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California State University of Northridge
Department of Electrical & Computer Engineering

Experiment 6
Design of Common Collector Amplifiers

ECE 340L
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Introduction:

The purpose of this experiment is to implement and verify the design of a common collector amplifier. The design was completed by making a few assumptions, which are the following.

$$Z_i \geq 5 \text{ K } \Omega$$

$$Z_o = 50 \text{ } \Omega$$

$$Av \geq 0.95$$

$$R_L = 5\text{K}\Omega$$

$$V_o \geq 2V_{p-p}$$

$$V_{cc} \leq 20\text{V}$$

This design is used to verify theoretical equations developed by analyzing the circuit such as input and output impedance and the current and voltage gain. This lab also covers pspice of each circuit to double verify the design.

Equipment:

Type	Model
Oscilloscope	Agilent Technologies DSO1002A
Digital Multimeter	Tektronix CDM250
Function Generator	Agilent 33220A
Power supply	Hewlett Packard E3630A
Curve Tracer	Tektronix 370A

Parts used:

QTY	Component	Value	Type
1	Resistor	3.3 k Ω	Carbon +/- 5%
1	Resistor	220 k Ω	Carbon +/- 5%
3	Resistor	33 k Ω	Carbon +/- 5%
1	Resistor	1 k Ω	Carbon +/- 5%
1	Capacitor	10 μF	Polypropylene film +/- 5%
1	Transistor	Q2N2222A	Silicon

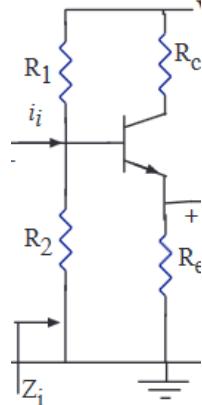
Software:

Pspice
Microsoft Word
Microsoft Excel

Procedure & Results:

The circuit in Figure 1 was built to test the DC biasing of the Common collector. The following resistance values were used. V_B , V_C , V_{BE} , V_{CE} , and I_C were measured and displayed in Table 1.

Figure 1.



$$R_1 = 286k \Omega$$

$$R_2 = 34k \Omega$$

$$R_C = 0$$

$$R_e = 3.3 k \Omega$$

$$V_{CC} = 16 V$$

Table 1.

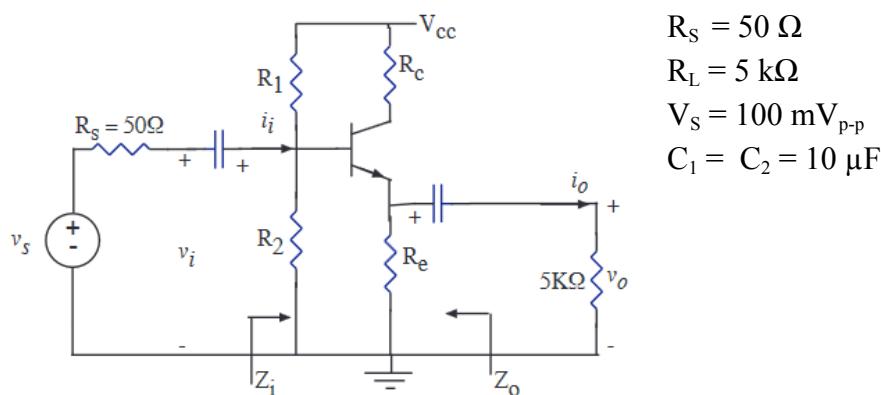
	V_{be}	V_{ce}	V_e	V_b	I_c
calc	0.7 v	15 v	1 v	1.7 v	0.5 mA
meas	0.60 v	14.95 v	1.02 v	1.62 v	.18 mA

