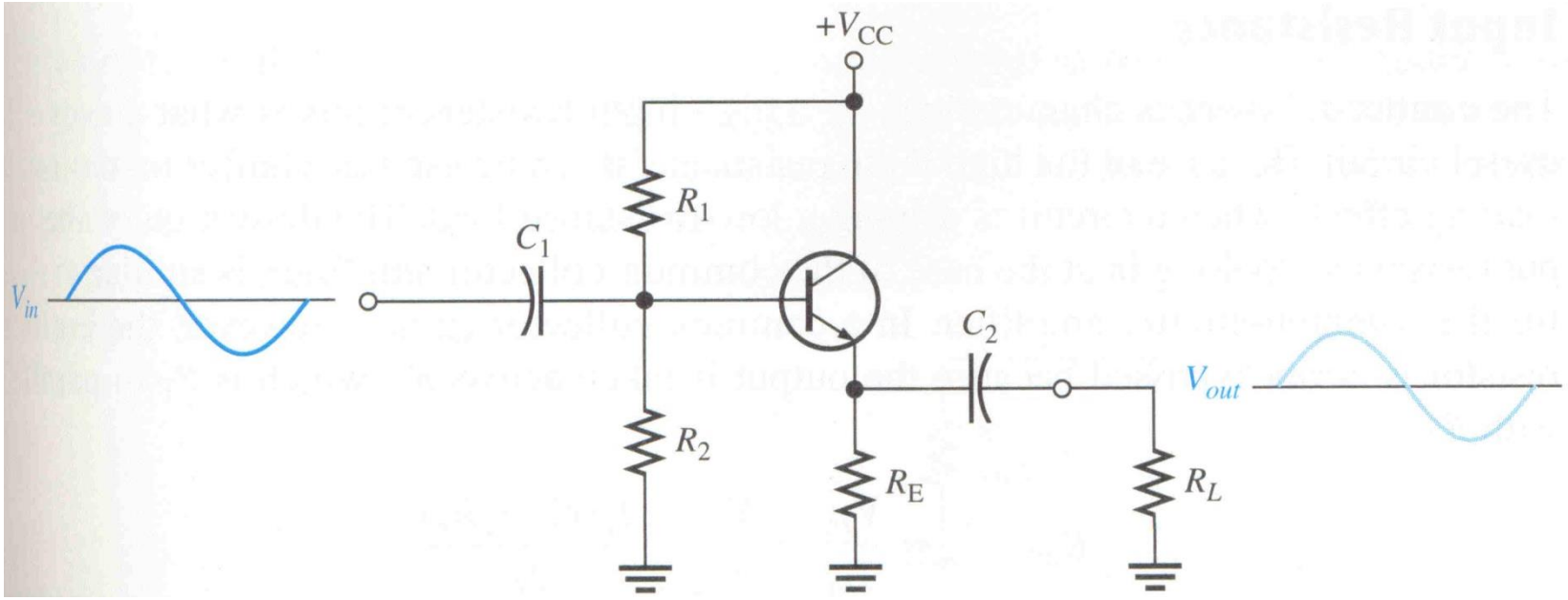
Lecture 28: Bipolar Amplifiers (2)

Common Emitter Amplifier, Input Resistance, Output Resistance, Voltage Gain, Current and Power Gains, Examples

