

# Music-Visualization and Motion-Controlled LED Cube

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## 1 Introduction

### 1.1 Objective

Our project's main inspiration came from a video about an art piece called *Kinetic Rain* at Singapore's Changi Airport. The sculpture cycles over 16 pre-programmed shapes, through fluidlike movement. [1] The construction of the sculpture was made using over 1,200 bronze droplets, steel wires to hold the droplets, and cost several million dollars. [2][3] Although *Kinetic Rain* looks very visually pleasing, we wanted to implement something that not only had visually pleasing animation, but through real time sound input. The *Kinetic Rain* device's engineering seems very complex and cumbersome to fix if there were any issues to arise. Also, we wanted to implement this in a manner that would be very cost effective compared to *Kinetic Rain*.

Our team decided we wanted to build a device that took advantage of LED technology's efficient and aesthetically pleasing properties. An LED grid allows us to display visually pleasing animations by turning off a set of LEDs and keeping others on to mimic the shape that we want. Although there are other LED displays that have music visualization capabilities, ours would not only use a sound's frequency, but its tempo, amplitude, and angle of arrival. Additionally, we'd like to have the user be able to interact with the LED grid to affect the animations within device. By taking something that is traditionally 2-dimensional and implementing a 3-dimensional version, we can show off the benefits of user interaction as well as increase the entertainment factor of the device. We plan on doing this by making a Snake game that uses proximity sensors to control the snake's direction.

## 1.2 Background

The *Kinetic Rain* sculpture's may be aesthetically pleasing, but that comes at a cost. The sculpture has a price tag of over \$7 million and has expensive and unique parts that are hard to replace. [2] Our device would also be more cost efficient and be easy to fix if something were to go wrong with any of the pieces. Additionally, the sculpture took around 2 years to put together. [3] The *Kinetic Rain* was damaged on November 2<sup>nd</sup>, 2013 by a woman who climbed and hung onto the bronze droplets. The repair took engineers several months and was costly. [4]

With our device, we'd have a low cost and easy to repair LED grid that would use live sound input to affect the animations, so visitors may be exposed to new unique animations each time they visit. Our device would be more scalable because of its modularity and cost. The tax payer burden would also be less if a government municipality were to commission our device versus something like *Kinetic Rain*. Although there are devices that can display aesthetically pleasing animations, ours uses four sources of input to affect the animation. Our device will also have an interactive mode to allow users to affect animations. Even with the LED Cube ECE 445 project from the Fall 2013 semester, they their phone application to affect user input. We will expand on this in terms of number of input as well as improve the way a user interacts with the LEDs.

## 1.3 High-Level Requirements

- Capture the frequency, amplitude, angle of arrival, and tempo from incoming sound in an accurate manner and make sure each of the sources affect the LEDs appropriately.
- Proximity sensors must be able to pick up motions of user to affect the 6 different directions (Up, Down, Left, Right, Outward, Inward) that the snake can move.
- Make sure the LEDs' colors and off/on states are correct with respect to the mode that the device is in.

