Senior Design 1

Laser Musical Instrument

Figure 1: Cover Image

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Initial Project and Group Identification Document

Divide and Conquer

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Index

List of Figures

List of Tables

2. **Project Narrative**

Music is one of the oldest and most fundamental ways to showcase human expression and creativity. It reaches deep into the human mind pulling on feelings, memories, and dreams. It is for this reason that for thousands of years mankind has been making music with no end. All music that is created requires two things, the musician and the instrument. As time has progressed so has the sounds of music. Part of the reason for the change in sounds is because new instruments have emerged from musicians chasing new sounds and means to express themselves. These new means of expressions also change the experience for any listener of the music. It is for this reason that we have chosen for our project to explore a fairly new type of instrument – laser instruments. From hobbyists who have created laser guitars to professional musicians who use laser harps in their concerts [1], the interest in using light – particularly lasers – as a median to create music has grown. Providing both a visual and auditory stimulation unique to its design, laser instruments captivate audiences in a fascinating way through its detection system. Our project seeks to engage music from an engineering perspective that is novel, feasible, and entertaining.

The goal for our laser instrument is to be able to produce a range of sounds, create an audio/visual experience, and be inexpensive while keeping the instrument versatile. A challenge for all electronic based musical instruments is the replication of natural acoustic harmonics. For our case it is where a string is plucked and vibrates emitting a decaying resonance after the string has been plucked. Another challenge that has appealed for us to take on is to implement a means for a musician to create vibrato variations in the pitch of the notes. Traditionally this is done on a string instrument by using one hand to lightly vibrate the string while the other plucks the string or vibrates the string by means of a tool such as a bow. On top of that it would be interesting to implement a detection system to determine how loud a note is to be played, that would signal the microcontroller to alter the decibels of the output signal. This it to replicate how hitting a sting harder creates a louder sound.

By combining these sounds with the visuals appeal of laser beams, the user can feel as if they are controlling sound with light. The observer can feel as if they can see sound. These sensations are unique to this type of musical instrument as the senses of sight and hearing are merged into one incredible experience. For this instrument to have significant impact on a sizeable amount of people the costs will have to be reasonably inexpensive. By keeping the price as affordable as possible, the average music consumer can enjoy the excitement of having a laser instrument in their home or studio.

Key functions for this to happen are being able to have an intensity detection system, a soundboard to appropriate each laser beam with a specific sound and having a sufficiently audible system. There are several ways to detect how a broken laser beam can correspond to a sound. First is to have the lasers pointed at a photosensor across from it. Once the laser's beam is interrupted the system will trigger the microcontroller to produce a note to send to the output. This will be a primary interruption for the system. Once a primary interruption is detected the system will engage an intensity detection system located near the source of the lasers. This will measure the intensity of light being reflected back toward the emitting end of the laser. The closer a hand is to the base the more intense the reflection will be. This variable intensity allows us to give more variability to the output sound produced. For example, higher reflection intensities could give off higher volume or higher pitches than a lower reflection intensity would.

To make this a reality a microcontroller can be used to create a soundboard. The role of the soundboard is to take the incoming signals from the detection system and interpret what sound to allocate to each broken beam. With this sorting mechanism, variability in sound can be achieved since a constantly changing live-feed of intensity signals can provide new information to emit new sounds. To prevent the reflections of one beam from triggering the intensity detection of another beam, a turn-on detector can be placed where the beam is incident. When the beam is broken, the turn-on detector can send a signal to the soundboard that a specific beam is ready to emit a sound and the soundboard will determine what sound to allocate to that beam. If reflections hit another beam’s intensity detector that has not been broken, the soundboard will read that the turn-on detector is off and would not emit a sound to it. In the end what is heard is only possible with the use of a speaker. The speaker will receive the sound determined by the soundboard and audibly emit it. The challenge for using the speaker will be ensuring that the respective sounds are emitted correctly and that they are appropriately audible to the human ear. By controlling the behavior of the circuitry, we believe we can achieve the audio amplification needed.