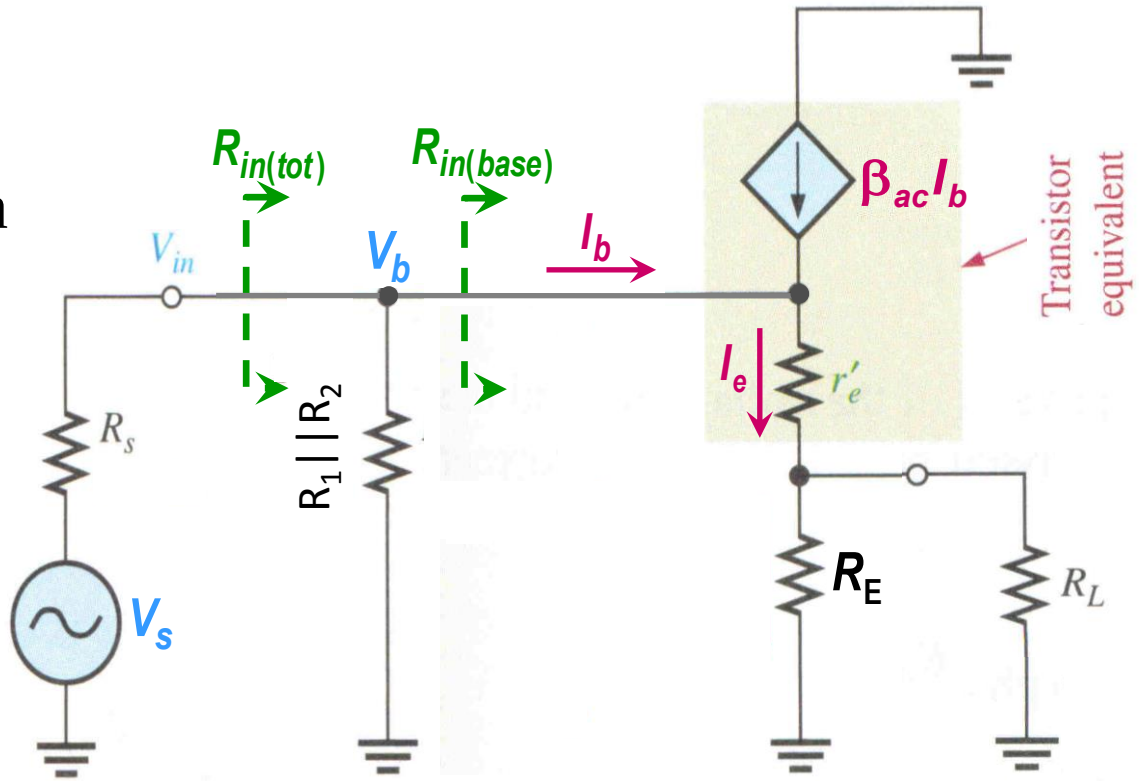
Common Collector Amplifier



For the common-collector (CC) amplifier there is no phase shift between V_{in} and V_{out}.

Input Resistance

the input resistance seen at the base of the BJT is:



$$R_{in(base)} = \frac{V_b}{I_b}$$

$$= \frac{I_e \left[r'_e + \left(R_E \| R_L \right) \right]}{I_b}$$

$$\therefore R_{in(base)} = \beta_{ac} \left[r'_e + \left(R_E \| R_L \right) \right]$$

$$\cong \beta_{ac} \left(R_E \| R_L \right) >> R_{in(base)}\Big|_{CE}$$

input impedance seen at the input port $R_{in(tot)} = R_1 \| R_2 \| R_{in(base)}$

