Noise-to-Color Visualizer (NCV) Device

Team 41

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ECE 445 Mock Design Review – Fall 2017

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1. Introduction

A. Objective

We are exposed to various intensity of sound daily. Constructions, sound bar, café and streets are all filled with noise generated by many different sources such as cars, animals, and human conversation. However, according to American Academy of Otolaryngology, one in 10 Americans has a hearing loss that affects his or her ability to understand normal speech [1]. Moreover, as the audio technologies advance, the demands for High-Fidelity headphones are skyrocketing, which also affects our hearing as the headphones and earphones greatly stimulate eardrums. Today, 1 in 5 teens has some form of hearing loss, which many experts believe is due to the increased use of headphones, as presented in American Osteopathic Association [2]. Clearly, the exposure to excessive noise may damage hearing, and we have to avoid such situation as much as we can.

Our project is to design a device that visualizes the noise level by classifying the noise levels into five different color: Red, Yellow, Green, Blue, and Pink. We will scale red being the loudest and pink being the quietest. By interpreting the decibel into a simple color, we can clearly observe how noisy the surrounding is. Moreover, with this device, people cannot be selfish and subjective about the noise level because the device would indicate the level of sound at a glance.

B. Background

Often, we are very subjective about the noise level around us. Some people desire listening to music with booming sound while some just want the music to be controlled at certain level. Or, when we are involved in conversation, we often ignore that the fact we are making noise that disturbs the people around us. There are cases like even in crowded space, some people say it’s manageable while some say the place is very noisy. Considering these facts, we believe it’s just too difficult to be neutral at judging the level of noise. Plus, numeric display of noise level does not actually make sense to children or those who are not familiar in the area. For them and in general, it would be much easier to visualize the noise level with a color so that when we tell our friends about the noise level at certain place, it would give them clear image of how quiet/noisy the place is. Additionally, we would be able to avoid unwanted exposure for loud and disturbing level of noise for several hours.

C. High-Level Requirements List

1. The microcontroller should be able to support Fast Fourier Transform or equivalent logic code and convert analog signal to digital signal as it should use the input, which is the level of noise, from bandpass filter to be under control of implemented logic.
2. The signal should be between 20 Hz to 20 kHz ideally because we will be dealing with the

noises in the range of human perception.

3. The LEDs should be able to light up to the corresponding noise level each represents.
4. There must be a way to collect noise level from multi-direction.

2. Design

We would divide the device into sections: Power Supply, Input-to-Output (I/O) system Circuit, and control system.

