ECE 312
Electronic Circuits (A)

Lec. 9: BJT Modeling and re Transistor Model (Hybrid Equivalent Model) (1)

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Agenda

- Two-Port Systems Approach
- Cascaded Systems
- The Hybrid Equivalent Model

Two Port SYSTEMS Approach

2-Port System

In the design process, it is often necessary to work with the terminal characteristics of a device rather then the individual components of the system.

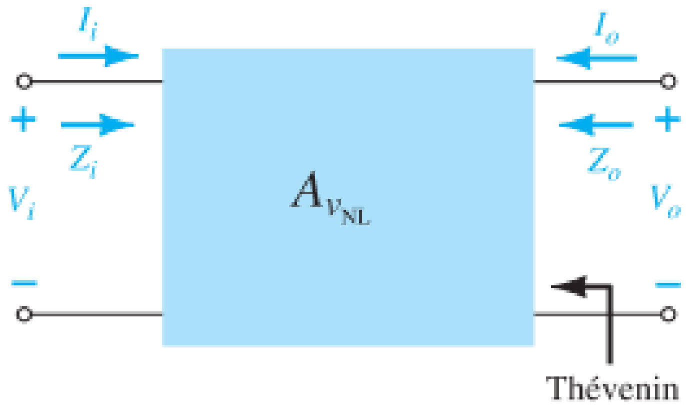


FIG. 5.61
Two-port system.

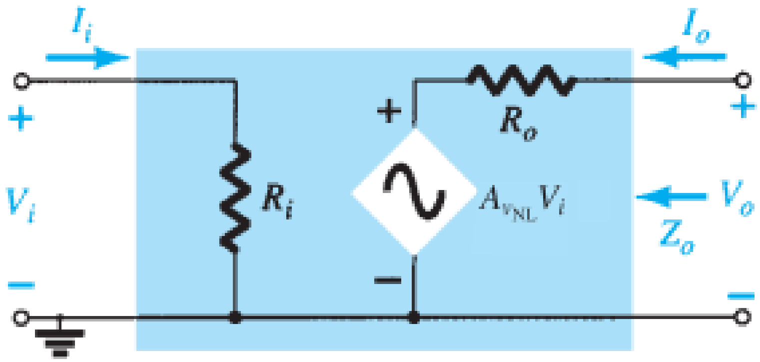


FIG. 5.62
Substituting the internal elements for the two-port system of Fig. 5.61.

$$V_o = A_{v_{NL}} V_i$$

$$Z_o = R_o$$

$$Z_i = R_i$$

2-Port System (effect of load resistance R_L)

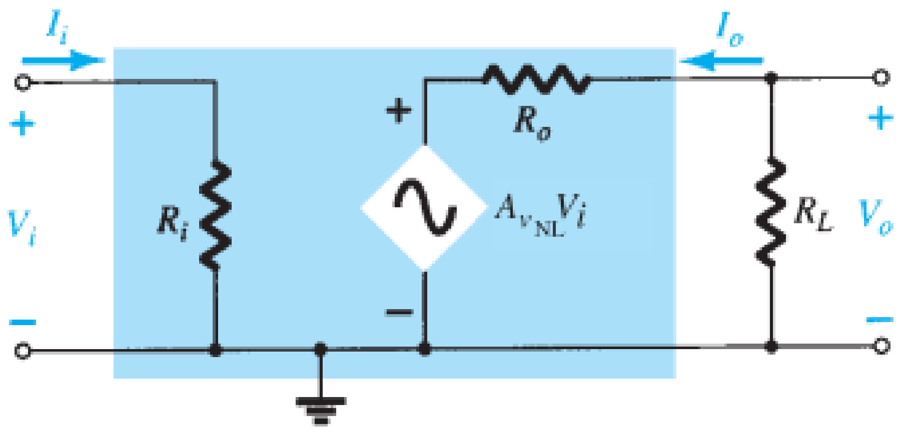


FIG. 5.63
Applying a load to the two-port system of Fig. 5.62.

$$V_o = \frac{R_L A_{v_{NL}} V_i}{R_L + R_o}$$

$$A_{v_L} = \frac{V_o}{V_i} = \frac{R_L}{R_L + R_o} A_{v_{NL}}$$

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

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

2-Port System (effect of input source resistance R_S)

