Department of Electrical, Computer, & Biomedical Engineering
Faculty of Engineering & Architectural Science

Course Title:	Ele 404
Course Number:	ELE404-042
Semester/Year	2023 Spring Sem

Instructor:	Sandeep Kaler

Assignment/Lab Number:	Lab 6
Assignment/Lab Title:	Common-Emitter Amplifiers

Submission Date	June 16th, 2023
Due Date:	June 16th, 2023

Student LAST Name	Student FIRST Name	Student Number	Section	Signature*
Yang	Nini	501137659	04	
Gohir	Usba	501014491	04	

*By signing above you attest that you have contributed to this written lab report and confirm that all work you have contributed to this lab report is your own work. Any suspicion of copying or plagiarism in this work will result in an investigation of Academic Misconduct and may result in a "0" on the work, "F" in the course, or possibly more severe penalties, as well as a Disciplinary Notice on your academic record under the Student Code of Academic Conduct, which can be found online at: http://www.ryerson.ca/senate/current/pol60.pdf

Table of Contents:

Introduction:

Lab 6 explores common-emitters and bipolar-junction transistors gain in active mode.

In this lab you will bias a Bipolar-Junction Transistor (BJT) in the active mode, and also tests a Common-Emitter (CE) amplifier. Moreover, you will learn a technique for experimental evaluation
of the input and output resistances of an amplifier. For this lab, you will use the 2N3904 NPN BJT.

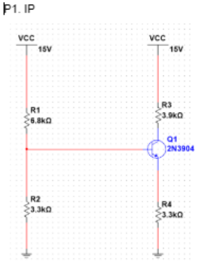
Objectives:

Determine the no load and loaded voltage gain of an active BJT.

Pre-lab:

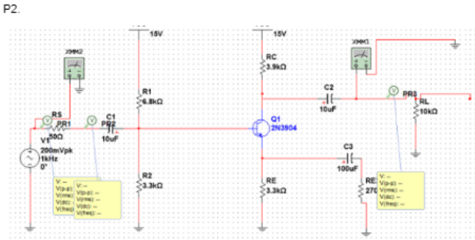
Usba:

P1. IP



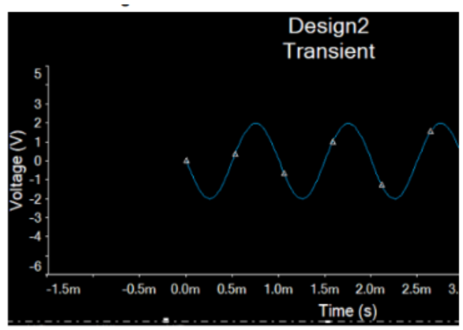
VB	VC	VE	IB	IC	IE	gm	RE	Rpi
4.88	10.08	4.191	0.00839	1.261	1.27	48.5	20.47	3.113

P2.

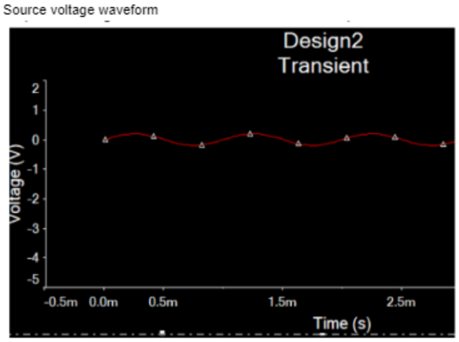


$Avo[V/V]$	$Av[V/V]$	$Ri[k\Omega]$	$Ro[k\Omega]$
-14.34	-10.32	3.113	3.9

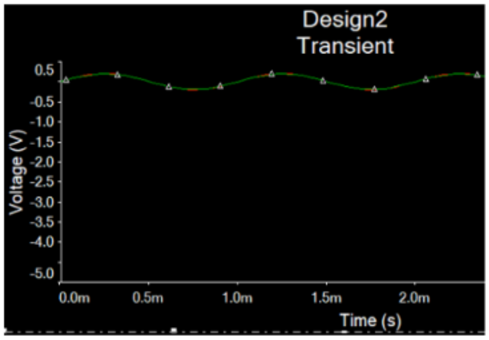
P3.



