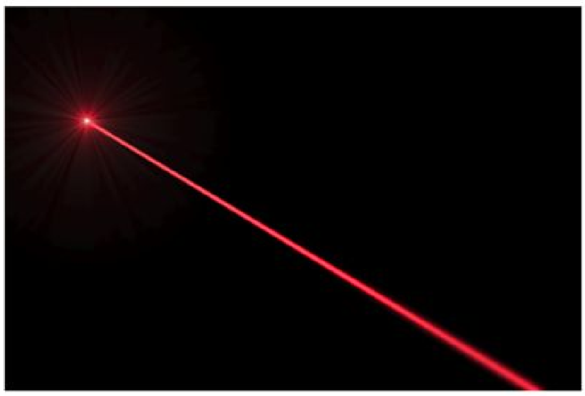
Laser Guitar Instrument



Initial Project and Group Identification Document
Divide and Conquer: Version 2.0

Group 1

Alexander Truong-Mai - Computer Engineer
Jacob Legler - Photonic Science and Engineering
Jonathan Spurgeon - Electrical Engineer
Juan Gamero - Computer Engineer

Project Narrative

For hundreds of years, instruments have been used as a form of entertainment and storytelling. There are a wide range of instruments from the violin to the guitar, and even older ones that indigneous people used such as the Didgeridoo. Making music today involves more digital systems and softwares to mimic traditional sounds from instruments. Guitars though are still widely used in bands and solo artists during concerts; however, learning the guitar is a struggle for many beginners due to the fact that it can be physically painful to play guitar strings with your bare hands over a period of time. With today's technology, we can solve this problem by removing the strings. By removing guitar strings entirely, we can replace them with lasers. Using lasers as the strings of the guitar will provide for a user friendly, fun, innovative, and new musical experience for musicians everywhere.

The motivation for this project is to develop an instrument with new, unique features that uses the knowledge we have gained from our studies at the University of Central Florida (UCF). This instrument will provide a way for beginners to learn guitar without the painful struggle of fretting strings for the first time, and also have the feel and musical capabilities of a normal guitar. With our instrument, we will also satisfy the requirements for Senior Design 1, and develop an open-ended solution to the advancements and visual effects we have for our guitar.

For the goals of our project, we will have three sectors separating them by short term, long term, and stretch goals. Starting with the long term goal, this consists of one main goal to achieve an accurate sounding guitar with lasers acting as the guitar strings. Building up to this, there are short term goals; consisting of implementing the laser diodes, build design, photodetectors, software implementation, PCB layout, etc. The end objective is an accurate, portable guitar that is reasonably priced for musicians or the general public that are interested in purchasing it. The stretch goals consist of ambitious ideas that can be implemented but not necessary for the design as a whole; sustaining notes being played based on frequency of strums.

As for implementing each necessary component, there will be two sets of strings consisting of either three or four laser diodes. The first set will be across the head of the guitar and the second across the neck. For the head of the guitar, the software implementation will detect which laser will be broken from the photodetector. Along the neck, the amount of reflected light at the point the laser is broken by the player's finger back to the photodetector will determine which note to play. To tie all of these strings together, a speaker and battery will be chosen with research to fit our needs and a MCU will be chosen from a list of researched ones with the necessary features. The PCB layout will be designed with the MCU, ADC, DC-DC converter, etc. The idea for this project is based on a previous senior design project from UCF called "Laser Musical Instrument". The features and new software/hardware implementations we will be adding will help our design look and mimic an actual guitar.

Requirement Specifications

The design of our instrument will result in a stringless guitar that uses laser light as the strings. The user requirements include the size and feel of the instrument, and general eye safety for the user. To make an instrument that feels natural to play, the size should be no longer than that of a bass guitar, and the spacing between frets should be reasonably small so that the user can play comfortably. Eye safety will be accounted for by using nothing more powerful than a class two laser with proper eyewear included if necessary. In terms of engineering requirements, we must ensure that the correct notes are being played based on which laser is being blocked by the user's finger, and the returned intensity signals the MCU to play a certain note. This note will be stored and played when the corresponding string is strummed on the strumming set of strings. To do this, two separate sets of laser systems will be designed. The first is a strumming system. This system simply tells the MCU to play a note when the beam is interrupted. A stretch goal of the system would be to determine the volume and sustain of the note played based on the velocity of the strums. The second system is the fretting system. This system uses two photodiodes in conjunction with a laser diode to determine what note will be played by the strumming system. The first photodiode tells the MCU whether the fretting system has been interrupted, and will be placed across the neck of the guitar. The second photodiode returns the amount of light that is reflected off the user's finger, and will be placed at the end of the guitar, next to the laser diode. This information will tell the MCU and strumming system what note to play. Next, we must implement this idea across several strings. To prevent noise from adjacent strings, each photodetector will be paired with a bandpass color filter which only allows light of the respective string's wavelength to pass on to the photodiode. The laser diodes will use light in the visible spectrum, with wavelengths of roughly 450nm (Blue), 550nm (Green), and 633nm (Red), so they can be easily filtered. This will also provide a more intuitive experience for the user as each string will essentially be color coded. The filters should also help with ambient light, as a good portion of the light will be filtered out of the system. Finally, to consider a system that will work under different light conditions, we can consider the change in current as opposed to the total amount of current being returned to the MCU. This change should be relatively consistent across both dark and light conditions.

