ECE 312
Electronic Circuits (A)

Lec. 8: BJT Modeling and re Transistor Model (small signal analysis) (3)

Instructor

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Agenda

- Effect of R_L and R_s (System approach)
- Determining the Current Gain
- Summary Table

Effect of R_L and R_S (System Approach)

Effect of R_L and R_s

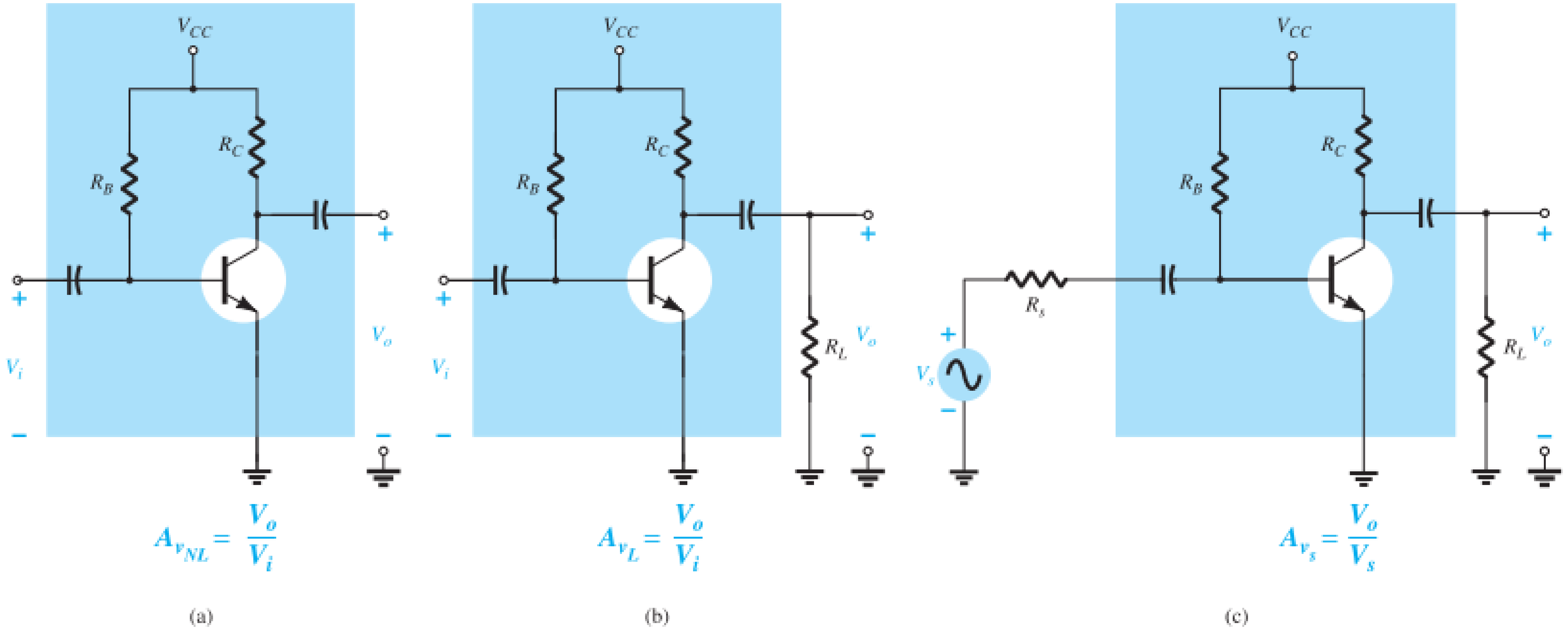
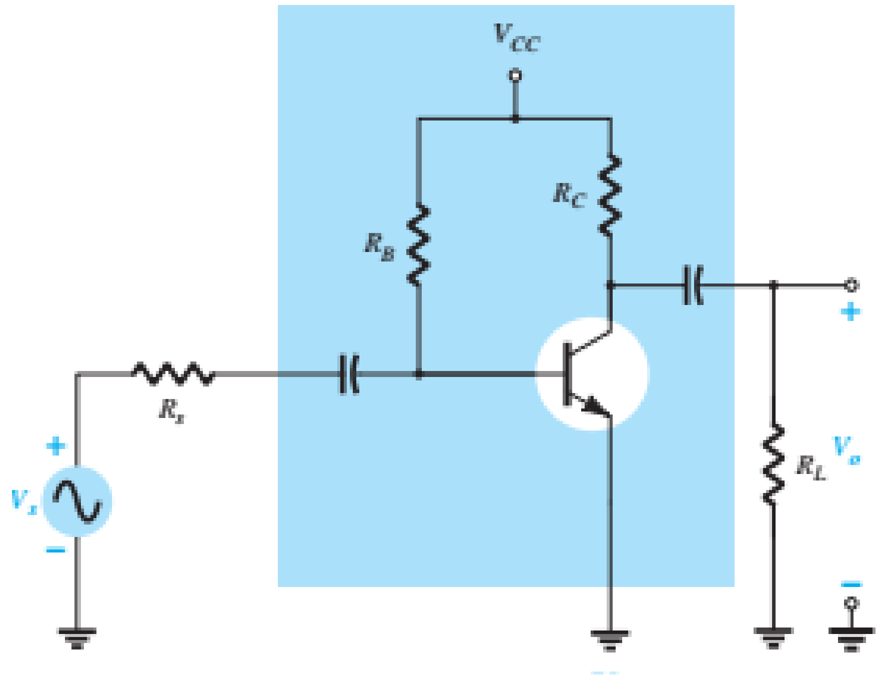