The project will start with the building and testing of a single string during the first semester. This is because once a single has been perfected all the other strings will be replications of the original. The purpose of starting the building and testing of a single string is to better select components for the final build and gaining a better understanding of what is feasible for the instrument to contain in its final prototype. This single string build serve as a controlled system that can be used for all testing before adding to the instrument itself. This is to help protect our prototype during testing so that we can minimize any damage to hardware that can arise from testing procedures.

The laser instrument is intended to provide an interesting way of approaching music. While there are some challenges to overcome, there is great potential to engineer light to do wonderful things. To hear light as a range of sounds as it is being played in real-time and at a reasonable price would be an achievement for us. The world of light is coming, and it can be heard.

3. **Requirements & Specifications**

Table 1: List of Specifications

Specifications
Audio output with a range of 20Hz to 20kHz
Weigh less than 50lb
Run off no more than 15 volts
No greater than 3ft in any single dimension

Table 2: List of Requirements

Requirements
Battery Powered
Portable so that the instrument can be moved when not being played
PCB design
Ignore ambient light with photoresistors
Minimum of four lasers
Microcontroller for signal processing (ADC)
Interrupting a beams path to produce a sound

Table 3: List of Constraints

Constraints
The frequency range a human can hear (20Hz-20kHz)
The lowest level of decibels a human can hear so the instrument can be heard
Max voltage rating of microcontroller (5V)
Limitation of programming language selection and use for microcontroller

Table 4: Goals Set

Goals		
Primary Goals	*Secondary Goals*	*Stretch Goals*
Intensity detection to determine how loud to make a note	Replication of a vibrato sound	The ability to change the note tuning for each laser
Intensity detection for variability in pitches	Laser beam to be visible	Replicate the feel of playing a real string instrument
To be played from a table top or stand	Protection circuit design for reverse voltage and overcurrent	Replication of sound decay that occurs when a string is plucked

Table 5: List of Standards

Standards
ANSI Z136.6: Safe Use of Lasers Outdoors
ANSI Z136.8: Safe Use of Lasers in Research, Development, or Testing

4. **House of Quality**

To consolidate the needs of the market with the realistic capabilities of the engineering team, as well as evaluate the tradeoffs amongst the engineering requirements, a house of quality was made. Below is an illustration of these tradeoffs.