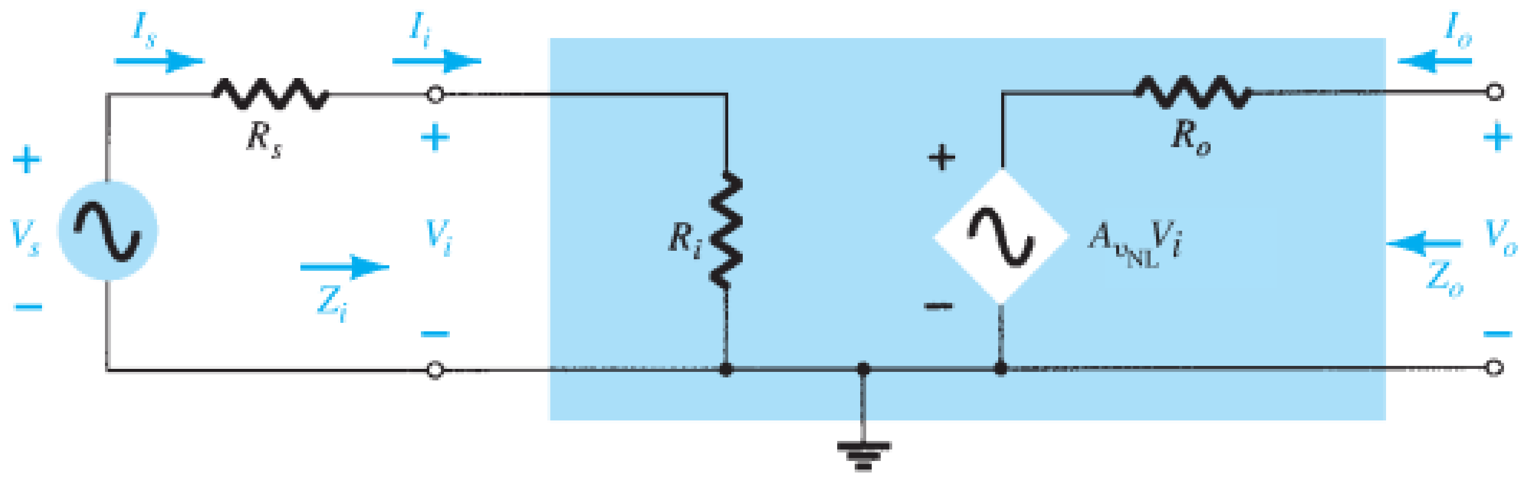


FIG. 5.64
Including the effects of the source resistance R_s.

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

$$V_o = A_{v_{NL}} V_i$$

$$V_o = A_{v_{NL}} \frac{R_i}{R_i + R_s} V_s$$

$$A_{v_s} = \frac{V_o}{V_s} = \frac{R_i}{R_i + R_s} A_{v_{NL}}$$

2-Port System (effect of both R_S and R_L)