FIG. 5.54

Amplifier configurations: (a) unloaded; (b) loaded; (c) loaded with a source resistance.

Effect of R_L and R_s

- The loaded voltage gain of an amplifier is always less than the no-load gain.
- The gain obtained with a source resistance in place will always be less than that obtained under loaded or unloaded conditions due to the drop in applied voltage across the source resistance.
- For the same configuration $A_{vNL} > A_{vL} > A_{vs}$.
- RL ↑ → AVS ↑
- RS ↓ → AVS ↑
- For any network that have coupling capacitors, the source and load resistance do not affect the dc biasing levels.



Effect of R_L and R_s ..

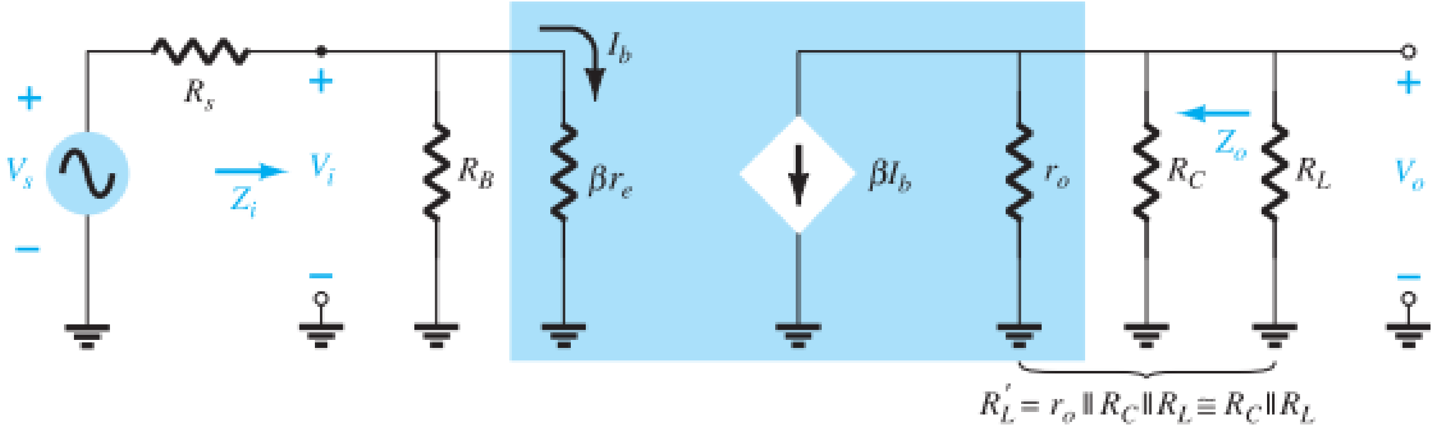


FIG. 5.55
The ac equivalent network for the network of Fig. 5.54c.

