Course Project - Microphone Circuit

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PCB Design Course

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I. Introduction

This course project will be focusing on the design and implementation of several critical audio processing circuits that together form a comprehensive system for audio signal manipulation and enhancement [2]. Each circuit is designed to perform specific functions that are essential for improving audio signal quality, particularly in environments where clear vocal communication is paramount. The project consists of three main sections, each detailed in a corresponding figure. The first section involves a microphone circuit designed to create a stereo output. It incorporates elements such as voltage dividers and gain stages, specifically tailored to accommodate the operating characteristics of an electret condenser microphone. This setup prepares the signal for further processing by amplifying the desired frequency components while minimizing noise. The second section extends the functionality of the system by integrating an LM386 audio amplifier with a tone control circuit. This part of the project focuses on mixing inputs from different sources, such as a stereo input jack and an auxiliary input, and adjusting their tonal qualities through a simple yet effective tone-control network. This allows for the customization of the audio output to better suit the listener's preferences or specific application needs. Finally, the third section of the project utilizes a 2nd-order active bandpass filter, critical for enhancing speech intelligibility in the final output. By selectively amplifying frequencies in the range typical of human speech, this filter ensures that vocal communications are clear and distinct against any background noise. Overall, this project will not only help deepen one’s understanding of various audio processing techniques but also enable the development of practical skills in designing and implementing circuits that improve the quality of audio systems.

