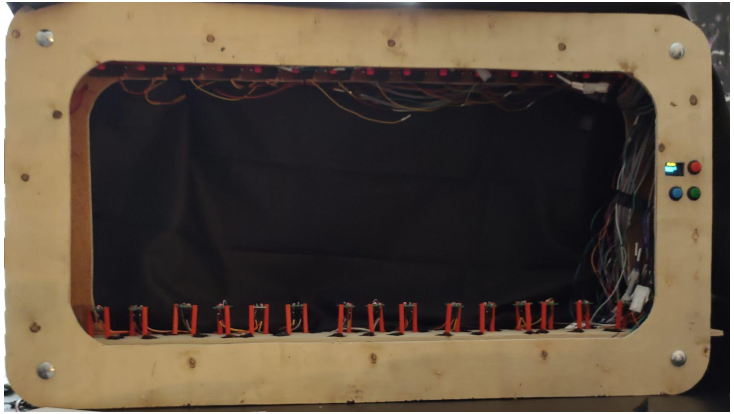
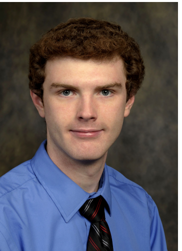
Expressive Laser Harp



Group 10
Christian Chang - Computer Engineering
Mohamed Jabbar - Photonic Science and Engineering
Matthew Kalinowski - Photonic Science and Engineering
Kyle Kaple - Electrical Engineering

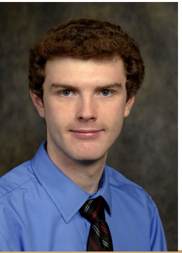


Motivation

- Our intentions are to create an instrument that could use lasers as a string to be plucked to make sound

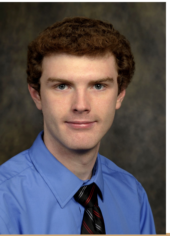
- Plenty of other instruments use electronics to create sound

- MIDI is a useful interface to pair with this instrument for electronic keying



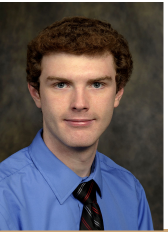
Goals and Objectives

- Design and construct a laser harp with built-in expression for performance
- Interface with external gear via Musical Instrument Digital Interface (MIDI)
- Utilize multiple types of sensors for note detection and distance sensing
- Implement a scale mode and transpose functions to maximize flexibility and ease-of-use

