# CSE 3323 - Electronics for Computer Engineering

# Fall 2015

# Term Project

# The University of Texas at Arlington

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## 1.1 Description

For my term project, I chose to construct a sound detector. The sound detector will use an electret microphone to detect sound and pass that signal to a pair of operational amplifiers. The first amplifier will amplify the signal that it receives and the second amplifier will buffer that signal based on the threshold of the circuit. Then the signal will be sent to a LED light and its brightness will depend on the output of the second amplifier. After that the same signal from the ouput of the second operational amplifier will be sent to a Teensy 2.0, where it will perform an analog-to-digital conversion and convert the value read to voltage and then use that voltage to calculate the decibels of the signal. Finally, based on the decibels calculated the proper LEDs will be turned on. If the decibels range is betweem -12 and 11, then the green LED will be turned on. If the decibel is 11 to 14, then the green and yellow LED will be turned on. And if the decibels range is greater than or equal to 14, then the green, yellow, and red LED will be turned on. If no sound is detected, then all the LEDs will be off.

The purpose of creating a sound detector is to improve my knowledge of the different types of amplifiers (how to they work, how to use them, etc.), filters (high pass, low pass, etc.), and apply some of the knowledge learned in this course and my digital signal processing course. Other reasons include being able to apply this circuit in different scenarios like security system that will sound the alarm if it hears a noice above a certain decibel. Also helping a person that has a hearing impairment if someone rang the door bell by modifying the threshold of the circuit to the same decibel as the door bell. This type of circuit may also be used in the robotics field by having a robot perform certain action based on the level of sound detected. By building this sound detector, in the future I can use it for more complex uses.

