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Experiment # 3

Common Collector Configuration

Objectives:

- Demonstrate the operation and characteristics of the small signal CE amplifier.
- Determine the maximum output available from a basic common-emitter amplifier.
- Calculate voltage gain, input, and output resistance experimentally.

Apparatus:

Transistor - 2N3904, Capacitors, Resistors, DMM, CRO, Function Generator, Jumpers, Connecting wires, bread board.

Theory:

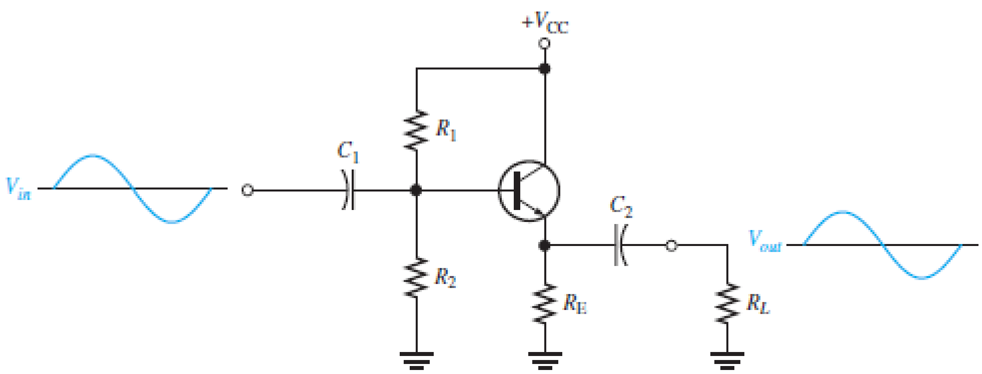
In a common-collector (CC) amplifier which is also known as emitter follower, the input signal is applied between the base and emitter and output signal is developed between the collector and ground. The transistor's *collector* is common to both the input and output circuits, hence the term common collector. The input and out signal gives no phase shift and also the output voltage is almost equal i.e. a bit less than the input voltage and hence its power gain is almost equal to its current gain.

The collector is directly connected to the dc power supply instead of connecting to ground like other cases because during a.c analysis, it is automatically grounded as the dc source becomes short. The main advantage is that the input impedance of a Common–Collector Amplifier is generally much higher than for other bipolar transistor circuits.

To amplify ac signal, the base-collector junction must be forward biased and the base-collector junction must be reverse-biased. The bias establishes and maintains the proper dc operating conditions for the transistor. After analyzing the dc conditions, the ac parameters for the amplifier can be evaluated.

Figure 1, below shows the transistor configured as a common collector amplifier. In this diagram, V_S is the a.c. signal source, and R_L is the load. V_{CC} is a power supply, which provides the transistor with the necessary power to amplify the a.c. signal. Resistors R_1 and R_2 are used to establish the correct voltage at the base of the transistor.

The capacitors C_1 and C_2 serve to isolate the signal source and load from the voltage source V_{CE}. (The capacitors are called "blocking capacitors" or "coupling capacitors", since they block the d.c. voltage but act like a short to the a.c. signal.)



General Procedure:

