Lab 5 – Audio Amplifier

CSE 3323 – Electronics for Computer Engineering

In this lab, we will discuss and construct the components required for a basic Audio Amplifier: 3.5mm stereo jack input, stereo-to-mono audio, pre-amp, virtual ground, power amp with speaker output, LED bar visualization, and low/band/high pass filtering. Also each student or pair will solder an audio jack breakout board adapter.

Students work in pairs (except one group of 3) during lab time.

What you specifically should include in your lab report, SCH, PCB, etc. is detailed at the end of this document with due dates.

Lab reports are **individual work** but include your lab partner's name in your report.

Tools Used:

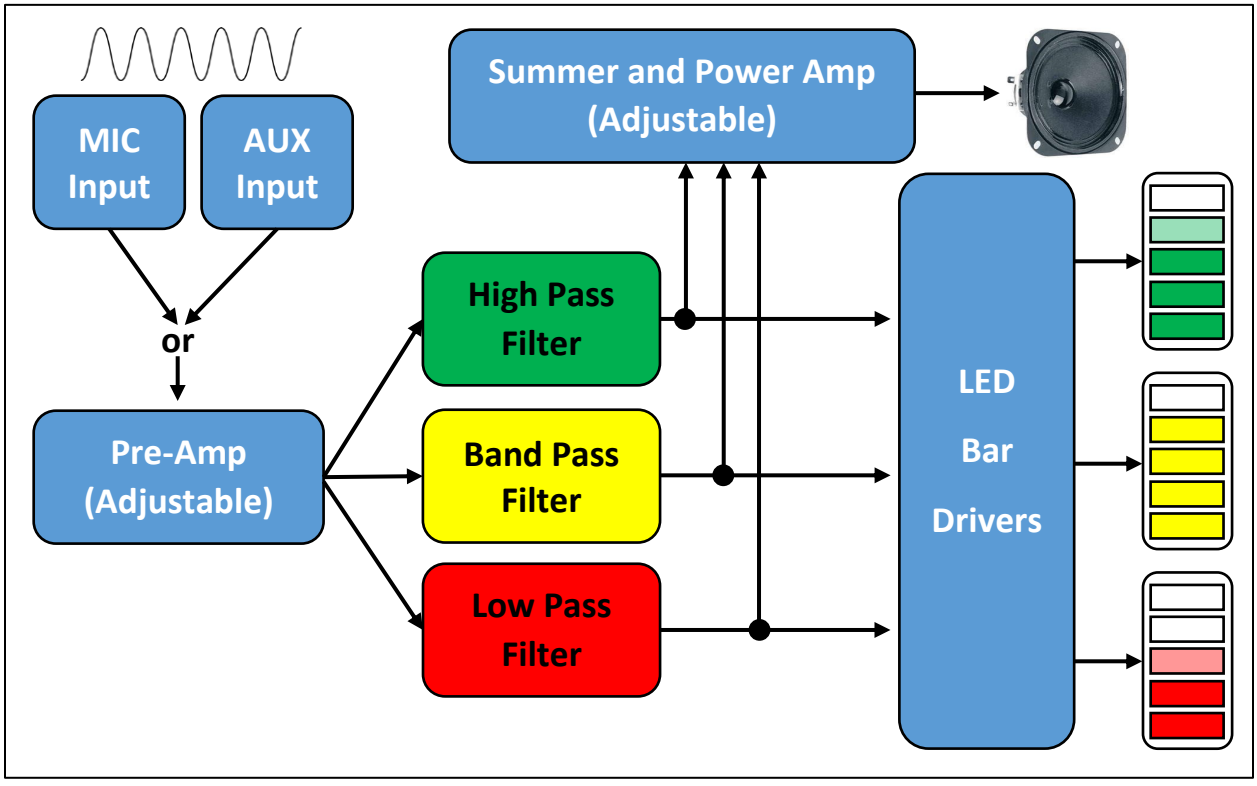
- **Digital Multimeters**
  - Thsinde 18B+ (yellow)
  - Mastech MS8268 (green)
- **Current-Limited Power Supplies**
  - DC Power Supply, Yihua YH-302D
  - DC Regulated Power Supply, Tekpower TP3005T
- **Digital Oscilloscope**
  - Siglent SDS 1202X-E, 200MHz
- **Signal Generator**
  - Siglent SDG1025, 25MHz, 125 MSa/s
- **Wire cutters/strippers, probes, banana connectors, alligator clips, jumper wires, etc.**

Components Used:

> **Note:** No components are listed in this document, instead they are organized in a separate **Bill of Materials** document on Blackboard named **"BOM_Audio_Amp.pdf"**

Directed Part of Lab:

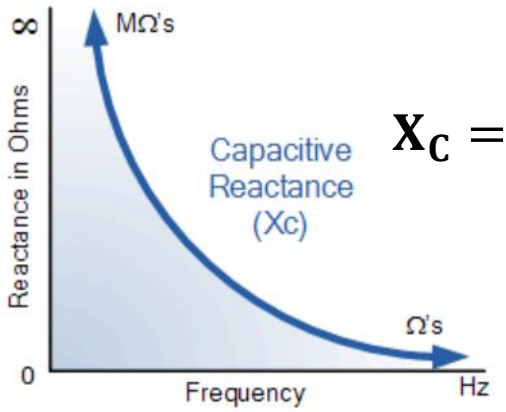
1. **Audio Amp Requirements**
    a. Audio input may come from two sources chosen by a SPDT Switch:
        i. Standard 3.5mm AUX cable connected to computer or phone
        ii. or Simple two-pin Electret Microphone
    b. Audio signal must be biased by a Virtual Ground to prevent the audio signal's negative voltages from being lost (clipped)
    c. The audio signal must immediately pass through a **Pre-Amplifier** to boost the audio signal's voltage amplitude
        i. The Pre-Amp's gain must be user adjustable ("**Pre-Amp POT**")
    d. The audio signal will then branch off into 3 active filters to extract 3 different audio frequency ranges (Bass, Midrange, Treble)
        i. Low Pass, Band Pass, and High Pass filters respectively
    e. Output from each of the 3 filters (via 3 POTs) will branch off in 2 directions:
        i. All 3 outputs will be summed together to recombine the audio signal; the recombined audio signal will be passed to a **Power Amplifier** which in turn outputs the final audio signal to the speaker
            1. Power Amp's gain must be adjustable ("**Power Amp POT**")
        ii. Each of the 3 outputs will also go to LED Bar Driver ICs that control different colored LED Bars to create a light organ effect that responds to audio signal amplitudes that belong to certain frequency ranges (Low/Bass, Band/Midrange, High/Treble)



