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Due Date:	

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*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, an "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

Toronto Metropolitan University
Department of Electrical, Computer and Biomedical Engineering

ELE 404: Electronics I
Common-Base (CB) Amplifier

Introduction

In this lab you will test a Common-Base (CB) amplifier, based on the 2N3904 NPN BJT. Like the CE amplifier, the CB amplifier features a large intrinsic gain and a moderate output resistance. However, unlike the CE amplifier, it presents a low input resistance and, therefore, has niche applications. For example, the CB amplifier may be used as the input stage of a high-frequency amplification chain, where a low input resistance is needed for impedance matching. Further, the CB amplifier offers a superior frequency response, as compared with the CE amplifier.

Pre-lab Assignment

P1. Consider the CB amplifier of **Figure 1**, for which $V_{CC} = 15\ V$, $R_S = 50\ \Omega$, and $R_L = 10\ k\Omega$. For the BJT, assume that $\beta = 150$, $V_{BE,on} = 0.7\ V$, and $V_{CE,sat} = 0.3\ V$, and ignore the Early effect. For the other resistances, however, assume the same values as those you used for the Common-Emitter (CE) amplifier lab (disregard the value for R_{E2}, as the resistor does not exist in the CB amplifier of **Figure 1**). Therefore, copy the same quiescent voltage and current values as those you found for the CE amplifier in **Table P1(a)**, or calculate them again if you don't have a copy. Then, manually calculate the no-load voltage gain A_{vo}, voltage gain $A_v = v_o/v_i$, input resistance R_i, and output resistance R_o of the CB amplifier. Complete **Table P1(b)**. Show all the work.

$V_e = V_B - V_{BE(on)}$

$V_B = V_{BE(on)} = 0.7V$

$V_e = 0.7V$

$V_{CC} - I_C R_C - V_E - I_C R_E = 0$

$I_C = \frac{V_{CC} - V_E}{R_C + R_E}$

$I_C = \frac{15V - 0.7V}{4.7k\Omega + 1k\Omega}$

$I_C = \frac{14.3V}{5.7k\Omega}$

$I_C = 2.51mA$

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

$I_B = \frac{2.51mA}{150}$

$I_B = 16.73\mu A$

$I_E = I_C + I_B$

$I_E = 2.51mA + 16.73\mu A$

$I_E = 2.526mA$

$V_C = V_{CC} - I_C R_C$

$V_C = 15V - (2.51mA \times 4.7k\Omega)$

$V_C = 15 - 11.8V$

$V_C = 3.2V$

since $V_B = V_E + V_{BE(on)}$

$V_B = 0.7V + 0.7V$

$V_B = 1.4V$

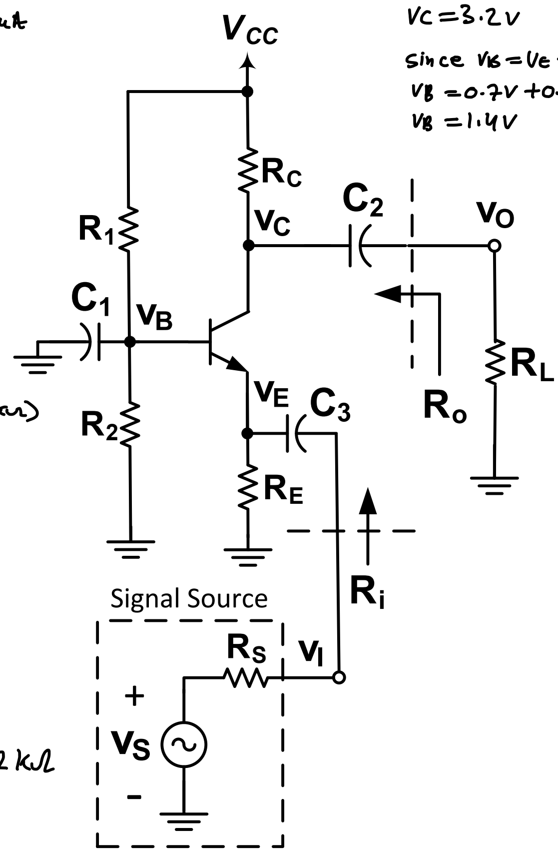


Figure 1. Common-Base (CB) amplifier.

