ECE 445 Proposal
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1. Introduction

1.1 Objective:

The Importance of lighting often goes unnoticed. Light, like sound, has a heavy influence on the vibe of a room and can affect the mood of the people in it. People often take notice of this and attempt to control the vibe of their living space by adding various types of lighting fixtures. However, the mood of a room changes constantly, unlike a fixed light source. Constantly adjusting the lighting to adapt to the sudden changes of the environment is too cumbersome and unreasonable for any sane person.

To deal with this issue, we are attempting to create an LED based lamp that can sense various aspects of the changing environment, and adjust itself accordingly. Specifically based on the noise level which changes based on the number of people in the room and based on what they are doing in the same space. The lamp will also be able to change color based on the frequency of loud noise, causing the lamp to “dance” along with whatever music is playing. This lamp would also adjust itself as easily in silence as it would itself dim the LED when the noise level is under a particular threshold, hence the lamp would work like a light sensor in this case and dim the lights incase the noise threshold is very low.

1.2 Background:

Being college students we entertain a lot of guests at home and it’s mostly the lights and the music that sets the tone of night. Rather than only music we want our lamp to generally detect the mood in the room with the general noise level. Therefore at times when someone forgets to shut the lamp it will itself dim or luminate based on the noise level in the room currently. It concept of the lamp is to basically adapt to its surroundings based on the number of people and current mood of the room. With the mood we mean the color changing ability based on different environments and situations, here we do not mean to apply a particular algorithm but rather configure the lamp to illuminate/dim/change the color based on the inputs that we detect from the microphone and send to the microcontroller. So the ‘mood’ essentially is deciphered by how we configure the microcontroller for the different types of inputs and that would be done by setting up thresholds for a particular range of frequency which would be different of different types of things, like for example, frequency of conversation vs frequency of music.

We were specifically enamored by this project because this is something that we see ourselves using and bragging to our friends and family about. We want this to be that ‘one cool thing’ that we did in college. We understand that there are already products that change light based on some input but no product really that detects noise and changes light based on that input . For that reason we realize that this is more of a luxury project rather than a useful one but it helps us implement everything that we have learnt in college into use and put use of two of the most overlooked but important phenomenon of noise and light into good use.


[1]

Image 1: Picture of what we want our final product to output

1.2.1 Application:

The target audience for our particular product would most likely be college environments. This would be a sort of product that would mostly dazzle people from the ages of 15-30 as the way we see it, it basically comes into use during a gathering when you have music playing where this device adds the ‘wow’ factor to the room.

1.3 High-Level Requirements

- Lamp responds to changes in the amount of sound in the room,Typically the range of the sound of the room would vary from 10dB to 100dB, Where 45dB is the minimum intensity required to awaken a sleeping person. Hence we set our microcontroller to react only to anything above 45dB. Where (45-55)dBs serve as quiet environments where we would just want our lamp to be dim , (55-70)dB's will serve as conversation where we want our lamp to be bright and (70-90)dB's to be loud music where the lamp would change its colors based on the changing frequencies. Anything above the 90dB mark the lamp would not change from it's previous behavior(we don't expect it should go there)
- Lamp reacts differently to loud music (70-90 dB) than to regular conversation (45-70 dB)
- Lamp reduces brightness during a prolonged quiet situation (<45dB on average for 10 seconds straight)

2. Design

The lamp could be divided into four sections: sound detection, microcontroller, LED array, and power supply. The sound detection includes a microphone component to capture noise of environment, and inputs the signal to ADC to feed to the Microcontroller. Microcontroller receives data and conduct mathematical analysis to manipulate LEDs. LED array is the output of the whole system to provide luminance. Power supply is a AC-DC circuit generating steady 5V and 12V voltage to support microcontroller and LED.

