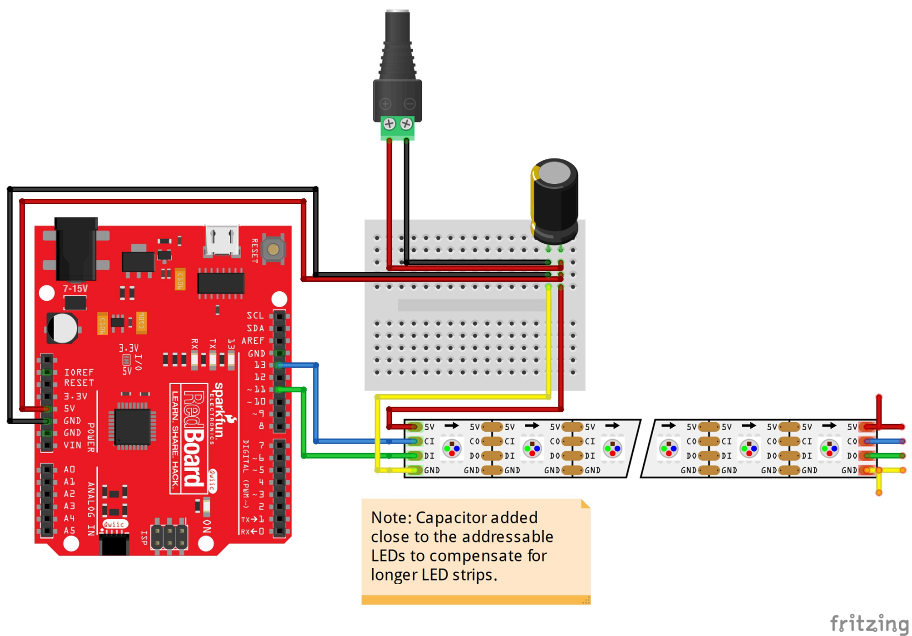



Figure 2: Lighting Diagram

<u>Mechanical Subsystem</u>

**Spring Loaded Launcher**

- We will incorporate the launcher from the previous design
- The design casing of the launcher is 10cm and the launcher is 2.5cm from the floor of the gameplay area – meaning the ball should be 5cm in diameter

**Paddles**

- Flippers will be 3D printed
- Driven by two push-pull solenoids requiring a minimum of 12V, 250 mA

- Push button completes the circuit, and thus does not require input from the microcontroller

