THE AMPLIFIER PROJECT

ELEC 3509A – L6

Lab 2 Report

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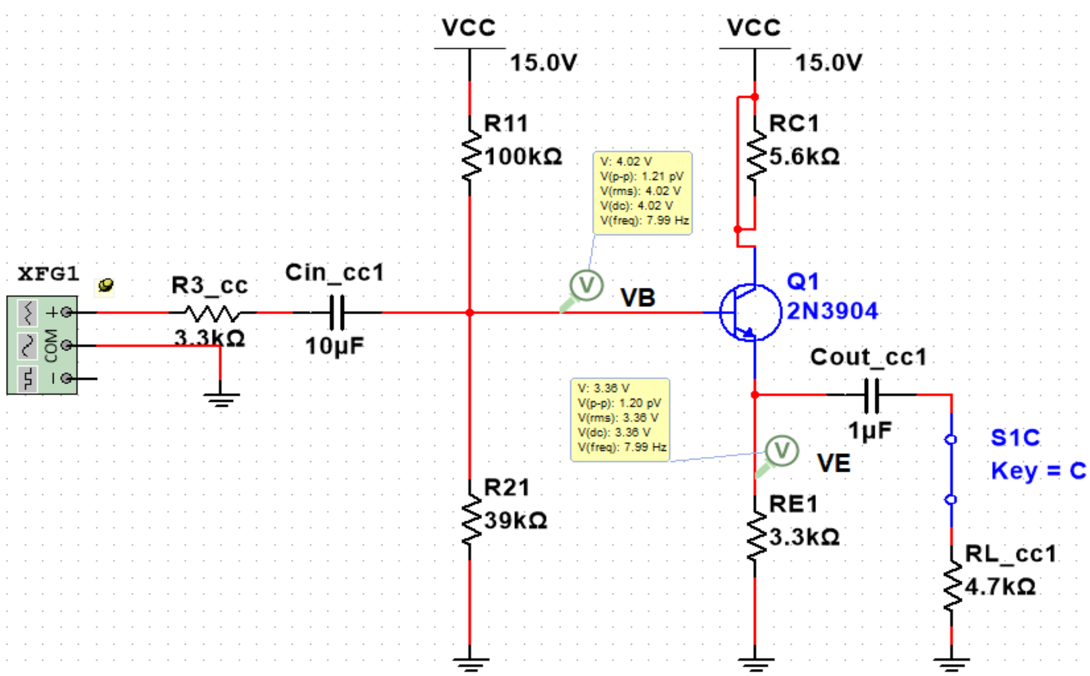
1.0 INTRODUCTION

The purpose of this laboratory is to investigate the use of BJTs as amplifier circuit elements. First, the three basic configurations (CE, CC, and CB) are observed. Then, by proper combinations and permutations, 2- transistor amplifier configurations can be studied for improved gain-bandwidth performance. Finally, a specific configuration is required to be designed to meet or exceed a prescribed set of specifications.

2.0 DAY 1: SINGLE-TRANSISTOR AND 2-TRANSISTOR AMPLIFIERS

2.1 Part 1: Circuit Construction and DC Measurements

- <u>Common Collector:</u>



DC Measurements:

V_B	4.01 V
V_E	3.34 V
V_C	9.36 V
V_{CC}	15.00 V

$$I_C = \frac{V_{CC} - V_C}{R_C}$$

$$I_E = \frac{V_E}{R_E}$$

$$I_B = I_{R1} - I_{R2} = \frac{V_{CC} - V_B}{R_1} - \frac{V_B}{R_2}$$

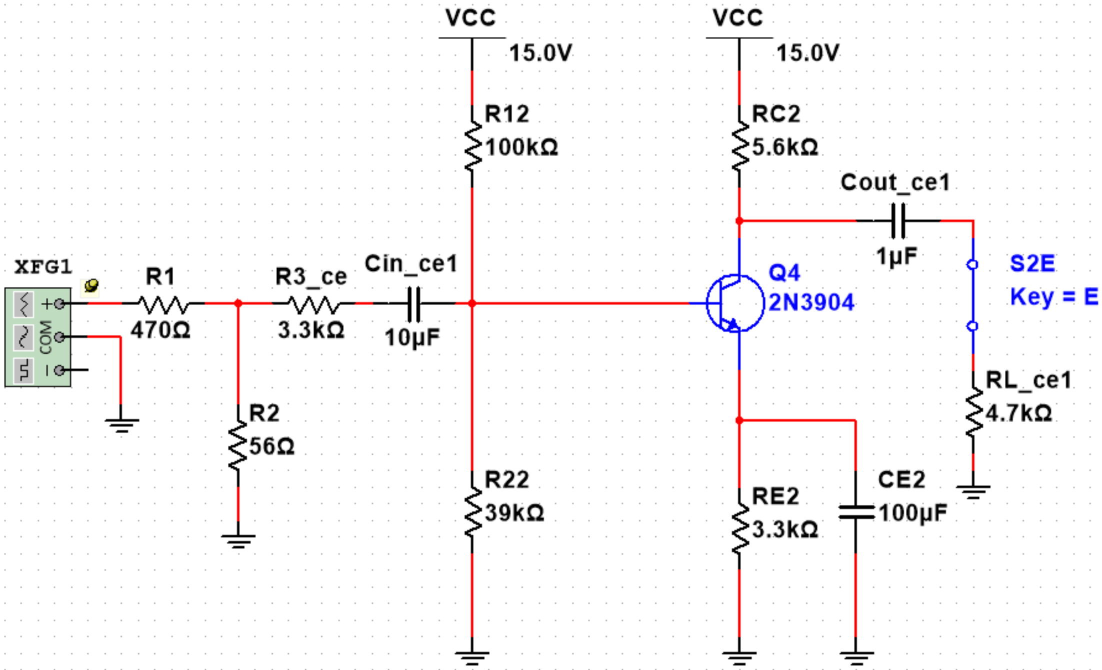
$$\beta = \frac{I_C}{I_B}$$

$$r_\pi = \frac{\beta}{gm}$$

Using the formulas shown above, I was able to find the values of I_C, I_E, I_B, β, and r_π as shown below:

I_C	1.007 mA
I_E	1.012 mA
I_B	7.079 µA
β	142.250 A/A
r_π	3.743 kΩ

- <u>Common Emitter:</u>



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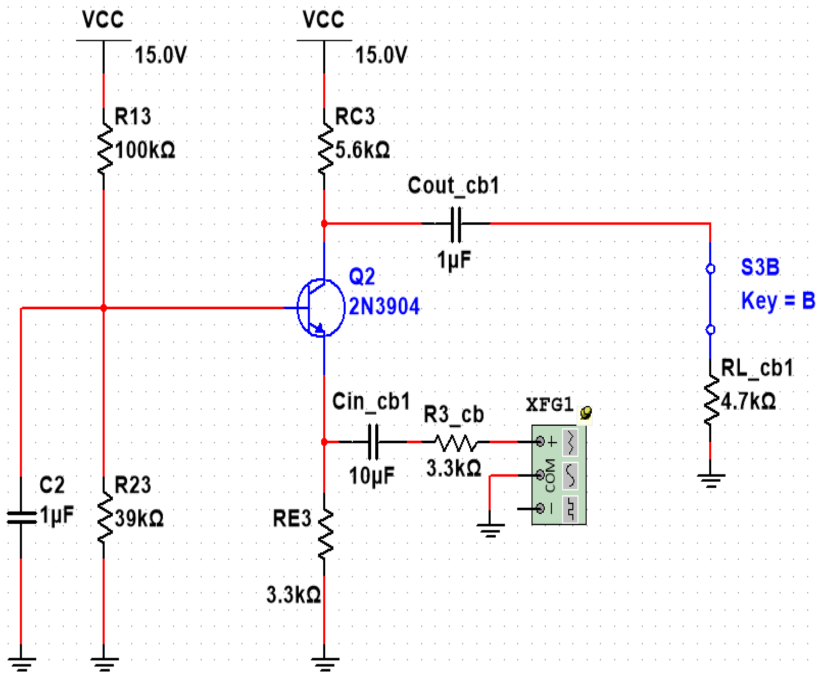
V_B	4.01 V
V_E	3.34 V
V_C	9.36 V
V_{CC}	15.00 V

I_C	1.007 mA
I_E	1.012 mA
I_B	7.079 µA
β	142.250 A/A
r_π	3.743 kΩ

- <u>Common Base:</u>



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V_C	9.36 V
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I_C	1.007 mA
I_E	1.012 mA
I_B	7.079 µA
β	142.25 A/A
r_π	3.743 kΩ

- <u>Why can R_{C1} be made 0 when testing the amplifier? Why do you need to have it when checking the DC operating point?</u>

R_{C1} can be made 0 when testing the amplifier since it has no effect on collector current during AC analysis. However, during the analysis, to find the DC operating point, we must find the collector current that keeps the transistor in proper biasing point, and the collector current depends on the value of R_{C1}. Hence, we need to have R_{C1} when checking the DC operating point.