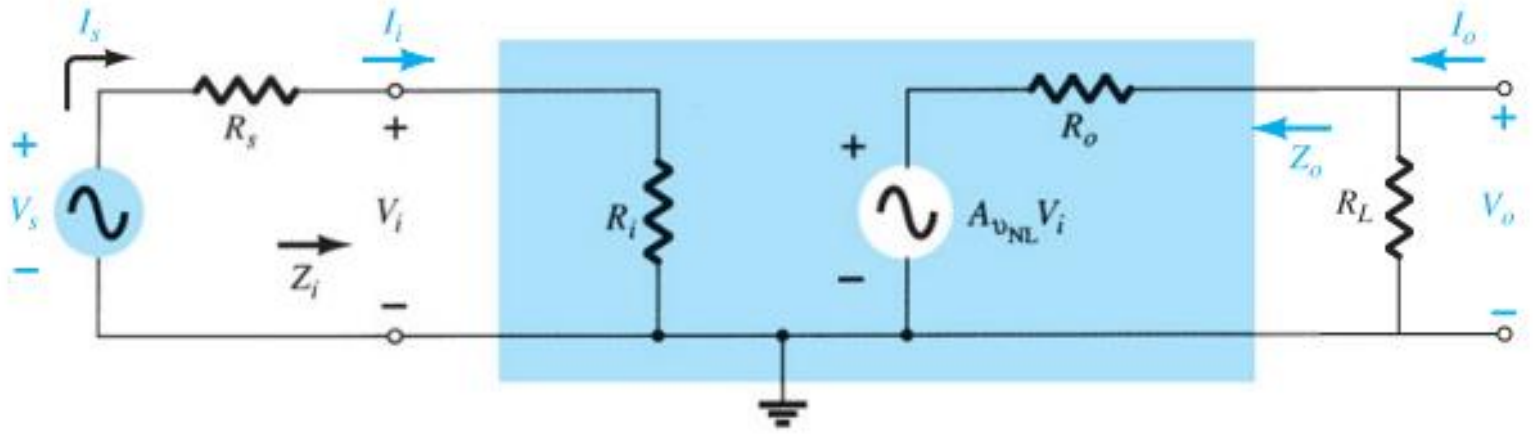


FIG. 5.65
Considering the effects of R_s and R_L on the gain of an amplifier.

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

$$V_o = \frac{R_L}{R_L + R_o} A_{v_{NL}} V_i$$

$$A_{v_L} = \frac{V_o}{V_i} = \frac{R_L A_{v_{NL}}}{R_L + R_o} = \frac{R_L}{R_L + R_o} A_{v_{NL}}$$

$$A_{v_s} = \frac{V_o}{V_s} = \frac{V_o}{V_i} \cdot \frac{V_i}{V_s}$$

$$A_{v_s} = \frac{V_o}{V_s} = \frac{R_i}{R_i + R_s} \cdot \frac{R_L}{R_L + R_o} A_{v_{NL}}$$

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

$$A_{i_s} = -A_{v_s} \frac{R_s + R_i}{R_L}$$

2-Port System (Example)

EXAMPLE 5.12 Determine A_{v_L} and A_{v_s} for the network of Example 5.11 and compare solutions. Example 5.1 showed that $A_{v_{NL}} = -280$, $Z_i = 1.07\ \text{k}\Omega$, and $Z_o = 3\ \text{k}\Omega$. In Example 5.11, $R_L = 4.7\ \text{k}\Omega$ and $R_s = 0.3\ \text{k}\Omega$.

Solution:

a. Eq. (5.89): $$A_{v_L} = \frac{R_L}{R_L + R_o} A_{v_{NL}} = \frac{4.7\ \text{k}\Omega}{4.7\ \text{k}\Omega + 3\ \text{k}\Omega}(-280.11) = \mathbf{-170.98}$$

as in Example 5.11.

b. Eq. (5.96): $$A_{v_s} = \frac{R_i}{R_i + R_s} \cdot \frac{R_L}{R_L + R_o} A_{v_{NL}} = \frac{1.07\ \text{k}\Omega}{1.07\ \text{k}\Omega + 0.3\ \text{k}\Omega} \cdot \frac{4.7\ \text{k}\Omega}{4.7\ \text{k}\Omega + 3\ \text{k}\Omega}(-280.11) = (0.781)(0.610)(-280.11) = \mathbf{-133.45}$$

as in Example 5.11.

Effect of R_S and R_L on Z_i and Z_o

- It is important to realize that when using the two-port equations in some configurations :
  - Z_i is sensitive to the applied load R_L (such as the emitter-follower and collector feedback).
  - Z_o is sensitive to the applied source resistance R_S (such as the emitter-follower).
- In such cases the no-load parameters for Z_i and Z_o have to first be calculated before substituting into the two-port equations.
- For most packaged systems such as op-amps this sensitivity of the input and output parameters to the applied load or source resistance is minimized to eliminate the need to be concerned about changes from the no-load levels when using the two-port equations.