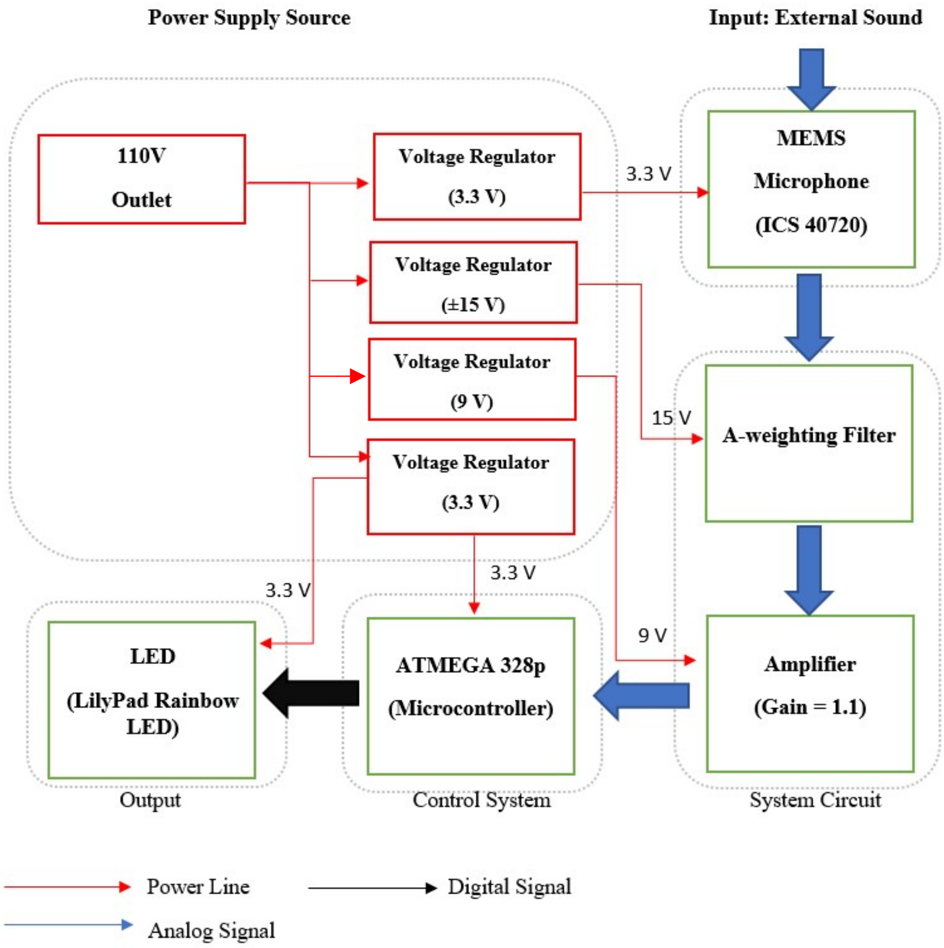

Figure 1. Block Diagram

2-1. Power Supply

To supply power into the device, we will use 110 V outlet from the wall or any adaptors. We will then use voltage regulator by implementing AC-to-DC converter to supply voltage into the microcontroller, which operates within 1.8 ~ 5.5 V and we are looking to provide 3.3 V. MEMS microphones and LilyPad LEDs both have 3.3 V.

Requirements	Verification
1. All devices must have corresponding or operating voltage level to perform its functions.	1. a). Set up regulators that converts the 110 V into corresponding voltage levels of each elements of the device. b). Allow tolerance level to ± 5% from the voltage so that small change would not disrupt the entire system.

2-2. I/O System Circuit

2-2-1 MEMS(Microelectromechanical Systems) Microphones (Model: ICS 40720)

We will be using MEMS microphone to collect the noise level of the surrounding. To be accurate, we will use 4 MEMS microphones to collect noise samples from 4 different directions in respective to the user. By taking the mean of the 4 signals, we can estimate more sense of how much decibel we are getting from multiple direction. Another fact about microphone is that it is already Band Pass filter because it detects the sound between the range 75 Hz to 20 kHz, according to the specification.

Requirements	Verification
1. The Microphones should be able to process good quality of sound within the human hearing ranges. 2. The Microphones should be able to collect sounds from multi-directions.	1. Aim for the high Signal-to-Noise Rate using the additional circuits that would remove unnecessary noise levels. 2. Two solutions a). Obtain omni-directional microphone. b). Install four microphones, each separated by 90 degree from each other.

2-2-2. A-Weighting Filter

By definition, A-Weighting Filter took model human ear perception because human ears are unable to sense certain high frequency sound levels as supported with the graph below.

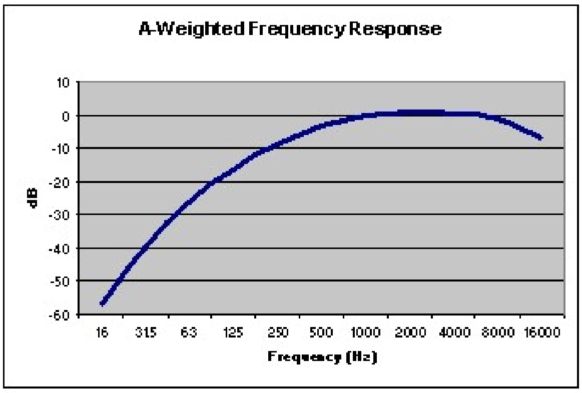

Figure 2. Ideal Frequency Response of A weighting Filter

When we measure the sound level through machine, this is not very accurate description of what we perceive because machines and human ears have different sensitivity. Human ear responds more to frequencies between 500 Hz and 8 Hz and less sensitive to very low or high pitch noises [3]. Therefore, weighting filters are used to help converting instrument-measured sound level to relative human-hearing loudness. Typically, A Weighting Filter is most commonly used filter for measuring the sound level because it effectively cuts off lower and higher frequencies that average person cannot hear, which resembles human ear.

Requirements	Verification
1. Human ear perception is much different from machine calibration of sound level.	1. Adopted the A-Weighted Filter to closely resemble the human ear-perception process.
2. The weighted filter should have 0 dB or near the value from 1kHz to 8 kHz approximately.	2. Adjusted the gain of second Op-Amp to be 1.56 to make the log-scaled dB to be close to 0 dB.

As implementing the schematics for the A-Weighted filter, we set the Op-Amps within the filter to be operated at 15V, using the model LM324 [4], with Unity gain for U3 for fully compensated internal frequency.

