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Transistor Amplifiers

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Introduction

The purpose of this report is to analyse 3 different transistor amplifier configurations and research their characteristics such as current gain, voltage gain and impedance. building off the research theoretical calculations will be made around designing a common emitter amplifier that can support a speaker, using the theoretical calculations a theoretical circuit of a single stage and two stage common emitter transistor amplifiers.

These theoretical circuit will be created and simulated on LTspice to compare to the expected gain; the output signal needs to achieve a high-quality amplification with minimal distortion. Once satisfied with the output gain of the simulation a practical build will be made with equivalent components and then measured with an oscilloscope, and gain will be calculated and compared to the simulated gain.

Objectives

- Research 3 different configurations of the Transistor Amplifier.
- Calculate Resistor Values for a Linear Amplifier when Load is 600Ω .
- Design a Single Stage Linear Transistor Amplifier using a 2N2222 or BC109 NPN Transistor.
- Design a Two Stage Linear Transistor Amplifier using a 2N2222 or BC109 NPN Transistor.
- Simulate the Single and Two Stage Transistor Amplifiers ensuring the single stage Transistor Amplifier has a Gain of 5 and the Two Stage Transistor Amplifier has a Gain of 2.
- Build the Single Stage and Two Stage Transistor Amplifier and compare the Theoretical Simulation to the Physical circuit.

Theory/research

(Motayed, et al., 2001) explains that transistor amplifiers in the linear region can provide high voltage, current and power gains.

The bipolar junction transistors (BJTs) can act as good amplifiers when operated in linear regions [1]. In these regions of operation, the BJTs have the capacity to provide high voltage, current, and power gains. (Motayed et al., 2001, p. 326)

(Horowitz & Winfield , 2015) explains that a common-collector configuration also known as an emitter follower has a larger impedance at the input compared to the output.

At first glance this circuit may appear quite thoroughly useless, until you realize that the input impedance is much larger than the output impedance, as this will demonstrated shortly. (Horowitz & Winfield , 2015, p. 79)

(Horowitz & Winfield , 2015, p. 79) also explains that the emitter follower provides current gain instead of voltage gain. “an emitter follower has current gain, even though it has no voltage gain.”

(Horowitz & Winfield , 2015, p. 440) states that a common-base transistor amplifier are non inverting, this means that the signal going in will be the same on the output but with a voltage gain. “Because an common-base amplifier is noninverting, the feedback signal is not inverted.”

(Aithekar, 2021, p. 125) states the different amplifier configurations voltage, current and power gains, and the input and output resistances. These are shown at Table 1.

Configuration Comparison among Transistor Configurations

Table 1. Comparison among Transistor Configurations

Transistor Configuration	Common Base	Common Collector	Common Emitter
Voltage gain	High	Low	Medium
Current gain	Low	Medium	High
Power gain	Low	Medium	High
Input resistance	Low (30-150ohm)	High (20-500)ohm	Medium (1k to 2 k)
Output resistance	High (500)	Low(50-1000k)ohm	Medium (50k)

(AITHEKAR, 2021, P. 125) - TABLE 1

From this table it shows that common base amplifier provides a high voltage gain but a low current and power gain, with a low input resistance (30Ω -50Ω) and high output resistance (500Ω).

The common collector amplifier provides a low voltage gain but a medium current and power gain, with high input resistance (20 Ω -500 Ω) and low output resistance (50Ω -1000KΩ).

The common emitter amplifier provides a medium voltage gain but high current and power gain with a medium input resistance (1KΩ -2KΩ) and output resistance (50KΩ).

(Sedra, Adel S; Smith, Kenneth C;, 2014) states that by adjusting the bias current, this will also change g_m and the output voltage gain will be adjusted in result.

The input resistance of the CE amplifier, $R_{in} = r_{\pi} = \frac{\beta}{g_m}$, is inversely Proportional to the dc bias current I_C . To increase R_{in} one is tempted to lower the bias current I_C ; however, this also lowers g_m and hence the voltage gain. (Sedra, Adel S; Smith, Kenneth C;, 2014, p. 431)

(Sedra, Adel S; Smith, Kenneth C;, 2014) explains that a common base amplifier provides a high frequency response and are used as high frequency amplifiers. "These two configurations exhibit a much better high-frequency response than that available from the CS and CE amplifiers. This makes them useful as high-frequency amplifiers." (Sedra, Adel S; Smith, Kenneth C;, 2014, p. 453)

(Sedra, Adel S; Smith, Kenneth C;, 2014) explains that a common collector amplifier (emitter follower) can be use as a buffer. This is useful for applications that need high current but the previous stage does not supply it. The Common Collector keeps the voltage the same but provides current gain.

The source follower (emitter follower) finds application as a voltage buffer for connecting a high-resistance source to a low-resistance load, and as the output stage in a multistage amplifier, where its purpose is to equip the amplifier with a low output resistance. (Sedra, Adel S; Smith, Kenneth C;, 2014, p. 453)

What this shows is that the common emitter amplifier is the most suitable when voltage gain is required, as it has a medium input resistance and a high-power gain (Aithekar, 2021). Whereas common base amplifier provides a high-frequency amplification (Sedra, Adel S; Smith, Kenneth C;, 2014) as well as being noninverting. The common collector amplifier also known as a emitter follower is more effective as a buffer between applications that cant drive the circuit properly providing a current gain and low to non-voltage gain (Sedra, Adel S; Smith, Kenneth C;, 2014).

equipment/apparatus

Simulation

- LTspice (Simulation Software) (DEVICES`, 2026)
- 10V Voltage Source
- GND
- 100Mv, 1000Hz Signal Source
- 3x 10uF Polarized Capacitors
- 2x 9095 Ω Resistors
- 2x 2043 Ω Resistors
- 1x 120 Ω Resistors
- 2x 600 Ω Resistors
- 1x 300 Ω Resistors
- 2x 2N2222 NPN Transistors
- 1x 1uF Ceramic Capacitor
- 2x 0.22uF Ceramic Capacitor
- 1x 0.1uF Ceramic Capacitor
- 1x 0.47uF Ceramic Capacitor
- 1x 1.5uF Ceramic Capacitor
- 1x 13uF Ceramic Capacitor
- 1x 10uF Ceramic Capacitor