Cascaded Systems

Cascaded Systems

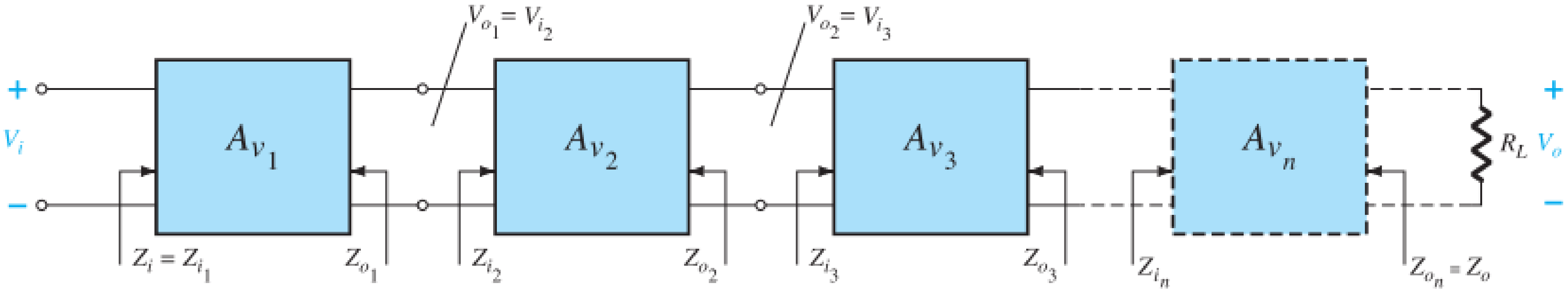


FIG. 5.67
Cascaded system.

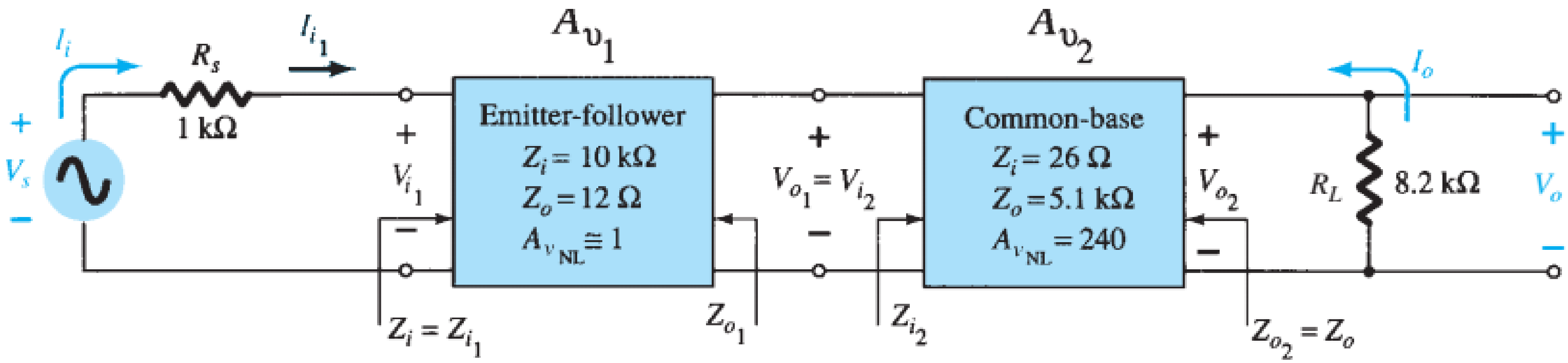
$$A_{v_T} = A_{v_1} \cdot A_{v_2} \cdot A_{v_3} \cdots$$

$$A_{i_T} = -A_{v_T} \frac{Z_{i_1}}{R_L}$$

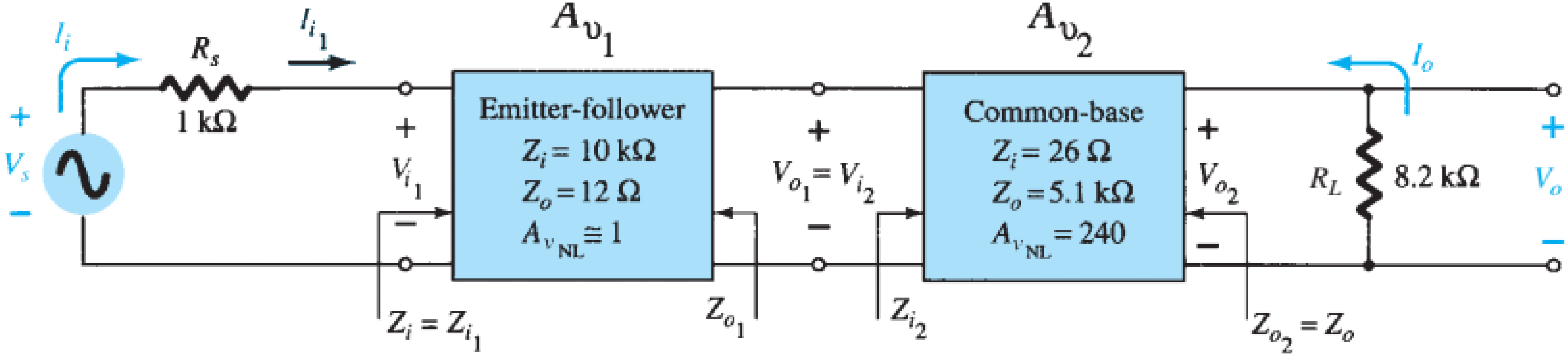
Cascaded Systems (Example)$_{1 \text{ of } 3}$

