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11/1/2023
4539-8897

EE Design 1 Technical Report
Amplifier Design

Introduction

The only constant in life is that nothing is constant. Nowhere is this truer than in the field of computing. Our predecessors used massive analog systems with operating voltages that ranged from 10’s to 100’s of volts, while we work with just a small fraction of that power. And yet, we seek to accomplish the same goals. We need to intelligently control screens, speakers, heavy machinery, but we need to do it with a digital processor running on a mere 5 volts. Operational Amplifiers are not a new invention, but it is for this reason that they are now more useful than ever before. They allow us to inflict massive amounts of work upon the world and do it from processors that are smaller than ever before. In this lab, we will explore the implementation of these amplifiers and examine one very common use case.

Methods

Op-Amp Circuit

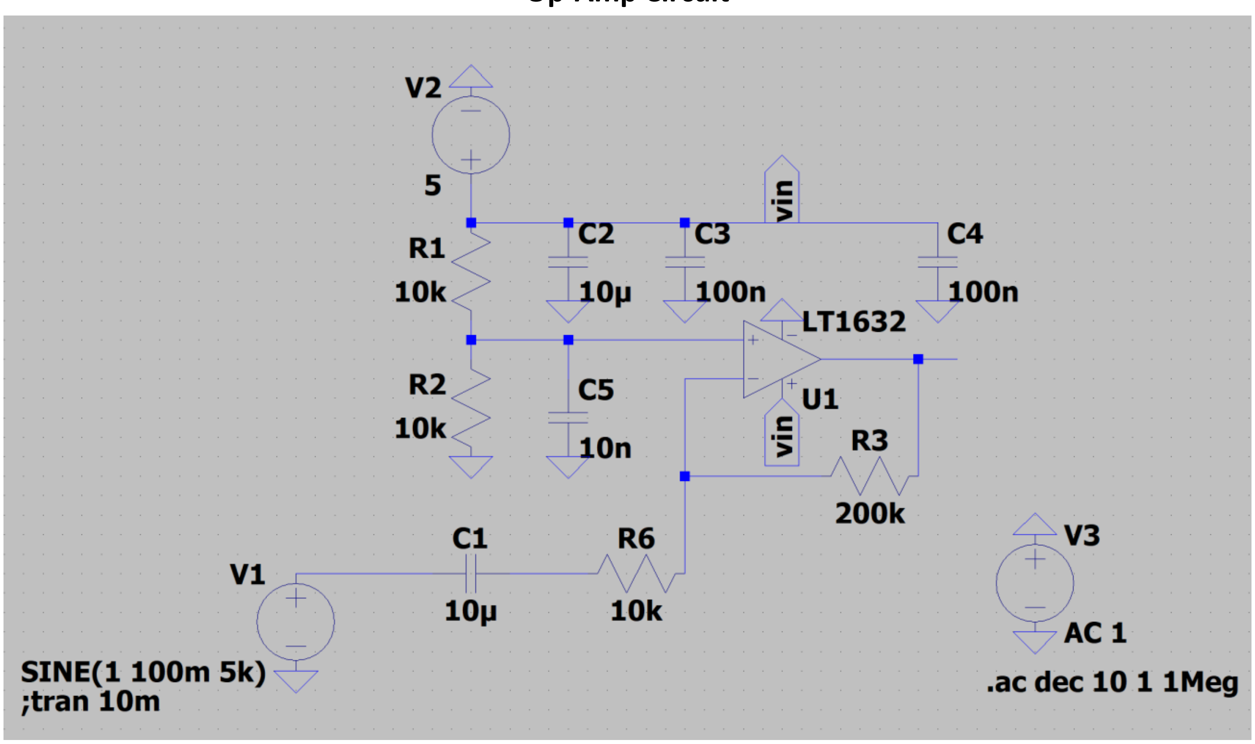

Figure 1: LT Spice Schematic for the Op-Amp Circuit.