- Could we instead use a capacitor like we do for the CE and CB amplifiers?

Yes, we could use a capacitor like we do for the CE and CB amplifiers to bypass the collector resistor.

- Why do we need RE2? Why can't we just short this node to ground?

We need RE2 since it stabilizes the Q-point regardless of changes in voltage supplied.

2.2 Part 2: AC Measurements for Single-Transistor Amplifiers

- Show a complete table summarizing the values of calculated and measured of R_{in}, R_{out}, Amid, f_H and f_L for all 3 amplifiers. Comment on any differences you see between measured and calculated values. Explain any differences you see. Try to be as specific as possible.

  - Common Collector: V_{Source}= 1.15 V_{Pk} = 2.3 V_{Pk-Pk}

V_o	2.00 V
V_o'	2.03 V
V_s	2.30 V
V_x	2.04 V
V_{s-x}	0.26V

  - Common Emitter: V_{Source} = 0.195 V_{Pk} = 0.39 V_{Pk-Pk}

V_o	2.0100 V
V_o'	4.2500 V
V_s	0.0412 V
V_x	0.0220 V
V_{s-x}	0.0192 V

  - Common Base: V_{Source}= 1.325 V_{Pk} = 2.65 V_{Pk-Pk}

V_o	2.0000 V
V_o'	4.3800 V
V_s	2.6500 V
V_x	0.0223 V
V_{s-x}	2.6277 V

$$R_{in} = R_3 + R_{inA} = R_3 + \frac{v_x}{i_{R_3}}$$

$$R_{out} = \frac{v_o' - v_o}{i_{R_L}}$$

$$A_{mid} = \frac{v_o}{v_s}$$

Using the formulas shown above, I was able to find the values of R_{in}, R_{out}, and A_{mid} as shown below:

- Common Collector:

	Prelab	**Measured**
R_{in}	25.50 kΩ	29.2 kΩ
R_{out}	46.40 Ω	70.5 Ω
A_{mid}	0.84	0.70
f_H	2.85 MHz	3.0 MHz
f_L	33.5 Hz	32.1 Hz

- Common Emitter:

	Prelab	**Measured**
R_{in}	3.30 kΩ	7.081 kΩ
R_{out}	5.60 kΩ	5.238 kΩ
A_{mid}	48.78	48.786
f_H	448 kHz	472 kHz
f_L	52.18 Hz	41.9 Hz

- Common Base:

	Prelab	**Measured**
R_{in}	25.90 kΩ	3.328 kΩ
R_{out}	5.60 kΩ	5.593 kΩ
A_{mid}	0.755	0.755
f_H	15.60 MHz	31.2 MHz
f_L	26.51 Hz	17.9 Hz

Table below summarizes the values of calculated and measured of R_{in}, R_{out}, Amid, f_H and f_L for all three amplifiers.

	Prelab					Measured				
	R_{in} ($k\Omega$)	R_{out} ($k\Omega$)	A_{mid}	f_H (MHz)	f_L (Hz)	R_{in} ($k\Omega$)	R_{out} ($k\Omega$)	A_{mid}	f_H (MHz)	f_L (Hz)
CC	25.50	0.046	0.84	2.85	33.50	29.20	0.0705	0.70	3.00	32.10
CE	3.30	5.60	48.78	0.45	52.18	7.08	5.24	48.79	0.47	41.90
CB	25.90	5.60	0.76	15.60	26.51	3.33	5.59	0.76	31.20	17.90

As it can be seen from the table above, there is no major difference between the measured and calculated values of R_{in}, R_{out}, A_{mid}, f_H, and f_L for all three amplifiers.

- In a normal circuit, the AC measurements could be prone to many sources of error. Try identifying some of these possible sources of error that would be encountered in a real circuit; how could we avoid these sources of error?

Possible sources of error that would be encountered in a real circuit is ignoring intrinsic resistance r_o and feedback resistance r_μ. Also the $C_\mu$and C_π used in the high cut-off frequency was not exact since the values of C_μ and C_π depends on the characteristics of BJT. We could avoid this source of error by including ignoring intrinsic resistance r_o and feedback resistance r_μ in our calculations and getting the exact the C_μ and C_π values from the information sheet of 2N3904.

- Comment on the differences between all 3 amplifiers. Mathematically explain any differences you see: for instance if one amplifier has a higher gain, explain why that is so. Which ones are better for which tasks and why?

Common Collector: has voltage gain of about 1 (unity gain), moderate low cut-off frequency, moderate cut-off frequency, high input impedance, and low output impedance. It is best for where a high impedance input source needs to be connected to a low impedance output load requiring a high current gain, it is usually used as a voltage buffer since the voltage gain is unity.

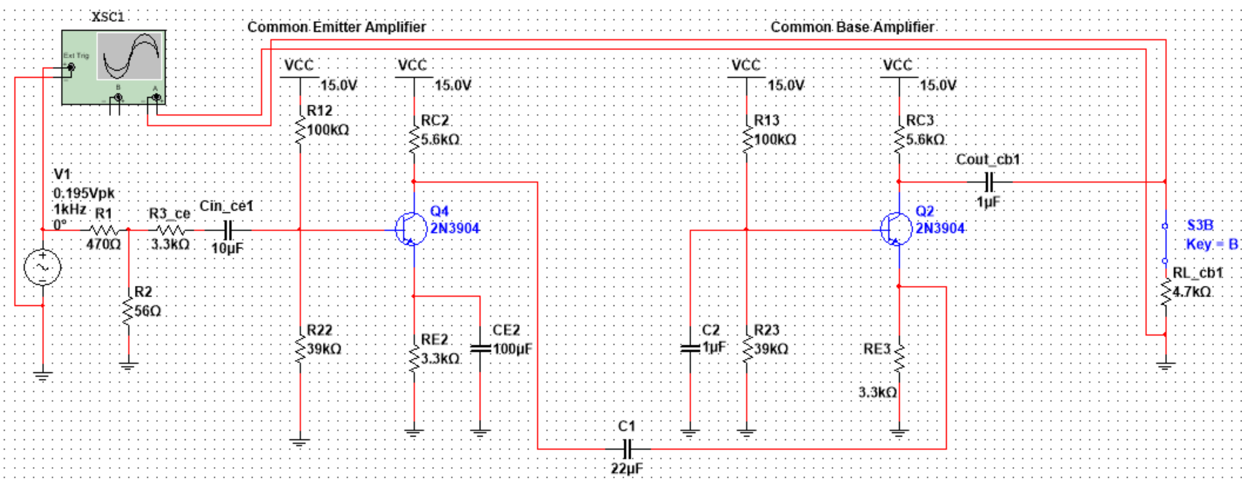
Common Emitter: has the highest voltage gain and is dependent upon $\frac{R_C}{R_E}$, highest low cut-off frequency due to miller's effect, lowest high cut-off frequency, moderate input impedance, and its output impedance equal collector resistance R_C. It is best for radio frequency circuits to amplify weak signals received by an antenna.

Common Base: Has a very low voltage gain since it depends on the source impedance R_S, very little low cut-off frequency, very large high cut-off frequency, low input impedance, and its output impedance equal collector resistance R_C. It is best for audio and radio frequency applications as a current buffer in order for it to match a low impedance source to a high impedance load or as a single stage amplifier in part of a cascaded or multi-stage configuration.

2.3 Part 3: 2-Transistor Amplifiers

- Include a table summarizing the measured values of Rin, Amid, fH and fL. Calculate expected values for these and compare them. Like with the 1 transistor amplifiers, explain any differences between the two set of values.