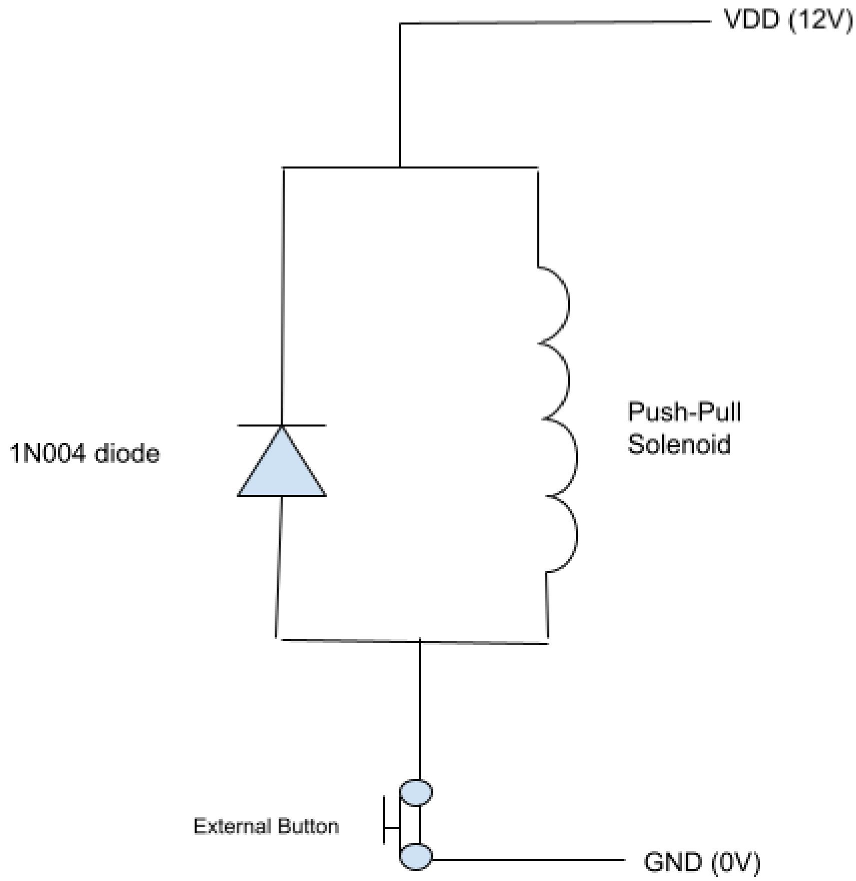
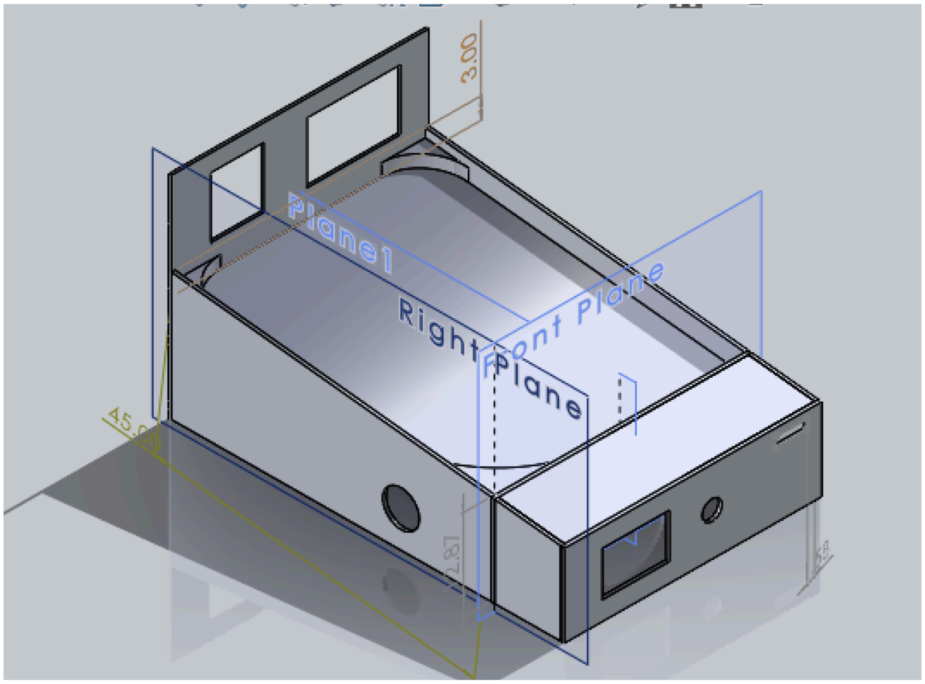
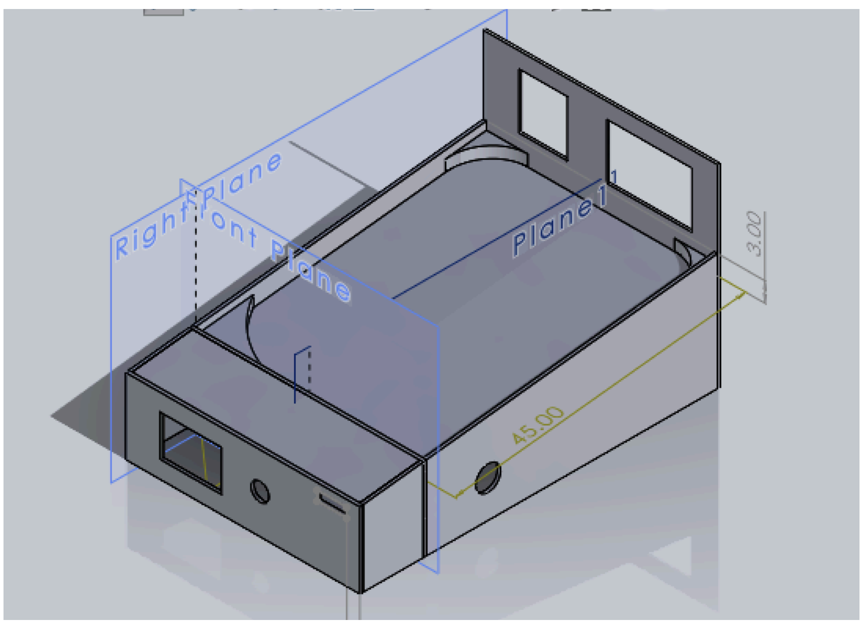