I began this journey of discovery by constructing a not-so-simple circuit in LTspice. The complexity of this circuit stems from the need to use a single power supply, meaning that this circuit will operate between 5v and 0v. Commonly, Op-Amps use supplies of +5v and -5v, with one input tied to ground (0v) so that the output will be centered against the supply range. Thus, in order to get a centered output, I used a voltage divider to obtain a node voltage of 2.5v at the positive input to the amplifier chip [1]. This reference voltage is exactly halfway between the supply voltages, so it should do the trick.

Given the choice between the LT1490 and the LT1632, I chose the 1632 without a second thought. After seeing the bizarre frequency response of the LT1490 in last week's lab, I decided to never use it again unless I was trying to waste my time. The instructions for this lab made it clear that a flat gain of 26db or 20x was the goal, and while I did not test the LT1490 in this circuit configuration, I know that it's behavior for last week's circuit was anything but flat, with many peaks and valleys as frequency increased.

The capacitor values throughout the power supply section of the circuit were chosen so that a wide range of unwanted frequencies would be removed from the input signal. The capacitor on the input served two purposes. It removed the 1v dc offset, since only ac signals pass a capacitor, which was key for keeping the op-amp's output from saturating at 5v [2]. It also allowed me to tune the frequency response of the circuit, with 10u allowing the -3db point to be very close to the goal of 100Hz.

The resistor values were much more methodically chosen. As with any inverting op-amp circuit, the equation for gain is Av = -Rf/Ri. In practice this meant that R3 (Rf) needed to be 20x the value of R6 (Ri) so that a gain (Av) of 20 could be achieved. This gain in v/v corresponded with the required gain of 26db, which I calculated by using the equation Gain(db) = 20*log(gain(v/v)). Technically, I could have used many different values here as long as the ratio remained the same, but I chose 10k and 200k since they are in what I would consider a safe range (1k-500k) and their values are relatively standard.

Audio-Amp Circuit

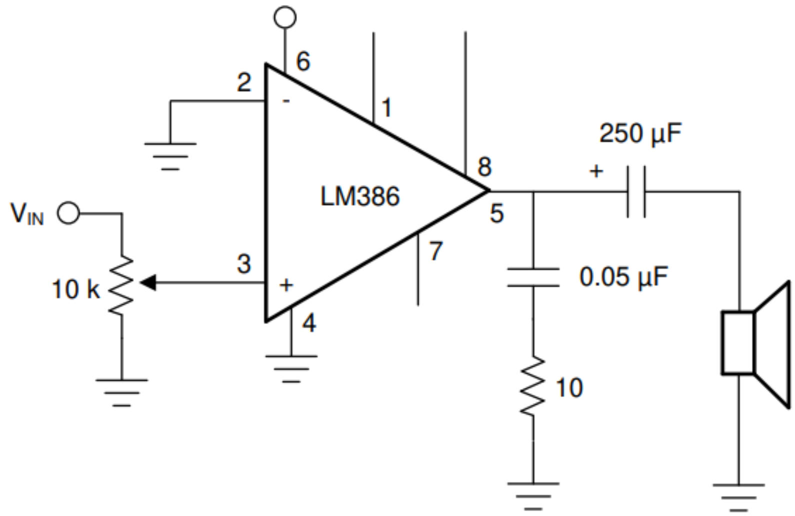

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Figure 9-1. LM386 with Gain = 20

Figure 2: Audio Amplifier Circuit from the LM386 datasheet.

For the audio amplifier circuit, I was at first very confused by the lack of direction provided by the instructions. I assumed this lack of information meant that the requirements for the regular op-amp circuit also applied, but I eventually came to realize this was not the case. Once I made this realization, I decided to use the schematic provided in the LM386's datasheet since it conveniently was modeled for a gain of 20, the exact gain that was required.

