

Low Noise, Single Supply, Electret Microphone Amplifier Design for Distant Acoustic Signals

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Abstract. Modern day electronics are often battery powered, forcing the design to be single supplied. Electret microphones are small and affordable, yet require additional circuitry. The amplifier described herein is low noise, relatively immune to supply oscillations, and can operate single supply with an electret microphone.

Keywords: Microphone amplifier, low noise amplifier, single supply design, biasing, electret microphone

1 Introduction

Amplifier design greatly varies depending on the type of signal to be amplified, what is available to power the amplifier, and what frequency response is desired. For high frequency applications, the amplifier will almost certainly use transistors instead of operational amplifiers (Op-Amps). In addition, high-frequency amplifiers should be impedance matched on their input and output. However in the audio band, impedance matching is not a concern. Due to the low frequency range the audio band covers, either Op-Amps or transistors can be used, although the implementation here was Op-Amp based. The frequency range of audio band amplifiers often requires large value electrolytic capacitors, which can introduce distortion due to their inferior quality.

Modern day electronics run off batteries, making single supply designs far superior to those requiring both a positive and negative supply. Though dual supply designs are simpler, the lack of the negative supply requirement will usually make the more complicated single supply amplifier preferable.

2 Objectives

The objective is to design and build a circuit to amplify the signal from an electret microphone. The amplifier should be robust against noise, powered by a single supply, and produce an output compatible with the data acquisition system of a PIC microcontroller.

3 Issues

3.1 Single supply driven

This is one of the central features of this design. All stages of the amplifier must operate without a negative supply voltage. This objective will likely put a constraint on the model of Op-Amp used.

3.2 Electret microphone compatibility

The input signal will be generated from an electret microphone. The electret microphone is different from the typical dynamic microphones used in that it includes a transistor (usually JFET) pre-amp built into the package. The transistor needs to be biased, so the electret microphone must have a DC voltage across it – even without any acoustic input. This DC voltage must be provided by the external circuit.

3.3 *Versatile output characteristics*

This design will allow the user to condition the output signal to arbitrary requirements. The user will be able to adjust the final DC offset and voltage swing by adjusting two potentiometers. The versatility of this will allow it to be used with an arbitrary microcontroller. The output DC offset should be half the maximum voltage accepted and the voltage swing should be sufficiently large such as to minimize digitization errors.

3.4 *Low noise characteristics*

The electret microphone may be mounted a distance from the actual amplifier. The longer the microphone leads the more noise that will likely be picked up. One technique would be to use a third wire to ground the shield, as the common XLR connector uses.[1] This application note assumes the cheaper twisted pair wiring configuration is used, and noise mitigation is a central issue.

4 Design and Results

4.1 *Electret microphone biasing network*

Operation of an electret microphone requires a DC voltage offset across the microphone's connectors. This bias voltage is needed to power the simple transistor amplifier that is built-in to the electret microphone housing. Electret microphones vary, but the component used in this design had an output impedance of 1200 Ω . The electret microphone's gain is directly related to the bias voltage. Therefore, any noise on the positive supply used to provide the DC offset will present on the output of the bias network. Further, because the electret's AC voltage will be very small, a very large gain amplifier is necessary. Any noise on the power line will make it into the amplifier through the bias network and be amplified one hundred fold. To resolve this issue, a zener diode is used to first drop the voltage from the supply to another DC level. Figure 1 depicts the use of a zener to hold the bias steady. The circuit should suppress oscillations on the power line almost up through an amplitude of 3.5V. Immunity to supply oscillations was tested by adding a 2.3 KHz AC voltage source in series with the 12V_{DC} battery. In-band noise was specifically used, because high frequency oscillations would be blocked by the amplifier anyway – it is specifically designed to pass the audio band. Figure 2 shows the results. The top waveform is the supply voltage, which has oscillations far above anything that can be

reasonably expected in the real world. The lower waveform is the microphone amplifier output. Clearly the 2.3 KHz oscillations on the power line do not make it through the biasing network.