Figure 3. Paddle Circuit

**Enclosure**


3.00
Plane1
Right Plane
Front Plane
45.00
2.81

Right Plane
Front Plane
Plane1
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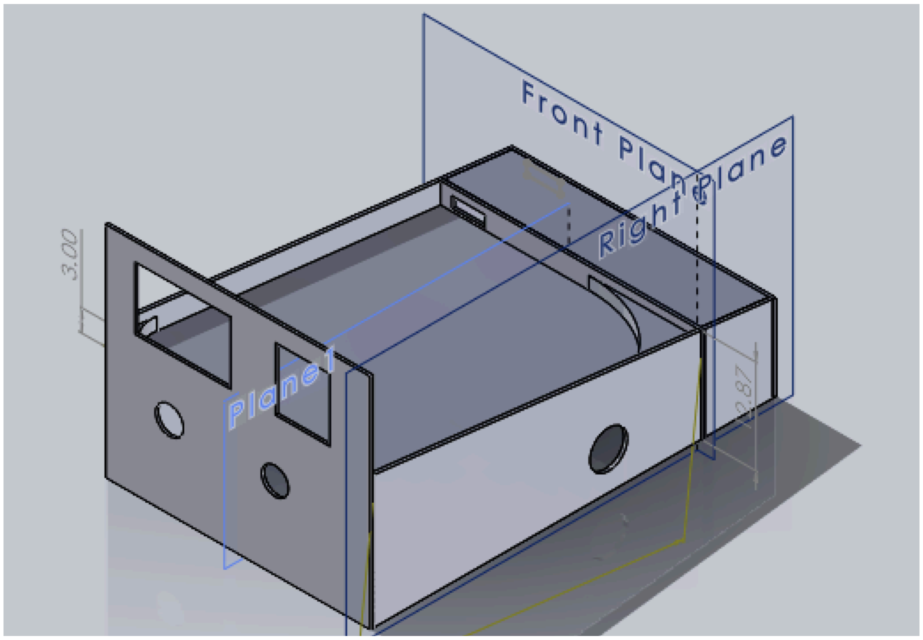


Figure 4. Enclosure CAD

Gameplay Surface

- Size
  - 30cm x 60cm
- Inclination:
  - The surface will be set at a 6.5° angle to ensure optimal ball dynamics and consistency with traditional pinball designs.
    - A steeper incline may cause the ball to move too quickly, reducing playability.
    - A shallower incline might hinder ball momentum, leading to inconsistent gameplay.
- Material:
  - Primary material: Casted acrylic, selected for its durability, transparency, and ease of drilling/tapping.
  - Previous experience: Acrylic performed well in the last project, making it a reliable choice.

Buffer Box

- Purpose:
  - Houses the plunger and speaker components.
  - Ensures secure ball alignment before launch to enhance gameplay precision.
- Design Features:
  - The housing is reinforced to minimize wear and ensure stability during repeated launches.

Underneath Enclosure

- Purpose:
  - Dedicated space for electronics, wiring, and electromechanical components.
- Design Features:

    - Maintenance access: A panel with screws will allow for convenient access to components during repairs and so that components don't fall out when the pinball machine is lifted up. This will be added at the very end of the project.

Construction Details

Fasteners:

- Use flat-head screws that are shorter than ¼' so they fit into the plastic casing. This worked well for the last group. The screws will be put in from opposite of the gamearea so that nothing pokes out on the board. Use the EIH drill press.
- Spacing: Place screws 1.5 inches apart along edges for structural stability.

Corner Brackets:

- Use corner brackets to reinforce the enclosure's joints, particularly at high-stress points like the buffer box and the underneath enclosure.
- Attach brackets with screws, ensuring they align perfectly for a square fit.

Challenges, Unknowns, and Action Plans

Component Spacing

- Challenge:
    - Finalize spacing of components on the gameplay surface and within the enclosure.
- Action Plan:
    - Use CAD to model the enclosure and verify subsystem placement, after material selection is finalized.