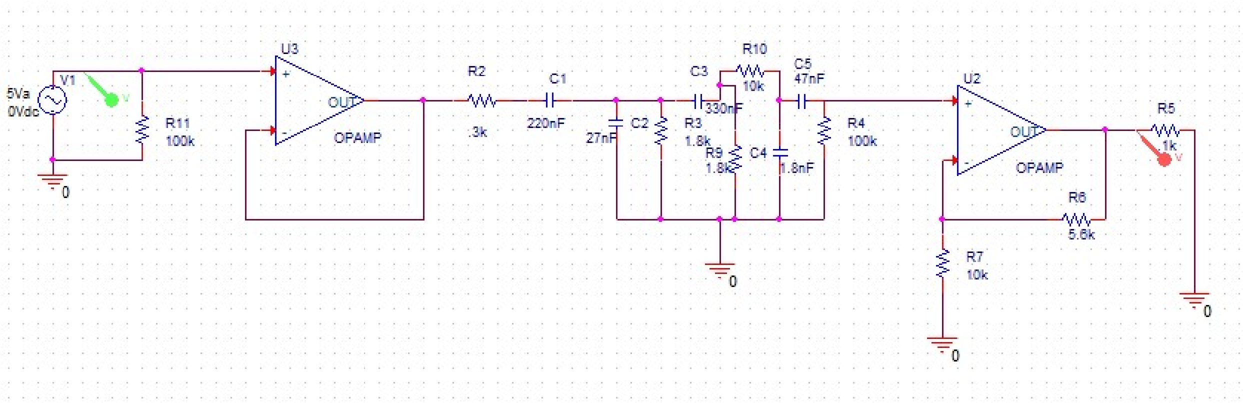

Figure 3. Schematics for A-Weighting Filter [5]

Second Op-Amp, denoted U2, has gain about

$$A_v = 1 + \frac{R_6}{R_7} = 1 + \frac{5.6}{10} = 1.56$$

to adjust the decibel level of around 1kHz (1000Hz) to 8 kHz to possess near 0 dB, as ideal A-weighted filter indicates that the humans are generally not aware of the noise with frequency range approximately between 1 kHz to 8kHz. The simulation of the above circuit through OrCAD is shown below. Note that the first graph shows the voltage response in non-log scale and the second graph shows the voltage response in log-scale, which is basically the decibel range as referring to the following equation [6].

$$P_o(Power)\ Watts = 2 * 10^{-6}\ Pascals = Universal\ Constant$$

$$L(sound\ level)\ dB = 10 \log\left(\frac{P}{P_o}\right)^2 = 20 \log\left(\frac{P}{P_o}\right)$$

