Ryerson University

Department of Electrical & Computer Engineering

ELE 404

Common-Collector (CC) Amplifier

Introduction

In this lab you will construct a Common-Collector (CC) BJT amplifier and acquaint yourself with its very important property, namely, *buffering.* This lab also provides you with an opportunity to analyze and test a multi-stage amplifier (a two-stage amplifier, to be exact). For this lab, you will need two 2N3904 NPN BJTs.

Pre-lab Assignment

P1. Consider the CE amplifier of **Figure 1**, driving a load R_L. Assume that $R_1 = 12\ k\Omega$, $R_2 = 15\ k\Omega$, $R_C = 2.7\ k\Omega$, $R_E = 6.8\ k\Omega$, $R_{E2} = 220\ \Omega$, $V_{CC} = 15\ V$, $\beta = 150$, $V_{BE,on} = 0.7\ V$, and $V_{CE,sat} = 0.3\ V$. Also assume the capacitors to be short at the operating frequencies of interest. Then, manually calculate the DC (quiescent) currents and voltages of the amplifier, as well as the no-load voltage gain A_{vo}, voltage gain $A_v = v_o/v_i$ (with $R_L = 180\ \Omega$), voltage gain $A_{vs} = v_o/v_s$ (with $R_s = 50\ \Omega$ and $R_L = 180\ \Omega$), and output resistance R_o. Complete **Table P1**. Show all work.

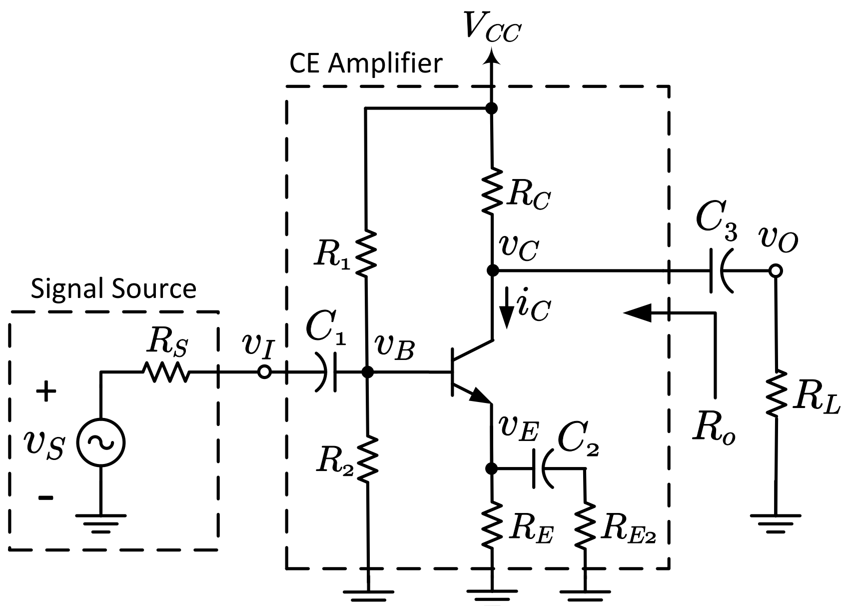


Figure 1. A Common-Emitter (CE) amplifier driving a load directly.

Table P1. Quiescent and AC parameters of the CE amplifier of **Figure 1**.

$V_C[V]$	$V_E[V]$	$I_C[mA]$	$A_{vo}[V/V]$	$A_v[V/V]$ $R_L = 180\ \Omega$	$A_{vs}[V/V]$ $R_L = 180\ \Omega$ $R_s = 50\ \Omega$	$R_o[k\Omega]$

P2. Now consider the two-stage amplifier of **Figure 2**, in which the **CE amplifier** of **Figure 1** is not directly connected to the load, but it **drives the load through a Common-Collector (CC) amplifier**. Thus, **the CC amplifier acts as a buffer** between the CE amplifier and the load. That is, it makes the load appear much larger to the CE amplifier, to not bring down the output voltage of the CE amplifier, while its own voltage gain is close to (albeit smaller than) unity. Then, repeat the analysis of **Step P1** for the amplifier chain of **Figure 2**. Assume the same parameters as those you assumed in **Step P1**, with the addition that $R_{E3} = 1.2\ k\Omega$. Complete **Table P2**. Show all the work.