  - CE-CB Amplifier: V_{Source}= 0.195 V_{Pk}= 0.39 V_{Pk-Pk}

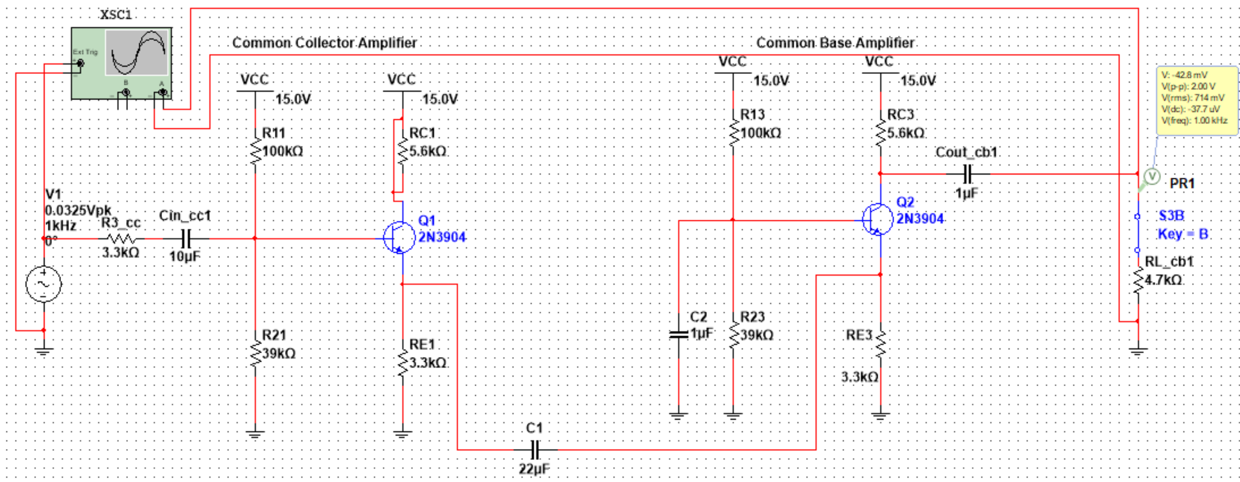


	Prelab	Measured
V_o	-	2.04 V
V_o'	-	4.48 V
V_s	-	0.0412 V
V_x	-	0.022 V
V_{s-x}	-	0.0192 V
R_{in}	3.302 kΩ	7.081 kΩ
R_{out}	5.6 kΩ	5.238 kΩ
A_{mid}	48.78	49.51
f_H	4.276 MHz	4.36 MHz
f_L	50.895 Hz	41.5 Hz

- What do you notice about the cascading amplifiers parameters?

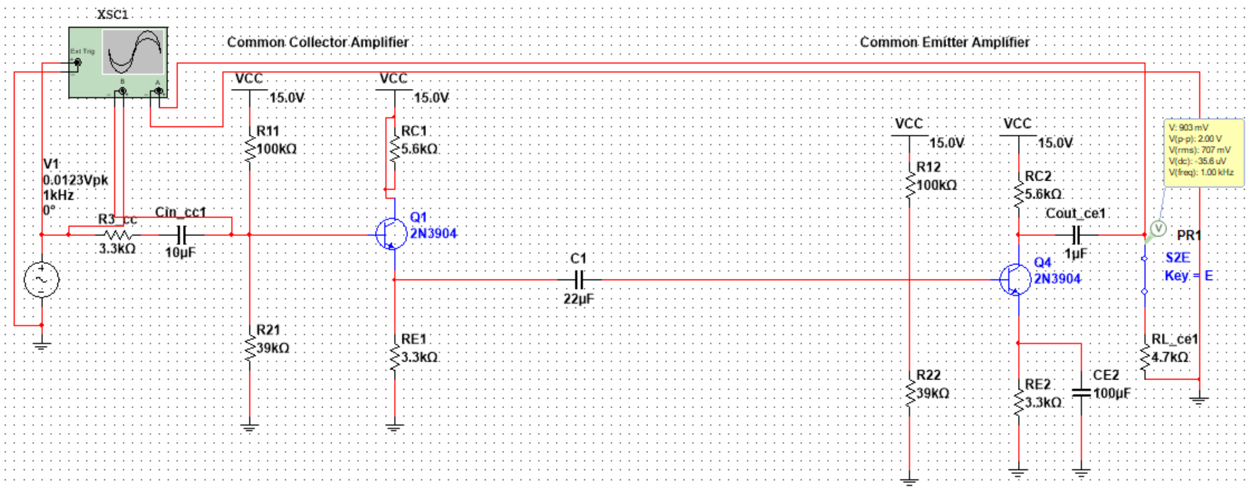
Cascading amplifiers have common parameters.

- <u>CC-CB Amplifier:</u> V_{Source}= 0.0325 V_{Pk} = 0.065 V_{Pk-Pk}



	Prelab	Measured
V_o	-	2.0 V
V_o'	-	4.32 V
V_s	-	0.0649 V
V_x	-	0.0444 V
V_{s-x}	-	0.0205 V
R_{in}	6 kΩ	10.45 kΩ
R_{out}	5.6 kΩ	5.45 kΩ
A_{mid}	34	30.82
f_H	3.68 MHz	5.4 MHz
f_L	136 Hz	113.7 Hz

- <u>CC-CE Amplifier:</u> V_{Source} = 0.0123 V_{Pk} = 0.0246 V_{Pk-Pk}



	Prelab	Measured
V_o	-	2.0 V
V_o'	-	4.23 V
V_s	-	0.0246 V
V_x	-	0.0218 V
V_{s-x}	-	0.0028 V
R_{in}	25.5 kΩ	28.992 kΩ
R_{out}	5.6 kΩ	5.24 kΩ
A_{mid}	88.2	81.30
f_H	6.2 MHz	10.1 MHz
f_L	79 Hz	65 Hz

Table below summarizes the values of calculated and measured of R_{in}, R_{out}, Amid, f_H and f_L for all three 2-transistor amplifiers.

	Prelab					Measured				
	R_{in} (kΩ)	R_{out} (kΩ)	A_{mid}	f_H (MHz)	f_L (Hz)	R_{in} (kΩ)	R_{out} (kΩ)	A_{mid}	f_H (MHz)	f_L (Hz)
CE-CB	3.30	5.60	48.78	4.78	50.90	7.08	5.24	49.51	4.36	41.5
CC-CB	6.00	5.60	34.00	3.68	136.00	10.45	5.45	30.82	5.40	113.70
CC-CE	25.50	5.60	88.20	6.20	79.00	28.99	5.24	81.30	101.10	65.00

As it can be seen from the table above, there is no major difference between the measured and calculated values of R_{in}, R_{out}, A_{mid}, f_H, and f_L for all three 2-transistor amplifiers.

- Comment on the differences between all three 2-transistor amplifiers. Like you did for the previous section, explain any differences in performance. Which ones are better for which tasks and why?

CE-CB: Moderate voltage gain, lowest high cut-off frequency, lowest low cut-off frequency, low input impedance, and low output impedance which is similar to CC-CE. It is best used when low input impedance is needed such as in moving coil microphones preamplifiers.

CC-CB: Lowest voltage gain, low high cut-off frequency but slightly larger than CE-CB's high cut-off frequency, highest low cut-off frequency, output impedance is slightly larger than CE-CB and CC-CE's output impedance, and moderate input impedance. It is best used in radio frequency applications with low-impedance source to high-impedance load.

CC-CE: Highest voltage gain, it has the biggest high cut-off frequency, moderate low cut-off frequency, output impedance is similar to CE-CB, and highest input impedance. It is best for voltage amplification especially at low frequencies, it is commonly used in radio frequency transceiver circuits and low noise amplifiers.

- In weeks 2 & 3 you will be designing a cascade amplifier, a variation on the CE-CB amplifier. Identify what advantages this has over any of the single transistor amplifiers you tested. What are the advantages and disadvantages of using the cascade topology over any of the 2-transistor topologies you just tested?

The benefits of using CE-CB over any single transistor amplifier is that CE-CB has an overall great voltage gain, high cut-off frequency, low cut-off frequency, input impedance, output impedance. It lowers the low cut-off frequency and lower the cost of circuit.