## 2 Design

### 2.1 Block Diagram & Physical Design

#### 2.1.1 Block Diagram

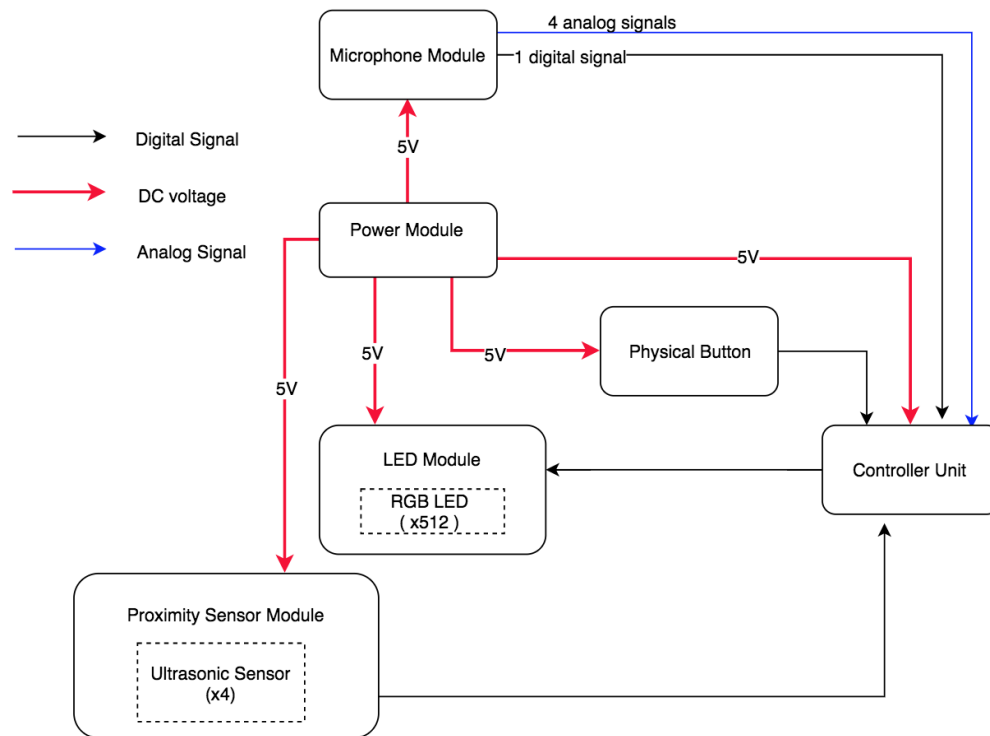
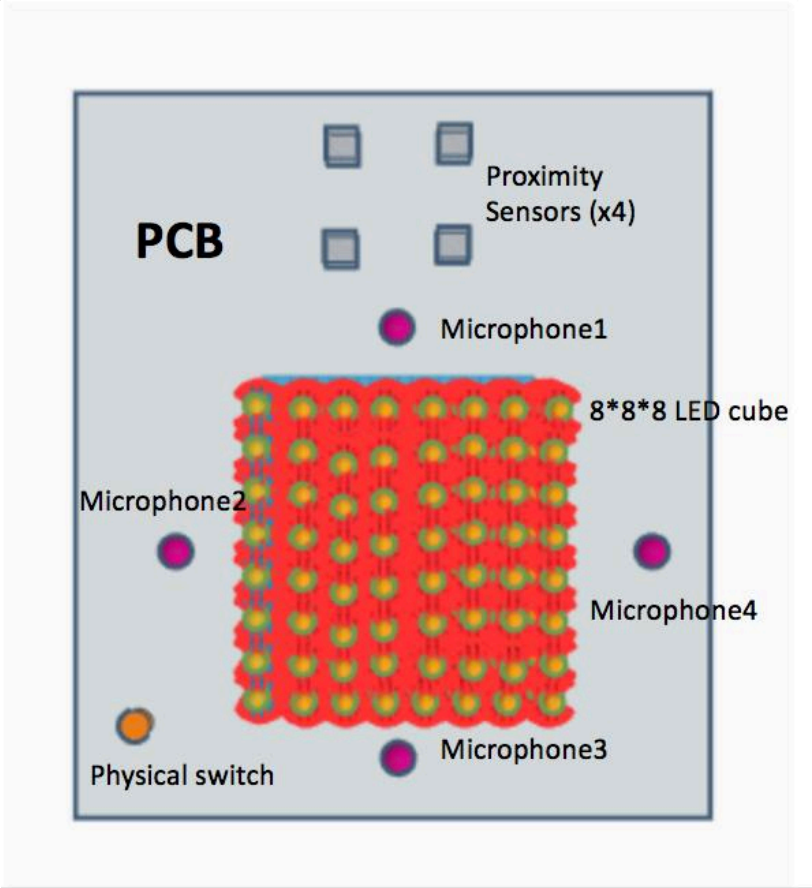