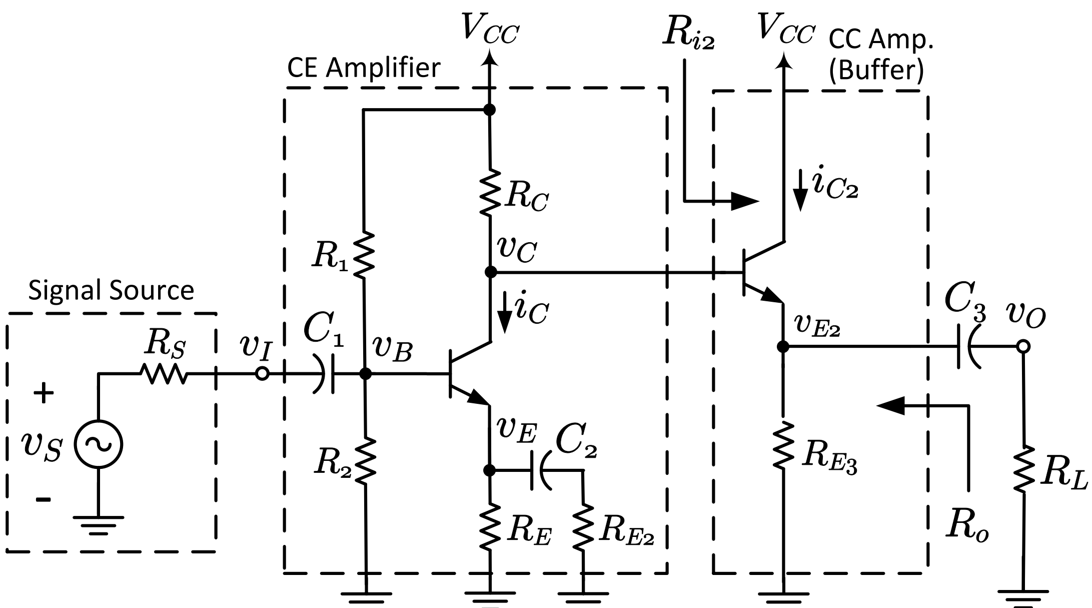
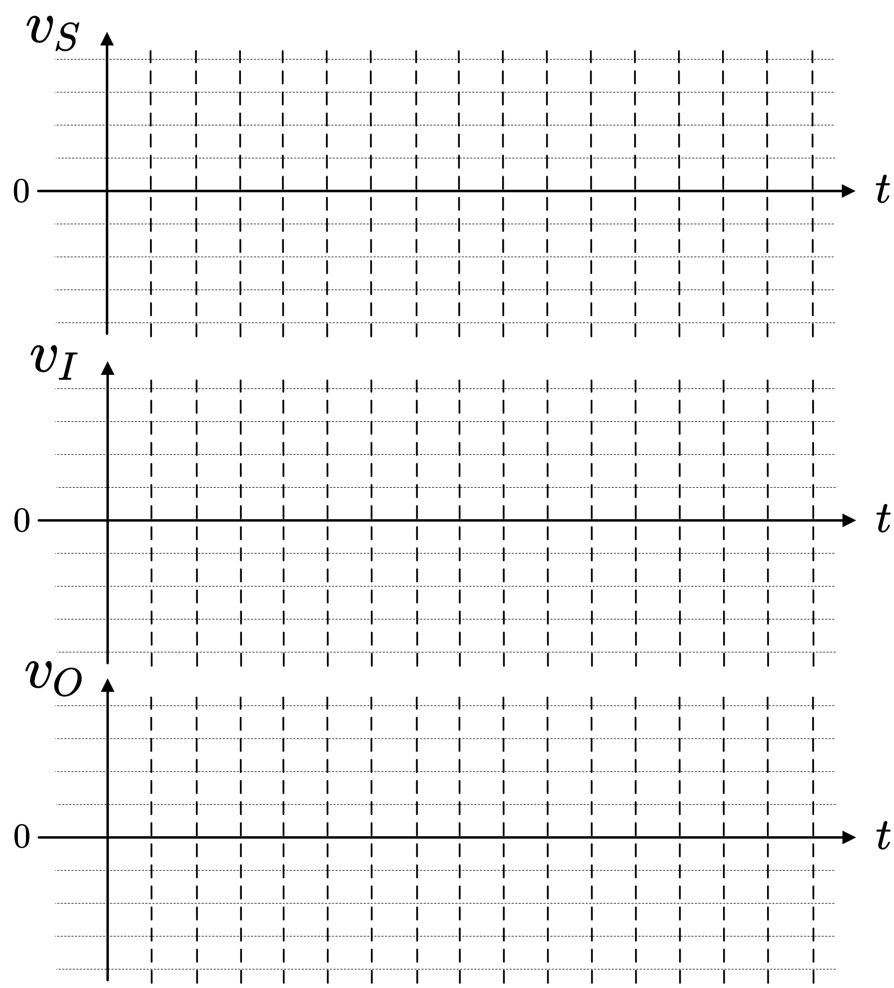


Figure 2. Common-Emitter (CE) amplifier of Figure 1 driving a buffered load.

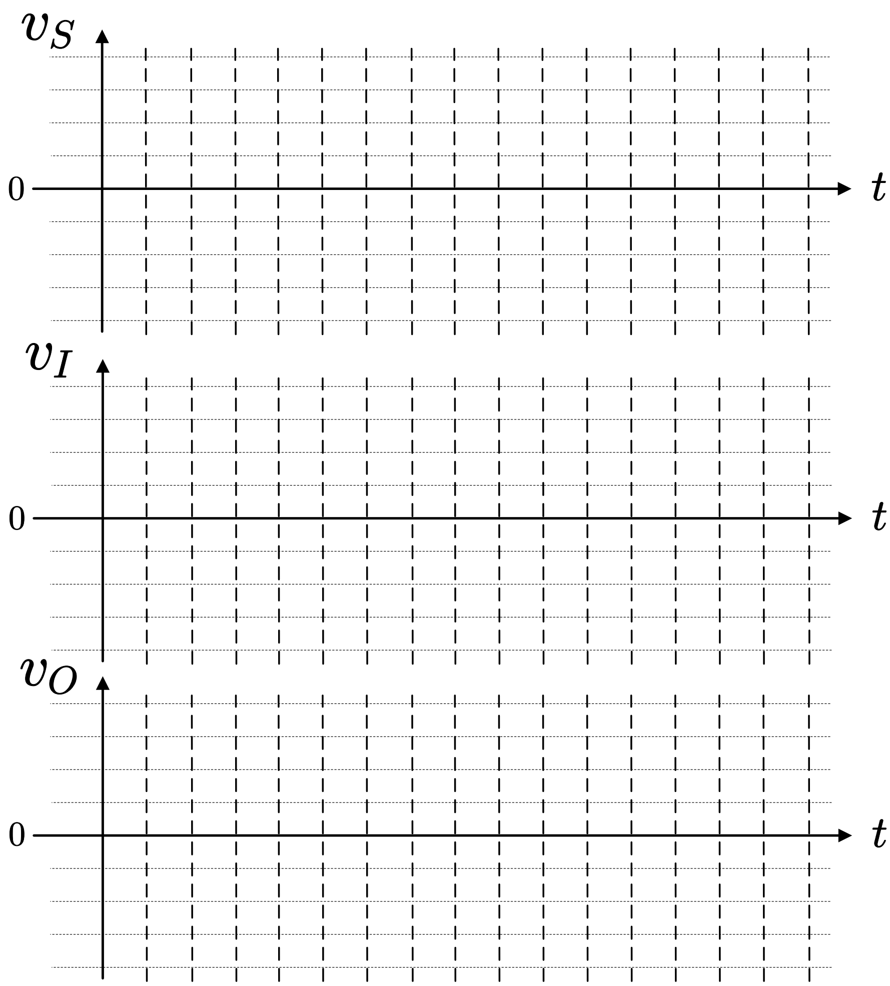
Table P2. Quiescent and AC parameters of the two-stage amplifier of **Figure 2**.