Practical

- Power Supply Unit
- Oscilloscope
- Function Generator
- Breadboard
- 2x 10K Resistors
- 2x 2K2 Resistors
- 2x 860 Ω Resistors
- 1x 120 Ω Resistors
- 1x 330 Ω Resistors
- 3x 10uF Polarized Capacitors
- 1x 1uF Polarized Capacitors
- 2x bc109 NPN Transistors
- 2x Banana to crocodile clip test leads
- 3x Oscilloscope Test probe leads

Experimental procedure/methodology

Specifications

$$\beta = 100$$

$$AV = 5$$

$$VCC = 10V$$

$$V_{be} = 0.7V$$

$$RL = 600\Omega$$

Calculations

$$VRC = \frac{VCC}{Gain}$$

$$VRC = \frac{10V}{2} = 5V$$

$$RC = RL$$

$$RC = 600\Omega$$

$$IC = \frac{VRC}{RC}$$

$$IC = \frac{5V}{600\Omega} = 0.0083A = 8.3mA$$

$$IC = IE$$

$$IE = 8.3mA$$

$$\beta = \frac{IC}{IB}$$

$$IB = \frac{IC}{\beta}$$

$$IB = \frac{8.3 \times 10^{-3}mA}{100} = 0.000083A = 83 \times 10^{-6} = 83\mu A$$

$$IR2 = 10IB$$

$$IR2 = 11(83 \times 10^{-6}\mu A) = 0.00083A = 830 \mu A$$

$$IR1 = 11IB$$

$$IR1 = 11(83 \times 10^{-6}\mu A) = 0.000913A = 0.913mA$$

$$Gain = \frac{RC}{RE}$$

$$RE = \frac{RC}{Gain}$$

$$RE = \frac{600\Omega}{5V} = 120\Omega$$

$$V_E = I_E \times R_C$$

$$V_E = 8.3 \times 10^{-3} \text{mA}(120\Omega) = 0.996V$$

$$V_{R2} = V_E + 0.7V$$

$$V_{R2} = 0.996V + 0.7V = 1.696V$$

$$R_2 = \frac{V_{R2}}{I_{R2}}$$

$$R_2 = \frac{1.696V}{830 \times 10^{-6} \mu A} = 2043\Omega$$

$$V_{R1} = V_{CC} - V_{R2}$$

$$V_{R1} = 10V - 1.696V = 8.304V$$

$$R_1 = \frac{V_{R1}}{I_{R1}}$$

$$R_1 = \frac{8.304V}{913 \times 10^{-6} \mu A} = 9095.29\Omega$$

Components Functionality

Using R1 and R2 to form a voltage divider that drops the 10V voltage supply down to roughly 1.8V. this provide the correct voltage to turn on the 2N2222/BC109 NPN Transistor to allow the input signal to be amplified.

RC is the Collector Resistor and is used to set the voltage gain. Its value is determined by basing the value off the speaker's impedance.

RE is the Emitter Resistor and it is used to provide AC gain and provides DC stability

CE is the Emitter Bypass capacitor, and these effects gain and provide DC stability on the output.

C1-C3 is used to block DC backflow, these are used to block the DC Voltage from going back into the previous circuit and blocks any DC Voltage from effecting the readings when it comes to measuring the AC voltage gain.

The 2N2222 and BC109 Transistors are used to amplifier the AC signal.

Results

Simulation

Single stage Common Emitter amplifier

Using the software tool LTspice to create the single stage linear amplifier with the values that was previously calculated.

For the simulation a 100mV 1KHz sine wave signal will be injected into the circuit. The aim of the circuit is to have a gain of 5 on the output.

Gain (no bypass capacitor)

Taking note that the injected voltage is not peak-to-peak instead it's an amplitude of 100mV. LTspice provides a built-in curser tool that allows the user to measure voltage, frequency and slope, by using two cursors to measure the peak-to-peak voltage of each wave form, gain can be calculated.

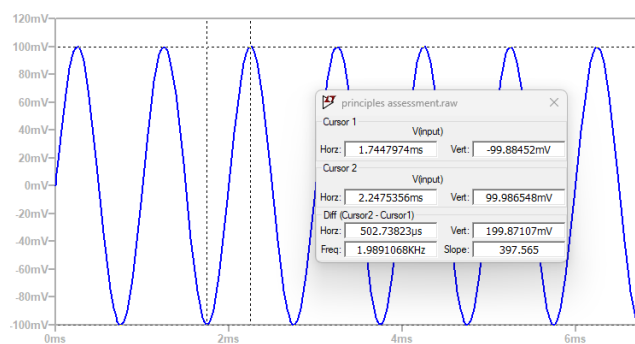
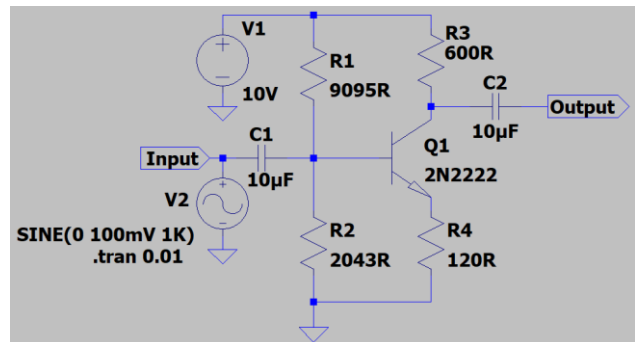


FIGURE 1: VIN

$$Gain = \frac{\text{Figure 2: } V_{out}}{\text{Figure 1: } V_{in}}$$

$$\frac{962 \times 10^{-3}V}{199 \times 10^{-3}V} = 4.8$$

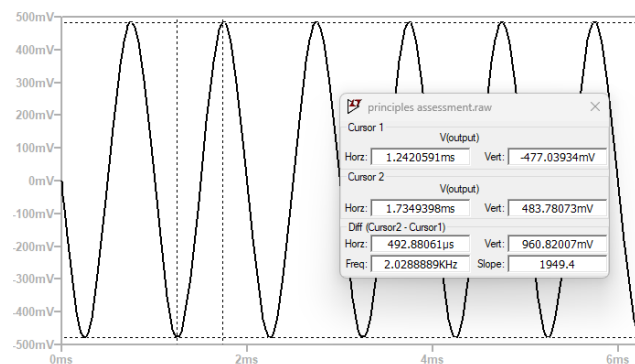


FIGURE 2: VOUT

Adding bypass capacitor

$$XC = \frac{1}{2\pi \times F \times C}$$

$$CE = \frac{1}{2\pi \times fl \times XC}$$

$$XC = \frac{R_{eff}}{10}$$

$$CE = \frac{10}{2\pi \times fl \times R_{eff}}$$

$$CE = \frac{10}{2\pi \times 1000 \times 120} = 13\mu F$$

$$Gain = \frac{\text{Figure 4: } V_{out}}{\text{Figure 3: } V_{in}}$$

$$\frac{7.5V}{199 \times 10^{-3}V} = 37$$

With the addition of a bypass capacitor parallel to the RE (Resistor Emitter), it increases gain by 32.

