



## Experiment

### CE Amplifier – Measurement of input resistance and output resistance

#### Object

To be familiarized with the measurement of the input resistance and output resistance of a Bipolar Junction Transistor common emitter single-stage amplifier.

#### Theory

The figure below shows a common-emitter amplifier with voltage-divider bias and coupling capacitors C1 and C3 on the input and output and a bypass capacitor, C2, from emitter to ground. The input signal,  $V_{in}$ , is capacitively coupled to the base terminal, the output signal,  $V_{out}$ , is capacitively coupled from the collector to the load. The amplified output is  $180^\circ$  out of phase with the input. Because the ac signal is applied to the base terminal as the input and taken from the collector terminal as the output, the emitter is common to both the input and output signals. There is no signal at the emitter because the bypass capacitor effectively shorts the emitter to ground at the signal frequency. All amplifiers have a combination of both ac and dc operation, which must be considered, but keep in mind that the common-emitter designation refers to the ac operation.

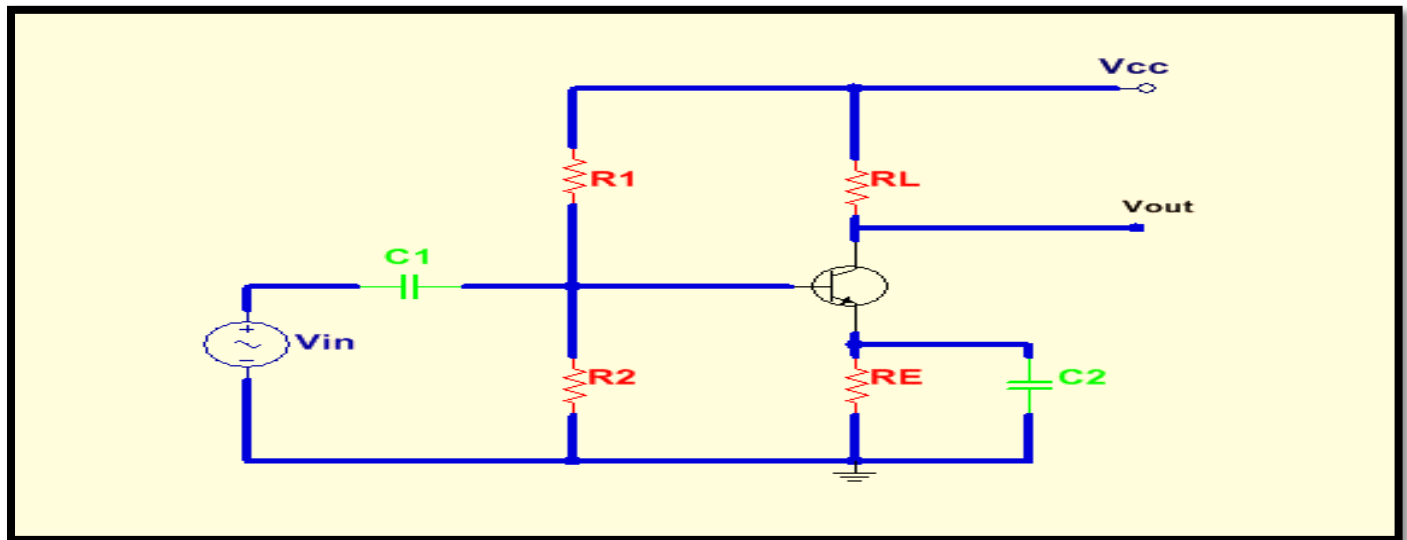


Fig 1: A common-emitter amplifier.

### AC Analysis

To analyze the ac signal operation of an amplifier, an ac equivalent circuit is developed as follows:

- 1 .The capacitors  $C_1$ ,  $C_2$ , and  $C_3$  are replaced by effective shorts because their values are selected so that  $X_C$  is negligible at the signal frequency and can be considered to be  $0 \Omega$ .
- 2 .The dc source is replaced by ground.