### 1.2 Flow of Control

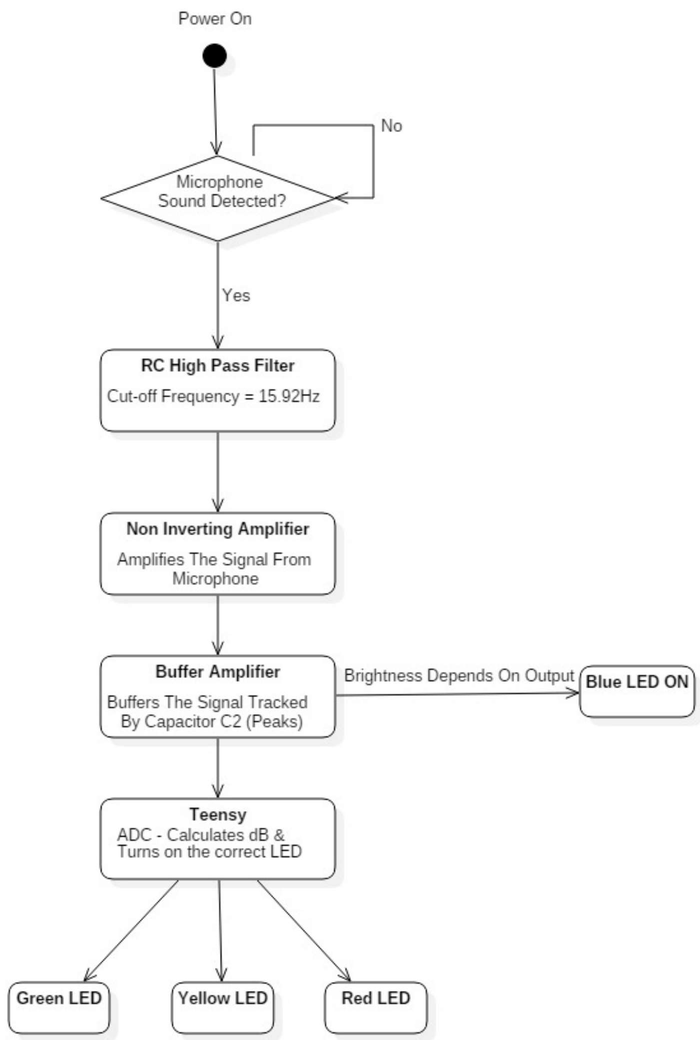



Figure 1: Flow of Control Diagram

# 2 Low Level Description

## 2.1 Components Role

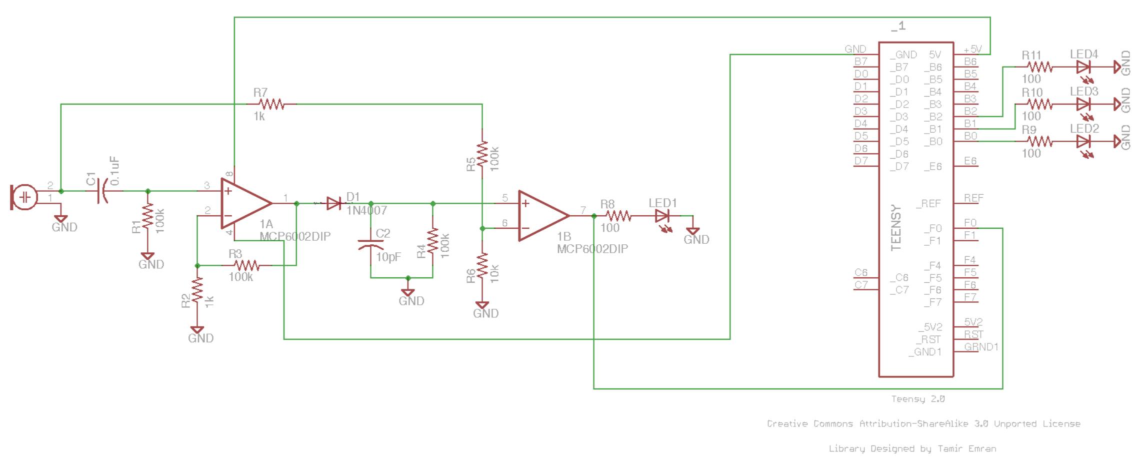
The role of the electret microphone is to pickup noise and transmit that signal in order to different portions of the circuit. As for the capacitor C1 and resistor R1 their role in their circuit is to serve as an RC High-Pass filter and only allow a signal with a cut-off frequency of 15.92Hz, any signal below that frequency will be ignored. Once the signal passes through the high-pass filter, it will go by the first operational amplifier (MCP6002), the purpose of this amplifier is to serve as a non-inverting amplifier. The non-inverting amplifier has resistors, R2 & R3, connected to the negative inputs because they need to amplify the signal transmited by the electret micrphone. The signal needs to be amplified because the output of the electret microphone is very small (mV). The gain of the operational amplifier is 101. The output of the non-inverting amplifier is connected with resistor R3 and by a diode (1N4007) in

order to prevent the signal from going back to the operational amplifier. After that the signal goes through capacitor C2 and resistor R4, both components serve as a circuit that peaks the signal. When the output of the non-inverting operational amplifier is high, C2 charges through R4, and C2 peaks the signal. Then the signal goes to the other operational amplifier, which serves as a buffer amplifier where it tracks the peak amplitude of the signal; the higher the sound, the higher the voltage. In order to track the peak in amplitude the operational amplifier negative inputs are connected to resistors R5, R6, and R7. All three resistors are connected in series and the terminal connections between R5 & R7 are connected to the +5V supply. The other terminal of R7 is connected to the electret microphone in order to buffer the signal.
Finally, the output of the buffer amplifier is connected to resistor R8 and LED1 (Blue) which will be illuminated according to the voltage that the operational amplifier outputs. The higher the voltage, the brighter the LED. The output of the buffer amplifier is also connected to pin F0 of the Teensy 2.0. This pin is set as input in order to receive the signal and perform an analog-to-digital conversion. Inside the micrcontroller, the analog signal is converted to voltage and then to decibels. Based on the decibels the correct LEDs will be transmitting light. LED2 (Green) is connected to pin BO and resistor R9, LED3 (Yellow) is connected to pin B1 and resistor R10, and LED4 (Red) is connected to pin B3 and resistor R11. If the decibels are greater than or equal to -11.00 and less than 11.00, then the LED2 will be turned on. If the decibels are greater than or equal to 11 and less than 14, then LED2 & LED3 will be turned on. If the decibels are greater than or equal to 14.00 then LED2, LED3, & LED4 will be turned on. And if the decibels is equal to -0.00 (infinity) or any other value less than -11.00, none of the LEDs will be turned on.