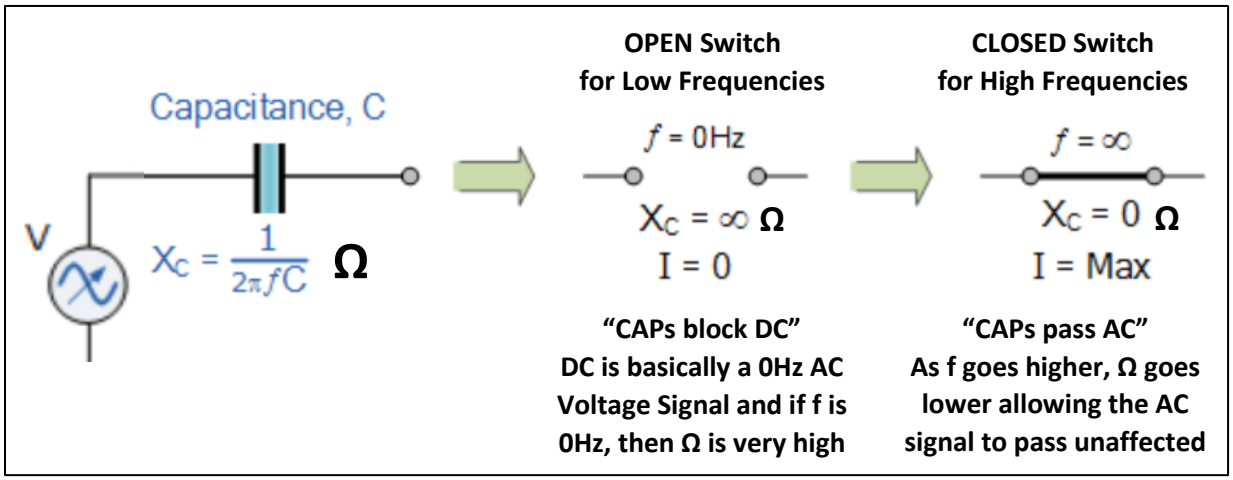
2. Capacitors Block DC and Allow AC to Pass Freely