A dc voltage source has an internal resistance of near  $0\Omega$  because it holds a constant voltage independent of the load (within limits); no ac voltage can be developed across it so it appears as an ac short. This is why a dc source is called an ac ground. The ac equivalent circuit for the common-emitter amplifier in Fig.1 is shown in Fig.2. Notice that both  $R_C$  and  $R_1$  have one end connected to ac ground (red) because, in the actual circuit, they are connected to  $V_{CC}$  which is, in effect, ac ground.

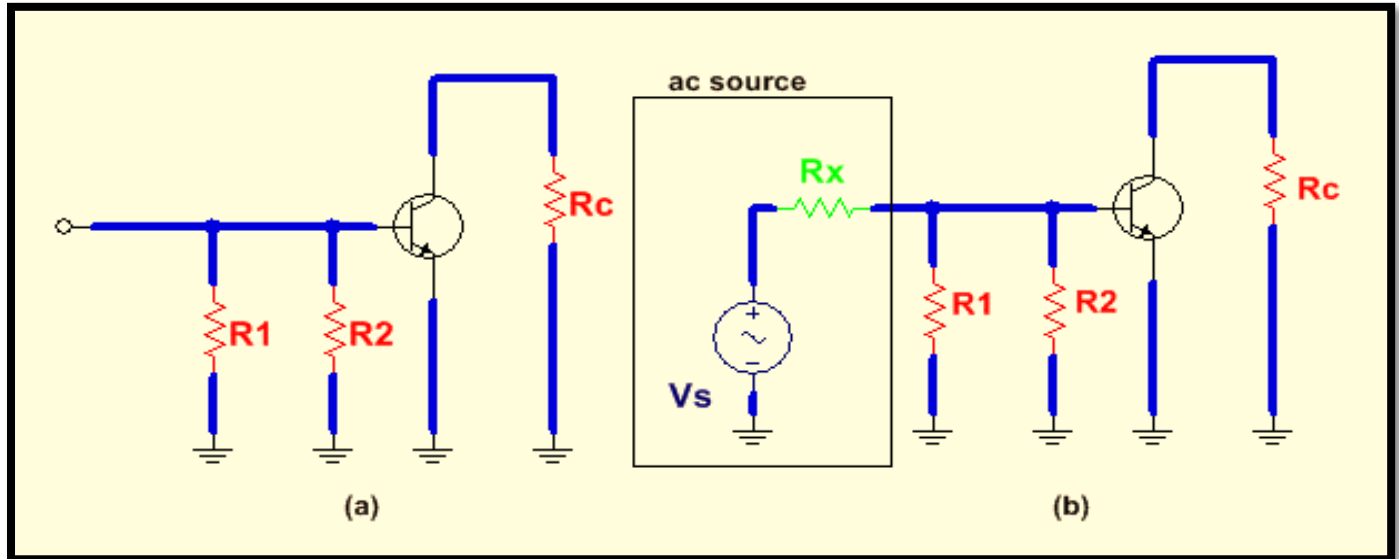


Fig.2: AC equivalent circuit for the amplifier in Fig.1

(a) without an input signal voltage. (b) with an input signal voltage.

In AC analysis, the ac ground and the actual ground are treated as the same point electrically. The amplifier in Fig.1 is called a common-emitter amplifier because the bypass capacitor  $C_2$  keeps the emitter at ac ground. Ground is the common point in the circuit.

Signal (AC) Voltage at the Base An ac voltage source,  $V_s$ , is shown connected to the input in Fig.2(b). If the internal resistance of the ac source is  $0\Omega$  then all of the source voltage appears at the base terminal. If, however, the ac source has a nonzero internal resistance, then three factors must be taken into account in determining the actual signal voltage at the base. These are the source resistance ( $R_s$ ), the bias resistance ( $R_1 \parallel R_2$ ) and the ac input resistance at the base of the transistor ( $R_{in(base)}$ ). This is illustrated in Fig.2(a) and is simplified by combining  $R_1$ ,  $R_2$ , and  $R_{in(base)}$  in parallel to get the total input resistance,  $R_{in(tot)}$ , which is the resistance “seen” by an ac source connected to the input, as shown in Fig.2(b). A high value of input resistance is desirable so that the amplifier will not excessively load the signal source. This is opposite to the requirement for a stable Q-point, which requires smaller resistors. The conflicting requirement for high input resistance and stable biasing is but one of the many trade-offs that must be considered when choosing components for a circuit. The total input resistance is expressed by the following formula:

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

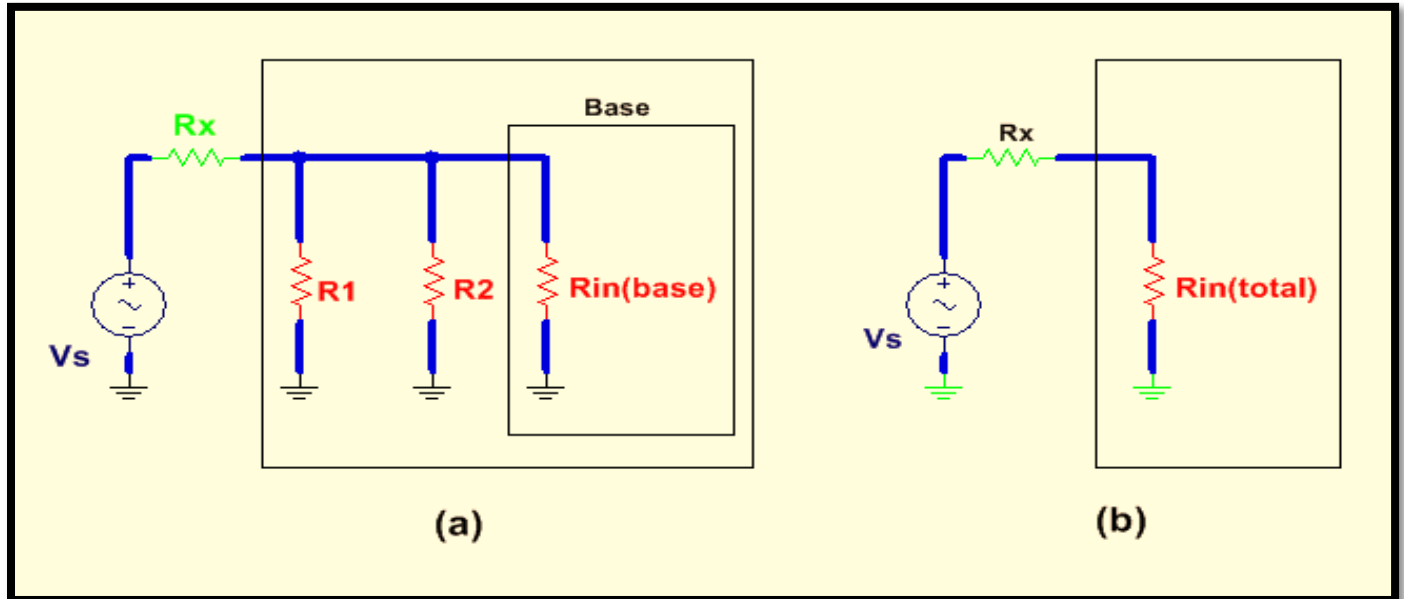


Fig.3: AC equivalent of the base circuit.

As you can see in the figure, the source voltage,  $V_s$ , is divided down by  $R_s$  (source resistance) and  $R_{in(tot)}$  so that the signal voltage at the base of the transistor is found by the voltage- divider formula as follows:

$$V_b = \left( \frac{R_{in(total)}}{R_s + R_{in(total)}} \right) V_s$$

If  $R_s \ll R_{in(total)}$ , then  $V_b \cong V_s$ , where  $V_b$  is the input voltage ( $V_{in}$ ) to the amplifier