$V_C[V]$	$V_E[V]$	$I_C[mA]$	$V_{E2}[V]$	$I_{C2}[V]$	$A_{vo}[V/V]$	$A_v[V/V]$ $R_L = 180\ \Omega$	$A_{vs}[V/V]$ $R_L = 180\ \Omega$ $R_s = 50\ \Omega$	$R_o[k\Omega]$

P3. Simulate the CE-CC two-stage amplifier of **Figure 2**, assuming the 2N3904 as the transistors, $V_{CC} = 15\ V$, $R_S = 50\ \Omega$, $C_1 = 10\ \mu F$, and $C_2 = C_3 = 100\ \mu F$. Also, assume v_S to be a **1-kHz symmetrical sinusoidal voltage**. However, choose its magnitude in such a way that, with no load (for the purpose of simulation, use $R_L = 100\ k\Omega$ as an infinite load resistance), v_O has a peak-to-peak swing of 2.0 volts. Then, present the waveforms of v_S, v_I, and v_O, for three cycles, for $R_L = 100\ k\Omega$, as **Graph P3(a)**. Next, repeat the simulations but with $R_L = 180\ \Omega$, and present the waveforms as **Graph P3(b)**. In both simulations, make sure that v_I and v_O are in-phase (in terms of their zero- crossings). Otherwise, check your simulation model and parameters. Also, verify that your manual calculations of the gains (reported in **Table P2**) agree well with the gains indicated by the simulated waveforms. Otherwise, check your calculations and/or your simulation model.



Graph P3(a). Source, input, and output voltage waveforms of the amplifier of Figure 2, with $R_S = 50\ \Omega$ and $R_L = 100\ k\Omega$.



Graph P3(b). Source, input, and output voltage waveforms of the amplifier of Figure 2, with $R_S = 50\ \Omega$ and $R_L = 180\ \Omega$.

Experiments and Results

E1. Construct the circuit of **Figure 3**, which is the circuit of **Figure 2** but divided into three sub-circuits, namely, the CE amplifier, the CC amplifier, and the load. Thus, it can be configured to either represent the CE amplifier of **Figure 1** or the two-stage amplifier of **Figure 2**.

Use the 2N3904 as the transistors (**Figure 4** helps you identify the pins of the transistor). Also, use the same resistances as those assumed in **Step P3** ($\boldsymbol{R_L = 180\ \Omega}$). Note that the capacitors are electrolytic and, therefore, need their polarities respected.

Set your bench-top power supply to ensure that the supply voltage is $V_{CC} = 15\ V$. However, do not interconnect the signal generator just yet. Then, **set the jumpers** as per **Table E1**, use your multimeter in the DC voltage measurement mode, and measure and record the node voltages. Based on the resistances and measured voltages, calculate the device currents. Complete **Table E1**.

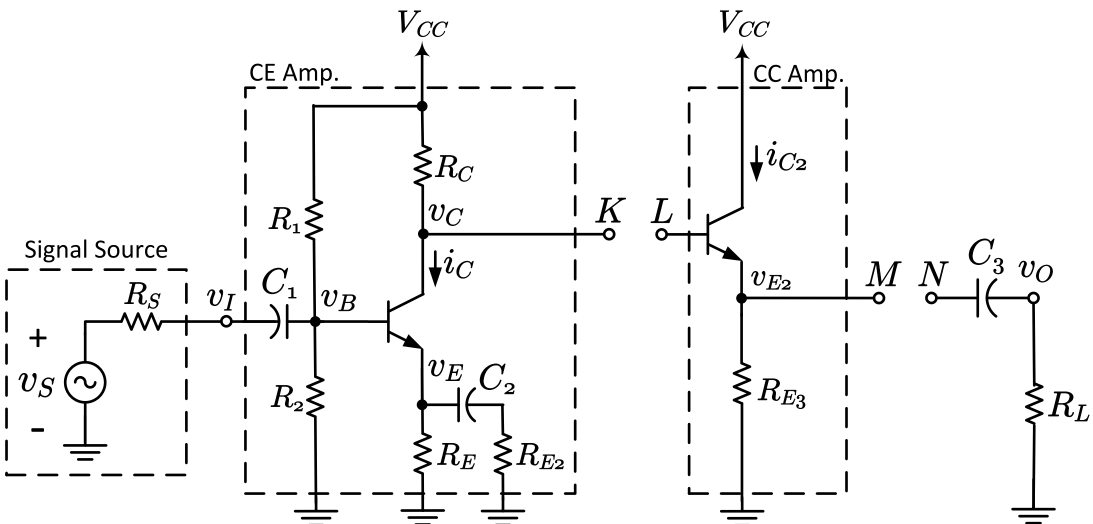


Figure 3. A circuit that can be configured to represent the CE amplifier of Figure 1 or the two-stage amplifier of Figure 2.

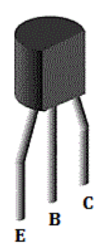


Figure 4. Terminals of the NPN BJT 2N3904.

Table E1. Quiescent parameters of CE amp. of Figure 1 and two-stage amp. of **Figure 2**.

Amplifier	Jumpers	$V_C\ [V]$	$V_E[V]$	$I_C[mA]$	$V_{E2}[V]$	$I_{C2}[mA]$
CE (Figure 1)	**None**				--	--
Two-Stage (Figure 2)	**K-L**					

E2. Now, **remove both jumpers.** Then connect the signal generator, and measure v_C by your multimeter in the AC voltage measurement mode. **Set the signal generator such that the meter reads about 0.71 V (rms) for v_C.** This corresponds to a peak-to-peak swing of 2 V, which you must confirm by the oscilloscope. The oscilloscope must also **confirm that v_C is sinusoidal and distortion-free**. Once the above are all confirmed, **measure and record the rms value of v_I.** For all subsequent steps, you must make sure that v_I is set to this value. Note that these aforementioned measurements correspond to no-load operation of the CE amplifier of **Figure 1**. Calculate A_{vo} based in them. Record all values in **Table E2**.

Table E2(a). No-load AC voltages and gain of the CE amplifier of **Figure 1**.

