UNIT II

BJT AMPLIFIERS

Small Signal Hybrid π equivalent circuit of BJT

BJT circuit models

- Small signal model (hybrid pi model)
- Large signal model (Charge control model)
- SPICE model

A large variety of bipolar junction transistor models have been developed. One distinguishes between small signal and large signal models. We will discuss here first the hybrid pi model, a small signal model, which lends itself well to small signal design and analysis. The next model is the charge control model, which is particularly well suited to analyze the large-signal transient behavior of a bipolar transistor. And we conclude with the derivation of the SPICE model parameters.

Small signal model (hybrid pi model)

The hybrid pi model of a BJT is a small signal model, named after the "p"-like equivalent circuit for a bipolar junction transistor. The model is shown in Figure 2.1.1. It consists of an input impedance, r_p, an output impedance r_0, and a voltage controlled current source described by the transconductance, g_m. In addition it contains the base-emitter capacitances, the junction capacitance, $C_{j,BE}$, and the diffusion capacitance, $C_{d,BE}$, and the base-collector junction capacitance, $C_{j,BC}$, also referred to as the Miller capacitance

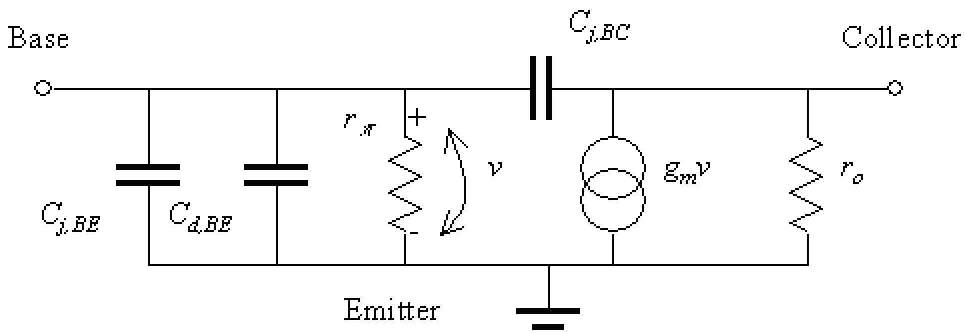

Figure 2.1.1 Small signal model (hybrid pi model) of a bipolar junction transistor.

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The transconductance, g_m, of a bipolar transistor is defined as the change in the collector current divided by the change of the base-emitter voltage.

$$g_m \stackrel{\Delta}{=} \frac{\partial I_C}{\partial V_{BE}} = \frac{I_C}{nV_t}$$

The base input resistance, r_p, is defined as the change of the emitter-base voltage divided by the change of the base current.

$$r_\pi \stackrel{\Delta}{=} \frac{\partial V_{BE}}{\partial I_B} = \beta \frac{\partial V_{BE}}{\partial I_C} = \frac{\beta}{g_m} = \frac{nV_t}{I_B}$$

The output resistance, r_o, is defined as:

$$r_o \stackrel{\Delta}{=} \frac{\partial V_{CE}}{\partial I_C} \cong \frac{\partial V_{CB}}{\partial I_C} = \frac{|V_A|}{I_C}$$

Introduction BJT Amplifiers

An amplifier is used to increase the signal level. It is used to get a larger signal output from a small signal input. Assume a sinusoidal signal at the input of the amplifier. At the output, signal must remain sinusoidal in waveform with frequency same as that of input. To make the transistor work as an amplifier, it is to be biased to operate in active region. It means base-emitter junction is forward biased and base-collector junction is reverse biased. Let us consider the common emitter amplifier circuit using voltage divider bias.

In the absence of input signal, only D.C. voltage is present in the circuit. It is known as zero signal or no signal condition or quiescent condition. D.C. collector-emitter voltage V_{CE}, D.C. collector current I_C and base current I_B is the quiescent operating point for the amplifier. Due to this base current varies sinusoidaly , I_{BQ} is quiescent DC base current If the transistor is biased to operate in active region, output is linearly proportional to the input.

The collector current is β times larger than the input base current in CE configuration. The collector current will also vary sinusoidal about its quiescent value I_{CQ}. The output voltage will also vary sinusoidal.

