Benha University
Faculty of Engineering at Shoubra

**ECE-322**
**Electronic Circuits (A)**

# Lecture #14
# Feedback Amplifiers

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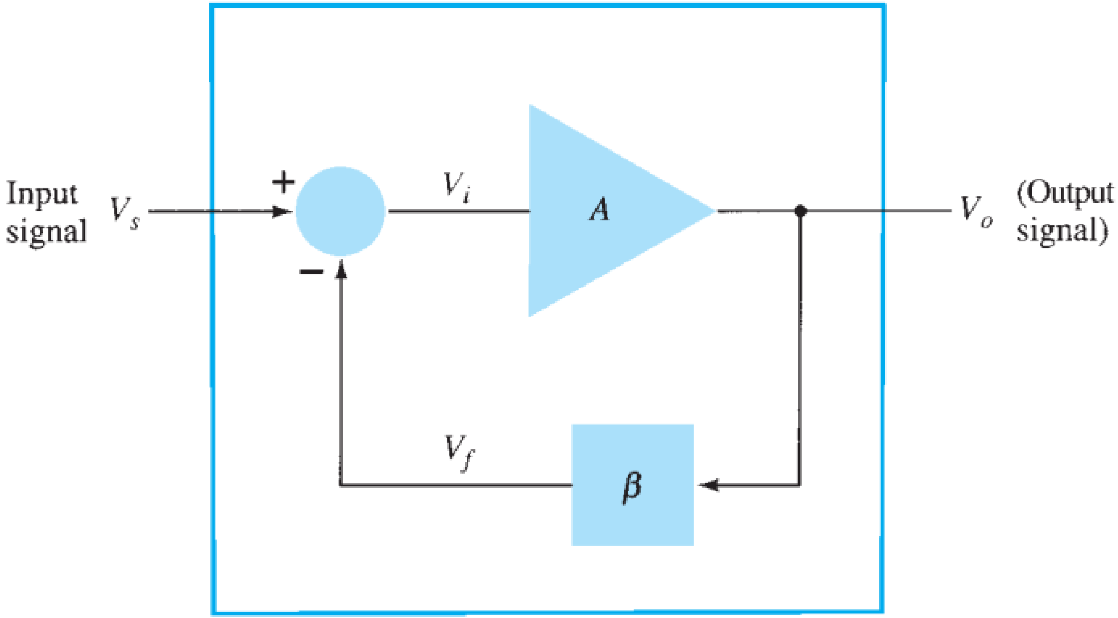
# Agenda

- FB Amplifiers Structure
- Different Topologies
- Examples
- Practical Feedback Circuits

# FEEDBACK AMPLIFIER BASICS

# Feedback Amplifier

- Block diagram of a typical feedback amplifier



Feedback amplifier

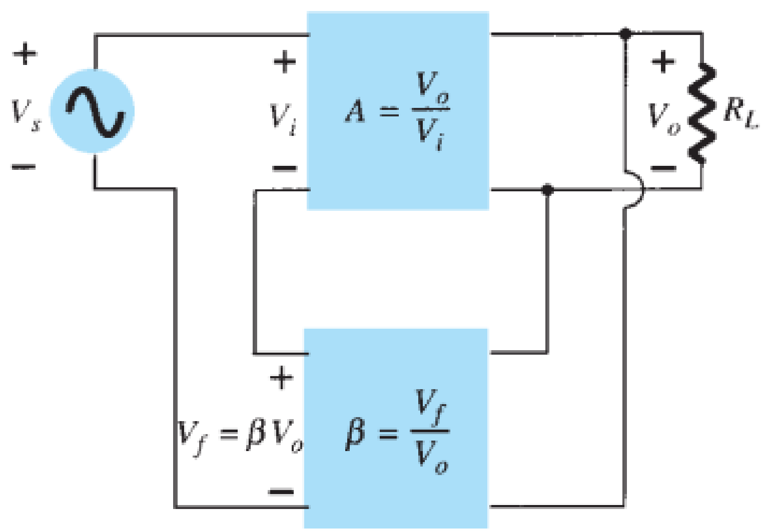
- Types:
  1. Negative feedback.
  2. Positive feedback.

