Pinball Machine Final Report

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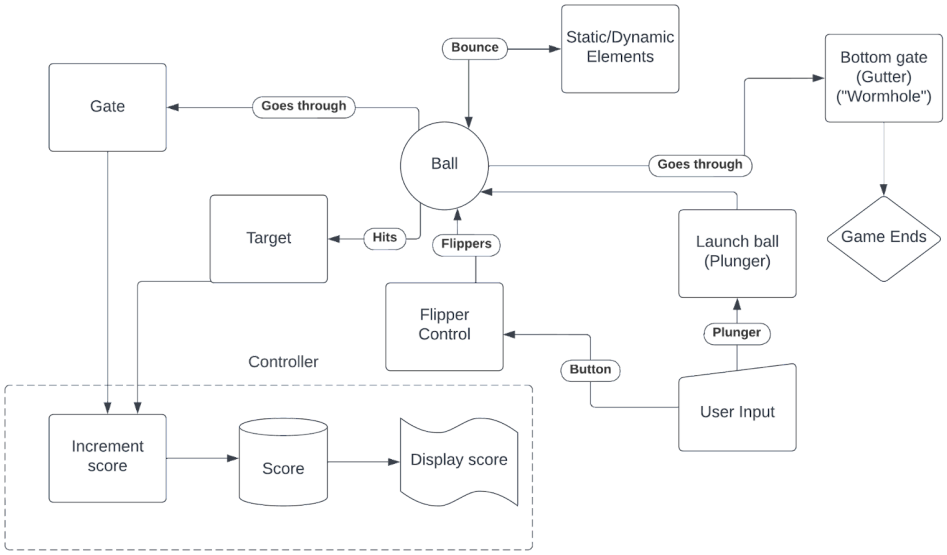
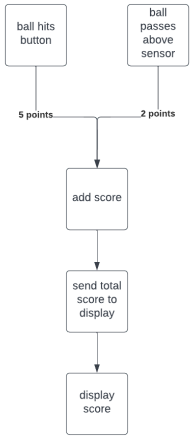
Pinball Machine Integration Cycle: Plan

Complete design and block diagram



controller sub diagram



Trace matrix: Electrical Requirements

5.1.1 LEDs turn on
5.1.2 LEDs flash in a waterfall pattern: the lights turn on and off to appear as if they are moving one after the other
5.1.3 LEDs are activated when the game is on, and are deactivated when the game is off (controlled via the switch)
5.1.4 Building this LED system is cheap and accessible to many people

Spec number	Spec description	Test to perform	Relevant req	Spec [units]	Measured [units]
5.1.1	LED turn on	Check if LEDs turn on	5.1.1	Yes/No	Yes

5.1.2	LEDs alternate	Check if LEDs operate	5.1.2	Yes/No	Yes
5.1.3	LED's activate	Check if LEDs are coordinated with the game switch for on and off	5.1.3	Yes/No	Yes
5.1.4	Total cost	Add total price of components together including price of labor	5.1.4	<$100	<$100

Pinball Machine Summary

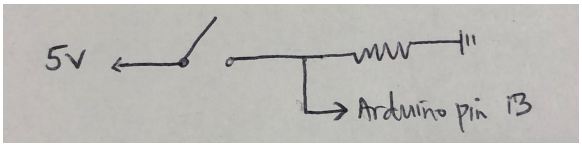
On/Off: Switch Button

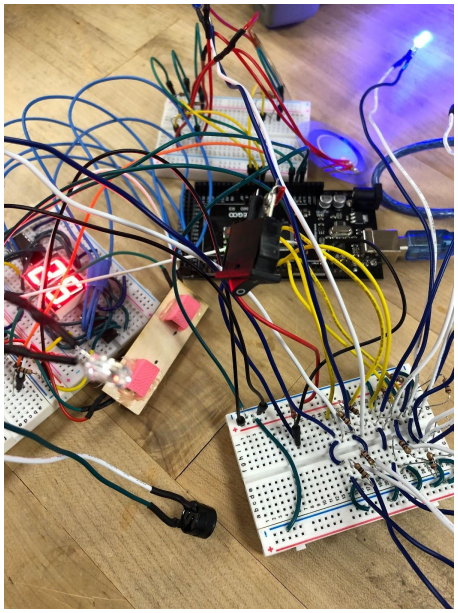
The switch button circuit turns the game on and off. When the board is in its idle state and the switch is turned on, a number of actions happen:

- The 7-segment display turns on
- The spinning obstacles start spinning
- The flashing LED lights turns on (just for aesthetic reasons)

When the button is turned on, the three actions above stop.