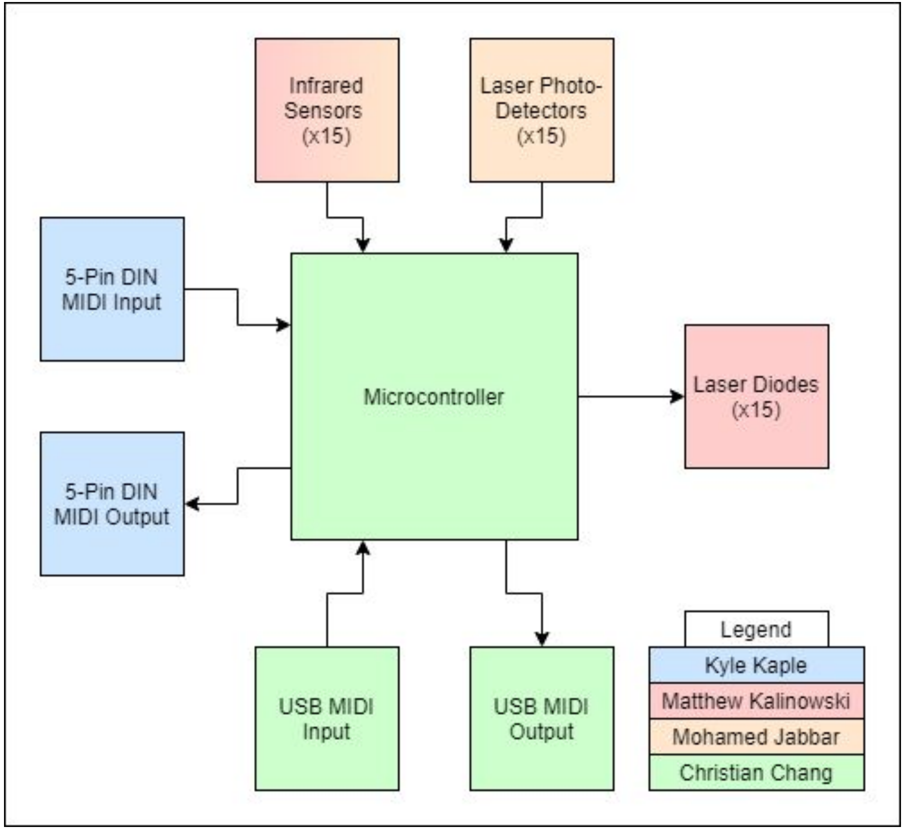


Specifications & Requirements

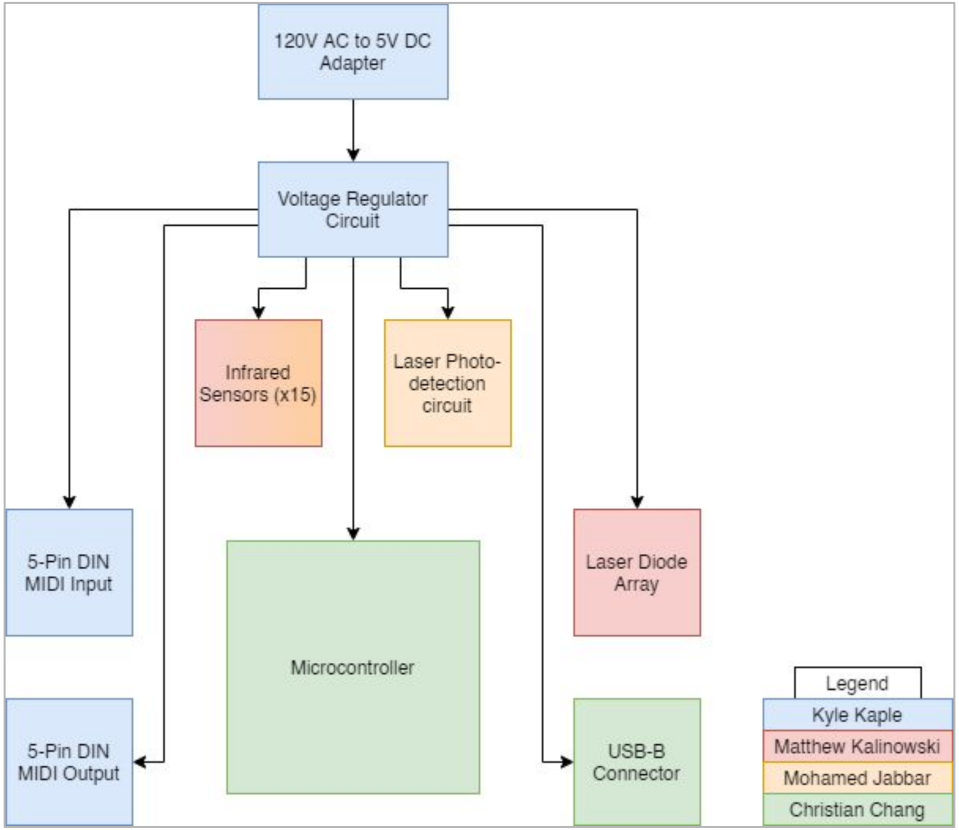
- The harp has 15 independent laser "strings" with full polyphony
- The distance sensors will detect a range of 1-11 inches
- The harp will transmit MIDI data via UART at a rate of 31.250 kbps
  - 5-pin DIN and USB
- By MIDI, the harp will transmit both note on/off messages and Continuous Control (CC) messages for distance detection.
- The microcontroller has at least 15 analog inputs for the analog distance sensor inputs and at least 15 GPIO pins for the note on/note off detection



Electronics/Data Transfer Block Diagram



Power Block Diagram

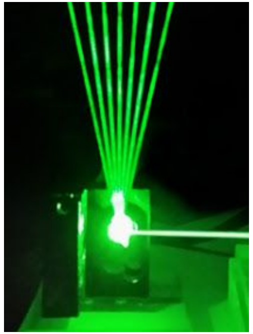


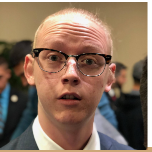
Design Constraints

- Size
  - Should be small enough to be considered portable.
  - Will need to big large enough to hold an entire scale without being too heavy from materials.
- Safety
  - There are laser diodes on this project and it is important to take precautions when designing the frame so that the user and any person nearby does not receive a beam to their eyes.
  - The beams will need to point downward and be covered by building materials to avoid unwanted eye contact.
- Economic
  - No sponsors so we are trying to make this a budget friendly project.

Framed vs Frameless

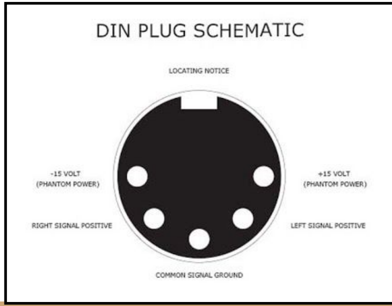
- Framed laser harps mount the lasers to a frame, and detect the beam from the opposite side
- Framed laser harps are safer
  - Less chance of accidental exposure to laser beams
- Framed laser harps are more sensible for home use
  - No infinite lasers pointing into the sky
- Frameless laser harps use a mirror attached to a stepping motor
  - Motion is imperceptible to human eye
- Frameless laser harps have limited number of strings
- Framed laser harp is the best option for our case





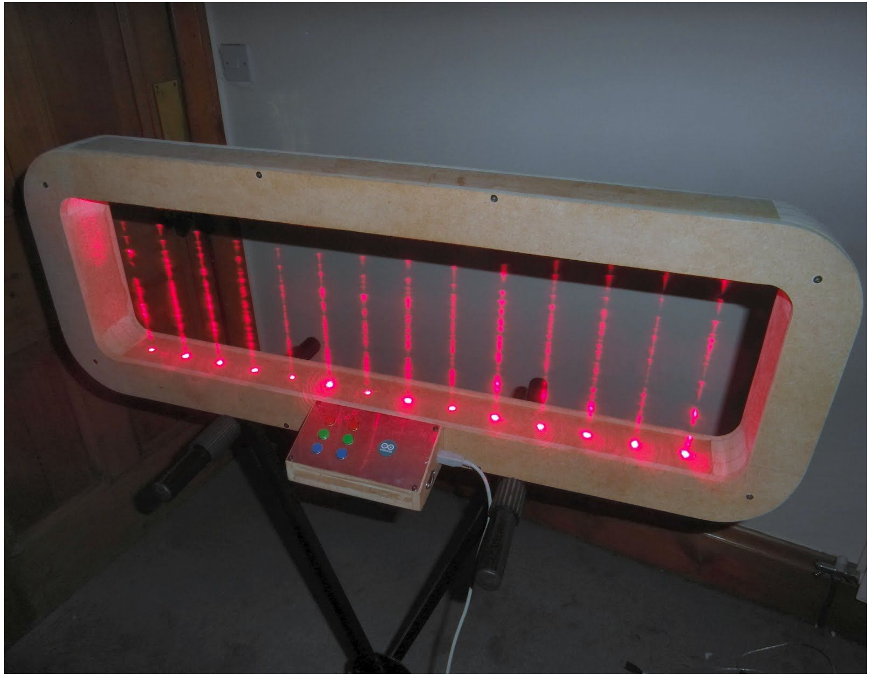
Musical Instrument Digital Interface (MIDI)

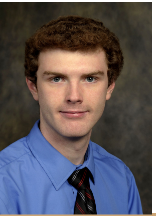
- Serial communication protocol standard in almost all synthesizers and samplers released since the 1980's
- Utilizes UART with a baud rate of 31.25 kbps
- Transfers messages for note on/note off and continuous control (CC) for parameter modulation
    - When laser is blocked, send corresponding "note on"
    - When laser is released, send corresponding "note off"
    - While laser is being blocked, send continuous "pressure" modulation via MIDI CC to modulate any modulatable parameter
- Will send and receive by both 5-pin DIN and USB



