ECE 255

12 October 2017

In this lecture, we will cover some examples.

Example 7.8

A CE amplifier utilizes a BJT with $\beta = 100$ is biased at $I_C = 1$ mA and has a collector resistance $R_C = 5$ kΩ. Find R_{in}, R_o, and A_{vo}. If the amplifier is fed with a signal source having a resistance of 5 kΩ, and a load resistance $R_L = 5$ kΩ is connected to the output terminal, find the resulting A_v and G_v. If $\hat{v}_\pi$ is to be limited to 5 mV, what are the corresponding $\hat{v}_{\text{sig}}$ and $\hat{v}_o$ with the load connected?

Solution

At $I_C = 1$ mA,

$$g_m = \frac{I_C}{V_T} = \frac{1 \text{ mA}}{0.025 \text{ V}} = 40 \text{ mA/V}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{40 \text{ mA/V}} = 2.5 \text{ k}\Omega$$

Printed on October 17, 2017 at 05 : 42: W.C. Chew and Z.H. Chen.

Example 7.8 *continued*

The amplifier characteristic parameters can now be found as

$$R_{in} = r_\pi = 2.5\ \text{k}\Omega$$

$$\begin{aligned} A_{vo} &= -g_m R_C \\ &= -40\ \text{mA/V} \times 5\ \text{k}\Omega \\ &= -200\ \text{V/V} \end{aligned}$$

$$R_o = R_C = 5\ \text{k}\Omega$$

With a load resistance $R_L = 5\ \text{k}\Omega$ connected at the output, we can find A_v by either of the following two approaches:

$$\begin{aligned} A_v &= A_{vo}\frac{R_L}{R_L + R_o} \\ &= -200 \times \frac{5}{5+5} = -100\ \text{V/V} \end{aligned}$$

or

$$\begin{aligned} A_v &= -g_m(R_C \parallel R_L) \\ &= -40(5 \parallel 5) = -100\ \text{V/V} \end{aligned}$$

The overall voltage gain G_v can now be determined as

$$\begin{aligned} G_v &= \frac{R_{in}}{R_{in} + R_{sig}} A_v \\ &= \frac{2.5}{2.5+5} \times -100 = -33.3\ \text{V/V} \end{aligned}$$

If the maximum amplitude of v_π is to be 5 mV, the corresponding value of $\hat{v}_{sig}$ will be

$$\hat{v}_{sig} = \left(\frac{R_{in} + R_{sig}}{R_{in}}\right)\hat{v}_\pi = \frac{2.5+5}{2.5} \times 5 = 15\ \text{mV}$$

and the amplitude of the signal at the output will be

$$\hat{v}_o = G_v \hat{v}_{sig} = 33.3 \times 0.015 = 0.5\ \text{V}$$

Example 7.9

For the CE amplifier specified in Example 7.8, what value of R_e is needed to raise R_{in} to a value four times that of R_{sig}? With R_e included, find A_{vo}, R_o, A_v, and G_v. Also, if $\hat{v}_\pi$ is limited to 5 mV, what are the corresponding values of $\hat{v}_{sig}$ and $\hat{v}_o$?

Solution

To obtain $R_{in} = 4R_{sig} = 4 \times 5 = 20\text{ k}\Omega$, the required R_e is found from

$$20 = (\beta + 1)(r_e + R_e)$$

With $\beta = 100$,

$$r_e + R_e \simeq 200\ \Omega$$

Thus,

$$R_e = 200 - 25 = 175\ \Omega$$

$$A_{vo} = -\alpha \frac{R_C}{r_e + R_e}$$

$$\simeq -\frac{5000}{25 + 175} = -25\text{ V/V}$$

$$R_o = R_C = 5\text{ k}\Omega \text{ (unchanged)}$$

$$A_v = A_{vo}\frac{R_L}{R_L + R_o} = -25 \times \frac{5}{5+5} = -12.5\text{ V/V}$$

$$G_v = \frac{R_{in}}{R_{in} + R_{sig}} A_v = -\frac{20}{20+5} \times 12.5 = -10\text{ V/V}$$

For $\hat{v}_\pi = 5$ mV,

$$\hat{v}_i = \hat{v}_\pi \left(\frac{r_e + R_e}{r_e} \right)$$

$$= 5\left(1 + \frac{175}{25}\right) = 40\text{ mV}$$

$$\hat{v}_{sig} = \hat{v}_i \frac{R_{in} + R_{sig}}{R_{in}}$$

$$= 40\left(1 + \frac{5}{20}\right) = 50\text{ mV}$$

$$\hat{v}_o = \hat{v}_{sig} \times |G_v|$$

$$= 50 \times 10 = 500\text{ mV} = 0.5\text{ V}$$

Thus, while $|G_v|$ has decreased to about a third of its original value, the amplifier is able to produce as large an output signal as before for the same nonlinear distortion.

