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7/31/26

EEL 3111C

Final Project Report

Abstract

The purpose of this project was to design and construct an audio-amplifier circuit that combines filtering, amplification, buffering, and threshold indication into one system. A low-amplitude audio signal containing a single 0.5 V DC offset was used as the input. An active high-pass filter removed the DC component while providing the first stage of voltage gain. Then, a variable-gain inverting amplifier increased the millivolt-level audio signal to a level capable of operating the speakers. Two voltage followers then isolate the amplifier from the left and right speakers and then provide the current needed by the load. After this, a pair of comparator circuits monitored the output that then controlled LEDs that indicated the circuits operating range. This complete circuit was then tested using transient-response, frequency-response, and spectral measurements. These results demonstrated a successful removal of the DC offset, output buffering, and audio reproduction of the original supplied audio signal.

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Procedure

High-Pass Filter Stage

The input signal was first applied to an active inverting high-pass amplifier made using one portion of a TLV272 operational amplifier. The 0.1µF input capacitor blocked the 0.5 V DC offset while enabling the audio-frequency portion of the waveform to pass. A 15 kΩ input resistor and a 120 kΩ feedback resistor established a high-frequency gain magnitude of approximately eight. These component values then produced an estimated cutoff frequency of 106 Hz which was calculated using $f_c = 1 / (2\pi RC)$. This cutoff was selected to remove the DC component of the signal without eliminating most of the frequencies contained in the signal.

Variable-Gain Stage

The filtered signal was then connected to a second inverting amplifier to provide adjustable amplification using a potentiometer. A potentiometer was used as the input resistance while a 33 kΩ resistor followed the feedback path. The gain of this stage was controlled, allowing the final output amplitude to be adjusted without changing components. During testing, the potentiometer was set such that a 10 mV, 1 kHz test signal produced an output close to 2 V. This kept the amplifier in its intended linear operating region and prevented clipping when measuring.

Output Buffer Stage

The output of the variable-gain amplifier was then connected to two voltage followers constructed from a second TLV272. Each of the buffers used direct negative feedback from the output to its inverting input which produced a gain of approximately one. The two buffers inputted the same amplified signal and supplied it independently to the left and right channels of the 3.5 mm connector. This configuration isolated the gain stage from the speaker and then increased the output current. Because both channels input the same waveform, the output was dual mono rather than stereo with distinct right and left audio information.

Comparator and LED Stage

A dual LM393 comparator monitored the amplified output and compared it with two reference voltages generated by a resistor ladder. The first comparator controlled the LED associated with normal linearity. The second comparator showed that the signal was approaching or entering saturation. When the output remained below the lower threshold, both LEDs were turned off. When the output crossed the lower threshold but not the upper threshold, only the first LED was on. When the upper threshold was exceeded, both LEDs illuminated, warning that clipping and distortion is much more likely.

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Custom Block Diagram

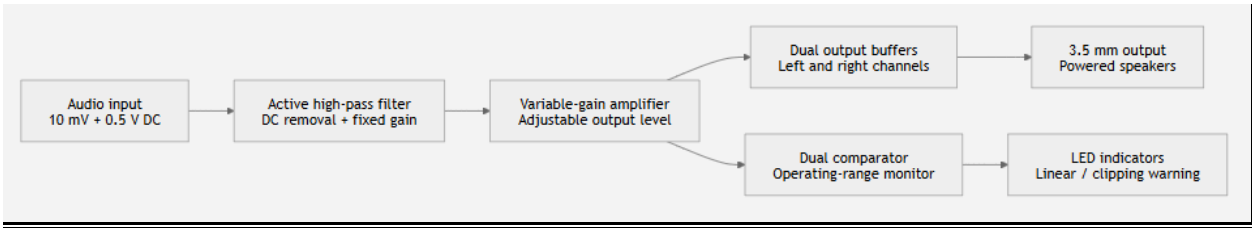


Figure 1: *Functional block diagram of the completed audio-amplifier system, showing the primary audio path and the separate comparator-based operating-range indicator.*

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Results

The completed amplifier was evaluated using LTspice simulation and measurements obtained from the physical circuit. The results included a complete circuit schematic, a transient simulation of the individual circuit stages, the Jingle19.wav input and buffered output, the measured frequency response, and the output spectrum. The potentiometer was then adjusted before testing so that the circuit operated in strictly its linear region with only the first threshold LED illuminated. This setting produced an amplified output without driving it into saturation. The following figures document the operation of the complete system.