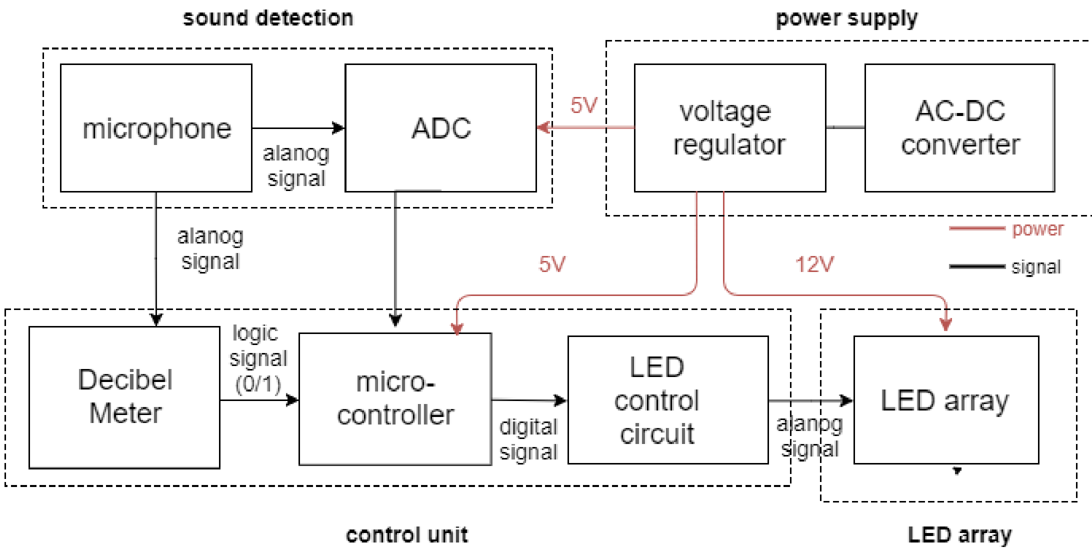


Figure 1: Design Block Diagram

The physical design of the lamp is similar to those sold on the market. Most part of circuits and power supply are inside the basement of the lamp. The led array, which is connected to basement with wire is on the top of a bendable pillar, so the user can change the orientation of light easily. There is a button on the basement for user to change different modes.

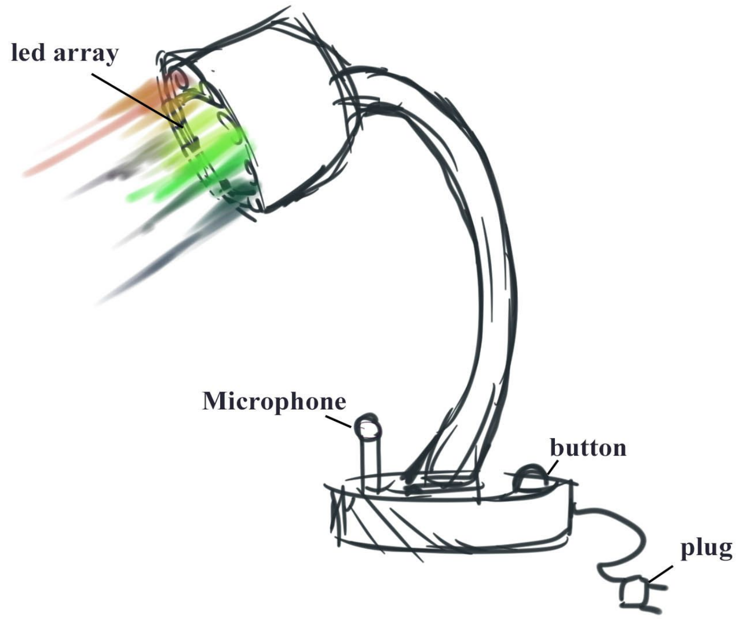


Figure 2: Physical Design Sketch

2.1 Sound Detection

The main feature of the lamp is its ability to respond to sound. This is accomplished using a microphone that detects the sound in the room, and then a filtering circuit to get rid of unnecessary data. Loudness thresholds will be determined by feeding the output of the microphone into a simple decibel measuring circuit.

2.1.1 Microphone

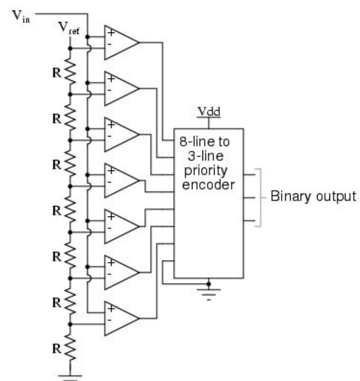
We will use a microphone to convert sound into a voltage waveform which we can then parse with Fourier analysis techniques.

Requirement	Verification
1. Frequency range: 20Hz to 16kHz 2. Sensitivity: (0dB = 1V/Pa) -30dB to -46dB	1. a. Use App called Sonic in smartphone to generate sine waves with different frequency(20Hz to 16kHz) and make the microphone receive the signals . b. Use oscilloscope to measure the outputs and observe if the outputs meet the expectation(sine wave with certain frequency without distortion)

	2. Use a decibel meter to verify the intensity levels of the sound

2.1.2 ADC Circuit

An analog to digital converter is a essential part in DSP, and how many information lost in the process depends on the number of bit we use to store digital information.
In the project we use flash ADC circuit to ensure speed because the device should be able to respond instantly to the sound change from environment.



[2]

Figure 3: Flash ADC circuit diagram

Requirement	Verification
1. To convert analog signal to 8-bits digital signal 2. To sample the signal at a rate of at least 20 kHz	1. Use oscilloscope to observe input analog signal and sent the analog signal into computer to compare with digital signal from microcontroller. 2. a. Feed output signal into oscilloscope and check frequency b. Since sampling rate is related to microcontroller, we would write a testing code to verify we have sampling rate with 20 kHz

2.1.3 Decibel Meter Circuit

In order to determine whether the loudness has passed certain thresholds, we will design a simple noise measuring circuit that only distinguishes between quiet, noisy, and loud music volumes. The circuit will look like the figure below, but with transistors that will turn on at each of the important sound thresholds.