3.0 DAY 2: THE AMPLIFIER PROJECT

Cascode Amplifier Requirements:

- $Z = 0 + 8 + 0 = 8$
- $|A_V| = 12\sqrt{8 + 35} = 78.69 \pm 10\% = 78.69 \pm 7.87\ v/v$
- $R_L = 6(8 + 40)^2 = 13824\Omega = 13.82k\Omega \approx 14k\Omega$
- $f_H > 1\ MHz$
- $V_{out} = 2\ V_{pk-pk}$
- No DC current flow in R_L and signal generator
- $f_L < 200\ Hz$
- Total circuit power ≤ 50mW
- All transistors used are 2N3904
- $I_C = 1.0\ mA \pm 10\% = (1.0 \pm 0.1)\ mA$
- Power-supply is +15V
- $\beta = 200;\ \alpha = 0.995;\ C_\mu = 4\ pf;\ C_\pi = 8\ pf$

DC Analysis:

$$V_E = 0.2 * V_{CC} = 0.2 * 15 = 3\ V$$

$$\therefore V_{CE} = 2\ V$$

$$V_{C1} = V_{E1} + V_{CE1} = 3 + 2 = 5\ V$$

$$V_{C2} = \frac{V_{CC} + V_{C1}}{2} = \frac{15 + 5}{2} = 10\ V$$

$$R_{E2} = \frac{V_E}{I_E} = \frac{3}{1\ mA} = 3\ k\Omega$$

$$R_C = \frac{V_{CC} - V_{C2}}{I_{C2}} = \frac{15 - 10}{1\ mA} = 5\ k\Omega$$

$$V_{B1} = V_{E1} + 0.7 = 3 + 0.7 = 3.7\ V$$

$$V_{B2} = V_{C1} + 0.7 = 5 + 0.7 = 5.7\ V$$

$$I_{B1} = I_{B2} = \frac{I_C}{\beta} = \frac{1\ mA}{200} = 5\ \mu A$$

$$I_{BB} = 10(I_{B1} + I_{B2}) = 10(5\ \mu A + 5\ \mu A) = 100\ \mu A$$

$$R_1 = \frac{V_{CC} - V_{B2}}{I_{BB}} = \frac{15 - 5.7}{100\ \mu A} = 93\ k\Omega$$

$$R_2 = \frac{V_{B2} - V_{B1}}{I_{BB} - I_{B2}} = \frac{5.7 - 3.7}{100\ \mu A - 5\ \mu A} = 21.05\ k\Omega$$

$$R_3 = \frac{V_{B1}}{I_{BB} - I_{B1} - I_{B2}} = \frac{3.7}{100\ \mu A - 5\ \mu A - 5\mu A} = 41.11\ k\Omega$$

AC Analysis:

$$g_m = \frac{I_C}{V_T} = \frac{1\ mA}{25\ mV} = 40\frac{mA}{V}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{200}{40 * 10^{-3}} = 5\ k\Omega$$

$$r_e = \frac{\alpha}{g_m} = \frac{0.995}{40 * 10^{-3}} = 24.88\ \Omega$$

$$V_S = \frac{V_O}{A_{Vmid}} = \frac{2}{78.69} = 24.42\ mV$$

$$Function\ generator\ amplitude = \frac{V_S}{2} = \frac{25.42}{2} = 12.71\ mV$$

$$R_{S1} = 470\ \Omega;\ R_{S2} = 56\ \Omega$$

$$A_V = \propto g_m(R_C//R_L)\frac{(R_2//R_S//r_\pi)}{R_{S1} + R_S + (R_2//R_3//r_\pi)} = 78.69 \pm 7.87\ V/V$$

$$R_S = \frac{\propto g_m(R_C//R_L)(R_2//R_3//r_\pi)}{A_V} - R_{S1} - (R_2//R_3//r_\pi) = 2.83\ k\Omega$$

$$R_{IN} = R_S + (R_2//R_3//r_\pi) = 6.51\ k\Omega$$

$$R_{OUT} = R_C = 5\ k\Omega$$

$$f_L = \frac{1}{2\pi}\left(\frac{1}{C_{OUT}R_{COUT}} + \frac{1}{C_{IN}R_{CIN}} + \frac{1}{C_B R_{CB}} + \frac{1}{C_E R_{CE}}\right) < 200\ Hz$$

$$\frac{1}{2\pi C_E R_{CE}} = 70\%\ f_L = 140\ Hz$$

$$\frac{1}{2\pi C_B R_{CB}} = \frac{1}{2\pi C_{IN} R_{CIN}} = \frac{1}{2\pi C_{OUT} R_{COUT}} = 10\%\ f_L = 20Hz$$

$$R_{CE} = R_E//\left(\frac{r_\pi + (R_2//R_S//R_3)}{1+\beta}\right) = 35.09\ \Omega$$

$$C_E = \frac{1}{2\pi * 140 * R_{CE}} = 32.4\ \mu F$$

$$\therefore Use\ C_E = 33\ \mu F$$

$$R_{CIN} = R_S + (R_2//R_S//r_\pi) = 5.879\ k\Omega$$

$$C_{IN} = \frac{1}{2\pi * 20 * R_{CIN}} = 1.35\ \mu F$$

$$\therefore Use\ C_{IN} = 1\ \mu F$$

$$R_{COUT} = R_C + R_L = 19\ k\Omega$$

$$C_{OUT} = \frac{1}{2\pi * 20 * R_{COUT}} = 0.419\ \mu F$$

$$\therefore Use\ C_{OUT} = 1\ \mu F$$

$$R_{CB} = R_1//R_2//\left(r_e * (1+\beta)\right) = 3.872\ k\Omega$$

$$C_B = \frac{1}{2\pi * 20 * R_{CB}} = 2.055\ \mu F$$

$$\therefore Use\ C_B = 10\ \mu F$$

$$f_L = \frac{1}{2\pi}\left(\frac{1}{(1\ \mu F)(19\ k\Omega)} + \frac{1}{(1\ \mu F)(5.879\ k\Omega)} + \frac{1}{(10\ \mu F)(3.872\ k\Omega)} + \frac{1}{(33\ \mu F)(35.09\ k\Omega)}\right)$$

$$\therefore\ f_L = 177\ Hz$$

$$f_H = \frac{1}{2\pi(\tau_1 + \tau_2 + \tau_3)} > 1\ MHz$$

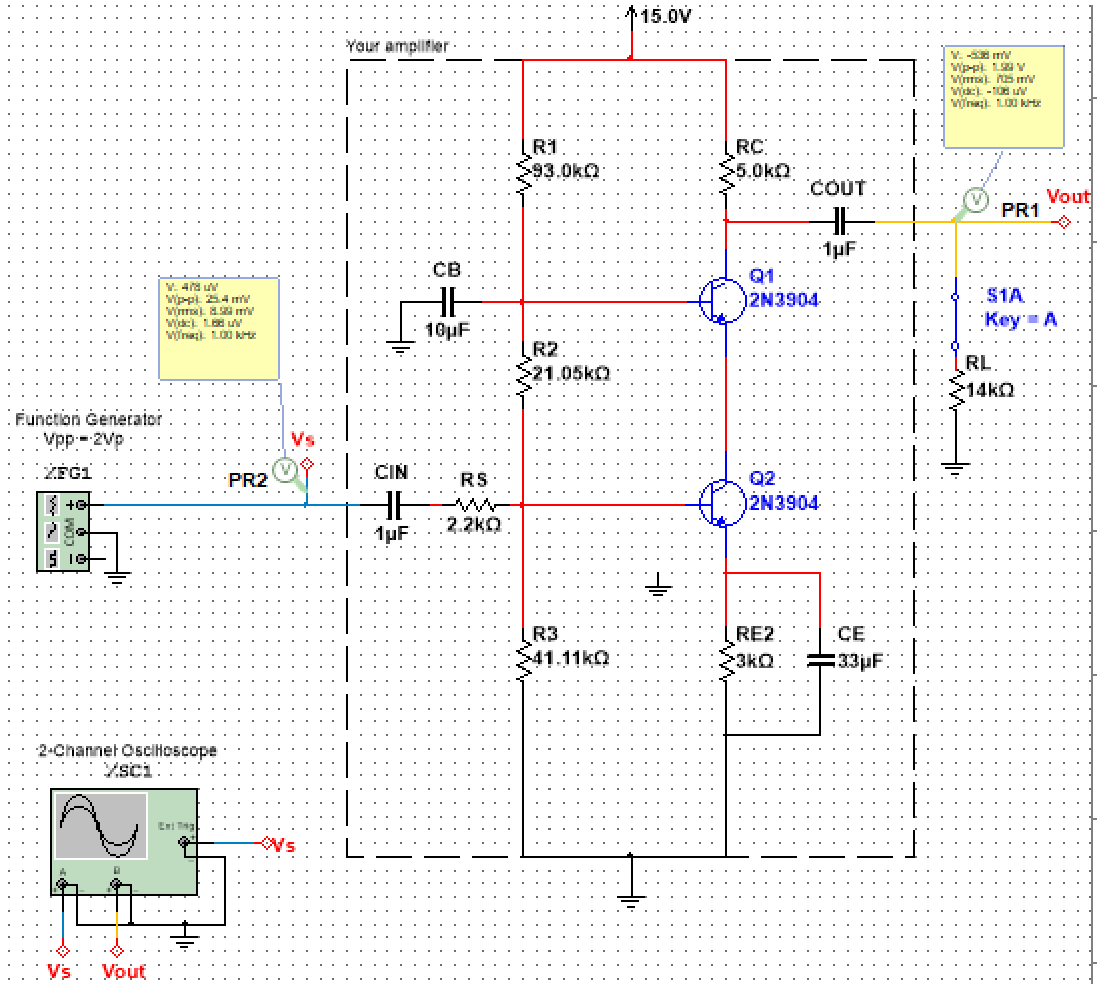
$$\tau_1 = (R_S//R_2//R_3//r_\pi)\left(2C_{\mu 1} + C_\pi\right) = 2.203 * 10^{-8}\ s$$