The Q-point was found to be Q: 14.95v, 0.18mA

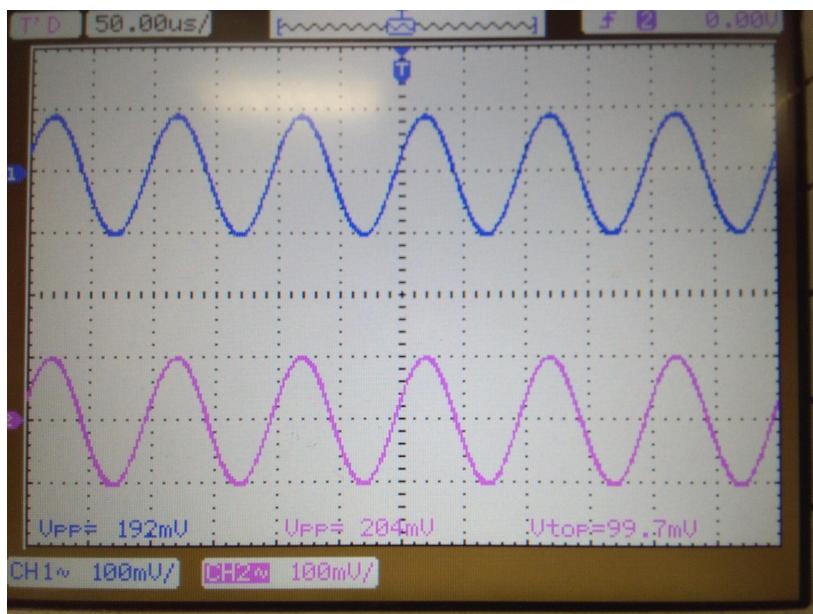
In the table, the calculated value and the measured value of I_c are significantly different. This is because the current is also determined by the load resistance which was used to design the circuit but not included in this biasing.

The circuit in Figure 2 was built using the previous values of R_1 , R_2 , and R_e . Coupling capacitors and a load resistance of values $10\mu F$ and $5k\Omega$ were added respectively. An input wave of $100mV_{pp}$ was added with an internal resistance of 50Ω .

Figure 2.



The following Graph 1 was the result.

Graph 1.

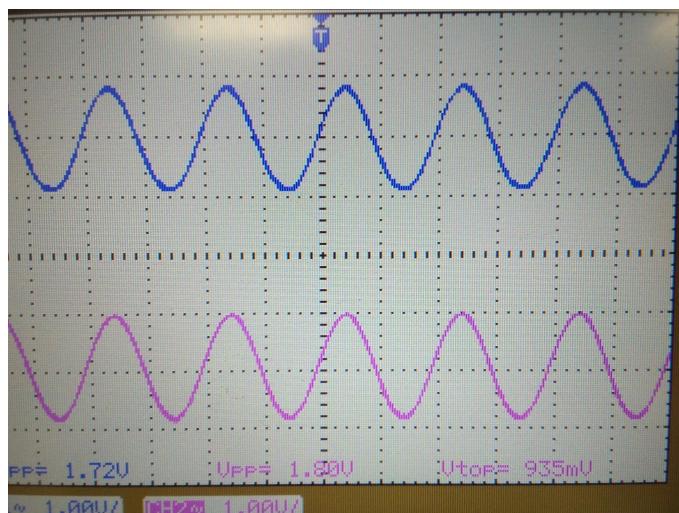
$$A_v = \frac{192\text{mV}}{204\text{mV}} = 0.941$$

In the pre-lab a value of $A_v = 1$ was calculated. The measured values are expected to be slightly less than 1.

The input signal of the circuit was increased until the oscilloscope showed distortion. Graph 2 shows the results before and after the distortion occurred.

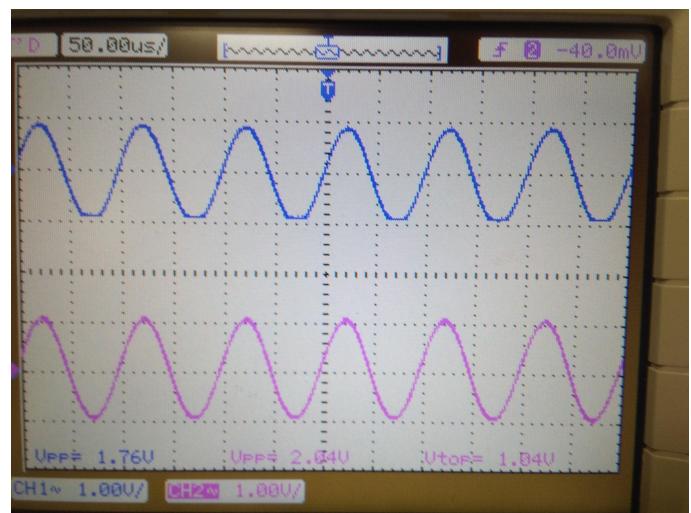
Graph 2.