# Feedback Amplifier

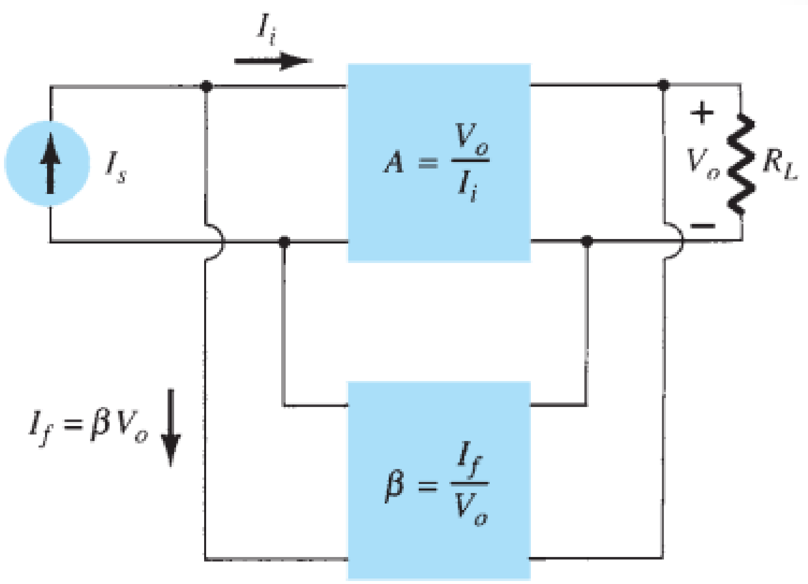
- **Depending on** the relative **polarity** of the signal being fed back into a circuit, one may have **negative** or **positive** feedback.
- **Positive** feedback drives a circuit into **oscillation** as in various types of oscillator circuits.
- **Negative** feedback results in decreased voltage gain, for which a number of circuit **features** are **improved**.
- Some **improvements** of negative feedback are :
  1. Higher input impedance.
  2. Lower output impedance.
  3. Better stabilized voltage gain.
  4. Improved frequency response.
  5. Reduced noise.
  6. More linear operation.