Source voltage waveform



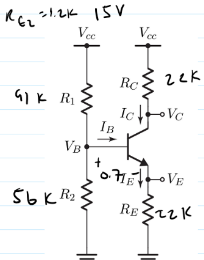
Input voltage waveform of the CE amplifier



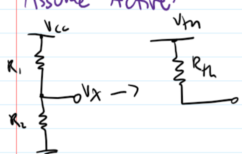
Output voltage waveform of the CE amplifier

Nini:

1. $R_{E_2}=1.2K$ 15V $\beta = 150$



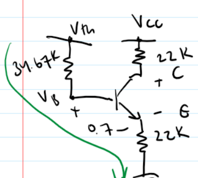
Assume Active:



$V_x = V_{cc}\cdot\frac{R_2}{R_1+R_2}$ $\quad R_{th}=R_1 \| R_2$

$=15\cdot\frac{56}{91+56}$ $\quad =\frac{91\cdot 56}{91+56}$

$V_x = 5.7143\ V = V_{th}$ $\quad R_{th} = 34.667\ k\Omega$



$V_{th}-34.67K i_B+V_{BE}-22K i_E=0$

$i_E=(\beta+1)i_B$

$5.7143-34.67 i_B+0.7-22K(\beta+1)i_B=0$

$6.4143 = 3\,356\,670\, i_B$

$i_B = 1.9109\times10^{-6}\ A$

$V_C = V_{cc}-i_C R_C$ $\quad i_C=\beta i_B$

$=15-(2.86637\times10^{-4})(22K)$ $\quad =150\,(1.9109\times10^{-6}\ A)$

$V_C = 8.694\ V$ $\quad i_C = 2.86637\times10^{-4}\ A$

$V_E = 22K(i_E)$ $\quad i_E = i_C+i_B$

$=22K(2.8855\times10^{-4})$ $\quad i_E = 2.8855\times10^{-4}\ A$

$=6.348$

$V_{BE}=V_B-V_E$ $\quad V_{BC}=V_B-V_C$

$V_B = V_{BE}+V_E$ $\quad =7.048-8.694$

$=0.7+6.348$ $\quad V_{BC}=-1.646$

$V_B = 7.048$

$V_{BC}<0.7$

$V_{CE}=8.694-6.348 > V_{CE(sat)}=0.3V$

$=2.346$

∴ Active

$g_m=\frac{i_C}{V_T}=\frac{2.866\times10^{-4}}{25.9mA}$ $\quad r_e=\frac{V_T}{i_E}$ $\quad r_\pi=\frac{\beta}{g_m}$

$g_m = 0.011140846$ $\quad =\frac{25.9mA}{2.8855\times10^{-4}}$ $\quad =\frac{150}{0.011140846}$

$r_e = 89.759\ \Omega$ $\quad r_\pi = 13\,463.97$

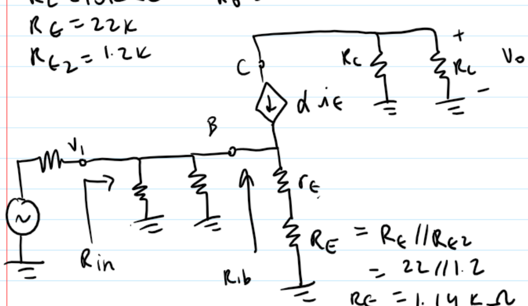
2. $V_{CC} = 15\,V$ $\quad A_v = \frac{V_o}{V_i}$

$R_S = 50$ $\quad R_i = ?$

$R_L = 10K\,\Omega$ $\quad R_o = ?$

$R_E = 22K$

$R_{E2} = 1.2K$



$R_E = R_E // R_{E2}$

$= 22 // 1.2$

$R_E = 1.14\,K\Omega$

$A_v = \frac{V_o}{V_1}$

$V_o = -g V_{be} R_c$

$V_o = -g_m V_{bE} (R_E // R_{E2})$

$A_v = \frac{V_o}{V_1}$

$V_{bE} = -V_1 \left(\frac{r_E}{r_E + R_E // R_{E2}} \right)$

$= -31.5 \left(\frac{89.76}{89.76 + 1.14K} \right) (22K // 10K)$

$= -11.515\,V$

$A_v = 11.52\,V/V$

$A_{v_o} = -31.5 \left(\frac{89.7}{89.76 + 1.141} \right) (22K)$

$= 50.667\,V/V$

$R_{in} = R_1 // R_2 // R_{ib}$

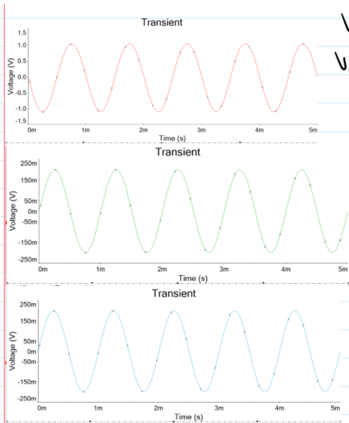
$= R_1 // R_2 // [(\beta+1)(r_e + R_e)]$

$= 91 // 56 // [151 (89.76 + 22)]$

$R_{in} = 34.5955\,K\Omega$

$R_L = R_o = R_c = 22K$

3.