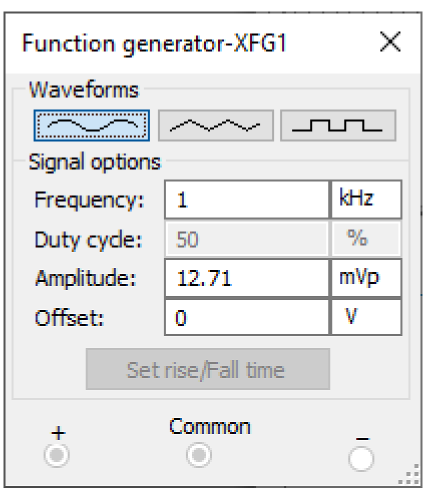
$$\tau_2 = r_e\left(2C_{\mu 1} + C_\pi\right) = \frac{r_\pi}{\beta}\left(2C_{\mu 1} + C_\pi\right) = 4 * 10^{-10}\ s$$

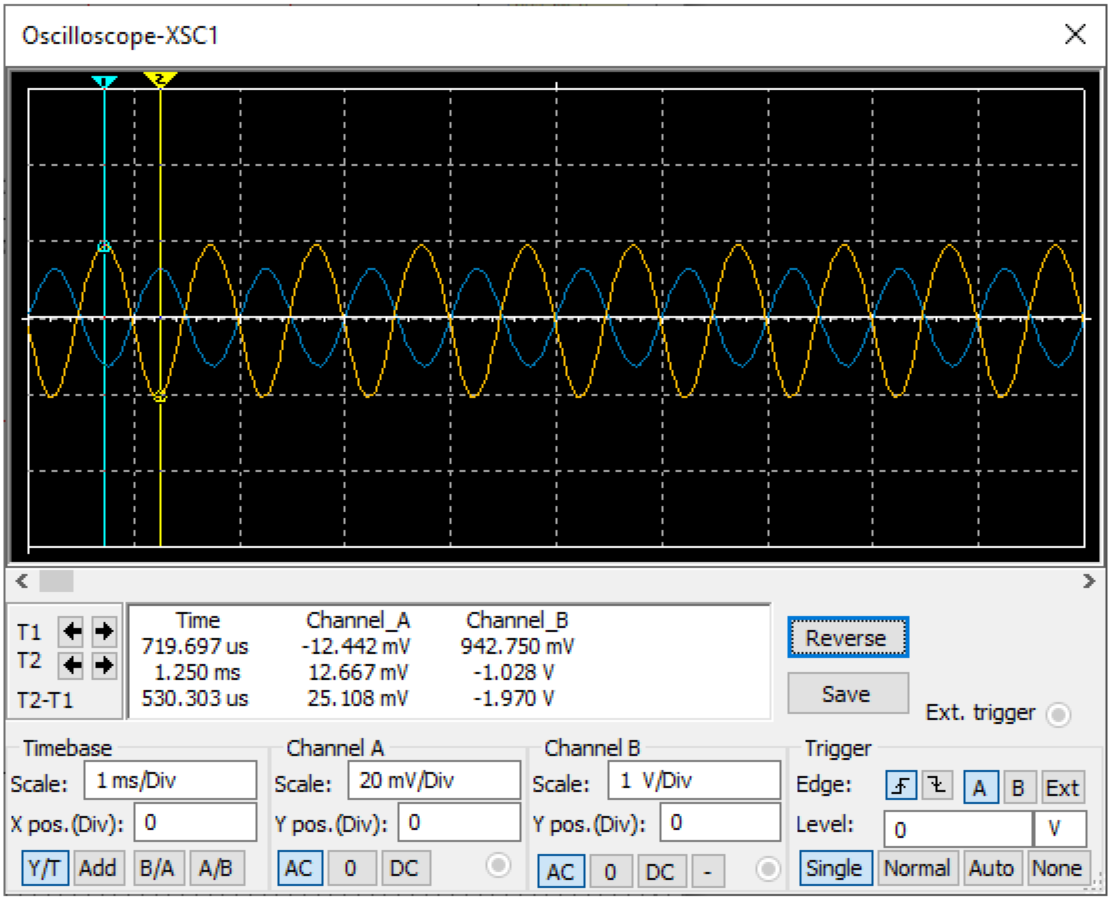
$$\tau_3 = (R_C//R_L)\left(C_{\mu 2} + C_L\right) = 1.474 * 10^{-8}\ s$$

$$f_H = \frac{1}{2\pi\left((2.203 * 10^{-8}) + (4 * 10^{-10}) + (1.474 * 10^{-8})\right)} = 4.282\ MHz$$

Component	**Design Value**
R_S	2.2 kΩ
R_1	93 kΩ
R_2	21.05 kΩ
R_3	41.11 kΩ
R_C	5 kΩ
R_L	14 kΩ
R_E	3 kΩ
C_{IN}	1 µF
C_E	33 µF
C_B	10 µf
C_{OUT}	1 µF


15.0V
Your amplifier
R1
93.0kΩ
RC
5.0kΩ
COUT
1µF
PR1
Vout
CB
10µF
Q1
2N3904
S1A
Key = A
R2
21.05kΩ
RL
14kΩ
Function Generator
Vpp = 2Vp
XFG1
PR2
Vs
CIN
1µF
RS
2.2kΩ
Q2
2N3904
R3
41.11kΩ
RE2
3kΩ
CE
33µF
2-Channel Oscilloscope
XSC1
Vs
Vs
Vout


Function generator-XFG1
Waveforms
Signal options
Frequency: 1 kHz
Duty cycle: 50 %
Amplitude: 12.71 mVp
Offset: 0 V
Set rise/Fall time
+
Common
−



Variable	Simulated Result
V_s	25.4 mV
$V_s - V_x$	10.2 mV
V_o	1.99 V
V_o'	2.69 V
I_{out}	0.142 mA
I_{in}	4.61 µA

- Measure R_{in}, R_{out}, A_{mid}, f_H and f_L.

Variable	Prelab Results	Simulated Results
A_V	78.69 V/V	78.35 V/V
R_{in}	6.51 kΩ	5.51 kΩ
R_{out}	5 kΩ	4.93 kΩ
f_L	177 Hz	140 Hz
f_H	4.282 MHz	5 MHz

- Measure the input and output peak-peak voltage swings at a low input signal amplitude ($6\ mV_{Pk-Pk}$ to $82\ mV_{Pk-Pk}$).

V_{in} (mV)	V_{out} (mV)
6	474
12	946
18	1420
22	1720
26	2030
30	2340
34	2650
38	2950
42	3240
48	3680
54	4110
62	4670
68	5070
76	5590
78	5710
82	5970

- Create a frequency response plot of gain vs frequency. Take 50 - 60 measurements starting lower than f_L and going significantly beyond than f_H.