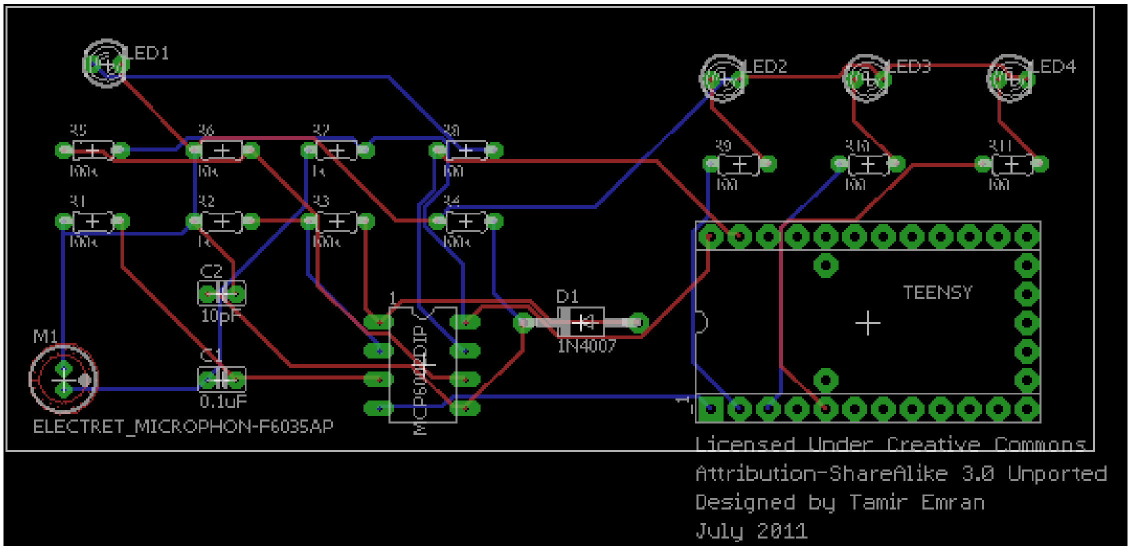
## 2.2 Output

Based on the amplitude of the signal(sound), the output of the circuit will vary. According to the datasheet from microchip, the manufacturer of the MCP6002, the circuit will have a maximum output of 5.5V. Based on the analog-to-digital conversion performed with the Teensy 2.0, the voltages range 0.2V to 3.00V for decibels between -11.00 and 11.00, 3.00V to 4.00V for decibels between 11.00 and 14.00, and 4.00V to 5.50V for decibles greater than or equal to 14.00.

## 2.3 Schematic Diagram



### 2.4 PCB Diagram




## 3 Component Description

### 3.1 Choosing Components

I decided to choose the electret microphone because after reading several datasheets, this electret microphone has a frequency range that meets my requirements and the operating voltage range did not required me to use a voltage divider or a voltage regulator. I chose to use resistors in my circuit because in the case of R1, I need a resistor in order to make a high-pass filter. I need resistors R2 and R3 in order to make the operational amplifier a non-inverting amplifier. Resistor R4, is needed in order to charge capacitor C2. Resistors R5, R6, and R7 are needed in order to buffer the signal picked up by the microphone. Resistors R8, R9, R10, and R11 were chosen for the connection of the LED lights in order to prevent them from burning while circuit is operating.