Requirement Specification Table

Requirements	Description
Size	Bass Guitar or smaller (<36"x4" Fretboard)
Weight	< 5lbs
# of Strings	4
Notes Per String	4 (Open Strings + 3 Frets)
Polyphony	4 Notes at once
Frequency of Notes Played	Proper Spacing between notes based on musical scale
Safety	Class 2 Lasers (<1mw Power)
Responsivity	Able to detect which fret and string is being held down
Response Time	< 50 ms (tentative)

Table 1: Requirement Specification

House of Quality

The House of Quality diagram below was made to display the desires and needs of the customer while also gauging the engineering specifics and their importance.

House of Quality

Customer Requirements	Polarity	Photodiode Reading	Response Time	Sound Reproduction	Laser Types	Filters	Housing Design	Software Design	Cost of Design	Saftey
		→	→	→	←	→	→	→	←	→
Speed of Device	→	↑	⇈	⇈				⇈		
Sound Accuracy	→		⇈	⇈			↑	⇈		
Functionality	←		↓	↑	↑	↑	↓		↓	↓
Design	→						↑		↑	⇈
Size	←	⇊			↓		⇈			
Cost	→								⇈	
Safety	→	⇈	⇈		⇈	⇈	⇈			⇈
Target Requirements		Difference in Illumination	Under 1 second	440Hz - 831 Hz	Various lasers in (nm)	Various wavelenths (lambda)	Under 30in x 4in	Under O(2^n) runtime	Under $800.00	Eye Saftey

Legend	
Positive Correlation	↑
Negative Correlation	↓
Strong Positive Correlation	⇈
Strong Negative Correlation	⇊
Positive Polarity	→
Netative Polarity	←

Figure 4: House of Quality

The target audience for our design will ultimately be anyone who enjoys music, and more specifically to those with an interest in guitar. In order to meet the expectations of our users, there is a list of user requirements to consider; speed, sound accuracy, design, cost, size and functionality. The speed of the device when the user plays notes and pitches should output sound promptly. The sound accuracy of the device is something customers will look for to gain the satisfaction of hearing their notes and pitches played out correctly. User's also have specific desires when it comes to the design, size and cost of the instrument, and thus these requirements are taken into consideration. Lastly, the functionality and the safety of the device will be essential to customers. Some user's want different functionalities such as the whammy bar and volume knob, while some may not need it. Safety is included in this list due to the usage of lasers, and therefore, it is essential that the user's feel safe when using the instrument.

Target engineering requirements for our project include the functionality and responsivity of the device. In terms of hardware, each of the photodiodes used for measuring the returned intensity should be able to detect the difference in intensity from one distance on the fretboard to the next in order to return a signal to the MCU that tells the program what note to play. The notes that are able to be played should all be within frequencies in the chromatic scale, so that they sound musical. Similarly, the strumming strings must detect the presence of the user's finger in order to tell the MCU when to play the selected notes. All detections should work under both dark and light conditions, the device should be small enough to be portable, while the spacing between strings should be large enough so that the player's fingers do not get in the way of each other when selecting which string to play. From the software perspective, a program must be written that selects which note to play based on the returned intensity of the light reflected off the user's fingers. This note will not be played by the speakers until the user strums the second set of strings, called the strumming strings. Lastly, eye safety is a big factor to consider. This can be achieved by containtaing the laser within the housing of our design. Also labels should be included to tell the customer to not look into.