$$R'_L = r_o \| R_C \| R_L \cong R_C \| R_L$$

$$V_o = -\beta I_b R'_L = -\beta I_b (R_C \| R_L)$$

$$I_b = \frac{V_i}{\beta r_e}$$

$$V_o = -\beta\left(\frac{V_i}{\beta r_e}\right)(R_C \| R_L)$$

$$A_{v_L} = \frac{V_o}{V_i} = -\frac{R_C \| R_L}{r_e}$$

$$Z_i = R_B \| \beta r_e$$

$$Z_o = R_C \| r_o$$

$$V_i = \frac{Z_i V_s}{Z_i + R_s}$$

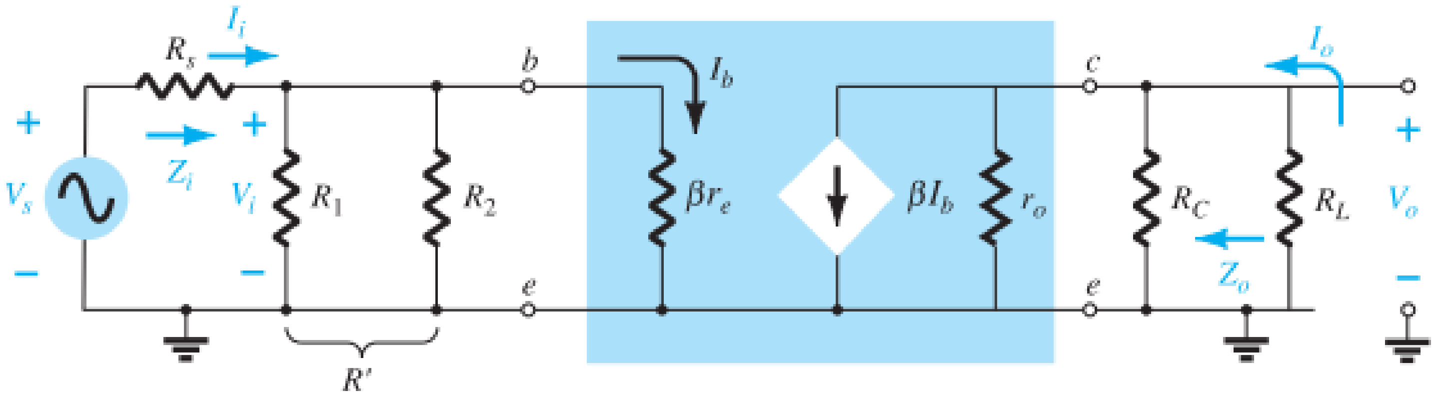
$$\frac{V_i}{V_s} = \frac{Z_i}{Z_i + R_s}$$

$$A_{v_S} = \frac{V_o}{V_s} = \frac{V_o}{V_i} \cdot \frac{V_i}{V_s} = A_{v_L} \frac{Z_i}{Z_i + R_s}$$

$$A_{v_S} = \frac{Z_i}{Z_i + R_s} A_{v_L}$$

Effect of R_L and R_s ..

Voltage-divider ct.

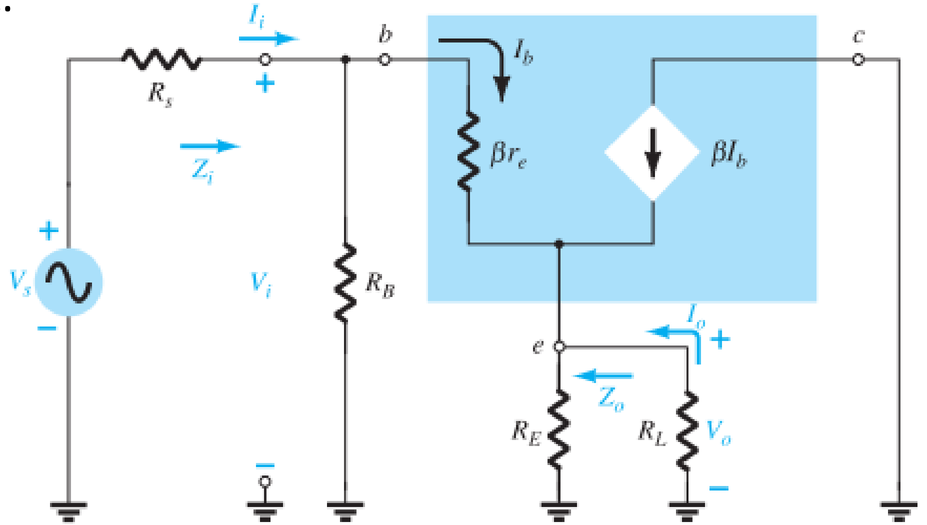


$$A_{v_L} = \frac{V_o}{V_i} = -\frac{R_C \| R_L}{r_e}$$

$$Z_i = R_1 \| R_2 \| \beta r_e$$

$$Z_o = R_C \| r_o$$

Emitter-Follower Ct.