Eq 1. Decibel Calculation

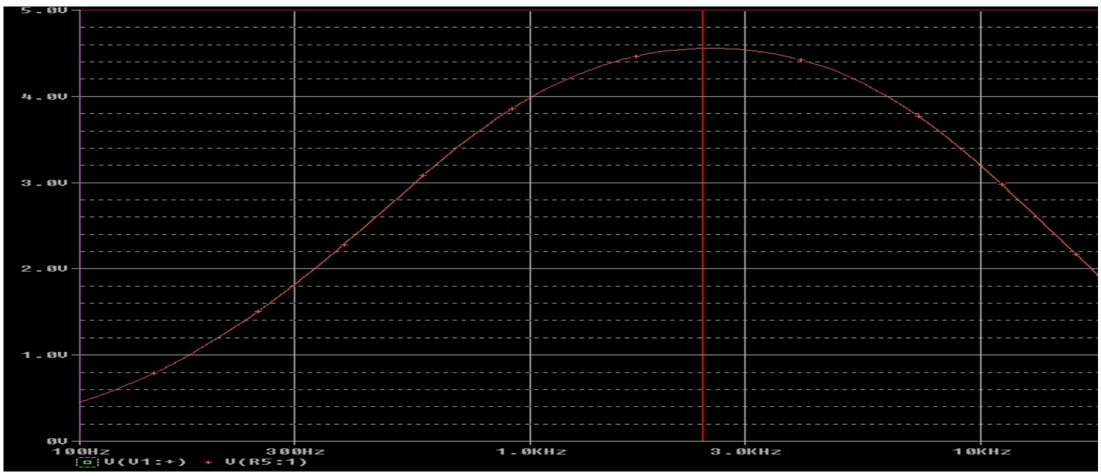

Figure 4. Voltage Response from 100 Hz to 20kHz

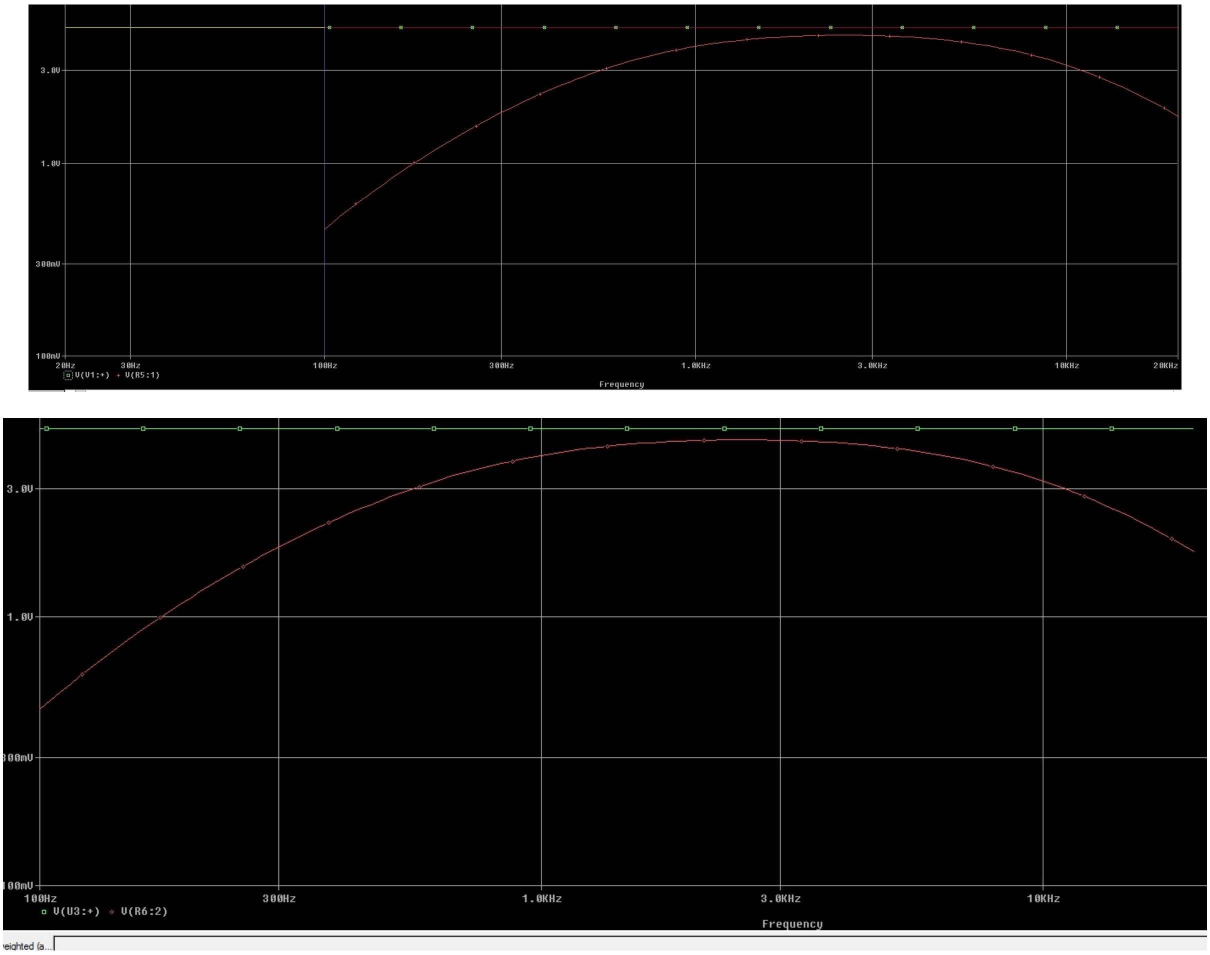

Figure 5. Log Scaled version of Voltage Response

2-2-5. Amplifier

Since all hardware circuits may possess loss in the amplitude of signal as it processes through all different elements of circuit, we would like to implement circuit for an amplifier to restore back to the original amplitude of signal. The gain of the amplifier depends on how much voltage level is achieved by the A Weighting filter. For example, when the original signal has amplitude of 5V and post-A Weighting filter amplitude was observed as 4.5, the gain of the amplifier would be $A_v = \frac{5}{4.5} \cong 1.111$. We might need slightly more than the gain we calculated because there could be some loss due to circuit elements. The desired output frequencies are frequencies between 20 Hz to 20 kHz, as long as it keeps the both ends.

Requirements	Verification
1. Amplifier should output analog signal that has amplitude very close to the original signal amplitude.	1. Set up equation that estimates the loss rate of the amplitude of signal, and adjust the gain rate of the amplifier circuit with

	calculation and simulations.