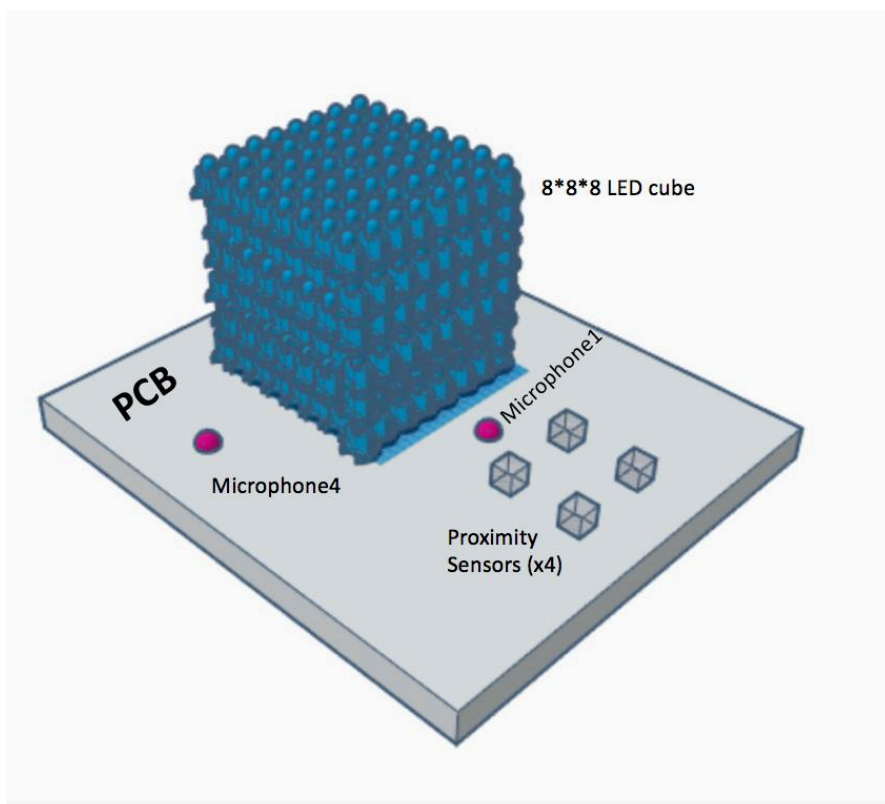
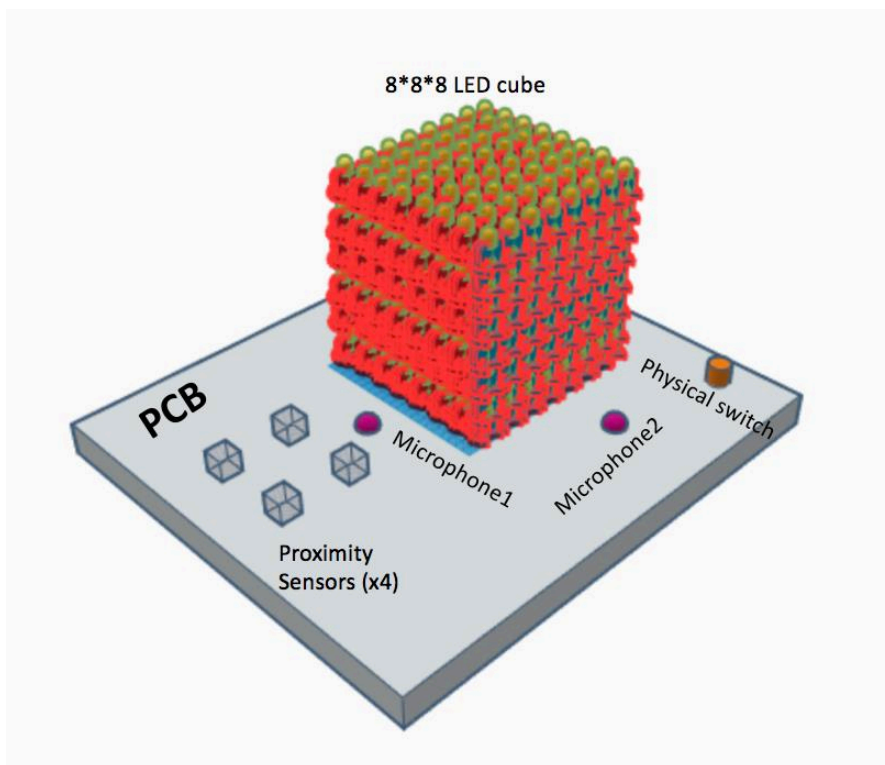
Figure 1