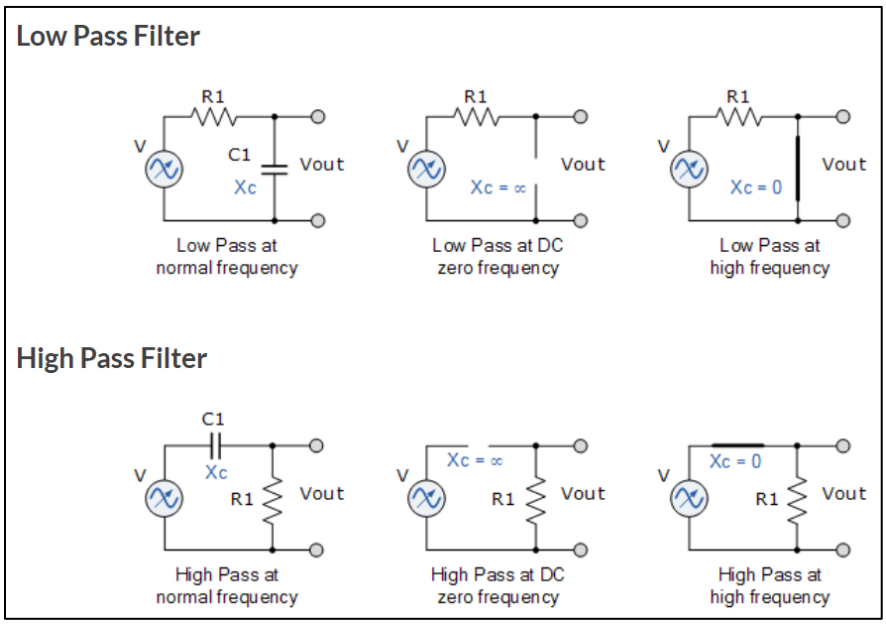
a. Capacitive Reactance

i. In Depth Details About Capacitive Reactance



$$X_C = \frac{1}{2\pi f C} \text{ in Ohms } (\Omega)$$

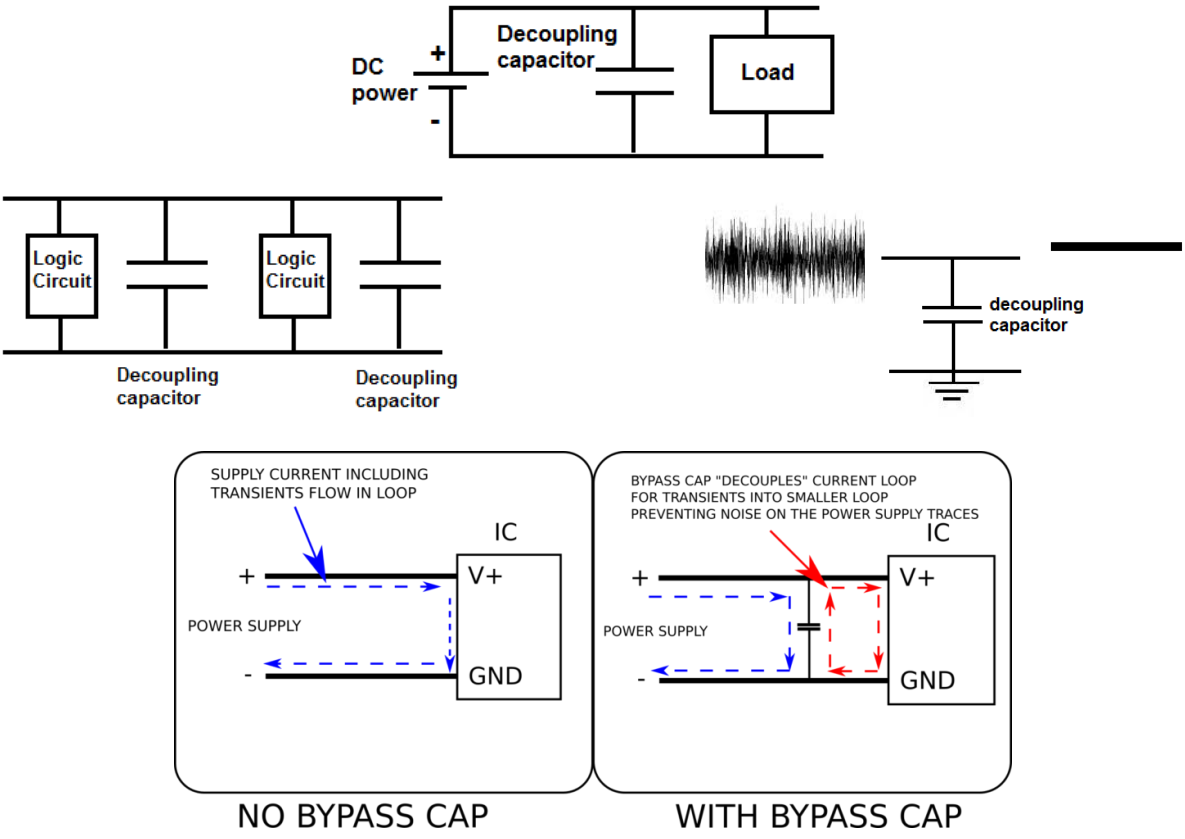




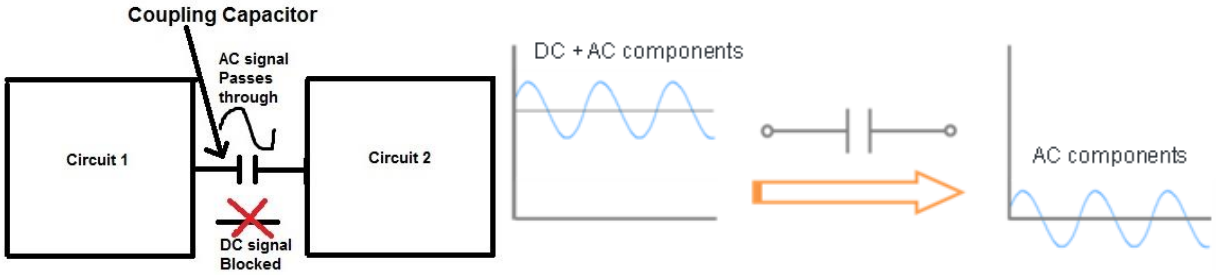
Think of the capacitor C1 as a resistor used in a voltage divider with the actual resistor R1 on the left.

In both of these basic filter setups, as the frequency of the input voltage signal increases or decreases, the Vout is pulled more towards the original V_input or towards GND.

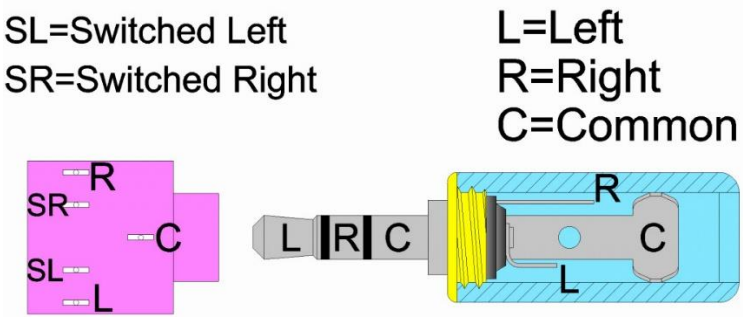
b. **Decoupling Capacitors ("Remove AC Components")**
   i. These are used to decouple a portion of a circuit (like an IC's power input) from AC voltages, random voltage spikes, or noises caused by other circuit components. When placed near the VDD or VCC input of an IC, these capacitors can protect it from damage by immediately shunting or shorting the voltage spike directly to GROUND.
   ii. "Pass unwanted AC to GND, DC is blocked and doesn't flow through CAP"
   iii. More Details 1, More Details 2

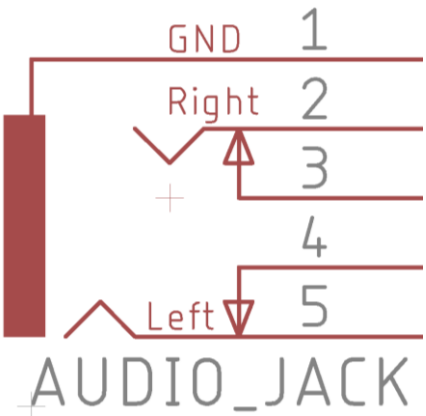


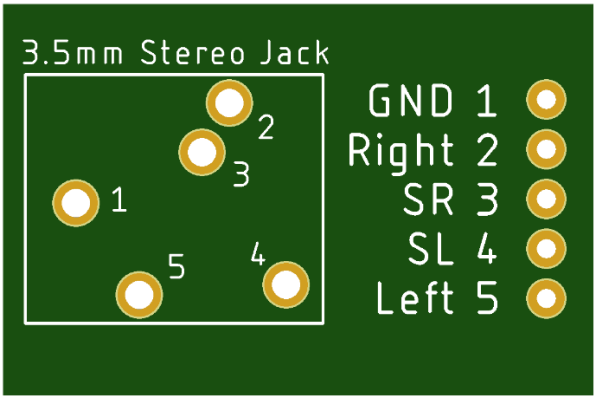
c. **Coupling Capacitor ("Remove DC Components")**
   i. We can also use series capacitors to block DC signals and allow AC signals through. Useful for removing constant DC offset voltages out of audio signals.
   ii. More Details on Coupling CAPs

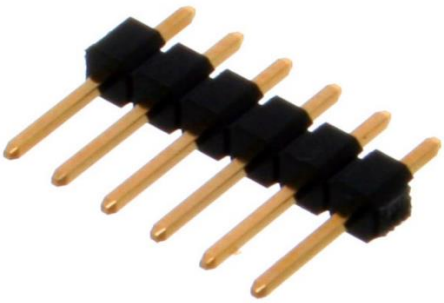


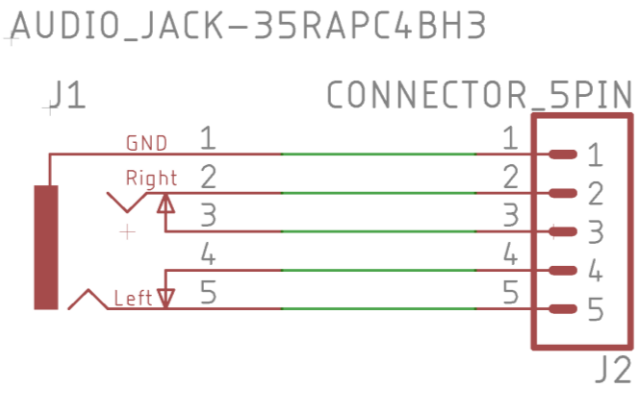
3. 3.5mm Audio Jack with Breakout Board PCB