V_o

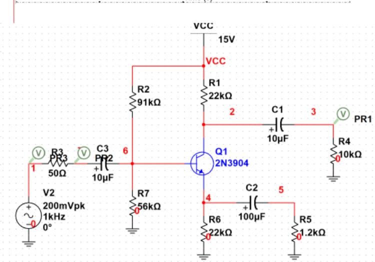
$V_{pp} = 1.0272 - (-1.0967)$

$= 2.1239\,V$

V_i

$V_{pp} = 199.6978 - (-195.1369\,m)$

$= 394.8347\,mV$



$A_v = \frac{V_o}{V_i}$

$= \frac{2.1333\,V}{394.835\,mV}$

$A_v = 5.379\,V$

$\frac{11.52 - 5.379}{5.379} \cdot 100$

$= 114\%$ error

4.

$V_1 = V_t \left(\frac{R_i}{R_{t\,in} + R_i} \right)$

$V_1 (R_{t\,in} + R_i) = V_t R_i$

$V_1 R_{t\,in} + V_1 R_i = V_t R_i$

$V_1 R_{tin} = R_1 (V_t - V_1)$

$R_i = \frac{V_1 R_{tin}}{V_t - V_1}$

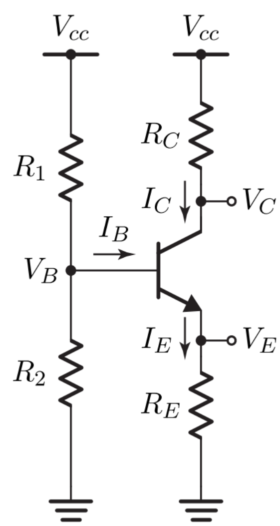
$R_i = R_{tin} \left(\frac{V_1}{V_t - V_1} \right)$

Experiment:

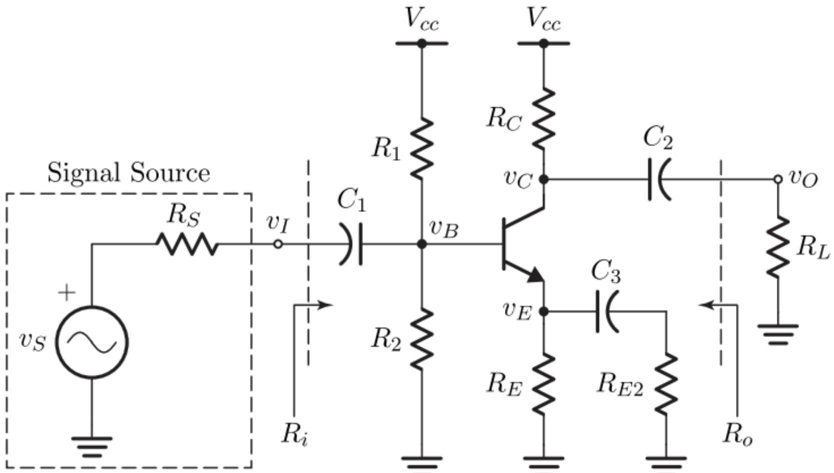
The section values that were used for the circuits were:

Section 4	91	56	22	1.2	22

1. Construct the circuit shown in the diagram below, using a BJT 2N3904 transistor. Ensure that V_{cc} = 15 V, and measure V_B, V_C, and V_E using the multimeter in DC voltage measurement mode. Use the measured voltages and given resistances to calculate I_B, I_C, and I_D.



2. From the current circuit build, create the one shown in the diagram below. C_1 = 10 uF and C_2 = C_3 = 100 uF. Use the channel 1 and 2 probes on the oscilloscope in DC coupled mode to monitor V_i and V_o. Set the signal generator to generate a 1 kHz symmetrical sinusoidal signal with a magnitude equal to the one calculated in the prelab. Use the maximum value that will produce an undistorted, sinusoidal V_o. Measure the V_i and V_o rms values by using the AC voltage measurement mode on the multimeter. Measure the V_i and V_o in dB by using the dB button on the multimeter. Calculate Av and Av(dB) using Av = V_o/V_i, and Av(dB)= $20\log(V_o/V_i)$. Remove R_L and measure V_o, V_i, V_o(dB), V_i(dB) again.



3. Use the multimeter in AC measurement mode to measure Vi. Then, return R_L into the circuit and insert the $R_{i,\ in}$ calculated from the prelab, as displayed in the diagram above, and measure the Vt. Calculate Ri using the following formula:

$$R_i = R_{t,in}\left(\frac{v_i}{v_t - v_i}\right)$$

4. Relace Ri with a wire, and replace R_L with the $R_{t,\ out}$ calculated in the prelab. Record the no load and load V_o (rms) values, and calculate R with the following formula:

$$R_o = R_{t,out}\left(\frac{A_{vo}v_i}{v_o} - 1\right)$$

Results:

$V_B(V)$	$V_C(V)$	$V_E(V)$	$I_B(mA)$	$I_C(mA)$	$I_E(mA)$
5.65	10.077	5.046	0.0621	0.224	0.238

Table E1. Measured terminal voltages and currents of the B]T in the circuit of Figure 1.