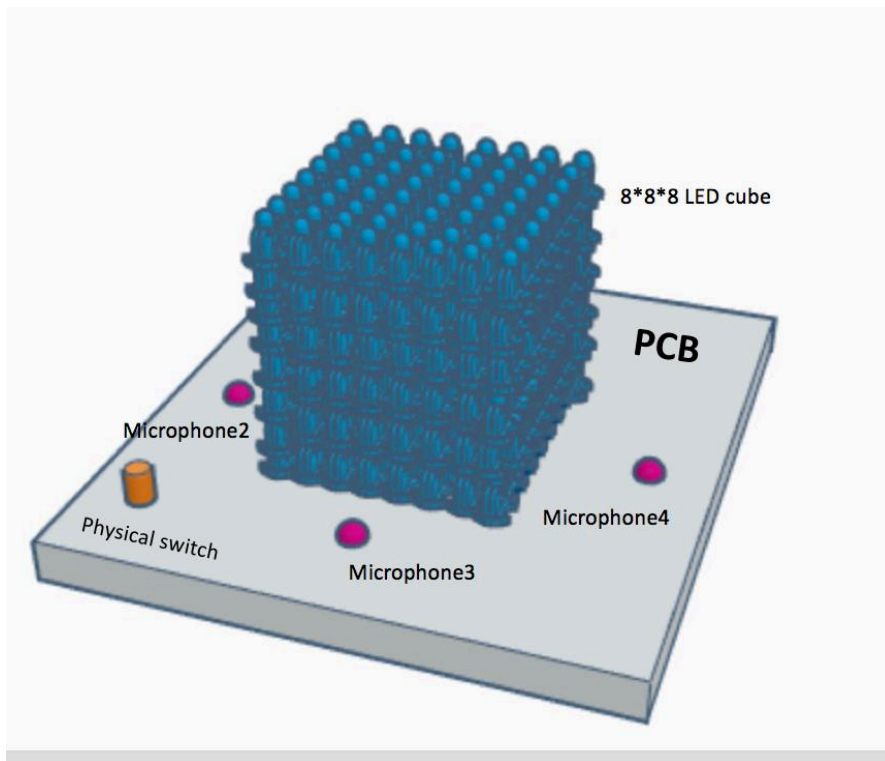
#### 2.1.2 Physical Design

The LED module consists of 512, 5mm RGB LEDs, which are arranged into a 8x8x8 grid. We plan to arrange the LEDs such that the horizontal and vertical distances between any 2 LEDs is 1.25 inches. This will be placed on a flat rectangular surface approximately 24 x 18 inches square, that will have our sensors hooked up to. The cube will be placed in the upper middle part of the whole design with dimension 8.75inches x 8.75inches x 8.75inches. 4 inches away from the three edges of the board where we are going to put the microphones at. The fourth edge is 2 inches away from the proximity sensor group, which also contains the fourth microphone within. Four proximity sensors are arranged two by two into a rectangular group with the distance 0.75 inches away from each other. The group dimension is 2 by 4 inches square. The diagram of

physical design is shown below.







## 2.2 Functional Overview

### 2.2.1 Power Module

This module is responsible for supplying power to the other components in our design. We estimate a voltage of 5VDC will be needed to power the LEDs, Microcontroller, the sensors, the microphones, and the analog to digital signal converter. These are estimates and may change depending on model of the parts specified above. The source of the power will be alternating around 120VAC and will need to be converted to 5VDC.

Requirement: Must power all components of the device, as well as the LEDs, with 5VDC.

Requirements	Verification
<b>1. Power rating greater than 60 Watts to ensure that our device is well powered and safe to use.</b>	1. Use a multimeter to ensure the HC-SR04 is receiving the appropriate amount of voltage and current.

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### 2.2.2 Microphone Module

This module is used to collect the sound from the environment. This module contains 4 electret microphones and 1 digital microphone (ICS-5200). All microphones must have frequency response from 20Hz to 20 kHz. For the digital microphone, it has more than 44 kHz sampling rate satisfying Nyquist rate for 20kHz signal. The output of the digital microphone will be fed directly to the controller unit. We use this microphone to analyze the frequency and amplitude of the sound. The 4 electret microphones will be used to detect the direction of arrival of the sound. The output of 4 electret microphones will be amplified by 4 amplifiers before going to the controller unit. Since we use Arduino Zero, we can directly feed the analog signals to it.