Requirement	Verification
1. To convert analog signal to 8-bits digital signal	1. Use oscilloscope to observe input analog signal and sent it into computer to compare with digital signal from microcontroller.

2.2 Power Supply

The power supply convert the 120V AC electricity from socket to steady DC voltage to the other parts of the device, and some of them have different voltage requirement. It means that power supply should provide different voltage values including 9V, 12V.

2.2.1 AC-DC Converter

Since we want the lamp to be powered through a wall outlet, we will need a 120V/12V voltage regulator. However, we will be buying one off the shelf instead of designing our own in the interest of safety**.** It can not only convert AC to DC but bear maximum power of the whole device to avoid heat up and explosion. In concern of safety we may apply a ready component in our device.

Requirement	Verification
120V (AC) (wall outlet) converted to 12 V (DC)	Using a multimeter where we attach one end to the ground and the other to the VCC and check if the value meets the expectation.

2.2.2 DC-DC Converter

Since the microcontroller required 2.7-5.5V to operate, we need to convert the 12V from voltage converter to steady 5V for proper operation of microcontroller. A simpler method to achieve it is voltage divider circuit, which has low efficiency. To reach max efficiency we would apply a DC-DC converter to get 5V.

Requirement	Verification
1. Convert 12V to steady 5V.	1. Use voltage meter to measure the voltage value.

2.3 Control Unit

The control unit consists of the microprocessor on which all logical operations including FFT will be performed. The microcontroller outputs its signal to a voltage control circuit that delivers different voltage to control LED array.

2.3.1 Microcontroller

To deal with signal processing, the most important requirement of microcontroller is it should be able to conduct some heavy mathematical computing (mainly FFT) with high speed.
In this project we use teensy as microcontroller.
We plan on creating a logic that disregards signals with intensity less than 45db and treat signals with intensity between (50-70)db as conversation ranging from quiet to loud and from (70-90)db. Essentially we plan on having our microcontroller programmed to do the following:
Detect what type of a signal it is, whether it is conversation or music or silence.
Detection of type of signal is done through thresholds: Everything under 70 db is counted as conversation, where the conversation between 50-55 db is quiet the light should just be dim, 55-65 db is normal where the light should be bright and 65-70 db is loud where the light should be very bright. This luminance control would be handled through the voltage regulator. Everything over 70 db would be treated as music, If the signal lies in the music

range then we move on to apply FFT's on the signal to access the frequency and create logic to change the color of the lights according to whichever frequency in the spectrum has the highest decibel value. During a prolonged period of silence(<50db) the light would itself become really dim.

Requirement	Verification
1. Could conduct FFT with delay time between input and output signal < 0.1s 2. Have at least three analog output. 3. We expect our code for the microcontroller to be under 20 kbytes which can be directly accessed from the Teensy 3.1/3.2 RAM which is 64 kbytes. 4. Operate voltage is between 3.3v to 5v	1. Write testing code to record the real time of FFT which MCU computing. 2. Fetch the Specifications to verify. 3. Connecting MCU to computer and check the size of program. 4. Input voltage between 3.3v to 5v to MCU and check if the MCU operate successfully.

2.3.2 LED Control Circuit

This part includes MOSFET as bridge connecting the analog output of microcontroller and LED array with current limit awareness, and a decoder with MOSFET as switch to make LED light up turn by turn.

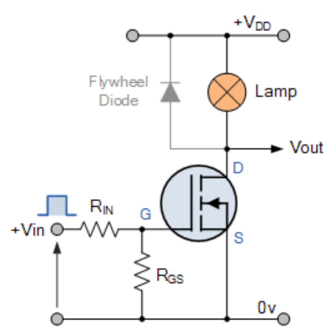


Figure 4: Mosfet as switch

Requirement	Verification

1.Total current tolerance > 0.6 A 2. Input 3-bit digital signal to control on/off 3. Input 3 analog signal to control color	1. Use current measurer to measure the value of current 2. Use decoder and mosfet as switch and verify they can work properly. 3. Use mosfet as bridge between MCU and led to bear large current flow. *

2.4 LED Array

The LED array consist of eight individual parts to perform different color and luminance. Generally the LED light consists of R,G,B input to determine the color performance. Since R, G, B inputs require analog signal and limit number of analog output of microcontroller, all the separate LED parts will have common R, G, B inputs, and then every LED take turn to light up in very short time as if they shined simultaneously.

2.4.1 LED Light

The main advantage of led light is low power consumption for safety and energy saving purpose. It's also easy to control by simple circuit. We consider to apply led strip in our device for providing sufficient luminance.

Requirement	Verification
1. Current draw < 250mA per 200cm 2. Luminance > 100 lux in room	1. Use current measurer to measure the value of current 2. Use luminance detect APP to measure the values with different distance and record the values.