I used this setup exactly, with the only differences being a 270uF capacitor in series with the speaker instead of the recommended 250uF. This was just because I did not have a 250uF. Initially, when I thought that the frequency requirement from the previous section still applied, I did attempt to shift the frequency response of the system so that it would more closely match the design requirements for part 1. Following the datasheet, I had added a capacitor between pin 7 and ground, but this was removed for the final version since it was not necessary.

Results

Op-Amp Circuit

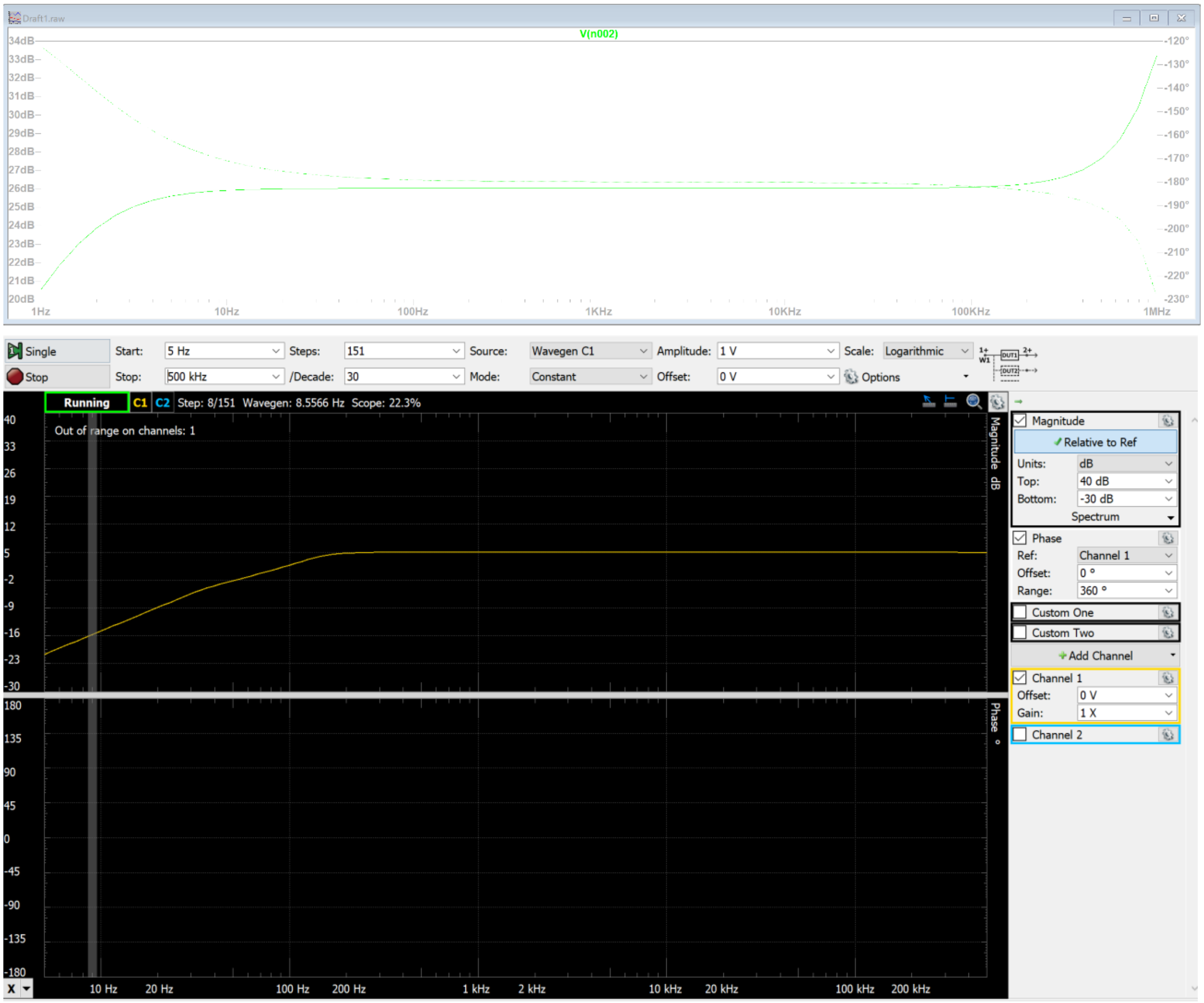

Figure 3: Frequency Response of LTspice and Breadboard implementation for Op-Amp Circuit.