# FEEDBACK CONNECTION TYPES

1. Voltage-series feedback

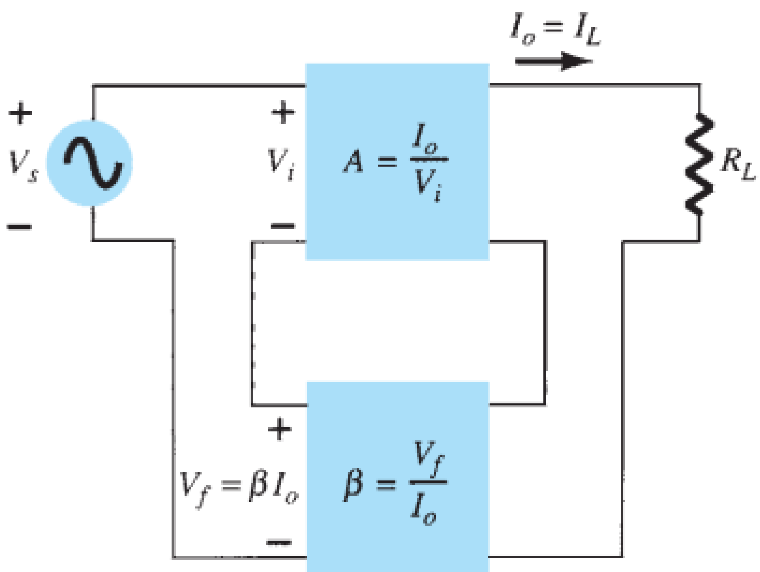



2. Voltage-shunt feedback

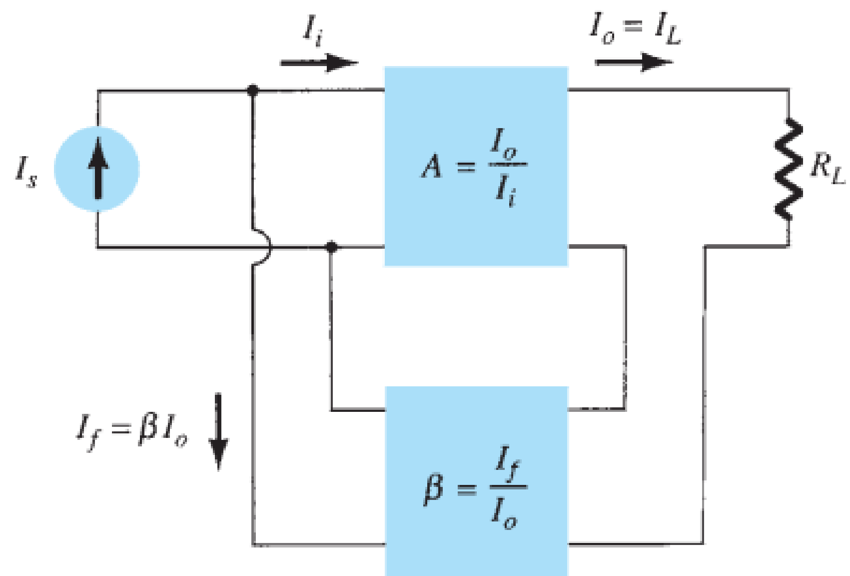


# FEEDBACK CONNECTION TYPES..

3. Current-series feedback




4. Current-shunt feedback



# Parameters improvement

*Effect of Feedback Connection on Input and Output Impedance*

| | Voltage-Series | Current-Series | Voltage-Shunt | Current-Shunt |
|---|---|---|---|---|
| $Z_{if}$ | $Z_i(1 + \beta A)$ (increased) | $Z_i(1 + \beta A)$ (increased) | $\frac{Z_i}{1 + \beta A}$ (decreased) | $\frac{Z_i}{1 + \beta A}$ (decreased) |
| $Z_{of}$ | $\frac{Z_o}{1 + \beta A}$ (decreased) | $Z_o(1 + \beta A)$ (increased) | $\frac{Z_o}{1 + \beta A}$ (decreased) | $Z_o(1 + \beta A)$ (increased) |

Effect of feedback on gain:

$$A_f = \frac{A}{1 + \beta A}$$

# Parameters improvement ..

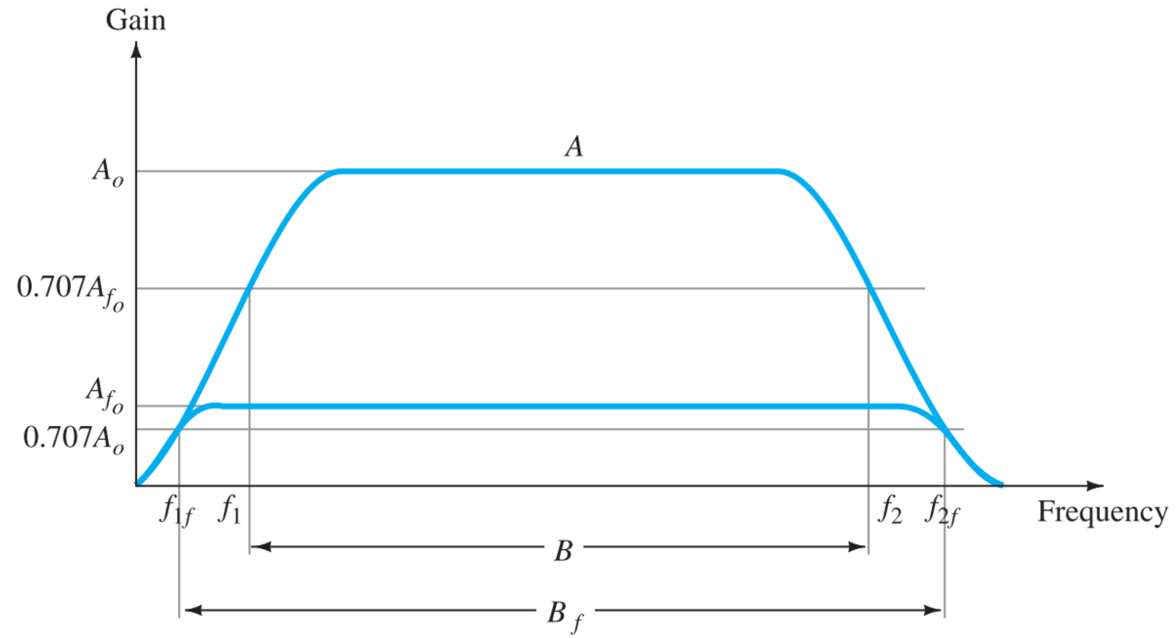



**FIG. 14.6**

*Effect of negative feedback on gain and bandwidth.*

**Gain Stability with Feedback**

$$A_f = \frac{A}{1 + \beta A}$$

$$\left|\frac{dA_f}{A_f}\right| = \frac{1}{|1 + \beta A|}\left|\frac{dA}{A}\right|$$

$$\left|\frac{dA_f}{A_f}\right| \cong \left|\frac{1}{\beta A}\right|\left|\frac{dA}{A}\right| \qquad \text{for } \beta A \gg 1$$

# FEEDBACK CONNECTION TYPES…

- **Series** feedback connections tend to **increase** the **input resistance**, whereas **shunt** feed-back connections tend to **decrease** the **input resistance**.

- **Voltage** feedback tends to **decrease** the **output impedance**, whereas **current** feedback tends to **increase** the **output impedance**.

# Example

**EXAMPLE 14.1** Determine the voltage gain, input, and output impedance with feedback for voltage-series feedback having $A = -100$, $R_i = 10\ \text{k}\Omega$, and $R_o = 20\ \text{k}\Omega$ for feedback of (a) $\beta = -0.1$ and (b) $\beta = -0.5$.

***Solution:*** Using Eqs. (14.2), (14.4), and (14.6), we obtain

a. $$A_f = \frac{A}{1 + \beta A} = \frac{-100}{1 + (-0.1)(-100)} = \frac{-100}{11} = \mathbf{-9.09}$$

$$Z_{if} = Z_i(1 + \beta A) = 10\ \text{k}\Omega\ (11) = \mathbf{110\ k\Omega}$$

$$Z_{of} = \frac{Z_o}{1 + \beta A} = \frac{20 \times 10^3}{11} = \mathbf{1.82\ k\Omega}$$

b. $$A_f = \frac{A}{1 + \beta A} = \frac{-100}{1 + (-0.5)(-100)} = \frac{-100}{51} = \mathbf{-1.96}$$

$$Z_{if} = Z_i(1 + \beta A) = 10\ \text{k}\Omega\ (51) = \mathbf{510\ k\Omega}$$

$$Z_{of} = \frac{Z_o}{1 + \beta A} = \frac{20 \times 10^3}{51} = \mathbf{392.16\ \Omega}$$