Requirements	Verification
<p><b>1. All four electret and one MEMS microphone can accurately receive sound input.</b></p> <p><b>2. Amplifier must properly amplify the signals so that the signal magnitude is in range 0-5V before feeding it to the control unit</b></p>	<p>1. Use an oscilloscope to measure the sound input from each microphone to ensure it is accurate enough.</p> <p>2. Use an oscilloscope to measure the output of Amplifier</p>

### 2.2.3 Proximity Sensor Module

The proximity sensor module is used to pick up how close the user's hand is in order to control the snake when the device is in gaming mode. This proximity sensor module contains 4 ultrasonic sensors arranged at certain positions. These sensors will detect if user's hand is above the sensors and generate analog outputs of 0-10VDC (depending on the model), which will be fed into the control unit. The control unit will then use the signal from the sensors to make decisions about where the snake should move.

Requirement: Each sensor must detect the hand positions from a range of 3 cm to 1m.

Requirement: Each sensor must detect the position of hand when hand is moving fast.

Requirements	Verification
<b>1. Ensure minimum working DC voltage and current is 5V and 15mA respectively.</b>	1. Use a multimeter to ensure the HC-SR04 is receiving the appropriate amount of voltage and current.
<b>2. Identify which four sensors are being used to detect the direction that one's hand is moving.</b>	2. Take the time difference between sensors to determine which direction a hand is moving. For example, with two sensors next to each other, if one sensor (A) detects a hand over it and then the sensor (B) to its left detects the hand over it, we can calculate the time difference between A and B to determine the direction the user wants the snake to move.
<b>3. Ensure that sensors can pick up signals from a minimum of 2cm.</b>	3. Use the time range between sending the trigger signal and the echo signal received to calculate appropriate distance read from the sensors.

#### 2.2.4 Control Unit

The controller unit will take 4 analog signals from 4 amplifiers in the microphone modules, 1 digital signal from the digital microphone, and 4 digital signals from 4 Ultrasonic sensors in Proximity sensor module. Furthermore, there is a button to switch between 2 modes, Music and Gaming modes. This control unit will output 4 digital signals to drive the LED module. For the control unit, we will use the Arduino Zero because of a few reasons. First of all, Arduino Zero is more powerful than older version, Arduino Uno. Next, it supports the I2C interface which allows us connect directly to the digital microphone. The control unit will perform tasks based on the mode of the device. When the device is in Gaming mode, the controller unit will use the 4 inputs from Proximity Sensor Module to run the algorithm of the



Snake Game described below. When the device is in Music mode, the control unit will calculate the FFT, amplitude of the sound based on the input from the digital microphone, and calculate the direction of arrival by comparing the input of the 4 electret microphones.

Requirements	Verification
<b>1. Supplies modules with the stabilized voltage that ranges from 3.3V to 5.5V to operate.</b>	1. Measure voltage and current using the appropriate device.

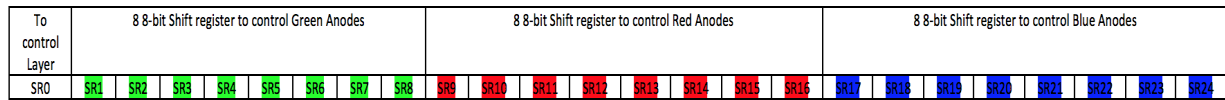
#### 2.2.5 LED Module

This module contains 8x8x8 a grid of 5mm RGB common cathode LEDs. Because we have 512 RGB LEDs each has 4 pins, we need to control  $512 * 4 = 2048$  pins. Instead of having 2048 outputs from the controller unit to control these LEDs, we will use 25 8-bit shift register to control these 512 LEDs. The controller unit will control the LED module by inputting 4 digital inputs: DATA, CLK, OE, and LATCH.

To make it easier to understand how we connect the LEDs, let imagine that these 512 LEDs are placed in a 3D grid, each LED will have a tuple (x, y, z) represent its position; z represents the layer, x and y represent position in a 2d horizontal plane.

