ECE 372A Final Project - Theremin

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Team Members and Roles

- AJ Sterner - Main/PWM code, debugging, packaging
- Vanessa Jaime - Main code, debugging
- Zhehao Zhang - Switch code, debugging
- Nick Hinrichs - ADC/PWM code, debugging

Statement of Problem

The problem to solve is obtain some instrument that works based on distance. It could be a source of creativity for children or those who might not have the physical ability to play any other instrument.

The overall goal of the project is to create a working theremin. The theremin will use a buzzer as an output and two infrared sensors as inputs.

Sub-Goals:

- The two sensors' analog data should be read and converted to a digital value
- The data should be scaled such that the highest and lowest frequencies that the theremin produces are audible to the ear
- The output pitch should be shown through some means to the user
- The theremin design should be compact and well-organized

Proposed Prototype Solution

- Our theremin will be created using 2 infrared sensors to measure the distance of the user’s hands from each sensor. The output voltage of the sensors will be used to determine the volume and frequency emitted by the theremin
- The audio output device will be an active buzzer
- An LED matrix panel will be used to display the current note

Requirements

▪Requirement 1:

○ The entire range of the theremin’s output should be audible to the ear. This can easily be measured by the frequency of the output pitch, as the range of human hearing is known and can be referenced.

▪Requirement 2:

○The volume and pitch of the buzzer should be able to be controlled separately. This can be done by changing the frequency and duty cycle of the buzzer. The frequency changes the pitch, while the PWM duty cycle changes the volume. This can be tested through independently manipulating each sensor and checking the input values.

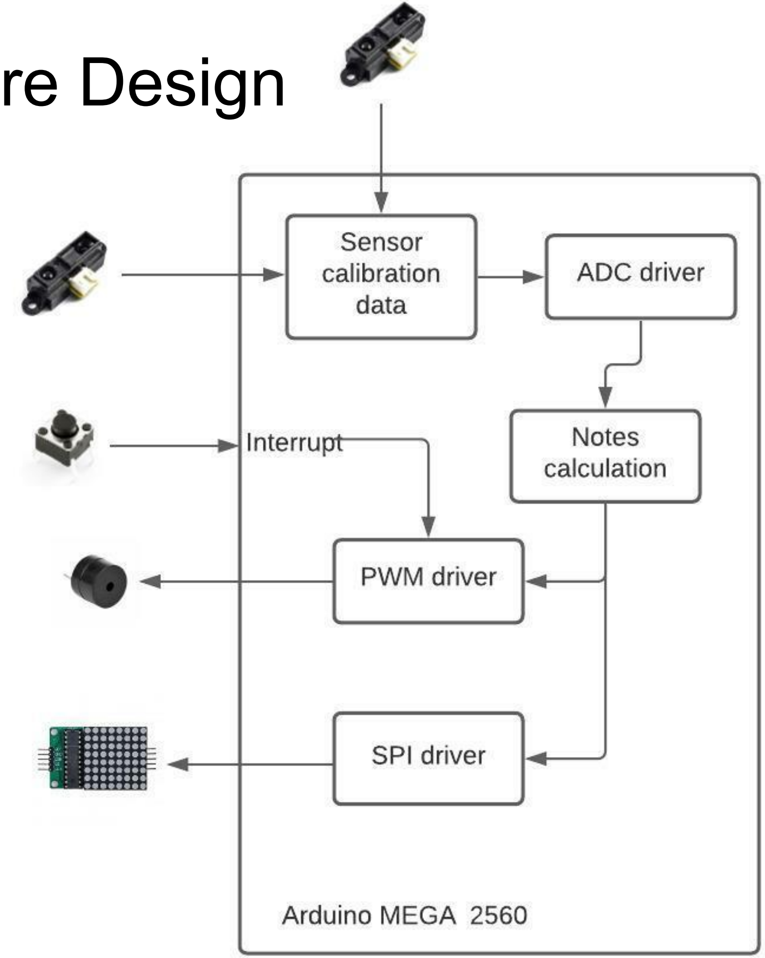
▪Requirement 3:

○The pitch is correctly displayed on the LED matrix panel. This is checked by manually checking the frequency against known values and seeing if the LED matrix panel displays the correct information

▪Requirement 4:

○Cleanliness and compactness of the design. Essentially, the wires must be organized and the theremin must be small enough to be easily transported and used.

