Microelectronics Final Lab - Laser Harp

J.Matteo, R. Stelts, A. Hollabaugh, R. Michaelchuck
Rowan University

December 20, 2019

1 Design Overview

A laser harp is a musical instrument which consists of lasers, a way to detect the laser's beams, a microcontroller, and a speaker. These devices work by using your hand to break the line of sight between the detector and the laser, which is detected by the microcontroller. This microcontroller then creates a tone of a certain pitch, based on which detector lost sight of the laser. In our design, the laser uses photoresistors to detect the light of the lasers. This photoresistor is connected to a voltage divider circuit which allows the change in resistance from the photoresistor to create a change in voltage, detectable by our microcontroller, the MSP430FR6989 from Texas Instruments. Our microcontroller then looks up a pitch based on a table of note frequencies from Michigan Technology University, and sends a square wave to the speaker output circuit. This circuit uses transistors to amplify the square wave to allow the speaker to play at a loud enough volume to hear the tone from a distance of at least 3 feet.

1.1 Design Features

- Plays the following notes denoted by musical frequencies from lowest to highest: C, D, E, F, G, A, B
- Ability to play one to seven notes at once, creating musical chords
- Three octaves can be selected, with each selection defining the octave for all notes
- Volume knob for master volume control
- User control based on the blockage of lasers by the user's fingers
- LCD screen outputs current note and octave being played
- UART communication for debugging and as a secondary input method

Note-Frequency Specifications

LETTER KEY EQUIVALENT	FREQUENCIES AT OCTAVE 1 (Hz)	FREQUENCIES AT OCTAVE 2 (Hz)	FREQUENCIES AT OCTAVE 3 (Hz)
C	130.8	261.6	523.2
D	146.8	293.7	587.3
E	164.8	329.6	659.2
F	174.6	349.2	698.4
G	196	392	784
A	220	440	880
B	246.9	493.9	987.8

Figure 1: Note list

1.2 Featured Applications

- Musical instrument capable of satisfying multiple roles in an ensemble
- Tuning system for other musical instruments
- Sound testing apparatus

1.3 Design Resources

Github Repository:
https://github.com/andrewhollabaugh/photo-harp

Onshape CAD Document:
https://cad.onshape.com/documents/e477811e3e66828e1681d50a/w/4e34916a476f661704c81022/e/76423785425c97a8dfcc5379

1.4 Block Diagram

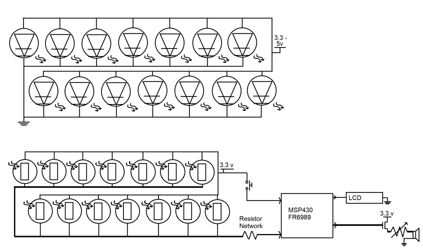


Figure 2: The Block Diagram

1.5 Board Image

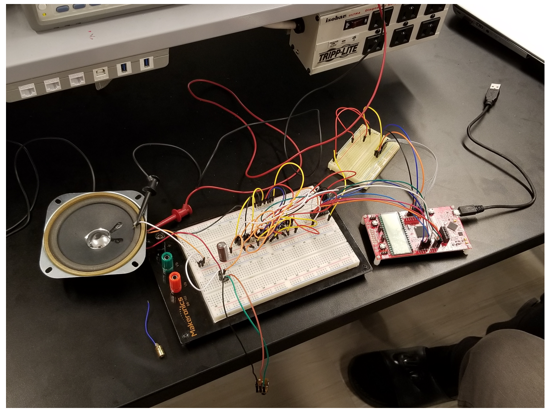


Figure 3: The Final Constructed Breadboard

2 Key System Specifications

Parameters	Specifications	Details
Notice laser breaks	is Tiggered when a input pin recieves threshold voltage	
Octave change	based on laser layer	ranging from 1 and 2

3 System Description

In order for the photoresistors to detect the lasers, they need to have line of sight of the lasers. To do this, a housing consisting of a baseplate, two standoff legs, and a top plate was 3D printed and fastened together using hot glue. The lasers are inserted into the top plate and the resistors are attached to the bottom plate. The legs are shaped like sideways “U”s to allow a hand to be inserted from the side. A separate speaker stand was also 3D printed but was never used.

CAD models of the laser photoresistor housings with legs (left) and speaker stand (right)

Our lasers are a class 3R, which allows for the user to not require safety glasses as the period of time it takes the laser to burn someone’s eyes is shorter than the time it takes someone to close their eyes and look away. Also, since the lasers are fastened to point downwards and the gap between the two plates is smaller than the human head, the only way to shine any of the lasers into someone's eyes are to dismantle the harp and willingly stare into the laser light.