Frequency (Hz)	Vout (Vp)	Vin (Vp)	Vout (Vpk-pk)	Vin (Vpk-pk)	Av (V/V)	Gain = 20*log(Av) (dB)
1	0.0002112	0.01271	0.0004224	0.02542	0.016616833	-35.58903492
1.122018454	0.000265423	0.01271	0.000530845	0.02542	0.020882975	-33.60415261
1.258925412	0.00033636	0.01271	0.00067272	0.02542	0.026464204	-31.54682313
1.412537545	0.000429972	0.01271	0.000859944	0.02542	0.03382941	-29.41411143
1.584893192	0.000554416	0.01271	0.001108832	0.02542	0.043620465	-27.20619414
1.77827941	0.000720822	0.01271	0.001441644	0.02542	0.056713	-24.9263475
1.995262315	0.000944293	0.01271	0.001888586	0.02542	0.07429528	-22.58077551
2.238721139	0.001245174	0.01271	0.002490347	0.02542	0.097968036	-20.17831194
2.511886432	0.001650607	0.01271	0.003301214	0.02542	0.129866779	-17.73003863
2.818382931	0.002196354	0.01271	0.004392708	0.02542	0.172805184	-15.24886467
3.16227766	0.002928804	0.01271	0.005857608	0.02542	0.230433046	-12.74910478
3.548133892	0.003906984	0.01271	0.007813968	0.02542	0.307394497	-10.24607824
3.981071706	0.005204262	0.01271	0.010408525	0.02542	0.409462037	-7.755727144
4.466835922	0.006909299	0.01271	0.013818597	0.02542	0.543611212	-5.294231891
5.011872336	0.009125697	0.01271	0.018251395	0.02542	0.717993504	-2.877589699
5.623413252	0.011969865	0.01271	0.023939731	0.02542	0.941767537	-0.52112568
6.309573445	0.015566796	0.01271	0.031133593	0.02542	1.224767614	1.761073882
7.079457844	0.020044012	0.01271	0.040088024	0.02542	1.577026896	3.956782004

7.943282347	0.025524525	0.01271	0.051049049	0.02542	2.008223807	6.056242225
8.912509381	0.032120289	0.01271	0.064240579	0.02542	2.527166743	8.052677955
10	0.039927822	0.01271	0.079855644	0.02542	3.141449391	9.942601353
11.22018454	0.0490273	0.01271	0.098054599	0.02542	3.857379996	11.72584848
12.58925412	0.059485552	0.01271	0.118971104	0.02542	4.680216513	13.40531889
14.12537545	0.071362239	0.01271	0.142724479	0.02542	5.614652978	14.98645838
15.84893192	0.084717697	0.01271	0.169435394	0.02542	6.665436411	16.47657179
17.7827941	0.099620619	0.01271	0.199241238	0.02542	7.837971584	17.88407369
19.95262315	0.116154051	0.01271	0.232308103	0.02542	9.1387924	19.21777624
22.38721139	0.134418719	0.01271	0.268837437	0.02542	10.57582364	20.486284
25.11886432	0.154533285	0.01271	0.309066571	0.02542	12.15840168	21.69752974
28.18382931	0.176631525	0.01271	0.353263049	0.02542	13.8970515	22.85845334
31.6227766	0.200856473	0.01271	0.401712946	0.02542	15.803027	23.97480564
35.48133892	0.227351606	0.01271	0.454703213	0.02542	17.88761655	25.05104953
39.81071706	0.256248933	0.01271	0.512497866	0.02542	20.16120639	26.09033031
44.66835922	0.287653862	0.01271	0.575307724	0.02542	22.63208985	27.09449317
50.11872336	0.321626802	0.01271	0.643253604	0.02542	25.30501982	28.06413364
56.23413252	0.35816187	0.01271	0.71632374	0.02542	28.17953342	28.99867596
63.09573445	0.397163825	0.01271	0.794327651	0.02542	31.24813733	29.89648269
70.79457844	0.438425474	0.01271	0.876850947	0.02542	34.49452979	30.75500458
79.43282347	0.481609108	0.01271	0.963218216	0.02542	37.89214069	31.57098282
89.12509381	0.526236776	0.01271	1.052473552	0.02542	41.40336554	32.3407129
100	0.5716946	0.01271	1.143389201	0.02542	44.97990561	33.06037079
112.2018454	0.617255418	0.01271	1.234510836	0.02542	48.56454901	33.7263872
125.8925412	0.66212107	0.01271	1.324242141	0.02542	52.09449806	34.33583716
141.2537545	0.705481097	0.01271	1.410962194	0.02542	55.50598717	34.88679662
158.4893192	0.746579576	0.01271	1.493159153	0.02542	58.73954181	35.37861109
177.827941	0.784778433	0.01271	1.569556865	0.02542	61.7449593	35.81203017
199.5262315	0.819605439	0.01271	1.639210879	0.02542	64.48508571	36.18918563
223.8721139	0.850778801	0.01271	1.701557602	0.02542	66.93774989	36.51342219
251.1886432	0.878206222	0.01271	1.756412444	0.02542	69.09569018	36.78901918
281.8382931	0.901962363	0.01271	1.803924727	0.02542	70.96478075	37.02085731
316.227766	0.922252455	0.01271	1.844504911	0.02542	72.56116879	37.21408539
354.8133892	0.939370752	0.01271	1.878741503	0.02542	73.90800564	37.37382967
398.1071706	0.953661025	0.01271	1.907322051	0.02542	75.03233875	37.50496967
446.6835922	0.965483653	0.01271	1.930967305	0.02542	75.96252184	37.61198748
501.1872336	0.975191153	0.01271	1.950382305	0.02542	76.72629053	37.69888404
562.3413252	0.983112059	0.01271	1.966224118	0.02542	77.34949323	37.76914945
630.9573445	0.98954184	0.01271	1.979083679	0.02542	77.85537684	37.82577222
707.9457844	0.99473916	0.01271	1.98947832	0.02542	78.26429269	37.87127329
794.3282347	0.998925819	0.01271	1.997851639	0.02542	78.59369154	37.90775376
891.2509381	1.00228896	0.01271	2.00457792	0.02542	78.85829741	37.93694792
1000	1.0049845	0.01271	2.009969	0.02542	79.07037765	37.96027626