Output Resistance

$$V_{out} = I_1 R_E$$

$$= I_e r_e' + I_b \left(R_s \| R_1 \| R_2 \right)$$

$$\cong I_e r_e' + \frac{I_e}{\beta_{ac}} \left(R_s \| R_1 \| R_2 \right)$$

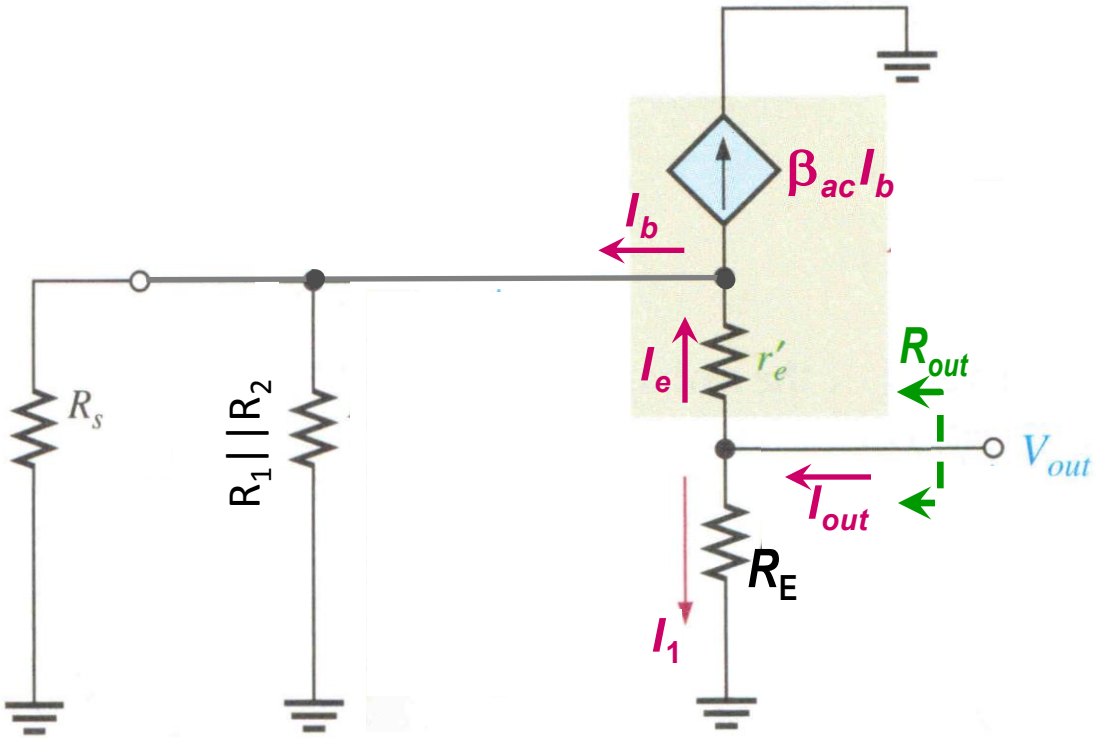
$$= I_e \left[r_e' + \frac{\left(R_s \| R_1 \| R_2 \right)}{\beta_{ac}} \right]$$

$$I_{out} = I_1 + I_e$$

$$= \frac{V_{out}}{R_E} + \frac{V_{out}}{r_e' + \left[\left(R_s \| R_1 \| R_2 \right) / \beta_{ac} \right]}$$

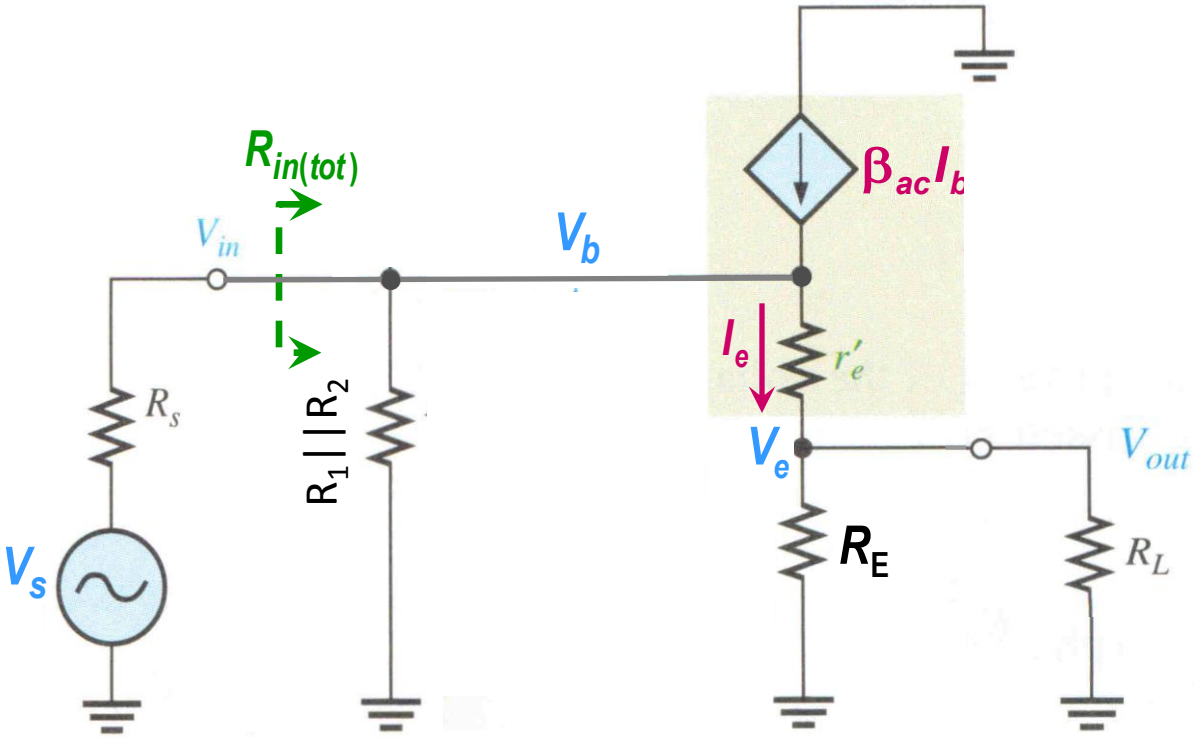
$$\frac{1}{R_{out}} = \frac{I_{out}}{V_{out}}\bigg|_{V_s \to \text{s.c.}} = \frac{1}{R_E} + \frac{1}{r_e' + \left[\left(R_s \| R_1 \| R_2 \right) / \beta_{ac} \right]}$$