Light Source

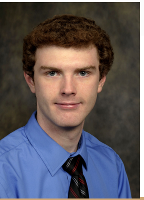
- Laser diodes used to create strings for the harp
- Using low powered and low cost diodes to keep the budget down
- Having small diodes allows easy mounting
- Can be ran in parallel sharing a single power supply and ground node





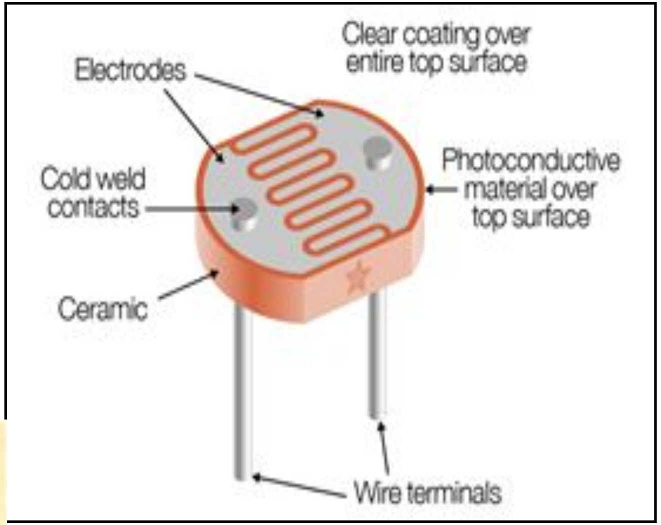
Light Source

Dimension	6.5 x 18mm
Cost	$5.99 10 pack
Wavelength	650nm
Voltage	5VDC
Operating current	>20mA
Manufacturer	HiLetgo



Light Detection

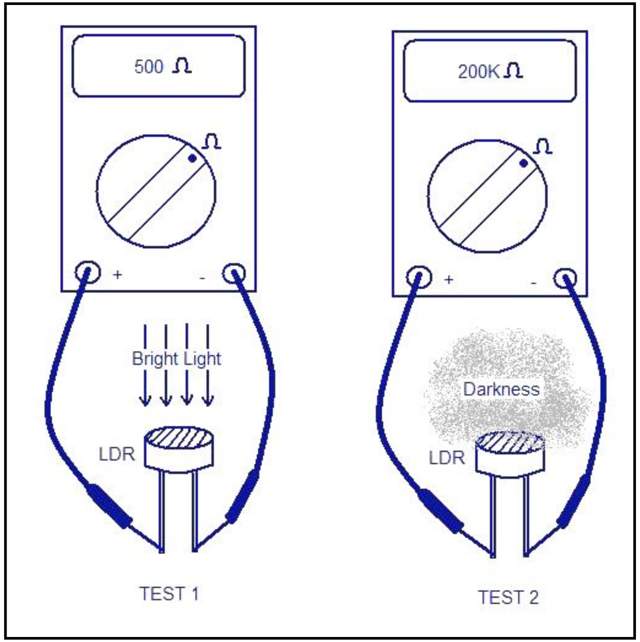
- Light-Dependent Resistor
  - Easy to install
  - Budget friendly
  - Simple integration into system



Dimension	Round 5mm
Cost	<$1.00
Resistance Range	200kΩ- 10kΩ
Sensitivity Range	400nm-600nm
Manufacturer	EBOOT

Light detection

- Is used to detect when the light is blocked
- The lasers will provide a low resistance
- The blocking will cause a high resistance
- Using this we can determine when and which laser diode is blocked allowing notes to be played

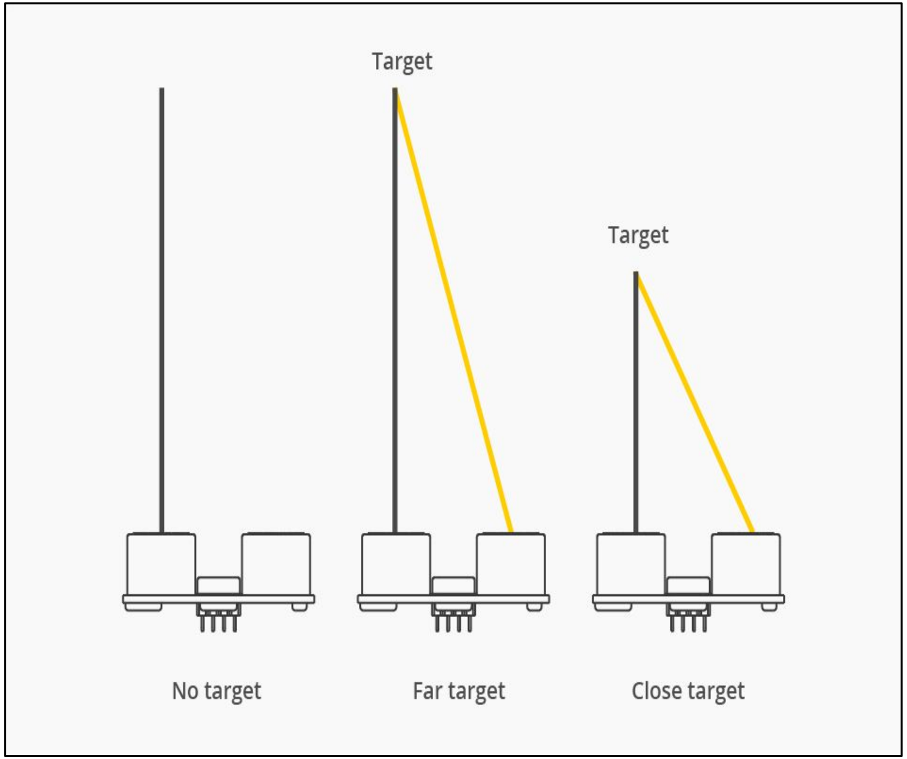


Distance Detection

Dimension	0.25 x 0.25 x 0.23 inches
Cost	$10.99 each
voltage	3.3-5VDC
Detection distance	2-30cm
Manufacturer	sharp-AIMELIAE

Distance Detection

- Uses triangulation to determine distance
- Can be used in light or dark settings
- Other alternative such as ultrasonic have low resolution and refresh rates or is too costly to use for this budget