$$A_{v_L} = \frac{V_o}{V_i} = \frac{R_E \| R_L}{R_E \| R_L + r_e}$$

$$Z_i = R_B \| Z_b$$

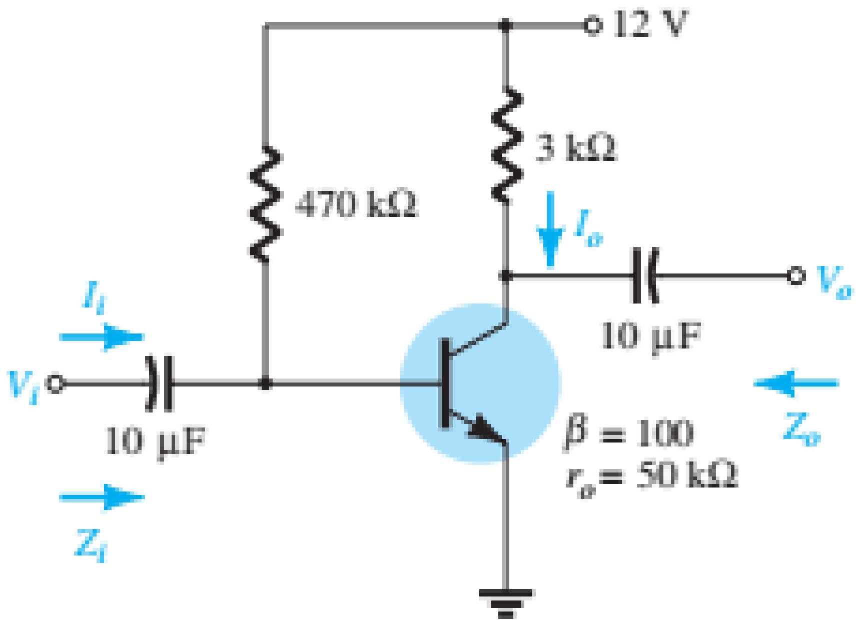
$$Z_b \cong \beta (R_E \| R_L)$$

$$Z_o \cong r_e$$

Effect of R_L and R_s (Example)

EXAMPLE 5.11 Using the parameter values for the fixed-bias configuration of Example 5.1 with an applied load of 4.7 kΩ and a source resistance of 0.3 kΩ, determine the following and compare to the no-load values:

a. A_{v_L}.
b. A_{v_s}.
c. Z_i.
d. Z_o.



Solution:

a. Eq. (5.73): $A_{v_L} = -\frac{R_C \| R_L}{r_e} = -\frac{3\text{ k}\Omega \| 4.7\text{ k}\Omega}{10.71\ \Omega} = -\frac{1.831\text{ k}\Omega}{10.71\ \Omega} = \mathbf{-170.98}$

which is significantly less than the no-load gain of −280.11.

b. Eq. (5.76): $A_{v_s} = \frac{Z_i}{Z_i + R_s} A_{v_L}$

With $Z_i = 1.07$ kΩ from Example 5.1, we have

$$A_{v_s} = \frac{1.07\text{ k}\Omega}{1.07\text{ k}\Omega + 0.3\text{ k}\Omega}(-170.98) = \mathbf{-133.54}$$

which again is significantly less than $A_{v_{NL}}$ or A_{v_L}.

c. $Z_i = \mathbf{1.07\ k\Omega}$ as obtained for the no-load situation.

d. $Z_o = R_C = \mathbf{3\ k\Omega}$ as obtained for the no-load situation.

The example clearly demonstrates that $A_{v_{NL}} > A_{v_L} > A_{v_s}$.

Determining the Current Gain

Determining the Current gain

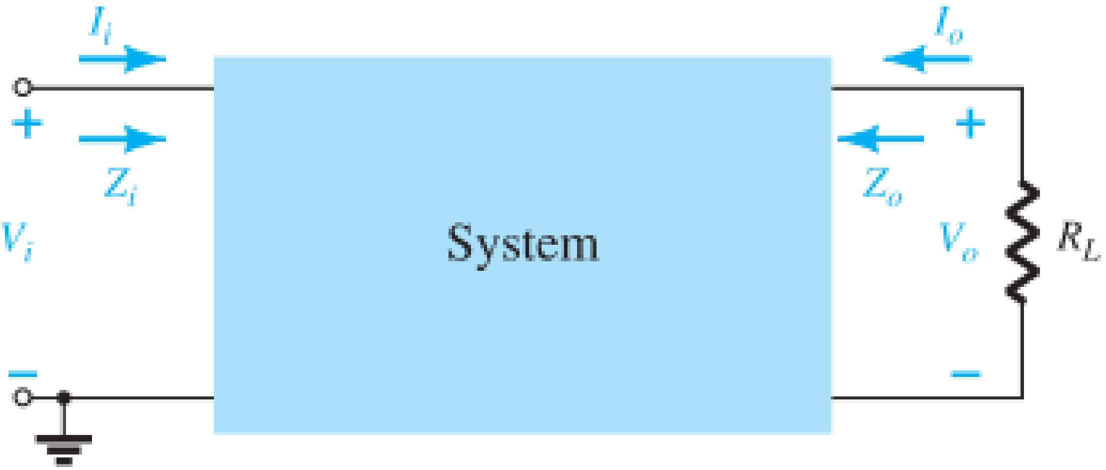


FIG. 5.60
Determining the current gain using the voltage gain.