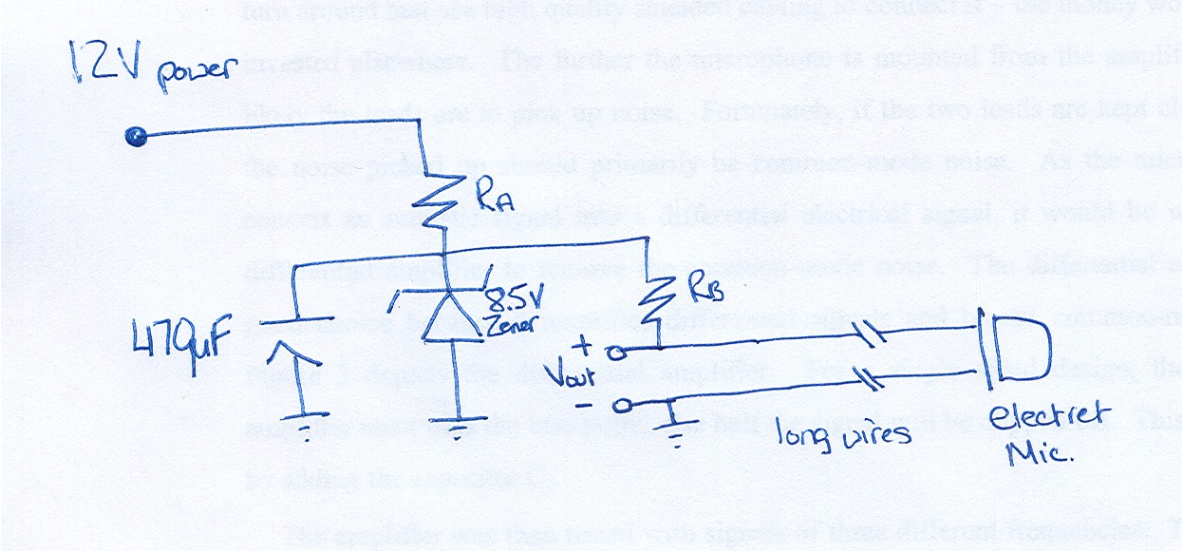


Figure 1 – Biasing network for the electret microphone.