Before distortion



$$V_{\text{OUT}} = 1.72 \text{ V}_{\text{P-P}} \quad V_{\text{IN}} = 1.80 \text{ V}_{\text{P-P}}$$

After distortion



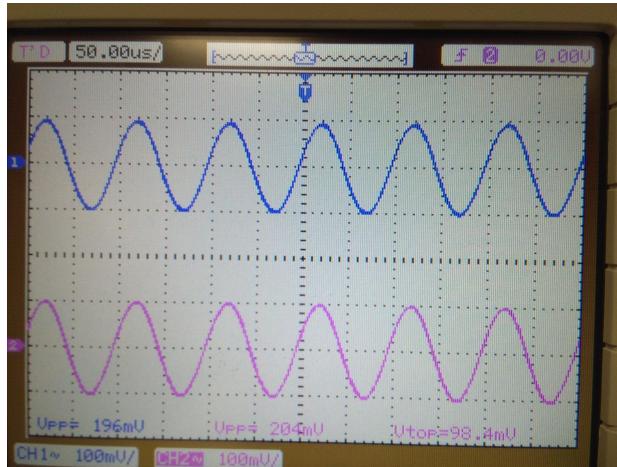
$$V_{\text{OUT}} = 1.72 \text{ V}_{\text{P-P}} \quad V_{\text{IN}} = 2.04 \text{ V}_{\text{P-P}}$$

The distortion was verified to occur at around $2V_{P-P}$ input.

The Input impedance Z_i was found by removing the Load resistance and inputting values of R_s until the Output voltage of the circuit dropped to half. Graph 3 shows the initial output voltage and the halved voltage. Table 2 shows a gradual decrease of Output Voltage as values of R_s increase.

Graph 3.

Initial Output: $V_{OUT} = 196 \text{ mV}_{P-P}$



Half Output: $V_{OUT} = 96 \text{ mV}_{P-P}$



Table 2.

R_s	V_{out}
$5.1 \text{ k}\Omega$	168 mV
$10 \text{ k}\Omega$	140 mV
$20 \text{ k}\Omega$	110 mV
$22 \text{ k}\Omega$	106 mV
$24 \text{ k}\Omega$	100 mV
$27.1 \text{ k}\Omega$	96 mV

The input impedance Z_i was found to be $27.1 \text{ k}\Omega$.

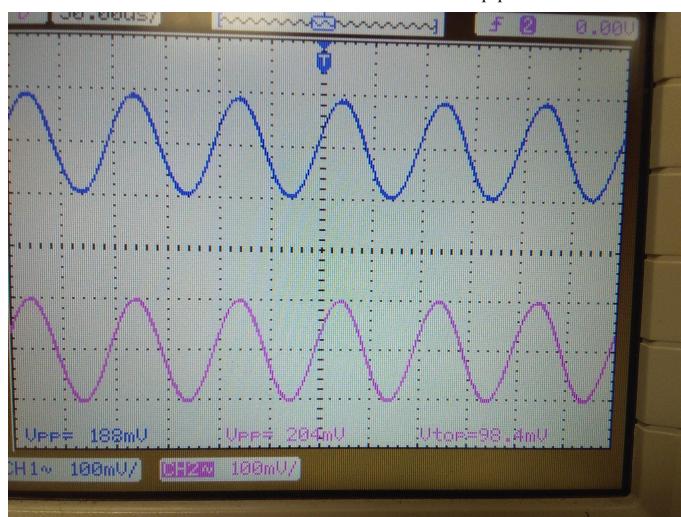
This fits the design of assumption that $Z_i \geq 5 \text{ K } \Omega$

Next, the output impedance was found by removing R_s and inputting values of R_L until the Output voltage was half the initial value. Graph 4 and Table 3 show these results.

A value of $R_L = 1000 \Omega$ was used at the start.

Graph 4.