$$A_i = \frac{I_o}{I_i}$$

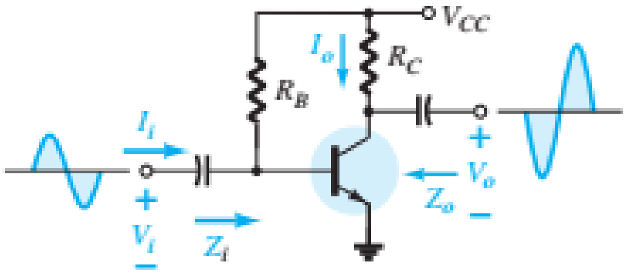
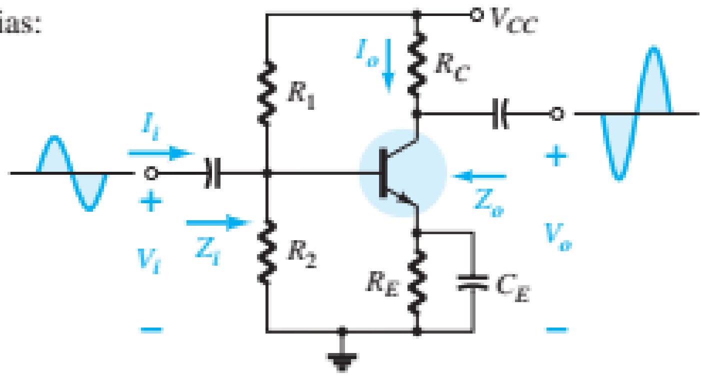
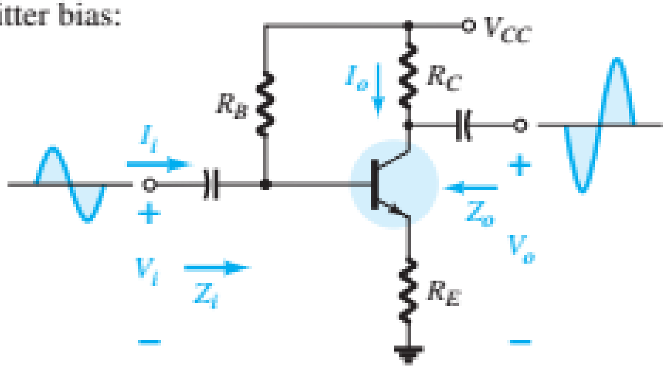
$$I_i = \frac{V_i}{Z_i} \quad \text{and} \quad I_o = -\frac{V_o}{R_L}$$

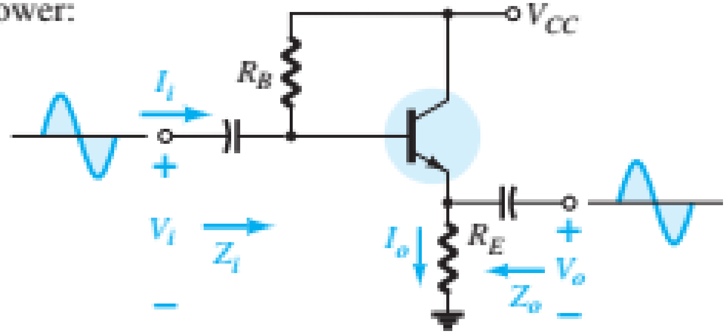
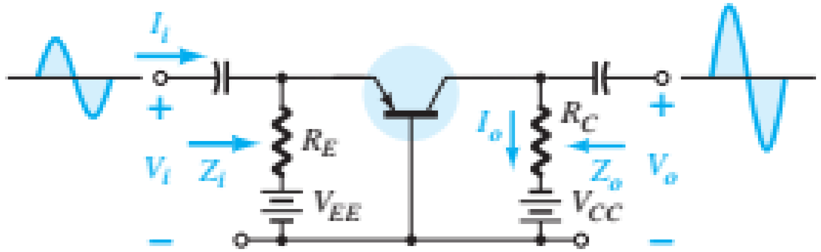
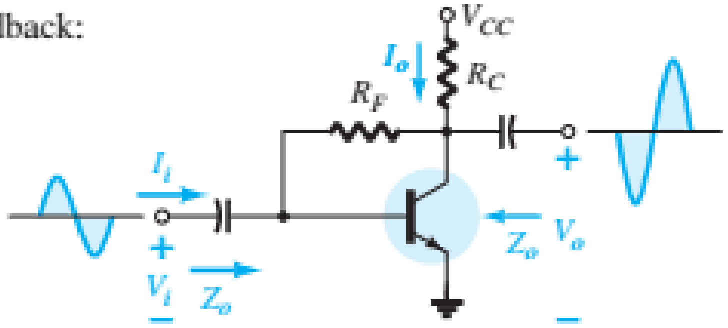
$$A_{i_L} = \frac{I_o}{I_i} = \frac{-\dfrac{V_o}{R_L}}{\dfrac{V_i}{Z_i}} = -\frac{V_o}{V_i} \cdot \frac{Z_i}{R_L}$$