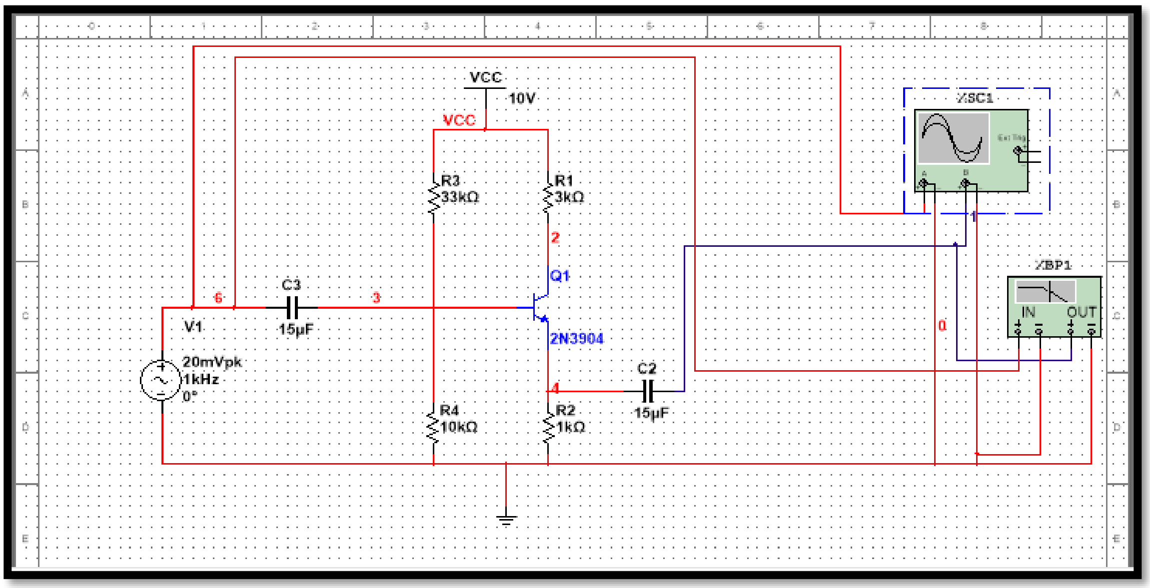
- Apply a sine wave and measure the output voltage using the double beam oscilloscope.
- Display both input and output signals on the oscilloscope and observe the phase shift. Measure the output voltage and compute the voltage gain. (Avoid using Auto set of the oscilloscope; adjust manually, if the display is distorted due to the use of the 20dB attenuator).
- You must observe that the output signal level (V_{out}) is almost equal to the input signal level (Vs). In addition, V_{out} is non-inverted or in phase with respect to the input. Those points are two major characteristics of a common collector amplifier.
- Remove the load resistance and calculate the voltage gain.

Design:

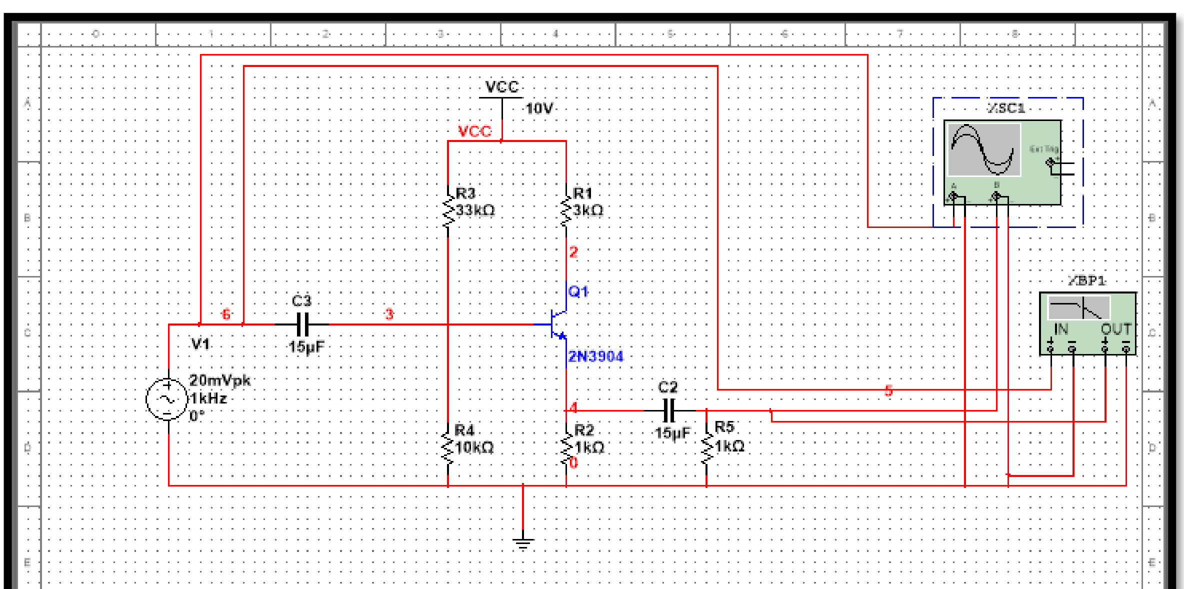
Design a small signal common collector amplifier and find out its voltage gain both with including and excluding load resistance (Refer to figure 6.27 Floyd book).