I chose capacitor C1 because it is the other essential component when making a high-pass filter. As for capacitor C2, I chose this one because I needed an electronic component that will peak the signal when the output of the non-inverting amplifier was high. Then I selected diode 1N4007, in order to prevent the output signal from the non-inverting amplifier to return to the amplifier. After that, I needed to select an operational amplifier in order to amplify and buffer the signal from the electret microphone, at first I chose the LM324, but after speaking with Dr. Zaruba about my project; he suggested that I change the LM324 with a MCP600x. When I purchased the MCP6002, I compared the voltages with the LM324 and the LM324 was giving me less acurate voltage results. Finally, I selected four different LEDs in order to clearly display the output of the circuit. The green, yellow, and red LEDs will be used to display the decibel levels of the signal, and the blue LED will be used to display how the output signal affects the brightness of that LED.

### 3.2 Component Values

In order to select certain signal from the electret microphone, I needed to build a high pass filter that accepted a signal above a certain frequency. Since I had a capacitor of $0.1\mu F$, I had to try different resistor values in order to get between a frequency cut-off range between 15 to 17 Hz. The calculation of the cut-off frequency is the following:

$$F_c = \frac{1}{2 \cdot \Pi \cdot R \cdot C} \tag{1}$$

$$F_c = \frac{1}{2 \cdot \Pi \cdot (100 \cdot 10^3 \Omega) \cdot (0.1 \cdot 10^{-6} F)} = 15.95 Hz \tag{2}$$

As for the non-inverting amplifier, I needed to get a gain of 100 since the output signal from the electret microphone is very small. So by using the following formula, I was able to test various resistor sizes in order to get the gain that I wanted for my circuit.

$$A_v = 1 + \frac{R_3}{R_2} \tag{3}$$

$$A_v = 1 + \frac{100 \cdot 10^3 \Omega}{1 \cdot 10^3 \Omega} = 101 \tag{4}$$

In order to determine the values for resistor R4 and capacitor C2, it looked at the schematic diagram of the sound detector that Sparkfun created and in that circuit they have a 10KΩ resistor and a 10$\mu$F capacitor [1]. After studying that portion of the circuit, I performed a unit conversion based on the electronic components that I have at my home and I conversion resulted in using a 100KΩ resistor and a 10pF capacitor.

Then for resistors R5, R6, and R7, I determined that resistor R5 and R7 had to be the same as resistors R2 and R3 in order to filter the signal. As for resistor R6, in order to determine its value I did some trial and error by using the blue LED. Based on the brightness, intensity, and voltage of the blue LED; I came up with the 10KΩ resistor for R6. Finally, for resistors R8, R9, R10, and R11, I used the following formula to determine the value of the resistance necessary for the four LEDs.

$$R = \frac{V_s - V_f}{I_f} \cdot 10^3 \tag{5}$$

$$R = \frac{5V - 3V}{20mA} \cdot 10^3 = 100\Omega \tag{6}$$

I performed other calculations on the Teensy 2.0 in order to convert the analog signal to voltage and then use that voltage to calculate the decibels of the signal.

$$Voltage = \frac{AnalogValue \cdot 5}{1023} \tag{7}$$

$$Decibels = 20 \cdot \log_{10} \frac{Voltage}{0.7746} \tag{8}$$

### 3.3 Constructing The Circuit

Before I started to construct the circuit, I studied the schematic diagram for various hours in order to understand how every component was connected to the circuit and how it affected the circuit. Once I had an understanding on how the circuit worked, I started connecting all the components on a breadboard without applying any power source to the circuit in order to prevent any damages to the electronic components. First I connected the electret microphone, then the high pass filter along with the MCP6002. After that I connected resistors R2 and R3 along with some jump wires on the circuit. Once I finished with those portions of the circuit, I proceeded with the diode, capacitor C2, and resistor R4. Then I connected those components to the second operational amplifier of the MCP6002 IC. After that I connected resistors R5, R6, and R7 to the second operational amplifier along with the power supply and the electret microphone. Then I connected resistor R8 to LED1 (Blue). Once I finished this connections, I checked them very carefully by reading again the datasheets of the electronic components and checking all the connections with the schematic diagram. Finally, I connected the Teensy 2.0 to the breadboard and used jumper wires to the appropriate pins of the device in order for the circuit to function properly. Once I tested multiple times the circuit on the breadboard and determined that the circuit was fully functional and meeting my expectations, I went ahead and used extra parts that I had and I started laying all the components on the prototype board. I followed the same steps like I did for laying out the parts on the breadboard, with the exception of making this circuit occupy less space than the breadboard and running most of the jump wires underneath the prototype board. This process took me around 2 hours to fully layout all the components of the circuit and making reasonable connections. Once I finished studying how I was going to connect all the parts on the prototype board, I started soldering all of the components. When I finished soldering all the components, I tested the circuit and I was able to determine that everything was working well since I compared those results with the ones from circuit on the breadboard.

