Divide and Conquer 2.0: Optical Harp

Group 10

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

This document is for the idea of an optical harp. Optical harps are not new, but are part of a niche of optical instruments. The harp will be referred to as an electrical instrument as well, as it will use electronic components in most use cases. The optical harp has been used on stage during musical performances as part of the show.

Requirements/Specifications:

As this design is for an optical harp, there are some requirements to the initial design. Firstly, it should play a note when something blocks the beam. It should do this for at least one octave, which consists of eight notes. The design should detect the distance that the strings are blocked. The design should also have Musical Instrument Digital Interface(MIDI) connectivity. Finally, the design should not cost over $500.

The list below summarizes these requirements:

- Plays a note when a beam is blocked
- Produce notes of at least one music octave
- Detect the distance that each string is plucked
- Have MIDI connectivity
- Not cost in excess of $500

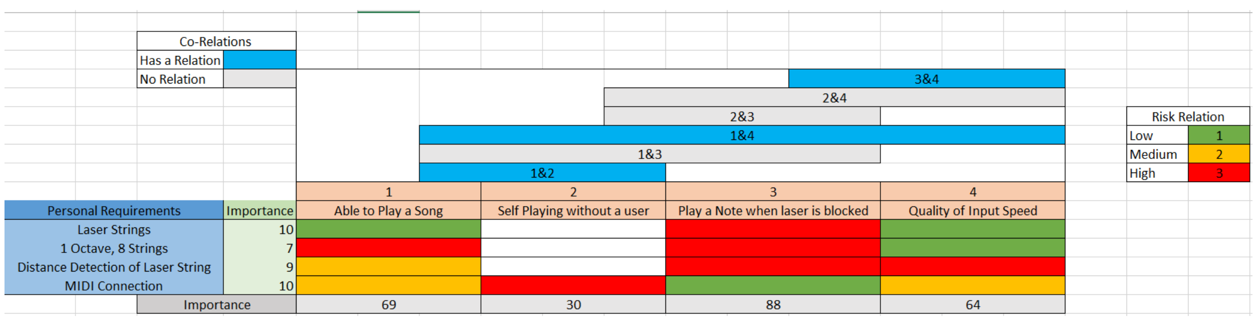

Figure 1- House of Quality Diagram

MIDI:

In order to develop a product that can be used in conjunction with existing electronic music hardware, a key element we need to implement is Musical Instrument Digital Interface, or MIDI. MIDI is the software standard for controlling electronic instruments, and has been since the early 1980's. MIDI is used in practically every synthesizer, drum-machine, and sampler since it was introduced, and is a necessity for any controller or electronic instrument. MIDI can be transmitted using a standard 5-pin DIN connector cable, as well as USB interface with a computer. Both of these should be implemented into our design in order to maximize compatibility with other musical devices, and to allow us to control a wide range of instruments with one device. Ideally, our device will then have a MIDI input, MIDI output, and a USB connection that can send and receive MIDI data.

MIDI messages are made of 8-bit words (bytes) transmitted by serial communication at a rate of 31.25 kbit/s. This is a standard based on early microcontrollers which operated at 1 MHz. The first bit identifies the byte as a status byte or a data byte, and the following 7 bits contain note information. The words also include a start and stop bit to aid in frame synchronization, so each message requires 10 bits to transmit. The 7-bit word allows for a range of values from 0 to 127, which allows for note information exceeding the number of keys on a traditional grand piano. These MIDI notes can be used to control a variety of parameters in an external instrument, but are generally used to control pitch.

Ideally, the MIDI OUT connection sources a 5 V source, uses two 220-ohm resistor, and connects a ground wire according to the schematic in Figure 1. The MIDI IN connection will use a 5V source, standard PN-junction diode, two resistors (220-ohm and 280-ohm), a ground wire and an optocoupler. The optocoupler is necessary to prevent an audible ground-loop hum due to the common ground that would otherwise be needed to complete the serial communication.