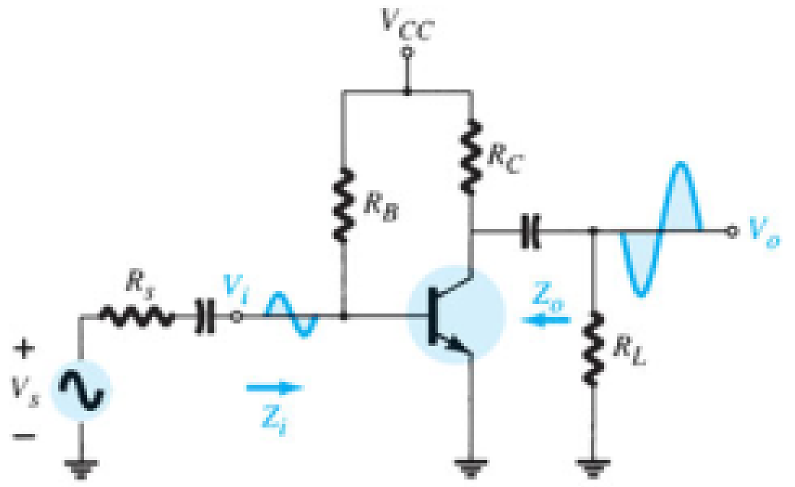
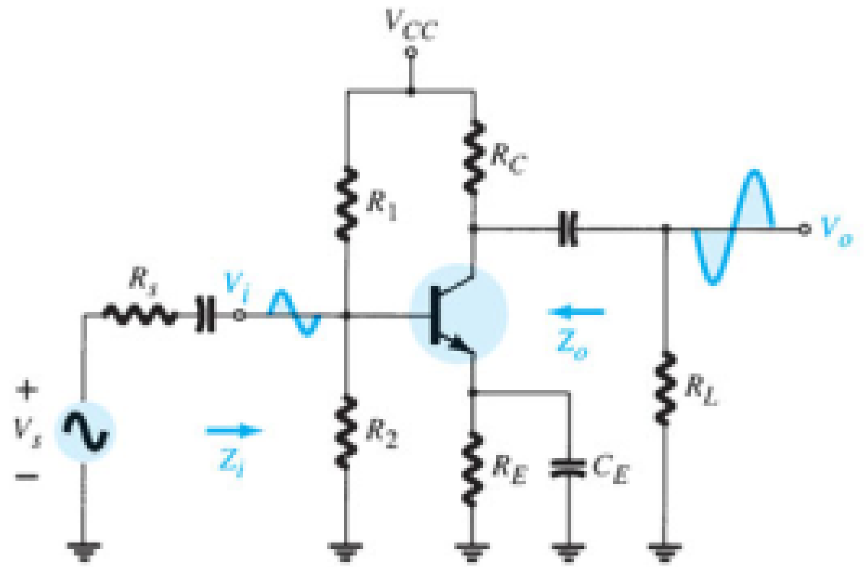
$$A_{i_L} = -A_{v_L}\frac{Z_i}{R_L}$$

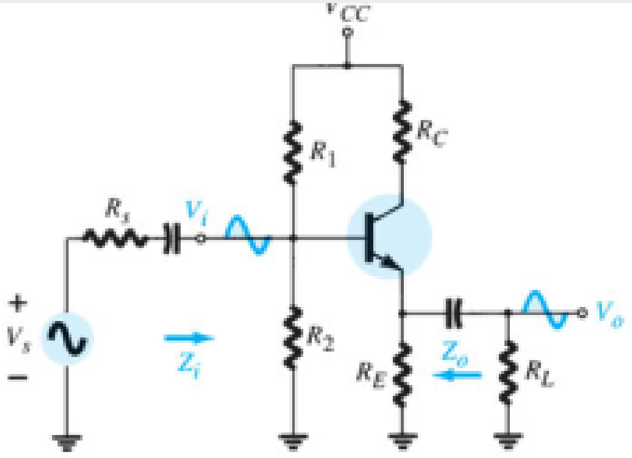
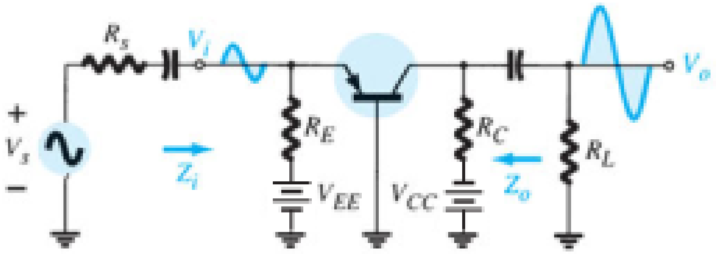
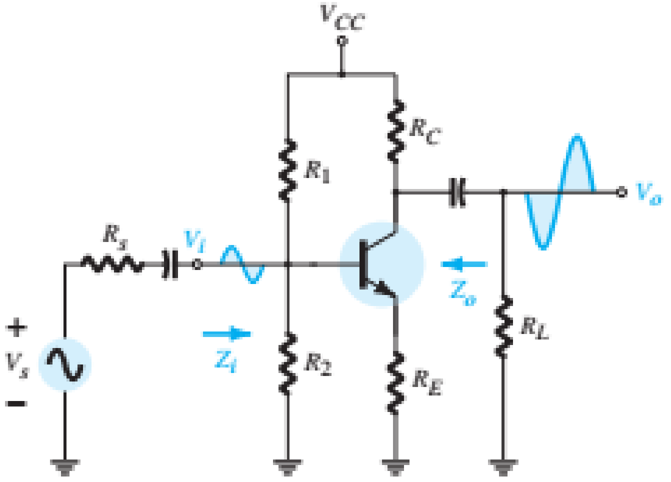
- For each transistor configuration, the current gain can be determined directly from the voltage gain, the defined load, and the input impedance.

