

Laboratory 2

Simple Transistor Amplifiers: Lecture 3

2.1 CE Amp Voltage Amplifier Equivalent Circuit, Input Resistance and Output Resistance

2.1.1 Input Resistance:

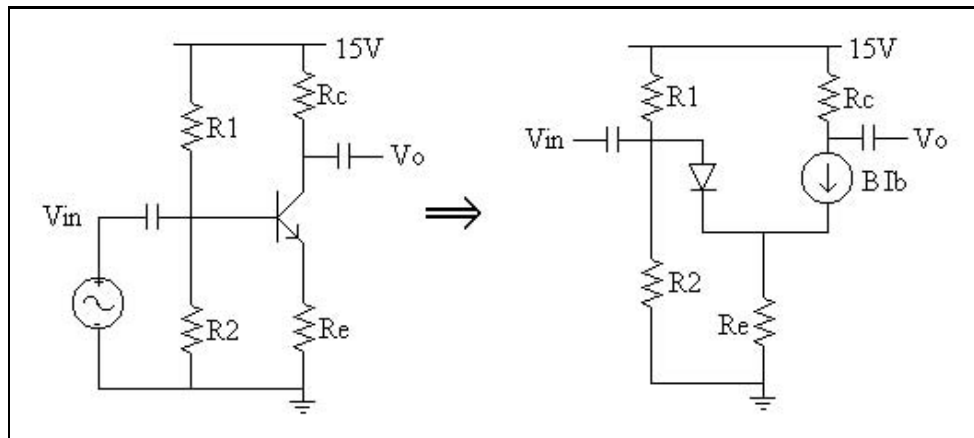


Figure 2.1: Common Emitter Amplifier

The input resistance is the resistance seen by the current source or voltage source which drives the circuit.

For example, Fig. 2.1, the impedance seen by sinusoidal input

signals looking into the capacitor is:

$$Z_{in} = \frac{1}{j\omega C_1} + R_B || R_{TB} \quad (2.1)$$

R_{TB} is the resistance looking into the base of the transistor.

$$R_B = R_1 || R_2$$

At midband frequencies $\frac{1}{j\omega C_1} \approx 0$, so

$$R_{in} = R_B || R_{TB} \quad (2.2)$$

R_B can be read directly from the circuit.

Determine R_{TB} .

$$R_{TB} = \frac{\Delta V_b}{\Delta I_b} \quad (2.3)$$

Find ΔV_b ;

Base emitter loop gives

$$V_b = I_e R_E + V_{be} \quad (2.4)$$

Use $I_e \approx I_c$ Make small change in V_b :

$$\Delta V_b = \Delta I_c R_E + \Delta V_{be} \quad (2.5)$$

Use $\Delta V_{be} = \frac{\Delta I_c}{g_m}$ to obtain

$$\Delta V_b = \frac{\Delta I_c}{g_m} + \Delta I_c R_E \quad (2.6)$$

Now, recalling that $\Delta I_b = \frac{\Delta I_c}{\beta}$, and dividing ΔV_b by ΔI_b , we obtain

$$R_{TB} = \frac{\Delta V_b}{\Delta I_b} = \frac{\beta}{g_m} + \beta R_E \quad (2.7)$$

Very good approximation

Since $\frac{1}{g_m}$ is usually much smaller than R_E , when an emitter resistor is present $R_{TB} \approx \beta R_E$.

It is interesting to observe that the resistance looking into the base is usually fairly large since it contains the multiplicative factor β .

2.1.2 Output Resistance of CE Amp

Output resistance is an indication of a source's ability to drive a load impedance.

An ideal voltage source has zero output resistance.

An ideal current source has infinite output resistance.

To find the output resistance of the CE amplifier, we ground the input and drive the output.

From the circuit in Fig. ??, the output resistance is then $R_C || R_{TC}$, where R_{TC} is the resistance looking into the collector.

Since, at this time, we are considering the collector to be modeled as an ideal current source (neglecting r_o for now,

$$R_o \approx R_C.$$

2.1.3 Voltage Amplifier Equivalent Circuit

We have determined CE:

Voltage gain,

Input resistance

Output resistance

Now represent CE amp a simple two-port circuit in Fig 2.2

$R_{in} = (r_{\pi} + \beta R_E) \parallel R_B$; $R_{out} = R_C$; and the open circuit output voltage given by $v_{out} = A_V v_{in}$.