$$\therefore R_{out} = R_E \left\| \left\{ r_e' + \left[\left(R_s \| R_1 \| R_2 \right) / \beta_{ac} \right] \right\} \cong R_E \left\| \left[r_e' + \left(R_s / \beta_{ac} \right) \right] \cong r_e' + \left(R_s / \beta_{ac} \right) << R_{out} \right|_{CE}$$



Voltage Gain

The ideal voltage gain of the CC amplifier can be expressed as follows:

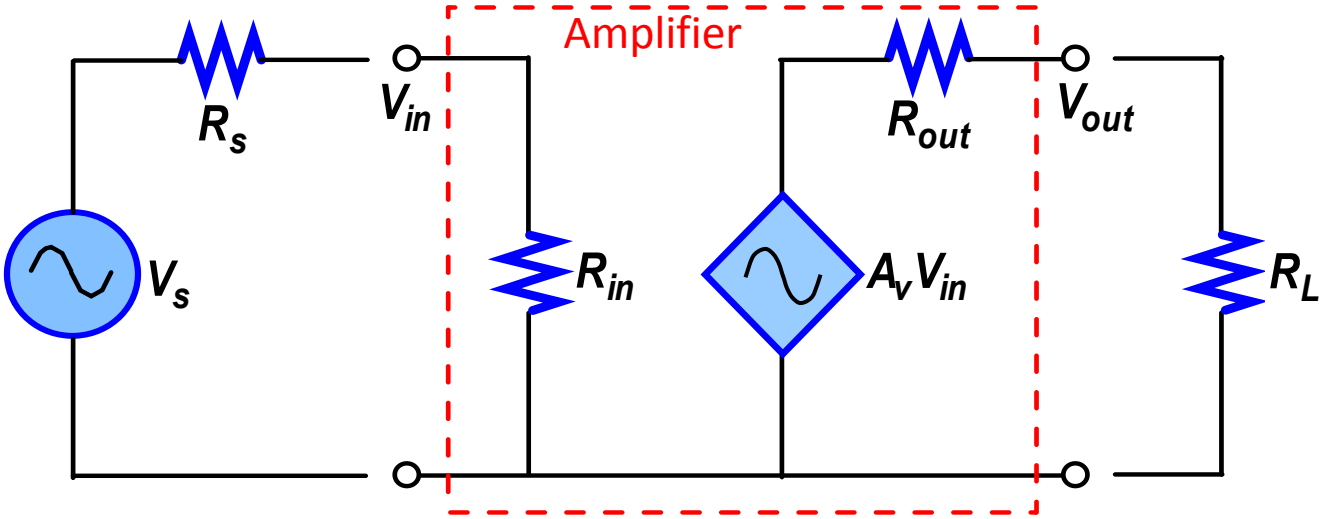


$$A_v \equiv \text{ideal voltage gain} = \frac{V_e}{V_b}$$

$$= \frac{I_e\left(R_E \| R_L\right)}{I_e\left[\, r'_e + \left(R_E \| R_L\right)\,\right]} = \frac{R_E \| R_L}{r'_e + \left(R_E \| R_L\right)} \Rightarrow A_v\Big|_{\left(R_E \| R_L\right) >> r'_e} \cong 1$$