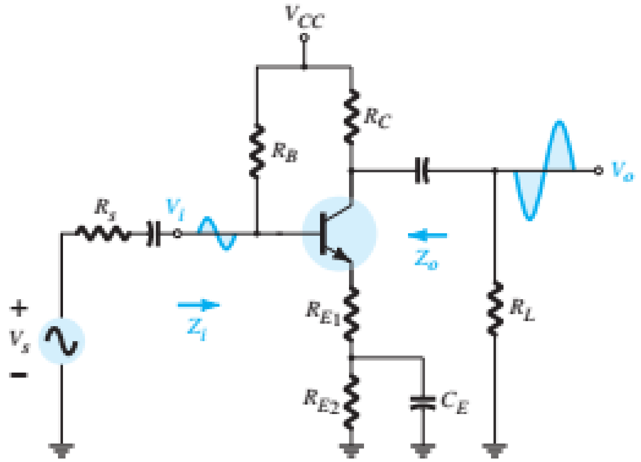
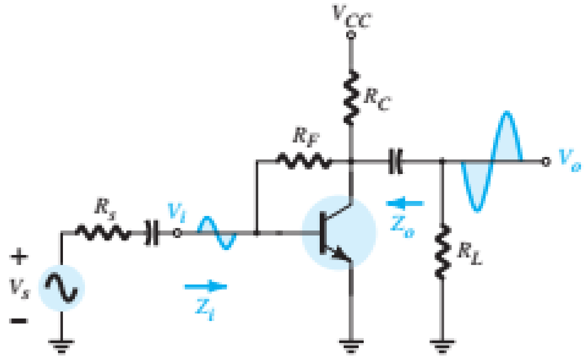
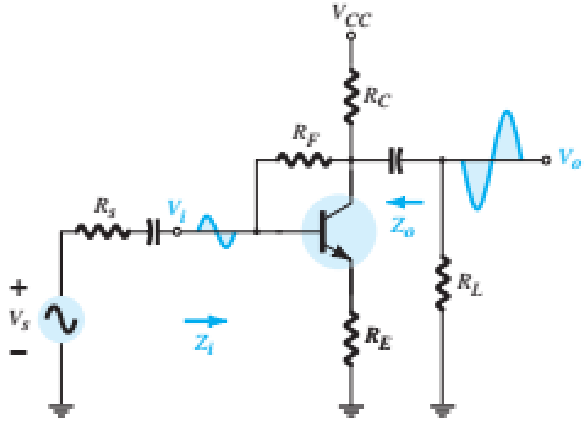
Summary Table

Configuration	Z_i	Z_o	A_v	A_i
Fixed-bias:  	Medium (1 kΩ) $= R_B \| \beta r_e$ $\cong \beta r_e$ $(R_B \geq 10\beta r_e)$	Medium (2 kΩ) $= R_C \| r_o$ $\cong R_C$ $(r_o \geq 10R_C)$	High (−200) $= -\frac{(R_C \| r_o)}{r_e}$ $\cong -\frac{R_C}{r_e}$ $(r_o \geq 10R_C)$	High (100) $= \frac{\beta R_B r_o}{(r_o + R_C)(R_B + \beta r_e)}$ $\cong \beta$ $(r_o \geq 10R_C,$ $R_B \geq 10\beta r_e)$
Voltage-divider bias:  	Medium (1 kΩ) $= R_1 \| R_2 \| \beta r_e$	Medium (2 kΩ) $= R_C \| r_o$ $\cong R_C$ $(r_o \geq 10R_C)$	High (−200) $= -\frac{R_C \| r_o}{r_e}$ $\cong -\frac{R_C}{r_e}$ $(r_o \geq 10R_C)$	High (50) $= \frac{\beta(R_1 \| R_2) r_o}{(r_o + R_C)(R_1 \| R_2 + \beta r_e)}$ $\cong \frac{\beta(R_1 \| R_2)}{R_1 \| R_2 + \beta r_e}$ $(r_o \geq 10R_C)$
Unbypassed emitter bias:  	High (100 kΩ) $= R_B \| Z_b$ $Z_b \cong \beta(r_e + R_E)$ $\cong R_B \| \beta R_E$ $(R_E \gg r_e)$	Medium (2 kΩ) $= R_C$ (any level of r_o)	Low (−5) $= -\frac{R_C}{r_e + R_E}$ $\cong -\frac{R_C}{R_E}$ $(R_E \gg r_e)$	High (50) $\cong -\frac{\beta R_B}{R_B + Z_b}$

