Basic Audio Amplifier Design

Work with your laboratory group partner to meet the design specifications detailed below. Compile a brief final report showing the derivation of the cascade amplifier's transfer function T(s), SPICE circuit, Bode plot, block diagram, and components list. You will be graded on the quality of your work and how well you meet the specifications detailed below.

Specifications

The amplifier is required to have a gain in the band pass of 24.0 dB, which can be inverting or non-inverting. The range of the amplifier is 100 Hz to 3 kHz. High frequency signal are less desirable and the roll off before 3 kHz is required to be -40dB/dec. Final components used in the design must be selected from standard resistor and capacitor values. You are allowed a ±5% error in the total gain and corner frequencies. You total cost of your parts cannot exceed $10.00.

Design

- Provide a hand analysis of your circuit design to obtain the transfer function of the circuit.
- Use OrCAD or LTSpice to verify your circuit design. Provide a Bode plot and check the maximum gain in the band pass.
- Make a list of components and give the cost of your circuit. Use the example shown below catalog the components needed. Compile the total cost of the parts needed to build your design.
- Build a block diagram showing the flow and mathematics of your circuit.

Component	Description	Supplier ID	Supplier	Quantity	Cost/Unit	Total
R1, R3, R4	10kΩ, 1/4w, ±5%	CF14JT10K0CT-ND	Digikey	3	$0.08	$0.24

Deliverables

- A cover page with project number, date, and names.
- Your hand-analysis of the transfer functions for the circuit.
- The block diagram of your circuit.
- Provide your SPICE circuit and simulation output. Verify and label the corner frequencies, passband, and slope transitions. Compare the SPICE output to your hand calculated transfer function using EXCEL or MATLAB.
- Provide a spreadsheet of your parts and total cost.

Example of searching for Resistors at Digikey.com

To get the most from Digi-Key's part search:

Only select from one box at a time, click the "Apply Filters" button, and repeat.
To select multiple values within a box, hold down 'Ctrl' while selecting values within the box.

Resistors | Through Hole Resistors

Series	Manufacturer	Resistance (Ohms)	Power (Watts)	Composition
-	Analog Devices Inc	9.9K	-	Carbon Composition
AAR	AVX Corporation	10K	0.05W, 1/20W	Carbon Film
AC	Bourns Inc.	10.1K	0.063W, 1/16W	Ceramic
ALSR	Caddock Electronics Inc	10.2K	0.1W, 1/10W	Metal Element
ALVR	Huntington Electric Inc.	10.4K	0.125W, 1/8W	Metal Film
BR	Ohmite	10.5K	0.167W, 1/6W	Metal Foil
C, CGS	Panasonic - ECG	10.6K	0.25W, 1/4W	Metal Oxide Film
CB	Riedon	10.7K	0.333W, 1/3W	Thick Film
CBT, Neohm	Stackpole Electronics Inc	10.8K	0.375W, 3/8W	Thin Film
CCR, CGS	TE Connectivity	10.9K	0.4W	Wirewound

☐ In stock
☐ Lead free
☐ RoHS Compliant

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Audio Amplifier Circuit Schematic and Magnitude plot in decibels