Input Resistance at the Base: To develop an expression for the ac input resistance looking in at the base, use the simplified r-parameter model of the transistor. Fig.4 shows the transistor model connected to the external collector resistor,  $R_C$ . The input resistance looking in at the base is:

$$R_{in(base)} = \frac{V_{in}}{I_{in}} = \frac{V_b}{I_b}$$

The base voltage is

$$V_b = I_e \dot{I}_r$$

And since  $I_e \cong I_c$

$$I_b \cong \frac{I_e}{\beta_{ac}}$$

Substitution for  $V_b$  and  $I_b$

$$R_{in(base)} = \frac{V_b}{I_b} = \frac{I_e r_e}{I_e / \beta_{ac}}$$

Cancelling  $I_e$

$$R_{in(base)} = \beta_{ac} r_e$$

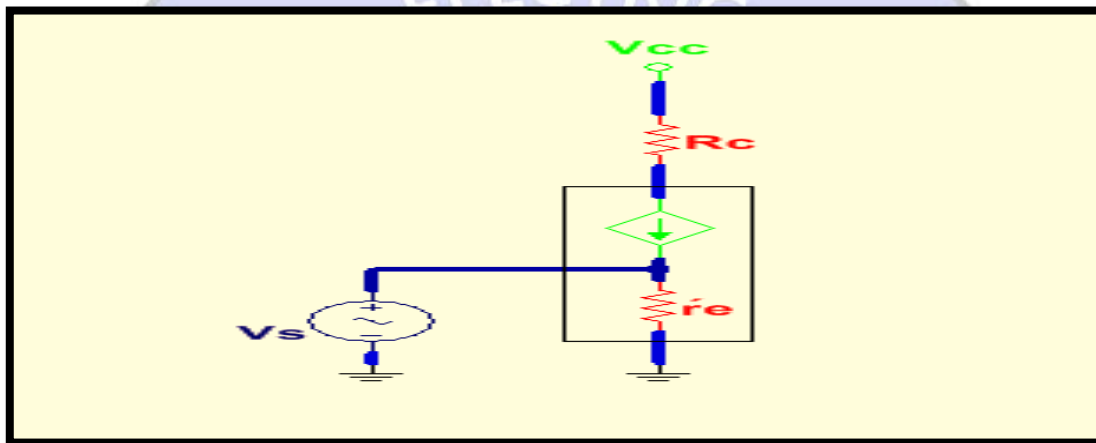


Fig.4: r-parameter transistor model (inside shaded block) connected to external circuit.

**Output Resistance:** The output resistance of the common-emitter amplifier is the resistance looking in at the collector and is approximately equal to the collector resistor.

$$R_{out} \cong R_c$$

Actually,  $R_{out} \cong R_c \parallel r_e$  but since the internal ac collector resistance of the transistor  $r_e$ , is typically much larger than  $R_c$ , the approximation is usually valid.

## Procedures



R1	22K
R2	4K7
R3	39K
R4	470Ω
R5	3K3
R6	2K7
R7	10K
R8	1K5
R9	3K3
C1	100KpF=100nF
C2	1μF
C3	100KpF=100nF
C4	1μF
C5	100KpF=100nF
P1	Trimmer 47K
P2	Trimmer 4K7
Q1	BC337
Q2	BC337

**Table 1**

❖ **CE Amplifier, Measurement of Input Resistance**

The setup used for this exercise is shown in Fig.5.