2.5 Schematic

A) MCU

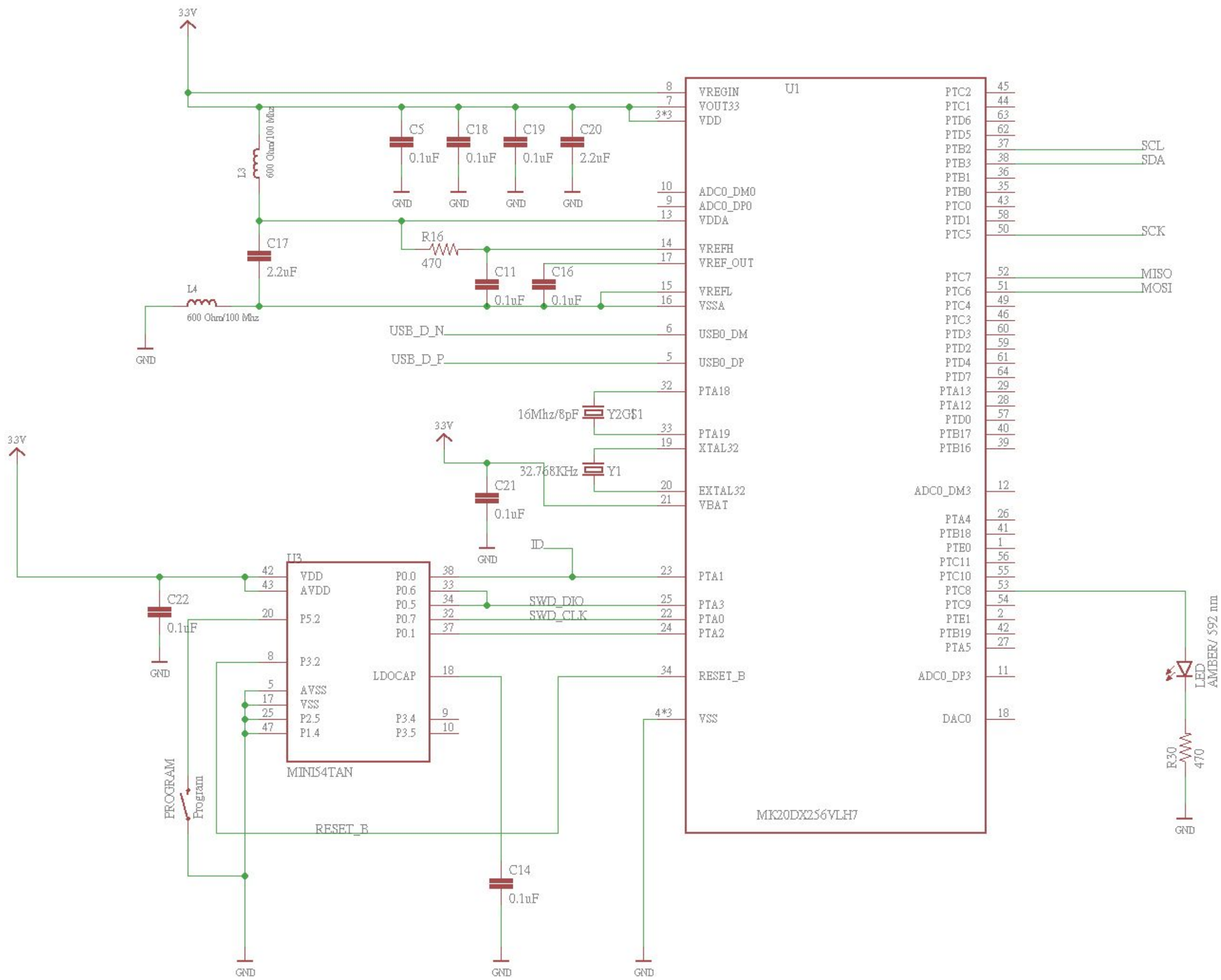


Figure 5: Schematic for Microcontroller Unit[5]