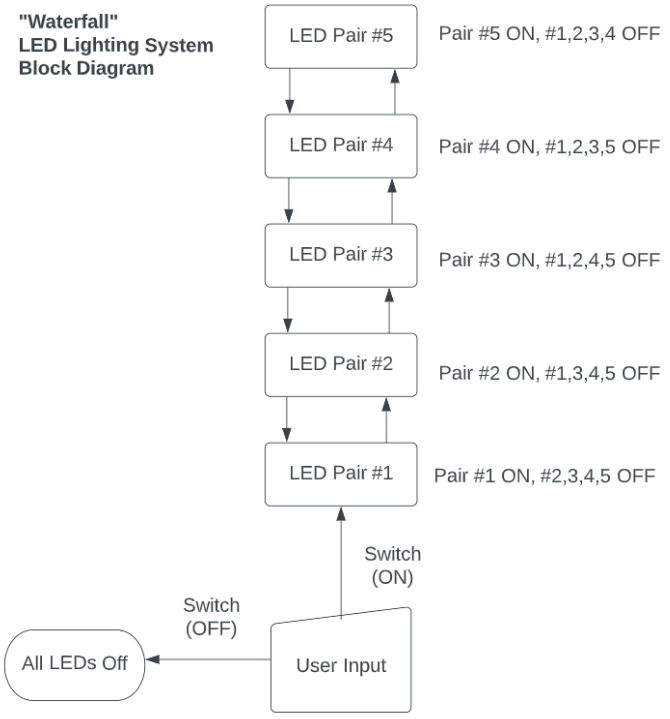
- The 7-segment display turns off
- The spinning obstacles stop spinning
- The flashing LED lights turns off

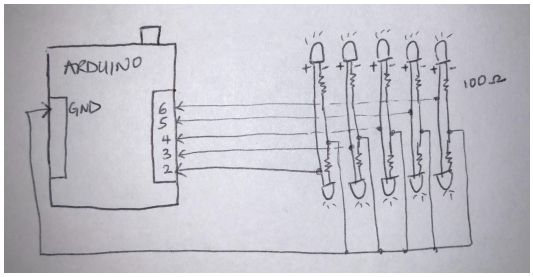


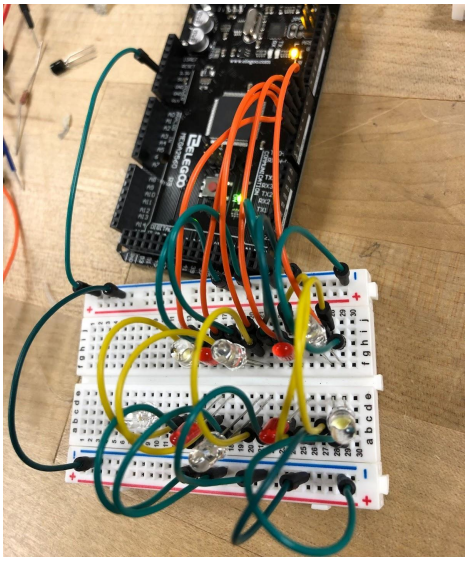


Flashing LEDs for Fun!

We put rows of two different colored LED lights inside our board to make the pinball machine feel more fun and entertaining. These LED lights will alternate with some delay. When the game turns on, these lights will activate. Since the LED design was an electronic component only, no parts were manufactured and thus no CAD design was necessary. Here are the diagrams and sketches:



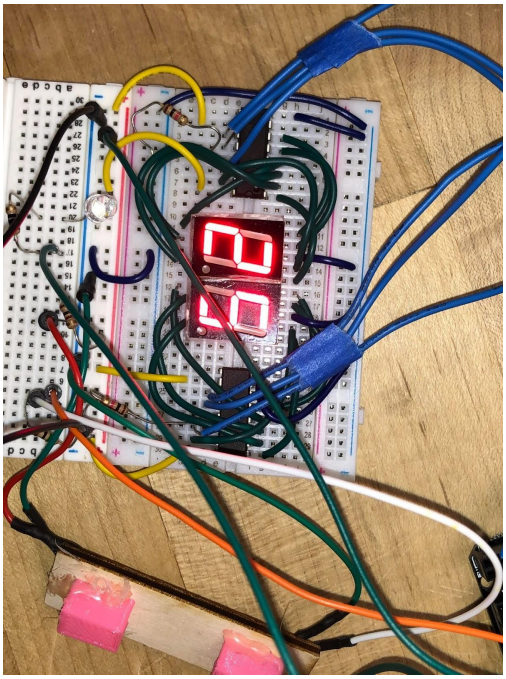


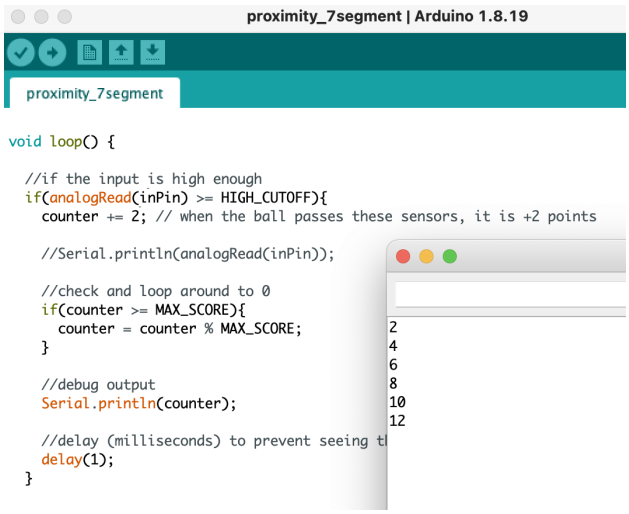


```
blinking_LEDs | Arduino 1.8.19

blinking_LEDs

// Blinking LEDs run 5 LEDs in a pattern of blinks

int led1 = 2;
int led2 = 3;
int led3 = 4;
int led4 = 5;
int led5 = 6;

// the setup routine runs once when you press reset:
void setup() {
  // initialize the digital pin as an output.
  pinMode(led1, OUTPUT);
  pinMode(led2, OUTPUT);
  pinMode(led3, OUTPUT);
  pinMode(led4, OUTPUT);
  pinMode(led5, OUTPUT);
}

// the loop routine runs over and over again forever:
void loop() {
```

Scoring #1: Optical Sensor & 7-Segment Display (+2 points)

The optical sensor circuit detects a ball rolling through and increments the score counter by 2 points using Arduino code. The score tally is displayed on the 7-segment display. While testing the circuit, we noticed that the ball was not being detected when it was moving too fast. We had a low pass filter (LPF) circuit attached to the optical sensor circuit. This was the cause of the failure to detect. When the ball moves fast, it is a high frequency signal so the LPF was filtering out that signal as noise. We removed the LPF, now it works well. An added functionality for entertainment is that whenever the ball passes these sensors, a green LED light beside the scoreboard will light up to indicate points being scored.

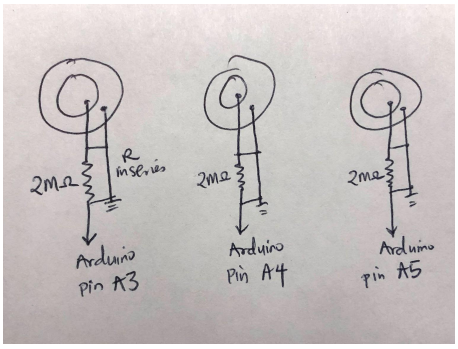


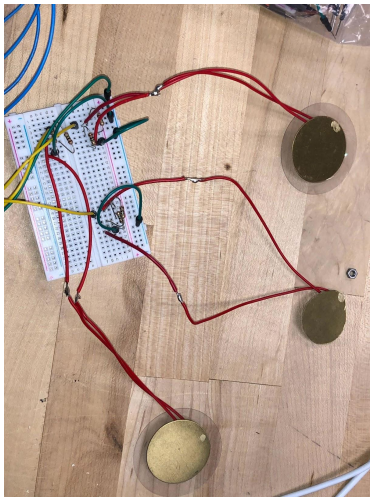


Scoring #2: Piezoelectric Sensor / Copper Plate (+5 points)

Definition: a device that uses the piezoelectric effect to measure changes in pressure, acceleration, temperature, strain or force by converting these into an electrical charge.

When the ball hits one of the 3 piezoelectric sensors we have, the score counter increases by 5 points. An added functionality for entertainment is that whenever the ball bits one of the three piezos, a green LED light beside the scoreboard will light up to indicate points being scored. In order to fit our pinball machine dimensions.