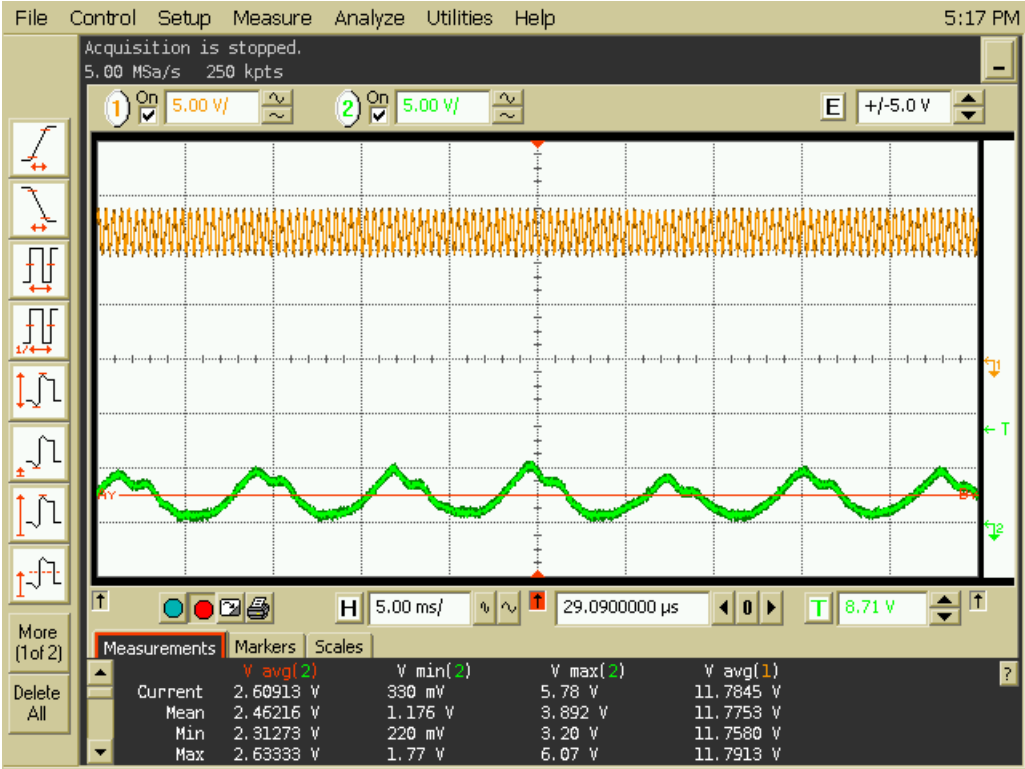


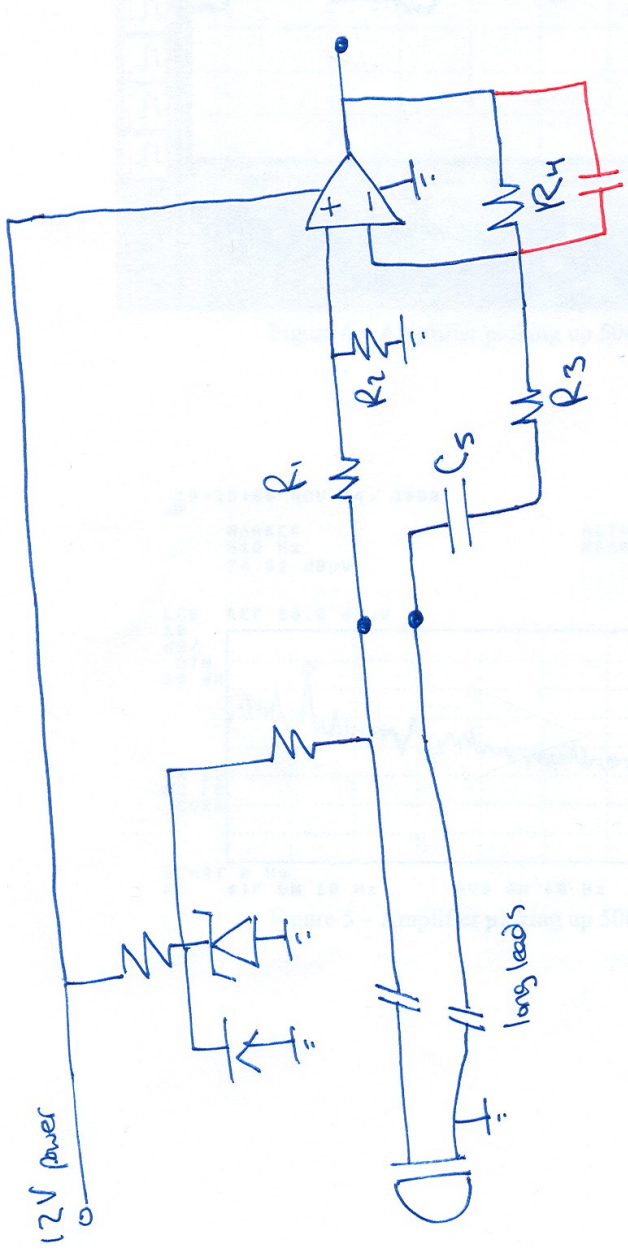
Figure 2 – Testing supply line noise immunity.

4.2 *Common-mode noise immunity*

Twisted pair wiring will almost certainly be used to wire the electret microphone to the amplifier. It would not make sense to buy the relatively cheap electret microphone, but then turn around and use high quality shielded cabling to connect it – the money would be better invested elsewhere. The further the microphone is mounted from the amplifier the more likely the leads are to pick up noise. Fortunately, if the two leads are kept close together, the noise picked up should primarily be common-mode noise. As the microphone will convert an acoustic signal into a differential electrical signal, it would be wise to use a differential amplifier to remove the common-mode noise. The differential amplifier is a good choice because it amplifies differential signals and blocks common-mode signals. Figure 3 depicts the differential amplifier. For a single sided design, the differential amplifier must pass the bias point; else half the signal will be clipped off. This was insured by adding the capacitor C_5 .