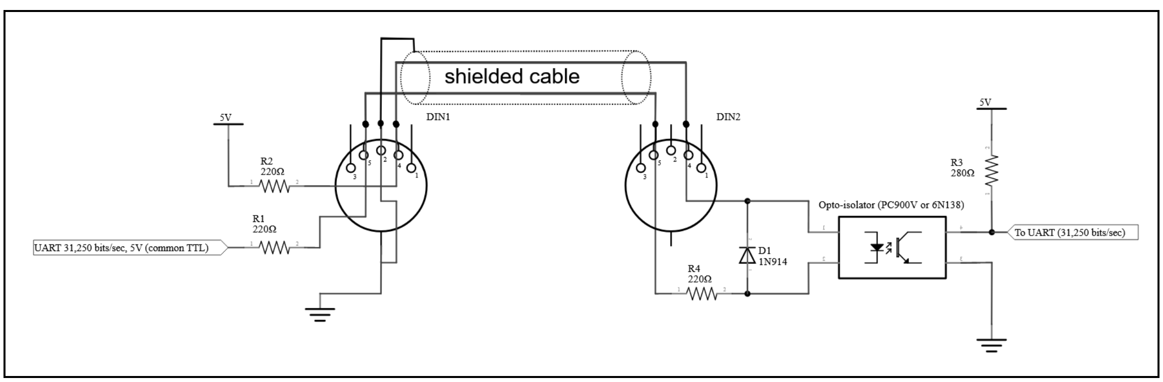

Figure 2 - MIDI Communication Diagram

Light Source:

The strings of an optical harp differ fundamentally from the strings of a typical harp. There would be parallel beams of light acting as the strings, which would be detected. The "strings" in this case would be created most likely from the radiation of a laser. Small laser diodes would act perfectly in this case as the light source for these strings. The strings could also have different colors to distinguish the different strings. This could be done by using a different laser for each note, or by using a different laser at the start of each octave, which would be one every seven strings.

Detection:

To communicate information to the controller there needs to be an interface that detects when the laser light is interfered. A photodiode is a semiconductor device that converts light into a current, which is generated when photons are absorbed. This absorbed light will generate an electrical signal output that will communicate with the system to fire off musical notes on the harp. There are also photoconductive cells that do not produce electricity but rather change physical properties when subjected to light. A photoresistor is a common type of photoconductive device that changes its electrical resistance to the changes in the intensity of light. The light dependent resistor (LDR) is made from a piece of exposed semiconductor material that changes its resistance, creating electron hole pairs, when light reaches the photocell.

Detecting the distance the beam is interfered can also be implemented in this project using infrared distance sensors to create another dimension of sound. A pulse of infrared light is emitted and the distance-to-object is determined by the angle of reflection of light returned to the receiver. The process of using the angle of reflection to calculate the distance is known as triangulation.

Programing:

Depending on what microcontroller we use the language we will be using will be either ARM, C/C++, or assembly language. When all the components are mounted to the board we will then communicate with the board via the selected programming language. Since we will be using two octaves we will have fourteen to fifteen laser strings and each string will have their own respective notes which will be stored by hexadecimal. Depending on how long the user will block the laser will provide a value in which it will track to get a note of a different pitch or velocity. Once the user unblocks the laser the note will resume its off position.

A function we would like to implement would be for the harp to play a pre existing song and without any user and flash the correct laser string that corresponds to the note in the song. The idea for this is we would need the harp to analyse the song using MIDI and playback the song.

Block Diagram:

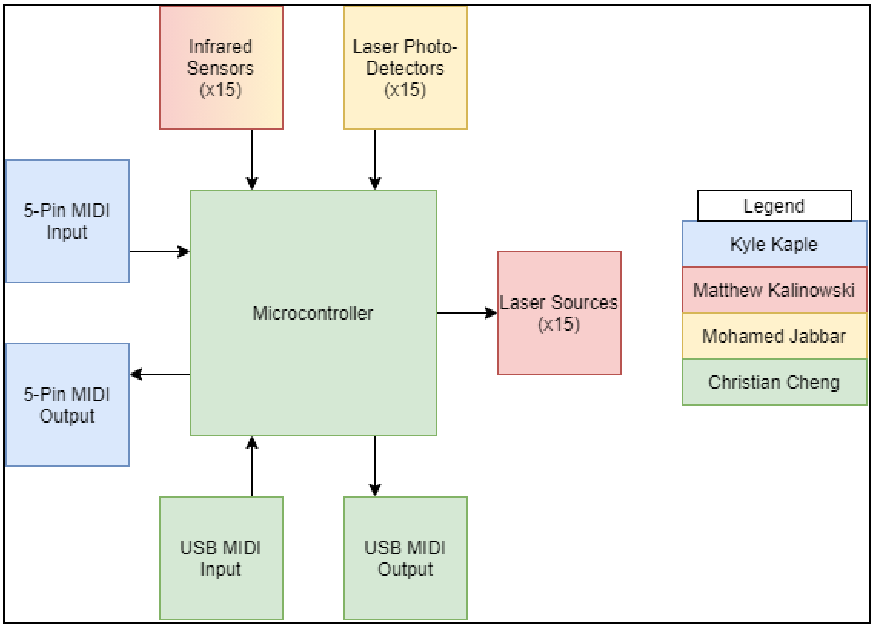

Figure 3 - Electronics Block Diagram

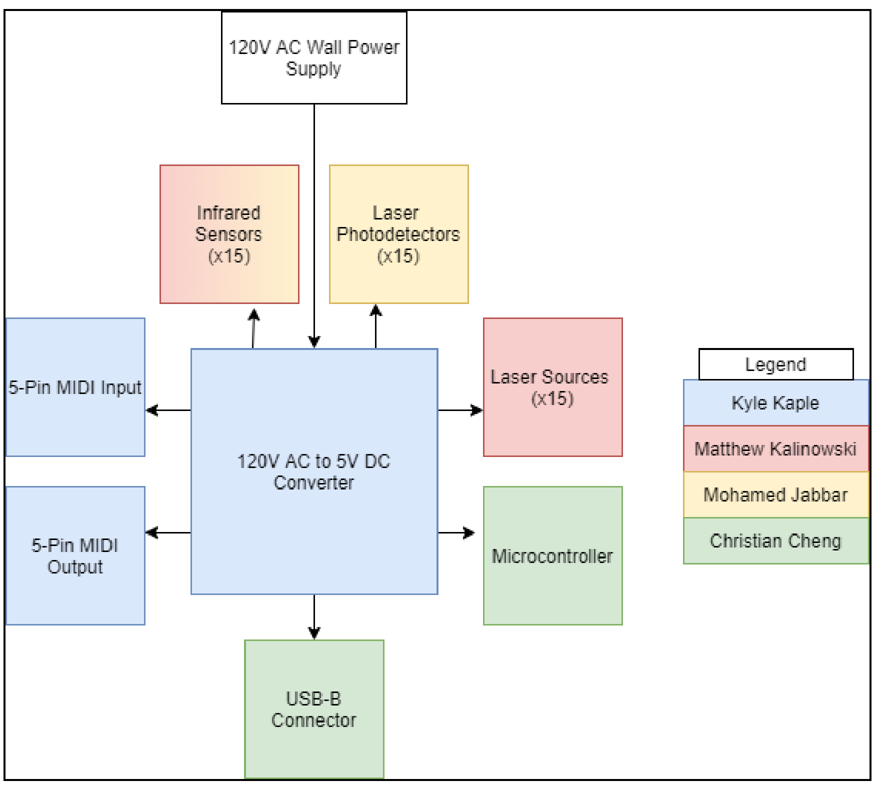

Figure 4 - Power Block Diagram

Budget:

The final design of the laser harp is to be no more than $500. This includes the microcontroller, base, laser diodes, detectors, infrared sensors and basic electronic components such as resistors, wires, capacitors, etc. A table of the estimated costs and final budget can be found in Table 1.

Estimated Project Budget	
Microcontroller	$50
Base	$200
Laser Diodes	$30
Detectors	$50
Basic Electronics	$40
Total:	**$370**

Table 1 - Estimated Cost

Project Milestones:

Here is a table of the projected milestones for the project

Project Milestones	
Form Group	August 27, 2020
Test Lab Equipment	September 7, 2020
Submit D&C Document 1.0	September 18, 2020
Initial Design Document	December 4, 2020
Purchase Components	Early November, 2020
Initial Testing Phase	Early February, 2021
Final Testing Phase	Early April, 2021
Submit Final Project	Late April, 2021

Table 2 - Project Milestones