The frequency response for the op-amp circuit was just as I had expected. With a -3db point that is very nearly at 100hz, and a continuous flat gain of 26db through 15kHz and even further, the filter aspect of this circuit worked perfectly.

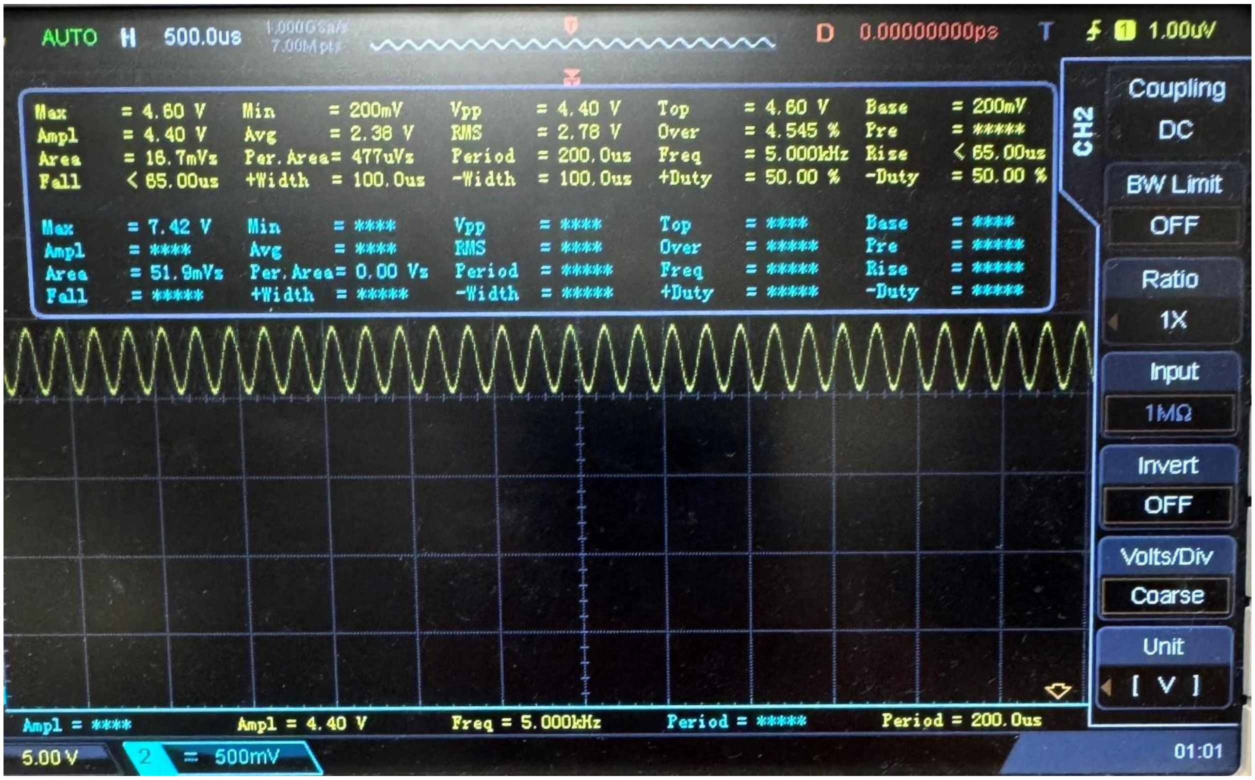

Figure 4: Transient Analysis of LTspice and Breadboard implementation for Op-Amp Circuit.