**Corner Rounders and Stationary Boundary by Plunger**

The corner rounders and stationary boundary near the plunger are designed to enhance gameplay by improving ball movement. The stationary boundary by the plunger helps guide the ball during launches, keeping that area separate and ensuring that the ball consistently follows a controlled path up the playfield. Both components will be 3D-printed and screwed into the gameplay surface.

Major Components

| Component | Function |
| --- | --- |
| Corner Rounders | Smooth out sharp corners to improve ball deflection. |
| Stationary Boundary | Separates the plunger area from the rest of the gameplay field to guide ball movement during launch. |
| Mounting Screws | Secure the 3D-printed pieces to the gameplay surface. |

Table 1. Stationary Boundary and Corner Rounder Major Components

Design Details

Corner Rounders

- Material:
  - 3D-printed plastic (e.g., PC-ABS) for durability and impact resistance.
- Shape:
  - Rounded with corners right against the corner of the gamefield. This will ensure predictable ball travel.
  - ~1.25 inches high.
    - A 1.25-inch height ensures the components are tall enough to prevent the ball from rolling over but not excessively high, keeping gameplay visible and accessible. This should remain stable and resistant to bending or breaking, striking a good balance between containment, visibility, and stability.
- Mounting:
  - Screwed securely into the gameplay surface using flat-head screws.
  - Screw placement ensures stability during repeated impacts.

Stationary Boundary by Plunger

- Material:
  - 3D-printed plastic to match the corner rounders.
- Shape:
  - Tall enough to prevent the ball from crossing into the main play area prematurely but low enough to avoid obstructing visibility.
  - ~1.25 inches high.
    - Same reason as stated above.
- Placement:
  - Positioned around the plunger lane, keeping the ball on a direct path from the plunger to the rest of the playfield.
- Mounting:
  - Screwed into the board to prevent shifting during ball launches.

Challenges, Unknowns, and Action Plans

Exact Shape

- Challenge:
  - The specific shape and curvature of the corner rounders and boundary have not been determined.
- Action Plan:
  - Create CAD models to finalize the shape, ensuring smooth ball deflection and containment.

<u>Power Subsystem</u>

- Use KiCad to design a separate board to handle all power connections instead of clogging up the main board with pins.

- Important connections to power the board are from the wall, to and from regulators, then every pin for power & GNDing.

Power Connections

| Part | Voltage | Amperage (if known) | Type of Connection | Major Subsystem | Link to Data Sheet (In Drive) | Notes |
|---|---|---|---|---|---|---|
| 12V AC Adapter | 120V Wall | 2A Max | Barrel | Power | Amazon | Notes |
| 5V Voltage Regulator | 12V | 1A Max | Wired | Power | Digikey | AZ1117IH - 12V to 5V |
| 3.3V Voltage Regulator | 5V | 1A Max | Wired | Power | Digikey (In EIH) | AZ1117IH - EIH Stock Part 5V to 3.3V |
| 7 Segment Display | 5V | 80mA | Wired | Feedback | Adafruit | Notes |
| Digital Amplifier | 3.3V | 866mA | Wired | Feedback | Amazon | Notes |
| LED Strip | 5V | 60 mA | Wired | Feedback | iPixel Led | 100μF Required on Power Supply |
| LCD | 3.3V | 150mA (LDO regulator) | Wired | Feedback | Adafruit | Notes |
| Left Flipper Push-Pull Solenoid | 12V | 250mA | Wired | Mechanical | Adafruit | 1N004 diode must be wired in parallel |
| Right Flipper Push-Pull Solenoid | 12V | 250 mA | Wired | Mechanical | Adafruit | 1N004 diode must be wired in parallel |
| Power supply for driver board and motor (x2) | 12V | 500mA | Wired | Obstacle | Sparkfun | Notes |

Table 2. Power Connections

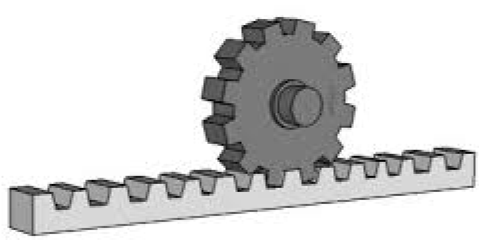
Obstacle Subsystem:

**Major Components**

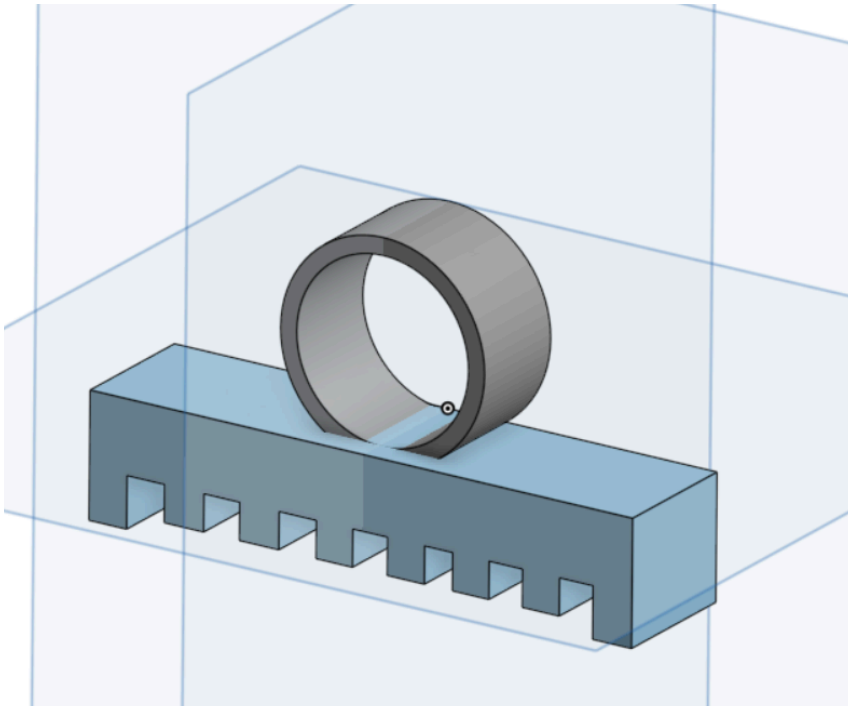
- 3D printed gears
- 3D printed spinner
- Mercury Motor Stepper Motors (x2) (SM-42BYG011-25) (own)
- Sparkfun Easy Driver Stepper Motor Driver (board) (x2) (here) ($17 a piece)

**Moving Obstacles**

- Stepper Motor Powered Linear Obstacle
    - Mechanism uses a rack and pinion, powered by stepper motor, to move a ring back and forth across the playing field



    - The pinion (circular gear) will attach to the stepper motor
    - The rack (linear actuator 'gear') will have an additional circular hole on the shown flat side, for our pinball to go through
    - Link to Sparkfun driver board, $17 here
    - Rough 3D printed rack:



- OPTIONAL: a cutout can be made in the center bottom of the ring, with two metal prongs attached to trigger additional points for the player
- Power Requirements:
  - Supply Voltage for motor and driver board 12V, 2Amax
- Stepper Powered Spinner
  - Stepper motor lies face up, with spinning gear attached onto spindle
  - Same power requirements as linear obstacle, with stepper motor and driver board

**Stationary Obstacles**
Material:

- VM-5 Zippy Microswitch 5A/250Vac NO/NC (There are many leftovers from the last pinball machine)

Major Components

| **Component** | **Function** |
|---|---|
| Target Frame | Attaches to the microswitch as a place for the ball to hit. |
| Back Boundary | Prevents the ball from hitting the back of the microswitch and triggering false outputs to the microcontroller. |
| VM-5 Zippy Microswitch | Detects when the target is hit and sends a |

Table 3. Moving Obstacle Component and Function

Design Details
Target Frame

- Material:
  - Plastic (PC-ABS) to withstand ball impacts while maintaining a lightweight structure.
- Construction:
  - 3D-printed piece that will slide into the actuator. This worked well for the last group.
- Shape:
  - Circular to prevent ball deflection at unpredictable angles.
  - ⅛' thickness deemed appropriate given past success with the design of this part.
- Mounting:
  - There will be a wide hole in the board where the targets will stick out of so that they can move back and forth.

Microswitch Integration

- Model:
  - VM-5 Zippy Microswitch (5A/250V AC, NO/NC)
    - Can do 1.8 or 3.3
- Function:
  - Detects ball impact and sends a signal to the microcontroller for score updates.
- Wiring:
  - The microswitch's NO (Normally Open) contact will be used to trigger events.
  - Power: 3.3V
  - Ground: Connected to the system ground.
  - Signal Line: Digital input to the microcontroller.