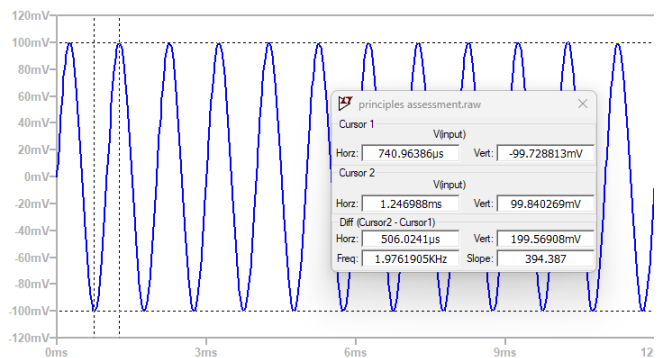
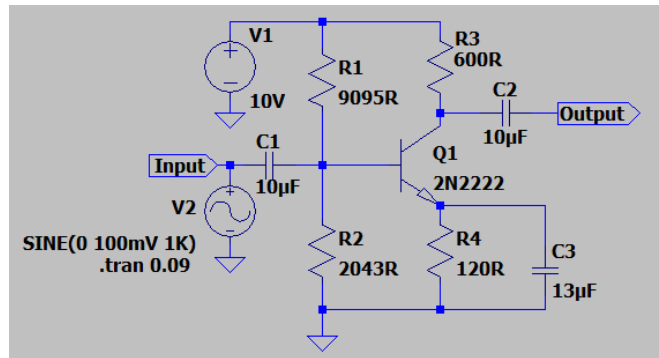


FIGURE 3: VIN

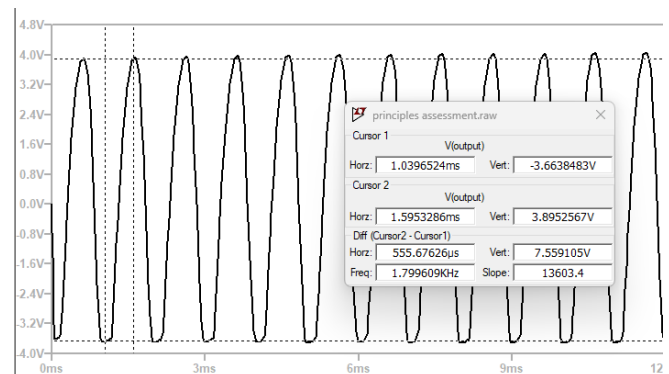


FIGURE 4: VOUT

To see if reducing the bypass capacitors value would make the output waveform cleaner, the new value for C3 is 10uF

$$Gain = \frac{\text{Figure 6: } V_{out}}{\text{Figure 5: } V_{in}}$$

$$Gain = \frac{6.8V}{199 \times 10^{-3}V} = 34.1$$

By decreasing the capacitor value of C3 Gain can be adjusted to make the circuit more accurate.

Due to the gain being too high when using a 10uF Capacitor, a 1uF will be used instead.

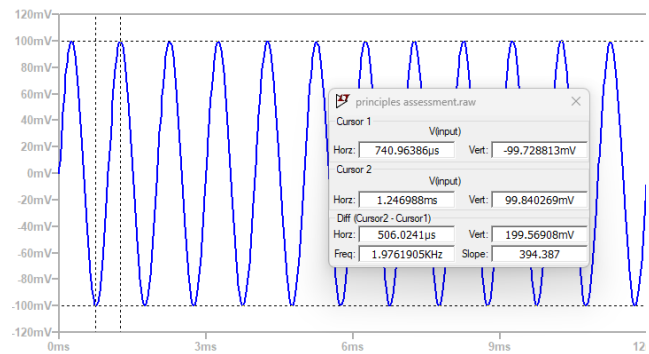
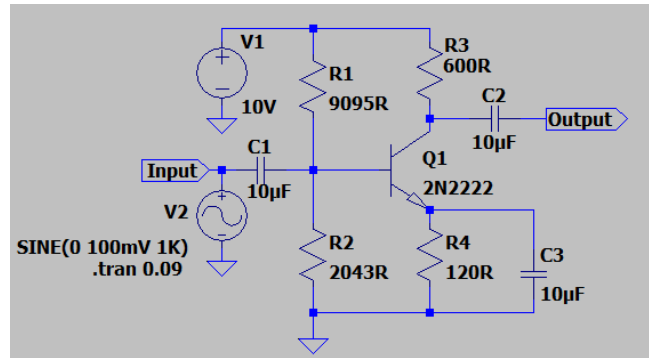


FIGURE 5: VIN

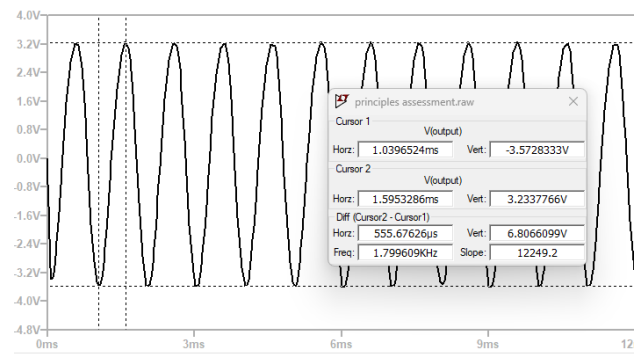


FIGURE 6: VOUT

$$Gain = \frac{V_{out}}{V_{in}}$$

$$Gain = \frac{1.1V}{199 \times 10^{-3}V} = 5.5$$

To make the gain more accurate two capacitors was used in parallel to add up to 0.44uF.