Block Diagrams

Block Diagram Overview

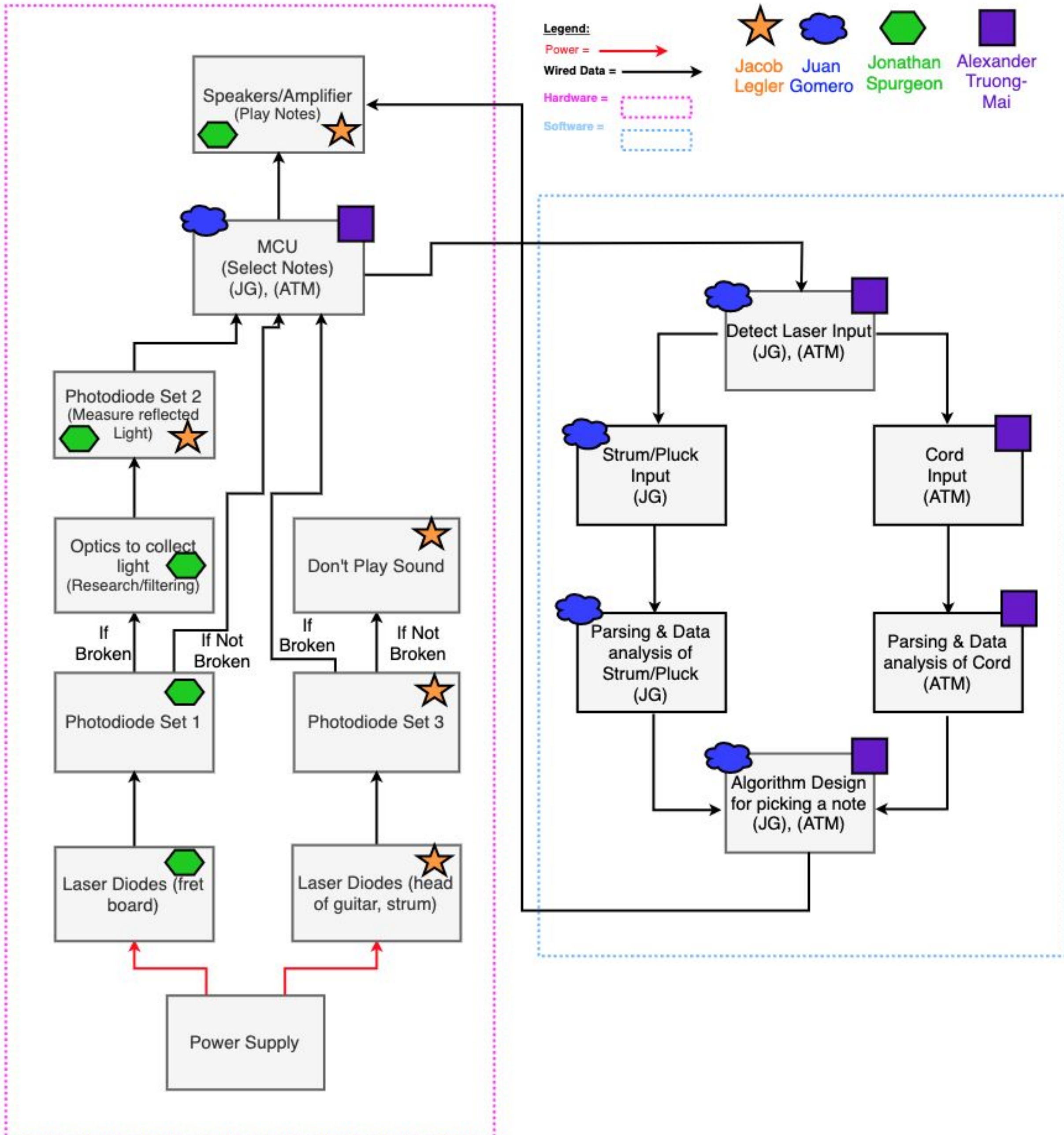


Figure 1: Block Diagram Overview

In figure 1, the overview of the entire project consists of two important implementations. The hardware and the software side. The modules and division of tasks given to each individual member of the group based on their respective colors. The blocks were made by looking at the objectives and requirements of the project. Each module represents a function of the system needed to complete the project. Each block shown is still being researched.