Amplifier	**Jumpers**	v_I $[Vrms]$	$v_C[Vrms]$	$v_{E2}[Vrms]$	$v_O[Vrms]$	$A_{vo}[V/V]$
CE	**None**			--	--	

Next, establish the **K-N** jumper, and repeat the measurements (***Note:*** $R_L = 180\ \Omega$). Make sure that v_I is unchanged with respect to its value in **Table E2(a)**. Also, make sure that the voltages are sinusoidal, regardless of their magnitudes. The measured values correspond to loaded operation of the CE amplifier of **Figure 1**. Complete **Table E2(b).**

Table E2(b). Loaded AC voltages and gain of the CE amplifier of **Figure 1**.

Amplifier	**Jumpers**	v_I $[Vrms]$	$v_C[Vrms]$	$v_{E2}[Vrms]$	$v_O[Vrms]$	$A_v[V/V]$
CE	**K-N**			--		

E3. Now, **remove K-N** jumper, but **establish K-L** jumper. Repeat the AC voltage measurements, and complete **Table E3(a)**. This configuration corresponds to no-load operation of the two-stage amplifier of **Figure 2**. Again, make sure that v_I is unchanged with respect to its value in **Table E2(a)**, and that the voltages are sinusoidal.

Table E3(a). No-load AC voltages and gain of the two-stage amplifier of **Figure 2**.

Amplifier	Jumpers	$v_I\ [Vrms]$	$v_C[Vrms]$	$v_{E2}[Vrms]$	$v_O[Vrms]$	$A_{vo}[V/V]$
Two-stage	**K-L**				--	

Next, also establish the **M-N** jumper, repeat the measurements (***Note:*** $\mathrm{R_L} = 180\ \Omega$), and complete **Table E3(b)**. Once again, make sure that v_I is unchanged with respect to its value in **Table E2(a)** and that the voltages are sinusoidal**.** Further, capture the waveforms of v_I and v_O for three cycles, and save the captured waveforms as **Graph E3**. Note that this experiment corresponds to loaded operation of the two-stage amplifier of **Figure 2**.

Table E3(b). Loaded AC voltages and gain of the two-stage amplifier of **Figure 2**.

Amplifier	Jumpers	$v_I\ [Vrms]$	$v_C[Vrms]$	$v_{E2}[Vrms]$	$v_O[Vrms]$	$A_v[V/V]$
Two-stage	**K-L, M-N**					

Conclusions and Remarks

C1. Compare the calculated and measured quiescent voltages for the CE amplifier of **Figure 1**, and complete **Table C1(a).** Calculate the percent error from the following expression:

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

Repeat the comparison for the two-stage amplifier of **Figure 2**, and complete **Table C1(b)**. Comment on the magnitude of errors, and provide reasons for discrepancies, if any.

Table C1(a). Calculated and measured (DC) voltages of the CE amplifier of **Figure 1**.

	$\boldsymbol{V_C[V]}$	$\boldsymbol{V_E[V]}$	$\boldsymbol{V_{E2}[V]}$
Calculated values (from Table P1)			---
Measured values (first column, Table E1)			----
Percent error, $e\%$			----

Table C1(b). Calculated and measured (DC) voltages of the two-stage amplifier of **Figure 2**.

	$\boldsymbol{V_C[V]}$	$\boldsymbol{V_E[V]}$	$\boldsymbol{V_{E2}[V]}$
Calculated values (from Table P2)			
Measured values (second column, Table E1)			
Percent error, $e\%$			

C2. Compare the calculated and measured voltage gains of the CE amplifier of **Figure 1**, and calculate the percent errors. Complete **Table C2(a)**. Repeat the analysis for the two-stage amplifier of **Figure 2**, and complete **Table C2(b).** Comment on the magnitudes of errors and provide reasons for discrepancies.

Table C2(a). Calculated and measured voltage gains of the CE amplifier of **Figure 1**.

	$\boldsymbol{A_v[V/V]}$	$\boldsymbol{A_{vo}[V/V]}$
Calculated Values (from Table P1)		
Measured Values (from Table E2(a) and Table E2(b))		
Percent Error, $e\%$		

Table C2(b). Calculated and measured voltage gains of the two-stage amplifier of **Figure 2**.

	$\boldsymbol{A_v[V/V]}$	$\boldsymbol{A_{vo}[V/V]}$
Calculated Values (from Table P2)		
Measured Values (from Table E3(a) and Table E3(b))		
Percent Error, $e\%$		

C3. Based on the measured and calculated results, explain how the CC stage (that is the buffer) in the two-stage amplifier has enabled us to drive a heavy load ($R_L = 180\ \Omega$) while maintaining a good overall voltage gain. Give your viewpoint another angle by calculating the resistance that the CC stage presents to the output of the CE stage in the two-stage amplifier of **Figure 2** (that is R_{i2}) both with and without the load, and comparing it with R_L (that is, the load that the CE amplifier of **Figure 1** sees).

TA Copy of Results

Table E1. Quiescent parameters of CE amp. of Figure 1 and two-stage amp. of **Figure 2**.

Amplifier	Jumpers	$V_C\ [V]$	$V_E[V]$	$I_C[mA]$	$V_{E2}[V]$	$I_{C2}[mA]$
CE (Figure 1)	**None**				--	--
Two-Stage (Figure 2)	**K-L**					

Table E2(a). No-load AC voltages and gain of the CE amplifier of **Figure 1**.

Amplifier	Jumpers	$v_I\ [Vrms]$	$v_C[Vrms]$	$v_{E2}[Vrms]$	$v_O[Vrms]$	$A_{vo}[V/V]$
CE	**None**			--	--	

Table E2(b). Loaded AC voltages and gain of the CE amplifier of **Figure 1**.

Amplifier	Jumpers	$v_I\ [Vrms]$	$v_C[Vrms]$	$v_{E2}[Vrms]$	$v_O[Vrms]$	$A_v[V/V]$
CE	**K-N**			--		

Table E3(a). No-load AC voltages and gain of the two-stage amplifier of **Figure 2**.

Amplifier	Jumpers	$v_I\ [Vrms]$	$v_C[Vrms]$	$v_{E2}[Vrms]$	$v_O[Vrms]$	$A_{vo}[V/V]$
Two-stage	**K-L**				--	

Table E3(b). Loaded AC voltages and gain of the two-stage amplifier of **Figure 2**.