Parts List

Component	Part Number	Quantity	Unit Price	Extended Price
Dual operational amplifier	TLV272	2	$0.560	$1.120
Dual comparator	LM393	1	$0.310	$0.310
Capacitor	0.1 µF	1	$0.100	$0.100
Resistor	120 KΩ	1	$0.440	$0.440
Resistor	33 KΩ	1	$0.260	$0.260
Resistor	15 KΩ	2	$3.300	$6.600
Resistor	5.6 KΩ	2	$2.660	$5.320
Resistor	1 KΩ	2	$0.890	$1.780
Resistor	100 Ω	1	$1.070	$1.070
Potentiometer	0 to 10 kΩ	1	$1.690	$1.690
LED	Red OSRAM	2	$0.950	$1.900
Total				$20.590

Table 1: *Component list and estimated cost of the final audio-amplifier circuit.*

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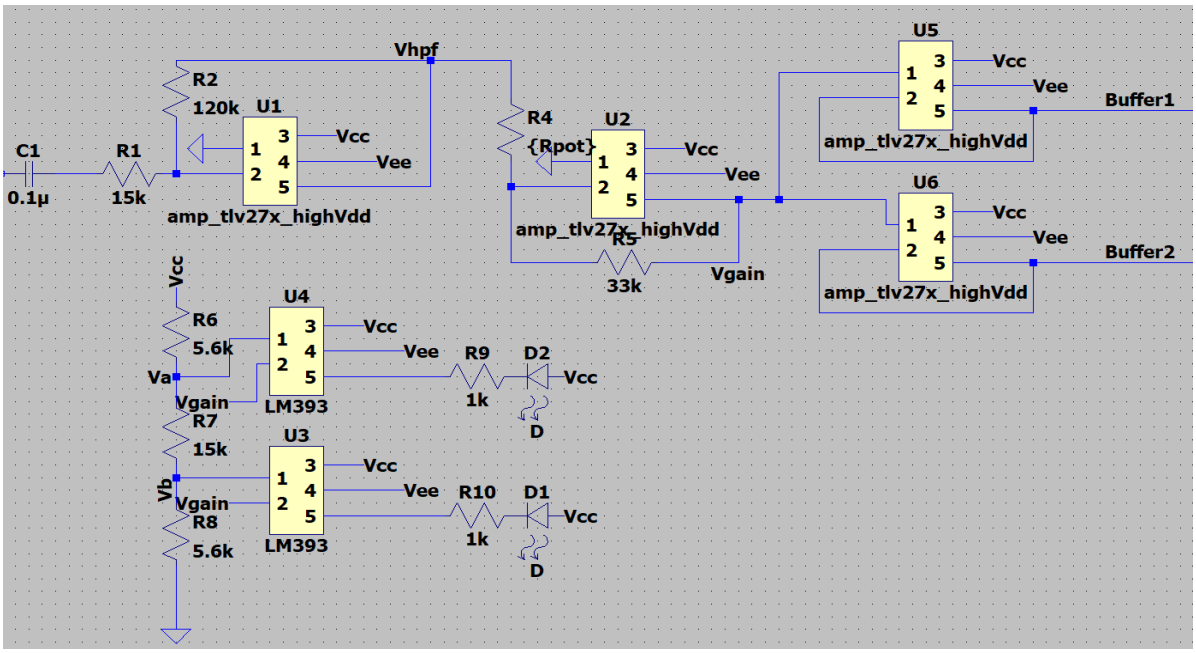


Figure 2: *Complete LTspice schematic of the final audio amplifier. The circuit consists of an active high-pass filter, variable gain amplifier, two comparator-based LED threshold indicators, and two unity-gain output buffers used to drive the left and right audio channels.*