Initial output : $V_{OUT} = 188 \text{ mV}_{P-P}$



Half Output: $V_{OUT} = 92 \text{ mV}_{P-P}$

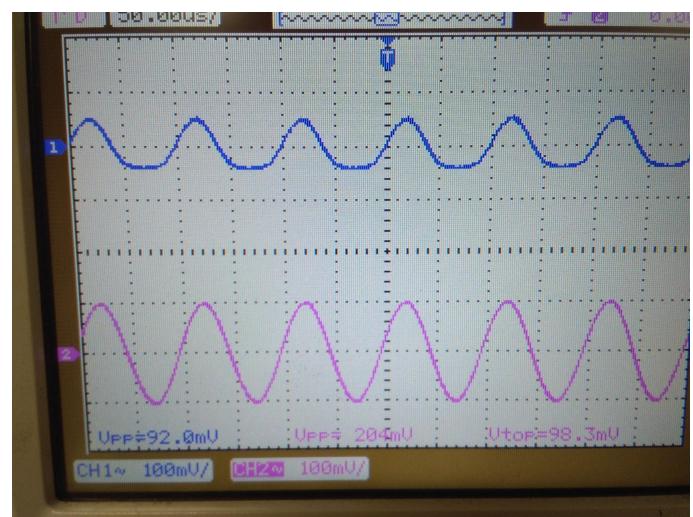


Table 3.

R_s	V_out
1 kΩ	184 mV
470 Ω	176 mV
150 Ω	152 mV
68 Ω	112 mV
51 Ω	100 mV
50 Ω	92 mV

The current and voltage gain was calculated by the following.

$$I_o = \frac{V_o}{Z_o} = \frac{192 \text{ mV}}{50 \Omega} = 3.92 \text{ mA}$$

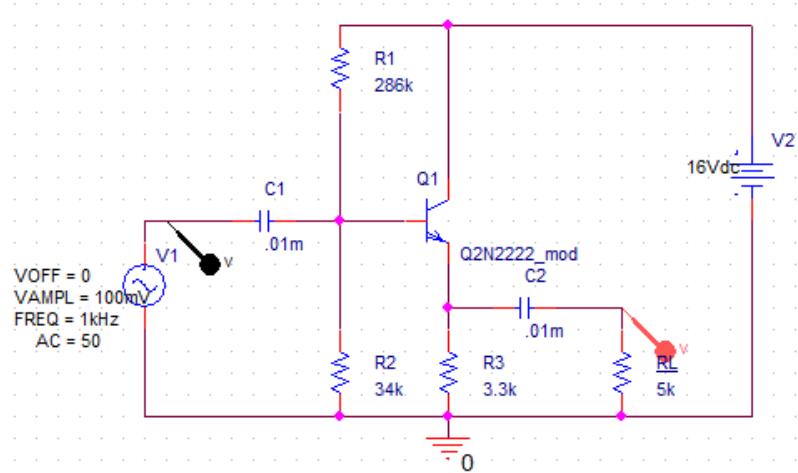
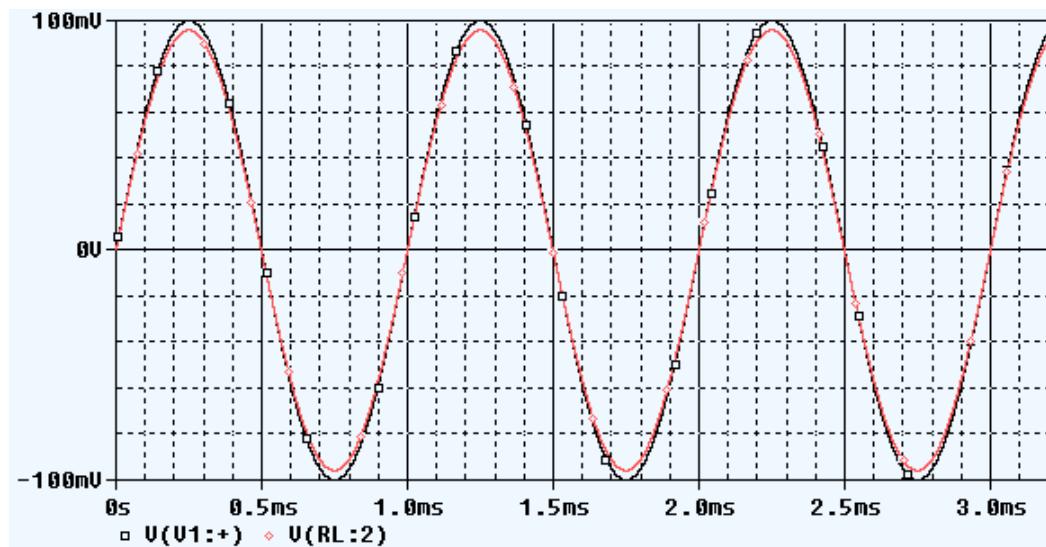
$$I_i = \frac{V_i}{Z_i} = \frac{204 \text{ mV}}{27.1 \text{ kΩ}} = 7.53 \mu\text{A}$$

$$A_i = \frac{I_o}{I_i} = 510.1$$

$$A_v = \frac{V_o}{V_i} = \frac{192 \text{ mV}}{204 \text{ mV}} = 0.94$$

Pspice

A Transient analysis of Figure 2 was done in PSpice. Schematic 1 shows the design in PSpice. Plot 1 shows the results.