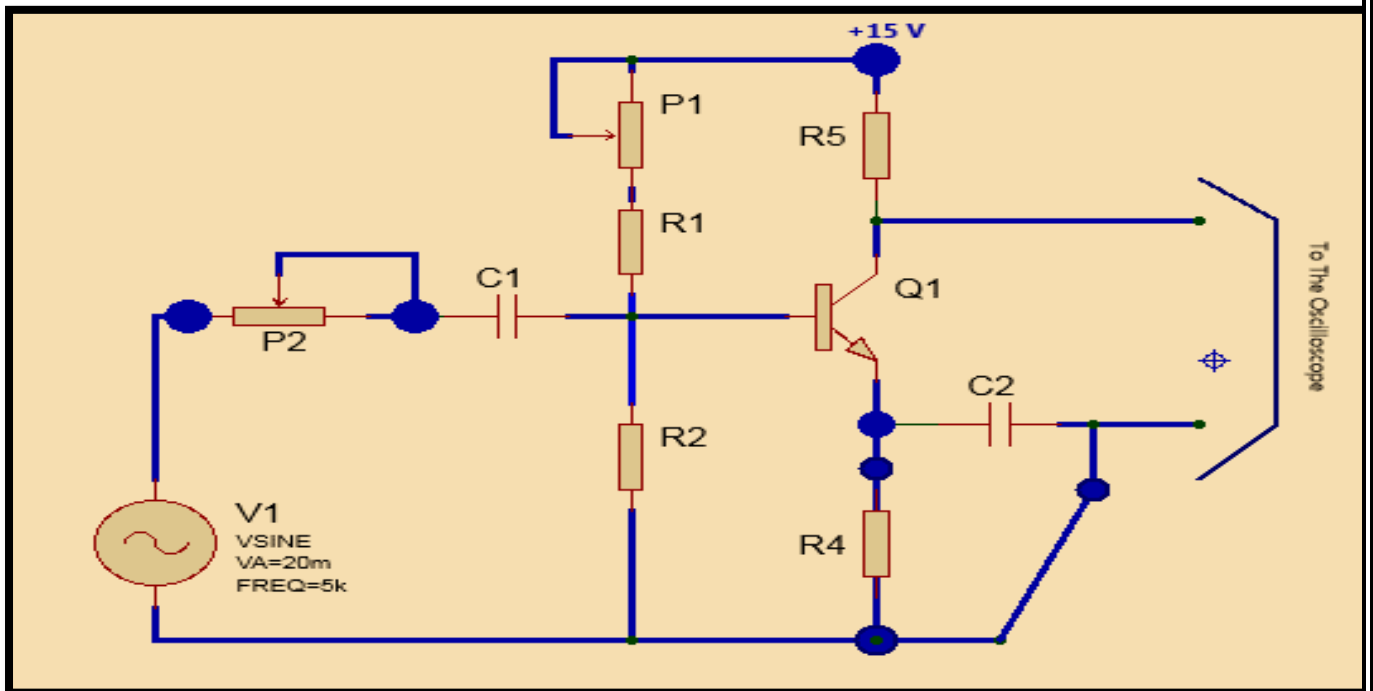


Fig.5 - Setup to determine the input R resistance of the CE AHP(M100IF5)

Basically, the difference with Fig.3 is that now we have a variable resistor placed in series with the generator feeding signal to the base input.

- The principle of the measurement is the following:
  - The variable ( $P_2$ ) resistor is initially set at 0 (short circuit). The generator is adjusted for 1 KHz sinewave and the amplitude is adjusted to have at the output an undistorted sinewave of, say, 5Vpp.
  - $P_2$  is slowly raised from its initial null value, to a point where the amplifier output signal is halved. This happens since the input signal is also halved. (see Fig .6), i.e.  $P_2 = R_i$ .

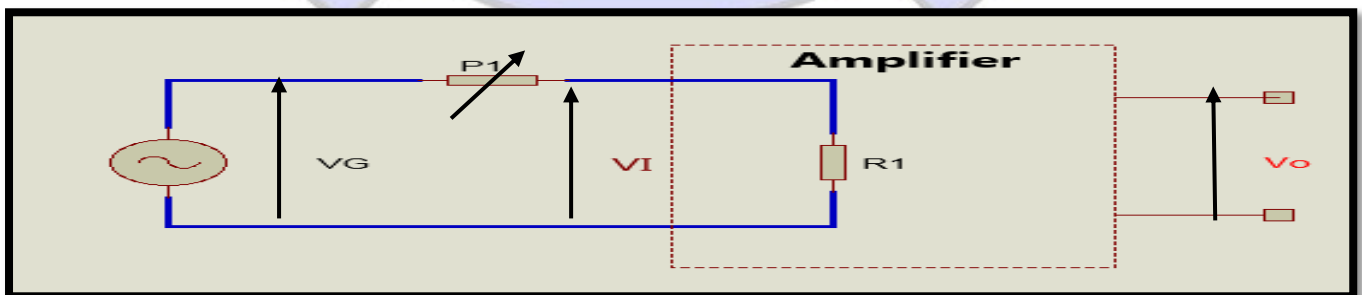


Fig.6 - Determination of the input resistance for the CE amplifier M1001F6

- The power supply is shut off,  $P_2$  disconnected from the circuit and measured with on ohmmeter.  
This value equals the input impedance of the amplifier (refer to Fig.6)