Block Diagram Overview - Hardware Section

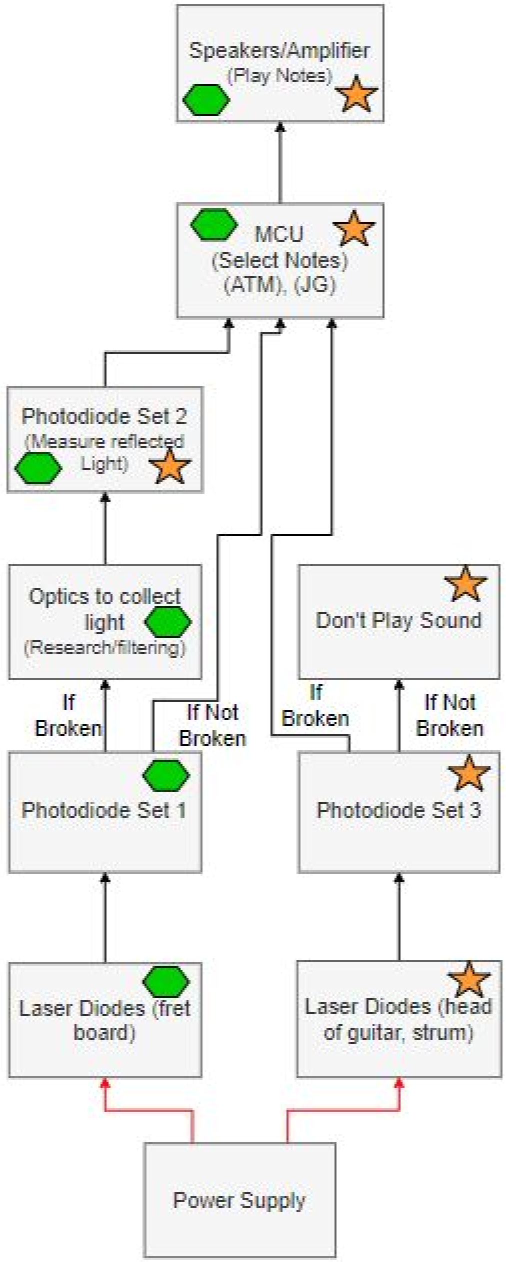


Figure 2: Block Diagram - Hardware view

Hardware:

The goal of the hardware implementation is to allow the MCU to detect which string is being played and where it is being fretted to determine what note to play. To do this, two sets of strings will be used that are directly correlated to each other. We will call these sets the "fretting" sets and "strumming" sets. The strumming set of strings will be placed at the head of the guitar and will operate by detecting when each string is interrupted. If a strumming string is interrupted, the note determined by the corresponding fretting string will be played. The fretting strings will operate by detecting the amount of light reflected off of the user's finger back to the photodiodes which will read the intensity of reflected light. Based on this intensity, which will vary with the distance of the user's finger on the fretboard, a note will be selected to be played when the strumming strings are interrupted. To prevent noise from ambient light and adjacent strings, the light will pass through a bandpass filter before hitting the photodiode.