System Architecture Design

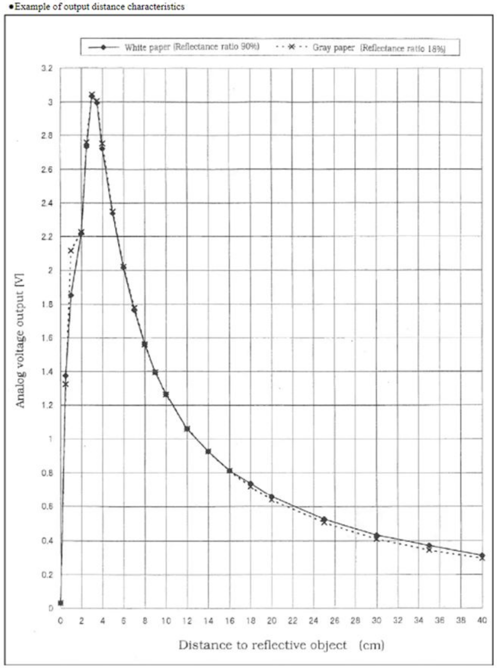


Input Sensors

2x IR Sensors GP2Y0A41SK0F Distance Measuring Sensor Unit

https://www.digikey.com/htmldatasheets/production/3133403/0/0/1/gp2y0a41sk0f.html

This graph shows the output voltage when an object is a certain distance from the sensor



Output Devices

- 1 Piezo Buzzer
- 1 LED Matrix Panel

How input sensors will be used by the output devices

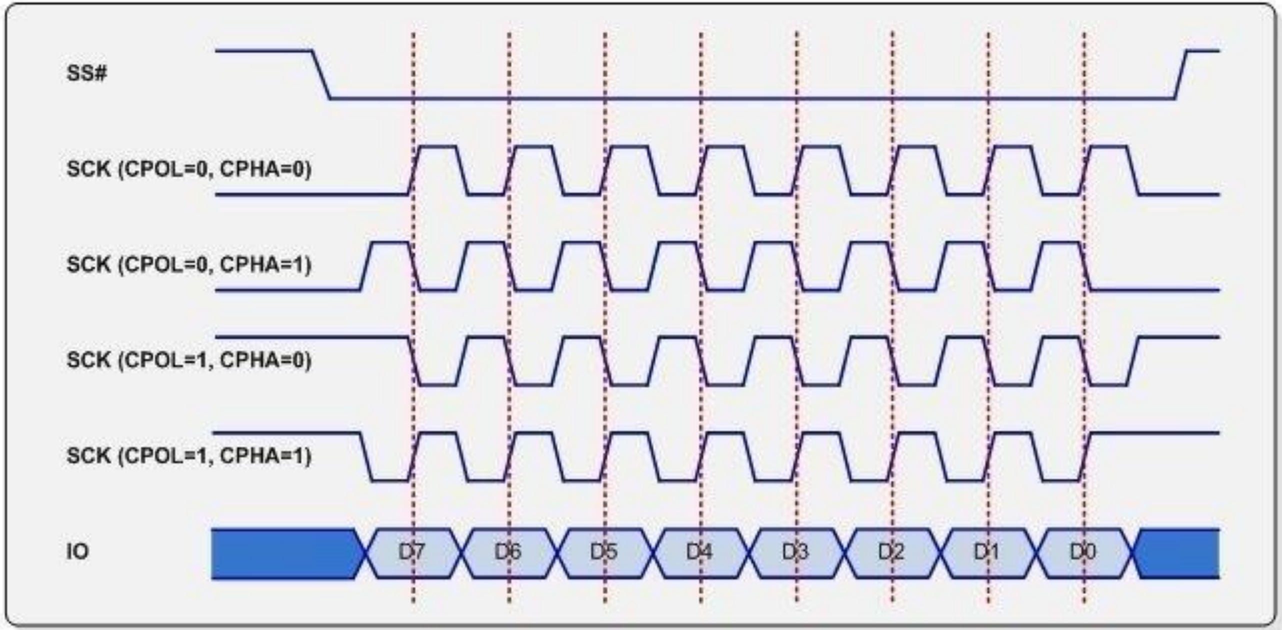
- One IR sensor will control the volume of the buzzer
- The other IR sensor will control the pitch of the output
- The input from the pitch sensor will be sent to the LED matrix and be displayed as a note (A, B, C, …)