While proceeding with the practical work, note the following:

- Choose for the frequency a high value (10KHz) in order to make  $C_1$  and  $C_2$  actually appear as short circuits to the AC signal.
- The gain of the amplifier is high, so the generator must be adjusted to deliver a low signal (10 to 50mVpp ore expected to be sufficient).

### ❖ CE Amplifier - Measurement of Output Resistance

The principle of this measurement is similar to that of the preceding case. Refer to Fig. 7, showing the setup, and to Fig.8 showing the equivalent schematic.

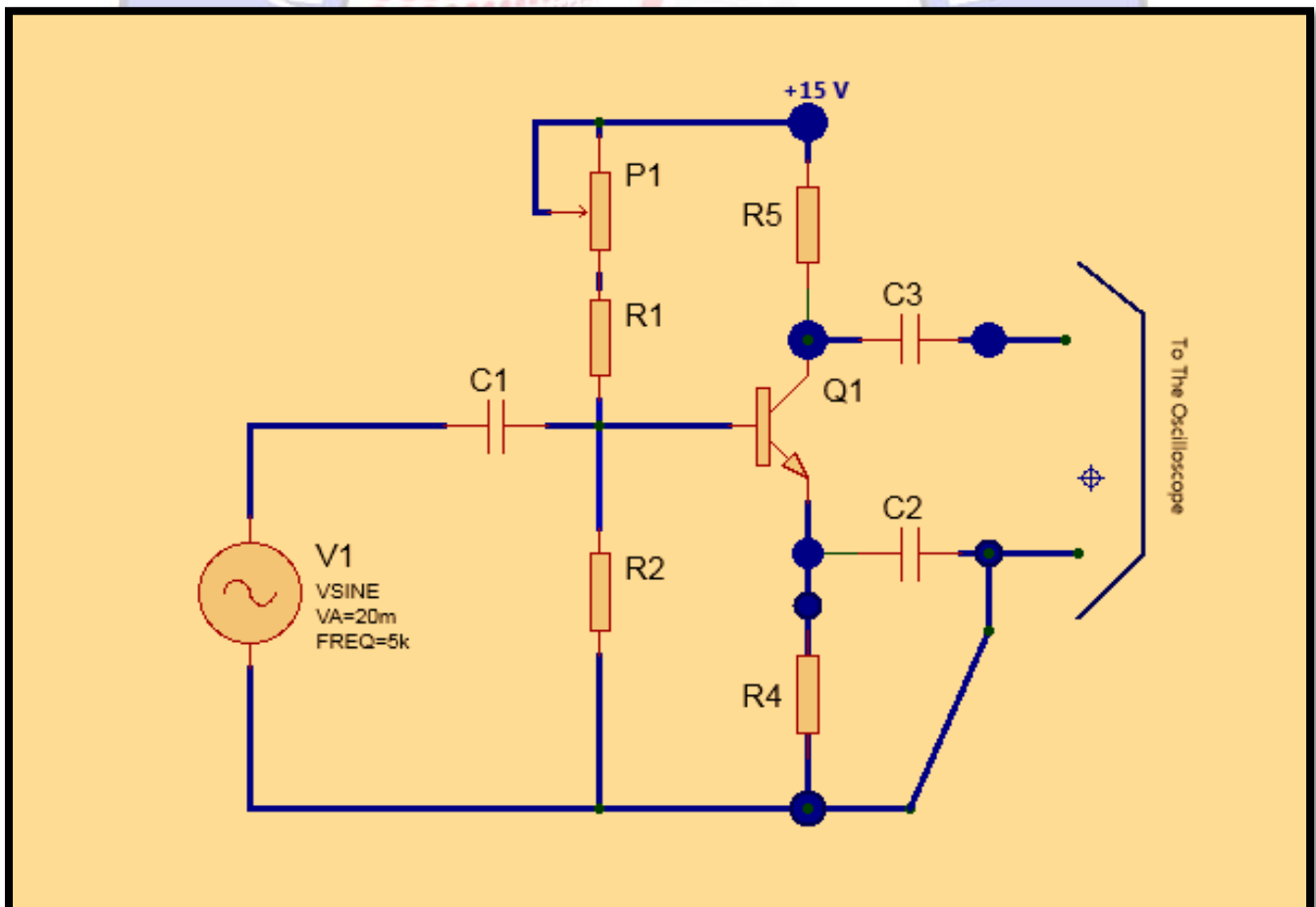


Fig.7 – Measurement of the output resistance M100F7

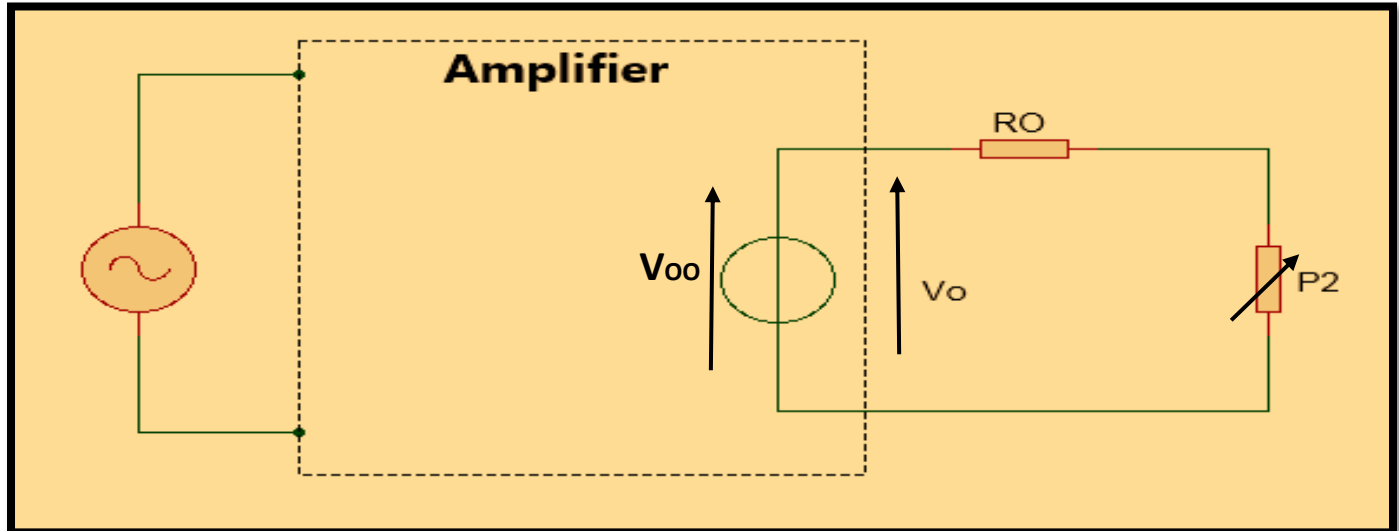


Fig.8 -The principle of the measurement, when  $V_o = \frac{1}{2} V_{oo}$ , then  $P_2 = R_o$

- A 10KHz sinewave is used as on input signal. Its amplitude is adjusted to convenient value to have an output of, for instance, 5Vpp. This should rein an input signal of 15 to 40mVpp.
- Trimmer  $P_2$  is then connected as a load, DC decoupled by means of  $C_3$ .  $P_2$  is adjusted to the point where the amplitude of the signal halves (with changing the level of the input signal).  
 In these conditions  $P_2$  has a resistance equaling the output resistance of amplifier.

Disconnect  $P_2$  and measure it with an ohmmeter.

## Results

Find input resistance and output resistance according to the previous mentioned procedures:

## Discussion

Theoretically, find the values of input resistance and output resistance of common emitter transistor according to the setup that you have used during the procedures' steps. Compare between theoretical and practical results.