1122.018454	1.007141057	0.01271	2.014282115	0.02542	79.24005171	37.97889501
1258.925412	1.008863902	0.01271	2.017727804	0.02542	79.37560204	37.99374065
1412.537545	1.010238661	0.01271	2.020477321	0.02542	79.4837656	38.00556868
1584.893192	1.011334642	0.01271	2.022669285	0.02542	79.56999547	38.01498667
1778.27941	1.012207729	0.01271	2.024415458	0.02542	79.63868836	38.02248197
1995.262315	1.012902839	0.01271	2.025805678	0.02542	79.69337836	38.02844476
2238.721139	1.013455989	0.01271	2.026911978	0.02542	79.73689922	38.03318686
2511.886432	1.013896003	0.01271	2.027792006	0.02542	79.77151872	38.03695721
2818.382931	1.014245912	0.01271	2.028491823	0.02542	79.79904891	38.0399543
3162.27766	1.014524095	0.01271	2.029048191	0.02542	79.82093591	38.04233631
3548.133892	1.014745208	0.01271	2.029490416	0.02542	79.83833265	38.04422917
3981.071706	1.014920923	0.01271	2.029841846	0.02542	79.85215759	38.0457331
4466.835922	1.015060534	0.01271	2.030121068	0.02542	79.86314193	38.04692784
5011.872336	1.015171435	0.01271	2.03034287	0.02542	79.87186742	38.04787677
5623.413252	1.015259506	0.01271	2.030519013	0.02542	79.87879673	38.04863028
6309.573445	1.015329422	0.01271	2.030658845	0.02542	79.8842976	38.04922842
7079.457844	1.015384896	0.01271	2.030769792	0.02542	79.88866216	38.04970297
7943.282347	1.015428875	0.01271	2.03085775	0.02542	79.89212234	38.05007917
8912.509381	1.015463697	0.01271	2.030927394	0.02542	79.89486208	38.05037703
10000	1.015491214	0.01271	2.030982429	0.02542	79.8970271	38.0506124
11220.18454	1.015512891	0.01271	2.031025781	0.02542	79.89873254	38.0507978
12589.25412	1.015529879	0.01271	2.031059758	0.02542	79.90006917	38.05094311
14125.37545	1.015543084	0.01271	2.031086168	0.02542	79.9011081	38.05105605
15848.93192	1.015553208	0.01271	2.031106415	0.02542	79.90190462	38.05114263
17782.7941	1.01556079	0.01271	2.031121579	0.02542	79.90250115	38.05120748
19952.62315	1.015566233	0.01271	2.031132466	0.02542	79.90292942	38.05125404
22387.21139	1.015569828	0.01271	2.031139655	0.02542	79.90321225	38.05128478
25118.86432	1.015571765	0.01271	2.03114353	0.02542	79.90336469	38.05130135
28183.82931	1.015572149	0.01271	2.031144297	0.02542	79.90339485	38.05130463
31622.7766	1.015570998	0.01271	2.031141996	0.02542	79.90330435	38.05129479
35481.33892	1.015568253	0.01271	2.031136506	0.02542	79.90308835	38.05127131
39810.71706	1.015563767	0.01271	2.031127533	0.02542	79.90273537	38.05123294
44668.35922	1.0155573	0.01271	2.0311146	0.02542	79.9022266	38.05117764
50118.72336	1.01554851	0.01271	2.031097019	0.02542	79.90153497	38.05110245
56234.13252	1.015536927	0.01271	2.031073854	0.02542	79.90062366	38.05100338
63095.73445	1.015521935	0.01271	2.031043871	0.02542	79.89944417	38.05087516
70794.57844	1.015502737	0.01271	2.031005475	0.02542	79.8979337	38.05071096
79432.82347	1.015478311	0.01271	2.030956622	0.02542	79.8960119	38.05050203
89125.09381	1.015447357	0.01271	2.030894715	0.02542	79.8935765	38.05023726
100000	1.015408229	0.01271	2.030816458	0.02542	79.89049797	38.04990256
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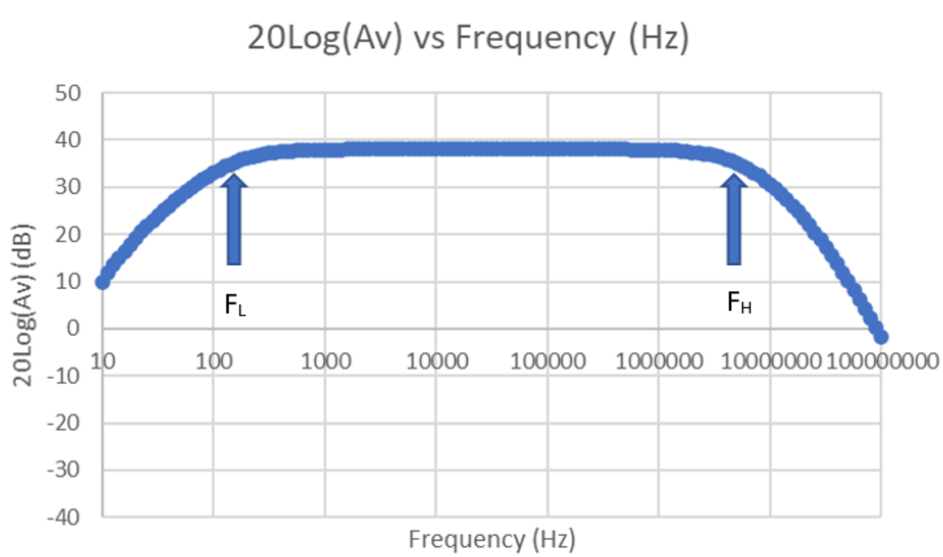
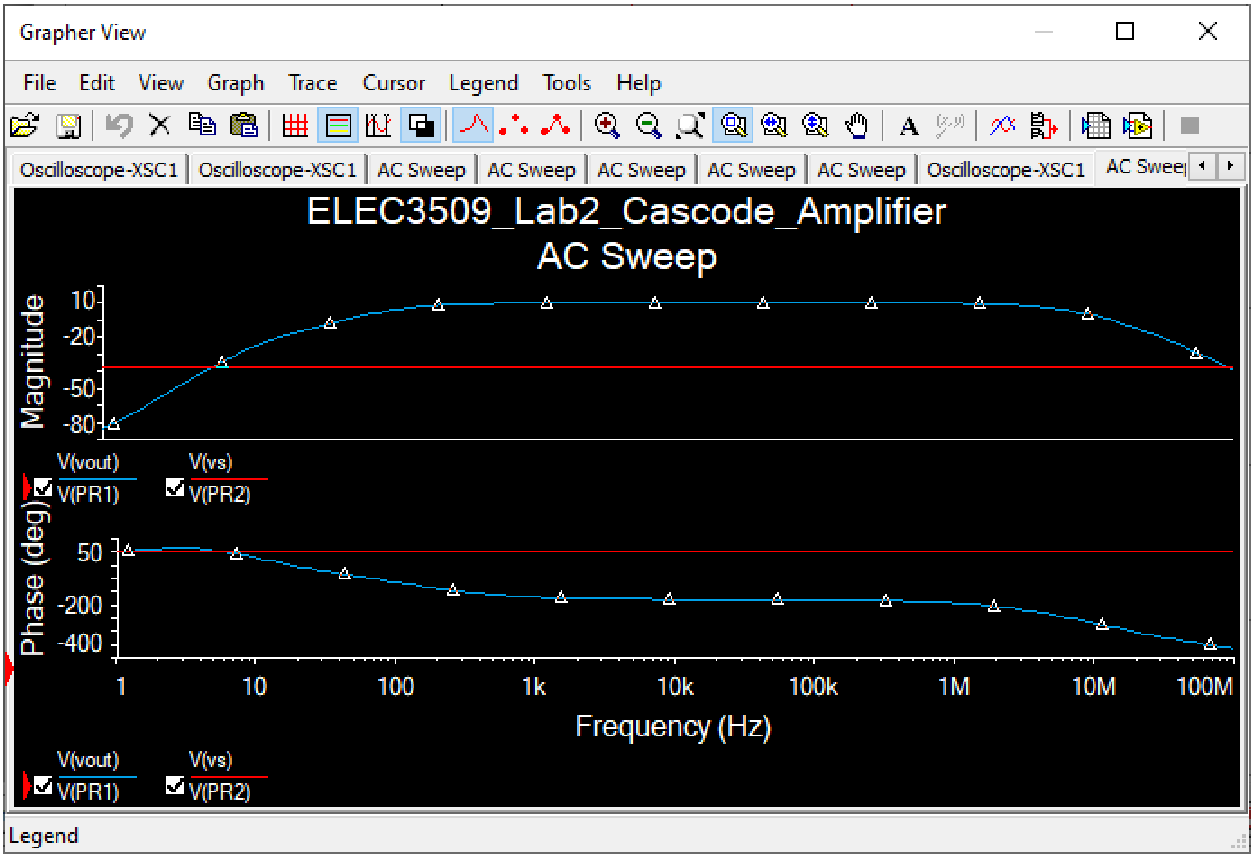
141253.7545	1.015218131	0.01271	2.030436263	0.02542	79.87554141	38.0482763