Amplifier	Jumpers	$v_I\ [Vrms]$	$v_C[Vrms]$	$v_{E2}[Vrms]$	$v_O[Vrms]$	$A_v[V/V]$
Two-stage	**K-L, M-N**					

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	Partner's Name	Pre-Lab (out of 20)	Set-Up (out of 10)	Data Collection (out of 10)	Participation (out of 5)
1					
2					

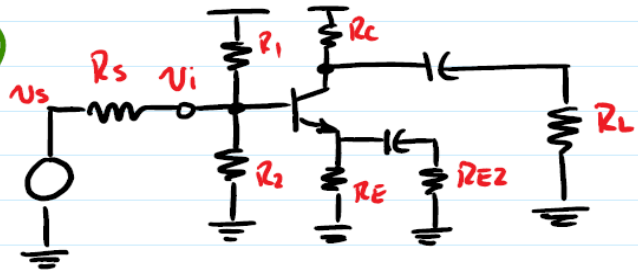
ELE404 – Common Emitter Amplifier Lab

Prelab Assignment

P1.

Common Collector Amplifier - Prelab

P1



Given:
- $R_1 = 12K\Omega$
- $R_2 = 15K\Omega$
- $R_C = 2.7K\Omega$
- $R_E = 6.8K\Omega$
- $R_{E2} = 0.22K\Omega$
- $V_{CC} = 15V$
- $\beta = 150$

→ Find DC currents & voltages, A_{vo}, A_v, A_{vs}.

Solution:

→ $V_B = V_{CC} \cdot \frac{R_2}{R_1 + R_2} = 8.33V$

→ $V_E = V_B - 0.7 = 7.63V$

→ $I_E = \frac{V_E}{R_E} = 1.1225mA$

→ $I_C = \alpha I_E = 1.11511mA$

→ $I_C + I_B = I_E$ → $I_B = 7.39\mu A$

→ $V_C = V_{CC} - I_C R_C = 11.989V$

$\rightarrow g_m = \frac{I_C}{V_T} = 44.6044 \frac{mA}{V}$

$\rightarrow R_e = R_E // R_{E2} = 0.213\ k\Omega$

$\rightarrow A_{vo} = \frac{-g_m R_C}{1 + g_m R_e} = -11.47 \frac{V}{V}$

$\rightarrow A_v = A_{vo} \cdot \frac{R_L}{R_o + R_L} = 0.716875 \frac{V}{V}$

$\rightarrow A_v = \frac{v_o}{v_i} \qquad A_{vs} = \frac{v_o}{v_s}$

from 2 port representation:

$v_i = v_s \cdot \frac{R_i}{R_s + R_i}$

In a CE Amp, $R_i = r_\pi + (\beta+1)R_e$

$\hookrightarrow r_\pi = (\beta+1) r_e = (\beta+1)\left(\frac{1}{g_m}\right)$

$= 3.38\ k\Omega$

$R_i = 35.543\ k\Omega$

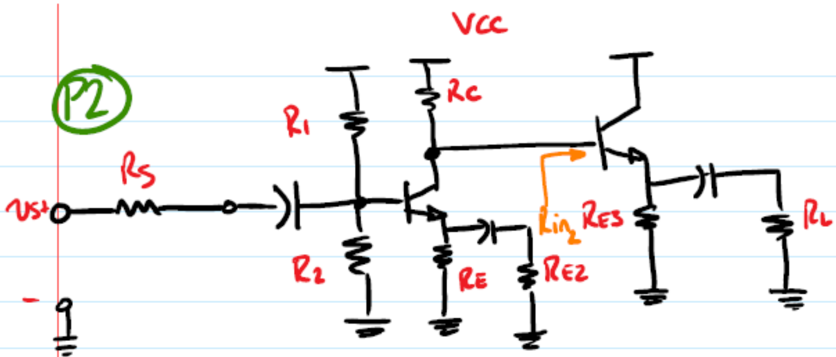
$\rightarrow v_i = \frac{v_o}{A_v} \rightarrow \frac{v_o}{A_v} = v_s \cdot \frac{R_i}{R_s + R_i}$

$A_{vs} = \frac{v_o}{v_s} = \frac{R_i}{R_s + R_i} A_v = 0.7158 \frac{V}{V}$

Table P1 - Quiescent and ac parameters of the CE amplifier of Figure 1

V_C (V)	V_E (V)	I_C (mA)	A_{vo} (V/V)	A_v (V/V) $R_L = 180\Omega$	A_{vs} (V/V) $R_L = 180\Omega$ $R_S = 50\Omega$	R_o (kΩ)
11.989	7.633	1.115	-11.464	-0.7165	-0.7158	2.7

P2.



Recalculate all parameters from P1:

SOLUTION:

→ $V_B = V_{CC}\dfrac{R_2}{R_1+R_2} = 8.33V$ → $g_{m1} = \dfrac{I_C}{V_T} = 44.604\,\frac{mA}{V}$

→ $V_E = V_B - 0.7 = 7.633V$

→ $I_E = \dfrac{V_E}{R_E} = 1.1225\,mA$

→ $I_C = \alpha I_E = 1.11511\,mA$

→ $I_B = 7.39\,\mu A$

→ $V_C = V_{CC} - I_C R_C = 11.989V$

→ $V_{E2} = V_C - 0.7 = 11.289V$

→ $I_{E2} = \dfrac{V_{E2}}{R_{E3}} = 9.41\,mA$

→ $I_{C2} = \alpha I_{E2} = 9.345\,mA$

$\rightarrow A_{vo\,CE} = \dfrac{-g_m R_C // R_{in2}}{1+g_m R_E}$

$\hookrightarrow R_{in_2} = R_{in}$ of $CC = (B+1)(r_{e_2} + R_{E3})$

$$g_{m2} = \frac{I_C}{V_T} = \frac{9.345}{0.025} = 373.8 \frac{mA}{V}$$

$$r_{e_2} = \frac{1}{g_{m_2}} = 2.67\,\Omega$$

So: $R_{in_2} = 151(2.67 + 1.2K) = 585K\Omega$

$\rightarrow$ Now $A_{vo} = A_{vo\,CE} \cdot A_{vo\,CC}$. But $A_{vo\,CC} = 1$ since there is no load so:

$$\boxed{A_{vo} = \frac{-g_{m_1} R_C // R_{in2}}{1 + g_{m1}(R_E // R_{E2})} \cdot (1) = -\frac{44.6(2.7//585)}{1 + 44.6(6.8//0.22)} = -11.41 \frac{V}{V}}$$