B)ADC

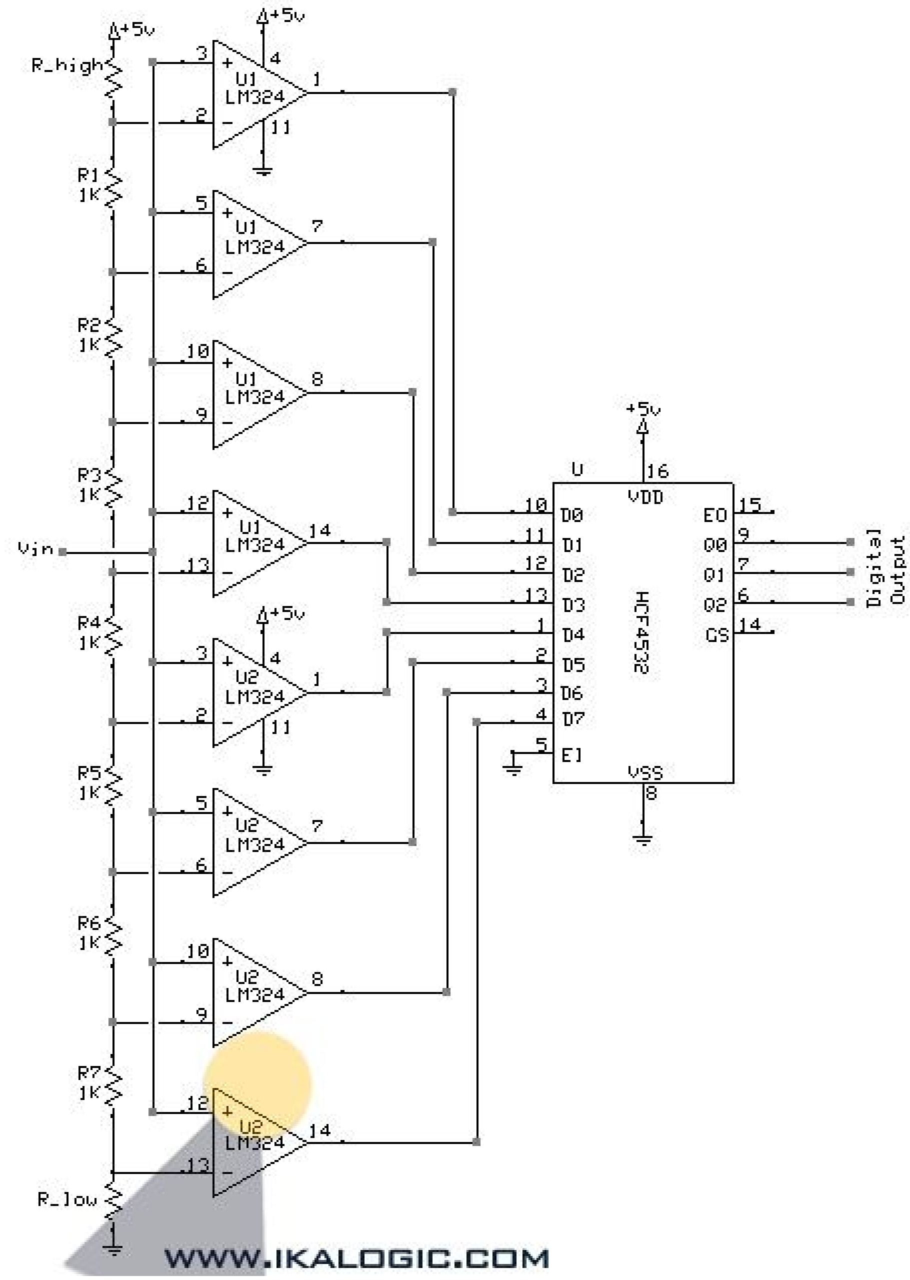


Figure 6: Schematic of ADC[6]