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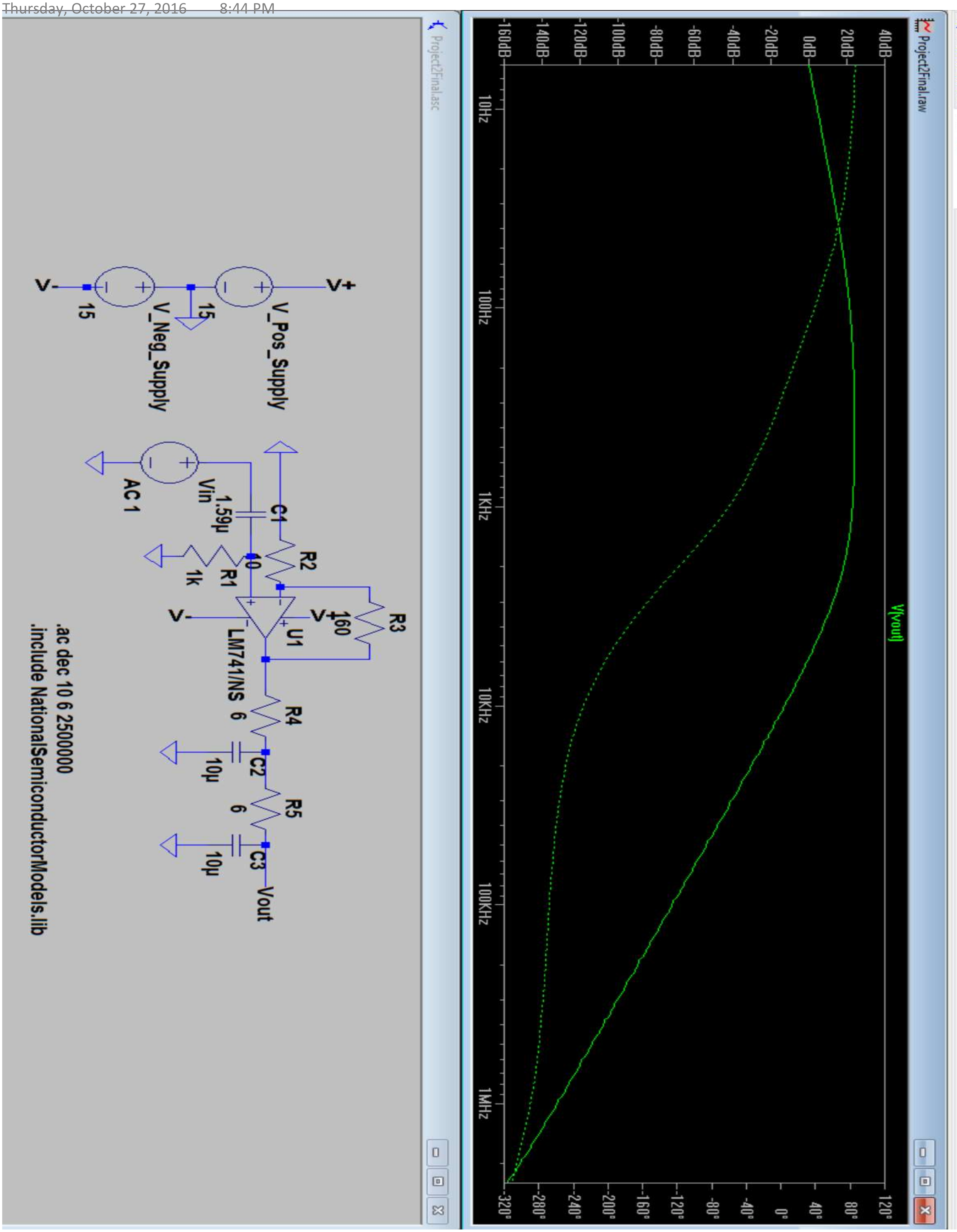

Transfer Function

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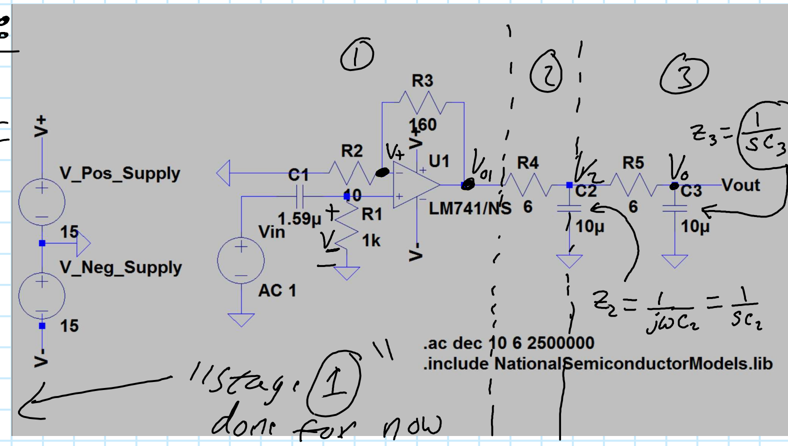
Stage ①:



Voltage divider across R_1 and noting that $V_+ = V_-$

gives us... $V_- = V_+ = \dfrac{V_{in} \cdot R_1}{R_1 + \frac{1}{sC_1}}$

KCL @ V_- : $0 = \dfrac{V_- - 0}{R_2} + \dfrac{V_- - V_{01}}{R_3}$

$0 = V_-\left(\frac{1}{R_2} + \frac{1}{R_3}\right) - V_{01}/R_3 \Rightarrow V_{01} = V_-\left(\frac{R_3}{R_2} + 1\right)$