Schematic 1Plot 1

Using the cursor, the plot shows a 200 mV_{P-P} input and a 190.6 mV_{P-P} output. The gain is calculated by the following.

$$A_v = \frac{V_o}{V_i} = \frac{190.6 \text{ mV}}{200 \text{ mV}} = 0.953$$

This value is significantly close to the measured value of 0.941 such that the difference in value can be explained by the differences in the nominal resistances.

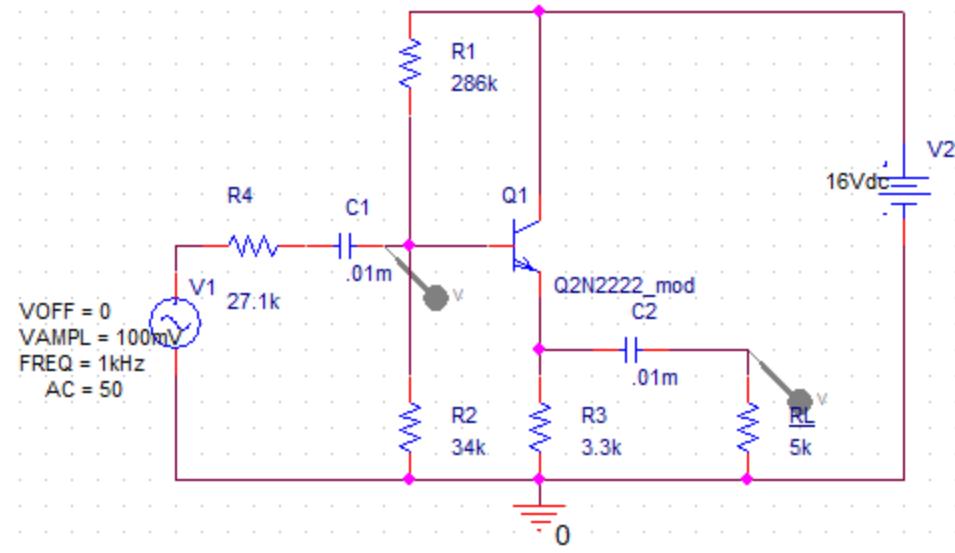
Table 4 shows the Operating information of the BJT.