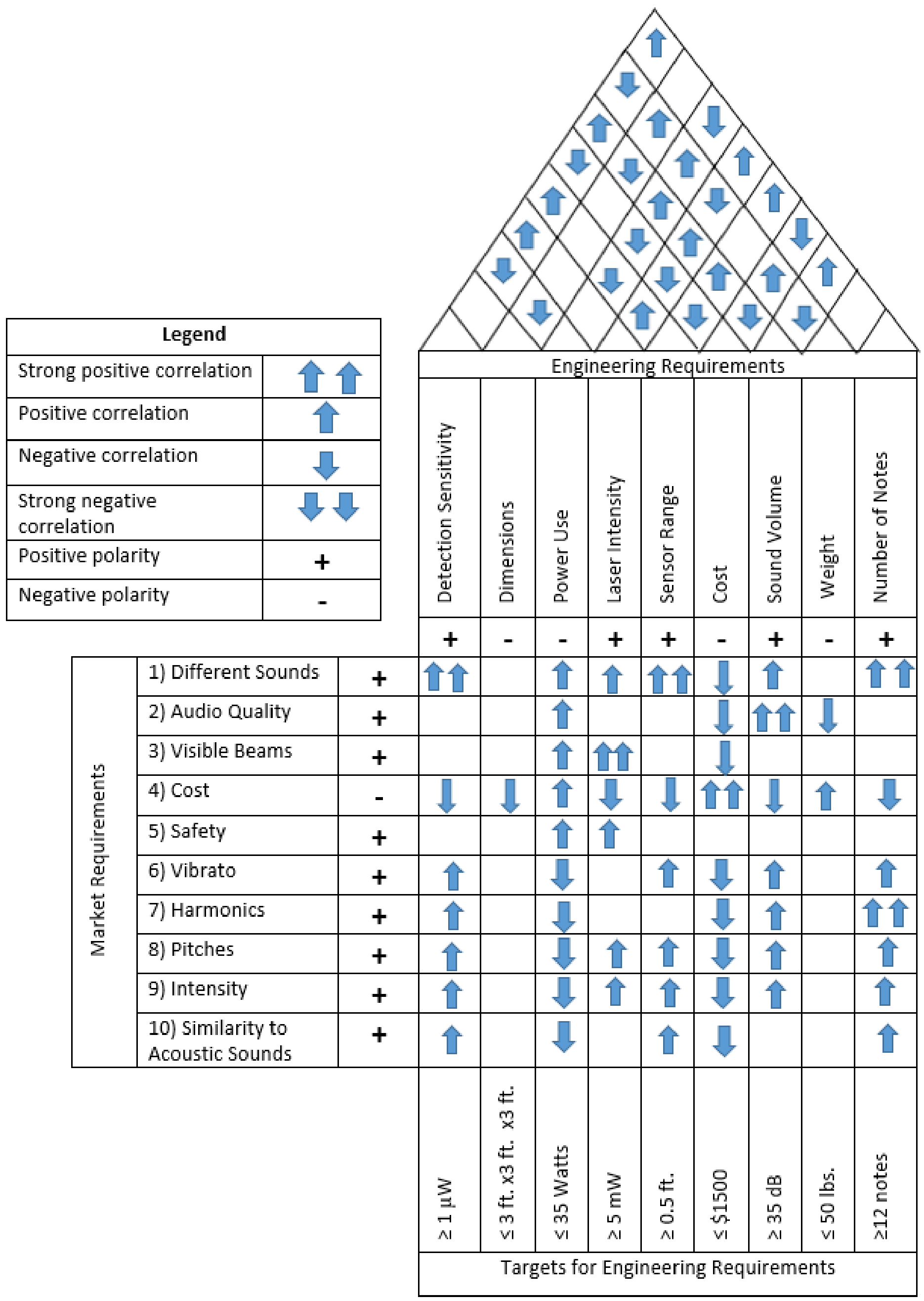
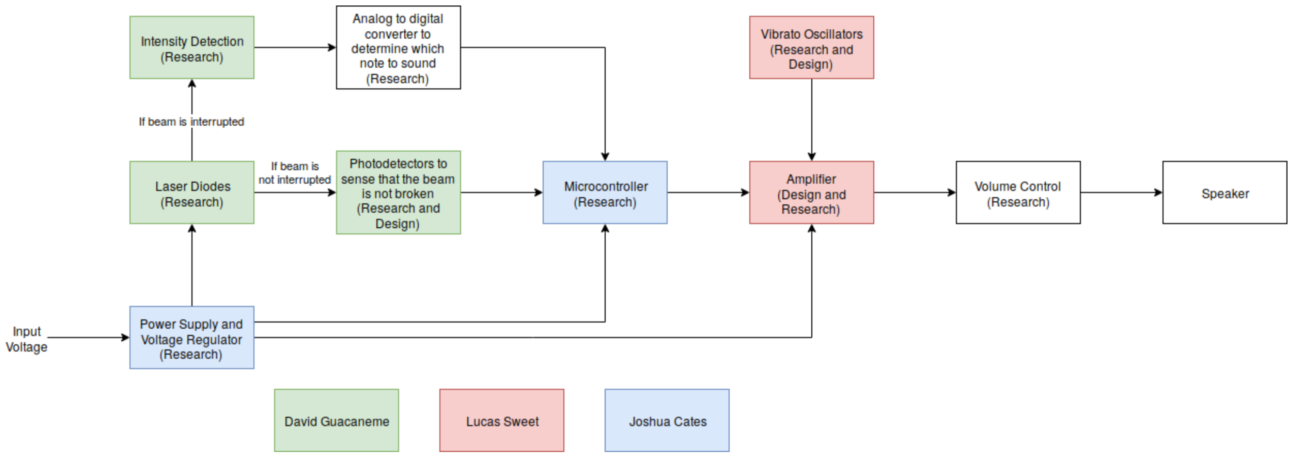