The amplifier was then tested with signals of three different frequencies. The test setup used a function generator to generate the signals, which drove an $8\ \Omega$ speaker. The acoustic signal was then picked up by the electret microphone and amplified by the amplifier. The amplifier's output signals are displayed on the scope, and a spectrum analyzer was used to verify the spectral content. Figures 4 and 5 depict the amplifier's output when the speaker was driven with a 500 Hz signal, figures 6 and 7 concern a 2000 Hz signal, and figures 8 and 9 were taken when the speaker was driven at 3500 Hz. The spectrum analyzer plots are far more useful, and indicate the amplifier's output does contain an amplified version of the tone from the speaker. When analyzing the spectrum analyzer plots below, it is important to note that the large amount of spectral content present in the plots was not generated from the speaker during the tests. The amplifier was used to measure the ambient noise of the testing environment, with the result shown below in figure 10. The noise floor was also taken by disconnecting the microphone, just to prove the spectral content is in fact acoustic noise. The noise floor is depicted in figure 11.

As a side note, the tones on the spectrum analyzer plots are all greater than 15 dB above surrounding spectral content. This provides support that matched should work on these tones, and by superposition, any signal that could be broken down into these tones. Although the source was not swept continuously, it is not a stretch to expect similar behavior throughout the entire audio band.



Differential Amplifier capable of being driven by single supply.

In Red: optional components used to band-limit the amp.

Figure 3



Figure 4 – Amplifier picking up 500 Hz tone from speaker.

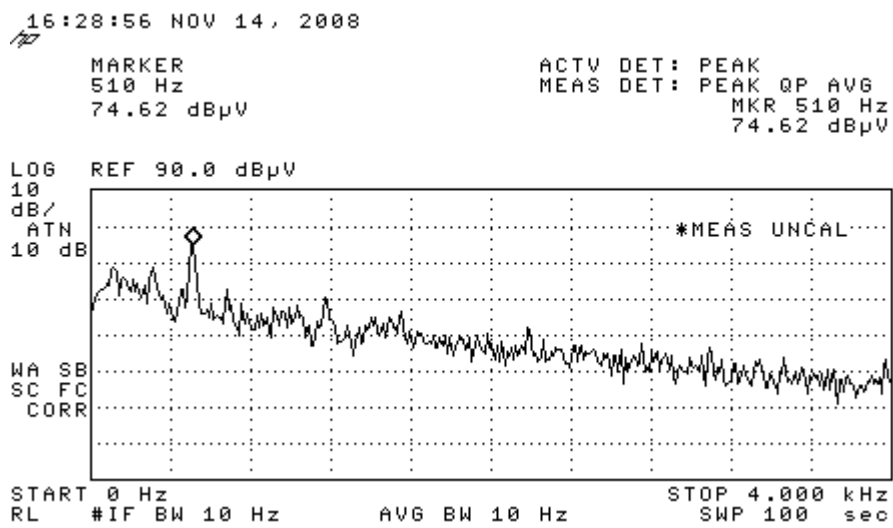


Figure 5 – Amplifier picking up 500 Hz tone from speaker.



Figure 6 – Amplifier picking up 2000 Hz tone from speaker.

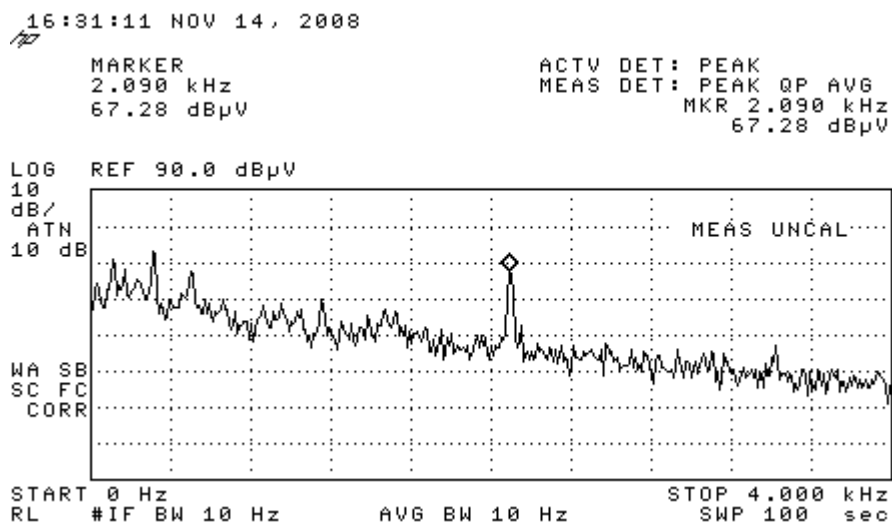


Figure 7 – Amplifier picking up 2000 Hz tone from speaker.