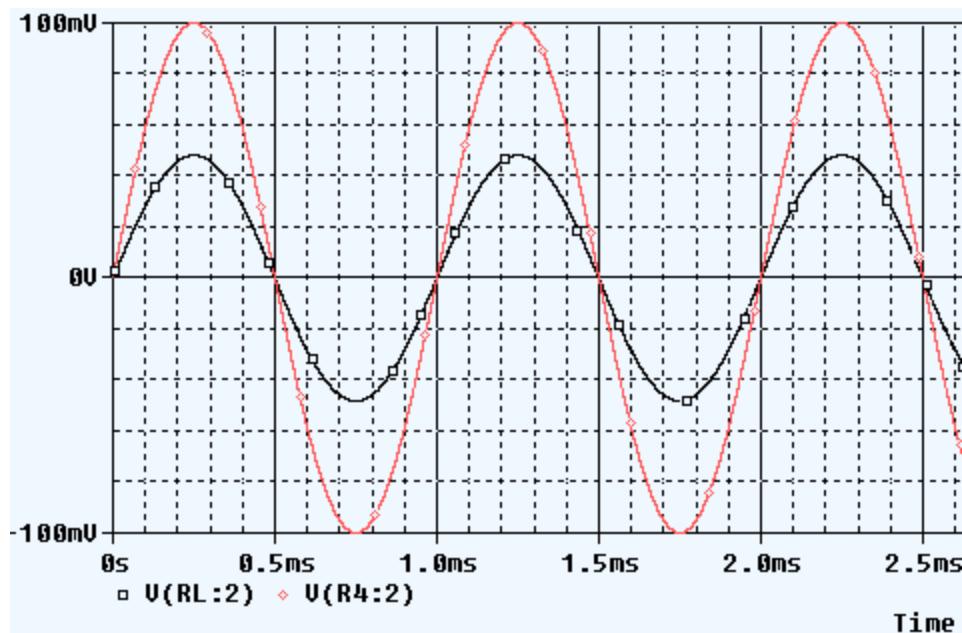
Table 4. Operating information

NAME	Q_Q1
MODEL	Q2N2222
IB	2.52E-06
IC	3.04E-04
VBE	6.10E-01
VBC	-1.44E+01
VCE	1.50E+01
BETADC	1.21E+02
GM	1.18E-02
RPI	1.13E+04
RX	1.00E+01
RO	2.90E+05
CBE	4.02E-11
CBC	2.62E-12
CJS	0.00E+00
BETAAC	1.33E+02
CBX/CBX2	0.00E+00
FT/FT2	4.37E+07

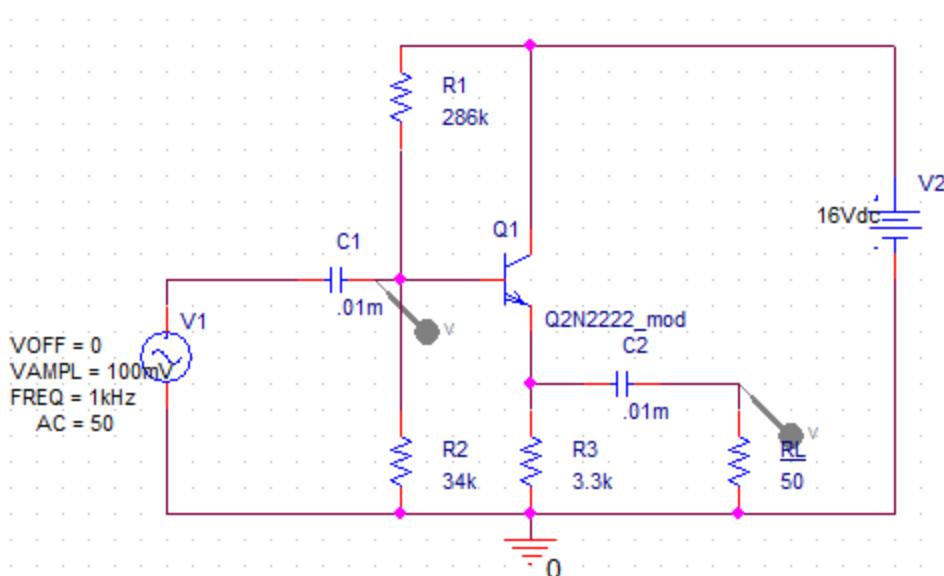
Looking closely at the table, the Q point is seen to be Q: 15.0, 0.3 mA. The voltage from collector to emitter is practically the same as the measured value of 14.95; however, the collector current was off from our measured value of 0.18 mA.

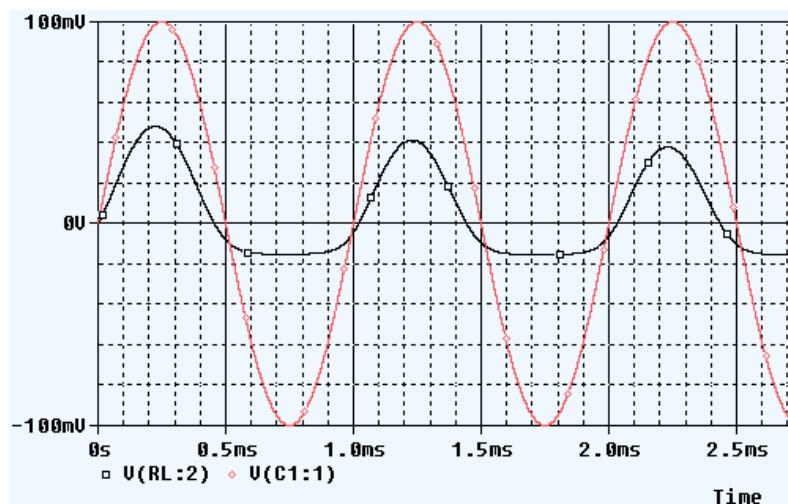
Next, the method to find input impedance was simulated in Pspice. Schematic 2 shows the change by adding a source resistance.