Figure 2: House of Quality

5. **Block Diagrams**

Hardware block diagram:



6: Legend for hardware block diagram

Software block diagram:

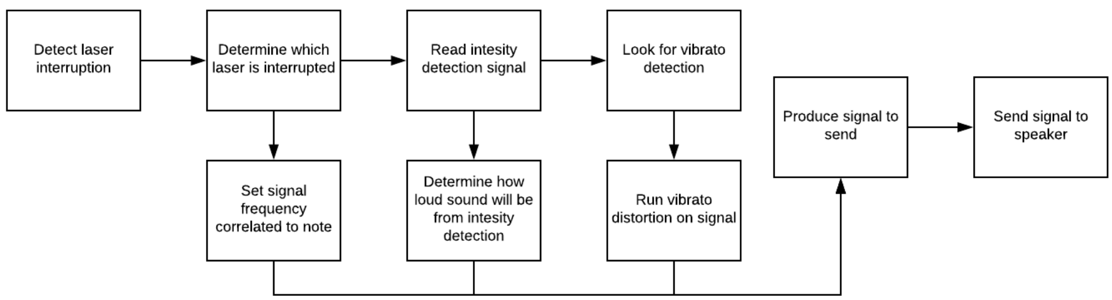


Figure 3: Software Block Diagram

As of 9/27/2018, for both hardware and software:

- All the blocks are being researched
- None of the blocks have been purchased or acquired
- All the blocks are being designed
- None of the blocks have been prototyped
- None of the blocks are completed

6. **Budget**

Our project is self-funded, so we plan to keep the project budget as low as possible. With that being said the prices below in the table are estimates on the higher side. Our miscellaneous is the highest individual cost because it includes any additional small cost and unseen costs that we may figure out while progressing on the project. We have a team budget of $1500 which is well over the estimated cost for the project. The team's budget is produced by equal contributions from each team member. We have set the team’s budget much higher than the estimated costs as a precaution to not be alarmed if the final costs at the end of the project is much higher than the initial estimate because we plan to allow our project to be scalable meaning that we can add more components to increase the complexity of our final product.

Table 6: Budget

Item	**Price Estimate**
Laser diodes	$80
Photoresistors	$10
microcontroller	$50
PCBs	$150
Speaker	$60
Packaging/Frame	$120
Batteries	$75
Miscellaneous	$200
Total	$745

7. **Project Milestones**

Table 7: Fall 2018 Milestones

Milestone	Approximate Completion Date
Project Idea Decision	9/14/18
Initial Theoretical Research	9/28/18
Table of Contents Organized	10/5/18
Single String Research	10/10/18
Parts and Components Research	10/17/18
Report Documentation 60 Page	10/26/18
Single Test String Built and Tested	10/27/18
Components Chosen	11/8/18
Report Documentation 100 Page	11/14/18
All Components Ordered	11/15/18
Components Checked	11/19/18
Report Documentation Full	11/26/18

Table 8: Spring 2019 Milestones

Milestone	Approximate Completion Date
Initial Testing Stage – Frame	1/25/19
Initial Testing Stage – Sensors	1/25/19
Replication of Single Test String	1/30/19
Initial Testing Stage – PCB	2/1/19
Initial Testing Stage – Power System	2/1/19
Initial Testing Stage – Audio System	2/8/19
First Alpha prototype Built	2/18/19
Design Finalization	3/1/19
Second Prototype Built	3/8/19
Complete Design Testing	3/22/19
Repeat Testing	4/5/19

Sources

1. https://jeanmicheljarre.com/

Laser Harp Picture

https://www.pinterest.com/pin/543247392253392263/