Software Functions

- ADC
  - The ADC reads the analog output of the two IR sensors and converts it to a digital signal
  - Since there is only one ADC output register, we have to swap which sensor is being read
- PWM
  - Used for the buzzer
  - Takes input from ADC and changes frequency and duty cycle accordingly
- SPI
  - Used by the LED matrix panel
  - Data is the frequency displayed as a note value
- Timer
  - Timer is used for creating delays for the ADC conversion
- Switch
  - The switch uses interrupts to cause the LED matrix and buzzer on and off by changing the state of the matrix and the output pin of the buzzer

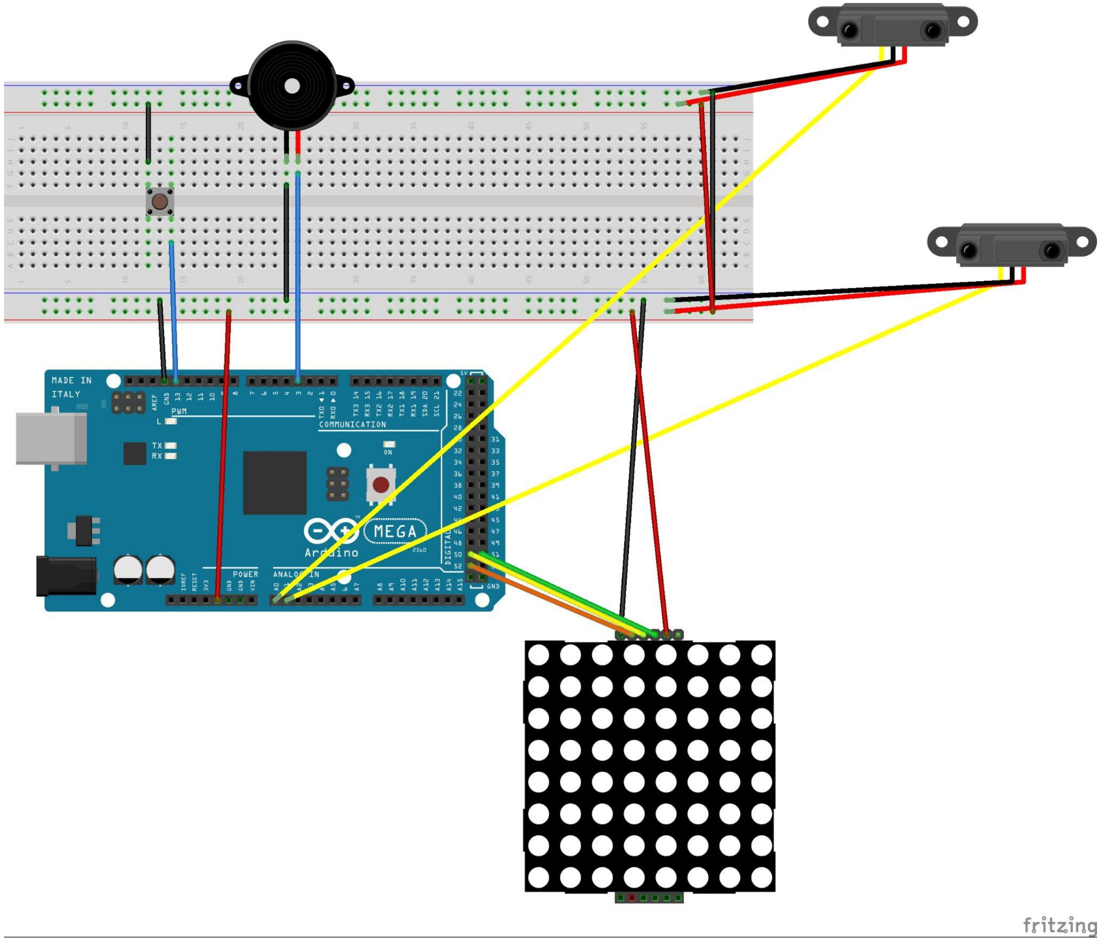
Communication Protocol

SPI was used to interface with the LED matrix panel



CPOL = 1, CPHA = 1

Circuit Diagram



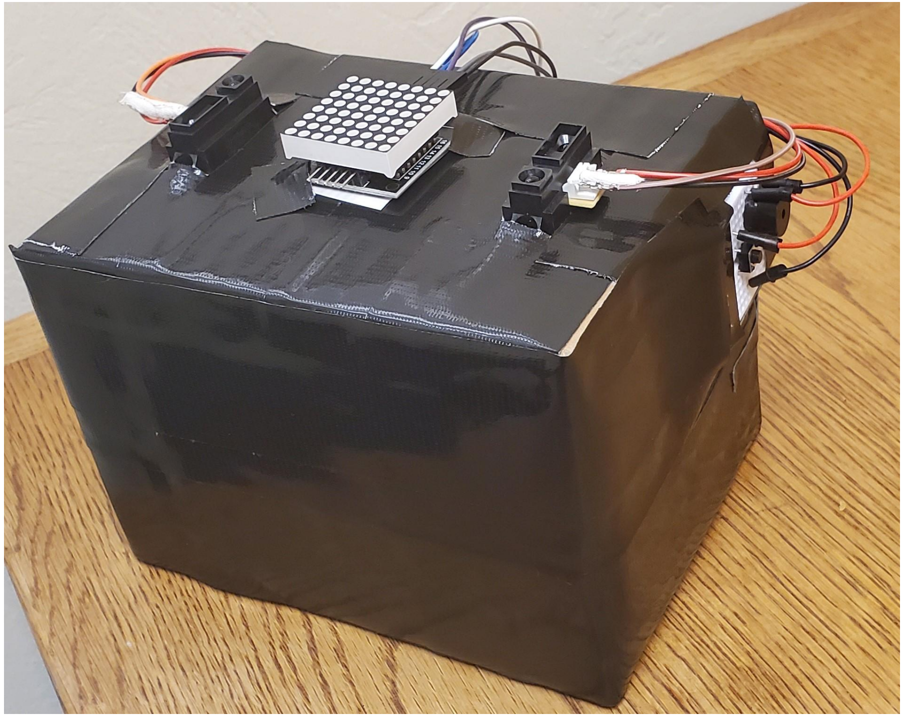
Mechanical Diagram

We decided to mount our sensors on the outside of the package, since placing a 30cm “outer bound” for the sensor was cumbersome

A small box contains the breadboard and microcontroller, with the buzzer, button, sensors, and matrix mounted on top for easy visibility and audibility.

In a real prototype the sensors and output devices would be protected from user error

Our box was 6x6x8 inches, but much of the space is taken up by the breadboard, so the final product could be conceivably smaller



Power Requirements

The microcontroller supplies all power for the system, so the product will be functional as long as the power requirements for the microcontroller are satisfied.

Microcontroller Power Requirements from datasheet:

7-12 V from external source

~70mA

= 0.63W

A typical 9V battery has 450mAH, meaning it can supply about 450mA for 1 hour. Thus, a 9V battery would be able to power our theremin for a little less than 6.5 hours.

Bill of Materials

Item	Price
2x GP2Y0A41SK0F IR Sensors	$30.82
ATMEGA2560 Kit	$53.00
Total	$83.82

Results