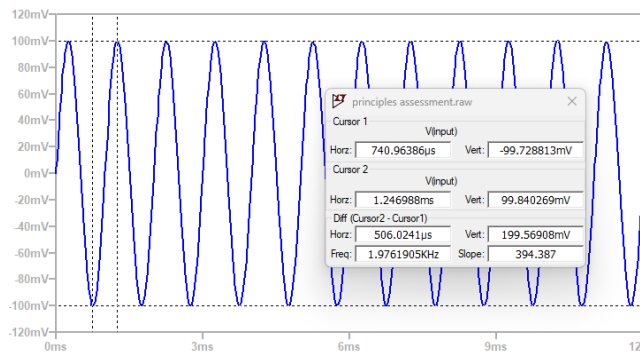
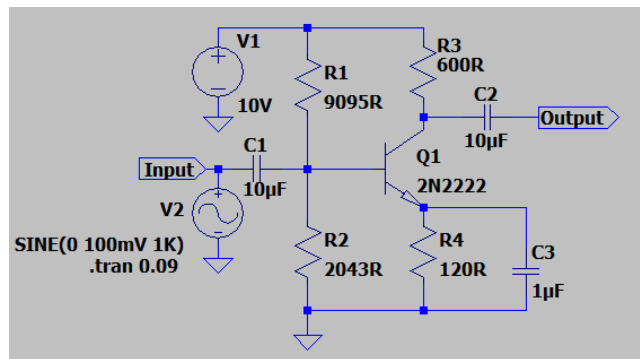


FIGURE 7: VIN

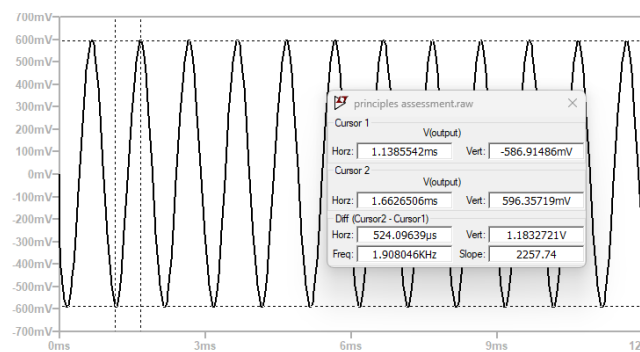


FIGURE 8: VIN

$$Gain = \frac{\text{Figure 10: } V_{out}}{\text{Figure 9: } V_{in}}$$

$$\frac{1.009V}{199 \times 10^{-3}V} = 5.07$$

by adding a 0.44uF the gain has become more accurate by 0.43V.

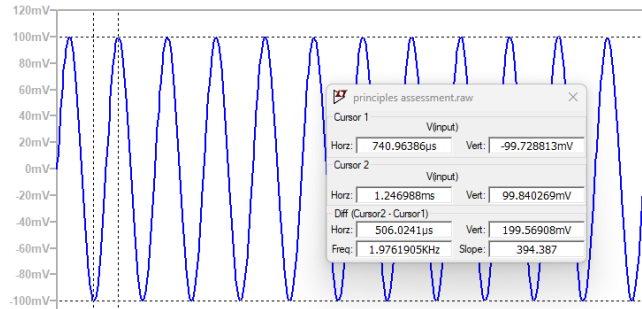
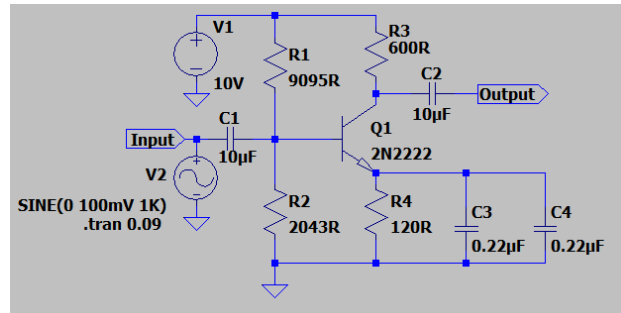


FIGURE 9: V_{in}

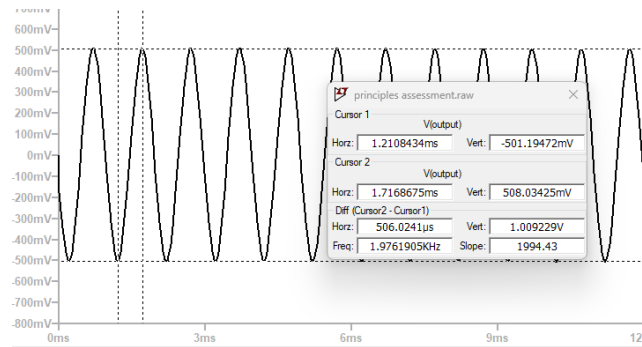


FIGURE 10: V_{out}

Two stage Common Emitter amplifier
According to the brief, the voltage gain for the two-stage transistor amplifier needs to have a voltage gain of 10.

Stage 1 needs to have a gain of 5 which will be 1V and then that will then be injected into the second stage which will need to have a gain of 2 and an output of 2V