We will connect all 64 cathode pins of 64 LEDs on the same level (LEDs that have the same z-value) together, then use an 8-bit shift register (SN54HC595) to control the status of these 8 layers. Then, for LEDs with same x-value and y-value we will connect their Red anodes together, Green anodes together, and Blue anodes together. Since, a horizontal plane has 64 LEDs, we will need 64 bits to control the 64 Red anodes, 64 bits to control the 64 Green anodes, and 64 bits to control the 64 Blue anodes. Therefore, we will need  $64 * 3 = 192$  bits to control the

RGB Anodes of LEDs. Therefore, we will need  $192/8 = 24$  8-bit shift registers. All the shift register will be connected in series as shown below so that the control unit can control the LEDs by shift out data into the series of shift registers.



To control the LED, the controller unit will need to shift 200 bits into these 25 registers, then set the Latch pins of these registers so that the values is load into LEDs. These 200 bits can be indexed as follow:

[0-7]: To control which level is ON

[8-71]: To control Green Anodes

[72-135]: to control Red Anodes

[136, 199]: To control Blue Anodes

To control the color of the LEDs, we will use the BAM (Bit Angle Modulation) method. We will use 4-bit BAM, which give us 16 Red levels, 16 Green levels, and 16 Blue levels. Therefore, we will have  $16*16*16 = 4096$  colors.

Requirements	Verification
<b>1. Make sure each LED works properly, as well as having combinations/columns of LEDs work together.</b>	1. Test each LED before adding it to the grid, as well as testing each column of LEDs when put together in the grid. Lastly, test the entire grid of LEDs to make sure it lights up.
<b>2. LEDs' RGB functionality works in an appropriate manner.</b>	2. Test each RGB color by enabling it from the microcontroller.

### 2.2.7 Physical Button

The physical button allows us to change between the two modes our project contains: music-visualization and motion-controlled 3D Snake. The button is directly powered by the power module and after being pushed, the signal will go to the control unit and the mode will be changed. The LEDs will receive the signal and change accordingly.

Requirement: must be able to send the signal to the control unit and be able to change the operation mode.

Requirements	Verification
<b>1. Ensure that the LED device switches from Music Visualization to Snake mode.</b>	1. Connect the Pushbutton Switch to the microcontroller. With two states to choose from, we make sure that each button click responds correctly to the mode it is supposed to be in.