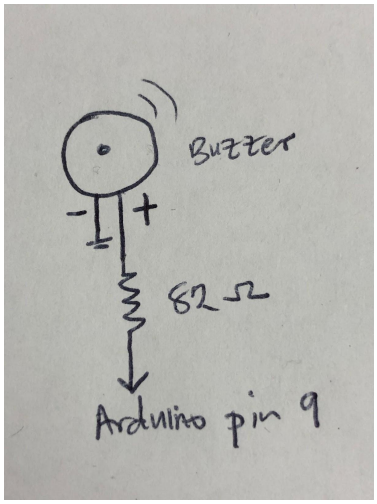


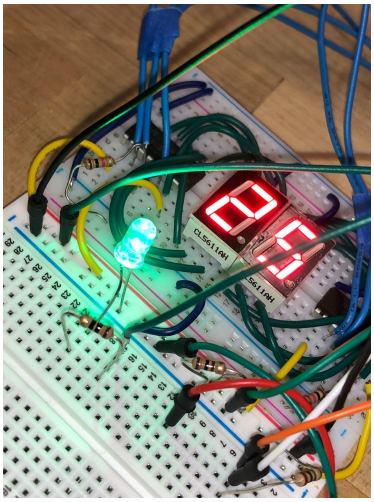
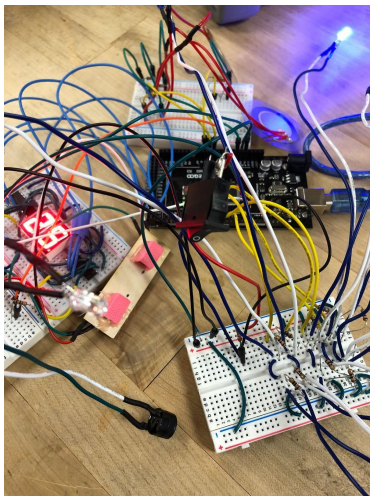


```
// PIEZOELECTRIC SENSOR
if (analogRead(piezoPin1) >= PIEZO_THRESHOLD){
  piezo_scoring();
} else{
  digitalWrite(ledoutput, LOW);
}

// PIEZO 2
if (analogRead(piezoPin2) >= PIEZO_THRESHOLD){
```

Buzzer and the Scoring Systems Combined

We combined both of the systems (optical and piezoelectric) into one system. If the ball rolls through the optical sensor, the score counter increases by 2. If it hits the piezoelectric plate, the score counter increases by 5. Also, a green LED lights up for entertainment to indicate points being scored. In addition to the green LED lighting up, the buzzer plays a tone. It serves as our auditory feedback for our score.

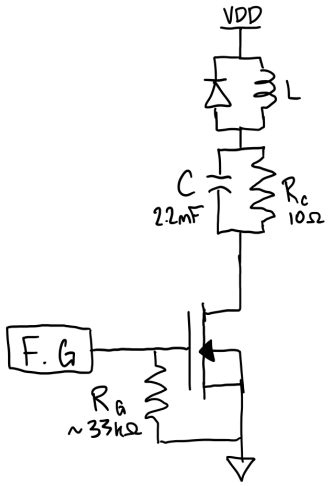


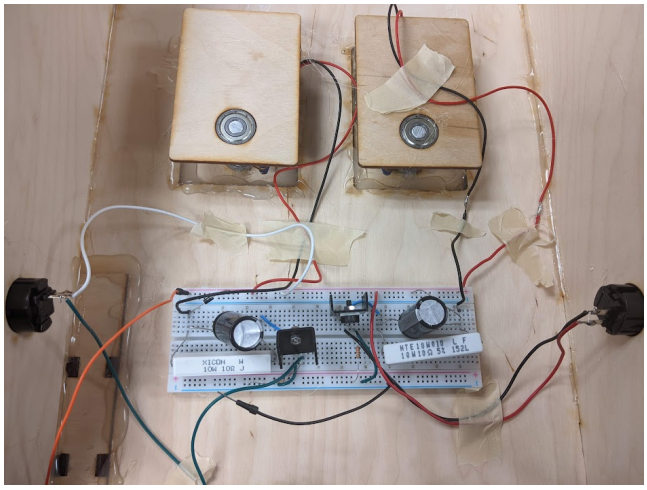



```
void piezo_scoring(){

  counter += 5; // when the ball passes, it is +5 points
  digitalWrite(ledoutput, HIGH);
  delay(50); // to make the LED visible
  // play a sound with the led when score is increased
  tone(buzzoutput, 2000); // Send 1KHz sound signal...
  delay(50);         // ...for 1 sec
  noTone(buzzoutput);     // Stop sound...
  delay(50);         // ...for 1sec

  //check and loop around to 0
  if(counter >= MAX_SCORE){
    counter = counter % MAX_SCORE;
  }
```

Flippers with Solenoid

Our flippers are powered by a circuit with a solenoid and button. We have two buttons to control the left and right flippers. The flippers are always active. Even if the switch of the machine is off, the flippers can be turned on. The flippers are controlled entirely by analog electronics. There is no Arduino interaction and thus no code.



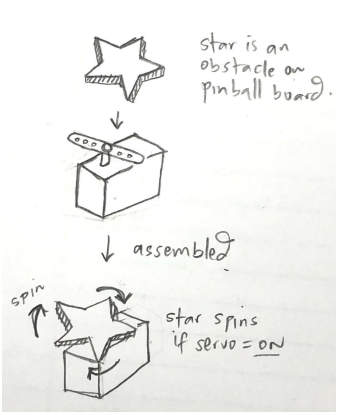


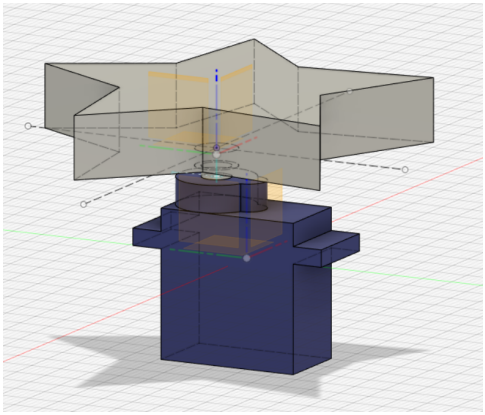
Servomotor Gating Mechanism

We designed a servo motor circuit that would stop the ball. The servomotor is in the bottom gate and it is rotated when optical sensors detect a ball at the end stage.

