ECE 3337 – Lab Report 1

BJT Amplifiers

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Objectives

1. To determine quiescent point of a common emitter and common collector amplifiers and calculate the values of the resistors Rc, Re, R1 and R2. .

2. To simulate and measure CE and CC amplifier gain at different frequencies using MicroCap software.

Prelaboratory Preparation

Only final results for each question are shown here, complete work can be found in screenshots at the end of this report under the **Prelab Work** section.

Common-Emitter Amplifier

1.1

N/A

1.2

DC Biasing the CE Amplifier as noted in the question gives the following resistor values

Resistor	Expression	Numerical Value [Ω]	Std Lab Value [Ω]
R_1	$\frac{V_{cc}-V_B}{10\cdot i_B}$	33.200 k	33.000 k
R_2	$\frac{V_B}{10\cdot i_B}$	6.800 k	6.800 k

R_C	$\frac{V_{cc}-V_C}{i_C}$	800	820
R_E	$\frac{V_E}{i_E}$	199	200

1.3

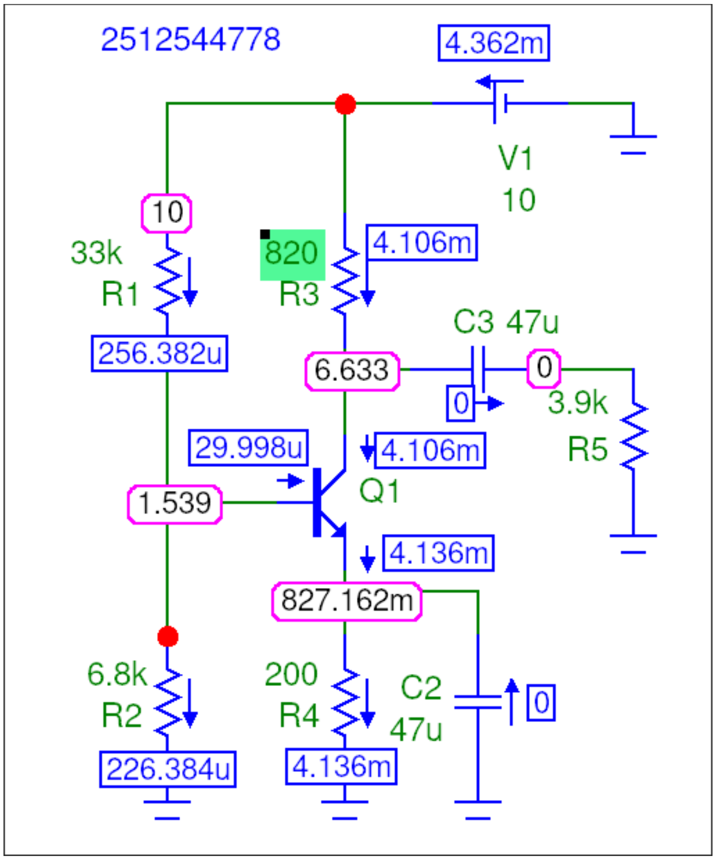
After Small Signal AC Analysis the following was found for the input/output resistances and voltage/current gains.

Note: All Output resistances are calculated such that we are not considering the load-resistance R_L

Value	Expression	Numerical Value
R_{inp}	$R_1 \| R_2 \| r_\pi$	849 [Ω]
R_{out}	R_C	800 [Ω]
A_v	$-g_m(R_C \| R_L)$	-132.765 [V/V]
A_i	$A_V \cdot \frac{R_{inp}}{R_L}$	-28.902 [A/A]

1.4

Schematic 1, shows the Microcap simulation with standard resistors, and DC bias point results of the BJT with $\beta = 200$.