Example 7.10

It is required to design an emitter follower to implement the buffer amplifier of Fig. 7.46(a). Specify the required bias current I_E and the minimum value the transistor β must have. Determine the maximum allowed value of v_{sig} if v_π is to be limited to 5 mV in order to obtain reasonably linear operation. With $v_{sig} = 200$ mV, determine the signal voltage at the output if R_L is changed to 2 kΩ, and to 0.5 kΩ.

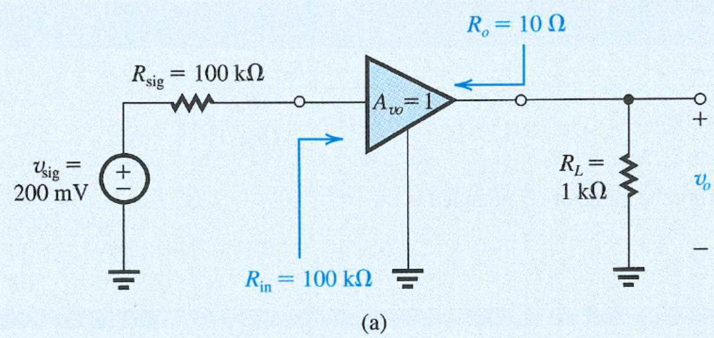

Figure 7.46 Circuit for Example 7.10.

Example 7.10 *continued*

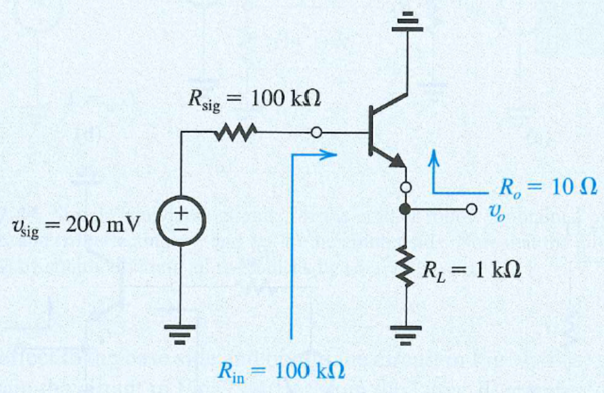

Figure 7.46 *continued*

Solution

The emitter-follower circuit is shown in Fig. 7.46(b). To obtain $R_o = 10\ \Omega$, we bias the transistor to obtain $r_e = 10\ \Omega$. Thus,

$$10\ \Omega = \frac{V_T}{I_E}$$
$$I_E = 2.5\ \text{mA}$$

The input resistance R_{in} will be

$$R_{in} = (\beta + 1)(r_e + R_L)$$
$$100 = (\beta + 1)(0.01 + 1)$$

Thus, the BJT should have a β with a minimum value of 98. A higher β would obviously be beneficial.

The overall voltage gain can be determined from

$$G_v \equiv \frac{v_o}{v_{sig}} = \frac{R_L}{R_L + r_e + \dfrac{R_{sig}}{(\beta + 1)}}$$

Assuming $\beta = 100$, the value of G_v obtained is

$$G_v = 0.5$$

Thus when $v_{sig} = 200$ mV, the signal at the output will be 100 mV. Since the 100 mV appears across the 1-kΩ load, the signal across the base–emitter junction can be found from

$$v_\pi = \frac{v_o}{R_L} \times r_e$$

$$= \frac{100}{1000} \times 10 = 1 \text{ mV}$$

If $\hat{v}_\pi = 5$ mV then v_{sig} can be increased by a factor of 5, resulting in $\hat{v}_{sig} = 1$ V.

To obtain v_o as the load is varied, we use the Thévenin equivalent of the emitter follower, shown in Fig. 7.45(a) with $G_{vo} = 1$ and

$$R_{out} = \frac{R_{sig}}{\beta + 1} + r_e = \frac{100}{101} + 0.01 = 1 \text{ k}\Omega$$

to obtain

$$v_o = v_{sig} \frac{R_L}{R_L + R_{out}}$$

For $R_L = 2$ kΩ,

$$v_o = 200 \text{ mV} \times \frac{2}{2+1} = 133.3 \text{ mV}$$

and for $R_L = 0.5$ kΩ,

$$v_o = 200 \text{ mV} \times \frac{0.5}{0.5+1} = 66.7 \text{ mV}$$