II. Circuit Description

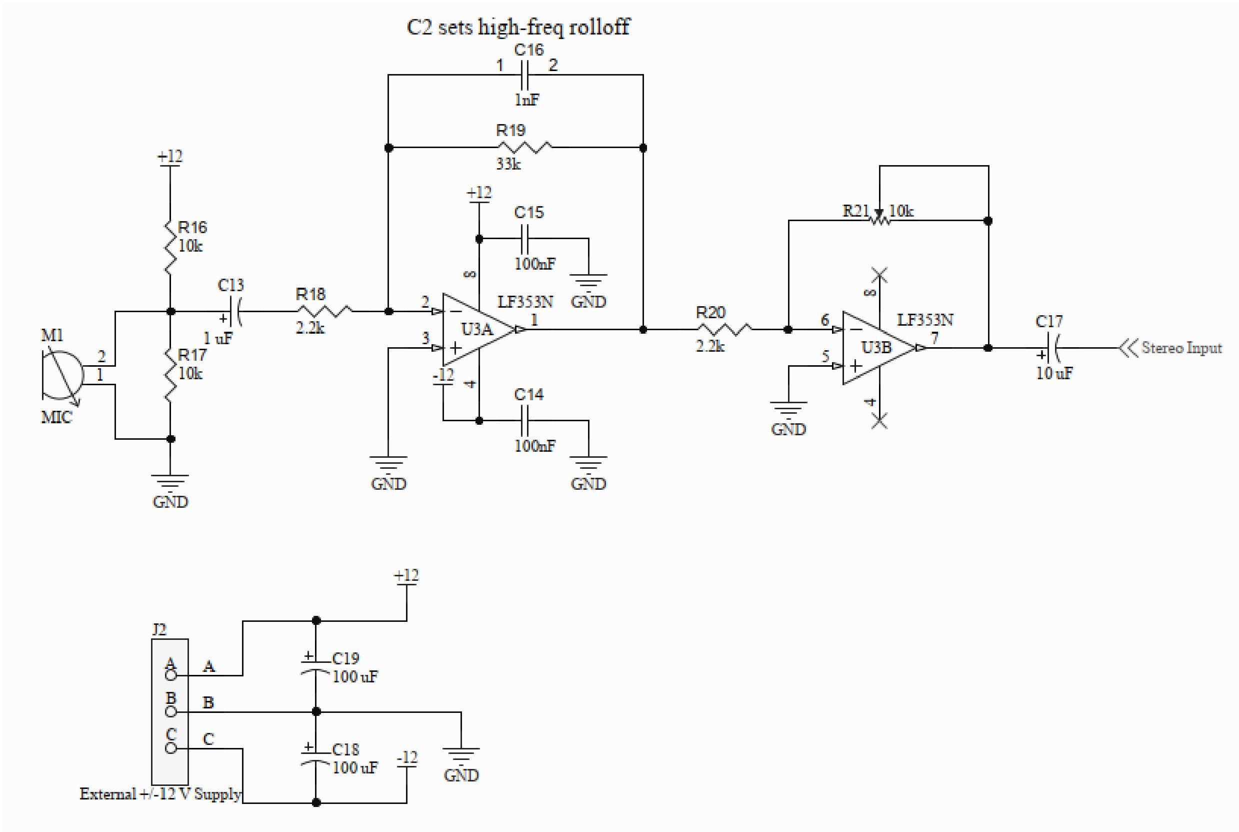

Figure 1: This is the microphone circuit that creates a stereo output. In the bottom left, +/- 12 volts is established, ground connections are set, and two large 100µF supply capacitors (C18 and C19) are added. This circuit is meant to set the VDD and VSS rails on the breadboard. In the upper left, R16 and R17 form a DC bias level (voltage divider with VDD=12V) for the electret condenser mic to operate. One should expect a 4-6V operating voltage depending on how much current the mic will draw. The output from the mic voltage divider is sent into the gain stage which begins with a coupling capacitor so that the DC component is blocked. This signal is then amplified by R19/R18=33k/2.2k=15V/V. At the low-frequency cutoff where the gain decreases by 3dB or 1/sqrt(2), the reactance of C1 starts to interfere with the total input impedance. This is calculated to occur at about 72.3Hz. When a 1nF capacitance is added in parallel with R4, a high-frequency pole is introduced at about 4823Hz. The op-amp itself is powered by VSS=-12V and VDD=12V. C15 and C14 are meant to smooth out the voltage supplied to the power rails. In short, the op-amp takes the now smoothed output of the mic and amplifies it to make the signal interpretable. The second op-amp amplifier is an inverting stage circuit. The input signal can be amplified or attenuated by an adjustable gain through the potentiometer. C17 is added to smooth the output.