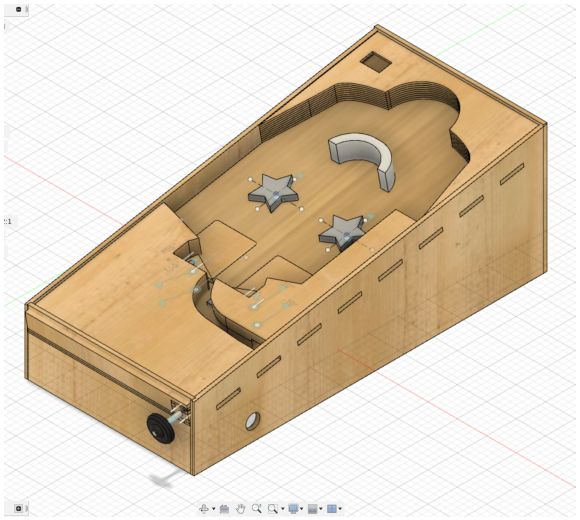
DC Motors with Spinning Obstacle

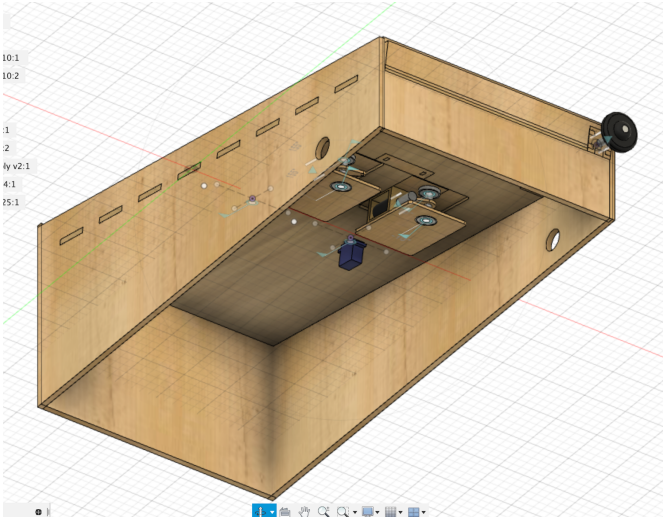
We included two DC motors in our system that spin a star continuously when the switch is powered on. The images below show what our circuit looks like but the servomotor is a DC motor. These are old images (we forgot to take pics of the updated one).



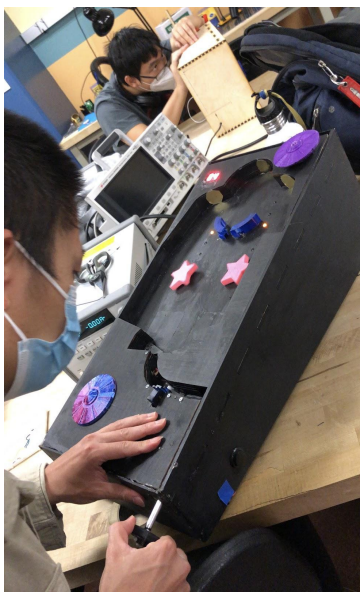


Complete CAD Assembly



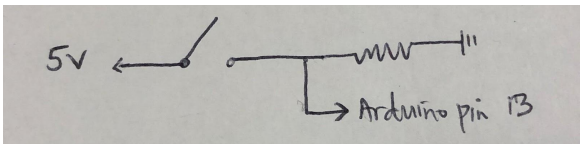


Pinball Machine in its Complete Glory

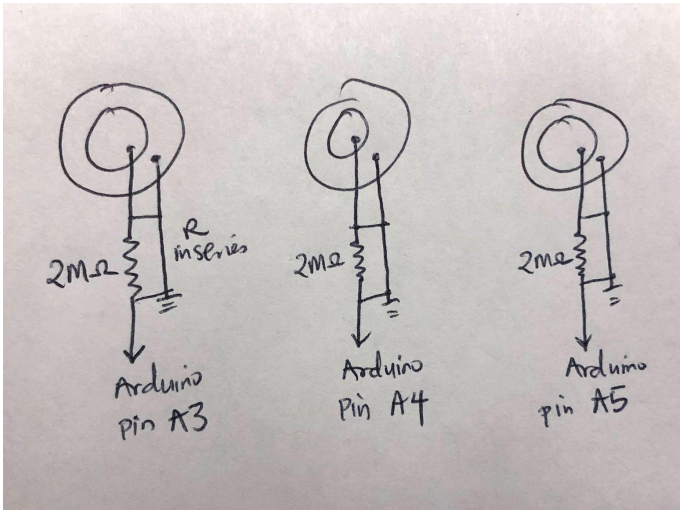


All circuit diagrams (including Arduino connections)