OLED Display

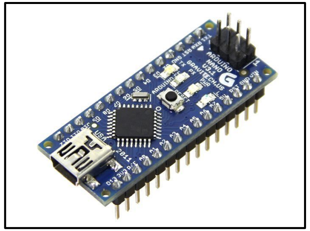
- Need a way to communicate with the harp to change scales
- Better viewing angles and contrast compared to LCD
- Uses the same voltage as the equipment 3.3-5VDC
- Design is important and and LCD looks old school
- Using Frieda OLED at 0.96 inch

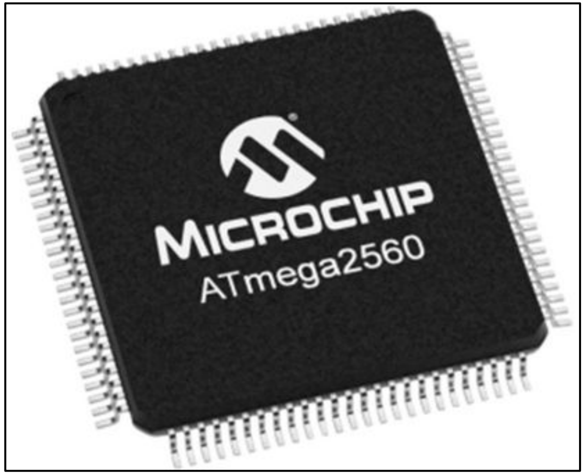
User Interface

- In order to allow easy control of the various scale and transposition functions, we included three buttons that are used to interface with the OLED display on the laser harp
- There are three parameters that we want users to be able to control
    - Scale selection
        - Changes the order of notes on the laser harp to control the scale the laser harp is locked into, such as major, minor, chromatic, etc.
    - Semitone transpose
        - Shifts all the notes on the laser harp up or down by number of semitones (or a half-note) selected by the user
    - Octave transpose
        - Shifts all of the notes on the laser harp up or down by a number of octaves (equivalent of 12 semitones) selected by the user
- One button cycles through the three main parameters with each press, and the two buttons on the bottom increase and decrease the value selected (left = decrease ; right = increase)

Microcontroller Selection

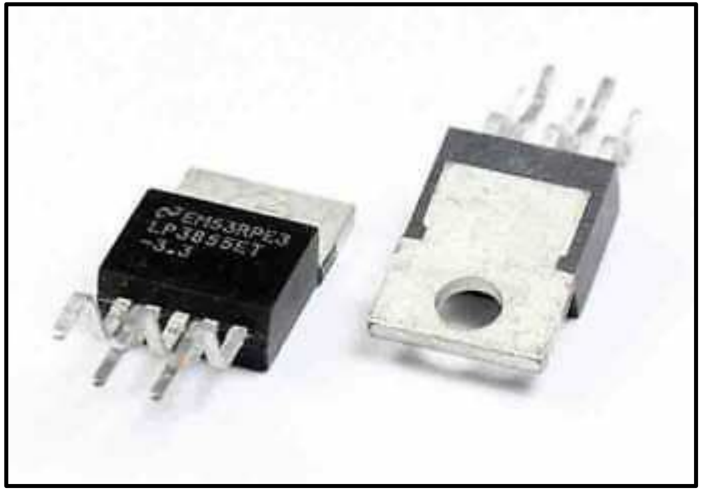
- Arduino Nano (based around Atmel ATmega328)
  - 14 GPIO pins
  - 6 analog input pins
  - Prototyping and small-scale testing only
- Atmel ATmega2560
  - 86 GPIO pins
  - 16-channel 10-bit A/D converter
  - 1.8V - 5.5V operating voltage
  - 4 UART channels





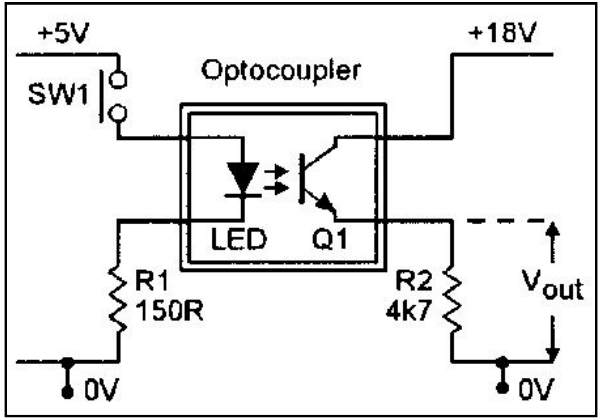
Voltage Regulator

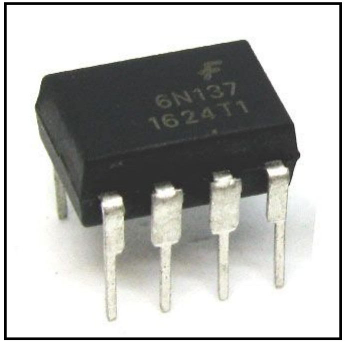
- To ensure consistent voltage input supply to the microcontroller, we need to add a simple voltage regulator circuit at the power supply input of the MCU
- Texas Instruments LP3855 linear voltage regulator
    - Low noise (improve infrared sensor accuracy)
    - TO-220 format with standard heatsink



Optocoupler

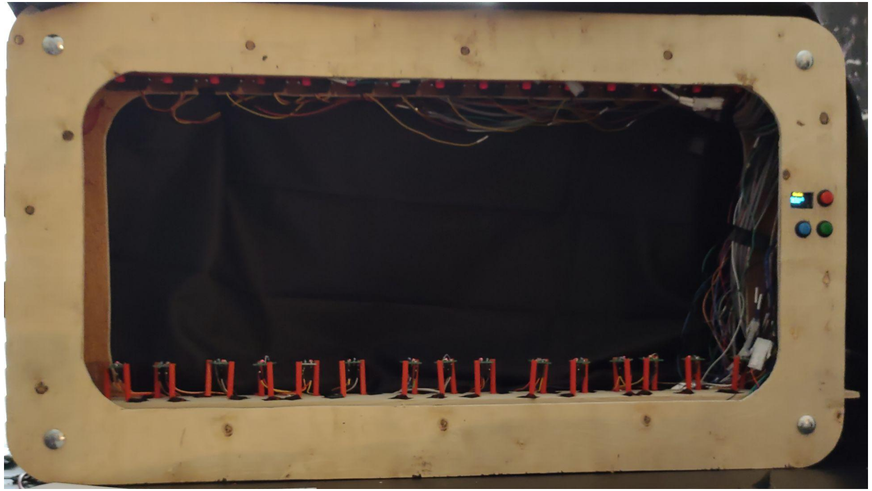
- Optical device that transfers electrical current between wires without direct connection
  - Similar to a transformer
- Included to isolate MIDI connection between external devices to remove any ground loop feedback hum
- Inexpensive and small
- 6N137 selected due to high switching speed