2-2-6. LED – LilyPad Rainbow LEDs

As the microcontroller makes instruction, the command signal would pass to LED panel to light up certain color. There are total six colors of LEDs, each with different colors, and depending on the sound level, one of the LEDs would light up. Lilypad Rainbow LED has 6 colors (Red, Blue, Green, Yellow, pink, and White) and furthermore can be customize the color as customer's sate.

Requirements	Verification
1. LEDs should receive command from the microcontroller unit for demonstrating the corresponding color of LED to the noise level.	1. a). Set the output of the Microcontroller unit to be digital to send true (1) and false (0), where 1 will be assigned to the corresponding LED with noise level it calculated b). All inputs to the LED must be connected to the "Digital Pin" of the Microcontroller.
2. No more than 1 LED should be lighten up simultaneously	2. Allow microcontroller to only send '1' for one of the digital outputs while ensuring '0's for the rest of the digital outputs.

2-3. Control System

Microcontroller: ATMEGA 328P

Operating Voltage Range: 1.8 – 5.5 V.   Allow ± 5% tolerance range

Requirements	Verification
1. The input to the microcontroller is the analog output from the amplifier circuit.	1. Connect the output wire to the Analog Pin of the microcontroller.
2. The microcontroller should pass the analog signal to Analog-to-Digital Converter in order to process the analog sampled sound profile and analyze its characteristics (noise level in dB).	2. a). Implement in following order: decibel calculation using the **Eq.1** the algorithms. b). Test it with arbitrary value of signal generated by the A-Weighted filter and read

3. The output of the microcontroller should be digital command of turn on or turn off (1 and 0) for each digital pin connected to each of the LEDs.	off the value through simulation by the microcontroller. 3. Only one of the digital outputs would be True(1) and the others be False(0) since there could not be overlapping sound level.

The ideal microcontroller for our project should be able to support Analog-to-Digital Converter (ADC) embedded and the functionality of FFT as well as programmable. Considering these qualifications, we decided to use ATEMGA 328P, which possesses the desired functionalities.

After getting the range of frequency to analyze, we will be implementing the following algorithm written in pseudo-code:

```
Color_Select(x){
Switch(x = noise level)

Case1 (x >= 110 dB) return Color Red;
Case2 (x >= 95 dB && x < 110 dB) return Color Yellow;
Case3 (x >= 80 dB && x < 95 dB) return Color Green;
Case4 (x > =65 dB && x < 80 dB) return Color Blue;
Case5 (x > =50 dB && x < 65 dB) return Color Pink;
Case6 (x < 50 dB) return Color White;

}
```

Figure 3 Pseudo-code for color selection

2-4. Risk Analysis

The block of greatest risk to be successful completion of the project is the filter. As seen, we will be using two filters, bandpass and A weighting filter, which require in-depth research in the area of sound detection techniques. We also have to take human ear perception into consideration because machine-detected sound level is not the level humans are feeling. Therefore, the accuracy would not be 100% satisfying because human ears are very complicated and different individually. There are many options of weighting filters as B-type, C-type, and Z-type yet A-type is most commonly used and demonstrate closest proximity to human ear sensitivity. Errors may exist and our task is to minimize the error for this block, which is the biggest concern.

3. Ethics and Safety

First, we will put our best effort for keeping our project ethical in accordance with IEEE code of Ethics #1, 2,4, and 8 [7]. We believe that the best way to solve the conflict is the frequent conversation to each other, enabling us to understand and aid each other whenever possible. Thus, there will be no discrimination on any types of background. All individual opinions will be valued and put into consideration. From beginning to the end, we will make sure the design engineering process is clearly visible to ensure reliable and trustworthy product as IEEE code of ethics #3 states.

Since our project involves complexity in hardware design as well as human ear response, sufficient amount of background research would be required to optimize the quality. Abiding IEEE Code Ethics #5, we are looking to use best possible technology with appropriate functionality to better the quality.

Under IEEE code of ethics #9, the priority will be placed on the safety of users. Our primary and only safety concern lies on the AC-to-DC conversion circuits, which would involve manipulating a high voltage that could cause accidents. Although we may keep ourselves away from potential dangers, we acknowledge that there could be unexpected dangers of using the power, and do our best to optimize the circuit and hardware design that minimizes the potential power and circuit failure with in accordance with IEEE code of ethics #1. Along with the rising role of Social Network Service as well as caution notes, we will be providing how to avoid and prevent dangerous circumstances.

Moreover, as IEEE code of ethics #7 states, we will accept the designated TA's advice in order to focus on the purpose of the ECE445 course as well as crediting the contributions of others by citing their works. Additionally, to correct errors in timely manner, the frequent debugging process would be recorded as we proceed in hardware and software designs.

References

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