

ECE 342

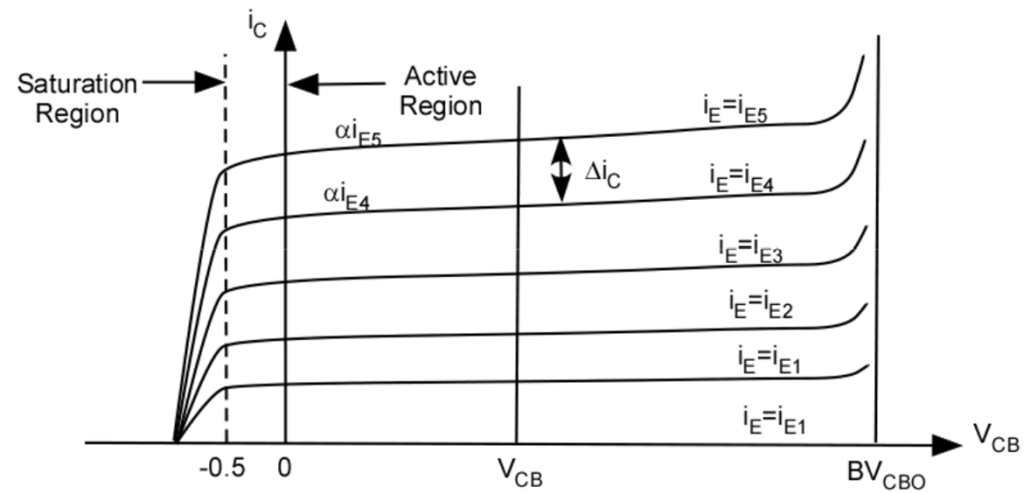
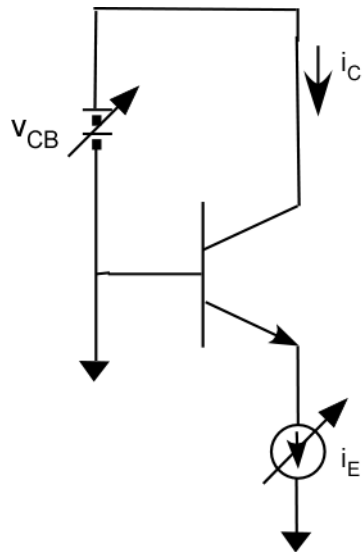
Electronic Circuits