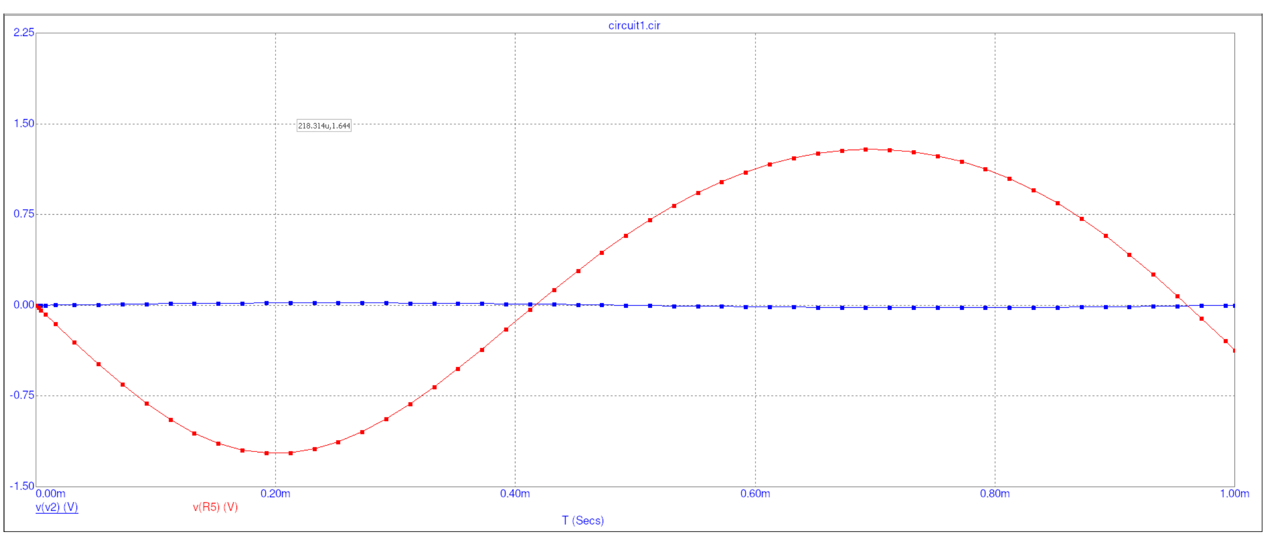


Schematic 1: DC Simulation of the Common-Emitter Amplifier

1.5

Plot 1 shows the Transient Analysis for a 1 kHz sine wave with 20mV amplitude.

Note: The plot in **red** is the load voltage, and the plot in **blue** is the AC source voltage



Plot 1: Transient Simulation of the Common-Emitter Amplifier with a 20 mV 1kHz sine input

Common-Collector Amplifier

2.1

DC Biasing the CC Amplifier as noted in the question gives the following resistor values

Resistor	Expression	Numerical Value [Ω]	Std Lab Value [Ω]
R_1	$\frac{V_{cc}-V_B}{10\cdot i_B}$	17.200k	18.000k
R_2	$\frac{V_B}{10\cdot i_B}$	22.800k	22.000k
R_E	$\frac{V_E}{i_E}$	995	1.000k

2.2

After Small Signal AC Analysis the following was found for the input/output resistances and voltage/current gains.

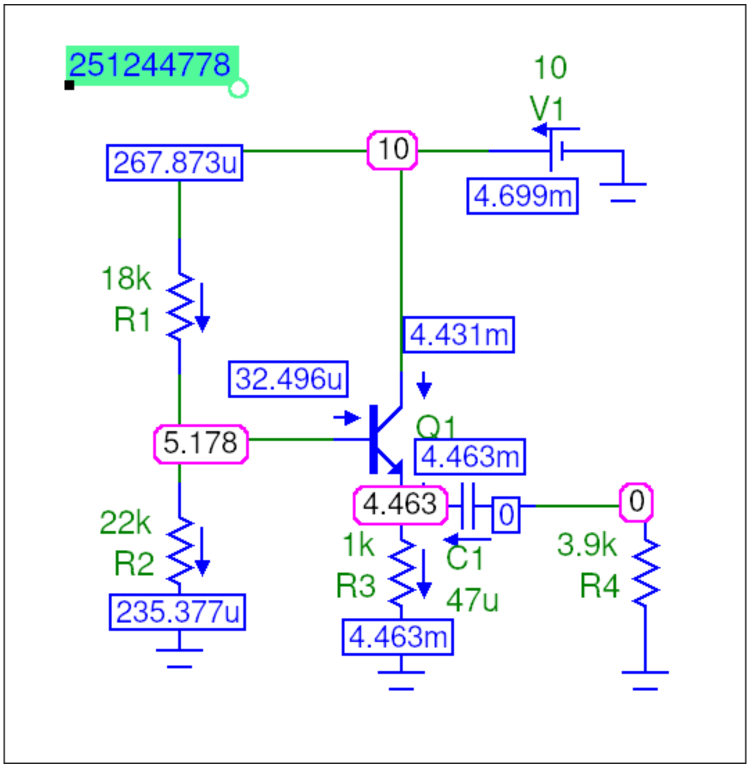
Note: All Output resistances are calculated such that we are not considering the load-resistance R_L

Value	**Expression**	**Numerical Value**
R_{inp}	$[R_1 \| R_2] \| [r_\pi + (1+\beta)(R_E \| R_L)]$	9.324k [Ω]
R_{out}	$R_E \| \frac{r_\pi + R_1 \| R_2}{1+\beta}$	51.42 [Ω]

A_v	$\dfrac{[g_m+\frac{1}{r_\pi}](R_E \Vert R_L)}{1+[g_m+\frac{1}{r_\pi}](R_E \Vert R_L)}$	0.9937 [V/V]
A_i	$A_V \cdot \dfrac{R_{inp}}{R_L}$	180.199 [A/A]

2.3

Schematic 2 shows the DC operating point of the Common-Collector amplifier with $\beta=200$.