$V_i(V)$ rms	$V_o(V)$ rms	$A_v(V/V)$	V_i(dB)	V_o(dB)	A_v(dB)
132.50 mV	0.7103	5.361	-15.34	-0.76	0.0495

Table E2(a). Input and output ac voltages and gain of the CE amplifier, with R, = 10 kg.

$V_i(V)$ rms	$V_o(V)$ rms	$A_v(V/V)$	V_i(dB)	V_o(dB)	A_v(dB)
128.56 mV	2.1742	16.91	-15.60	8.96	-0.5744

Table E2(b). Input and output ac voltages and gain of the CE amplifier, with R,, = co.

$R_{t,in}(k\Omega)$	$V_t(V)$ rms	$V_i(V)$ rms	$R_i(k\Omega)$
2.7	132.18 mV	119.26 mV	24.9

Table E3. Parameters of the CE amplifier for determining its input resistance.

$R_{t,out}(k\Omega)$ (i.e., the load)	$V_o(V)$ rms without load (i.e., $A_{vo}v_i$)	$V_o(V)$ rms with load	$R_o(k\Omega)$
3.9k	2.2611	0.5289	12.46

Table E4. Parameters of the CE amplifier for determining its output resistance.

Conclusion:

C1.

$$e_{\%} = \frac{\text{theoretical value} - \text{measured value}}{\text{measured value}} \times 100$$

Complete Table 8 and comment on the magnitude of, and reasons for, the errors.

	V_B(V)	V_C(V)	V_E(V)
Calculated values (P1)	4.88	10.8	4.191
Measured values (E1)	5.65	10.077	5.046
Percent error, e%	12.23%	7.17%	16.9%

The laboratory experimental error is very low. Despite that being very good, there may have been factors that lead to the discrepancies. For example, outdated equipment could have introduced inaccuracies in the measurements, while human error and component tolerances might have impacted the results as well. Additionally, the circuit's performance could have been influenced by temperature effects on electronic components, as well as the presence of stray capacitance and inductance resulting from the circuit's layout.

C2. Compare the calculated and measured AC parameters of the Common-Emitter amplifier, and calculate the percent errors. Complete Table 9. Comment on the magnitudes of, and reasons for, the errors.

	A_V(V/V)	A_{vo}(V)	R_i(kΩ)	R_o(kΩ)
Calculated values (P1)	14.34	10.32	3.113	3.9
Measured values (E1)	16.91	8.96	24.9	12.46
Percent error, e%	15.20%	15.18%	87.50%	68.70%

There exists a large percentage error for the resistances. This might be due to the fact that the experiment was performed incorrectly, as the R_i and R_o test values were selected to be the same as the ones calculated in the pre-lab, not selected to theoretically give R_i and R_o values of those calculated in the pre-lab.

C3. Based on the measured results, calculate the current gain A_i and power gain A_p of the Common-Emitter amplifier. The current gain is defined as the ratio of the output current, io to the input current i_i (see Figure 3 and Figure 4 to identify those currents). Also, the power gain is defined as the ratio of the power that the amplifier delivers to the load to the power that the amplifier draws from the signal source, i.e., through its input port. Therefore, $A_p = A_v A_i$

$$A_p = A_v A_i$$

$$A_i = \frac{i_o}{i_i}$$

$$i_o = \frac{V_o}{R_L} = \frac{2.1742}{24.91k} \qquad i_i = \frac{V_i}{R_i} = \frac{-15.60}{12.46k}$$

$$i_o = 87.317 \times 10^{-6}\,A \qquad i_i = 1.252 \times 10^{-3}\,A$$

$$A_i = \frac{i_o}{i_i} = \frac{87.317 \times 10^{-6}\,A}{1.252 \times 10^{-3}\,A}$$

$$A_i = 0.069742\ A/A$$

$$A_p = 16.91 \cdot 0.06742$$
$$= 1.17933$$
$$= 1.18$$

C4. The effect of RE2 of the CE amplifier on:

Voltage Gain:

The increase of RE2 leads to a corresponding increase in the voltage gain due to their reciprocal relationship.

Input Resistance:

When RE2 increases, the input resistance decreases.

Output Resistance:

RE2 has no impact on the output resistance since it is not included in the equation.

Magnitude of Vi:

RE2 determines the maximum voltage for Vi. Therefore, if RE2 increases, the input voltage decreases, resulting in a lower Vi.