Lecture 16

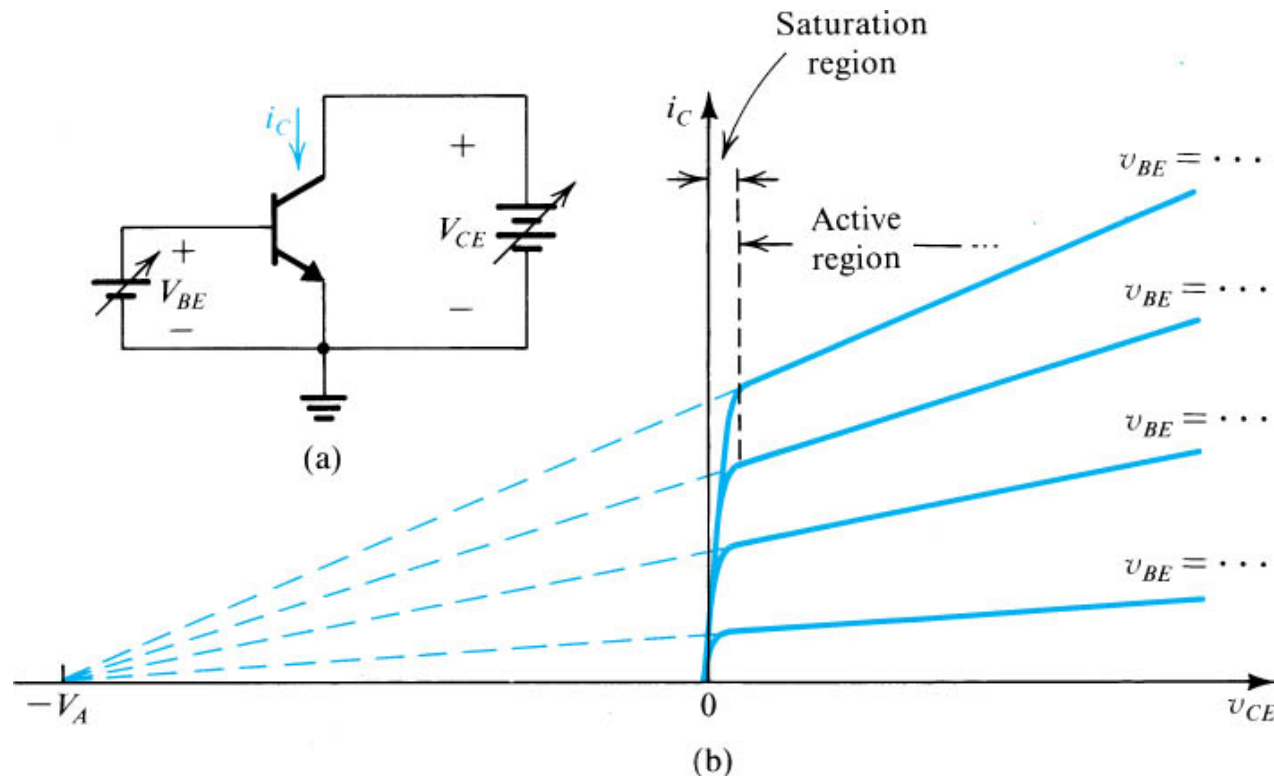
BJT – Small Signal Analysis

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Common Emitter I-V Characteristics



Early Voltage



- **Early Voltage V_A**
 - Dependence of collector current on collector voltage
 - Increasing V_{CE} increases the width of the depletion region

Output Resistance

r_o is output resistance seen from collector terminal

$$i_C = I_S e^{v_{BE}/V_T} \left(1 + \frac{v_{CE}}{V_A} \right)$$

$$r_o = \left[\frac{\partial i_C}{\partial v_{CE}} \Big|_{v_{BE} = \text{constant}} \right]^{-1}$$

$$r_o = \frac{V_A + V_{CE}}{I_C}$$

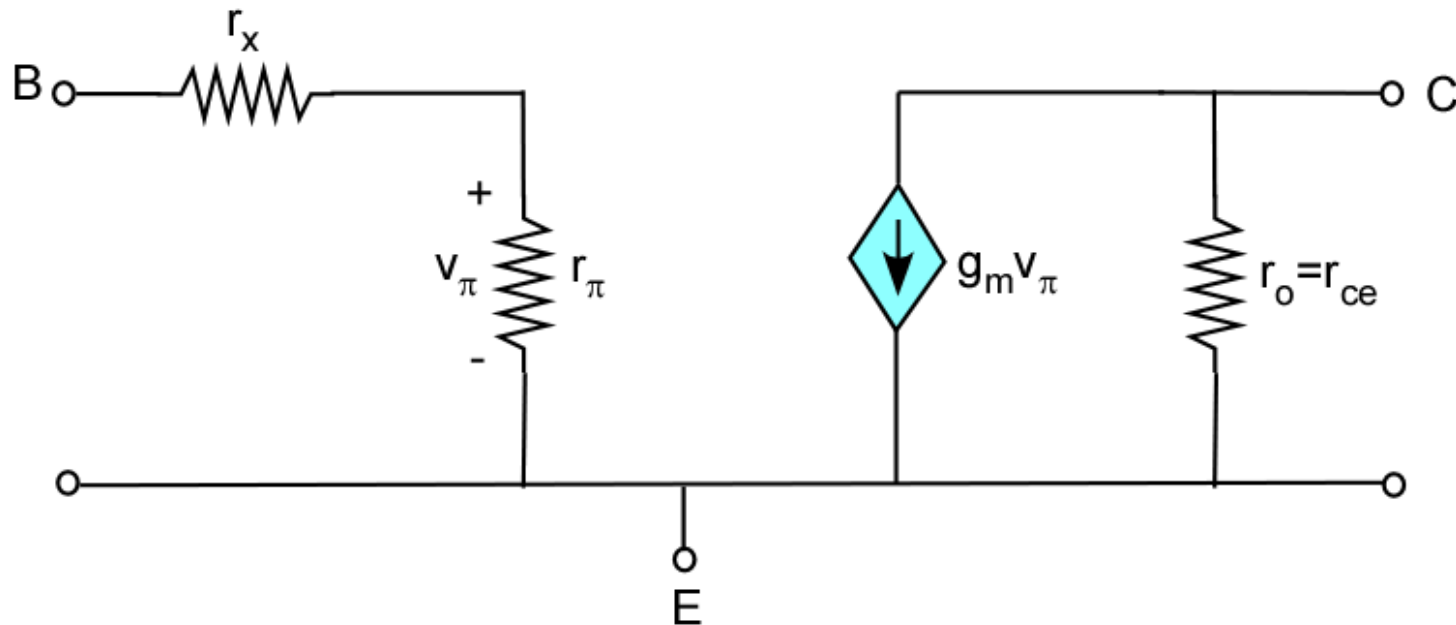
Alternatively, neglecting the Early effect on the collector current, we define