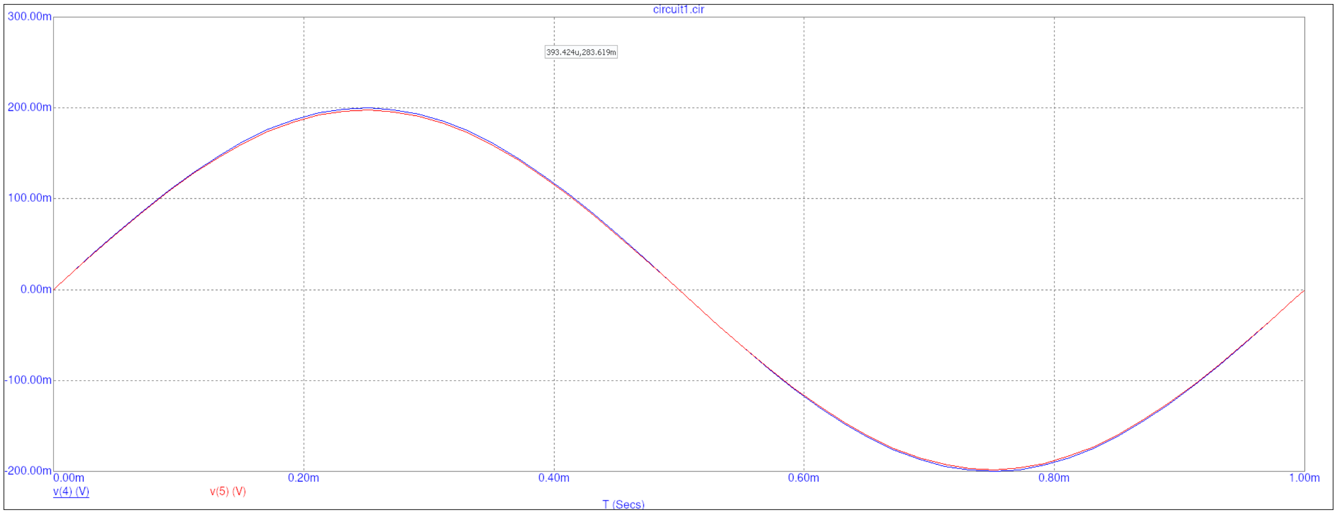


Schematic 2: DC Simulation of the Common-Collector Amplifier

2.4

Plot 2 shows the Transient Analysis for a 1 kHz sine wave with 20mV amplitude.

Note: The plot in **red** is the load voltage, and the plot in **blue** is the AC source voltage



Plot 2: Transient Simulation of the Common-Collector Amplifier with a 0.2 V 1kHz sine input

Procedure

1.1 – N/A

1.2 – N/A

1.3 – N/A

1.4 – N/A

1.5, 1.6, 1.7

See Table 1 for Enumerated Values.

During the lab the oscilloscopes were not working, the drawings cannot be done as I had to take the values of someone else.

	Micro-Cap Simulation			Lab Measurements		
f [Hz]	V_{inp} [V]	V_{out} [V]	A_v [dB]	V_{inp} [V]	V_{out} [V]	A_v [dB]
50	20m	197.8m	19.904	23.6m	202m	18.65
100	20m	371.7m	25.384	24m	380m	23.99
200	20m	678.9m	30.616	23.6m	690m	29.32
500	20m	1.19	35.457	23.6m	1.28	34.68
1k	20m	1.41	36.973	23.6m	1.62	36.73
10k	20m	1.52	37.618	22.4m	1.82	38.19
20k	20m	1.52	37.618	22.4m	1.82	38.19
100k	20m	1.52	37.618	22.4m	1.82	38.19

Table 1: Common-Emitter Amplifier Frequency Response

1.8

The Frequency Response of the Common-Emitter (CE) amplifer meets expectations, it has a low gain at low frequencies due to the decoupling capacitors, and the midband gain is relatively stable, I do not think we see the high-frequency behaviour in the tables above as the max frequency is relatively low at around 100kHz. These observations also align with the Micro-Cap simulations within the degree of reasonable error.