EXAMPLE 5.14 The two-stage system of Fig. 5.68 employs a transistor emitter-follower configuration prior to a common-base configuration to ensure that the maximum percentage of the applied signal appears at the input terminals of the common-base amplifier. In Fig. 5.68, the no-load values are provided for each system, with the exception of Z_i and Z_o for the emitter-follower, which are the loaded values. For the configuration of Fig. 5.68, determine:

a. The loaded gain for each stage.
b. The total gain for the system, A_v and A_{v_s}.
c. The total current gain for the system.
d. The total gain for the system if the emitter-follower configuration were removed.



Cascaded Systems (Example) 2 of 3



Solution:

a. For the emitter-follower configuration, the loaded gain is (by Eq. (5.94))

$$V_{o_1} = \frac{Z_{i_2}}{Z_{i_2} + Z_{o_1}} A_{v_{NL}} V_{i_1} = \frac{26\ \Omega}{26\ \Omega + 12\ \Omega}(1)\, V_{i_1} = 0.684\, V_{i_1}$$

and $$A_{V_i} = \frac{V_{o_1}}{V_{i_1}} = \mathbf{0.684}$$

For the common-base configuration,

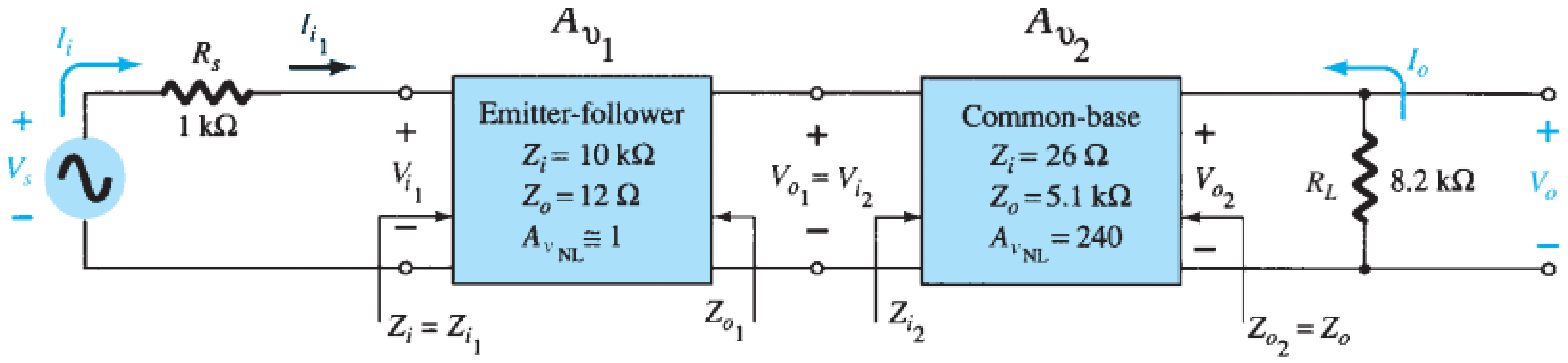
$$V_{o_2} = \frac{R_L}{R_L + R_{o_2}} A_{v_{NL}} V_{i_2} = \frac{8.2\ \text{k}\Omega}{8.2\ \text{k}\Omega + 5.1\ \text{k}\Omega}(240)\, V_{i_2} = 147.97\, V_{i_2}$$

and $$A_{v_2} = \frac{V_{o_2}}{V_{i_2}} = \mathbf{147.97}$$

b. Eq. (5.99): $A_{v_T} = A_{v_1} A_{v_2}$
$= (0.684)(147.97)$
$= \mathbf{101.20}$,