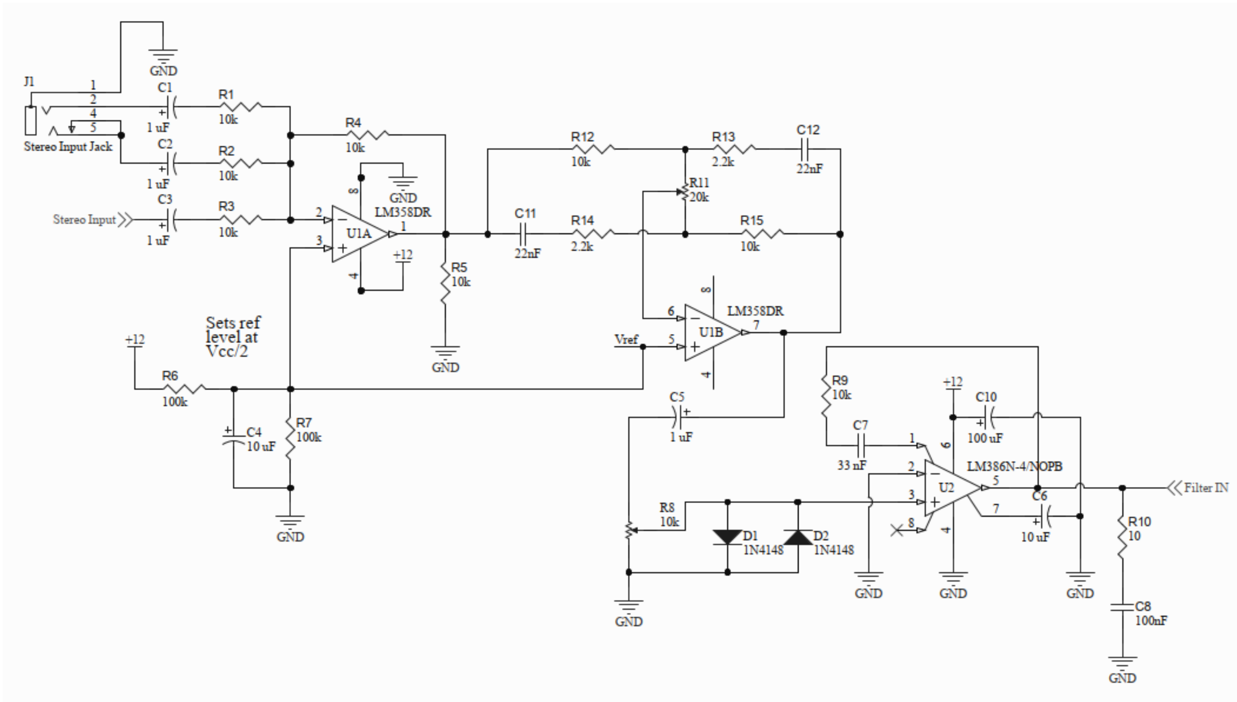

Figure 2: Schematic of LM386 Audio Amplifier and tone-control circuit. The input of this circuit is the output of Figure 1. In the upper left is a single-ended unity-gain summing network. The upper two lines hook up to a stereo input jack (mp3 player, CD player) meaning there are two channels, 2 and 3, that input a wider sound (1 is grounded both channels for reference), however, these two channels get summed into a mono output. The aux input is connected to the third line which can be used for inputting a sinewave. C1-C3 and R1-R3 are all the same. This means the frequency is going to be the same. The low frequency cutoff is going to be determined by the capacitance 1µF and resistance 10kΩ. Capacitor coupling at the input introduces a low-frequency pole which gives the summing network a high-pass frequency response. To maximize AC swing, the voltage level at reference to the op-amp is set to VCC/2=4.5V. This equal split is caused by the voltage division of R6=R7. C4 helps to maintain a constant Vref value. An external DC path is recommended when capacitively coupling the output of this circuit hence R5. The circuit in the upper right is the tone-control which essentially selectively boosts or "cuts" (attenuate) signals depending on their frequency. U1B is part of the same dual op-amp as U1A. Pin 5 is also supplied with Vref=4.5V. The output of the unity-gain inverting amplifier configuration (Pin 1) is connected in series with RC networks in parallel with feedback resistors. The potentiometer controls the gain of the frequency spectrum which is then output to Pin 6. When the wiper is set to the midpoint, all frequencies have equal gain since both sides of the feedback network are identical. According to the procedure, "When the wiper is at the top, there is a low-frequency gain of around 3 (10dB), and high-frequency attenuation of about 1/3 (-10dB). When the wiper is at the bottom, the action reverses so that the low-frequencies are cut, and the high-frequencies are boosted" [2]. On the bottom right, the LM386 is used to support the relatively high currents used to power the speaker. C5 AC couples the input to the right side. The 10kΩ trimpot, R8, is a voltage divider, aka a volume controller. C6 is an internal AC bypass capacitor. C7 and R9 are a bass boost feedback circuit to help compensate for a poor low-frequency response of the speaker. C9 is a DC-blocking capacitor. R10 and C8 form a snubber circuit for high-frequency stabilization (prevents oscillations from inductive loads). D1 and D2 form a diode clamp. It clamps the voltage on Pin 3 of the LM386 to either ±0.7V to prevent excessive voltage. In short, the left side takes either an aux input (sinewave) or a stereo jack input (stereo music) and sums together whatever signals are being applied at each branch to the output of the LM358 (Pin 1). The right side amplifies the output of the left side so that the speaker can function. The diodes will clamp/limit the output so that the

speaker is not damaged. VCC can be disconnected to measure the current there. If the volume is increased, then the current increases since the voltage is increased. The same applies to an increase of voltage at the aux/stereo jack input. A higher current or higher volume would make the battery last shorter.