$$R_E = \frac{RC}{2}$$

$$\frac{600\Omega}{2} = 300\Omega$$

$$Gain = \frac{V_{out}}{V_{in}}$$

Figure 12: Stage 1 V_{out}

Figure 11: V_{in}

$$= \frac{702 \times 10^{-3}V}{199 \times 10^{-3}V} = 3.5$$

Figure 13: Stage 2 V_{out}

Figure 12: Stage 1 V_{out}

$$= \frac{1.3V}{702 \times 10^{-3}V} = 1.85$$

Figure 13: Stage 2 V_{out}

Figure 11: V_{in}

$$= \frac{1.3V}{199 \times 10^{-3}V} = 6.83$$

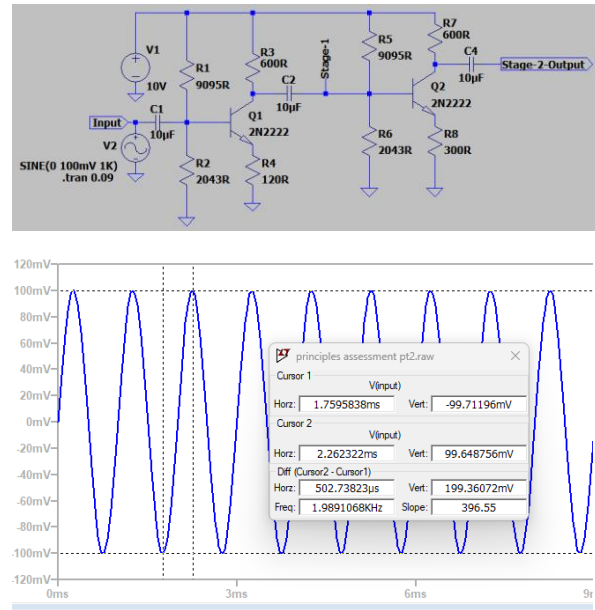


FIGURE 11: VIN

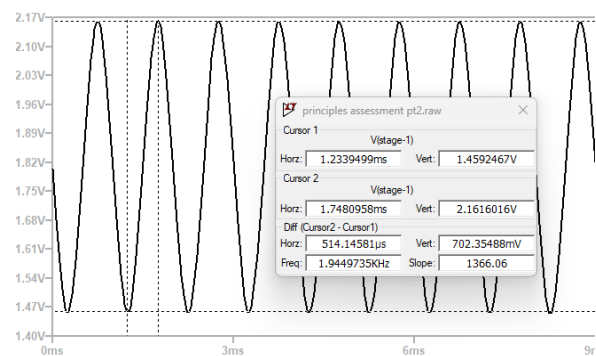


FIGURE 12: STAGE 1 VOUT

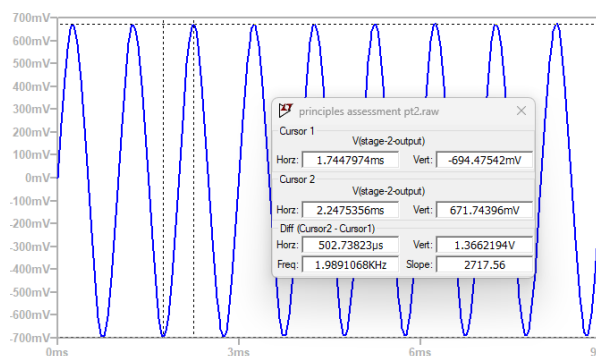


FIGURE 13: STAGE 2 VOUT

Adding bypass Capacitors

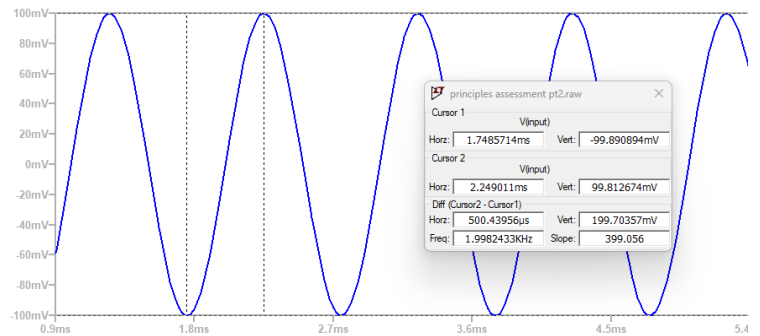
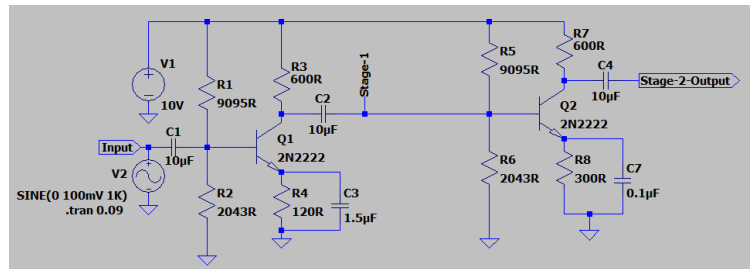


FIGURE 14: VIN

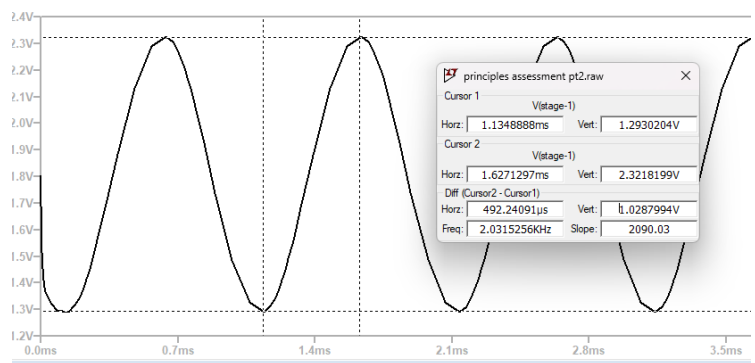


FIGURE 15: STAGE 1 VOUT

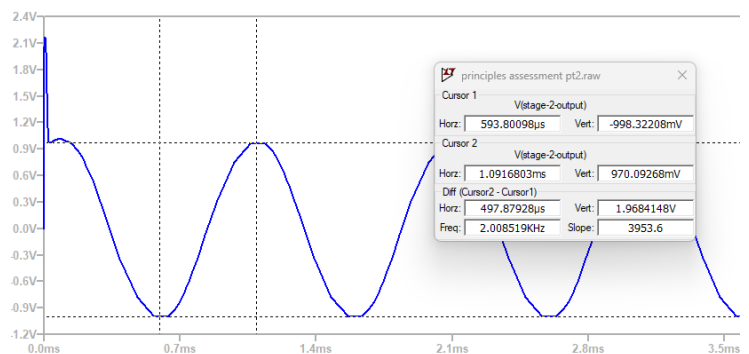


FIGURE 16: STAGE 2 VOUT

$$\text{Voltage Gain} = \frac{V_{out}}{V_{in}}$$

Figure 14: Stage 1 V_{out}

Figure 14: V_{in}

$$\frac{1.02V}{199 \times 10^{-3}V} = 5.1$$

Figure 16: Stage 2 V_{out}

Figure 15: Stage 1 V_{out}

$$= \frac{1.96V}{1.02V} = 1.92$$

Figure 14: Stage 2 V_{out}

Figure 14: V_{in}

$$\frac{1.96V}{199 \times 10^{-3}V} = 9.84$$

More Accurate Gain

By adjusting the bypass capacitors, a more accurate gain was produced.