- The frequencies were able to be changed easily to correspond to the distance read in from the sensor
    - The noise from the sensor coupled with the fact that the input voltage scales inversely with distance means that the further distances are slightly less stable in terms of note
- The changes to the duty cycle change the timbre of the pitch more than the volume, which is a limitation of the buzzer used.
- The LED matrix is responsive to any change in the buzzer output, and can be turned on and off easily along with the buzzer

Rubric

Criteria	Level 4	Level 3	Level 2	Level 1	Outcome
Output of Theremin	Pitch is clearly defined and audible, volume is clearly defined and audible	Either pitch or volume is not clearly defined and audible	Both pitch and volume are unclear or undefined	Output does not exist	Level 3
Sensors	Sensors operate independently, stable output	Sensors operate independently, unstable output	Sensors do not operate independently	Sensors do not work at all	Level 3
LED Matrix Panel	LED Matrix displays the correct note	LED Matrix rarely shows incorrect note	LED Matrix frequently displays incorrect note	LED Matrix does not work	Level 4
Design	Compact, minimal wires visible	Compact, most wires visible	Not Compact	Not packaged	Level 3

Summary

We designed this product as a source of creativity for children and those who might not have the physical ability to play a more complex instrument. For example, certain disabilities impair fine motor skills.

This project is controlled by two IR sensors, which convert a distance reading into an output voltage. Those output voltages are then converted into values that are sent to the PWM for a buzzer, which changes its output. An LED matrix outputs the specific note played.

For the next steps, we will improve the housing for the theremin and further stabilize the readings to produce a more consistent sound. A more fitting speaker would also improve the volume control from the limited range of the buzzer.