$\rightarrow$ In the loaded scenario, the CC gain & input resistance will change as they both depend on R_L. So, the overall gain will also change. We can start by recalculating the CC input resistance:

$$R_{in2} = (B+1)(r_{e_2} + R_L) = 27.58\,K\Omega$$

$$A_{vCC} = \frac{R_L}{R_L + r_e} = 0.985 \frac{V}{V}$$

$$A_{vCE} = \frac{-g_{m_1} R_C // R_{in2}}{1 + g_{m1}(R_E // R_{E2})} = \frac{109.65}{10.50} = 10.44 \frac{V}{V}$$

→ Therefore the overall gain A_v is:

$$\boxed{A_v = A_{vCE} \cdot A_{vCC} = 10.44 \cdot 0.985 = 10.29\,\frac{V}{V}}$$

→ Similar to P1, A_{vs} can be found using the 2 port model:

$$A_{vs} = A_v \cdot \frac{R_{in\text{-}CE}}{R_{in\text{-}CE} + R_S}$$

$$R_{in\text{-}CE} = (B+1)(r_{e1} + R_E) = 151\left(\frac{1}{44.6} + 6.8 \| 0.22\right)$$

$$= 35.6\,k\Omega$$

$$\boxed{A_{vs} = 10.29 \cdot \frac{35.6}{35.6 + 0.05} = 10.28\,\frac{V}{V}}$$

Table P2 - Quiescent and ac parameters of the two-stage amplifier of Figure 2

V_C (V)	V_E (V)	I_C(mA)	V_{E2} (V)	I_{C2}(mA)	A_{vo} (V/V)	A_v (V/V) $R_L = 180\Omega$	A_{vs} (V/V) $R_L = 180\Omega$ $R_S = 50\Omega$	R_o (kΩ)
11.989	7.633	1.115	11.289	9.345	-11.41	-10.29	-10.28	0.00267

P3.