Eq. (5.91): $$A_{v_s} = \frac{Z_{i_1}}{Z_{i_1} + R_s} A_{v_T} = \frac{(10\ \text{k}\Omega)(101.20)}{10\ \text{k}\Omega + 1\ \text{k}\Omega}$$
$= \mathbf{92}$

Cascaded Systems (Example) 3 of 3



c. Eq. (5.100): $A_{i_T} = -A_{v_T}\dfrac{Z_{i_1}}{R_L} = -(101.20)\left(\dfrac{10\text{ k}\Omega}{8.2\text{ k}\Omega}\right)$

$= \mathbf{-123.41}$

d. Eq. (5.91): $V_i = \dfrac{Z_{i_{CB}}}{Z_{i_{CB}} + R_s}V_s = \dfrac{26\ \Omega}{26\ \Omega + 1\text{ k}\Omega}V_s = 0.025\ V_s$

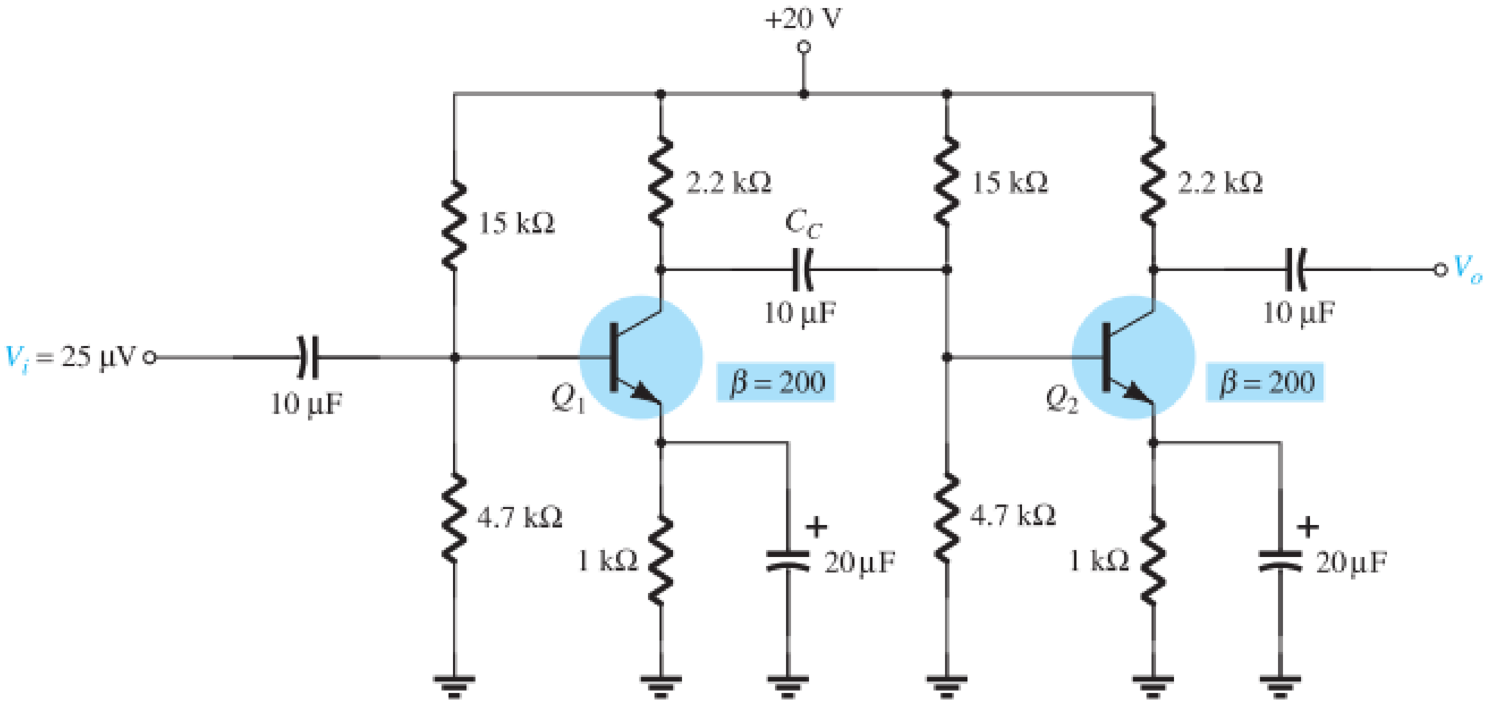
and $\dfrac{V_i}{V_s} = 0.025$ with $\dfrac{V_o}{V_i} = 147.97$ from above