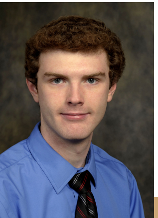




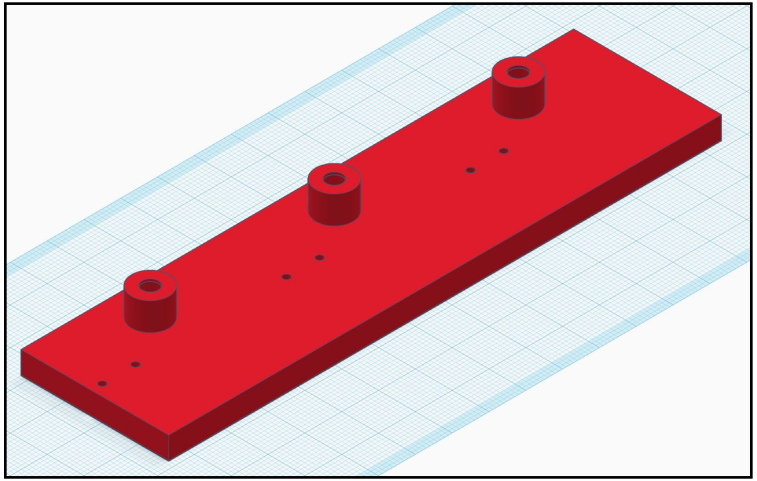
Frame Design

- We chose to make a framed laser harp for both safety purposes and to allow for a small device with equal “string” spacing
- Approximate dimensions of 27”x16.5”x7.5”
- It is constructed with wood and aluminum rod
  - Cost-Effective
  - Can be built without metal machining tools or plastic molds





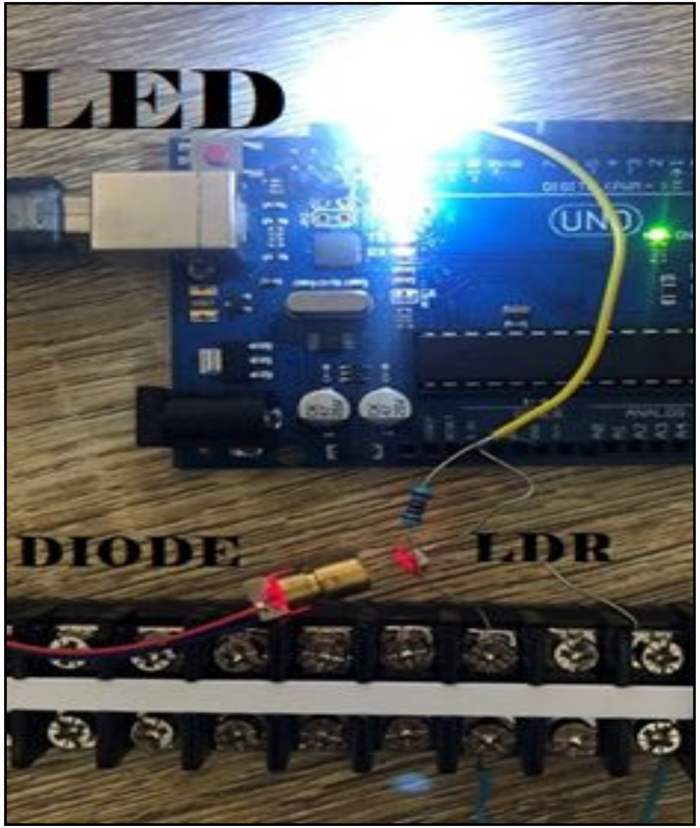
Laser Diode Mount



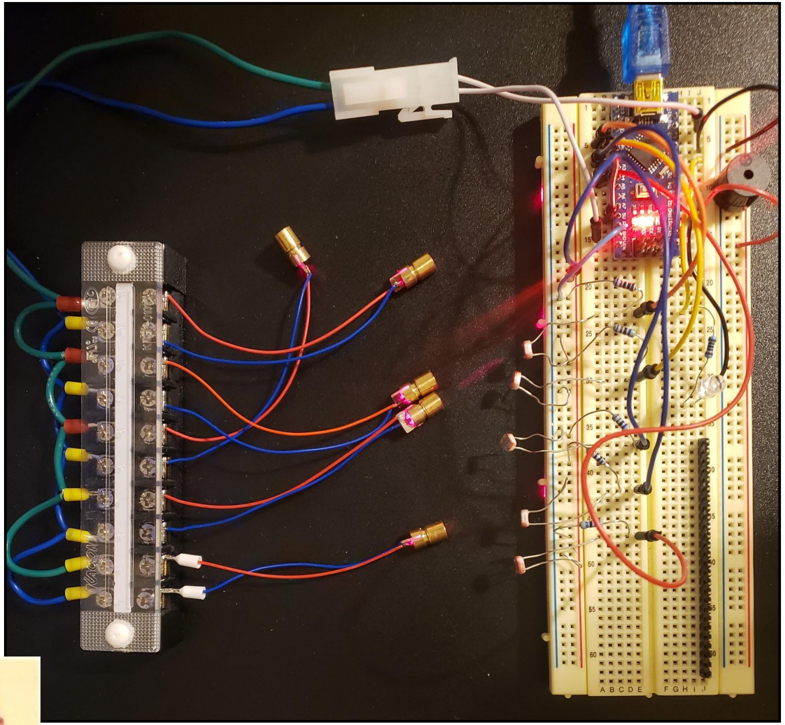
- Used a 3D printer to create the mounts
- The diodes will be fixed in pairs of three and will be attached to one another for easy maintenance
- We used a wooden square dowel to fix the 3D printed mounts to the frame

Prototyping- Single string

- Using a single laser diode and a single LDR hooked up to a microcontroller and breadboard for initial testing
- The goal was to ensure that a musical note could be played by interfering the path of the beam
- Arduino has a way to define musical notes based on code