C)Led Control Circuit

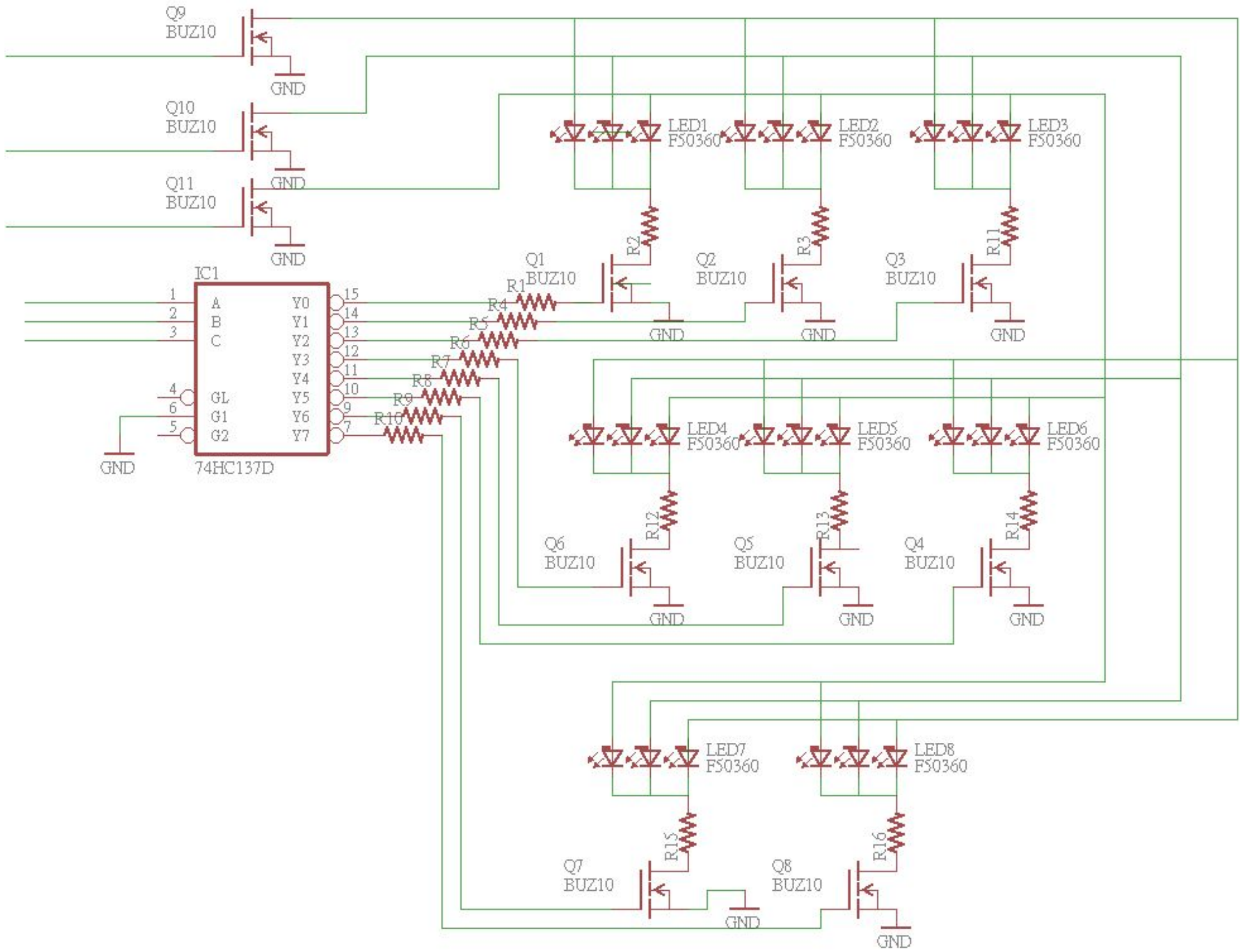


Figure 7: Schematic of LED Array

D)Decibel Meter

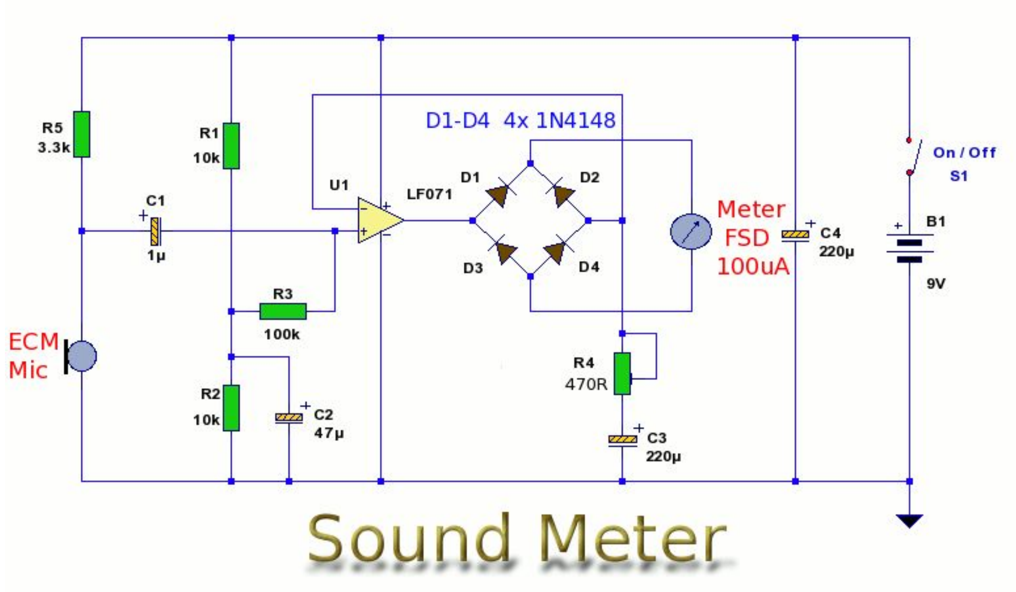


Figure 8: Schematic of Decibel Meter[7]

2.6 Software Flowchart

The purpose of this flowchart is to detail the higher level reason behind the lamp's operation. It starts by checking the amplitude of the sound waveform (revised in our design to be the output of our decibel meter circuit) against a low threshold (50 dB, still subject to adjustment of at most +5 dB). The result initiates a counter to keep track of how many cycle iteration a particular state (above or below the low threshold) has been maintained. If the state has been maintained for 10 seconds, the overall condition of the general noise level is set (QUIET or NOISY). Both of these states correspond to a constant light level. NOISY is a mid brightness white light, and QUIET is a soft yellow light. However, both of these states can be momentarily (immediately as opposed to after 10 seconds) interrupted by the MUSIC state, which corresponds to a decibel level above our high threshold (70 dB), which is checked next. This mode of operation hightens the overall brightness of the lamp and changes the color to match the associated note (pitch) associated with the most dominant frequency measured by the FFT analysis. The changing colors will simulate a musical lightshow when reacting to the changing frequencies of loud music.