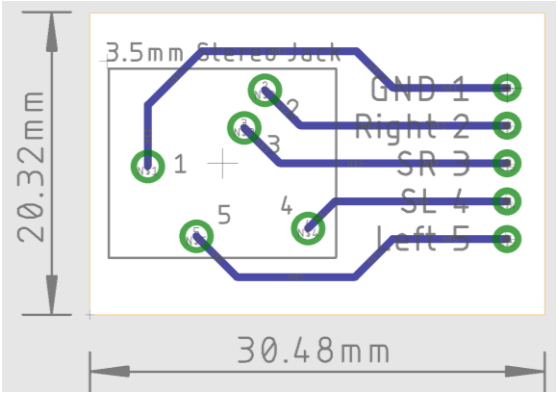




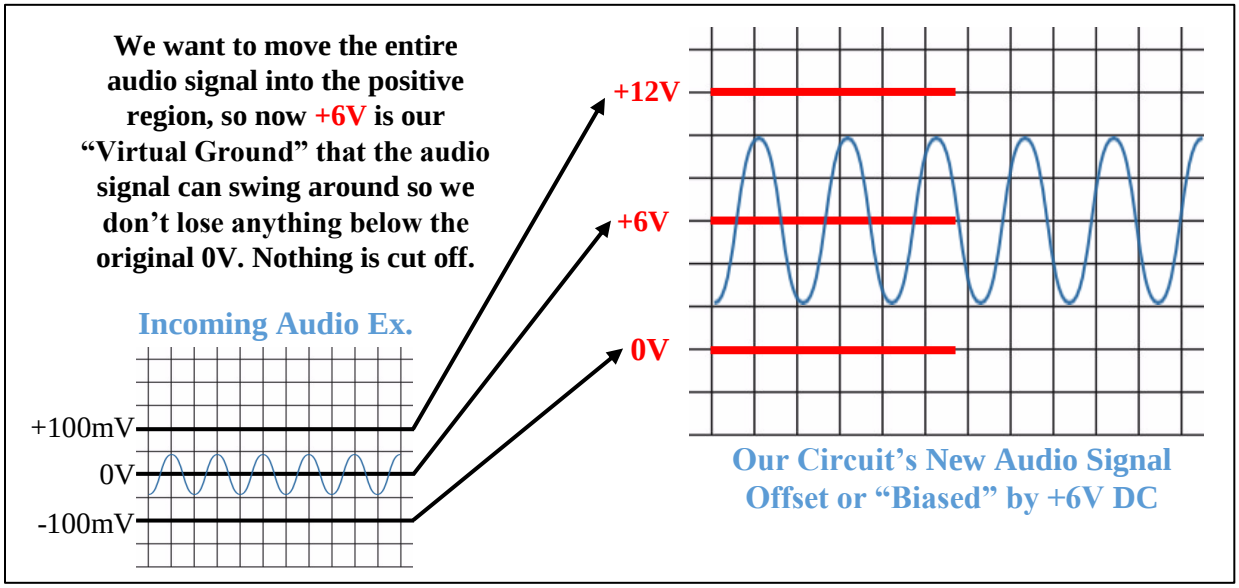








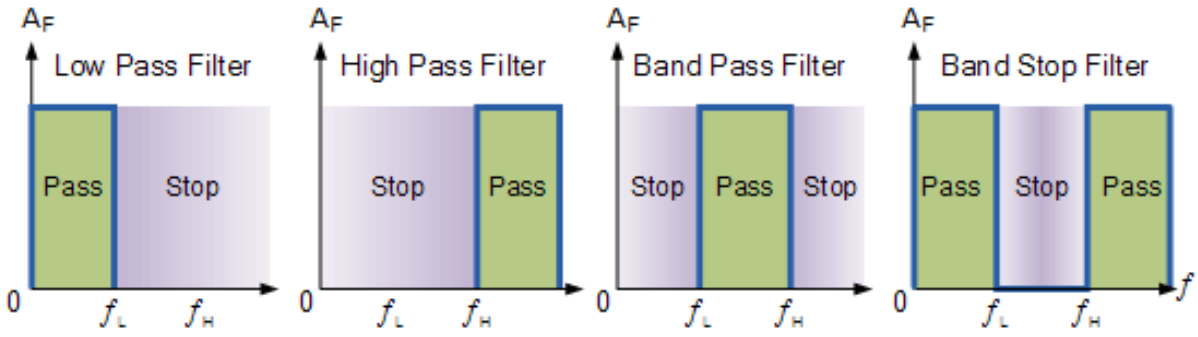
4. Virtual Ground (DC Bias, DC Offset)



5. Filters: Low Pass, Band Pass, and High Pass

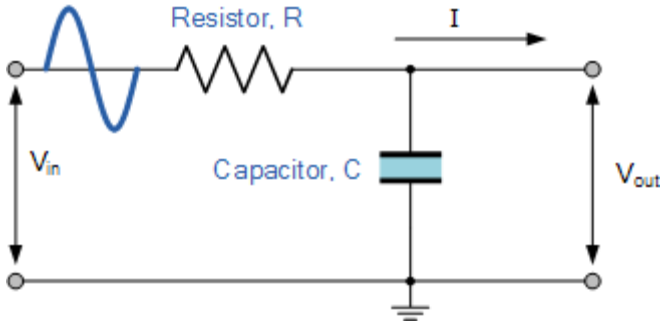
a. **Links for further reading/watching:**

i. Decibels Video 1
ii. Decibels Video 2
iii. Filters Video
iv. 2nd Order Filters Tutorials



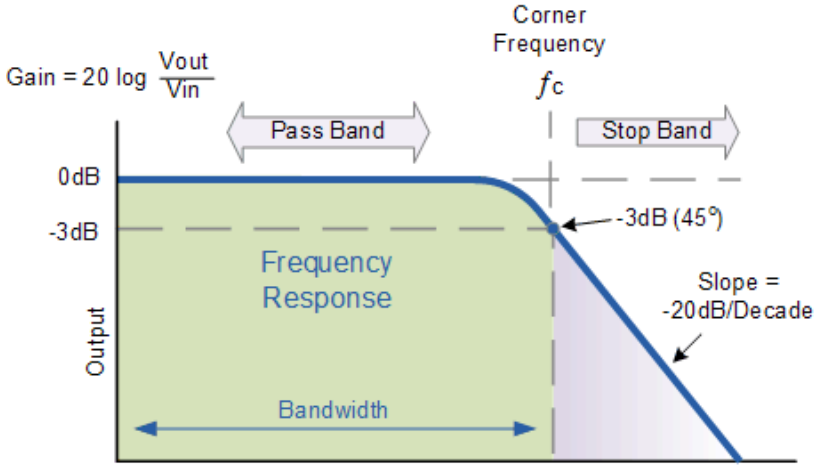
Ideal Filter Responses, but not practical/actual

$$\textbf{\textit{Time Constant}} \quad \tau = \mathrm{RC} = \frac{1}{2\pi f_c}$$