$$\text{Capacitor Total} = C1 + C2$$

Stage 1 Bypass Capacitor Total

$$1 \times 10^{-6} + 0.22 \times 10^{-6} + 0.22 \times 10^{-6}$$

$$= 0.00144 = 0.54 \times 10^{-6}$$

Stage 2 Bypass Capacitor Total

$$\frac{1}{\frac{1}{0.47 \times 10^{-6}} + \frac{1}{0.1 \times 10^{-6}}} = 0.0824561404 \times 10^{-6}$$

$$0.1 \times 10^{-6} + 0.0824561404 \times 10^{-6}$$

$$= 0.1824561404 \times 10^{-6}$$

$$\text{Voltage Gain} = \frac{V_{out}}{V_{in}}$$

Figure 18: Stage 1 V_{out}
Figure 17: V_{in}

$$= \frac{1.003V}{199 \times 10^{-3}V} = 5.04$$

Figure 19: Stage 2 V_{out}
Figure 18: Stage 1 V_{out}

$$= \frac{2.00004V}{1.003V} = 1.99$$

Figure 19: Stage 2 V_{out}
Figure 17: V_{in}

$$= \frac{2.00004V}{199 \times 10^{-3}V} = 10.05$$

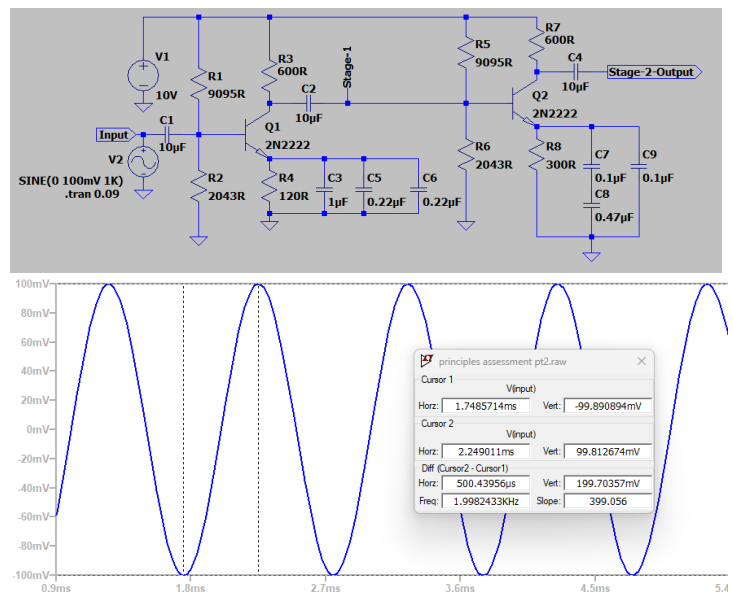


FIGURE 17: V_{in}

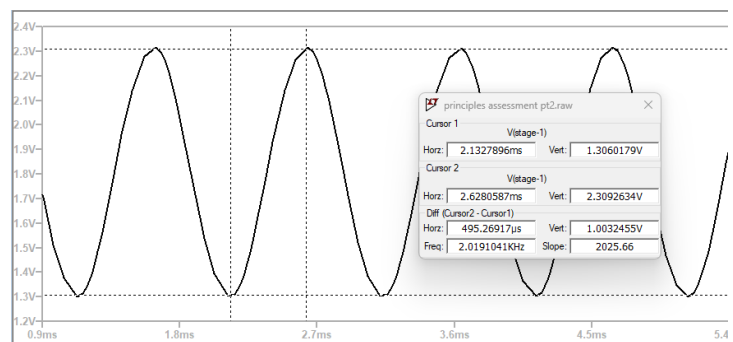


FIGURE 18: STAGE 1 V_{out}

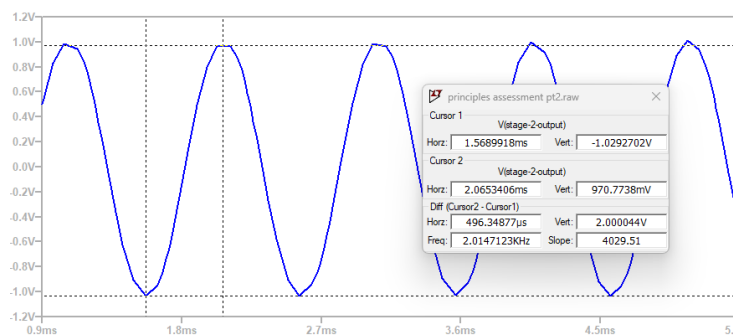


FIGURE 19: STAGE 2 V_{out}

Practical

For this practical a Power Supply Unit (PSU) and a Function Generator will be used.

The PSU will be used to provide 10V DC Voltage to the circuit via the power rails located at the top and bottom of the Breadboard.

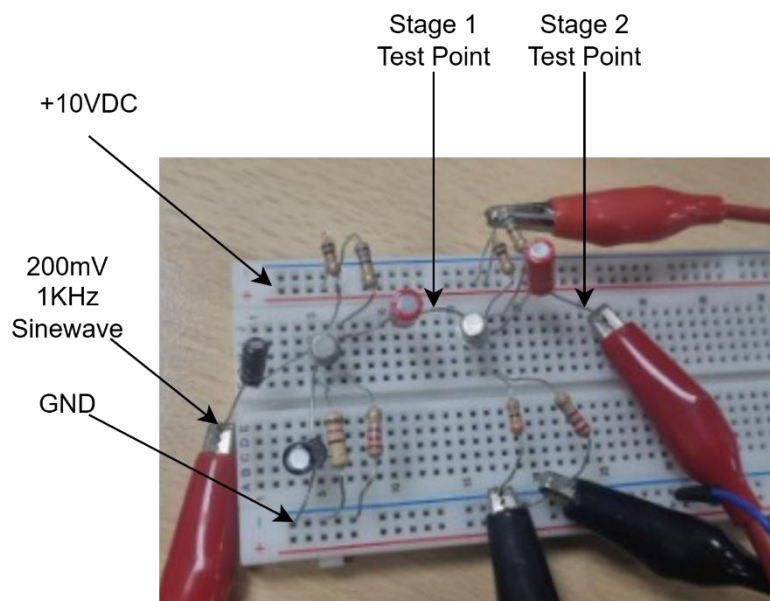
The Function Generator will be used to inject 200mV, 1KHz Sine wave signal into the circuit.