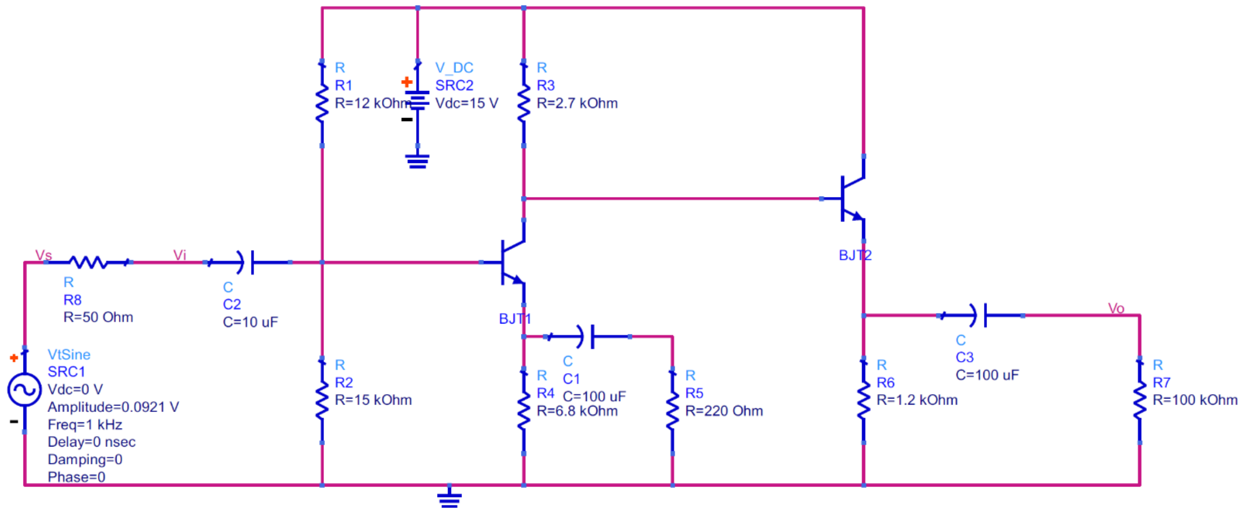
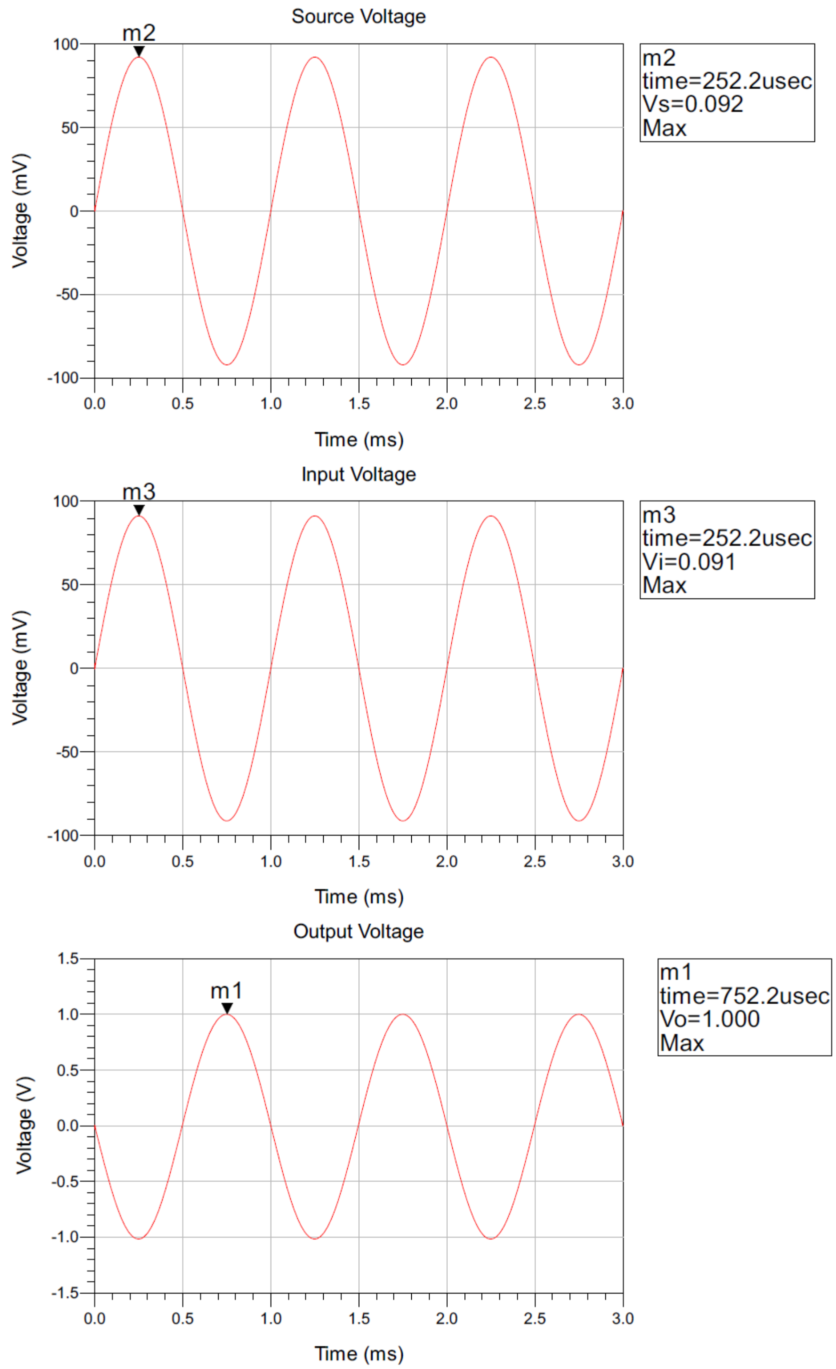
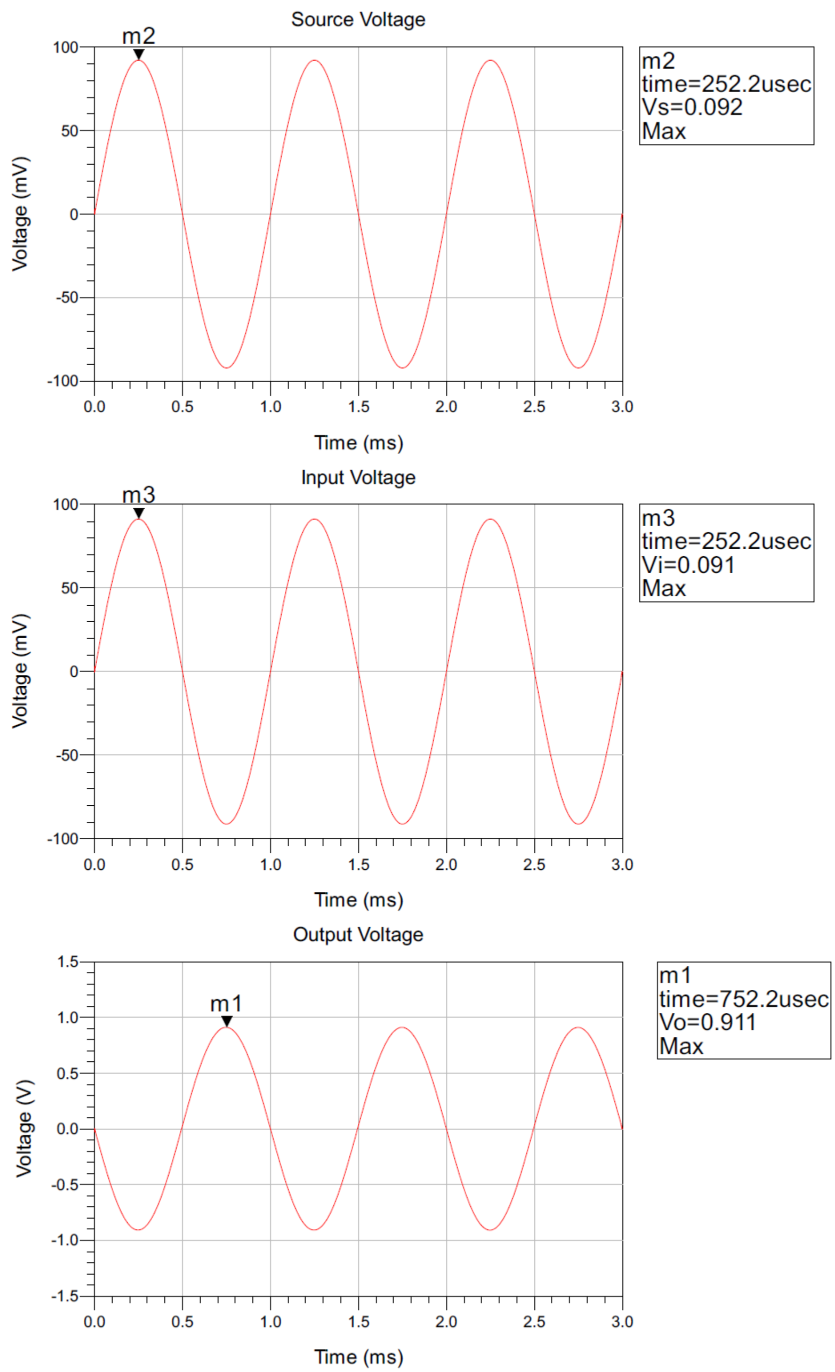


Figure 1 - ADS simulation schematic for Figure 2 assuming a load resistance of 100kΩ



Graph P3(a) - Source, input, and output voltage waveforms of the amplifier of Figure 2, with R_s=50Ω and R_L = 100kΩ



Graph P3(b) - Source, input, and output voltage waveforms of the amplifier of Figure 2, with R_s=50Ω and R_L=180Ω

Experiment & Results

E1.