EARLY Effect (Base-width modulation)

As the voltages applied to the base-emitter and base-collector junctions are changed, the depletion layer widths and the quasi-neutral regions vary as well. This causes the collector current to vary with the collector-emitter voltage as illustrated in Figure 2.1.2

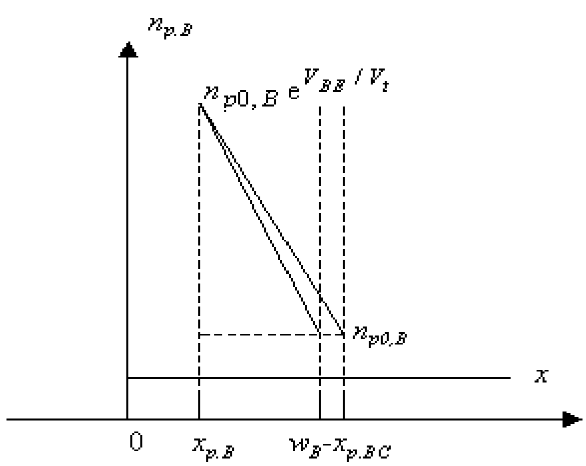

Figure 2.1.2 Variation of the minority-carrier distribution

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A variation of the base-collector voltage results in a variation of the quasi-neutral width in the base. The gradient of the minority-carrier density in the base therefore changes, yielding an increased collector current as the collector-base current is increased. This effect is referred to as the Early effect. The Early effect is observed as an increase in the collector current with increasing collector-emitter voltage .The Early voltage, VA, is obtained by drawing a line tangential to the transistor I-V characteristic at the point of interest. The Early voltage equals the horizontal distance between the point chosen on the I-V characteristics in the figure 2.1.3.

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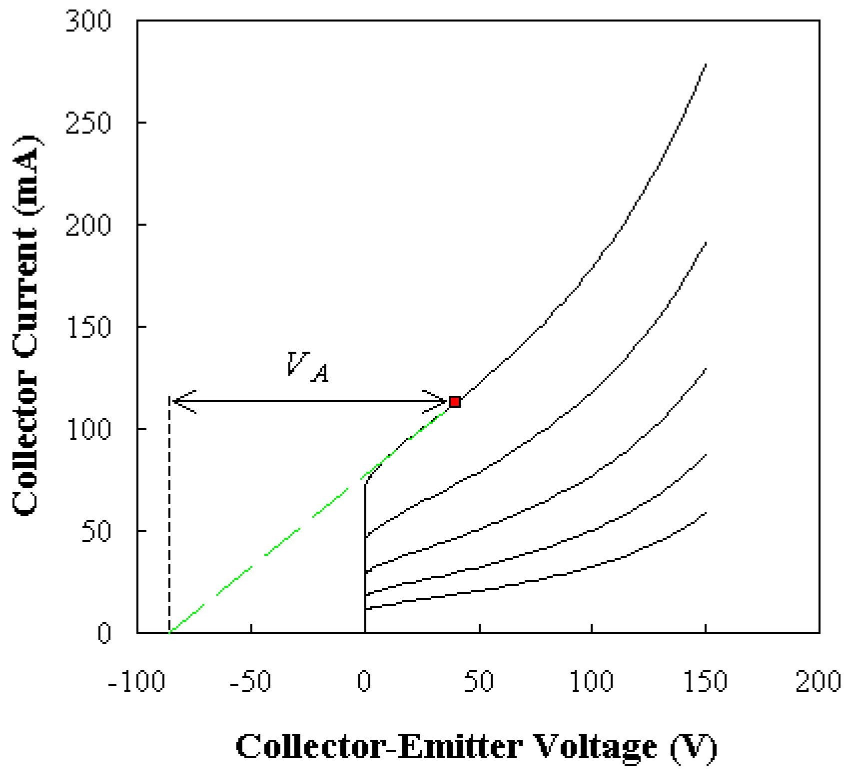

Figure 2.1.3 Collector current increase with an increase of the collector-emitter voltage

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The change of the collector current when changing the collector-emitter voltage is primarily due to the variation of the base-collector voltage, since the base-emitter junction is forward biased and a constant base current is applied. The collector current depends on the base-collector voltage since the base-collector depletion layer width varies, which also causes the quasi-neutral width, wB', in the base to vary in te figure 2.1.3 .

. The collector current depends on the base-collector voltage since the base-collector depletion layer width varies, which also causes the quasi-neutral width, $w_B{}'$, in the base to vary. This variation can be calculated for a piece-wise uniformly-doped transistor using the ideal transistor mode as described by equations given below.

$$\frac{dI_C}{dV_{CE}} \cong -\frac{dI_C}{dV_{BC}} = \frac{I_C}{w_B^{'}} \frac{dw_B^{'}}{dV_{BC}}$$

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