## 4 Prototype Board Pictures

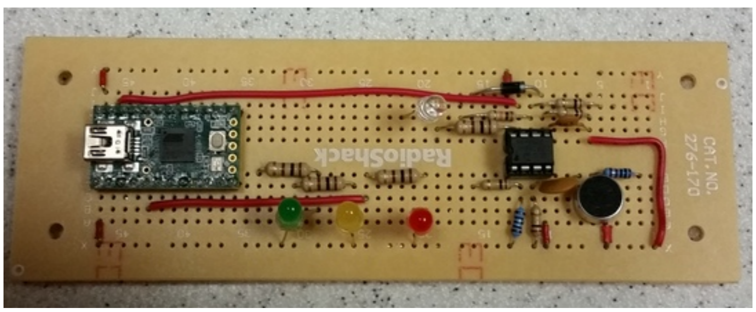


Figure 2: Front of Prototype Board

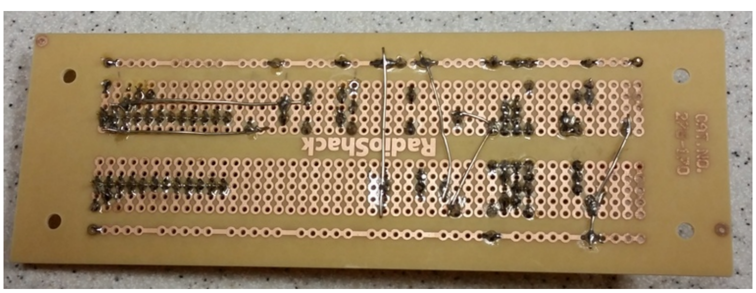


Figure 3: Back of Prototype Board

## 5 Issues Faced

Throughout this project I faced many issues. One of them was laying out the circuit on the prototype board, I was able to overcome this issue by patiently laying out all of the components and then stuying how to make all of the connections without interfering with other connections of the circuit. Laying out the circuit on the prototype board took me approximately 2 hours and soldering all of the components and connections took me nearly 1 hour. Another factor that helped me overcome this issue was the soldering and prototype lab that we had in this course. This helped me improve my soldering technique

and skills.
Another issue that I faced was mistakenly soldering one of the LEDs to the incorrect pin of the Teensy 2.0, I was able to overcome this issue by using a soldering pump and desoldering wick. Using the soldering pump was a little difficult at first, but after a few tries and watching some videos on YouTube, I was able to understand and learn how the soldering pump worked.

## 6 Increased Knowledge of Concepts & Skills

Throughout this term project, I increased my knowledge of non-inverting amplifiers since I was able to take what we learned in class about the non-inverting amplifier circuit, how it operates and how the circuit is built. By applying the concepts learned, I was able to acquire practical knowledge on this type of circuit and I was able to calculate the resistors needed in order to get the gain that I needed for my circuit. Another skill that I was able to increase my knowledge of was soldering, since when the semester started I only had some basic skills and I was also missing desoldering skills needed in order to fix mistakes on a prototype board. By performing this term project along with the soldering and prototype laboratory assignment, I was able to increase my soldering skills along with learningthat how to desolder IC and electronic components from a prototype board. Another concept that I was able to increased my knowledge of is RC High-Pass filter, since this was a crutial part of my circuit because I needed to filter which signals I want the circuit to process and which signals to ignore. For this particular skill, I took what I learned from the signal processing class and what was taught to me in this electronics course and actually apply the concepts taught to me by calculating the cut-off frequency and applying the circuit to my project.