Table E1 – Quiescent parameters of the CE amplifier of Figure 1 and two-stage amplifier of Figure 2.

Amplfiier	Jumpers	V_C (V)	V_E (V)	I_C (mA)	V_{E2} (V)	I_{C2} (mA)
CE (Figure 1)	None	11.969	7.615	1.123	--	--
Two-Stage (Figure 2)	K-L	11.806	7.641	7.641	11.075	9.168

E2.

Table E2(a) – No-load ac voltages and gain of the CE amplifier of Figure 1

Amplfiier	Jumpers	v_i (mV rms)	v_c (V rms)	v_{E2} (V rms)	v_o (V rms)	A_{vo} (V/V)
CE	None	61.09	0.6907	--	--	11.306

Table E2(b) – Loaded ac voltages and gain of the CE amplifier of Figure 1

Amplfiier	Jumpers	v_i (mV rms)	v_c (mV rms)	v_{E2} (V rms)	v_o (mV rms)	A_{vo} (V/V)
CE	K-N	61.07	43.50	--	43.42	0.711

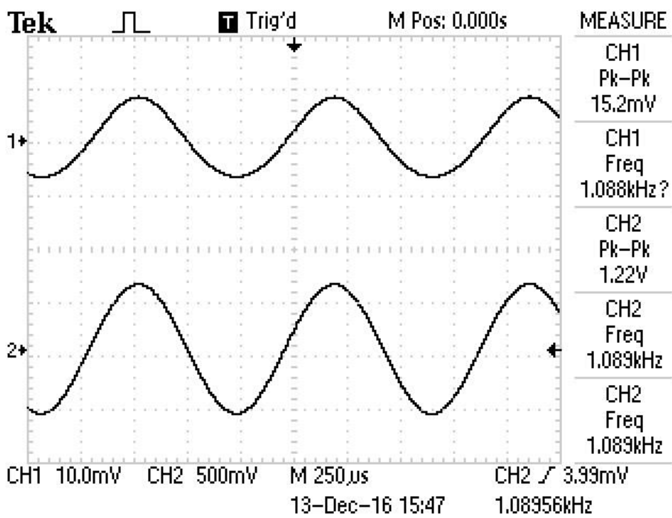
E3.

Table E3(a) - No-load ac voltages and gain of the two-stage amplifier of Figure 2

Amplfiier	Jumpers	v_i (mV rms)	v_c (mV rms)	v_{E2} (V rms)	v_o (V rms)	A_{vo} (V/V)
Two-Stage	K-L	60.98	0.7023	0.6793	--	11.140

Table E4(b) – Loaded ac voltages and gain of the two-stage amplifier of Figure 2

Amplfiier	Jumpers	v_i (mV rms)	v_c (mV rms)	v_{E2} (V rms)	v_o (V rms)	A_{vo} (V/V)
Two-Stage	K-L, M-N	60.98	0.6304	0.6160	0.6044	9.911



Graph E3 - v_i and v_o corresponding to part E3 of the experiment

<u>Conclusions</u>

C1.

Table C1(a) - Calculated and measured (dc) voltages of the CE amplifier of Figure 1.

	V_C (V)	V_E (V)	V_{E2} (V)
Calculated (Table P1)	11.989	7.633	---
Measured (Table E1)	11.969	7.615	---
Percent Error (%)	0.167	0.236	---

Table C1(b) - Calculated and measured dc voltages of the two-stage amplifier of Figure 2.

	V_C (V)	V_E (V)	V_{E2} (V)
Calculated (Table P2)	11.989	7.633	11.289
Measured (Table E1)	11.806	7.641	11.075
Percent Error (%)	1.55	0.105	1.932

The results from Table C1(a) and Table C1(b) are all within a reasonable percent error.

C2.

Table C2(a) - Calculated and measured voltage gains of the CE amplifier of Figure 1

	A_v (V/V)	A_{vo} (V/V)
Calculated Values (Table P1)	-0.7165	-11.464
Measured Values (Table E2(a) & Table E2(b))	-0.711	-11.306
Percent Error (%)	0.774	1.397

Table C2(b) - Calculated and measured voltage gains of the two-stage amplifier of Figure 2

	A_v (V/V)	A_{vo} (V/V)
Calculated Values (Table P2)	-10.156	-11.464
Measured Values (Table E3(a) & Table E3(b))	-9.9114	-11.140
Percent Error (%)	2.468	2.908

C3.

The purpose of the CC stage is to provide a large input resistance to the CE amplifier while providing a small output resistance to the load. As mismatches in resistance (or impedance in general) result in unnecessary power loss, it is generally good practice to ensure that the resistance looking into the input of an amplifier is large, while the resistance looking into the output of the amplifier is small. In the case when the input resistance is large, there will be a minimal voltage drop across the input of the amplifier (since the source resistance is typically very small). At the same time, if the output resistance is small (close to the order of the load resistance) then the same logic applies and there will not be a large voltage drop across the output resistance of the amplifier. Therefore, the majority of the voltage will be provided to the load.

In regards to the CC amplifier, it is known that the input resistance is defined as:

$$R_i = (\beta + 1)(r_e + R_L)$$

which means that the input resistance of the CC stage depends on the load. First, we'll consider the input resistance of the CC stage without the load resistance R_L so:

$$R_{i2\ no-load} = (\beta + 1)(r_e)$$

$$R_{i2\ no-load} = (151)\left(\frac{1}{g_m}\right) = 151 \times \frac{V_T}{I_{C2}} = 403.17\Omega$$

So clearly when the CC stage is unloaded, the input resistance is quite small which is highly undesirable. However, if we consider the 180Ω load when calculating the input resistance:

$$R_{i2\ loaded} = (\beta + 1)(r_e + R_L)$$

$$R_{i2\ loaded} = (151)\left(\frac{V_T}{I_{C2}} + 180\Omega\right)$$

$$R_{i2\ loaded} = 27.5\ \mathrm{k}\Omega$$

Thus, the loaded CC stage provides a large enough input resistance as seen by the CE amplifier to ensure that the incoming signal is not lost across the input terminals. The loaded CC stage provides a much larger resistance to the CE stage and therefore the no-load gain of the CE stage is not significantly reduced by the load.