$g_m = \frac{I_C}{V_T}$

$g_m = \frac{2.51mA}{25mV}$

$g_m = 0.1004S$

$A_{vo} = g_m R_C$

$A_{vo} = (0.1004S) \times (4.7k\Omega)$

$A_{vo} = 471.65V/V$

$R_C^{eff} = \frac{R_C R_L}{R_C + R_L}$

$= \frac{4.7k\Omega(10k\Omega)}{4.7k\Omega + 10k\Omega}$

$= \frac{47M\Omega}{14.7k\Omega}$

$= 3.2k\Omega$

$R_i = \frac{1}{g_m}$

$R_i = \frac{1}{0.1004S}$

$R_i = 9.97\Omega$

$R_o = R_C^{eff} = 3.2k\Omega$

$A_v = g_m R_C^{eff}$

$A_v = (0.1004S) \times (3.2k\Omega)$

$= 320.85V/V$

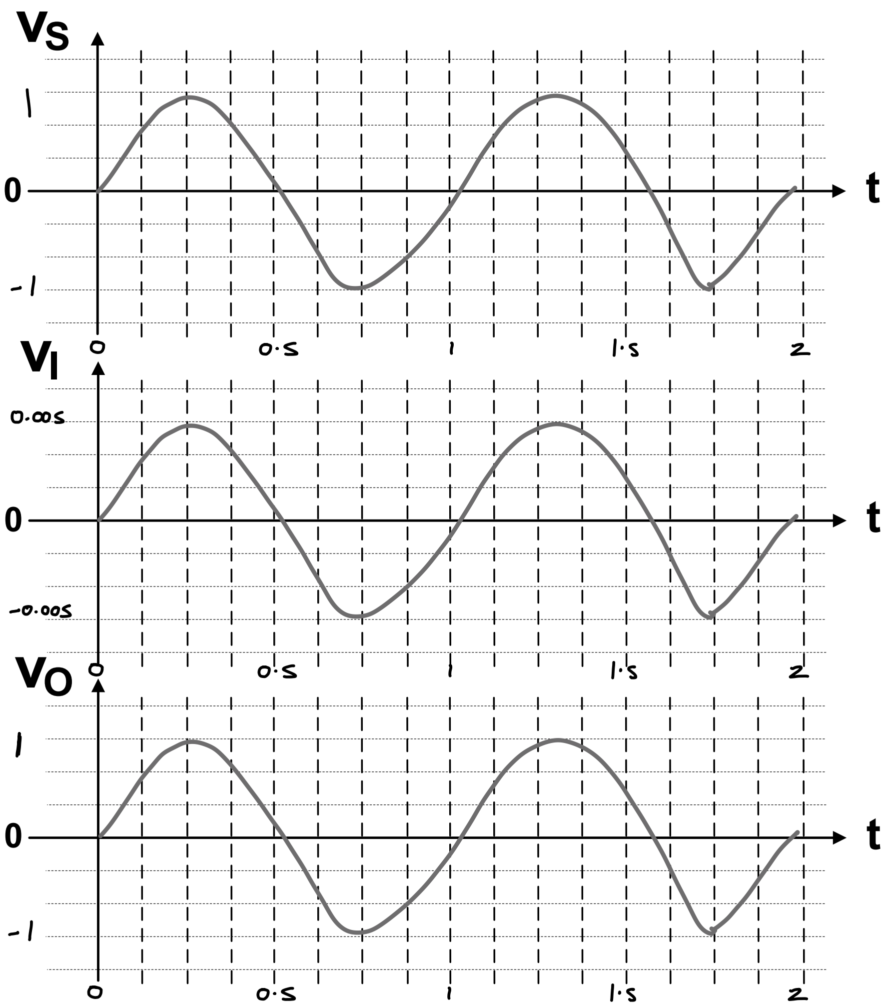
Table P1(a). Quiescent voltages and currents of the CB amplifier.

$V_B[V]$	$V_C[V]$	$V_E[V]$	$I_B[mA]$	$I_C[mA]$	$I_E[mA]$
1.4V	3.2V	0.7V	0.01673mA	2.51mA	2.526mA

Table P1(b). Parameters of the CB amplifier of **Figure 1**.

$A_{vo}[V/V]$	$A_v[V/V]$ for $R_L = 10\ k\Omega$	$R_i[k\Omega]$	$R_o[k\Omega]$
471.65	320.85	0.00997	3.2

P2. Simulate the CB amplifier of **Figure 1**, assuming that the transistor is the 2N3904, $V_{CC} = 15\ V$, $R_S = 50\ \Omega$, $R_L = 10\ k\Omega$, $C_1 = C_2 = 10\ \mu F$, and $C_3 = 100\ \mu F$. Also assume v_S to be a **1-kHz symmetrical sinusoidal voltage**. However, choose the magnitude of v_S in such a way that the waveform of v_O is not clipped and also v_I does not swing by more then $\pm 5\ mV$ (or $10\ mV$, peak-to-peak). Present the waveforms of v_S, v_I, and v_O for three cycles (periods) as **Graph P2**. Make sure that v_I and v_O are in-phase. Otherwise, check your simulation model and parameters. Also, verify that your manual calculation of A_v (reported in **Table P1(b)**) agrees more or less with the gain indicated by the waveforms of **Graph P2.** Otherwise, check your calculations and/or your simulation model.