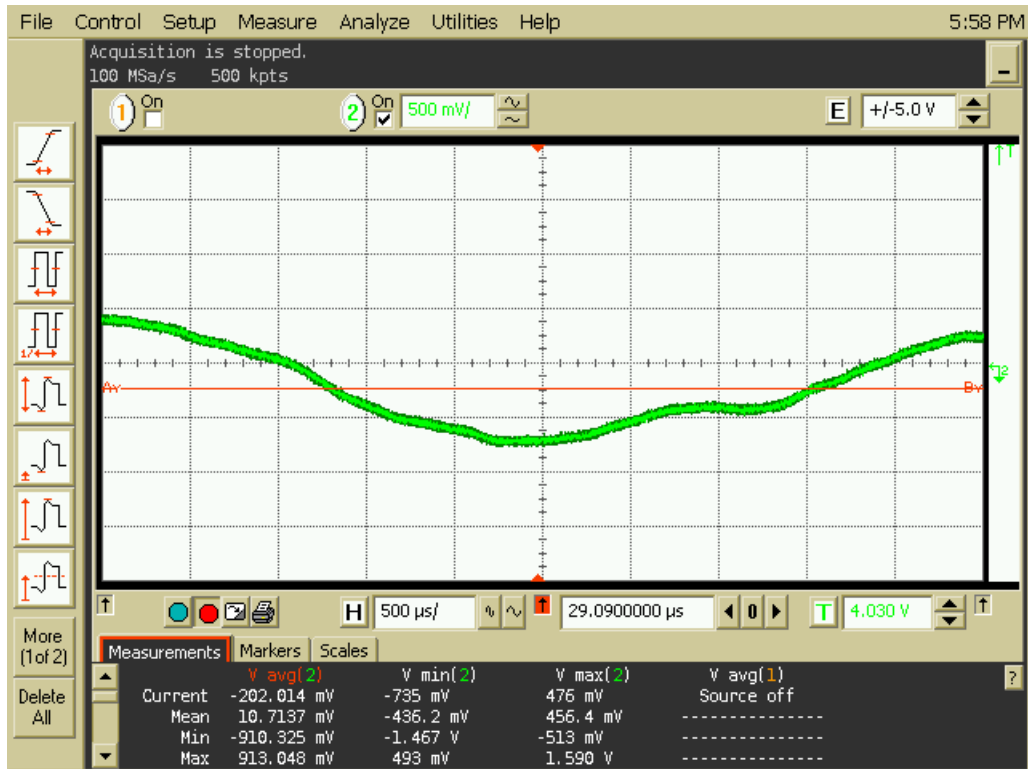


Figure 8 – Amplifier picking up 3500 Hz tone from speaker.

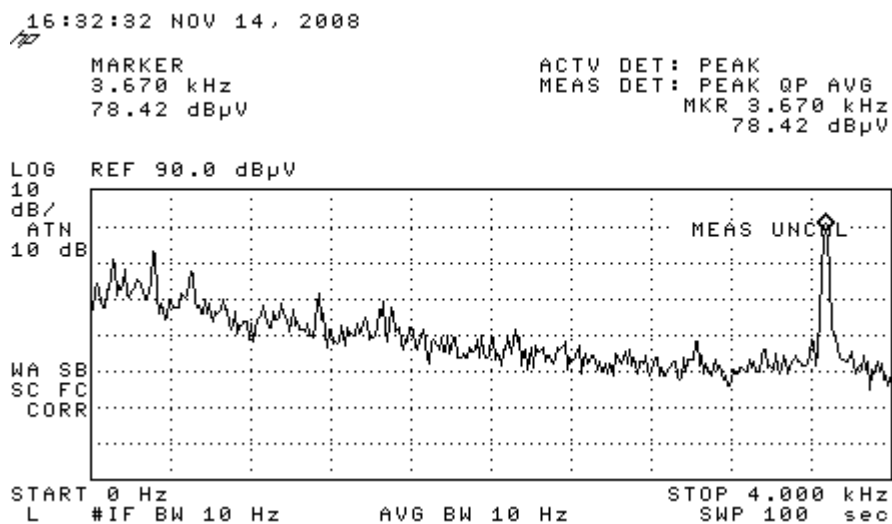


Figure 9 – Amplifier picking up 3500 Hz tone from speaker.