1.9

Without access to a working oscilloscope I can only approximate these values. The Supply voltage sets an approximation of the maximum output voltage of the CE amplifier, so around 10V. The corresponding input for this 10V output wave would be dependent on the gain, supposing the input signal was used at 1kHz, we observe a dB gain of 36.967 dB, we can use this to approximate the input voltage as 141.8 mV.

1.10

The CE Amplifier is an inverting amplifier, as it has a phase-shift of approximately 180. This is because the current flows upwards from ground and through the load resistor during the positive sweep of the input (causing a voltage drop), and the inverse happens during the negative sweep of the signal (causing a voltage gain).

2.1 - N/A

2.2 – N/A

2.3 – N/A

2.4

See Table 2

2.5

During the lab the oscilloscopes were not working, the drawings cannot be done as I had to take the values of someone else.

2.6

The Common-Collector (CC) amplifier is essentially a voltage-buffer, but current gain amplifier, this is evident due to the constant-voltage gain of about 0dB from Table 2.

2.7

Once again, without access to working oscilloscopes I can only estimate this value. Here since the voltage is buffered (approx 0 gain) we can assume clipping appears at the output when there is an input of > 10V on the input.

2.8

The CC Amplifier is a voltage buffer, this means it is a non-inverting amplifier.

	Micro-Cap Simulation			Lab Measurements		
f [Hz]	V_{inp} [V]	V_{out} [V]	A_v[dB]	V_{inp} [V]	V_{out} [V]	A_v[dB]
50	200m	197.903m	-0.0916	212m	208m	-0.1655
100	200m	197.929m	-0.0939	216m	216m	0
200	200m	197.936m	-0.0901	212m	216m	0.1624
500	200m	197.938m	-0.0902	212m	216m	0.1624
1k	200m	197.938m	-0.0901	212m	216m	0.1624
10k	200m	197.938m	-0.0901	212m	216m	0.1624
20k	200m	197.938m	-0.0901	212m	216m	0.1624
100k	200m	197.938m	-0.0901	212m	216m	0.1624

Table 2: Common-Collector Amplifier Frequency Response

Questions

1. Do your experimental results agree with the MicroCap simulation? Comment on both the DC and the AC values. Explain any discrepancies.

Yes, the real-life and Micro-Cap simulated results align quite well and are within the 10% boundary. This holds true for both the DC Biasing values, as well as the AC values recorded in Tables 1 and 2.

2. What will the voltage gain of your CE amplifier be if RL=8Ω (input resistance of a speaker)?

We can use the derived formula from the table under the prelab section and sub in the proper values.

$$-g_m\left(R_C \| R_L\right)$$

Here the values for the small-signal trans-conductance, and collector resistance are 0.2 S and 800 Ohms. This gives a -1.584 V/V Gain or approx 4dB magnitude gain.

3. Is your CE amplifier suitable for an audio amplifier?

After googling it, Most consumer-grade audio amps can provide gains of 20 to 30 dB, our CE's 4dB gain is very small in comparison. So no this would not be suitable as an audio amplifier.

4. What is the main purpose of using the emitter follower?

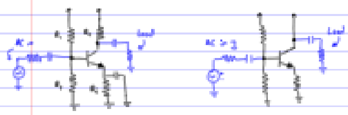
As discussed previously, the emitter follower (or CC amp) can be used as a voltage-buffer with current gains. This can be useful to impedance match (isolate) different sub-blocks within a complex analog circuit design. As the input and output are not *directly* connected, but are essentially *coupled* through a transistor.

Prelab Work

This section holds the screenshots of the manual work done for the prelab

ECE 3337 LAB 1 → BJT AMPS

Common Emitter   Common Collector



PRELAB

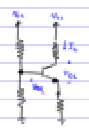
Bias the CE Amp such that

↳ $V_{cc} = 10V$

↳ $V_{ce} = 5V$

↳ $I_c = 5mA$

DC Analysis of CE



From Lab Assume

↳ $V_E = \frac{1}{10} V_{cc}$

↳ $I_{R_2} = 10(i_B)$

$V_E = \frac{1}{10}(10V) = 1V$

$V_{BE} = 0.7 \Rightarrow V_B - V_E = 0.7$ → $V_C - V_E = 5V$

$V_B = 1.7V$ $V_C = 5 + 1 = 6V$

Thus Q point (Voltage

↳ $V_B = 1.7V$

↳ $V_E = 1V$

↳ $V_C = 6V$

$R_c = \frac{10-6}{5m} = \frac{4}{5}k$

$= 0.8k$

$R_c = 800\Omega$

we know that $i_c = \beta i_B \Rightarrow i_B = i_c/\beta = \frac{5m}{200} = \frac{1}{40} mA$