Stage 2:

"Voltage divider across Z_2 yields" $\rightarrow V_2 = \dfrac{V_{01} \cdot \frac{1}{sC_2}}{\left(\frac{1}{sC_2} + R_4\right)} = \dfrac{\left(V_{01} \cdot \frac{1}{sC_2}\right)}{\left(\frac{1}{sC_2} + R_4\right)} \cdot \dfrac{sC_2}{sC_2} = \dfrac{V_{01}}{1 + sR_4C_2} \ldots$ ②

Stage 3:

"Voltage divider across Z_3 gives us V_0":

$$V_o = \frac{\left(V_2 \frac{1}{sC_3}\right)}{\left(\frac{1}{sC_3} + R_5\right)} \cdot \frac{sC_3}{sC_3} = \frac{V_2}{(1 + sR_5C_3)} \ldots ③$$

"putting V_2 in terms of V_{01}"

$$V_o = \frac{V_2}{1 + sR_5C_3} = \frac{\left(\frac{V_{01}}{1 + sR_4C_2}\right)}{(1 + sR_5C_3)} = \frac{V_{01}}{(1 + sR_4C_2)(1 + sR_5C_3)}$$

"putting V_{01} in terms of V_-"

$$V_o = V_{01} \Big/ \left[(1 + sR_4C_2)(1 + sR_5C_3)\right] = (V_-)\left(\frac{R_3}{R_2} + 1\right) \Big/ \left[(1 + sR_4C_2)(1 + sR_5C_3)\right]$$

"now putting V_- in terms of V_{in} and now we let $s = j\omega$"

and since $V_- = \dfrac{V_{in} R_1}{R_1 + \frac{1}{j\omega C_1}}$ as seen earlier...

Now in solving all the algebra as seen below we note that we must obtain the gain of "V_o/V_{in}" to properly to derive the correct transfer function of the circuit that we have constructed. We also have to consider $s = j\omega$ and theoretically we should be able to obtain the following transfer function in terms of the radian frequency (ω)...

$$\Rightarrow H(\omega) = \frac{V_o(\omega)}{V_{in}(\omega)}$$

$$V_o = \left(\frac{V_{in} \cdot R_1}{R_1 + \frac{1}{j\omega C_1}}\right)\left(\frac{R_3}{R_2} + 1\right) \Big/ \left[(1 + j\omega R_4C_2)(1 + j\omega R_5C_3)\right]$$

$$= \frac{j\omega C_1}{j\omega C_1} \cdot \left(\frac{V_{in} \cdot R_1}{R_1 + \frac{1}{j\omega C_1}}\right)\left(\frac{R_3 + R_2}{R_2}\right) \Big/ \left[(1 + j\omega R_4C_2)(1 + j\omega R_5C_3)\right]$$

$$\frac{V_o}{V_{in}} = \frac{j\omega C_1R_1(R_3 + R_2)}{(j\omega C_1R_1 + 1)R_2 \cdot (1 + j\omega R_4C_2)(1 + j\omega R_5C_3)} = \frac{\cancel{j\omega}}{\cancel{j\omega}} \cdot \frac{R_1C_1(R_2 + R_3)}{R_2\left(R_1C_1 + \frac{1}{j\omega}\right) \cdot \left(R_4C_2 + \frac{1}{j\omega}\right)\left(R_5C_3 + \frac{1}{j\omega}\right)}$$

$$\frac{V_o(\omega)}{V_{in}(\omega)} = \boxed{H(\omega) = \frac{R_1C_1(R_2 + R_3)}{R_2\left(R_1C_1 + \frac{1}{j\omega}\right) \cdot \left(R_4C_2 + \frac{1}{j\omega}\right)\left(R_5C_3 + \frac{1}{j\omega}\right)}}$$

"This filter passes high frequencies as $\omega \to \infty$"

as $\omega \to \infty$ ... $\dfrac{V_o(\infty)}{V_{in}(\infty)} = H(\infty) = \dfrac{\cancel{R_1C_1}(R_2 + R_3)}{R_2\cancel{R_1C_1} \cdot R_4C_2 \cdot R_5C_3} = \dfrac{R_2 + R_3}{R_2R_4C_2 \cdot R_5C_3}$