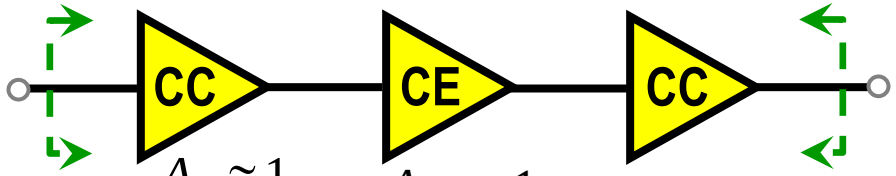
$$A'_v \equiv \text{overall gain} = \frac{V_e}{V_s} = \frac{V_e}{V_b}\frac{V_b}{V_s} = \frac{A_v}{\eta}, \quad \eta = \frac{V_s}{V_b} = \frac{R_s + R_{in(tot)}}{R_{in(tot)}}$$

Combination of CC and CE Amplifiers



$$V_{in} = V_s \frac{R_{in}}{R_s + R_{in}} \qquad V_{out} = A_v V_{in} \frac{R_L}{R_{out} + R_L}$$

$$V_{in(\max)}\Big|_{R_{in}=\infty} = V_s \qquad V_{out(\max)}\Big|_{R_{out}=0} = A_v V_{in}$$



large R_{in} small R_{out}

Current and Power Gains of the CC Amplifier

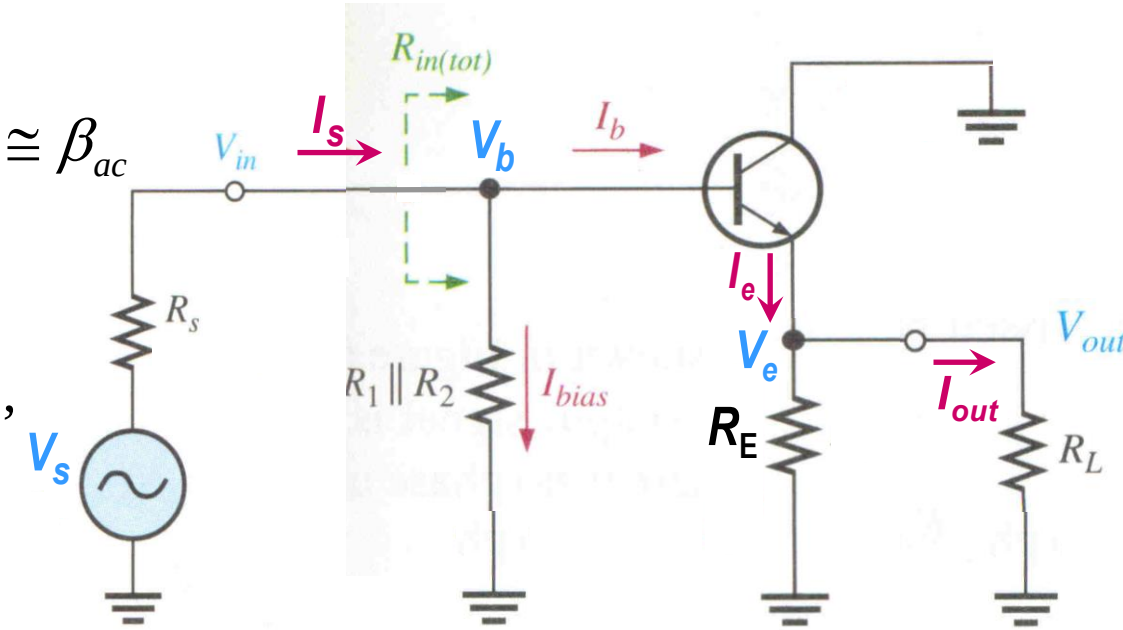
ideal current gain of the CC amplifier is:

$$A_i \equiv \text{ideal current gain} = \frac{I_e}{I_b} \cong \beta_{ac}$$

overall current gain

$$A_i' \equiv \text{overall current gain} = \frac{I_{out}}{I_s},$$

$$I_{out} = \frac{V_e}{R_L}, \quad I_s = \frac{V_s}{R_s + R_{in(tot)}}$$



overall power gain:

$$A_p' \equiv \text{overall power gain} = \frac{\text{output power}}{\text{input power}} = \frac{V_e\ I_{out}}{V_s\ I_s} = \left(\frac{V_e}{V_s}\right)\left(\frac{I_{out}}{I_s}\right) = A_v'\ A_i'$$

CC Amplifier Summary

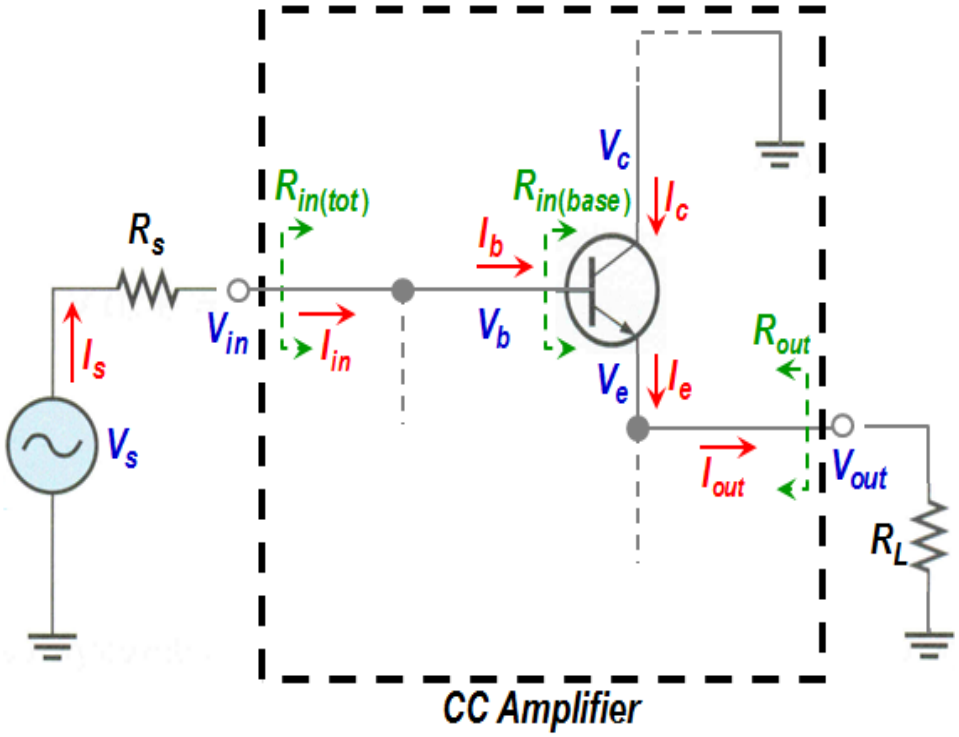
$$R_{in(base)} = \frac{V_b}{I_b}, \quad R_{in(tot)} = \frac{V_{in}}{I_{in}} = \frac{V_b}{I_s}$$

$$R_{out} = \left.\frac{V_{out}}{I_{out}}\right|_{V_s \to \text{s.c.}}$$

$$A_v = \frac{V_e}{V_b}, \quad A_v' = \frac{V_e}{V_s}$$

$$\eta \equiv \frac{A_v}{A_v'} = \frac{V_s}{V_b} = \frac{R_s + R_{in(tot)}}{R_{in(tot)}} \geq 1$$

$$A_i = \frac{I_e}{I_b} \cong \beta_{ac}, \quad A_i' = \frac{I_{out}}{I_s}$$



CE versus CC Amplifier

Attribute	CE	CC
R_{in}	Medium	Large
R_{out}	Medium	Small
A_v	Large	1
$\Delta\phi(V_{out}, V_{in})$	180^o	0^o
A_i	Large	Large
A_p	Very Large	Large