10VDC



200mV 1KHz SINEWAVE



Stage 1 Common Emitter Amplifier

Due to not having the same values used in the simulation, the following values will be used instead for the single stage amplifier.

Component name	Theoretical Values	Replacement value
R1	9095 Ohm	10K
R2	2043 Ohm	2K2
RC	600 Ohm	860 Ohm
RE	120 Ohm	120 Ohm
C1	10uF	10uF
C2	10uF	10uF
Bypass Capacitor C3	1uF	1uF
NPN Transistor	2N2222	BC109

Stage 1 Transistor Amplifier Waveforms

As shown in Figure 20 the input is 220mV and Figure 21 the output is 1.024V

$$\text{Voltage Gain} = \frac{V_{out}}{V_{in}}$$

Figure 21: V_{out}

Figure 20: V_{in}

$$\frac{1.024V}{220 \times 10^{-3}V} = 4.65$$

If the input signal voltage was decrease slightly lower than 200mV so it appeared as 200mv on the oscilloscope the output would have been more accurate. For the gain

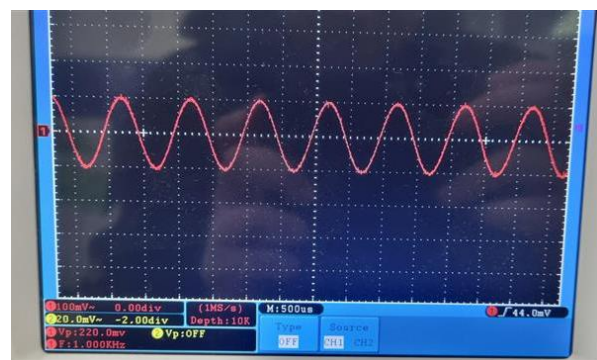


FIGURE 20: VIN



FIGURE 21: VOUT

Two stage Common Emitter Amplifier

For the two-stage transistor amplifier these are the new values being used

Component name	Previous value	Replacement value
R1	9095 Ohm	10K
R2	2043 Ohm	2K2
RC	600 Ohm	860 Ohm
RE 1	120 Ohm	120 Ohm
RE 2	300 Ohm	330 Ohm
C1	10uF	10uF
C2	10uF	10uF
C4	10uF	10uF
Bypass Capacitor C3	0.54uF	1uF
Bypass Capacitor C5	0.18uF	
NPN Transistor	2N2222	BC109

2 Stage Transistor Amplifier Waveforms

As shown by Figure 22 V_{in} is 220mV and the output of the 2 Stage Transistor Amplifier is 2V

$$\text{Voltage Gain} = \frac{V_{out}}{V_{in}}$$

$$= \frac{\text{Figure 21: } V_{out}}{\text{Figure 22: } V_{in}} = \frac{1.024V}{220 \times 10^{-3}V} = 4.65$$

total gain from Stage 1 V_{out} – Stage 2 V_{out}

$$= \frac{\text{Figure 23: } V_{out}}{\text{Figure 21: } V_{out}} = \frac{2V}{1.024} = 1.95$$

total gain from V_{in} to Stage 2 V_{out}

$$= \frac{\text{Figure 23: } V_{out}}{\text{Figure 22: } V_{in}} = \frac{2V}{220 \times 10^{-3}V} = 9.09$$

As shown by figure 24 there is a 180° phase shift between the stage 1 and stage 2 outputs.

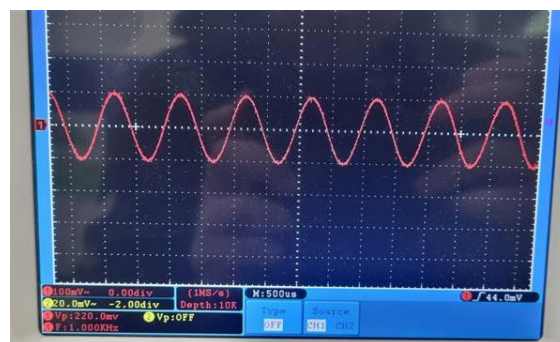


FIGURE 22: V_{in}

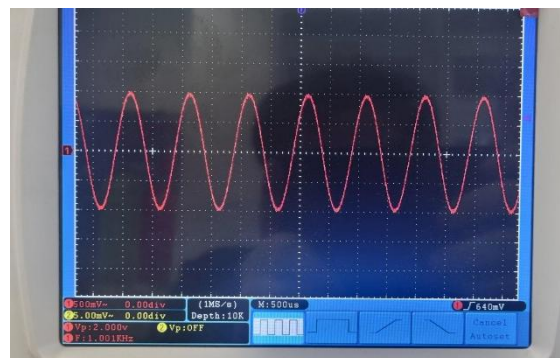


FIGURE 23: STAGE 2 OUTPUT



FIGURE 24: STAGE 1 AND STAGE 2 OUTPUT

Analysis

The Linear Transistor Amplifier in the common-emitter configuration was tested by injecting a small AC input signal and comparing it to the output voltage. The input amplitude was set to 200mV peak-to-peak, and the output signal was measured on both an Oscilloscope and simulation.

Single Stage Common Emitter Amplifier Simulation

A 200mV AC signal was injected into the single stage Linear amplifier without including a bypass capacitor, using LTspice the approximate output voltage is 962mV which has a gain of 4.8. After adding a 0.44uF bypass capacitor the output voltage is 1.009V and the gain is 5.07.

$$\text{Gain} = \frac{\text{Figure 2: } V_{out}}{\text{Figure 1: } V_{in}} = \frac{962 \times 10^{-3}V}{199 \times 10^{-3}V} = 4.8$$

$$\text{Gain} = \frac{\text{Figure 10: } V_{out}}{\text{Figure 9: } V_{in}} = \frac{1.009V}{199 \times 10^{-3}V} = 5.07$$

Single Stage Common Emitter Amplifier Practical

Using a function generator set at 200mV a reading was taken and a measurement of 220mV was taken, this will be injected into the single stage Linear Amplifier. The measurement on the output was taken at 1.024V which has a gain of 4.65

$$\text{Gain} = \frac{\text{Figure 21: } V_{out}}{\text{Figure 20: } V_{in}} = \frac{1.024V}{220 \times 10^{-3}V} = 4.65$$