Circuit:

- **No Resistance at Load:**



- **Resistance at Load:**



Calculations:

- **For No load Resistance:**

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For No Resistance at Load

$R_E = 1k\Omega$

$R_{in} \cong \beta_{ac} R_E \boxed{= 175k\Omega}$

The total input resistance is

$R_{in(total)} = R_1 \| R_2 \| R_{in}$

$$R_{in(total)} = \frac{(33k)(10k)(175k)}{(33+10+175)k}$$

$$R_{in(total)} = \frac{57750}{218}$$

$$\boxed{R_{in(tot)} = 264.9k\Omega}$$

* The voltage gain $A_v \approx 1$. So, using r_e' you can determine a more precise value of A_v.

$$V_E = \left(\frac{R_2}{R_1+R_2}\right) V_{CC} - V_{BE}$$

$$= \left(\frac{10}{33+10}\right) 10 - 0.7$$

$$\boxed{V_E = 1.63V}$$

$$I_E = \frac{V_E}{R_E} = \frac{1.63V}{1k\Omega}$$

$$\boxed{I_E = 1.63mA}$$

$$re' \cong \frac{13.2mV}{I_E} = 8.1\Omega$$

$$A_V = \frac{R_E}{re' + R_E} = \frac{1k}{8.1\Omega + 1k}$$

$$\longrightarrow \boxed{A_V = 0.909}$$

Now,

$$I_e = \frac{V_e}{R_e} = \frac{A_V V_b}{R_e}$$

$$I_e = \frac{(0.909)(20mV)}{1k\Omega}$$

$$\boxed{I_e = 18.18mA}$$

$$I_{in} = \frac{V_{in}}{R_{in(1d)}} = \frac{20mV}{264.9k\Omega}$$

$$\boxed{I_{in} = 7.57 \times 10^{-2} A}$$

$$A_i = \frac{I_e}{I_{in}} \boxed{= 24.1}$$

The power Gain is

$$A_p = A_v A_i \quad (A_v \cong 1)$$

$$A_p \cong A_i$$

$$\boxed{A_p = 24.1}$$

- **For Resistance at Load:**

For Resistance at Load

$$R_e = R_E \| R_L = \frac{1k \times 1k}{1k + 1k}$$

$$\boxed{R_e = 0.5\,k\Omega}$$

$$R_{in(Base)} \cong \beta R_e = (175)(0.5)$$

$$\boxed{R_{in(Base)} = 87.5\,k\Omega}$$

The total input Resistance:-

$$R_{i(total)} = R_1 \| R_2 \| R_{in(Base)}$$

$$R_{i(total)} = \frac{33k \times 10k \times 87.5k}{33k + 10k + 87.5}$$

$$R_i = \frac{28,875}{130.5}$$

$$\boxed{R_i = 221.3\,k\Omega}$$

The voltage gain $A_v \cong 1$.

r_e' is determined.