The transient analysis was similarly effective. The output was a perfect amplified version of the input, stretched fully over the 0-5v range, and centered at 2.5v. That is, with no load. With a load (the 8ohm speaker) the output fell to a dc 0v. This was because the LT1632 could not supply the proper output current of 500mA to power the speaker. It seems to be for this reason that the second part of this lab exists: to make an amplifier circuit that can power a speaker.

Audio-Amp Circuit

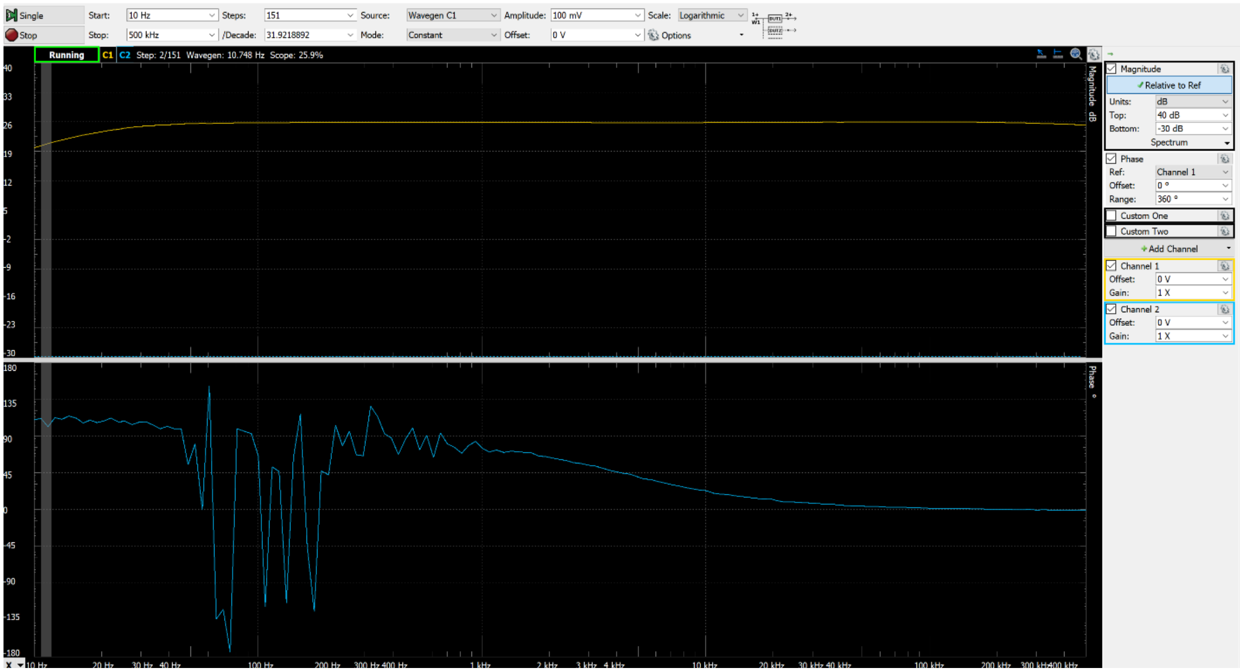

Figure 5: Frequency response of Breadboard implementation of Audio Amplifier Circuit.

The frequency response of the audio amplifier circuit was also as expected. A very flat 26db gain from 10Hz to at least 400kHz, but probably even further.