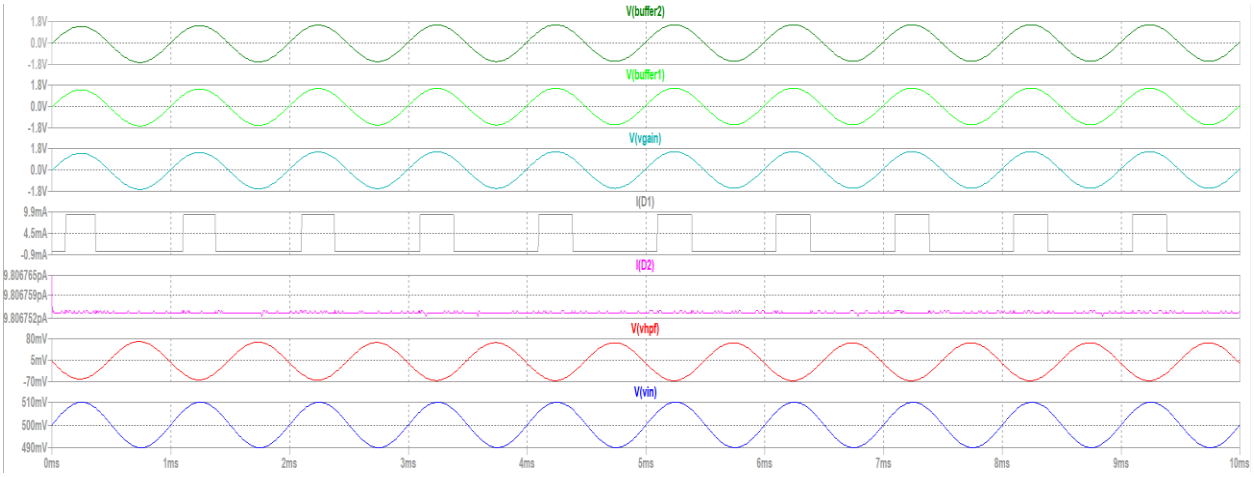


Figure 3: *LTspice transient simulation of the final audio amplifier using a 10 mV amplitude, 1 kHz sine wave with a 0.5 V DC offset as the input. The plot shows the input signal, high-pass filter output, gain stage output, buffered output, and the currents through the two indicator LEDs, verifying correct operation of the linear gain region.*

Circuit and Simulation Results

Figure 2 presents the complete amplifier and identifies the connection between each of the functional stages. The simulated waveforms in Figure 3 show that the high-pass filter removed the DC offset before the signal was amplified. The output-buffer trace closely followed the gain-stage output which was expected for a properly operating gain voltage follower. The LED-current traces were used to confirm the state of the comparator indicators.

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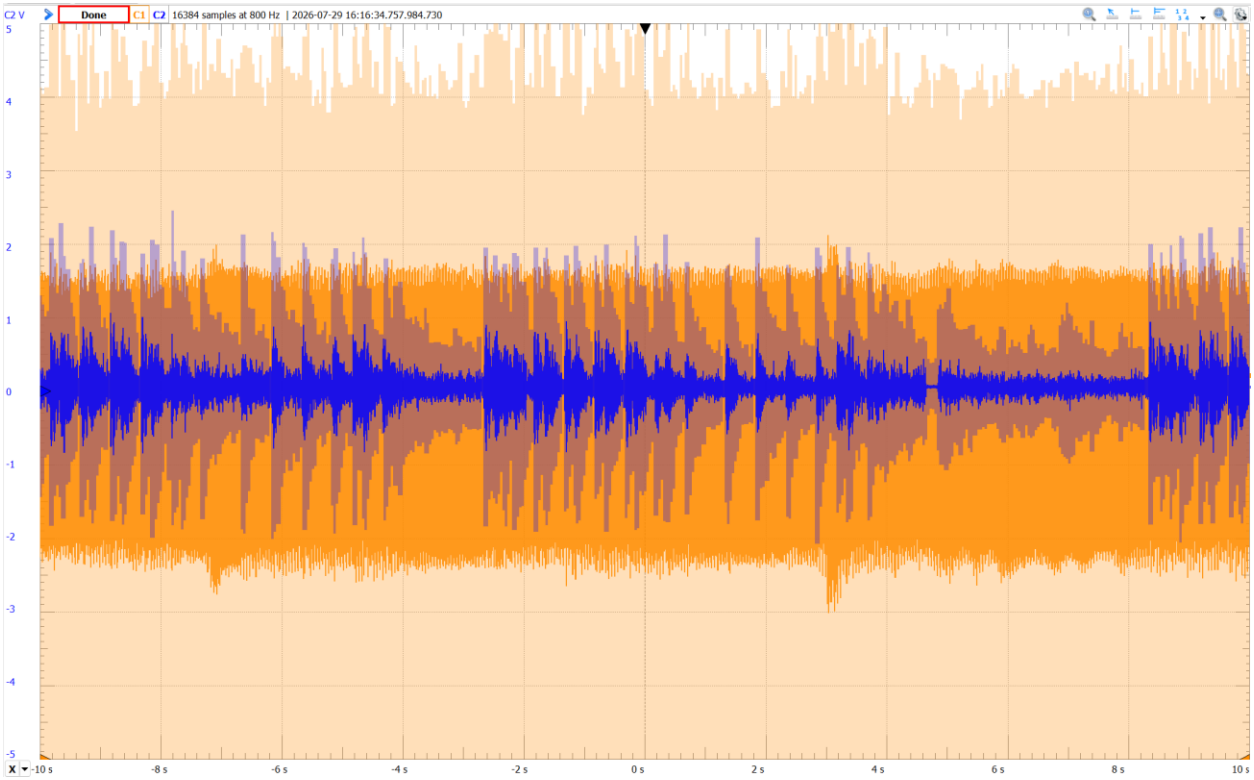