$$V_E = \left(\frac{R_2}{R_1+R_2}\right)V_{cc} - V_{BE}$$

$$= \left(\frac{10}{10+33}\right)10 - 0.7$$

$$\boxed{V_E = 1.63V}$$

$$I_E = \frac{1.63}{1K} = \boxed{1.63mA}$$

$$r_e' = \frac{6.52mV}{1.63mA} = 0.004\Omega$$

$$\rightarrow A_v = \frac{0.5K}{0.004+0.5K} \boxed{= 0.99}$$

$$I_e = \frac{(0.99)(20mV)}{0.5K} = \boxed{39.6mA}$$

$$I_{in} = \frac{20mV}{87.5K\Omega} = \cancel{0}.22A$$

$$\rightarrow A_i = \frac{39.6}{1.23} \boxed{= 32.2 \cancel{mA}}$$

Power Gain

$\because (A_v \cong 1)$

$$A_p \cong A_i$$

$$\boxed{A_p = 39.2}$$

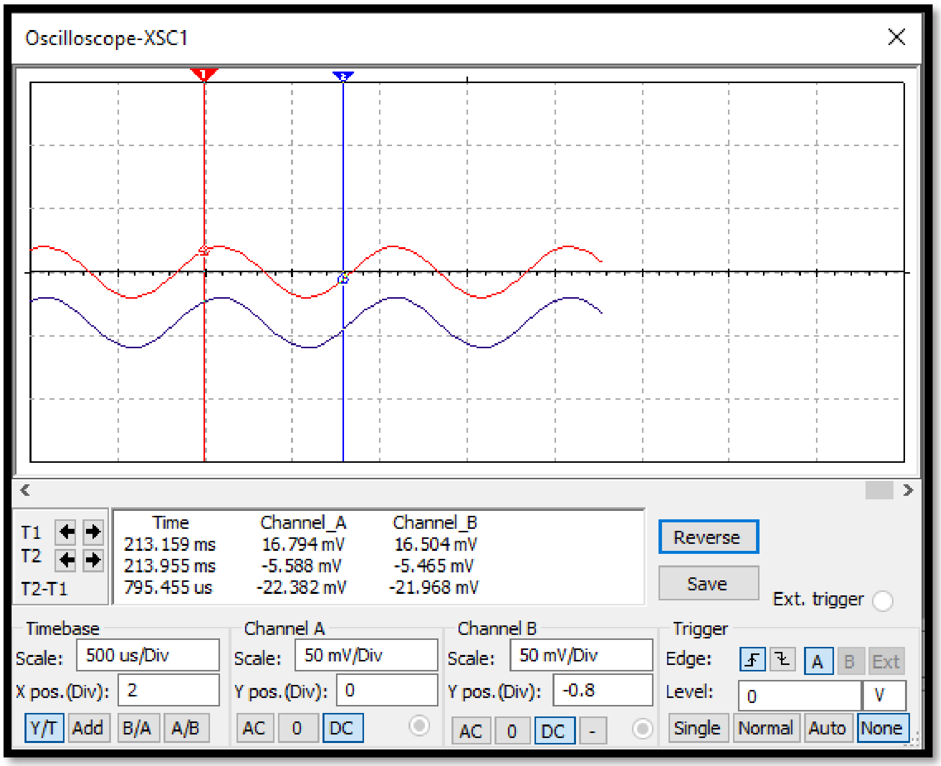
Since $R_L = R_E$, Half of the powers are dissipated in R_L and R_E. So.