158489.3192	1.015119326	0.01271	2.030238651	0.02542	79.86776756	38.04743091
177827.941	1.014994923	0.01271	2.029989846	0.02542	79.85797979	38.04636639
199526.2315	1.014838328	0.01271	2.029676657	0.02542	79.8456592	38.04502621
223872.1139	1.01464125	0.01271	2.0292825	0.02542	79.83015341	38.04333928
251188.6432	1.014393267	0.01271	2.028786535	0.02542	79.8106426	38.04121615
281838.2931	1.014081294	0.01271	2.028162588	0.02542	79.78609707	38.03854442
316227.766	1.013688903	0.01271	2.027377806	0.02542	79.75522448	38.03518283
354813.3892	1.013195496	0.01271	2.026390992	0.02542	79.71640411	38.030954
398107.1706	1.012575267	0.01271	2.025150534	0.02542	79.66760558	38.02563529
446683.5922	1.011795927	0.01271	2.023591855	0.02542	79.60628855	38.01894753
501187.2336	1.010817145	0.01271	2.021634291	0.02542	79.52927972	38.01054098
562341.3252	1.009588641	0.01271	2.019177282	0.02542	79.43262321	37.9999781
630957.3445	1.008047895	0.01271	2.01609579	0.02542	79.31140008	37.98671233
707945.7844	1.006117418	0.01271	2.012234836	0.02542	79.1595136	37.97006234
794328.2347	1.003701554	0.01271	2.007403107	0.02542	78.96943774	37.94918092
891250.9381	1.000682825	0.01271	2.001365651	0.02542	78.73192961	37.92301791
1000000	0.996917886	0.01271	1.993835771	0.02542	78.4357109	37.89027674
1122018.454	0.992233244	0.01271	1.984466488	0.02542	78.06713171	37.84936446
1258925.412	0.986421094	0.01271	1.972842188	0.02542	77.60984216	37.798336
1412537.545	0.979235778	0.01271	1.958471557	0.02542	77.04451442	37.73483445
1584893.192	0.970391737	0.01271	1.940783475	0.02542	76.34868114	37.65603079
1778279.41	0.959564118	0.01271	1.919128235	0.02542	75.49678344	37.55856898
1995262.315	0.946393593	0.01271	1.892787187	0.02542	74.46055022	37.43852482
2238721.139	0.930497193	0.01271	1.860994387	0.02542	73.20984999	37.29139034
2511886.432	0.91148689	0.01271	1.822973779	0.02542	71.71415339	37.11209752
2818382.931	0.888997112	0.01271	1.777994224	0.02542	69.94469802	36.89509599
3162277.66	0.862720973	0.01271	1.725441945	0.02542	67.87733853	36.63449611
3548133.892	0.832452723	0.01271	1.664905446	0.02542	65.49588695	36.32428056
3981071.706	0.798131126	0.01271	1.596262252	0.02542	62.79552527	35.95857395
4466835.922	0.75987586	0.01271	1.51975172	0.02542	59.78566956	35.53194195
5011872.336	0.718008025	0.01271	1.43601605	0.02542	56.49158341	35.03967496
5623413.252	0.673047488	0.01271	1.346094976	0.02542	52.95416901	34.47800314
6309573.445	0.62568442	0.01271	1.25136884	0.02542	49.22772779	33.84419581
7079457.844	0.576728733	0.01271	1.153457467	0.02542	45.37598216	33.13652077
7943282.347	0.52704683	0.01271	1.05409366	0.02542	41.46709915	32.3540731
8912509.381	0.477497792	0.01271	0.954995584	0.02542	37.56866972	31.49651635
10000000	0.428879853	0.01271	0.857759705	0.02542	33.74349745	30.56380189
11220184.54	0.38189362	0.01271	0.763787241	0.02542	30.04670499	29.55593706
12589254.12	0.337123092	0.01271	0.674246184	0.02542	26.52424014	28.47285902
14125375.45	0.295031089	0.01271	0.590062178	0.02542	23.21251682	27.31444463
15848931.92	0.255963595	0.01271	0.51192719	0.02542	20.13875647	26.08065301
17782794.1	0.220157654	0.01271	0.440315308	0.02542	17.32160926	24.77176475
19952623.15	0.187749327	0.01271	0.375498653	0.02542	14.77178023	23.38865676

22387211.39	0.158780662	0.01271	0.317561324	0.02542	12.49257764	21.93304114
25118864.32	0.133206621	0.01271	0.266413241	0.02542	10.48045796	20.4076052
28183829.31	0.110903758	0.01271	0.221807517	0.02542	8.725708763	18.81601427
31622776.6	0.091682039	0.01271	0.183364078	0.02542	7.213378351	17.16277424
35481338.92	0.075299949	0.01271	0.150599898	0.02542	5.924464907	15.45298263
39810717.06	0.061481774	0.01271	0.122963549	0.02542	4.837275713	13.69201684
44668359.22	0.049935124	0.01271	0.099870249	0.02542	3.928806005	11.8852117
50118723.36	0.040366765	0.01271	0.080733529	0.02542	3.175984619	10.03756781
56234132.52	0.032495357	0.01271	0.064990713	0.02542	2.556676367	8.153515138
63095734.45	0.026060486	0.01271	0.052120971	0.02542	2.050392267	6.236739106
70794578.44	0.020828057	0.01271	0.041656113	0.02542	1.638714127	4.290063956
79432823.47	0.016592607	0.01271	0.033185214	0.02542	1.305476572	2.315381647
89125093.81	0.013177293	0.01271	0.026354587	0.02542	1.036765808	0.313613322
100000000	0.010432303	0.01271	0.020864607	0.02542	0.820794909	-1.715306919



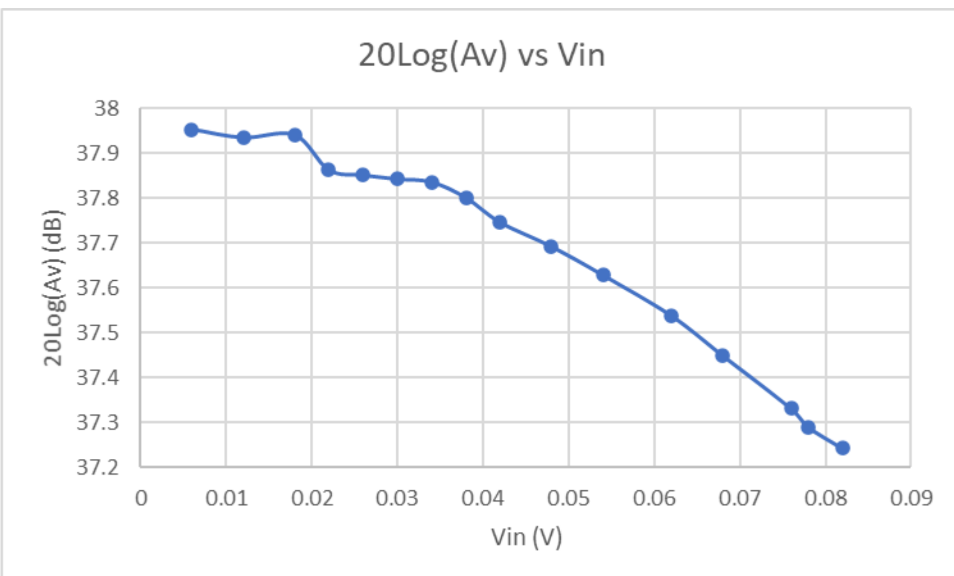


- <u>As with all labs, you must show your pre-lab work and calculations for both parts of the lab. You need to show several plots and tables in order to clearly demonstrate that your circuit meets specifications. For Rin and Rout, show a table comparing measured and calculated results. Explain any significant differences.</u>

		CC	CE	CB	CE-CB	CC-CB	CC-CE
Prelab	R_{in} $(k\Omega)$	25.50	3.30	25.90	3.30	6.00	25.50
	R_{out} $(k\Omega)$	0.046	5.60	5.60	5.60	5.60	5.60
Measured	R_{in} $(k\Omega)$	29.20	7.08	3.33	7.08	10.45	28.99
	R_{out} $(k\Omega)$	0.705	5.24	5.59	5.24	5.45	5.24

- <u>Show a plot measuring gain as a function of input peak-peak voltage swing.</u>

Vin (V)	Vout (V)	Av (V/V)	Gain = 20Log(Av) (dB)
0.006	0.474	79	37.95254183
0.012	0.946	78.83333333	37.93419781
0.018	1.42	78.88888889	37.94031679
0.022	1.72	78.18181818	37.86211532
0.026	2.03	78.07692308	37.8504538
0.03	2.34	78	37.84189205
0.034	2.65	77.94117647	37.83533914
0.038	2.95	77.63157895	37.80076839
0.042	3.24	77.14285714	37.7459144
0.048	3.68	76.66666667	37.69213163
0.054	4.11	76.11111111	37.62896124
0.062	4.67	75.32258065	37.53850382
0.068	5.07	74.55882353	37.44998093
0.076	5.59	73.55263158	37.33196431
0.078	5.71	73.20512821	37.29083011
0.082	5.97	72.80487805	37.24320957



The location where the gain differs from the low signal gain by 1 dB is when V_{in} = 25.42 mV and Gain = 29.56 dB

DISCUSSION

Overall, prelab values and measured values were very close to each other, and in day 2 all the simulated results successfully achieved the cascode amplifier requirements.

Comparing the three fundamental BJT configurations, we can conclude that CE has the highest mid-band gain and lowest high cut-off frequency also it was determined that it can be used to amplify weak signals, CC has the lowest mid-band gain and highest input impedance and lowest output impedance was determined that it can as a voltage buffer, CB has the lowest input impedance and lowest low cut-off frequency and highest high cut-off frequency also it was determined that it can act as a current buffer.

While out of the three 2-transistor configurations, the CC-CE has the highest mid-band gain and highest input impedance and it acts like a good voltage amplifier circuit, CE-CB has moderate mid-band gain and lowest high cut-off frequency and it acts as moderate amplifier circuit, while CC-CB has the lowest mid-band gain and highest low cut-off frequency and it acts like a poor voltage amplifier circuit.