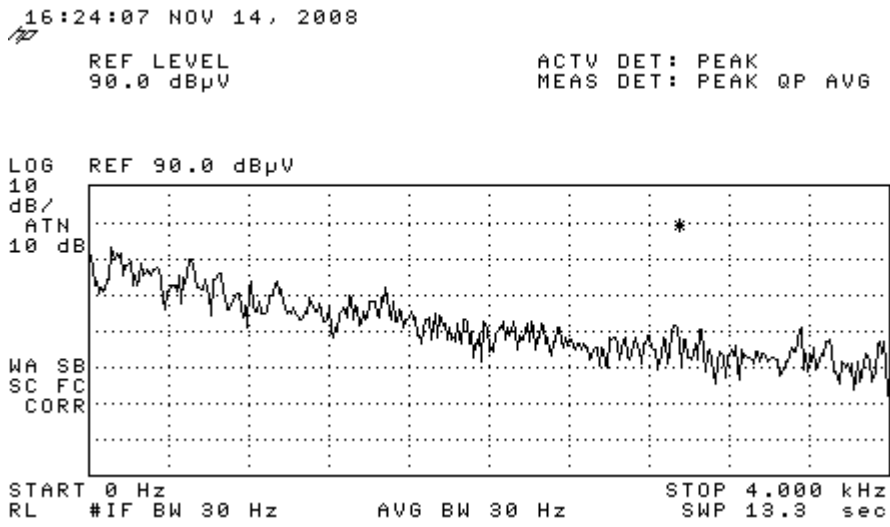


Figure 10 – Ambient acoustic noise in the testing environment.

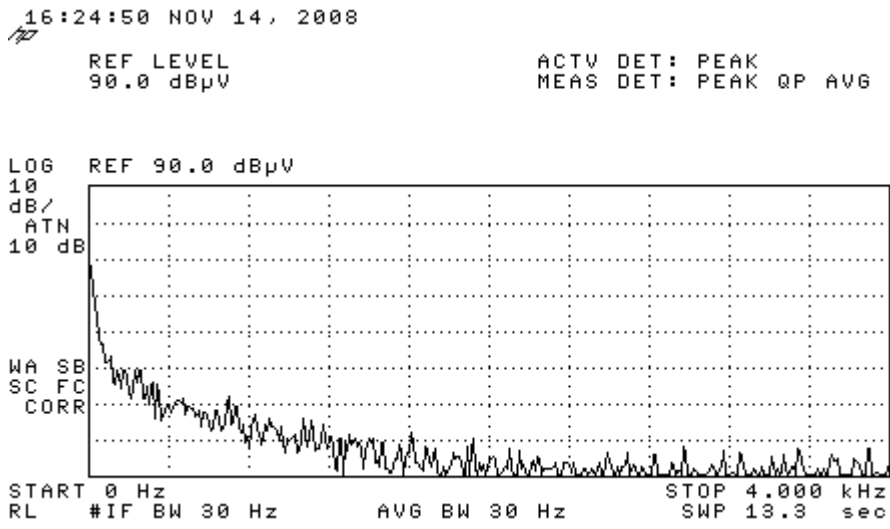


Figure 11 – Electrical noise floor of the spectrum analyzer.

To test the amplifier's ability to reject common-mode noise, a 2V peak to peak signal was added to both of the microphone's lines. Figure 12 shows the common-mode noise and

the resulting output. The output is practically flat, despite the incredibly large noise signal.