$$I'_C = I_S e^{v_{BE}/V_T}$$

The output resistance then becomes

$$r_o = \frac{V_A}{I'_C}$$

Hybrid- π Incremental Model for BJTs



r_{π} : input resistance looking into the base

r_x : parasitic series resistance looking into base – ohmic base resistance

g_m : BJT transconductance

$r_o=r_{ce}$: output collector resistance related to the Early effect

Hybrid- π Parameters

$$g_m = \left. \frac{\partial i_C}{\partial v_{BE}} \right|_{I_C = \text{constant}} = \frac{I_C}{V_T}$$

r_π is defined as: $r_\pi = \frac{v_\pi}{i_b}$

Since $i_b = \frac{g_m v_\pi}{\beta}$ then $r_\pi = \frac{\beta}{g_m}$

Can show that

$$r_\pi = (\beta + 1) r_e$$

$$g_m = \frac{\alpha}{r_e}$$

$$\beta = g_m r_\pi$$

$r_{ce} = r_o$ is associated with the Early effect

$$r_{ce} = r_o = \frac{|V_A|}{I_C} = \frac{|V_A|}{\beta I_B}$$

$$g_m + \frac{1}{r_\pi} = \frac{1}{r_e}$$

Common Emitter Configuration

The emitter current I_E can be approximated as:

$$I_E \approx I_S e^{V_{BE}/V_T}$$

An incremental conductance g_e can be defined as

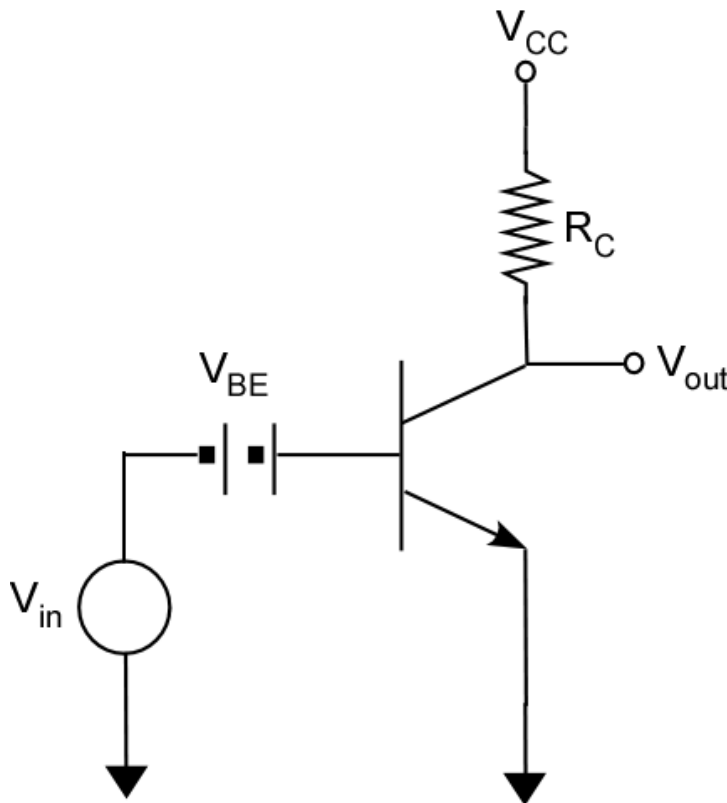
$$g_e \equiv \frac{\partial I_E}{\partial V_{BE}} = \frac{I_S}{V_T} e^{V_{BE}/V_T} = \frac{I_E}{V_T}$$