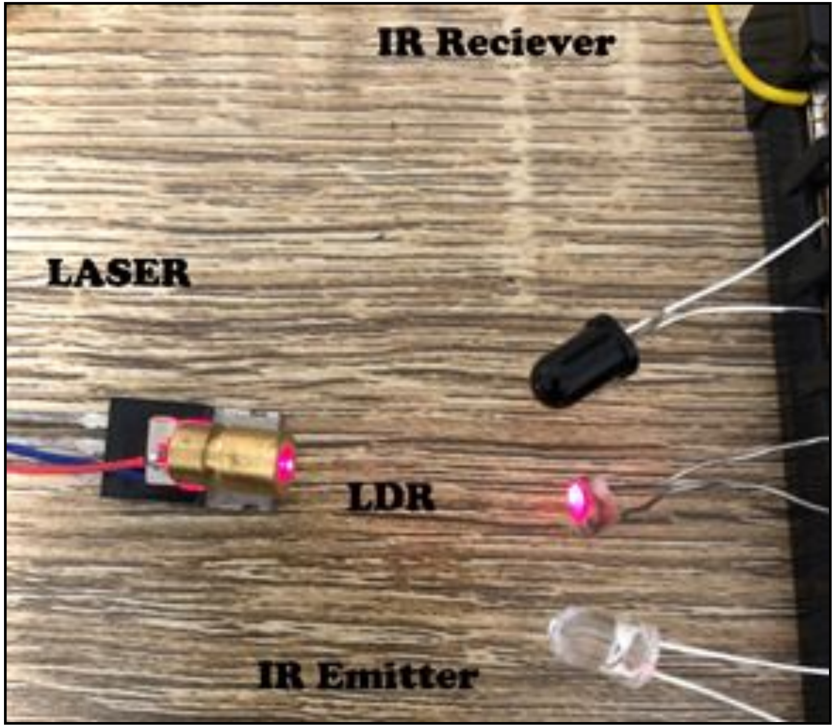
Prototyping multi string



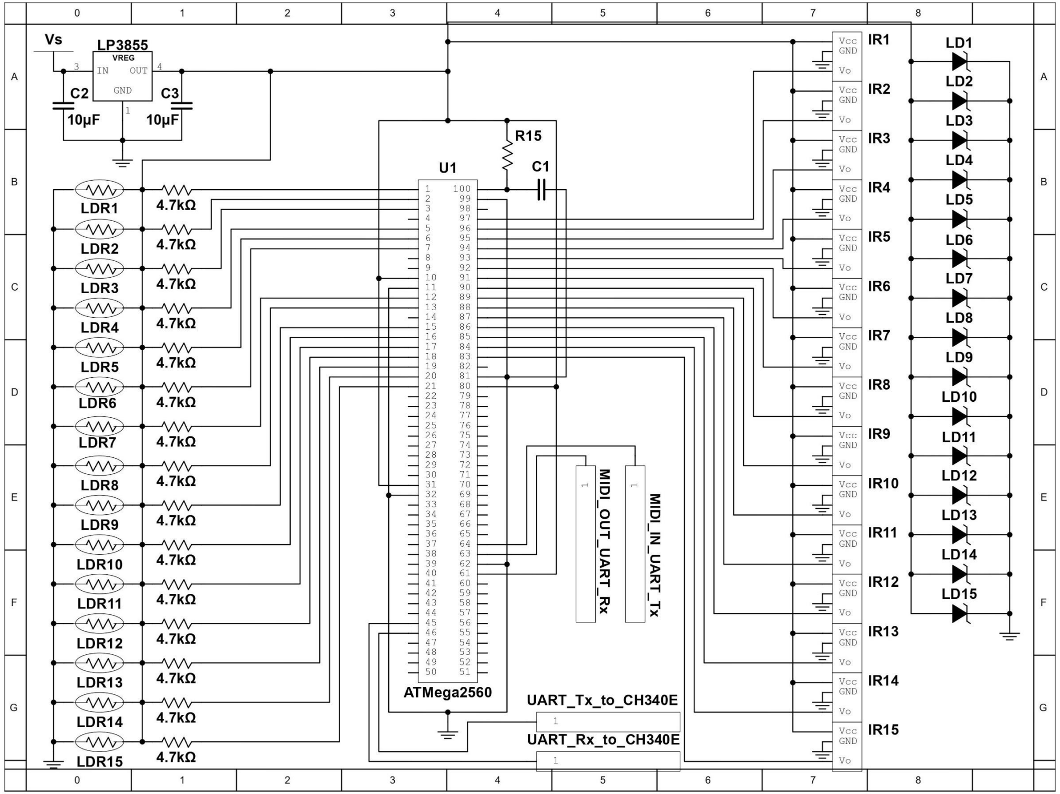
- Adding additional laser diodes and LDRs to the breadboard maxing pin outputs
- The test was to determine the amount of reasonable spacing for the system as a whole
- With twelve diodes we will need to create a rather long harp frame to account for the addition of distance detectors