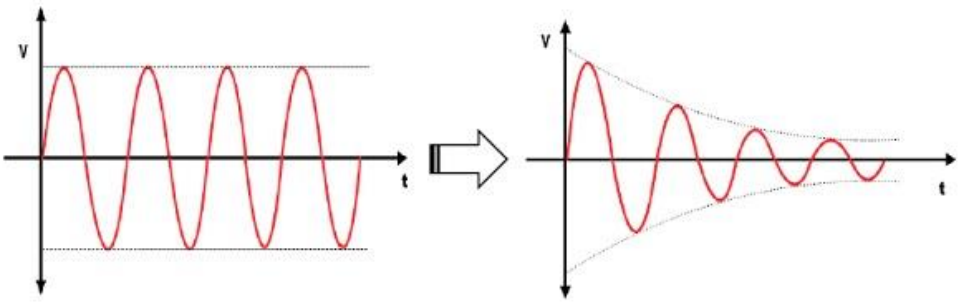


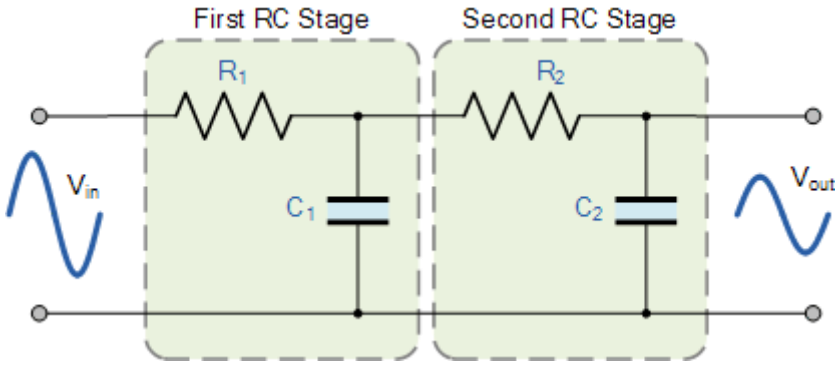
Simple RC Low-Pass Filter Circuit

$$\textbf{\textit{Cutoff Frequency}} \quad f_C = \frac{1}{2\pi RC} \text{ in Hertz (Hz)}$$



By the time your AC voltage signal reaches the cutoff frequency f_C it's voltage amplitude is already attenuated (reduced) by -3dB (now only 0.708 of original voltage amplitude).

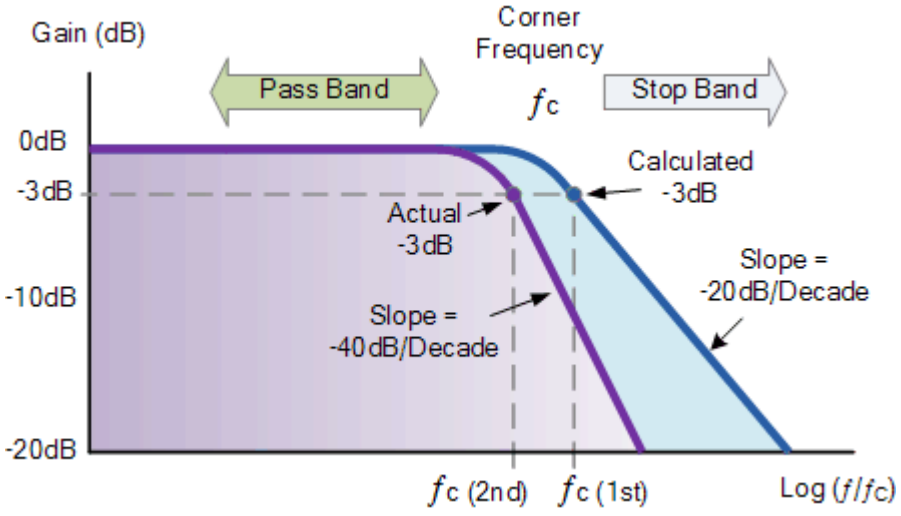




2nd Order RC Low-Pass Filter Circuit

(Faster slope of attenuation → BETTER)

$$\textbf{\textit{Cutoff Frequency}} \quad f_C = \frac{1}{2\pi\sqrt{R1C1R2C2}} \textbf{ in Hertz (Hz)}$$



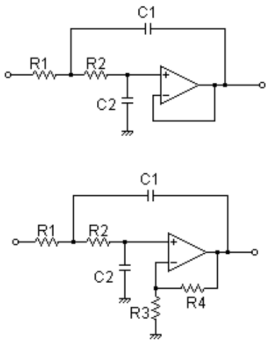
BLUE is 1st Order LPF Results

PURPLE is 2nd Order LPF Results (faster rolloff)

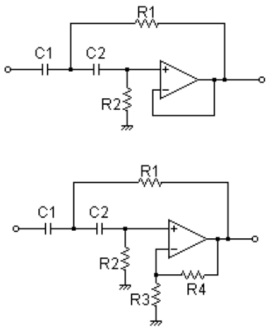
b. More Sophisticated Filters

i. Filter Design Tool

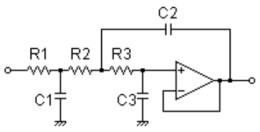
Sallen-Key Active Filter



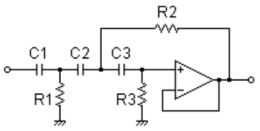
Sallen-Key Low-pass Filter Tools
[Sample calculation]



Sallen-Key High-pass Filter Tools
[Sample calculation]

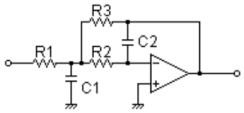


3rd order Sallen-Key Low-pass Filter Tools
[Sample calculation]

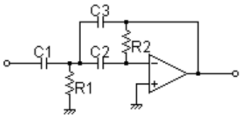


3rd order Sallen-Key High-pass Filter Tools
[Sample calculation]