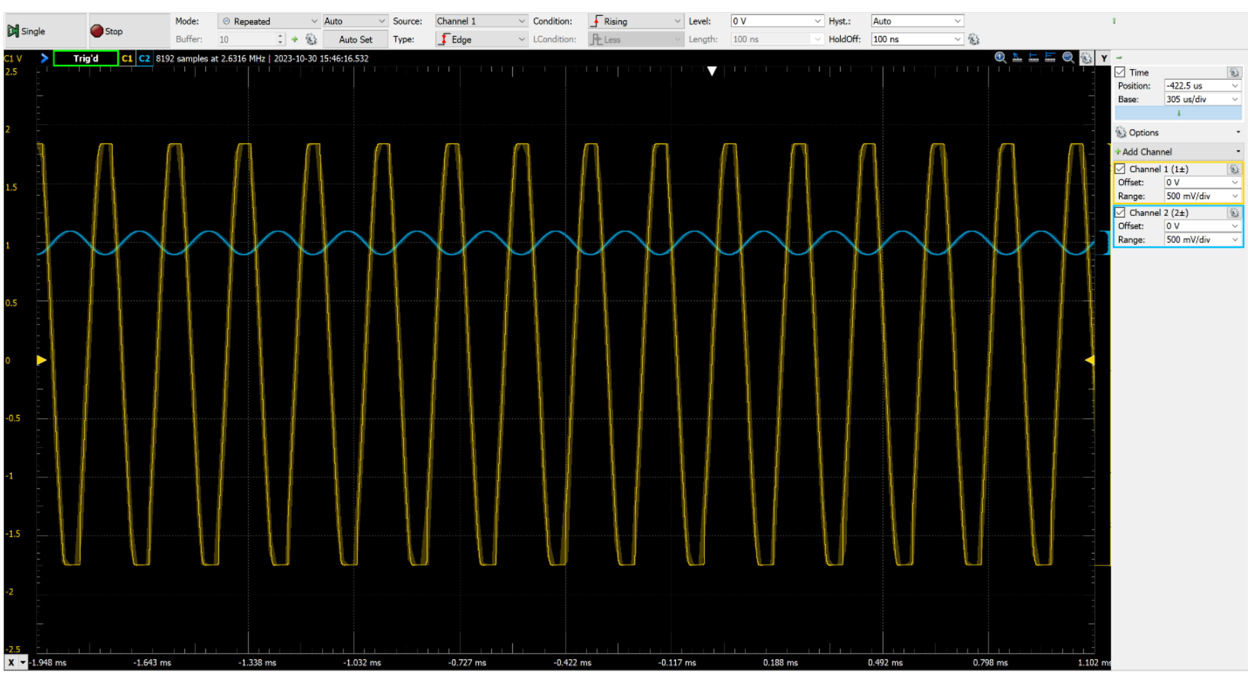

Figure 6: Transient analysis of Breadboard implementation of Audio Amplifier Circuit with 10ohm load.

Using a 10ohm resistor as the load, so as not to blow out anyone's eardrums, I recorded a very solid transient analysis for the circuit. Notably, this is different from the previous circuit configuration, as it is centered around 0v instead of 2.5. Additionally, there was some attenuation at the peaks of the sine wave output, which could have been fixed by adjusting the gain or the magnitude of the input signal. Figure 6 also proved that the LM389 was much more capable of outputting a current than the LT1632.

That being said, the LT1632 does still have its uses. Its voltage range lends itself much more to applications on battery powered devices or in systems with a positive dc power supply. The LM389 on the other hand does have a larger output current rating and can have an incredibly high gain, as I saw a configuration in the datasheet for a gain of 200. For this reason, it may be more useful in systems where more power is required.

Conclusion

Amplifiers are hugely important to modern circuitry, but they are also varied, as are their use cases. Some amplifiers like the LT1632 are better used in small, low-power circuits where only a single positive voltage source exists. Others like the LM389 are more useful in high-power circuits where gain values like 200 wouldn't just cause saturation. And others still like the LT1490 aren't very useful at all, though I imagine that's an outlier. Regardless, amplifiers are a integral part of modern circuitry, and now we know how to use them in our own designs.

References

[1] "single-supply op amp design techniques" - Texas Instruments India, https://www.ti.com/lit/an/sloa030a/sloa030a.pdf (accessed Nov. 1, 2023).

[2] Limchengwei, "Removing DC offset voltage with resistor and capacitor," Hackster.io, https://www.hackster.io/limchengwei/removing-dc-offset-voltage-with-resistor-and-capacitor-f1ded5 (accessed Nov. 1, 2023).