$$A_p = \frac{39.2}{2}$$

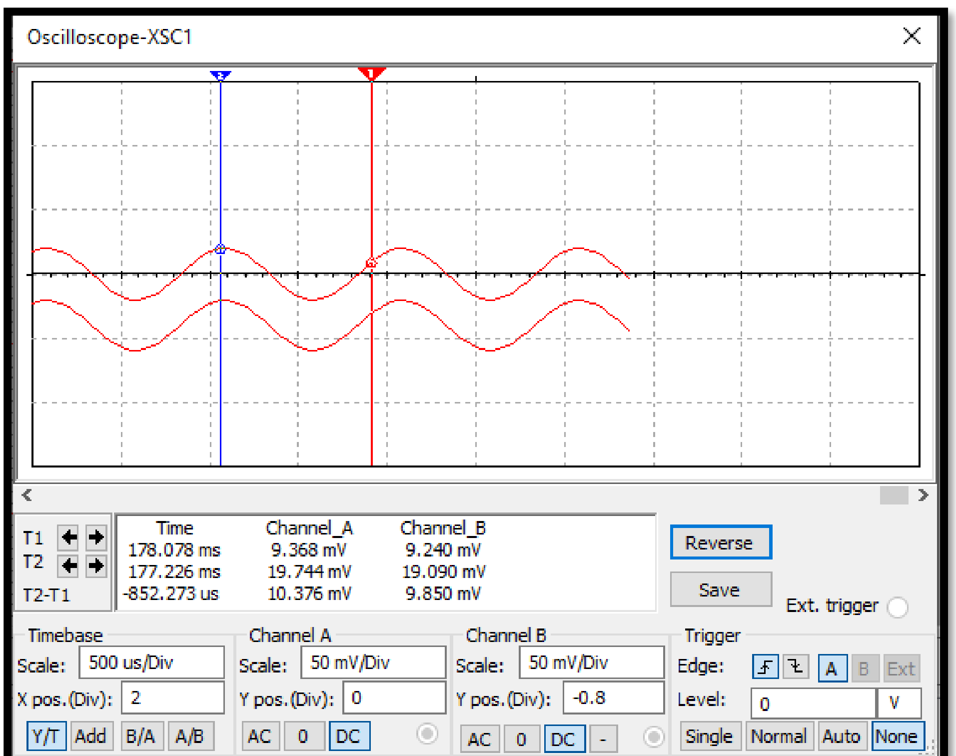
$$\boxed{A_{p(Load)} = 16.1}$$

Input and Output Graph:

- **For No Resistance at Load:**



- **For Resistance at Load:**



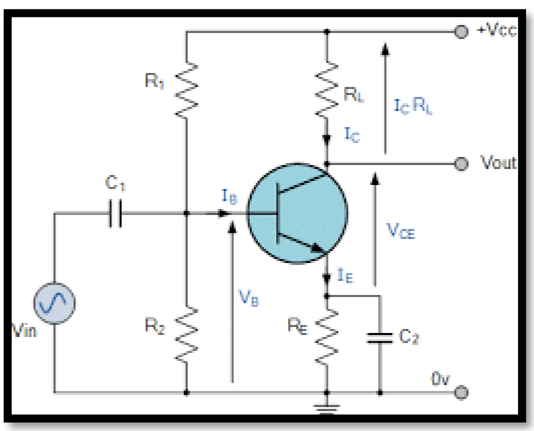
Result:

Sr. #	**With or without Load Resistance**	**Input Voltage**	**Output Voltage**	**$A_{V(Theoretical)}$**	**$A_{V(Practical)}$**
01	Without load Resistance	***16.794mV***	***16.504mV***	***0.91***	***0.98***
02	With load Resistance	***9.368mV***	***9.240mV***	***0.99***	***0.99***

Questions:

- **What is common collector amplifier called and why?**

The common emitter amplifier is a three basic single-stage bipolar junction transistor and is used as a voltage amplifier. The input of this amplifier is taken from the base terminal, the output is collected from the collector terminal and the emitter terminal is common for both the terminals.



It is also named common- collector amplifier because the collector of the transistor is common to both the input circuit and output circuit. The output signal appears across ground and the collector of the transistor.

- **What is ideal maximum gain of a collector amplifier?**

The voltage gain of the common collector amplifier is approximately equal to unity ($A_v \cong 1$). And that its current gain, A_i is approximately equal to Beta, ($A_i \cong 1+\beta$) which depending on the value of the particular transistors Beta value can be quiet high. And thus the power gain of Collector amplifier is$(1+\beta)$.

- **What characteristics of common collector amplifier make it useful circuit?**

Power gain	High
Input / output phase relationship	180°
Input resistance	Medium

The variation of collector current(I_C) with the base current(I_B), keeping Collector-Emitter voltage(V_{CE}) constant. The resulting current gain has a value greater than 1.

Common-emitter amplifiers are also used in radio frequency circuits, for example to amplify faint signals received by an antenna. In this case it is common to replace the load resistor with a tuned circuit. This may be done to limit the bandwidth to a narrow band centered around the intended operating frequency.