Prototyping IR integration

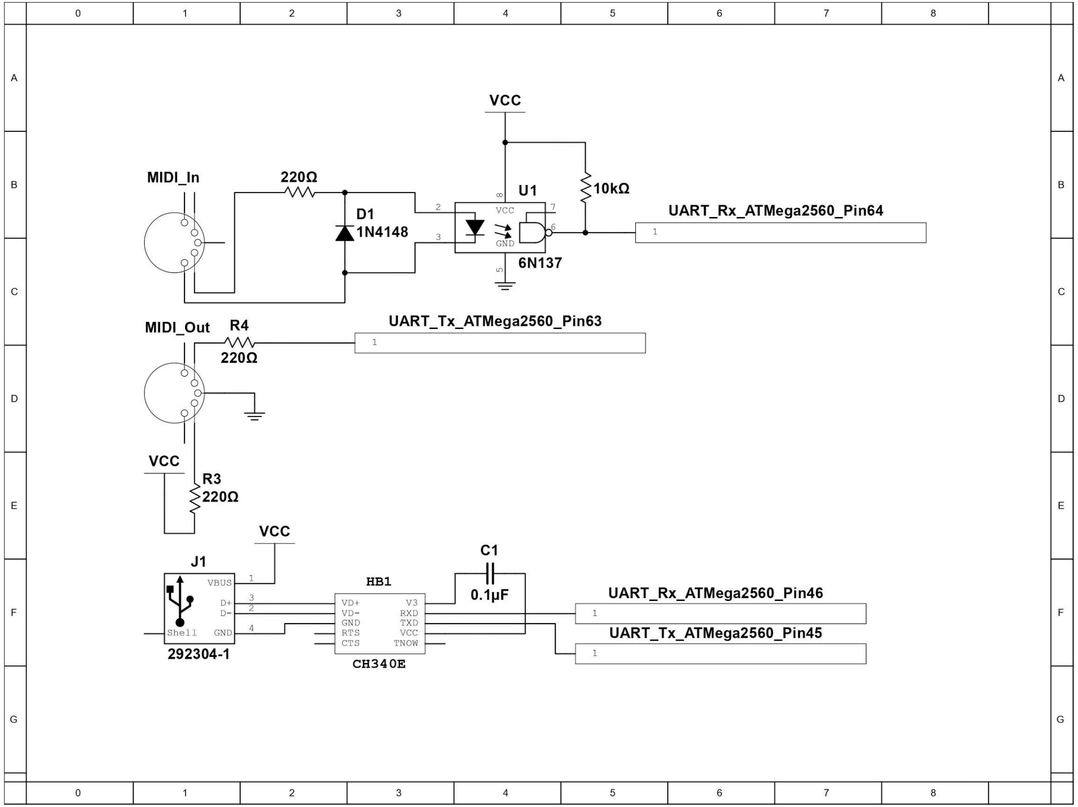
- Using basic IR LED and receiver to test distance integration
- Will be using a premade configuration rather than individual components from Sharp
- Uses triangulation to calculate the distance of the interfering object



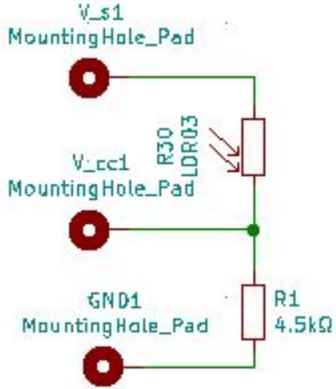
Microcontroller and Sensing Subsystem Schematic