Block Diagram Overview - Software Section

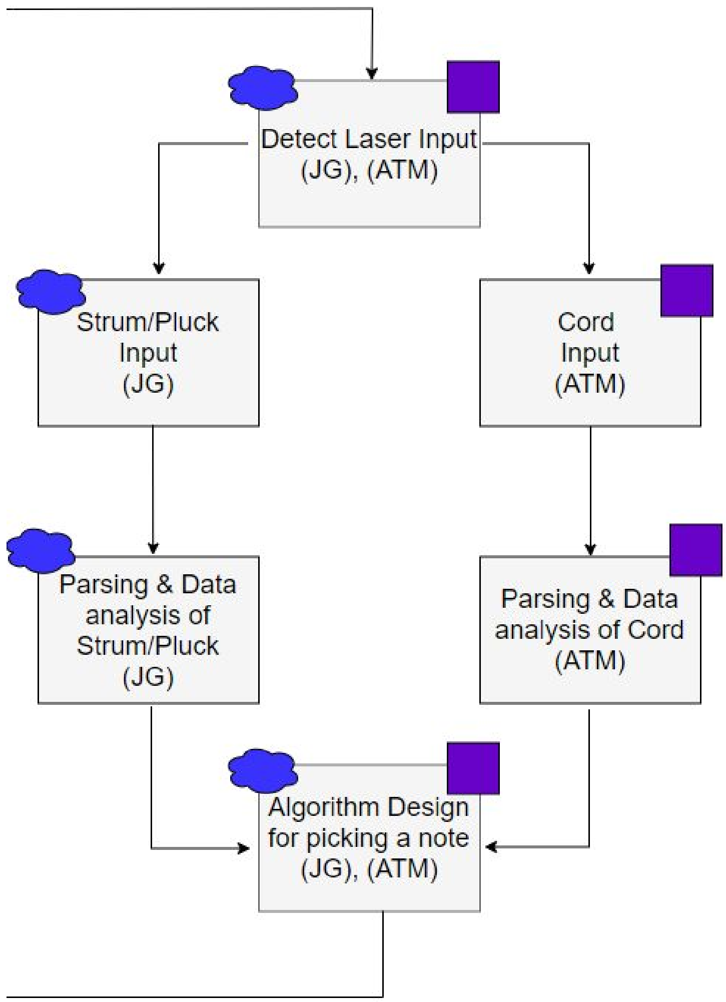


Figure 3: Block Diagram - Software view

Software:

The goal of the software implementation of the project is to produce the correct frequency/pitch according to the laser intensity when another laser is strummed/plucked. When reading the laser from the sensors, there are two lasers to record and analyze. The first laser is the sturm/pluck, and the second laser is the cord. Both of these laser detection needs its own algorithm to process because they are two different systems of lasers, but the cord laser corresponds to a strum/pluck laser emulating one guitar string. By reading the laser intensity, we can assign a frequency/pitch. When the laser is strummed/plucked we can use this reading as a trigger to play the frequency/pitch to the speaker.

Budget/Financing

Projected Budget

Items	Quantity	Cost
400nm Laser Diodes	2	~$30
500nm Laser Diodes	2	~$30
600nm Laser Diodes	2	~$30
Photodiodes	9	~$50
400nm Bandpass Filter	1	~$50
500nm Bandpass Filter	1	~$50
600nm Bandpass Filter	1	~$50
MCU	1	~$50
Instrument Housing	1	N/A
PCB	1 or 2	~$250
Speakers	3	~$30
Miscellaneous Electronic Components	N/A	N/A
Approximate Total Cost		~$620

Table 2: Projected Budget

For the project there will not be any type of outside funding or sponsors from any parties. Instead, the project will be funded by the members of the group. Figure 4 below, shows the breakdown of what items we need, the quantity amount, and the cost. These items are subject to change based on design, safety, and implementation constraints that we may or may not encounter.

Project Milestones

Milestones

Senior Design			
Description	Group Member	Start	End
Initial Design Requirements			
Form	All Members	5/11/2020	5/11/2020
Project Approval	All Members	5/11/2020	TBD
Boot Camp Document	All Members	5/21/2020	5/29/2020
Divide & Conquer paper v1	All Members	5/14/2020	5/20/2020
Research			
Research MCU	Jacob & Jonathan	5/15/2020	5/30/2020
Research Photodiodes	Jacob	5/15/2020	5/30/2020
Research Types of lasers	Jacob	5/15/2020	5/30/2020
Research housing manufacture	Alexander	5/15/2020	5/30/2020
Research Software tools	Juan	5/15/2020	5/30/2020
Implementation			
Design PCB Board	All Members	6/2/2020	6/5/2020
Design Housing	All Members	6/2/2020	6/5/2020
Manufacture PCB	Jacob & Jonathan	6/5/2020	6/18/2020
Attach MCU and laser to PCB board	Jacob & Jonathan	6/18/2020	6/25/2020
Program MCU	Juan & Alexander	6/25/2020	6/30/2020
Test Design Code	Juan & Alexander	6/25/2020	7/5/2020
Test Prototype	All Members	7/5/2020	7/17/2020
Documentations			
Divide and Conquer v2	All Members	6/1/2020	6/5/2020
New Standards	All Members	6/22/2020	6/26/2020
60 Page Draft	All Members	6/22/2020	7/3/2020
100 Page Report	All Members	7/16/2020	7/17/2020
Final Document	All Members	7/20/2020	7/28/2020
Senior Design 2			
Manufactured House	Alexander	TBD	TBD
Redesign attachments MCU and laser to PCB board	Jacob & Jonathan	TBD	TBD
Redesign & Test Code	Juan & Alexander	TBD	TBD
Test Design Again	All Members	TBD	TBD
Finalize and House everything	Juan & Jacob	TBD	TBD
Final Document	All Members	TBD	TBD
Final Presentation	All Members	TBD	TBD

Table 3: Project Milestones

The table representing the expected initial begin dates and end dates for the milestones we currently have. The first half represents the Senior Design 1 milestones and the second half are the milestones for Senior Design 2. Everything currently listed is expected. but can change depending on how progress is moving online through the semester.