↳ $i_B = 0.025mA = 25\mu A$

↳ $i_E = (1+\beta) i_B = 5.025 mA$

↳ $i_c = 5 mA$

Thus our resistances become

$R_1 = \frac{V_{cc} - V_B}{10 i_B} \Rightarrow \frac{10-1.7}{250\mu} = 33.2k$

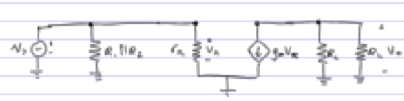
$R_2 = \frac{V_B}{10 i_B} \Rightarrow \frac{1.7}{250\mu} = 6.8k$

$R_c = \frac{V_{cc} - V_c}{i_c} \Rightarrow \frac{10-6}{5m} = 800\Omega$

$R_E = \frac{V_E}{i_E} \Rightarrow \frac{1}{5.025m} = 199\Omega$

AC Analysis

Small Signal Equivalent



$R_{in} = R_1 || R_2 || r_\pi$

$R_{out} = R_C || R_L$ or R_C depending on if including R_L or not.

Voltage gain $A_v = \frac{V_\pi}{V_s} \cdot \frac{V_o}{V_\pi}$

$= (1) \cdot \left(-g_m V_\pi [R_c || R_L]\right)$

$A_v = -g_m [R_c || R_L]$

Common Collector DC Biasing

Here we have the following

$i_c = 5mA$

$i_B = \frac{i_c}{\beta} = 25\mu A$

$i_E = 5.025 mA$

$V_c = V_{cc} = 10V$

$V_c - V_E = 5V$

$V_E = V_c - 5 = 5V$

$V_B - V_E = 0.7V$

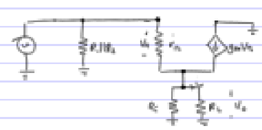
$V_B = 5.7V$

$R_E = \frac{V_E}{i_E} = \frac{5}{5.025m} = 995\Omega$

$R_1 = \frac{V_{cc} - V_B}{10 i_B} = \frac{4.3}{250\mu} = 17.2k$

$R_2 = \frac{V_B}{10 i_B} = \frac{5.7}{250\mu} = 22.8k$

AC Analysis



$R_{in} = [R_1 || R_2] \,||\, r_\pi + (1+\beta)(R_E || R_L)$

$R_{out} = R_E \,||\, \left(\frac{V_\pi + R_1||R_2}{1+\beta}\right)$

$A_v = \frac{V_o}{V_s} = \frac{V_o}{V_\pi} \cdot \frac{V_\pi}{V_s}$

$\frac{V_o}{V_\pi}$: $V_o = i_e (R_E || R_L)$

$= (i_c + i_b)(R_E || R_L)$

$= \left[g_m V_\pi + \frac{V_\pi}{r_\pi}\right](R_E || R_L)$

$V_o = V_\pi \left[g_m + \frac{1}{r_\pi}\right](R_E || R_L)$

$\frac{V_o}{V_\pi} = \left[g_m + \frac{1}{r_\pi}\right](R_E || R_L)$

$= \begin{cases} V_o = \left[g_m + \frac{1}{r_\pi}\right](R_E || R_L) V_\pi \\ V_o = V_s - V_\pi \end{cases}$

$\left[g_m + \frac{1}{r_\pi}\right](R_E || R_L) V_\pi + V_\pi = V_s$

$V_\pi \left[1 + \left[g_m + \frac{1}{r_\pi}\right](R_E || R_L)\right] = V_s$

$\frac{V_\pi}{V_s} = \frac{1}{1 + \left[g_m + \frac{1}{r_\pi}\right](R_E || R_L)}$

Thus $\frac{V_o}{V_s} = \frac{V_o}{V_\pi} \cdot \frac{V_\pi}{V_s}$ $\frac{\left[g_m + \frac{1}{r_\pi}\right](R_E || R_L)}{1 + \left[g_m + \frac{1}{r_\pi}\right](R_E || R_L)} \approx 1$ for large $\left[g_m + \frac{1}{r_\pi}\right](R_E || R_L)$

A_v

$A_i = \frac{V_o}{V_s} = \frac{V_o / R_L}{V_s / R_{in}} = A_v \cdot \frac{R_{in}}{R_L}$