From which we get:

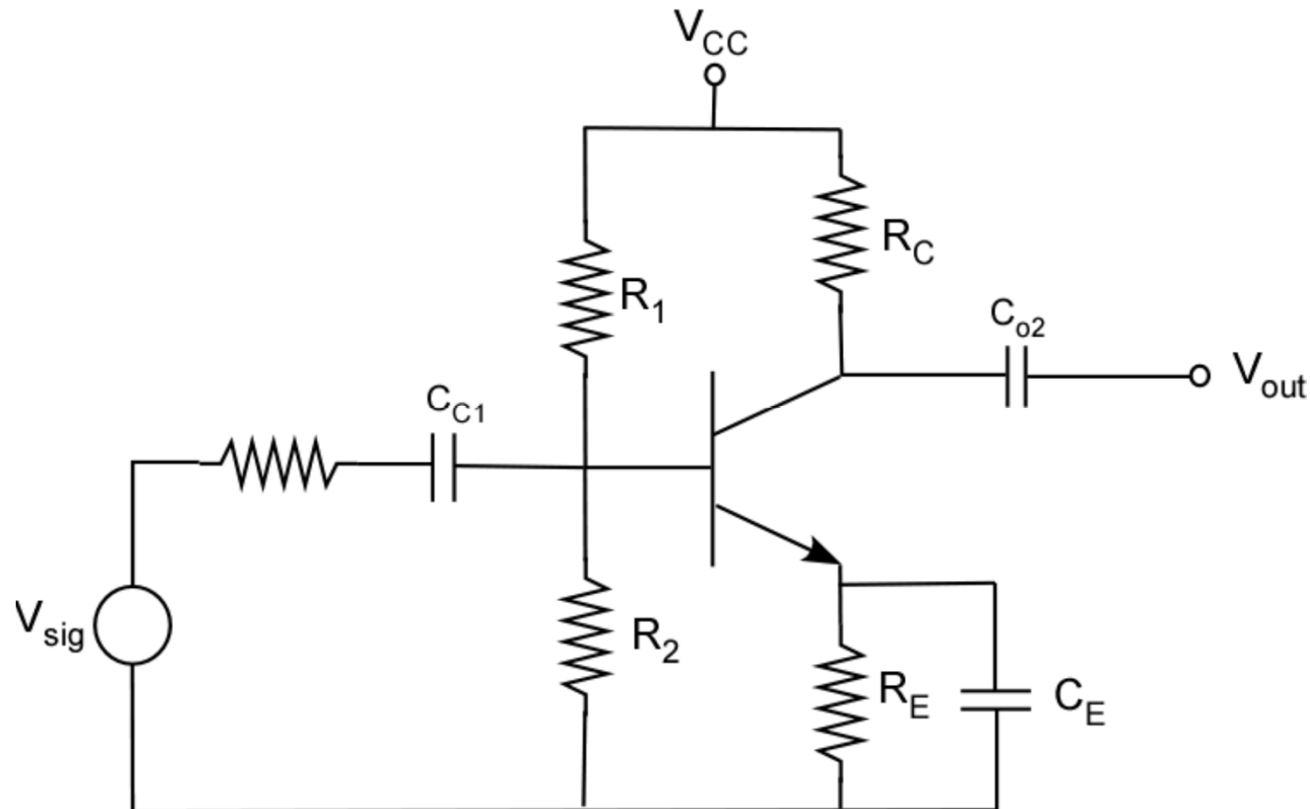
$$r_e = \frac{1}{g_e} = \frac{V_T}{I_E}$$