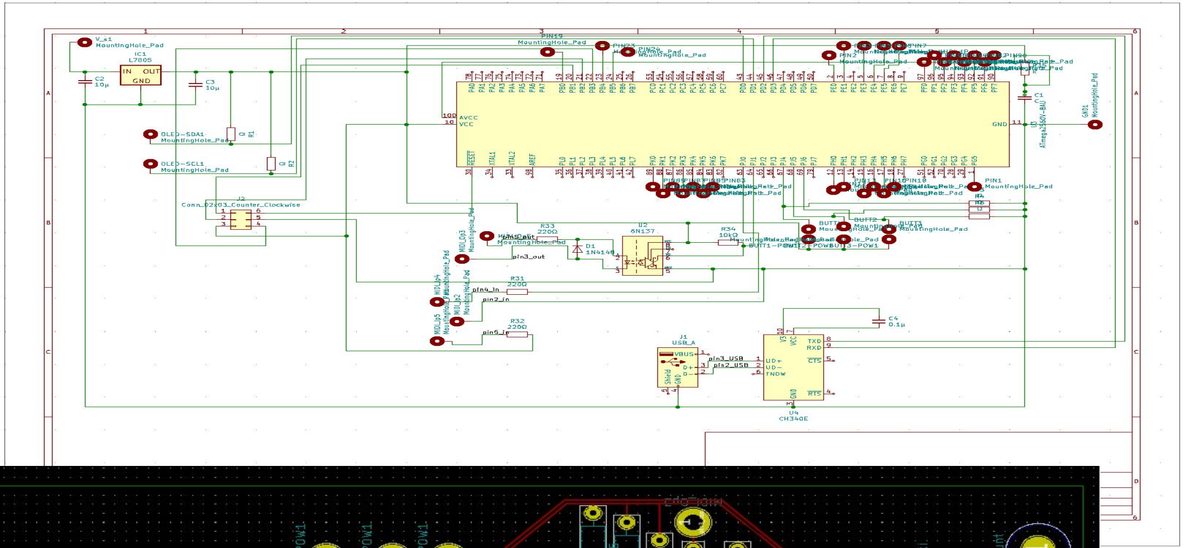


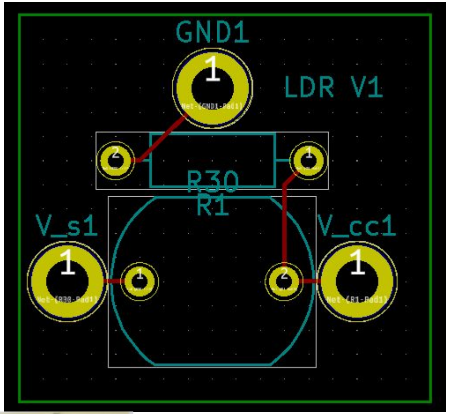
MIDI and USB Connector Schematic

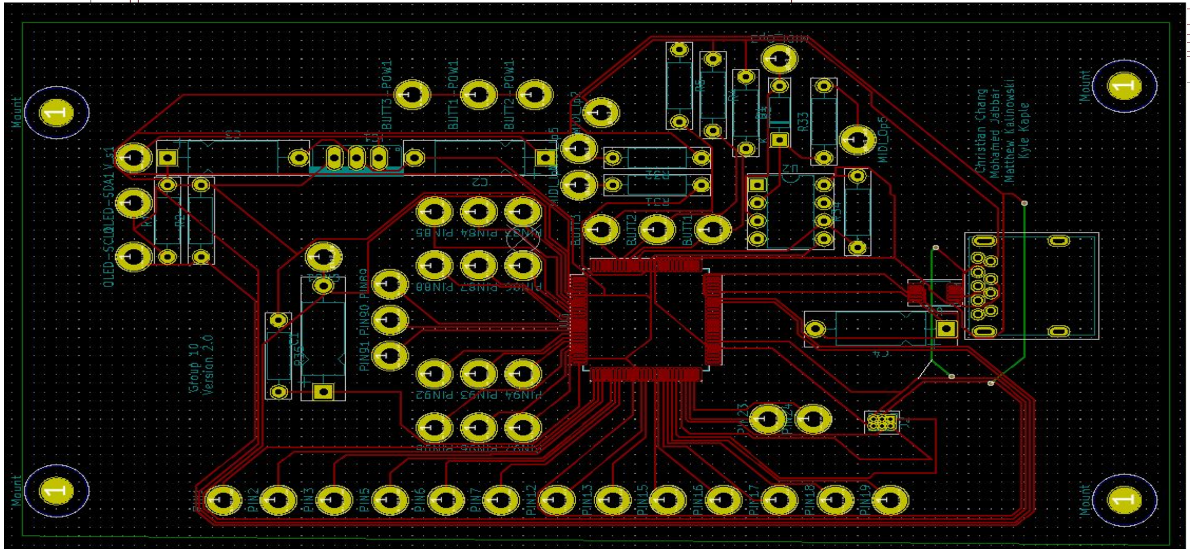


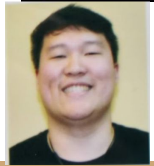
PCB


V_s1
MountingHole_Pad
R30
LDR03
V_cc1
MountingHole_Pad
GND1
MountingHole_Pad
R1
4.5kΩ


L7805
6N137
1N4148
USB_A
CH340E
Conn_02x03_Counter_Clockwise


GND1
LDR V1
R30
R1
V_s1
V_cc1

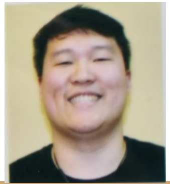

Christian Chang
Mohamed Jabbar
Matthew Kalinowski
Kyle Kaple
Group 10
Version 2.0



Software Design - Key Functions

- We used the Arduino IDE as our development environment, primarily for the ease of use with the development board we used during our initial tests
  - Primary language: C++

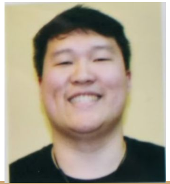
- Key Arduino functions
  - void setup{}: Use it to initialize variables, pin modes, start using libraries, etc. which can execute the initial conditions of the code once
  - void loop{}: runs after void setup, runs an infinite loop with the main code within it
  - digitalRead(): reads whether the voltage at a GPIO input pin is high or low
  - analogRead(): reads the value of the analog infrared sensors, which is then passed to an integer
  - map(): re-maps a number to another range of values
    - Used primarily to map the 10-bit analog sensor value to 7-bits for MIDI compatibility
  - constrain(): limits a number within a certain range
    - Used to adjust for any values that might be outside the 0-127 range we need for MIDI



Software Design - Libraries

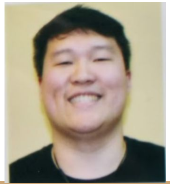
- In order to simplify our programming load, we utilized a few public Arduino libraries
  - MIDI
    - Contains simplified functions to setup UART connection and send/receive MIDI data
  - ArducamSSD1306
    - Contains functions that convert character strings into pixel maps to display on the OLED display

- Key Library Functions
  - MIDI.sendNoteOn() - Sends MIDI Note-On with parameters for note value, velocity, and channel
  - MIDI.sendNoteOff() - Sends MIDI Note-Off with parameters for note value, velocity, and channel
  - MIDI.sendAfterTouch() - Sends MIDI AfterTouch with parameters for MIDI CC value and channel
  - display.setCursor() - Sets where any subsequent print commands will start on the OLED
  - display.clearDisplay() - Clears the OLED display
  - display.print() - converts strings of characters to pixel maps and writes them to the OLED buffer
  - display.display() - prints whatever is in the OLED buffer to the display



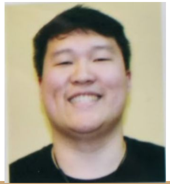
Software Design - External Connections

- Pins
  - 18 digital input pins
    - 15 light-dependent resistors
    - 3 buttons
  - 15 analog input pins
    - 15 analog infrared sensors
- Communication Lines
  - All are set to 32.5 kbps to match the MIDI standard
  - 2 UART channels
    - TX0/RX0: MIDI receive/transmit
    - TX1/RX1: USB MIDI receive/transmit
  - 1 SPI channel
    - SCL/SDA: OLED display output



Lithium-Ion Battery

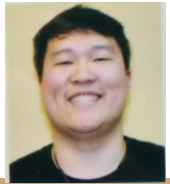
- Has the best energy storage 3000mAh
- Longest Lasting
- Fast Charging
- Low Self Discharge
- Durable



https://www.amazon.com/TalentCell-Rechargeable-3000mAh-Lithium-External/dp/B01M7Z9Z1N/ref=sr_1_4?dchild=1&keywords=lithium+ion+battery+pack+usb+5V&qid=1612287319&sr=8-4

Bill of Materials

Part	Price per unit	Quantity	Cost
Laser Diodes	$0.39	15	$12.98
Photoresistors	$0.16	15	$4.95
Infrared Sensor	$8.74	15	$131.10
Optocoupler	$1.78	1	$1.78
OLED module	$4.00	1	$4.00
Microcontroller	$11.99	1	$11.99
Voltage Regulator	$4.90	1	$4.90
PCB	$2.66	5	$13.30
Frame lumber	$45.98	1	$45.98
Total cost			$240.83



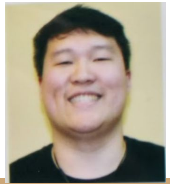
Work Distribution

Name	Software	Photonics	Electrical	Misc.
Christian	X		X	X
Mohamed		X	X	X
Matthew				X
Kyle	X		X	X

Software: Coding
Photonics: Light Detection, Laser Components
Electrical: Wiring, Soldering, PCB
Miscellaneous: Documentation, Assembly

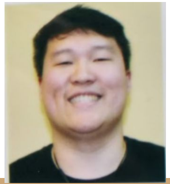
Complications

- Finalizing the PCB and making sure it is delivered in time
- Debugging
- Distance detections wasn’t working properly
- Aligning all 15 lasers diodes precisely to match the LDR
- The interaction with MIDI
- IR sensors
- Improper components being used



Plans for future upgrades

- More powerful laser diodes
- Full control over laser diodes to create automatic playing
- Bluetooth
- A mounting system that allows for easy and more stable alignment
- Changing the frame material to a more sturdy one for longevity



Questions?