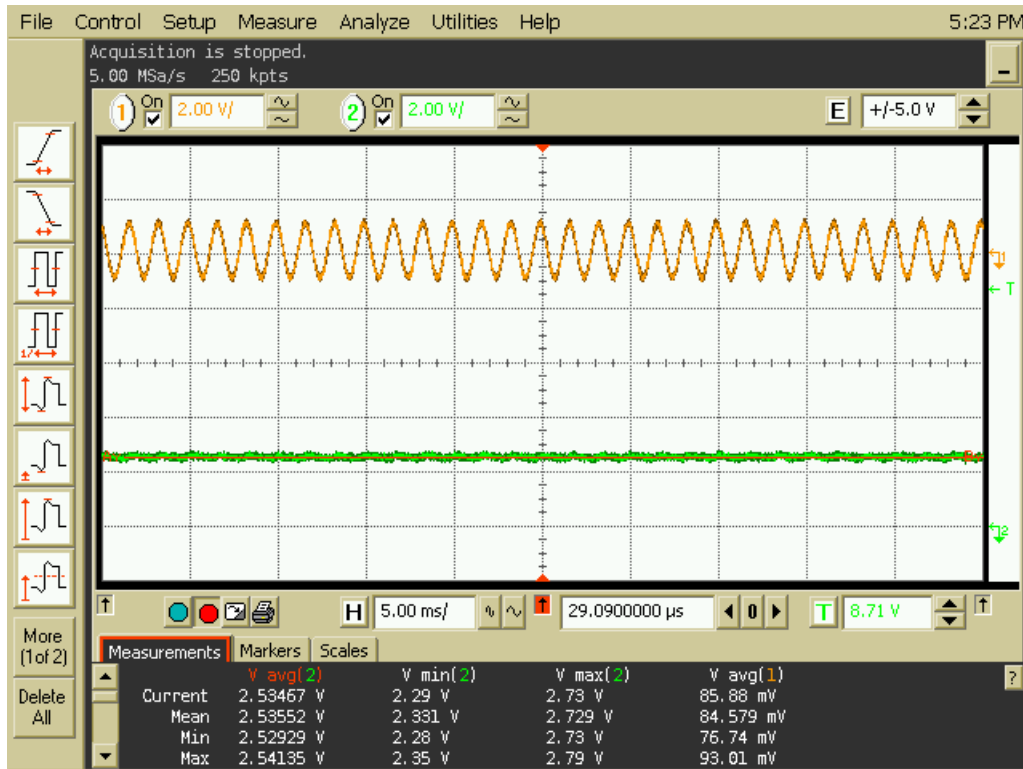


Figure 12 – Common-mode noise rejection capabilities. The top waveform is the common mode signal present on the microphone’s lines. The lower waveform is the output.

4.3 Direct microcontroller compatibility

A final stage needs to be added, one that will produce an output that can be directly connected to the analog-to-digital converter of a microcontroller. The design set forth here will not assume a particular microcontroller, and will allow the user to tweak both the bias point and voltage swing using potentiometers. Thus a single design can be mass-produced, yet will find application in a wide variety of areas thanks to the ability to set the output characteristics.

The final stage will re-set the bias point, depending on the setting of a potentiometer. Further, the AC swing will be separately adjustable through the use of another potentiometer. To insure a very stable bias point, the potentiometer will act as a voltage divider to the 8.5V zener line that is already employed by the initial bias stage. This will