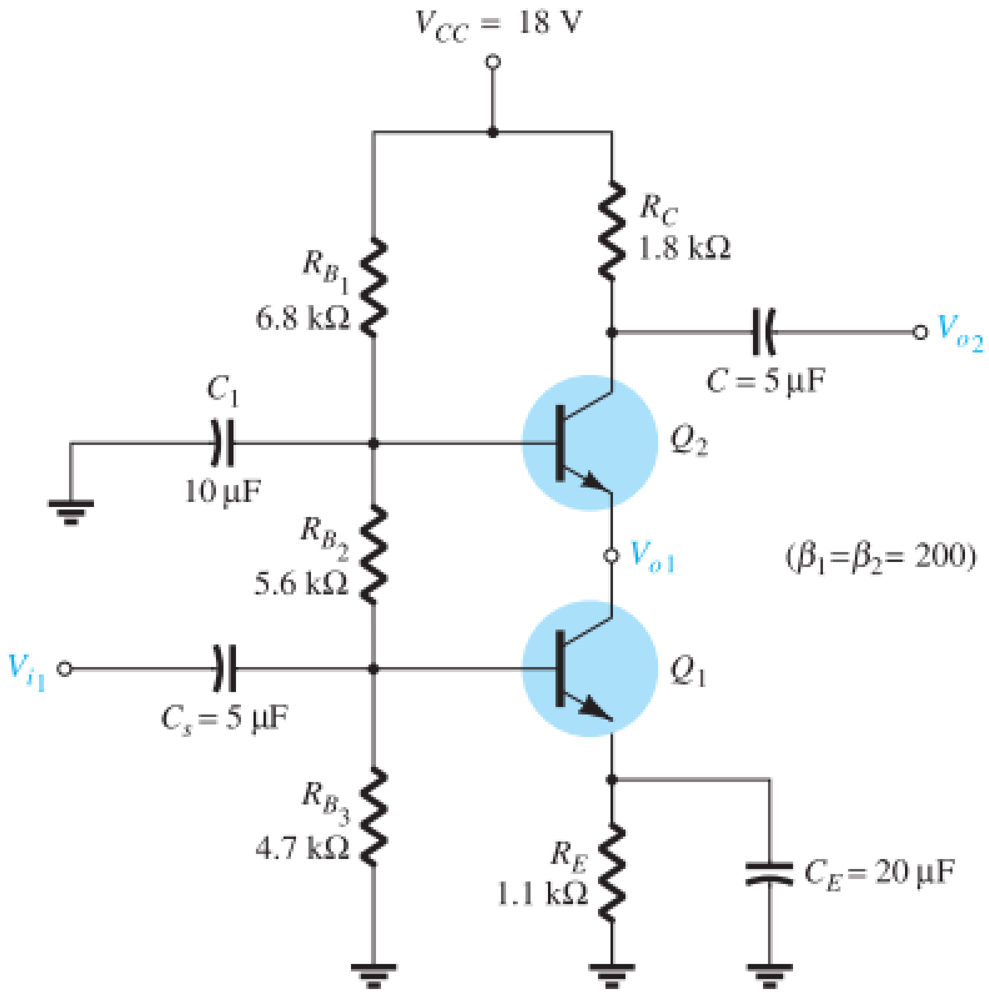
and $A_{v_s} = \dfrac{V_o}{V_s} = \dfrac{V_i}{V_s}\cdot\dfrac{V_o}{V_i} = (0.025)(147.97) = \mathbf{3.7}$

In total, therefore, the gain is about 25 times greater with the emitter-follower configuration to draw the signal to the amplifier stages. Note, however, that it is also important that the output impedance of the first stage is relatively close to the input impedance of the second stage, otherwise the signal would have been "lost" again by the voltage-divider action.

Cascaded Systems

- Examples: RC Coupled ct & Cascode ct
- Check Examples: 5.15 & 5.16






Thank You!