Configuration	Z_i	Z_o	A_v	A_i
Emitter-follower: 	High (100 kΩ) $= R_B \| Z_b$ $Z_b \cong \beta(r_e + R_E)$ $\cong R_B \| \beta R_E$ $(R_E \gg r_e)$	Low (20 Ω) $= R_E \| r_e$ $\cong r_e$ $(R_E \gg r_e)$	Low (≅1) $= \frac{R_E}{R_E + r_e}$ $\cong 1$	High (−50) $\cong -\frac{\beta R_B}{R_B + Z_b}$
Common-base: 	Low (20 Ω) $= R_E \| r_e$ $\cong r_e$ $(R_E \gg r_e)$	Medium (2 kΩ) $= R_C$	High (200) $\cong \frac{R_C}{r_e}$	Low (−1) $\cong -1$
Collector feedback: 	Medium (1 kΩ) $= \frac{r_e}{\frac{1}{\beta} + \frac{R_C}{R_F}}$ $(r_o \geq 10R_C)$	Medium (2 kΩ) $\cong R_C \| R_F$ $(r_o \geq 10R_C)$	High (−200) $\cong -\frac{R_C}{r_e}$ $(r_o \geq 10R_C)$ $(R_F \gg R_C)$	High (50) $= \frac{\beta R_F}{R_F + \beta R_C}$ $\cong \frac{R_F}{R_C}$

Configuration	$A_{v_L} = V_o/V_i$	Z_i	Z_o
	$\dfrac{-(R_L \parallel R_C)}{r_e}$	$R_B \parallel \beta r_e$	R_C
	Including r_o: $-\dfrac{(R_L \parallel R_C \parallel r_o)}{r_e}$	$R_B \parallel \beta r_e$	$R_C \parallel r_o$
	$\dfrac{-(R_L \parallel R_C)}{r_e}$	$R_1 \parallel R_2 \parallel \beta r_e$	R_C
	Including r_o: $\dfrac{-(R_L \parallel R_C \parallel r_o)}{r_e}$	$R_1 \parallel R_2 \parallel \beta r_e$	$R_C \parallel r_o$

Configuration	$A_{v_L} = V_o/V_i$	Z_i	Z_o
	$\cong 1$	$R'_E = R_L \| R_E$ $R_1 \| R_2 \| \beta(r_e + R'_E)$	$R'_s = R_s \| R_1 \| R_2$ $R_E \| \left(\frac{R'_s}{\beta} + r_e\right)$
	Including r_o: $\cong 1$	$R_1 \| R_2 \| \beta(r_e + R'_E)$	$R_E \| \left(\frac{R'_s}{\beta} + r_e\right)$
	$\cong \frac{-(R_L \| R_C)}{r_e}$	$R_E \| r_e$	R_C
	Including r_o: $\cong \frac{-(R_L \| R_C \| r_o)}{r_e}$	$R_E \| r_e$	$R_C \| r_o$
	$\frac{-(R_L \| R_C)}{R_E}$	$R_1 \| R_2 \| \beta(r_e + R_E)$	R_C
	Including r_o: $\frac{-(R_L \| R_C)}{R_E}$	$R_1 \| R_2 \| \beta(r_e + R_e)$	$\cong R_C$

Configuration	$A_{v_L} = V_o/V_i$	Z_i	Z_o
	$\dfrac{-(R_L \parallel R_C)}{R_{E_1}}$	$R_B \parallel \beta(r_e + R_{E_1})$	R_C
	Including r_o: $\dfrac{-(R_L \parallel R_C)}{R_{E_1}}$	$R_B \parallel \beta(r_e + R_E)$	$\cong R_C$
	$\dfrac{-(R_L \parallel R_C)}{r_e}$	$\beta r_e \parallel \dfrac{R_F}{\lvert A_v \rvert}$	R_C
	Including r_o: $\dfrac{-(R_L \parallel R_C \parallel r_o)}{r_e}$	$\beta r_e \parallel \dfrac{R_F}{\lvert A_v \rvert}$	$R_C \parallel R_F \parallel r_o$
	$\dfrac{-(R_L \parallel R_C)}{R_E}$	$\beta R_E \parallel \dfrac{R_F}{\lvert A_v \rvert}$	$\cong R_C \parallel R_F$
	Including r_o: $\cong \dfrac{-(R_L \parallel R_C)}{R_E}$	$\cong \beta R_E \parallel \dfrac{R_F}{\lvert A_v \rvert}$	$\cong R_C \parallel R_F$


Thank You!