Emitter resistance

$$\text{Usually, } V_T = 26 \text{ mV} \Rightarrow r_e = \frac{26 \text{ mV}}{I_E}$$



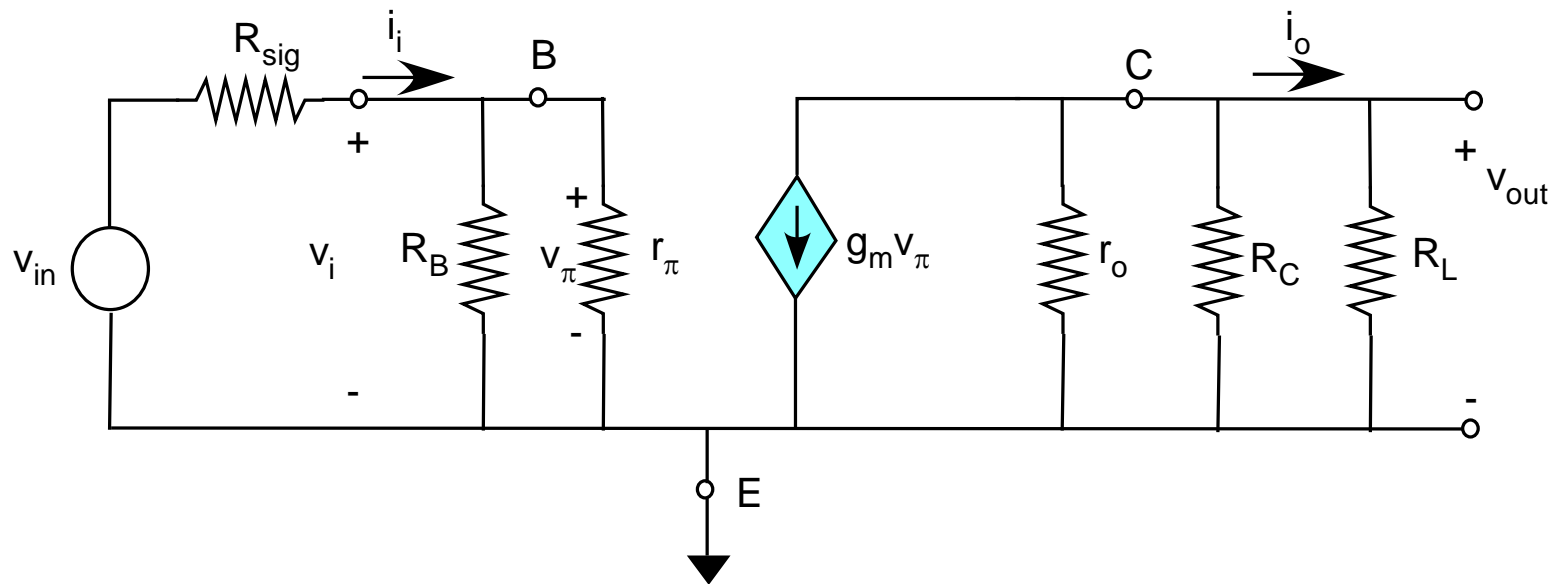
Common Emitter (CE) Amplifier



Bias: Choose R_1 & R_2 to set $V_B \rightarrow V_E$ is then set. Choose R_E to set $I_E \sim I_C$.
Quiescent point of V_{out} will be determined by R_C . Emitter is an AC short.

Incremental Model for CE Amplifier

Hybrid- π model (ignoring r_x)



$$R_B = R_1 \parallel R_2$$

$$R_{in} = \frac{v_i}{i_i} = R_B \parallel r_\pi$$

Sometimes $R_B \gg r_\pi$ and $R_{in} \approx r_\pi$