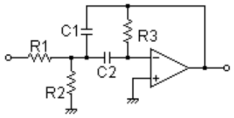
Multiple feedback Active Filter



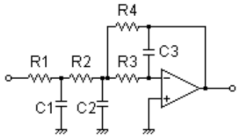
Multiple feedback Low-pass Filter Tools
[Sample calculation]



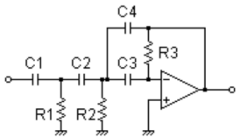
Multiple feedback High-pass Filter Tools
[Sample calculation]



Multiple feedback Band-pass Filter Tools
[Sample calculation]

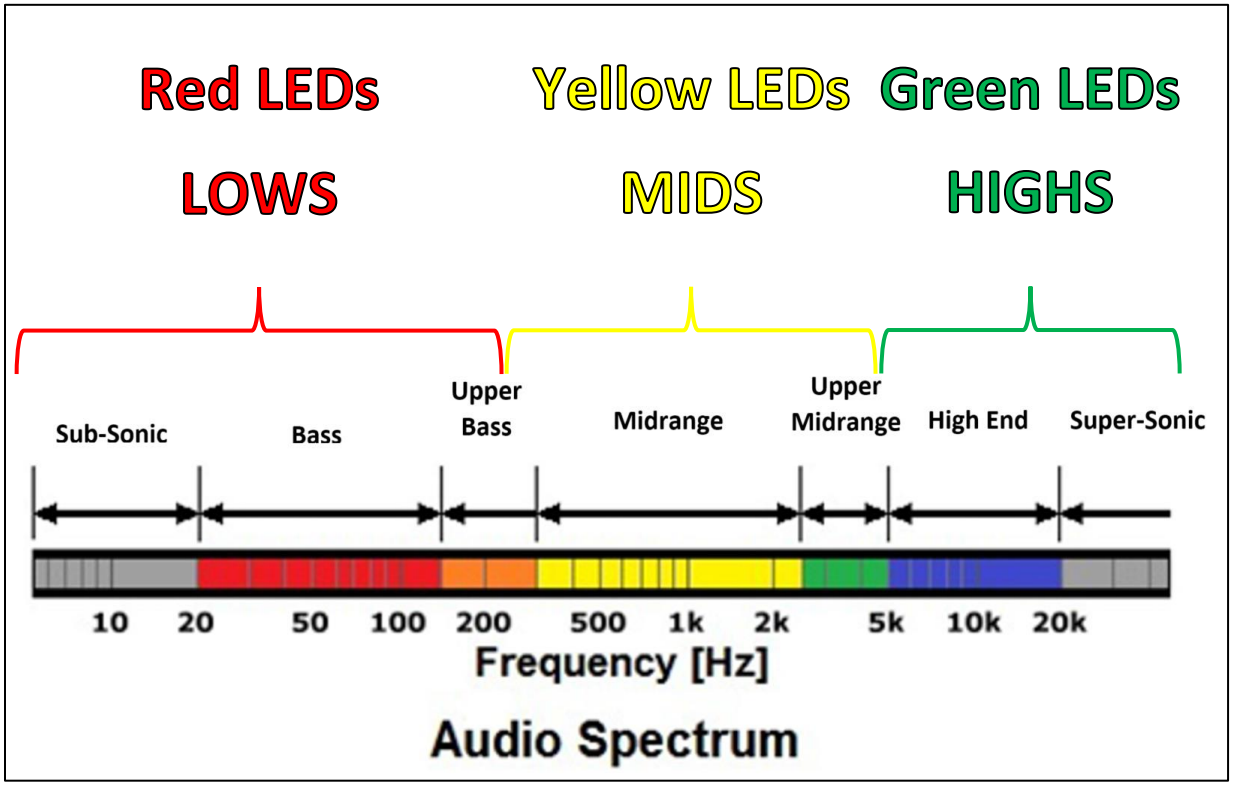


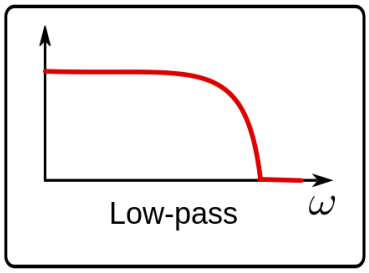
3rd order Multiple feedback Low-pass Filter Tools
[Sample calculation]

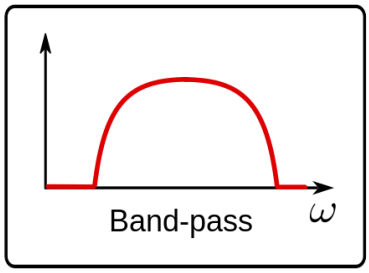


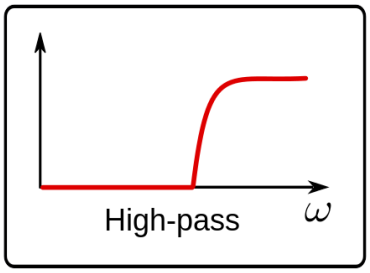
3rd order Multiple feedback High-pass Filter Tools
[Sample calculation]