Figure 4: *Measured oscilloscope acquisition of the Jingle19.wav input and amplifier buffer output. Channel 1 (orange) represents the small input waveform with its DC offset while Channel 2 (blue) represents the larger AC output supplied to the speaker channel.*

Time-Domain Results

Figure 4 compares the supplied Jingle19.wav signal with the buffered amplifier circuit. The output followed the changes in input audio while showing a substantially larger amplitude. The output was centered around approximately 0 V since the series capacitor removed the input's 0.5 V DC offset. The potentiometer is adjusted such that the circuit remains in linear operating range as indicated by a single illuminated LED.

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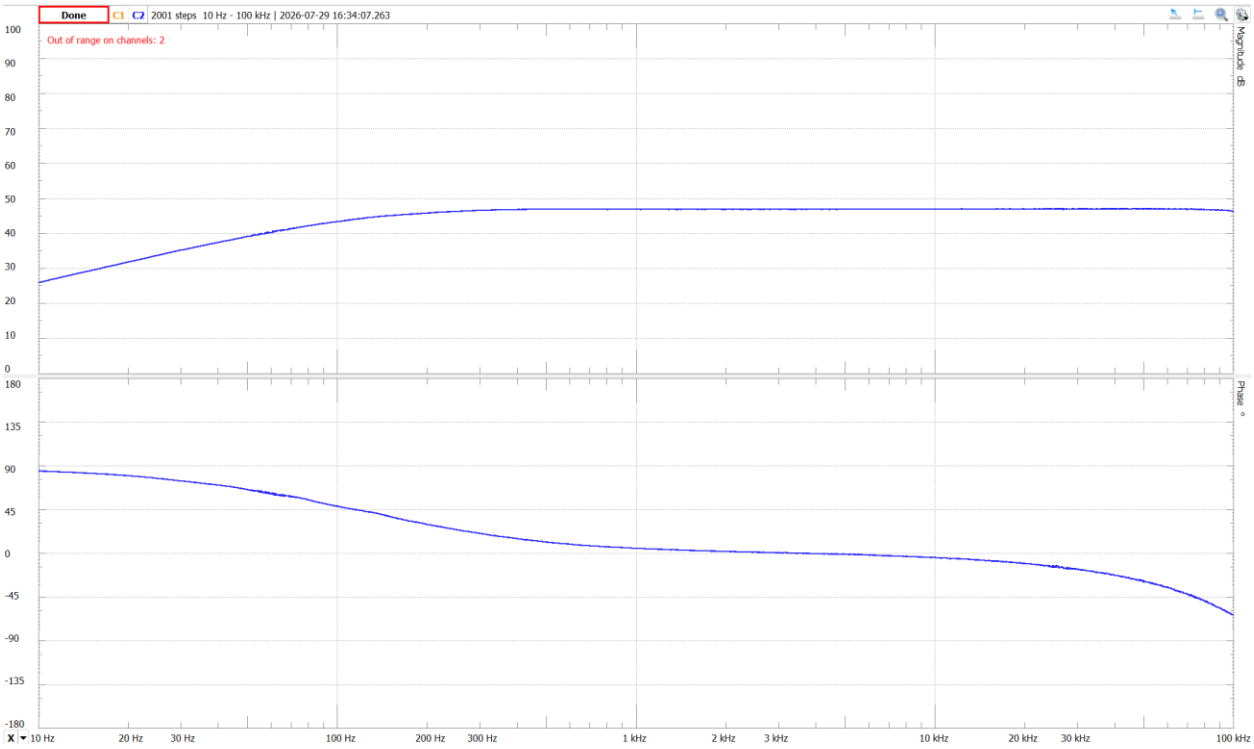


Figure 5: *Measured frequency response from the amplifier input to one buffered output over a sweep from 10 Hz to 100 kHz. The upper trace shows the output magnitude while the lower trace shows the corresponding phase response.*

Frequency-Response Results

Figure 5 shows the combined frequency response of the cascaded high-pass filter, gain stage, and buffer. The response initially increased with frequency because frequencies below the high-pass cutoff were attenuated. Then, it approached a constant midband and at higher frequencies, the response began to decrease due to the finite bandwidth of the cascaded operational-amplifier stages. The phase variation across this sweep was due to the high-pass filter and the frequency dependent behavior of the active components.