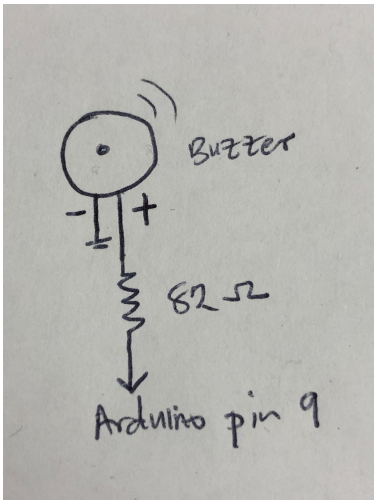
Switch:



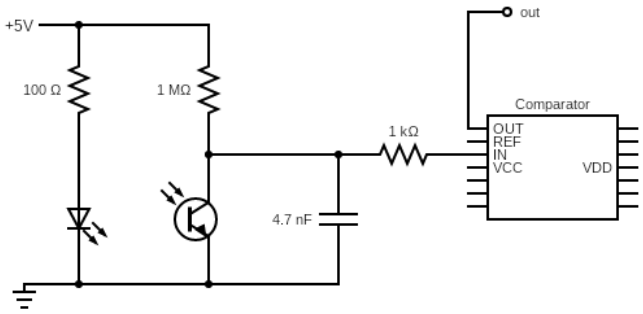
Piezoelectrics:



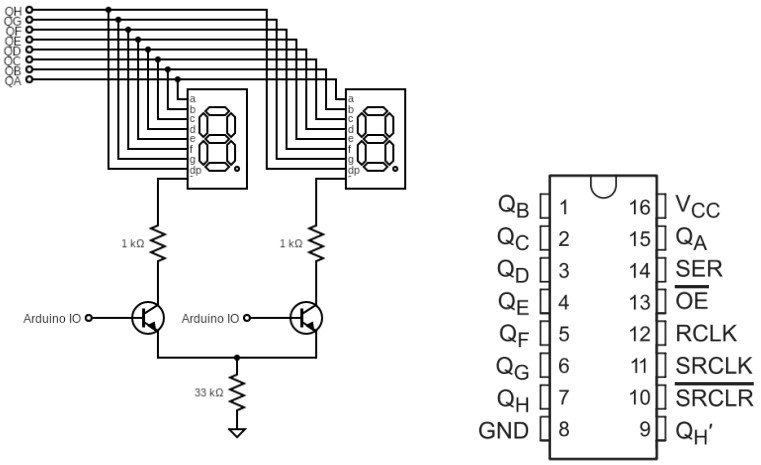
Buzzer:

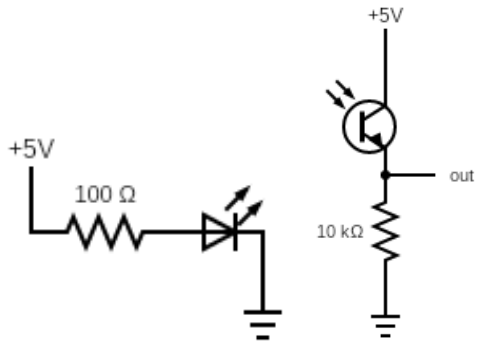


Optical Sensor:



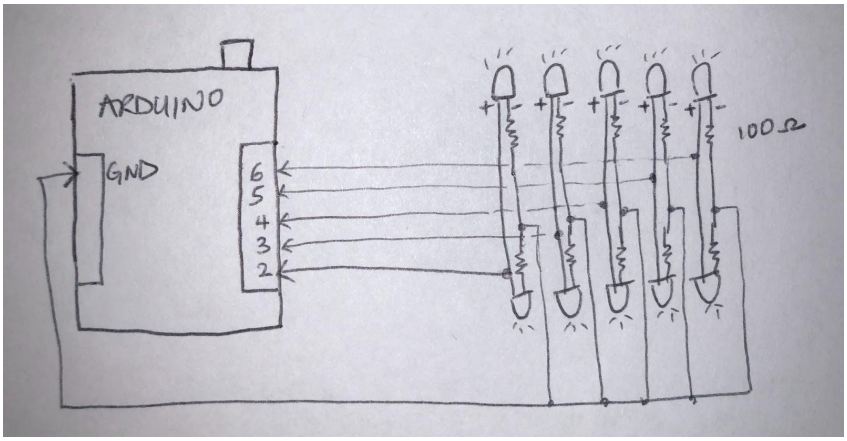
Seven segment display:

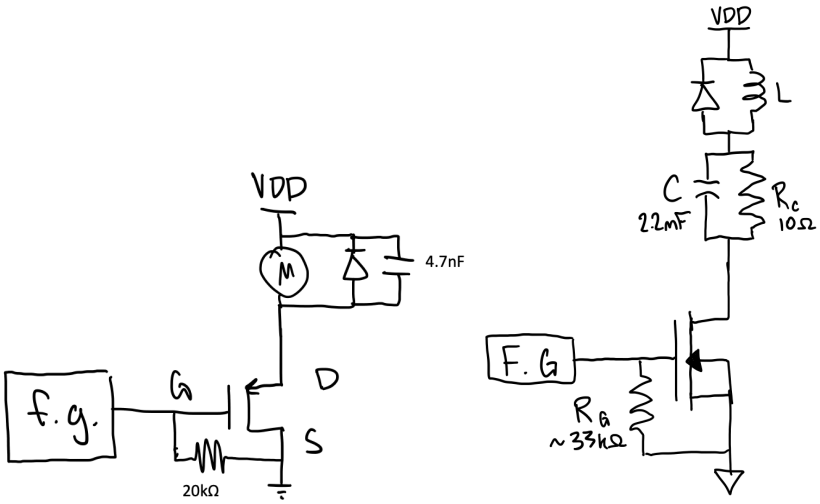




Phototransistor / LED Circuit Diagram:

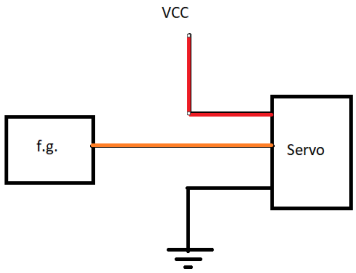
Flashing LED lights:





Flipper motor controller:

Servomotor:



Final trace matrix: Mechanical and Electrical Sub-System Design

Plunger Testbed
4.2.3.1 Uses available materials
4.2.3.2 Plunger launches ball to a distance of ≥ 1.5m
4.2.3.3 Easy to operate by user
4.2.3.4 Plunger can be held retracted indefinitely
4.2.3.5 Various launch strengths are possible via different pull distances of the plunger
4.2.3.6 Testbed holds plunger mechanism well

Servomotor Application
4.2.3.7 Servo should be able to spin
4.2.3.8 Maximum voltage servo receives is 5V
4.2.3.9 Servo should maintain a safe temperature
4.2.3.10 Current going through servo should be at most 250mA
4.2.3.11 Servo can be easily controlled
4.2.3.12 Servo mechanical design should be functional on the pinball machine

Flipper Testbed
4.2.3.13 Maximum voltage servo receives is 5V
4.2.3.14 Flipper launches ball to a distance of ≥ 1.5m
4.2.3.15 Flipper returns back to original position
4.2.3.16 Flipper must be able to work with the switch being either on/off
4.2.3.17 Flipper testbed design is reliable
4.2.3.18 All components should assemble and fit well in the flipper testbed

Optical Sensor for Scoring
4.2.3.19 The sensors should detect the ball that passes through
4.2.3.20 The Arduino should assign a score to the ball passing through
4.2.3.21 The Arduino should increment the score by 2
4.2.3.22 The 7-segment display should show the increased score

Piezoelectric Sensor for Scoring
4.2.3.23 The sensors should detect the ball that hits the copper plate
4.2.3.24 The Arduino should assign a score to the ball that hits the plate
4.2.3.25 The Arduino should increment the score by 5
4.2.3.26 The 7-segment display should show the increased score

Switch to Power Pinball Machine
4.2.3.27 The switch must turn on flashing lights, servomotor, piezoelectric & optical circuits
4.2.3.28 The switch must turn off flashing lights, servomotor, piezoelectric & optical circuits
4.2.3.29 The switch must reset scoreboard to 0 when turned off

Flashing LEDs for Entertainment
4.2.3.30 The LEDs should blink moderately fast (high tempo for an energetic effect)
4.2.3.31 The LEDs stay turned on throughout the game play if the switch is on
4.2.3.32 The LEDs stay turned off if the switch is off

Special Requirements
4.2.3.33 Paddle(s) are activated electronically (i.e., cannot be a manual mechanism)
4.2.3.34 Auditory feedback for score.
4.2.3.35 Actuator that fires / moves when it detects a ball.
4.2.3.36 Uses optical sensors for at least two applications.
4.2.3.37 Uses at least one of each: electric motors, solenoids, RC servos
4.2.3.38 Automated gating that introduces ball into play, or stops ball once all rounds are over
4.2.3.39 Visual Appeal