Schematic 2

Plot 2

Next, the output impedance was found in Pspice by changing the values of the load resistance. Schematic 3 shows the design in Pspice and Plot 3 shows the result.
Schematic 3.

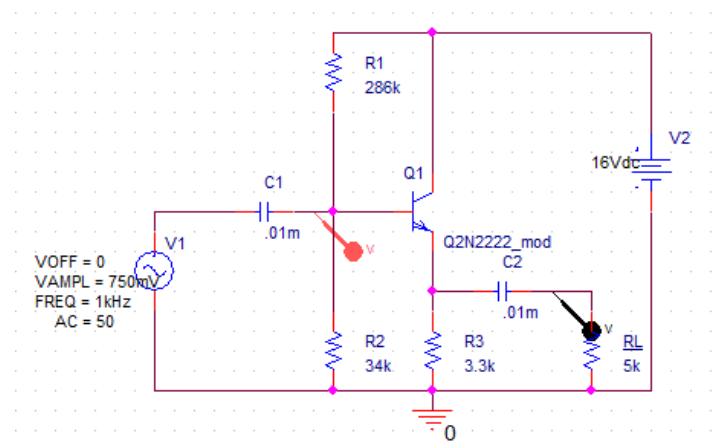
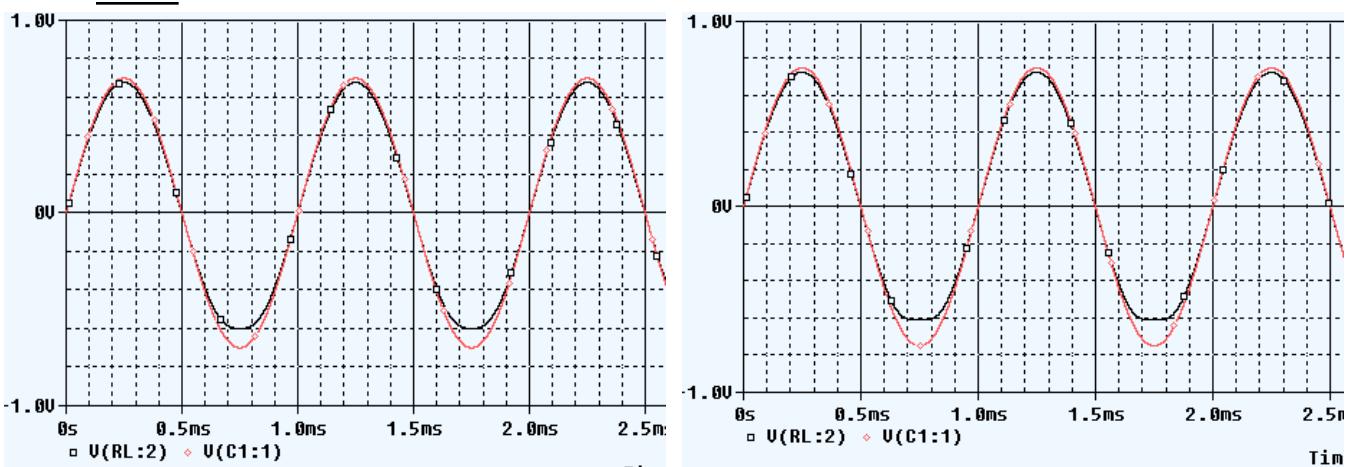


Plot 3.

At 50Ω load resistance, the output voltage shows about $\frac{1}{2}$ the input voltage. It also shows some distortion on the negative values of V_{OUT} .

Lastly, the maximum swing was tested by increasing the value of the input voltage.

Schematic 4 shows the design and Plot 4 shows the change as it occurred.

Schematic 4.Plot 4.

The distortion occurs closer to $1.6 \text{ V}_{\text{P-P}}$. This value is smaller than our measured value where distortion occurred around $2\text{V}_{\text{P-P}}$.

Conclusion

Overall, the experiment was a success in the design of a common collector amplifier. The calculated gain of 1 is close enough to the measured gain of 0.943. The amplifier also met the specifications of input impedance and output impedance. The only issue was that the Q-point of the design and the current through the collector was not exactly the same as calculated.