3.1 Highlighted Devices

- MSP430FR6989: The microcontroller for this project. The program is loaded using a UART serial connection. Reads photoresistor inputs, outputs square waves to amplifier circuit, outputs status to LCD, and accepts commands over UART
- Lasers: Produce a beam of focused light onto the photoresistors, so the user's fingers can be detected. A simple load run at 3.3 - 5 volts.
- Photoresistors: Change resistance based on the amount of light above them. Used to detect if an object is obstructing the path of the laser, to determine the input.
- Speaker: Creates sound based on the signal given
- MOSFETs: PUT STUFF HERE
- Volume Knob: Changes the amplitude of the signal sent to the speaker to change the volume of the sound.
- LCD: Displays current note and octave. Directly embedded into the MSP430FR6989 development board used.

3.2 Device - MSP430FR6989

The MSP430 family of microprocessors includes many different boards with hundreds of features. The MSP430FR6989 family is a part of the MSP430 series that includes multiple 16-bit timers, 40 accessible pins, ultra-low power, and UART communication capability. This specific board includes a 12 bit analog to digital converter. This board was chosen due to the integrated LCD screen on the development board. LCD screens use a lot of pins and are typically very complicated to control, but the integrated LCD and TI's documentation makes this easier. The 6989 chip also contains enough timers for use with this project, as well as the processing power needed to generate seven simultaneous square waves partially in software.

3.3 Device - PHOTORESISTORS

The photoresistors are rated at 1 mega ohm, meaning they have a resistance of 1 million ohms with no light. The resistance drops the greater the intensity of light. For our purposes, the photoresistors have a resistance of around 2 kilo ohms in standard lighting conditions and around 500 ohms when the laser is shining on them. A resistor divider was constructed with the photoresistor and a 600 ohm resistor, which creates an analog voltage input to the MSP430. This apparatus is used for every input of the device.

3.4 Device - AMPLIFIER CIRCUIT

The speaker output was amplified using a low side switch for each PWM output. The CSS-1021028N speaker connected to 5 volts and the drain of a N Channel MOSFET for each of the outputs. The source of each MOSFET connected to ground and the gate of each MOSFET connected to the PWM output coming from the MSP430FR6989. By connecting the PWM output to the gate of the MOSFET, the MOSFET turns on and off periodically at the rate specified by the PWM. A common ground was created between the MSP and the amplifier circuit.

4 SYSTEM DESIGN THEORY

This system consists of four main components, the speaker output, photoresistor input, LCD output, and UART communication. Each of these parts communicates with one another using function calls and global variables.

4.1 Speaker Output

The square wave output to the speaker is generated using PWM from a combination of seven pins. Pins P1.5, P1.6, P1.7, P2.4, P2.5, P2.6, and P2.7 were used. These pins are split across two timers, where the pins on port 1 are from TimerA0 and the pins on port 2 are from TimerB0. These pins are all PWM outputs of the timers. TimerB0 does have seven PWM outputs all by itself, but not all are accessible on the MSP430FR6989 development board, so a combination of the two timers was used.

Typically, a single timer can only output square waves of one frequency on all of its output pins, and the outputs are used to vary the pulse width. For this project, the frequency is varied individually for each timer output. This was done in software by using the timer's continuous mode. The timer counts from 0x000 to 0xFFFF, and hits the values in each compare register along the way. When each compare register equals the timer value (triggered by an interrupt), the compare register is set to itself plus a half period. This way, the compare register hits the timer value twice every period. The frequency of the output is varied by adjusting the period values added to the compare registers. The timer's output mode is set to toggle the output pin on compares, so a square wave appears on the output with the frequency assigned.

The seven square wave outputs, each corresponding to a single note, is amplified and combined in hardware.

4.2 Photoresistor Input

The ADC (Analog to Digital Converter) of the MSP430 was attempted to be used for inputting the photoresistor signals. The photoresistor voltage divider would output an analog voltage to the MSP430, which is then converted to a digital number, from 0 to 4095. A threshold value, calculated to be around 2300, would be compared to the input to determine if the laser is striking the photoresistor or not. Seven pins were used: P8.4 (A7), P8.5 (A6), P8.6 (A5), P8.7 (A4), P9.0 (A8), P9.1 (A9), and P9.5 (A13). These pins were chosen since they are all pins connected to the MSP430's ADC and are all accessible on the development board. The reason we could not get the ADC to work is unknown, but is likely to the setup of the ADC peripheral or configuration of pins.

4.3 LCD Output

The LCD code relies on a driver library which can be found on Texas instruments(TI). It allows easy control of the LCD by having a library for each capital letter and numbers 0-9 as preset functions so you do not need to assign each segment of the display. The LCD screen on the FR6989 has 6 16 segment displays. They can be set by using the provided function and listing the input and position. The function will auto clear when a new input is set.