## 2.3 Software Flowchart

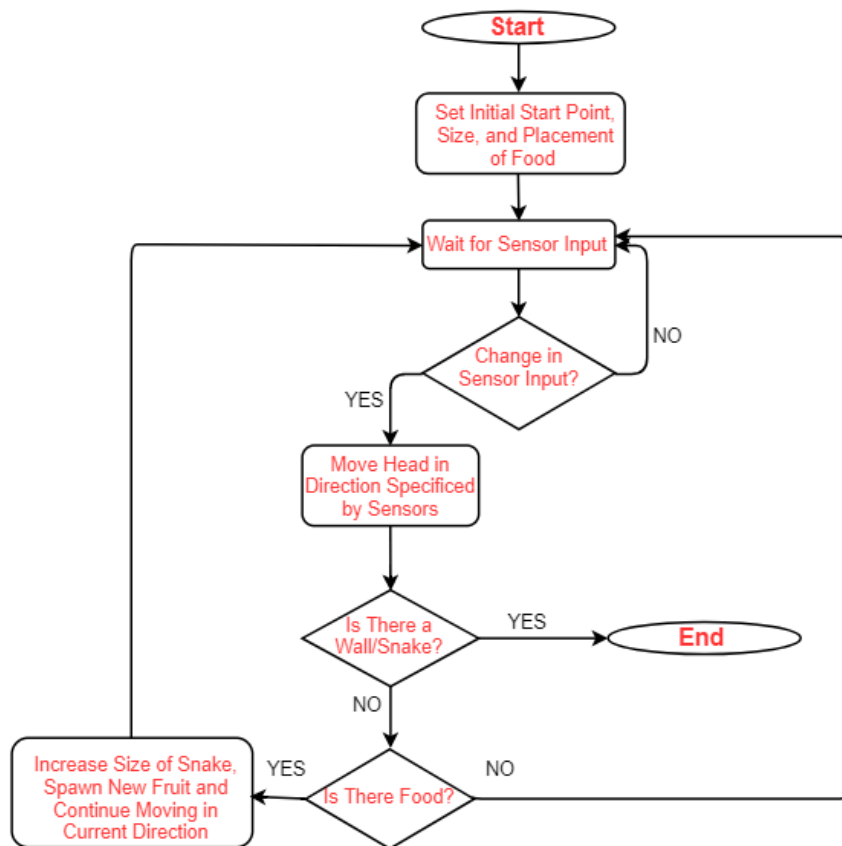


Figure for 3D Snake Game Flow Chart

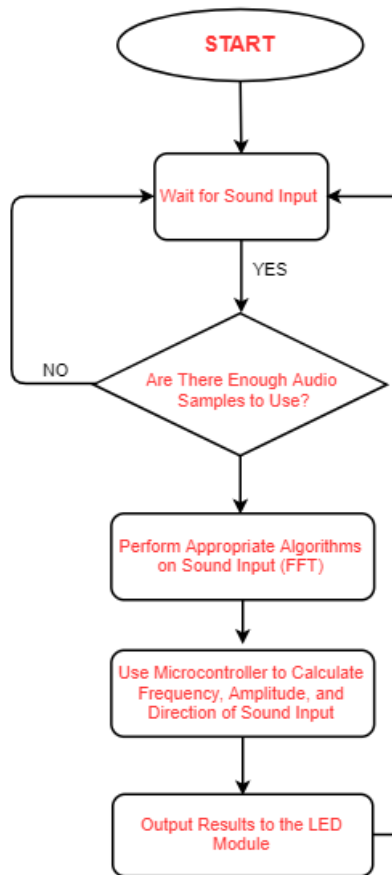


Figure for Music Visualization LED Device Flow Chart

## 2.4 Schematics

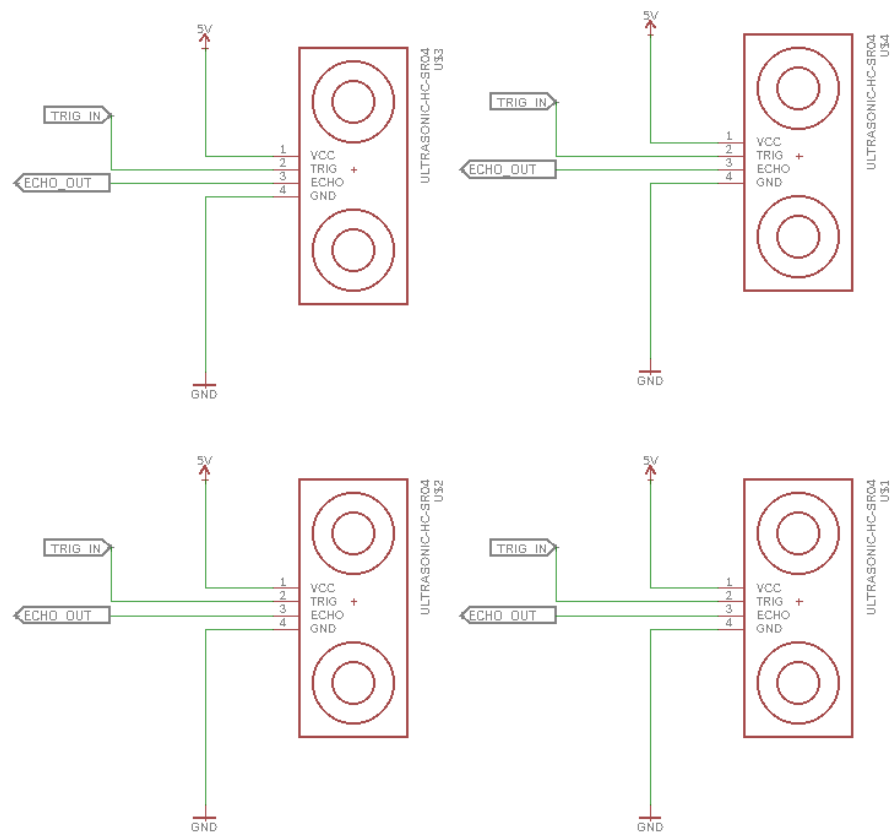


Figure for Ultrasonic Sensor Module

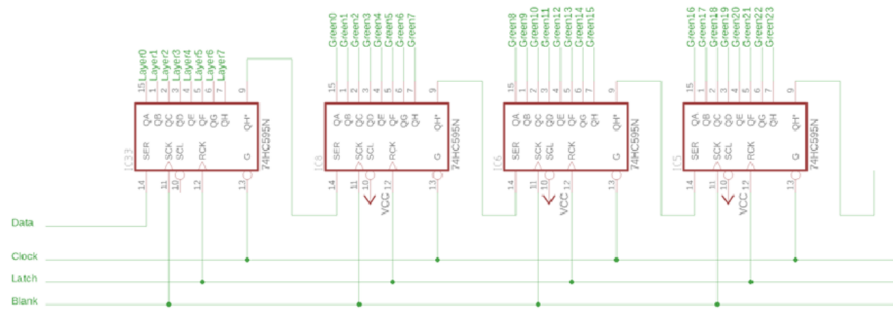


Figure for Registers

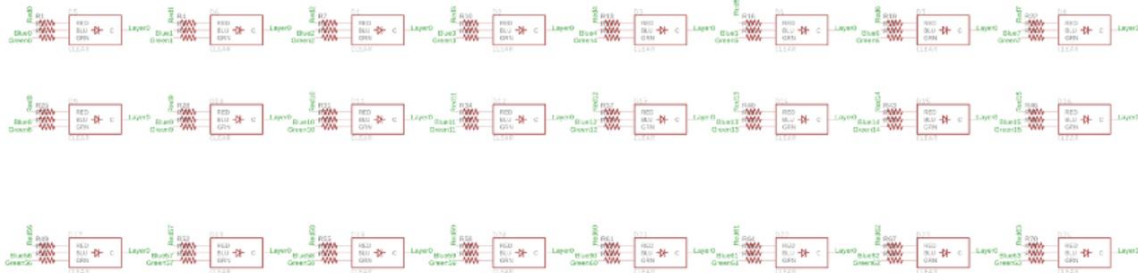


Figure for LEDs

## 2.5 Risk Analysis

The most difficult part of the project will be making sure all the LEDs in our grid are properly connected and functioning. Because we have so many LEDs, making sure all of them work immaculately is pivotal to our project succeeding. Some LEDs may also be faulty so replacing them could be very cumbersome. Additionally, making sure that the proximity sensors pick up the right signals and that we can translate them to directions for the Snake game will be somewhat difficult due to the nature of a sensor potentially not picking up the correct signal. Lastly, the microphones may not pick up the sound accurately and that could impair the visualizations made on the LED grid.

## 3 Ethics & Safety

For this project we will abide by IEEE's Code of Ethics [5] and also use our moral judgement when needed. We will respect all intellectual property laws and be honest with all the estimations and results during the entire process of our project.