Microswitch Casing
Material:

- 3D-printed to allow secure mounting to the frame.

Construction:

- Designed to be screwed into the board from the opposite side of the gameplay surface, preventing the drill from sticking out on the surface side.
- Allows for easy alignment of the microswitch actuator with the target frame.

Back Boundary
Material:

- 3D-printed plastic.

Function:

- Semi-circular guard positioned behind the microswitch to prevent the ball from hitting the back of the switch and causing false outputs.

Design:

- Sized to cover only the back of the switch without obstructing the target frame or ball movement.

**Ramp**

Major Components

| **Component** | **Function** |
|---|---|
| Ramp Structure | Provides a guided pathway for the ball. Slope and curvature determine smooth ball travel. |
| 5mm IR Break Beam Sensor | Detects the ball passing through the top of the ramp to trigger scoring, audio, and visual updates. |
| Material | Supports wear and tear from rolling balls and impacts, while maintaining a smooth surface. |
| IR Beam Housing | Prevents interference from ambient light |
| EE Support Structure | Adds a design element and supports the ramp |
| Attachment to Casing | Securely mounts the ramp to the gameplay surface |

Table 4. Ramp Component and Function

Design Details

Ramp Shape and Structure

- The ramp is U-shaped both horizontally and vertically:
    - The ball rolls up one side, follows a semicircular curve at the top, and descends symmetrically.
    - Designed in SolidWorks CAD, ensuring precise dimensions and symmetry for smooth ball travel.

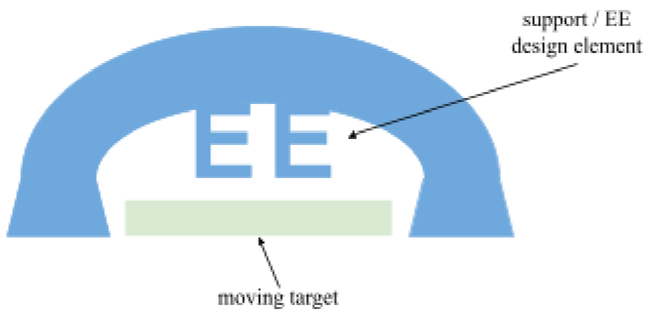


Figure 5. Ramp and Moving Target Design

Dimensions and Slope
- Width:
    - The ramp will be slightly wider than the largest metal ball in testing (e.g., add 2-5 mm clearance on both sides). The mouth of the ramp will be wider and become flush with the game board.
- Incline Adjustment:
    - The slope may need adjustment based on the ball's weight and initial speed.
    - Testing will determine the optimal slope angle to maintain ball momentum without stalling or bouncing.

Material Selection
- Plastic Type: PC-ABS at 1/4-inch (6.35 mm) thickness.
    - Strong and impact-resistant, suitable for repeated ball impacts.
    - Rigid enough to maintain shape without sagging or flexing.
    - Offers a smooth surface finish, which is important for ball travel.

Visibility Consideration
- Positioning will be optimized to avoid blocking the player’s view during gameplay. Ensure that ramps do not obstruct visibility of:
    - The OLED display.
    - The 7-segment display.

Ball Detection
- Sensors will be embedded to detect when the ball passes the top of the ramp (not the sides, as the ball could roll back down before making its way over to the other side).
- Detection components include:
    - 5mm IR LED break beam sensor.
    - Housing for the sensor to prevent interference to the IR beam.

Attachment to gameplay
- Where the entrance/exit of the ramps are, there will be screws, screwing in from the opposite side of the game area.
- There will also be screws at the ‘EE’ support system, screwed in from the opposite side.

Power

Break Beam Sensor (5mm IR)
- Connections:

    - Power:
        - 5V
            - Adafruit description: “You can power it from 3.3V or 5V, but 5V will get you better range and is what we suggest”
    - Ground:
        - Connected to system ground.
    - Signal Line:
        - Output pin sends a digital signal to the microcontroller when the beam is broken by the ball.
        - The microcontroller reads this input and triggers the corresponding event (e.g., score update, audio clip, and LED flash).

Challenges, Unknowns, and Action Plans

IR Interference

- Challenge:
    - Potential interference from ambient light.
- Action Plan:
    - Design and test a sensor housing to block external light sources. The housing will cover both the emitter and receiver, ensuring sensor accuracy even under bright lighting conditions and surrounded by flashing LEDs.