Graph P2. Source, input, and output voltage waveforms of the CB amplifier of Figure 1, with $R_S = 50\ \Omega$ and $R_L = 10\ k\Omega$.

Experiments and Results

E1. Construct the CB amplifier of **Figure 1**, using the BJT **2N3904** as the transistor; **Figure 2** helps you identify the pins of the transistor. Use the same resistance values as those assumed in **Step P2.** Use 10-μF electrolytic capacitors for C_1 and C_2, and a 100-μF (again, electrolytic) capacitor for C_3 (observe the polarities, as explained in the manual for the CE amplifier lab). Set your bench-top power supply to ensure that the supply voltage is $V_{CC} = 15\ V$, but **do not connect the signal generator** to the input terminal of the amplifier. Then, using your multimeter in the DC voltage measurement mode, measure (the DC values of) voltages v_B, v_C, and v_E, and make sure that they are more or less equal to the values listed in **Table P1(a)**; if not, check the circuit and/or you manual calculations for the quiescent voltages and currents.

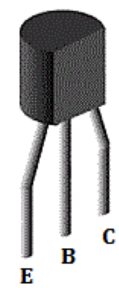


Figure 2. Terminals of the NPN BJT 2N3904.

E2. Connect the signal generator to the amplifier. Set Channel 1 and Channel 2 of your oscilloscope to the DC-coupled mode and use them to monitor v_i and v_o, respectively. Set the signal generator to produce a **1-kHz asymmetrical sinusoidal signal with the smallest magnitude**. Then **gradually increase the magnitude of v_S.** Continue this until either v_O starts to get distorted or clipped, or until v_I is about to exceed 10 mV peak-to-peak (or about 3.5 mV rms). However, if this is not possible even with the smallest amplitude setting of the signal generator, insert a 1-$k\Omega$ resistance (or so!) in series between the signal generator's output and the amplifier's input, to artificially increase R_S (be careful! v_I is always the voltage at the input port of the amplifier, regardless of what is sitting before the amplifier). Capture the waveforms of v_I and v_O for about three cycles and save the captured waveforms as **Graph E2.** If the waveforms are noisy by any chance (for example, due to their small magnitudes), use the oscilloscope's "Acquire" button to capture the "Average" of the waveforms.

Next, set the multimeter to the AC voltage measurement mode and measure the rms values of v_I and v_O. Then press the ***"dB"*** button of the multimeter, to measure v_I and v_O in dB. From the measurements, determine the voltage gain $A_v = v_o/v_i$, in both V/V and dB. Remember that the value of a voltage V in dB is defined as $V\,[dB] = 20\log{(V/V_R)}$, where V_R is a reference voltage (for example, 0.7746 V rms) identified by the datasheet of the meter. The voltage gain in dB is, therefore, simply the output voltage in dB minus the input voltage in dB, i.e., $A_v\,[dB] = 20\log{(V_o/V_i)} = 20\log{(V_o/V_R)} - 20\log{(V_i/V_R)}$.

Record the measured values of v_I and v_O, as well the corresponding voltage gains (in V/V and dB) in **Table E2(a)**.

Table E2(a). Input and output AC voltages and gain of the CB amplifier, with $R_L = 10\ k\Omega$.

$V_i\,[Vrms]$	$V_O[Vrms]$	$A_v[V/V]$	$V_I[dB]$	$V_O[dB]$	$A_v\,[dB]$
1.093	8.2154		−24.650	dBAC 12.860	

Remove the 10-$k\Omega$ load and repeat the AC voltage measurements used for **Table E2(a)**. These measurements will give us the no-load voltage gain, A_{vo}. Complete **Table E2(b)**.

Table E2(b). Input and output AC voltages and gain of the CB amplifier, with $R_L = \infty$.

$V_i\,[Vrms]$	$V_O[Vrms]$	$A_{vo}[V/V]$	$V_I[dB]$	$V_O[dB]$	$A_{vo}\,[dB]$
1.09 mVAC	0.179VAC		−24.66	19.6 dB AC	

E3. Let us now measure the input resistance of the CB amplifier built in **Step E1**. To that end, set the multimeter in the AC voltage measurement mode to measure voltages in terms of their rms values. Then, bring the 10-$k\Omega$ load back into the circuit. Next insert a test resistance, $R_{t,in}$, between the output terminal of the signal generator and the input terminal of the amplifier, as **Figure 3** illustrates. Choose a value for $R_{t,in}$ that is close to the value of R_i you expect the amplifier to have (based on your analysis in **Step P1**). For instance, if R_i to be measured is expected to be about 50 Ω, then $R_{t,in}$ should also be of the same order of magnitude (e.g., from about a few tens to a few hundreds of ohms). Measure voltages v_t and v_i, and based on the measured values calculate R_i. Complete **Table E3.**