We will be using an AC wall outlet to power our device so we need to make sure the voltage regulator is working properly. We must never allow a short circuit to occur as this could make the device overheat and potentially make LEDs explode. Our design will contain hundreds of LEDs, which will most likely be wired manually. The glass material and the fact that LEDs could be fragile could make the process challenging and dangerous. Because the device might be

viewed by the public, safety and proper containment of the device will be followed. Also, because we might use the soldering iron during the building of the device. We will follow the directions for using the soldering iron with utmost caution.

## 4 References

- [1] 'Kinetic Rain', Changai Airport Singapore, 2012. [Online] Available: <http://www.changiairport.com/en/airport-experience/attractions-and-services/kinetic-rain.html> [Accessed: 2-Feb-2018].
- [2] 'Metalier saves \$6.3 million dollars on kinetic sculpture', Metalier Coatings, 2015. [Online]. Available: <https://www.metaliercoatings.com/save6-3m-on-kinetic-sculpture/> [Accessed: 2-Feb-2018].
- [3] Emilie Chalcraft, 'Kinetic Rain by ART+COM', dezeen, 2012. [Online]. Available: <https://www.dezeen.com/2012/07/19/kinetic-rain-artcom/> [Accessed: 2-Feb-2018].
- [4] Chai Hung Yin, 'Woman arrested for damaging Changi Airport's kinetic rain sculpture', 2013. [Online]. Available: <http://www.asiaone.com/singapore/woman-arrested-damaging-changi-airports-kinetic-rain-sculpture> [Accessed: 2-Feb-2018].
- [5] IEEE.org, "IEEE IEEE Code of Ethics", 2018. [Online]. Available: <http://www.ieee.org/about/corporate/governance/p7-8.html> [Accessed: 4-Feb-2018].