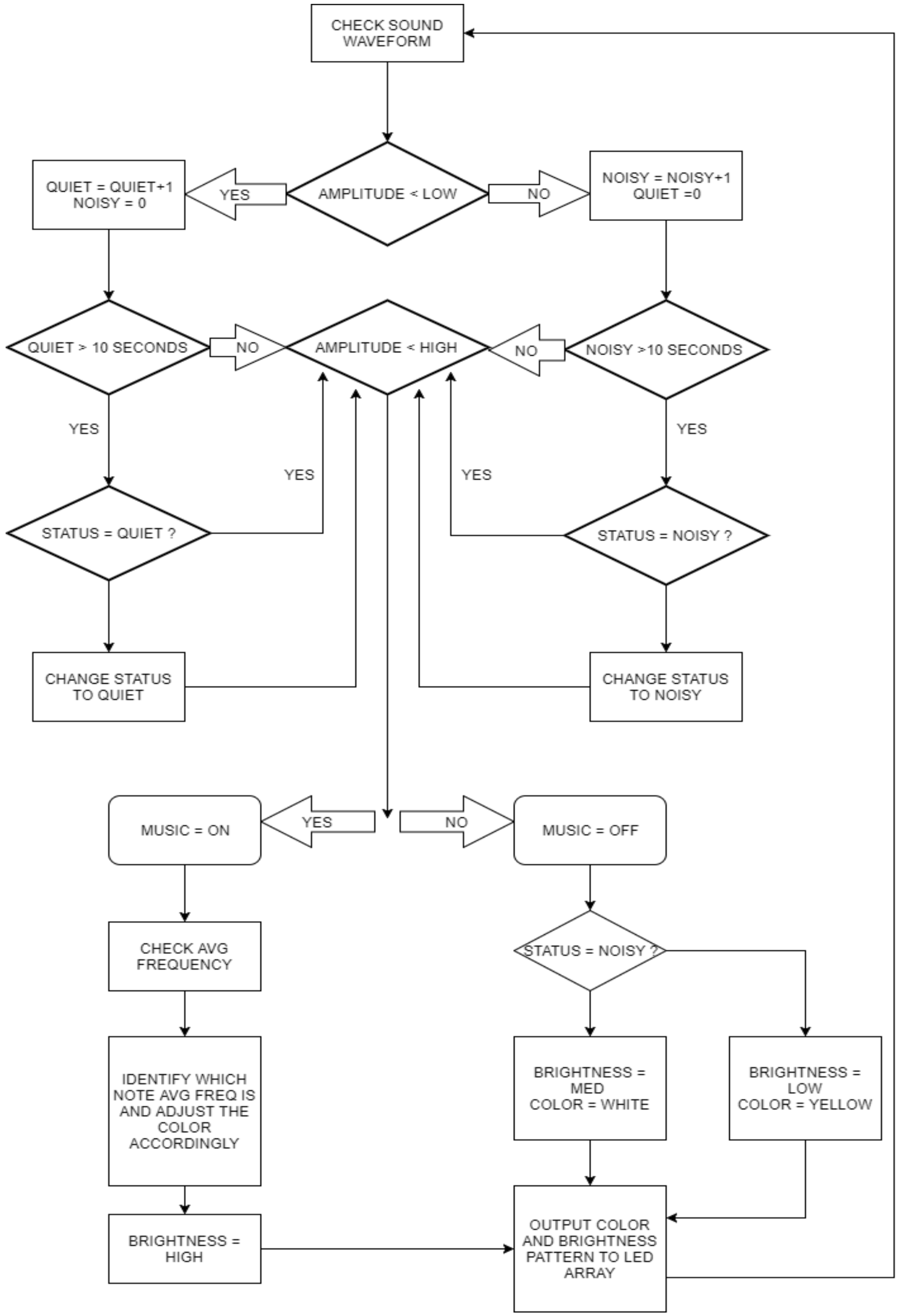


Figure 9: Software Design Flowchart

2.7 Tolerance Analysis

One consideration of analog to digital processing is aliasing. According to Nyquist theorem, the sampling rate should be twice of the frequency of input signal. Since the operation frequency of MCU is 2 MHz, so the sampling rate is definitely twice of the 16 kHz, which is the max of the frequency range we set. In other hand, we just need proper sampling rate to deal with 16 kHz input signal. In this case, we apply a anti-aliasing circuit to prevent aliasing causing by the signal component with frequency being over 16 kHz.

A anti-aliasing circuit is basically a low pass filter to filter out unrequired high frequency component. We apply the active low-pass filter as below:

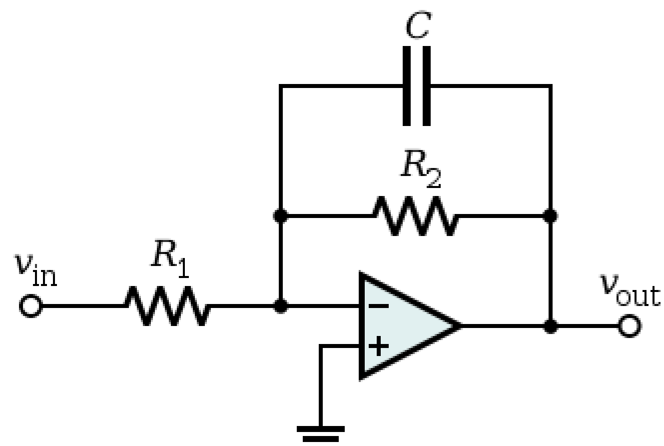


Figure 10: Active low-pass filter[8]

The cutoff frequency (in hertz) is defined as: R

$$fc = \frac{1}{2\pi RC}$$

To get cut frequency equal to 16 kHz, RC should be 9.95* 10^{-6} .