4.4 UART Communication

The MSP430FR6989 processor is able to communicate to a host computer over universal asynchronous receiver-transmitter, or UART, communication. UART's transmission speed to a baudrate of 9600, 8 data bits and 1 stop bit. The purpose for this feature was for debugging purposes, though it can also be used instead of the photoresistor array for input. All communication through UART is done using ASCII characters for ease of use.

Commands can be sent to the system, which are one uppercase letter, followed by an argument, which is a number in decimal. The commands include one for each note value (C, D, E, F, G, A, and B), which controls the output of each note value. The three octaves can be selected by making the argument 0, 1, or 2. Any other number will turn the output off. The Q command does the same but for all outputs.

The processor uses an interrupt to receive incoming bytes, then pushes them to a queue. The main loop of the program runs a function that checks the queue, executes commands that are sent. This includes converting the command argument from a string of bytes to a number.

5 Getting Started/How to use the device

For the current use of this device, you must pick a note and set it as note=(desired note);

After hitting run one can change octave by pushing the button on the bottom right of the device. to play multiple notes just do the above function multiple times.

If working as fully desired, the user simply needs to put their finger in the way of the beam to the photoresister. depending on which beam it will play a corresponding note. to lay a chord one would simply break multiple at the same time.

To control the volume you simply turn the potentiometer. if working as intended it would also be controllable by which laser column was broke.

6 Getting Started Software/Firmware

To use this device one must download Codecomposer. Next go to https://github.com/Intro-To-Embedded-Systems-RU09342/LazerHarp and downlaod the files. Next unzip the files and place them in a known location. Next add the driver libraries to included library's in codecomposer. To do this click project/files/include and select the file.

from this debugg the code and hit run. this should output the note a and allow octave cintrol. To change the note look into the first loop of the code and change the number not is equal to 1 being A 7 being G.

6.1 Test Data

When running the original code it should play an A. a music not detecting app can be used to verify it.

7 Design Files

7.1 Schematics

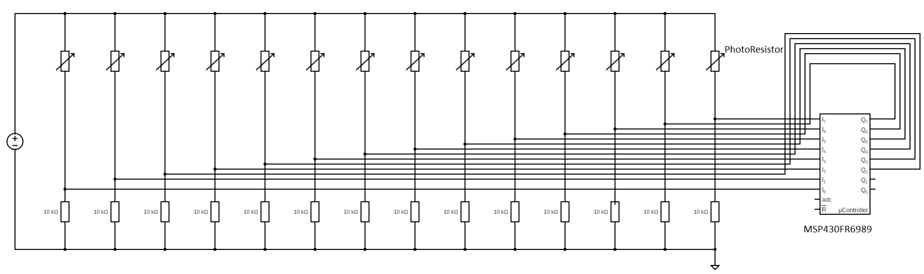


Figure 4: Photo-resister Voltage Divider Circuit

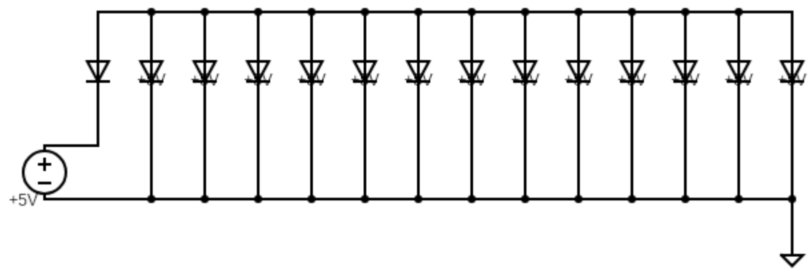
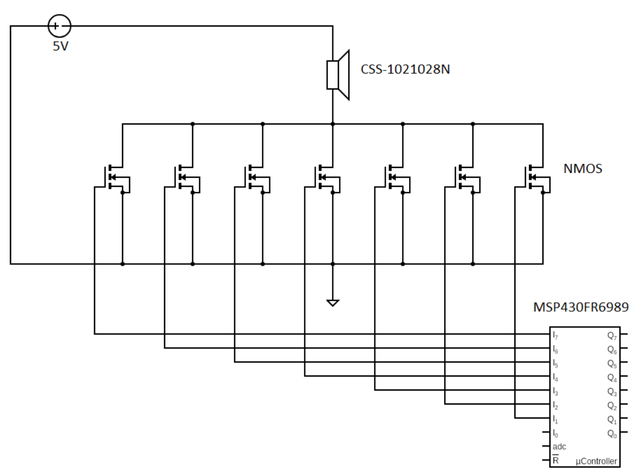


Figure 5: Laser Array Circuit



circuit.png

Figure 6: Speaker Amplifier Circuit