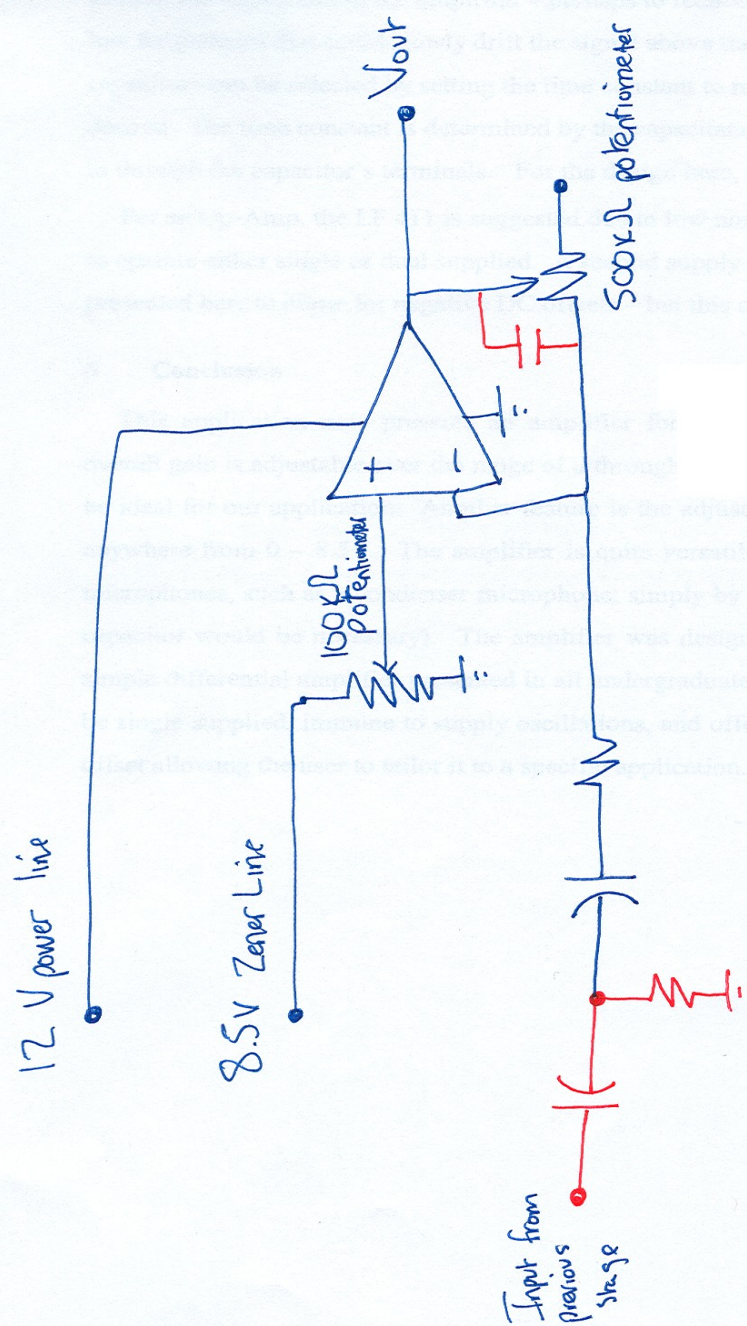
prevent fluctuations on the power supply from altering the output's DC offset. By rotating the potentiometers, one can adjust both the DC offset and the AC gain. Figure 14 depicts the final stage of the amplifier.

4.4 Final testing

The DC offset and AC gain of the final stage was set to the requirements of the Microchip's most common microcontroller, the PIC. The PIC's analog-to-digital converters accept an input signal in the range of 0 – 5V. Thus the DC offset was adjusted to 2.5V by turning the 100KΩ potentiometer. The AC swing increased to reduce digitization errors by adjusting the 500KΩ potentiometer. The resulting AC gain, from electret microphone output to final stage output was measured as 325. Note that this number is not obtainable from the waveforms displayed in figure 13 below due to significant noise pickup of the oscilloscopes probes. This noise is not actually present on the microphone lines, or else it would have been amplified and present on the output as well.



Figure 13 – Complete system gain. Note the visible noise on channel 1 is artificial – it is due to the oscilloscope probe's picking up noise and is not actually present in the circuit.



Red denotes optional components used to band limit the amplifier.

Figure 14 - 2nd Stage

5 Component selection

The schematics often have components drawn in red. These are optional and can be used to limit the bandwidth of the amplifier – perhaps to reduce high frequency noise or block low frequencies that could slowly drift the signal above the microcontroller’s limit. The capacitors can be selected by setting the time constant to match the critical frequency desired. The time constant is determined by the capacitance and the resistance seen looking in through the capacitor’s terminals. For the design here, this can be done by inspection.

For an Op-Amp, the LF 411 is suggested due to low noise characteristics and its ability to operate either single or dual supplied. A second supply could be added to the design presented here to allow for negative DC offsets – but this case finds far fewer applications.

6 Conclusion

This application note presents an amplifier for use with electret microphones. The overall gain is adjustable over the range of 0 through 500. A gain of 325 was determined to be ideal for our application. Another feature is the adjustable DC offset, which can be set anywhere from 0 – 8.5V. The amplifier is quite versatile, and could be adapted to other microphones, such as a condenser microphone; simply by bypassing the first stage (a series capacitor would be necessary). The amplifier was designed completely by modifying the simple differential amplifier presented in all undergraduate electrical engineering courses to be single supplied, immune to supply oscillations, and offer an adjustable AC gain and DC offset allowing the user to tailor it to a specific application.