If the input ac signal was set to be lower so it was measured at 200mV the gain could have been roughly:

$$\text{Gain} = \frac{1.024V}{200 \times 10^{-3}V} = 5.12$$

Two Stage Common Emitter Amplifier Simulation

For the Two Stage Linear Transistor Amplifier the 200mV AC signal was injected into the circuit. The circuit did not include bypass capacitors.

$$\text{Gain} = \frac{\text{Figure 12: Stage 1 } V_{out}}{\text{Figure 11: } V_{in}} = \frac{702 \times 10^{-3}V}{199 \times 10^{-3}V} = 3.5$$

$$\text{Gain} = \frac{\text{Figure 13: Stage 2 } V_{out}}{\text{Figure 12: Stage 1 } V_{out}} = \frac{1.3V}{702 \times 10^{-3}V} = 1.85$$

$$\text{Gain} = \frac{\text{Figure 13: Stage 2 } V_{out}}{\text{Figure 11: } V_{in}} = \frac{1.3V}{199 \times 10^{-3}V} = 6.83$$

This Gain was not accurate, so bypass capacitors were added. For the single stage a 0.56uF Capacitor was added and the second stage a 0.18uF Capacitor was added.

$$\text{Gain} = \frac{\text{Figure 18: Stage 1 } V_{out}}{\text{Figure 17: } V_{in}} = \frac{1.003V}{199 \times 10^{-3}V} = 5.04$$

$$\text{Gain} = \frac{\text{Figure 19: Stage 2 } V_{out}}{\text{Figure 18: Stage 1 } V_{out}} = \frac{2.00004V}{1.003V} = 1.99$$

$$\text{Gain} = \frac{\text{Figure 19: Stage 2 } V_{out}}{\text{Figure 17: } V_{in}} = \frac{2.00004V}{199 \times 10^{-3}V} = 10.05$$

Two Stage Common Emitter Amplifier Practical

Using a function generator set at 200mV a reading was taken and a measurement of 220mV was taken, this will be injected into the Two Stage Linear Amplifier. The measurement on the output was taken at 2V which has a gain of 9.09 from the input and a gain of 1.95 from the output of stage 1.

$$\text{Gain stage 1} = \frac{\text{Figure 21: } V_{out}}{\text{Figure 20: } V_{in}} = \frac{1.024V}{220 \times 10^{-3}V} = 4.65$$

$$\text{Stage 2 Gain from stage 1 output} = \frac{\text{Figure 23: } V_{out}}{\text{Figure 21: } V_{out}} = \frac{2V}{1.024} = 1.95$$

$$\text{Total Gain} = \frac{\text{Figure 23: } V_{out}}{\text{Figure 22: } V_{in}} = \frac{2V}{220 \times 10^{-3}V} = 9.09$$

Bringing The Results Together

Across both the Single Stage and Two Stage Linear Amplifiers, the results show that by adding an emitter bypass capacitor the gain increases because the capacitor reduces emitter degeneration. The practical and simulation gains differ slightly due to the real input signal being slightly different to the simulation, and component tolerance in the physical circuit.

In the Two stage Linear Amplifier, the first common-emitter stage produces a 180° phase shift, meaning that the signal is 180° out of phase compared to the input signal. once introduced into the second common-emitter stage it goes through another 180° phase shift putting the signal back into phase with the input signal.

Discussion

When comparing the theoretical circuits gain to the expected gain, the common emitter amplifiers did not reach the intended gain until an emitter bypass capacitor was introduced into the circuit, this increased the gain and went slightly over by 0.05 and 0.07.

Compared to the simulation the practical did not reach the intended gain and was slightly under by 0.2V, this was expected due to the components not being exact and results could be affected by the component tolerances.

When it came to building the two-stage common emitter amplifier circuit, Emitter bypass capacitors were used close to the values used in LTspice. Though when it came to the actual practical waveform was distorted and was not smooth. Removing the second Emitter bypass capacitor the signal became clean and gain dropped. By adjusting the Emitter bypass capacitor at the first stage the gain had increased and still retained the clean output signal.

Conclusion

This report successfully demonstrates that common emitter amplifiers can be designed even when only the value of the load impedance (speaker) is given. By using the impedance value and assuming the RC resistor value is the same, the voltage divider resistors, R1 and R2 can be calculated, by knowing the expected gain on the output RE can also be calculated.

Using the calculated resistor values a theoretical circuit for the single stage common emitter amplifier was created on LTspice and proved that the common emitter amplifier can be used to provide sufficient gain. To make the gain more accurate an adding 0.44uF Emitter bypass capacitor bringing the output voltage to have a gain of 5.07 and an output voltage of 1.009V.

By using the same values for R1, R2, RE and RC the first stage was recreated, and a second stage was introduced using the R1, R2 and RC values again, though because a different gain was needed RE was recalculated for the second stage, so it had a gain of 2 on the output.

Due to the gain being lower when the second stage was introduced a different value Emitter bypass capacitors was used, for the first stage 0.54uF Emitter bypass capacitor was applied and the second stage 0.18uF Emitter bypass capacitor was introduced, this produced a voltage gain of 1.003V and a gain of 5.04 on the first stage and 2.00004V on the second stage output and a gain of 1.99 and an overall gain of 10.05.

After successfully achieving the expected gain on LTspice, the first stage common emitter amplifier was reconstructed on a breadboard. The theoretical values of the resistors were not available so the resistor values closely around the same value were used instead.

Using the new values of the resistors and a 1uF Emitter bypass capacitor the first stage was built and gain was calculated. The first stage common emitter output had a voltage gain of 1.024V and a gain of 4.65, this was lightly lower than expected due to having a slightly higher input ac signal, and component tolerances.

Using the same values and only having the 1uF Emitter bypass capacitor at the first stage common emitter amplifier the second stage was built and introduced on the output of the first stage. The output of the first stage stayed the same, and the voltage gain of the second stage was 2V and had a gain of 1.95 and an overall gain of 9.09.

Although the practical results did not match the theoretical values, the calculations proved that a gain of 5 and 2 can be achieved when only given the speakers impedance as a starting point to calculate the resistor values. Using LTspice and building the physical circuit further validates these calculations.

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