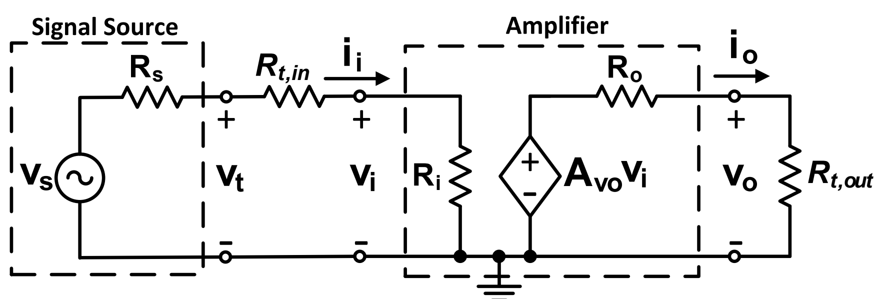


Figure 3. An amplifier energizing a test load, $R_{t,out}$, through a signal source in series with a test resistance, $R_{t,in}$.

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

$R_{t,in}\,[k\Omega]$	$V_t[Vrms]$	$V_i[Vrms]$	$R_i[k\Omega]$

E4. Next, replace the input test resistance by a short link, to bring the amplifier back to the state it had in **Step E2**. Then, replace the 10-$k\Omega$ load resistance with a test resistance, $R_{t,out}$, as shown in **Figure 3**, whose value is of the same order of magnitude as the value you expect for R_O (based on your manual calculations in **Step P2**). Then, record the no-load and loaded rms output voltages of the amplifier. Based on the measured values, calculate R_O and complete **Table E4.**

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

$\boldsymbol{R_{t,out}}$ $[\boldsymbol{k\Omega}]$ **(i.e., the load)**	$\boldsymbol{V_O[Vrms]}$ **without load (i.e.,** $\boldsymbol{A_{vo}v_i}$**)**	$\boldsymbol{V_o[Vrms]}$ **with load**	$\boldsymbol{R_o[k\Omega]}$

Conclusions and Remarks

C1. Compare the calculated and measured AC parameters of the CB amplifier, and calculate the percent errors from:

$$e\% = \frac{calculated\ value - measured\ value}{measured\ value} \times 100$$

Complete **Table C1**. Comment on the magnitudes of errors and provide reasons for discrepancies.

Table C1. Calculated and measured AC parameters for the CB amplifier of **Figure 1**.

	$\boldsymbol{A_v[V/V]}$	$\boldsymbol{A_{vo}[V/V]}$	$\boldsymbol{R_i[k\Omega]}$	$\boldsymbol{R_o[k\Omega]}$
Calculated Values (from Table P1(b))				
Measured Values (from Tables E2, E3, and E4)				
Percent Error, $e\%$				

C2. Based on the measured results, calculate the current gain A_i and power gain A_p of the CB amplifier. The current gain is defined as the ratio of the output current i_o to the input current i_i (see **Figure 3** 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, $A_p = A_v A_i$.

TA Copy of Results

Table E2(a). Input and output AC voltages and gain of the CB amplifier, with $R_L = 10\ k\Omega$.

$V_i\ [Vrms]$	$V_O[Vrms]$	$A_v[V/V]$	$V_I[dB]$	$V_O[dB]$	$A_v\ [dB]$
0.5×10^{-3}	40×10^{-3}	80	-31	0.6	31.6

Table E2(b). Input and output AC voltages and gain of the CB amplifier, with $R_L = \infty$.

$V_i\ [Vrms]$	$V_O[Vrms]$	$A_{vo}[V/V]$	$V_I[dB]$	$V_O[dB]$	$A_{vo}\ [dB]$
0.5×10^{-3}	87×10^{-3}	174	-30	13.4	43.4

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

$R_{t,in}\ [k\Omega]$	$V_t[Vrms]$	$V_i[Vrms]$	$R_i[k\Omega]$
100kΩ	0.325×10^{-3}	0.349×10^{-3}	1.2

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

$R_{t,out}\ [k\Omega]$ (i.e., the load)	$V_O[Vrms]$ without load (i.e., $A_{vo}v_i$)	$V_o[Vrms]$ with load	$R_o[k\Omega]$
100kΩ	0.285×10^{-3}	0.297×10^{-3}	-4.04

	Partner's Name	Set-Up (out of 10)	Data Collection (out of 10)	Participation (out of 5)
1	HamzaMalik	✓	✓	✓
2	Ryan Taing	✓	✓	✓