Spec #	Spec description	Test to perform	Relevant req	Spec [units]	Measured value [units]
Plunger Testbed					
1	Availability of materials	Verify if all the materials for the testbed are available	4.2.3.1	Yes/No	Yes
2	Ball is launched	Check if ball launched ≥ 1.5m	4.2.3.2	meters	
3	Usability	Plunger is easy to operate?	4.2.3.3	Yes/No	Yes
4	Comfortability of the plunger	Plunger can be held retracted for a long time comfortably?	4.2.3.4	Yes/No	Yes
5	Launch strength for the ball using test bed	The ball travels far if pulled with a lot of strength	4.2.3.5	Yes/No	Yes

6	Compatibility	Plunger and test bed fit nice together	4.2.3.6	Yes/No	Yes
Servomotor Application					
7	Spin	Observe	4.2.3.7	Yes/No	Yes
8	Voltage	Measure (o-scope)	4.2.3.8	≤ 5V	4.98V
9	Temperature	Observe smoke	4.2.3.9	Yes/No	No
10	Current	Measure (o-scope)	4.2.3.10	≤ 250mA	1.6mA
11	Control	Attempt	4.2.3.11	Yes/No	Yes
12	Functional	Observe	4.2.3.12	Yes/No	Yes
Flipper Testbed					
13	Voltage	Measure (o-scope)	4.2.3.13	≤ 12V	7.136V
14	Launches ball	Test: attempt launch	4.2.3.14	≥ 1.5m	1.524m
15	Returns to position	Test: actuate several times	4.2.3.15	Yes/No	Yes
16	Circuit	Flipper work with switch on/off	4.2.3.16	Yes/No	Yes
17	Reliability	Observe: breaks after use?	4.2.3.17	Yes/No	No
18	Assembly	Observe: components fit well?	4.2.3.18	Yes/No	Yes
Optical Sensor for Scoring					
19	Sensing	Check arduino logic (serial out)	4.2.3.19	Yes/No	Yes
20	Detection	Check arduino logic (serial out)	4.2.3.20	Yes/No	Yes
21	Increment	Check arduino logic (serial out)	4.2.3.21	Yes/No	Yes
22	Display	Look at display (visual check)	4.2.3.22	Yes/No	Yes
Piezoelectric Sensor for Scoring					
23	Sensing	Check arduino logic (serial out)	4.2.3.23	Yes/No	Yes
24	Detection	Check arduino logic (serial out)	4.2.3.24	Yes/No	Yes
25	Increment	Check arduino logic (serial out)	4.2.3.25	Yes/No	Yes
26	Display	Look at display (visual check)	4.2.3.26	Yes/No	Yes

Switch to Power Pinball Machine					
27	On state	Output & motion sensors are on?	4.2.3.27	Yes/No	Yes
28	Off state	Output & motion sensors are off?	4.2.3.28	Yes/No	Yes
29	Resetting	Check scoreboard to see if it is off	4.2.3.29	Yes/No	Yes
Flashing LEDs for Entertainment					
30	Visuals	Rate LED light speed on scale of 0 (slowest) -10 (fastest)	4.2.3.30	Integer	8
31	On state	LEDs are on if the switch is on?	4.2.3.31	Yes/No	Yes
32	Off state	LEDs are off if the switch is off?	4.2.3.32	Yes/No	Yes
Special Requirements					
33	Paddles	Are paddles activated electronically?	4.2.3.33	Yes/No	Yes
34	Auditory	Buzzer for score is present and plays when triggered	4.2.3.34	Yes/No	Yes
35	Actuator in motion	Actuator (servomotor) moves when it detects ball	4.2.3.35	Yes/No	Yes
36	Optical sensors	How many times are optical sensors used?	4.2.3.36	Integer	2
37	Motors and solenoids	There is at least one of electric motors, solenoids, servomotors	4.2.3.37	Yes/No	Yes
38	Automated gating mechanism	Mechanism introduces ball or stops it	4.2.3.38	Yes/No	Yes
39	Visual appeal	The board must be visually appealing	4.2.3.39	Yes/No	Yes1

Safety, Ethics & Diversity Considerations

The Professor, TA and the ECE Makerspace lab personnel all went out of their ways to ensure the safety of all members of our project and other projects. Mistakes were made, but we learned from them :) Below is an image of an LED that exploded. It was not working, so we incorrectly removed the resistance and this happened …

Nevertheless, safety goggles were provided and students were supervised to make sure no one forgot to wear them. The TA, professor and lab personnel were also keen to help students with any questions they might have. There was never a time we felt unsafe in the lab and never a time we felt that help was unavailable to us. To ensure our own safety, we followed lab protocol, wore PPE and worked with a partner. When tools like drills or dremels were used our partner was at standby to help.

We believed that this course fostered diversity. Our team consisted of multicultural, multiracial members from different countries across the globe. We worked together without disagreement. The professor and TA were very inclusive and supportive of us and all of the other groups.