6. **Audio Spectrum (Frequency Band Labels)**

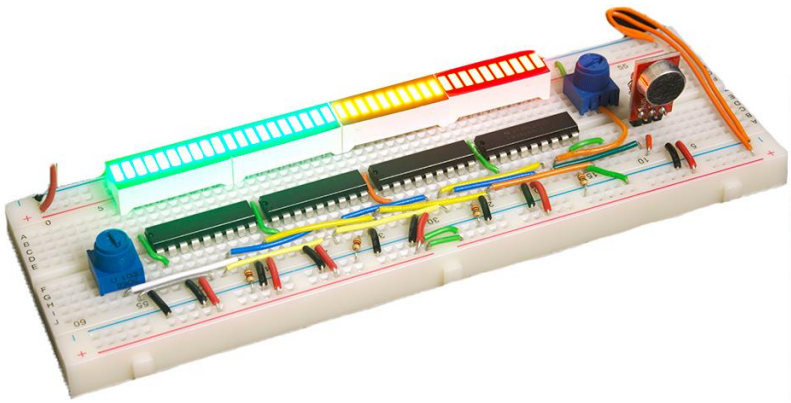


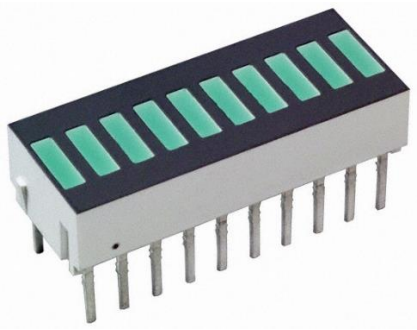




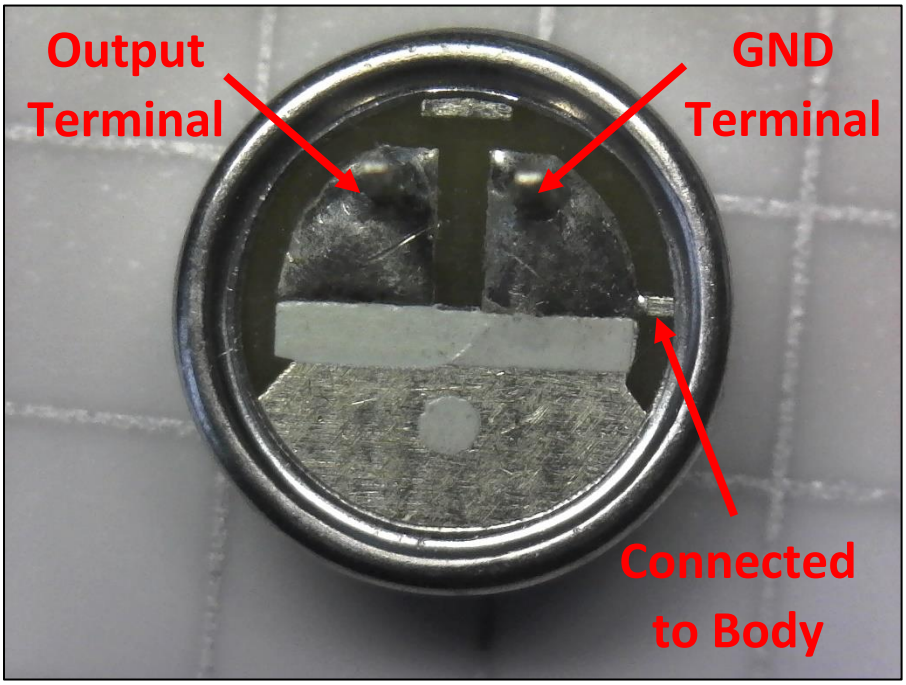


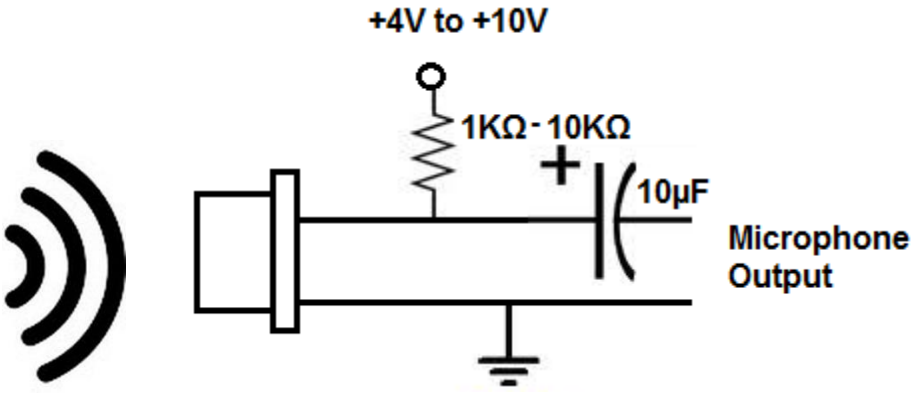
a. **LED Bars to Show Bass, Mid-level, and Treble Audio Frequencies**
   i. [SparkFun LED Bar Driver Tutorial]



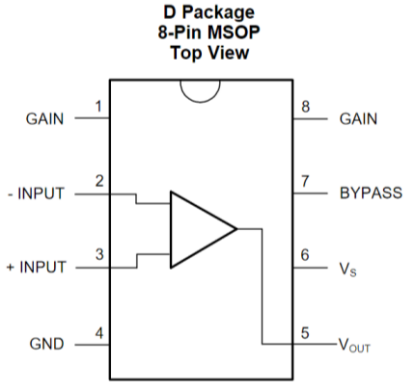


7. Electret Microphone





8. Power Amplifier (Speaker Output) – LM386



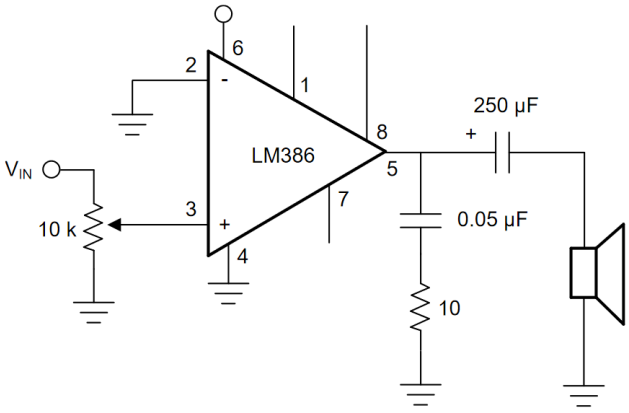


Figure 10. LM386 with Gain = 20

Individual Part of Lab:

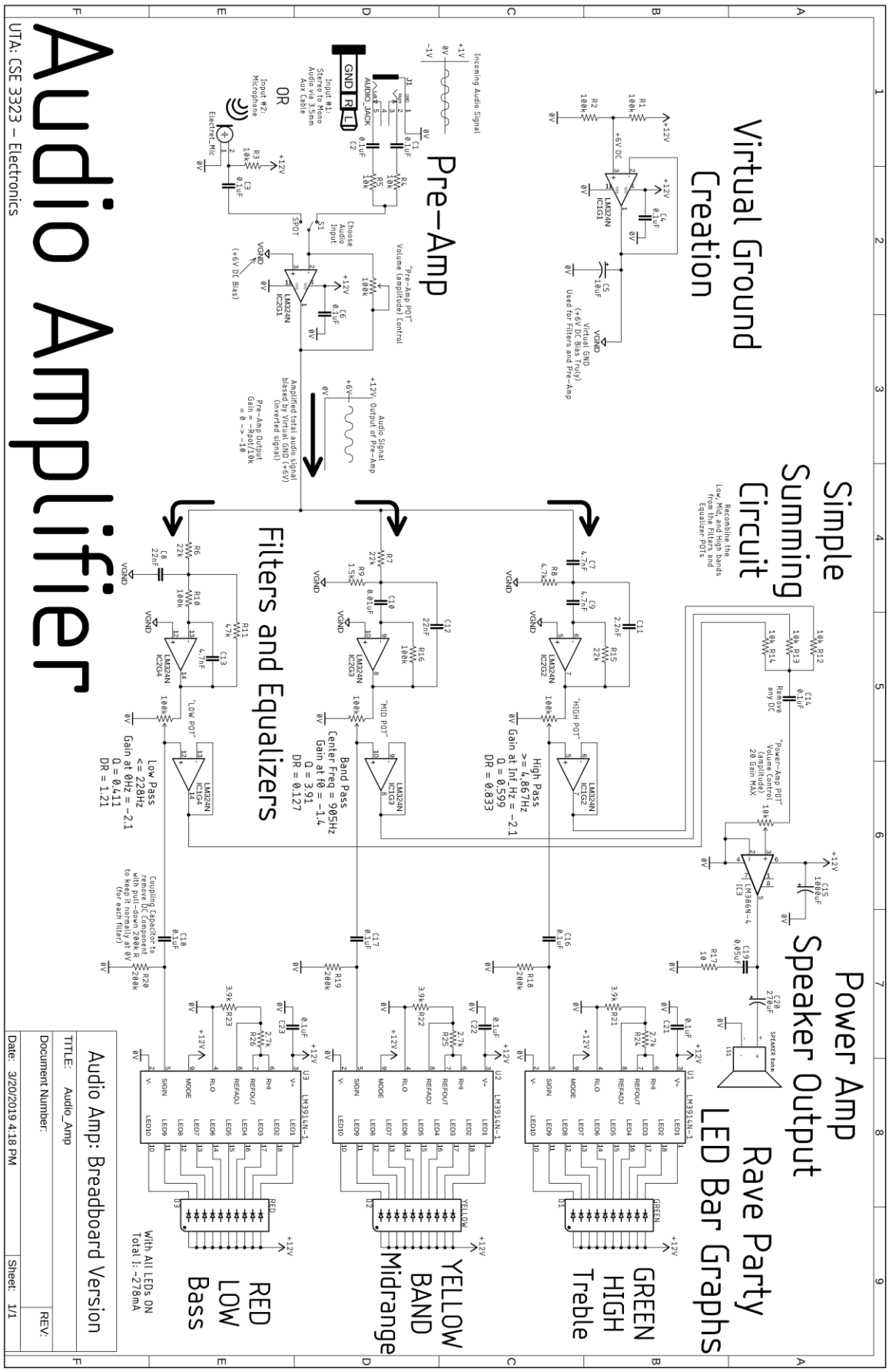
1. **Breadboard** (Work in Pairs)
    a. Breadboard **"Audio_Amp.sch"** in a modular fashion to simplify debugging
    b. It will take multiple lab periods to complete the circuit fully and things will get messy fast with wiring so triple-check every connection
    c. **Demo your working circuit when it is fully complete**
    d. **Volume Setting Sequence (after fully breadboarded):**
        i. **Turn both Pre-Amp POT and Power-Amp POT completely OFF**
        ii. **Turn Power-Amp POT completely ON (100%)**
        iii. **Slowly turn the Pre-Amp POT up until the speaker outputs your ideal MAX volume**
        iv. **Once reached, leave the Pre-Amp POT permanently in that position**
        v. **Now you can freely turn the Power-Amp POT to act as your normal Volume Knob**

Additional Submission Details:

1. **Part 1** (Due 3/29/2019) - **Lab Report (.pdf)**
    a. Discuss in **detail** the differences between the following Audio Power Amplifier Classes: Class A, B, AB, C, and D
    b. There are many resources and videos online regarding this subject. Put things in your own words but be sure to include sources/links you reference. Include images, graphics, and circuit drawings within the report.

2. **Part 2** (Due 4/5/2019) - **PCB File (.brd)**
    a. Using the .SCH I provided (or creating your own) you need to create the PCB design for a "breadboard compatible breakout board PCB" for only the **LED Bar Graph portion** of the Audio Amp circuit.
    b. Similar to this or this.
    c. Include the LED Bar driver ICs, the LED Bars, and all the other various passive components required to make them operate.
    d. Similar to the audio jack board you soldered in lab, you soldered a non-compatible component onto a PCB and then soldered pin headers to allow it to plug into the regular breadboard easily.
    e. You will need to have a total of 5 pin header connections: +12V, GND, Green SigIn, Yellow SigIn, and Red SigIn.
    f. Reference the datasheets in the Bill of Materials; pay close attention to the dimensions of the components and the pitch of the pin headers you use.

3. **Part 3** (Due 4/12/2019) - **Lab Report (.pdf)**
    a. Design your own High and Low Pass Filters.
    b. Go to this Filter Design Wizard website and use the “Sallen-Key Active Filter” tools to create HIGH Pass and LOW Pass filters.
    c. You determine the exact cutoff frequencies, but they should match conventional audio spectrum frequencies (LOW Pass for Bass and HIGH Pass for Treble/High-End).
    d. In your report, include many screenshots from the filter website to show all the relevant math and what component values were chosen.
    e. Then you will simulate these 2 filter circuits (independently) in EveryCircuit. The input for the filters should be an AC Source with a sine wave frequency you can alter.
    f. Provide screen shots for both filters you created in EveryCircuit. Also provide screen shots of the top "Oscilloscope View" when the circuit is simulating and running. Note: there are two yellow arrows you can use to run/simulate your circuit (Run Transient: Space and Run AC); use both of them. Be sure to provide these oscilloscope screen shots at different **MEANINGFUL** frequencies for your AC Sine Wave input. Use the "Show Waveform: W" Eye icon on your input and the outputs to make them appear in the oscilloscope view.


Audio Amplifier
UTA: CSE 3323 – Electronics
Virtual Ground Creation
Pre-Amp
Simple Summing Circuit
Filters and Equalizers
Power Amp
Speaker Output
Rave Party LED Bar Graphs
RED LOW Bass
YELLOW BAND Midrange
GREEN HIGH Treble
Low Pass <= 228Hz Gain at 0Hz = -2.1 Q = 0.411 DR = 1.21
Band Pass Center Freq = 905Hz Gain at f0 = -1.4 Q = 3.91 DR = 0.127
High Pass >= 4,867Hz Gain at Inf_Hz = -2.1 Q = 0.599 DR = 0.833
With All LEDs ON Total I: ~270mA
Audio Amp: Breadboard Version
TITLE: Audio_Amp
Document Number:
REV:
Date: 3/20/2019 4:18 PM
Sheet: 1/1