**Essential Connections of All Components**

| Part 1 | Connection to | Part 2 | Connection Type | Notes |
|---|---|---|---|---|
| 7 Segment Display | → | Microcontroller | SPI | - |
| 7 Segment Display | → | 5V Power | Wired | 80mA |
| LCD | → | Microcontroller | 8 Pin Digital + SPI | - |
| LCD | → | 3.3V | Wired | 150mA (LDO regulator) |
| Microcontroller | → | Digital Amplifier | I2S | - |
| Digital Amplifier | → | 3.3V | Wired | 866mA |
| Speaker | → | Digital Amplifier | Wired | - |

| | | | | |
|---|---|---|---|---|
| LED Strip | → | Microcontroller | Wired | - |
| LED Strip | → | 5V | Wired | 100µF Required on Power Supply |

Table 5. Feedback Subsystem Essential Connections

Microcontroller Essential Specifications:

- Connections:
  - SPI for 7-Segment
  - SPI for LCD
  - 8 pin digital connection for
  - I2S pins for Amplifier (Speaker)
  - 2 pin connection for LEDs
- Clocking:
  - LCD has 10MHz internal clock
- Memory:
  - LCD has SD card attachment so memory considerations are not necessary

**Plan for Design Review 2**

Expected Problems:

1. We expect to have trouble with the libraries for the LCD. Because of this, we will spend extra time prototyping and testing animations.
2. We expect to have issues laser cutting after break. Because of this, we will try and get the entire body cut before then.
3. We expect to have issue designing the board so we will invoke everyone in the group's knowledge and experience.

Action Items:

Our first order of business will be to purchase all the parts which should be done by the end of the weekend. From there, we will rapidly prototype the designs assigned to each person and get working prototypes by the design review. We will each share the responsibility of designing the board while Gavin will take on the responsibility of designing the power supply board.

Action Items

| Item Description | Status | Assigned Members | Due date | Date Completed | Dependencies |
|---|---|---|---|---|---|
| Purchase Parts | Not started | Gavin Carr, Everyone | 2/24/2025 | | |
| Design Board | Not started | Everyone | 3/6/2025 | | |
| OLED (with buttons) and 7 Segment Prototyp | Not started | Toby Bradshaw | 3/6/2025 | | Parts Purchased |
| Audio Prototype | Not started | Toby Bradshaw | 3/6/2025 | | Parts Purchased |
| Lighting Prototype | Not started | Allison Fleming | 3/6/2025 | | Parts Purchased |
| Plunger Prototype | Not started | Allison Fleming | 3/6/2025 | | Parts Purchased |
| Paddles Prototype | Not started | Mary Rose Nelligan | 3/6/2025 | | Parts Purchased |
| Enclosure Prototype | Not started | Clare Nickerson | 3/6/2025 | | Parts Purchased |
| Power Board Design | Not started | Gavin Carr | 3/6/2025 | | |
| Stationary Obstacles (+Ramp) Prototype | Not started | Clare Nickerson | 3/6/2025 | | Parts Purchased |
| Moving Obstacles Prototype | Not started | Mary Rose Nelligan | 3/6/2025 | | Parts Purchased |
| Design Review 2 | Deadline | Mary Rose Nelligan | 3/6/2025 | | |

Table 6. Action Items

<u>Questions</u>:

1) If we make a separate board for power is it bad to make a ton of pins to have extra connections just in case. Say 20 3.3V pins, 20 5V pins, 20 12V pins. Is too many connections a problem on a singular power source?
2) How many layers is the max amount for KiCad and manufacturing? If the power board had a GND, 3.3V, 5V, and 12V layer is that a problem?
3) For the boards last semester, power came through a USB-C connection from a computer. Can we still use a USB connection for power from another board, or is it better just to wire that in?
4) Clearly don't use external regulators. However, if current draw is too much would it be bad to get multiple regulators of a certain type for the board or just find a bigger regulator that allows for more current to be sent through it? Kinda off Q1 too
5) DON'T USE HEADER PINS - use connectors w/ direction to them & latch reasonably well. Can add the JST connectors to break out boards you buy based on the space. Want to plug in and unplug, so JST is the winner for that. Need hot & GND for all connections.