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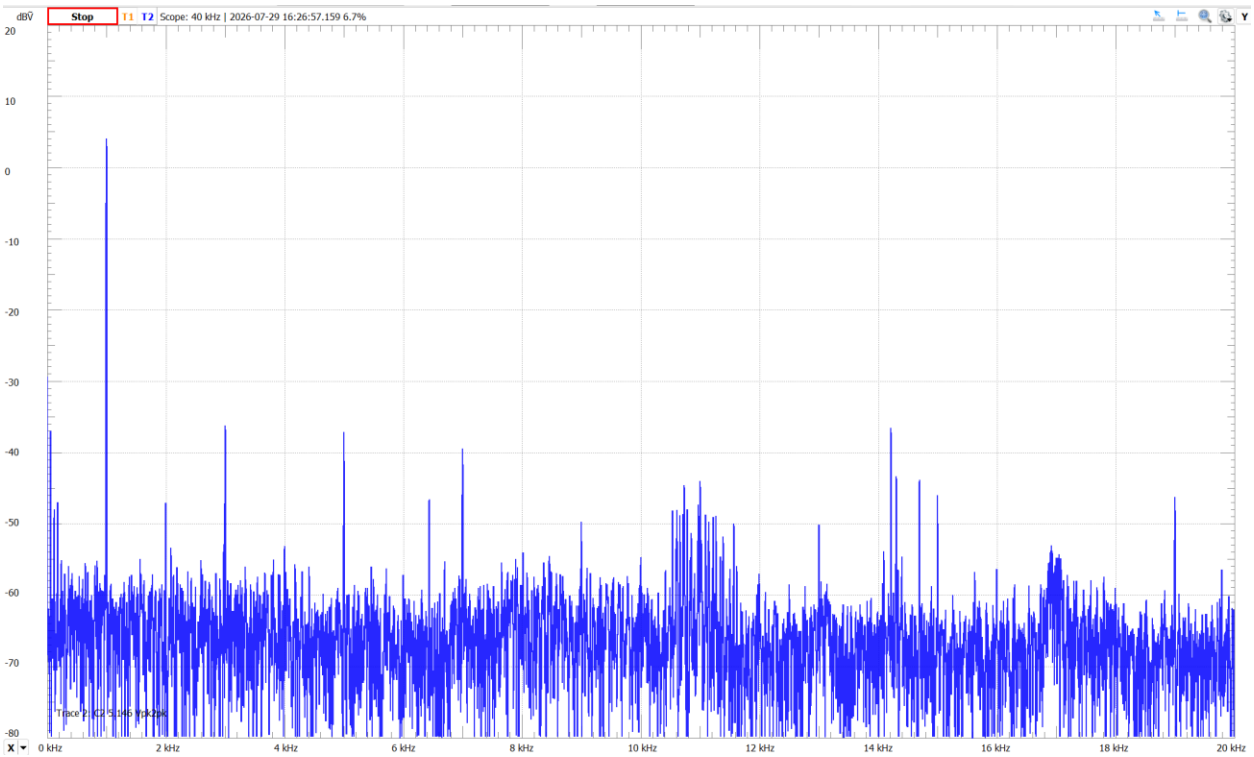


Figure 6: *Measured output spectrum of one buffer for a 10 mV-amplitude, 1 kHz sinusoidal input with a 0.5 V DC offset. The dominant spectral component occurs at the 1 kHz fundamental frequency, while the remaining components represent noise and harmonic content in the measured output.*

Spectrum Results

Figure 6 shows a dominant peak at approximately 1 kHz which corresponds to the frequency applied by Wavegen. However, smaller peaks and a visible noise floor remain in the measured spectrum. These components may have resulted from electrical noise, power-supply coupling, breadboard parasitic, wire parasitic, measurement settings, or a non-linear distortion. The absence of harmonics comparable in magnitude to the fundamental indicated that the amplifier was not heavily clipped during this test.

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Conclusion

The final circuit successfully combines the active high-pass filter, adjustable-gain amplifier, dual output buffers, and comparator-based LED indicators into a functional audio system. The high-pass filter removed the 0.5 V DC offset while maintaining the majority of the useful audio signal. These two amplification stages increased the input to a level that could be reproduced by the powered speakers. The potentiometer allowed the output amplitude to be adjusted among the cutoff, saturation, and linear regions. Both of the output buffers reproduced the amplified waveform and supplied the exact same signal to the left and right speaker channels. The measured response displayed the expected high-pass behavior, midband gain region, and a high-frequency roll-off. Spectral testing produced a cominant component at the applied 1 kHz frequency yet smaller noise and harmonic components were also visible. All in all, the completed circuit met the project objectives by producing an audible, adjustable output while providing a visual indication of its operating range.