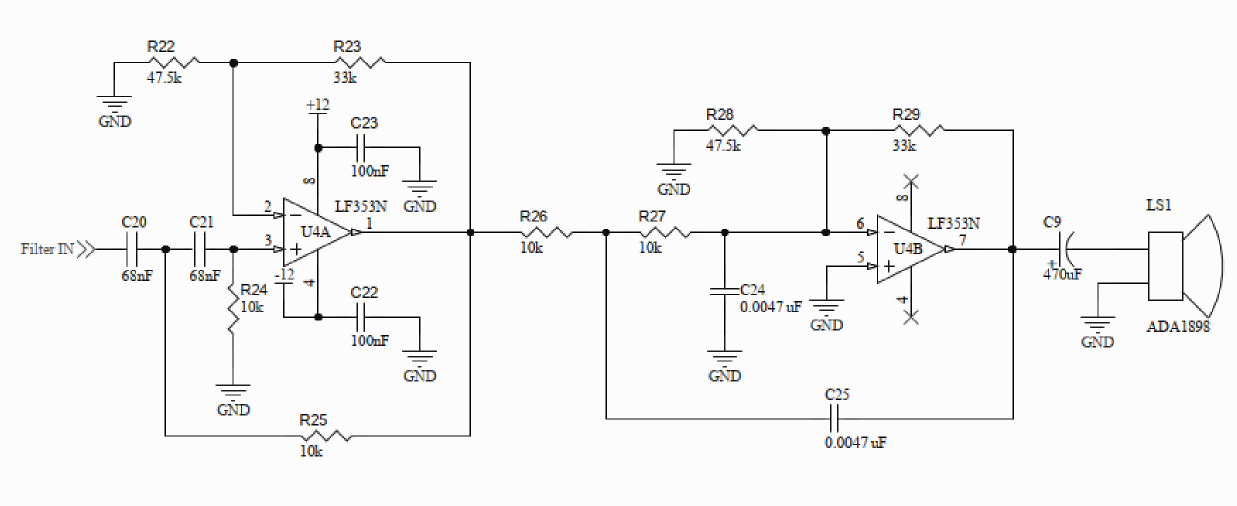

Figure 3: This is a 2nd-order active bandpass filter designed to pass frequencies typically found in human speech (300-3000 Hz). This filter is a critical part of systems where vocal clarity and intelligibility are important, such as in telecommunications or voice recognition systems. One LF353 dual op-amps is used. The first op-amp is configured as a high-pass filter, and the second as a low-pass filter. This dual op-amps is powered by a dual supply voltage of ±12V which allows for a greater dynamic range and avoids the need for a DC biasing circuit for AC signals. R24 and R25 form part of the feedback loop in the first op-amp and are used in setting the high-pass cutoff frequency. R26 and R27, along with C24 and C25, define the low-pass cutoff frequency in the second op-amp. R29 and R23 are used to adjust the "Q factor" or quality factor of the filter, affecting the sharpness of the filter's peak near its cutoff frequency. R28 provides feedback for the second op-amp and, along with R1, influences the passband characteristics.

III. Conclusion

In conclusion, this Altium PCB design project has been a comprehensive exercise in applying theoretical knowledge to a practical design challenge. The project required the design of a PCB that adheres to stringent specifications, including a minimum of 60 components, all of which needed to be functional and integrated into a unique PCB shape of personal significance. Throughout the process, I developed a deeper understanding of Altium's powerful capabilities, from drawing detailed schematics to generating the necessary output files like PCB and schematic prints, assembly drawings, and even Gerber files. This project not only reinforced my PCB design skills but also prepared me for future endeavors in electronics design, emphasizing the importance of precision, creativity, and technical proficiency.

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