Choose C = 1 uF, we get R = 9.95 Ω.

With implementation of low-pass filter, we can lower the sampling rate to reduce the burden of microcontroller if necessary.

3. Cost

$$3 * \frac{\$40}{hour} * \frac{10hour}{week} * 10week * 2.5 = \$30000$$

Our labor cost are estimated to be $0.88/hour and 10 hour/week with 10 week to finish our project.

Part	**Cost**
Microphone	**$0.95**
AC-DC converter (120V-12V**)**	**$8.95**
RGB Led *30	**$45**
Microcontroller (Teensy USB Development Board**)**	**$19**
N-channel MOSFET(IRLB8721 **)**	**$4.04**
Resistors, capacitors, ICs, crystals, sockets, etc.	**$20**
PCBs (PCBway)	**$0**
Total	**$97.94**

The grand total of the cost is $30097.94

4. Schedule

Week	**Event**	**Sahil**	**Brian**	**Yu**
10/9/17	Sound Detection Block	Building of ADC circuit , Installing and testing the microcontroller device on computer	Building of ADC circuit	Building of ADC circuit for PCB, Installing and testing the microcontroller device on computer
10/16/17	Sound Detection Block	Building of decibel meter circuit	Building of decibel meter circuit	LED Array, Start with PCB design for decibel meter on Eagle
10/23/17	First round PCB order	Coding Microcontroller	Start with Voltage regulator Design	Coding Microcontroller
10/30/17	Test the whole system on breadboard(11/4)	Coding Microcontroller, Verification of Microcontroller	Building Voltage regulator design	Coding Microcontroller, Verification of Microcontroller
11/6/17	Final round PCB order	Multiplexer/Decoder for control circuit, Finish PCB design on Eagle	Multiplexer/Decoder for control circuit	Finish PCB Design on Eagle
11/13/17		Solder PCB, Adding components	Solder PCB, Adding components	Solder PCB, Adding components
11/20/17	Thanksgiving	Polishing up Final Design document	Polishing up Final Design document	Polishing up Final Design document
11/27/17		Verification of all components	Verification of all components	Verification of all components
12/4/17	Demonstration	Prepare for Presentation	Prepare for Presentation	Prepare for Presentation
12/11/17	Presentation			

5. Safety and Ethics

The main safety concern of our device is about the power supply. With improper design the whole device will heat up to burn due to short circuit or other reasons. To avoid any accidence, we may buy a supply rather than design by ourselves.

The other potential safety problem is about our eyes. Human's eyes are vulnerable so the light luminance should be controlled in a proper range. Some color of light with certain frequency may bring damage to eyes. According to these reasons, the output of the lamp are required to provide sufficient luminance but be gentle at the same time.

There are not any ethical concerns related to our project because it is a lamp. As long as we buy a premade AC/DC converter to deal with wall outlet power, there are also no safety concerns. Although we will have to be courteous to our peers and the lab guidelines and maintain a strict rule of not getting food or drinks to the lab and making sure our workbench is clean before we leave. We should also maintain the safety guideline mentioned in the Safety page of ECE 445 of *'No one is allowed to work in the lab alone. At least 2 people must be in the lab at all times.'* [3]

We still need to maintain a safe environment not only for ourselves but for everyone working in the lab, we need to comply by the rules in the safety manual and report any dangerous activities. As mentioned in the IEEE Code of Ethics *'As a researcher you are responsible for performing your work safely. Make sure to complete all required safety training and follow all laboratory safety procedures and campus policies. Report unsafe conditions and faulty safety equipment to your PI or another responsible person.'* [4]

6. References

[1] Google Images: https://www.google.com/search?q=color+changing+lights+room&source=lnms&tbm=isch&sa=X&ved=0ahUKEwiantGOlNjWAhWJrVQKHTuZAOEQ_AUICygC&biw=1366&bih=662#imgrc=wwwwkD7PeVW1BM:

[2]https://www.allaboutcircuits.com/textbook/digital/chpt-13/flash-adc/

[3]https://courses.engr.illinois.edu/ece445/guidelines/safety.asp

[4]IEEE Code of Ethics: https://captivate.research.illinois.edu/263/index.html

[5]https://www.pjrc.com/teensy/eagle_lib.html

[6]http://ikalogic.cluster006.ovh.net/wp-content/uploads/flash.jpg

[7]http://www.zen22142.zen.co.uk/Circuits/Testgear/soundlevelmeter.htm

[8]https://en.wikipedia.org/wiki/Low-pass_filter#/media/File:Active_Lowpass_Filter_RC.svg