ECE 255

16 October 2017

In this lecture, the basic configurations of a BJT amplifier will be studied. Previously, it has been shown that with the transistor DC biased at the appropriate point, linear relations can be derived between the small signals. With these linear relations, the principles of linear systems can be applied to solve them. Moreover, they can be easily handled by commercial software such as SPICE for highly complex circuits as long as they are linear. The take home message here is that linear problems are a lot simpler to solve compared to nonlinear problems.

1 The Three Basic Configurations

The three basic configurations of a BJT are (a) common emitter (CE), (b) common base (CB), (c) common collector (CC) of emitter follower. These basic configurations are shown in Figure 1.

The replacement of the basic configurations with equivalent circuit models and the small signal approximations convert the original nonlinear problem into a linear one, greatly simplifying the analysis.

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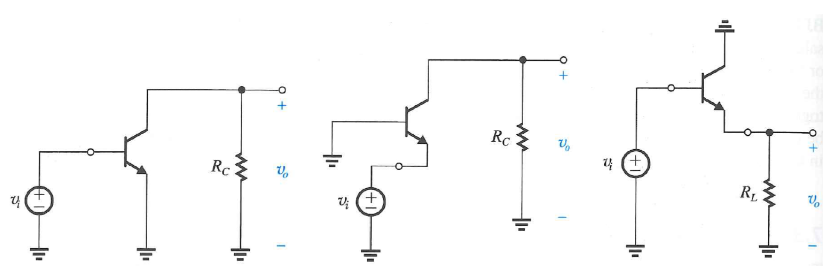

Figure 1: Basic configurations of a transistor amplifier: (a) common emitter (CE), (b) common base (CB), (c) common collector (CC) (Courtesy of Sedra and Smith).

2 Characterizing Amplifiers

An amplifier can be denoted by functional block as expressed in Figure **??**(a), where a triangle block encapsulates the details of the small-signal equivalent circuit model as shown in Figure **??**(b). The equivalent circuit model indicates that the amplifier has a finite internal impedance, R_{in}. Moreover, it has a finite output resistance R_o.

The internal input resistance can be found from

$$R_{in} = \frac{v_i}{i_i} \tag{2.1}$$

The amplifier is also defined with an **open-circuit voltage gain** A_{vo} defined as

$$A_{vo} = \left.\frac{v_0}{v_i}\right|_{R_L=\infty} \tag{2.2}$$

The output resistance can measured by setting $v_i = 0$ and

$$R_o = \frac{v_x}{i_x} \tag{2.3}$$

With the load resistor R_L connected, the actual output voltage is

$$v_o = \frac{R_L}{R_L + R_o} A_{vo} v_i \tag{2.4}$$

Hence, the actual **voltage gain of the amplifier proper** is A_v given by

$$A_v = \frac{v_o}{v_i} = A_{vo}\frac{R_L}{R_L + R_o} \tag{2.5}$$

and the **overall voltage gain** of the entire circuit is given by

$$G_v = \frac{v_o}{v_{\text{sig}}} = \frac{v_o}{v_i}\frac{v_i}{v_{\text{sig}}} \tag{2.6}$$

Using (2.5) and the fact that $\frac{v_i}{v_{\text{sig}}} = \frac{R_{\text{in}}}{R_{\text{in}}+R_{\text{sig}}}$ give

$$G_v = \frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}}\frac{R_L}{R_L + R_o} A_{vo} \tag{2.7}$$

3 Common Emitter Amplifier

This is the most popular amplifier design, and by cascading a number of them, the aggregate gain of the amplifier circuit can be increased.

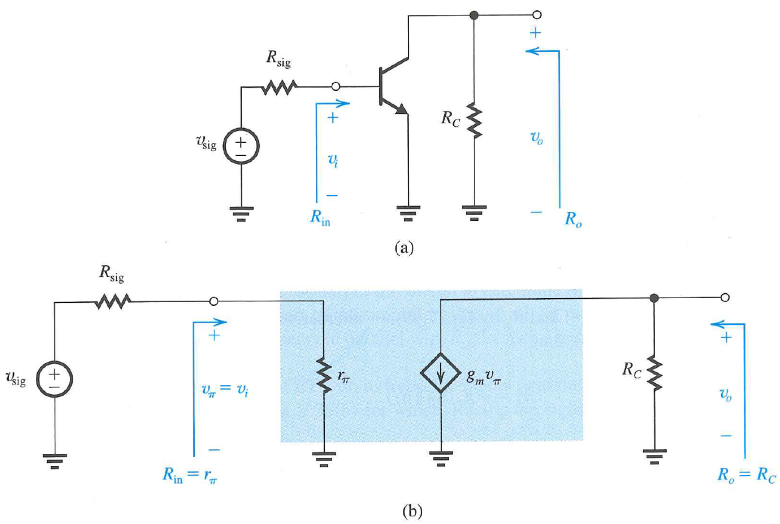

Figure 2: A CE amplifier (a) and its equivalent circuit hybrid-π model (b) (Courtesy of Sedra and Smith).

3.1 Characteristic Parameters of the CE Amplifier

Figure 2 shows the BJT CE amplifier and its small-signal equivalent circuit model.

It is seen that

$$v_i = \frac{r_\pi}{r_\pi + R_{\rm sig}} v_{\rm sig} v_o = -g_m v_i R_C \tag{3.1}$$

Then

$$A_{vo} = \frac{v_o}{v_i} = -g_m R_C \tag{3.2}$$

With the load resistance R_L, then

$$A_v = -g_m (R_C || R_L) \tag{3.3}$$

and the overall voltage gain

$$G_v = \frac{v_o}{v_{\rm sig}} = \frac{v_o 1}{v_{\rm sig}} \frac{v_o}{v_i} = -\frac{r_\pi}{r_\pi + R_{\rm sig}} g_m (R_C || R_L) \tag{3.4}$$