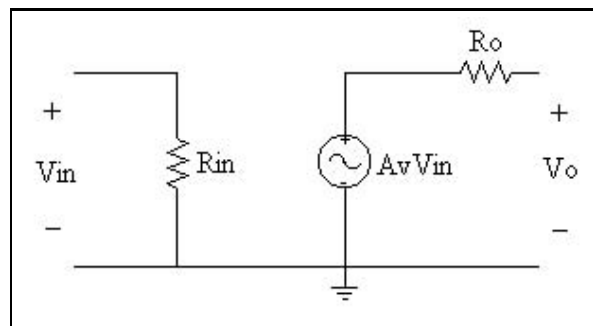


Figure 2.2: Two-Port Equivalent Amplifier Circuit

Example:

CE amp that is driven by a voltage source with source resistance R_S , and the amp is supplying current to a load R_L . The actual circuit is drawn below.

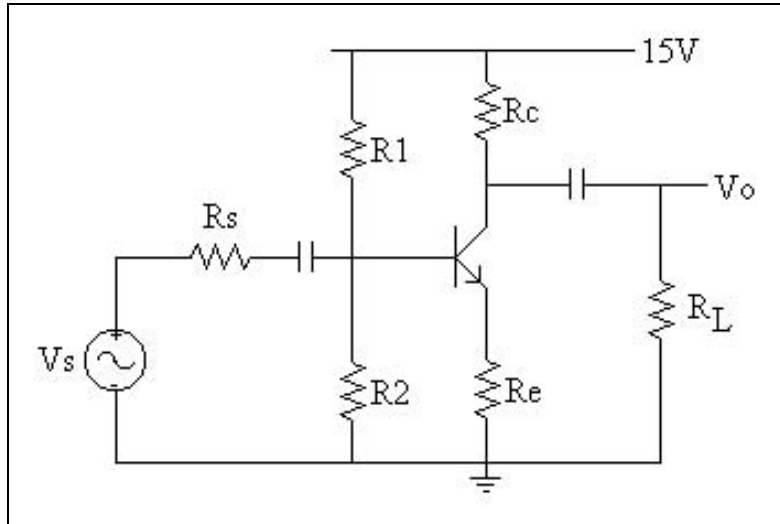


Figure 2.3: CE amp driven by nonideal source of resistance R_S and driving a load R_L

Replace the small signal part of the CE amp with its two-port amp equivalent circuit:

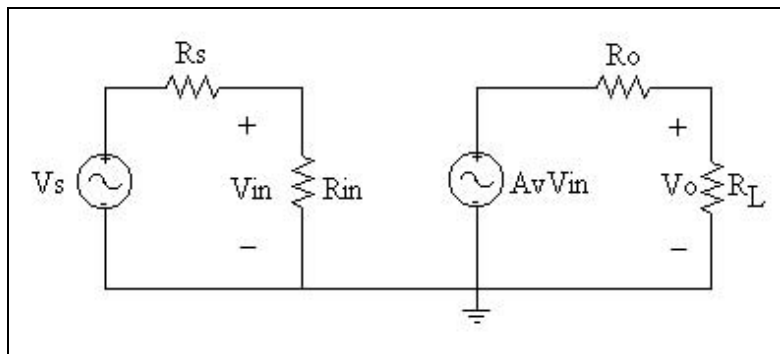


Figure 2.4: Equivalent circuit of CE amp described by voltage amplifier

Find the voltage gain by dividing the circuit into three stages and finding the gain of each stage.

The total gain is then the product of the three individual stage gains.

First stage: voltage divider consisting of v_S , R_S , and R_{in} .

$$A_{V1} = \frac{v_1}{v_s} = \frac{R_{in}}{R_S + R_{in}} \quad (2.8)$$

Where V_1 is the voltage seen at the input of the CE two-port amp equivalent circuit.

Second stage: CE two-port amp equivalent circuit.

$$A_{V2} = \frac{V_2}{V_1} = \frac{-R_C}{\frac{1}{g_m} + R_E} \quad (2.9)$$

Where V_2 is the open circuit voltage at the CE amp output that would be measured if the load R_L were not there.

Final stage is the voltage divider consisting of V_2 , R_{out} , and R_L .

$$A_{V3} = \frac{v_{out}}{V_2} = \frac{R_L}{R_L + R_{out}} \quad (2.10)$$

The total gain of the circuit A_V is the product of the three stages:

$$A_V = \frac{v_{out}}{v_s} = A_{V1}A_{V2}A_{V3} = \left(\frac{R_{in}}{R_S + R_{in}} \right) \left(\frac{-R_C}{\frac{1}{g_m} + R_E} \right) \left(\frac{R_L}{R_L + R_{out}} \right) \quad (2.11)$$