# Practical Feedback Circuits

## Voltage-Series Feedback

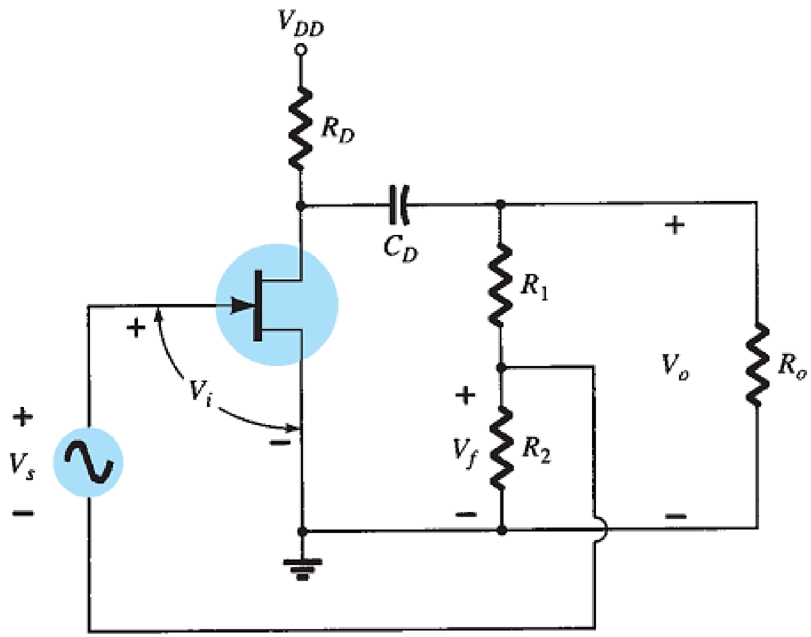



**FIG. 14.7**
*FET amplifier stage with voltage-series feedback.*

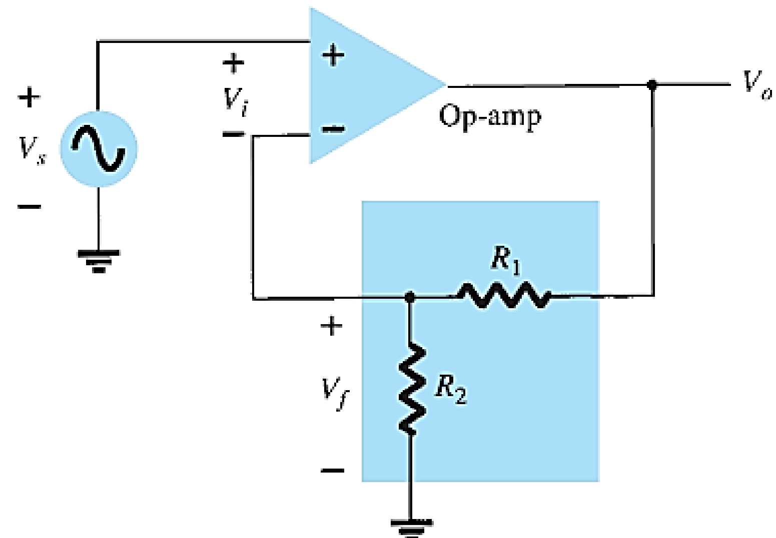



**FIG. 14.8**
*Voltage-series feedback in an op-amp connection.*

# Voltage-Series Feedback circuit

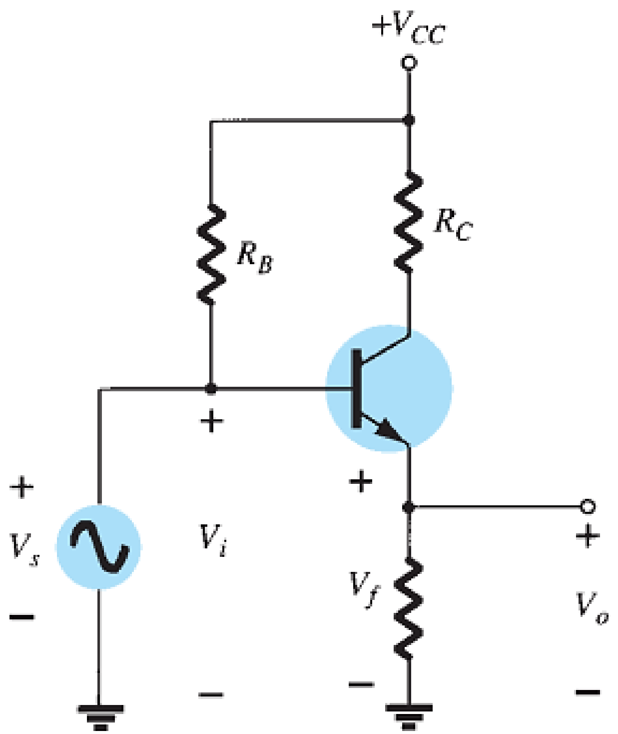



**FIG. 14.9**
*Voltage-series feedback circuit (emitter-follower).*

$$A = \frac{V_o}{V_s} = \frac{h_{fe} I_b R_E}{V_s} = \frac{h_{fe} R_E (V_s / h_{ie})}{V_s} = \frac{h_{fe} R_E}{h_{ie}}$$

$$\beta = \frac{V_f}{V_o} = 1$$

$$A_f = \frac{V_o}{V_s} = \frac{A}{1 + \beta A} = \frac{h_{fe} R_E / h_{ie}}{1 + (1)(h_{fe} R_E / h_{ie})} = \frac{h_{fe} R_E}{h_{ie} + h_{fe} R_E}$$

For $h_{fe} R_E \gg h_{ie}, \quad A_f \cong 1$

# Current-Series Feedback circuit

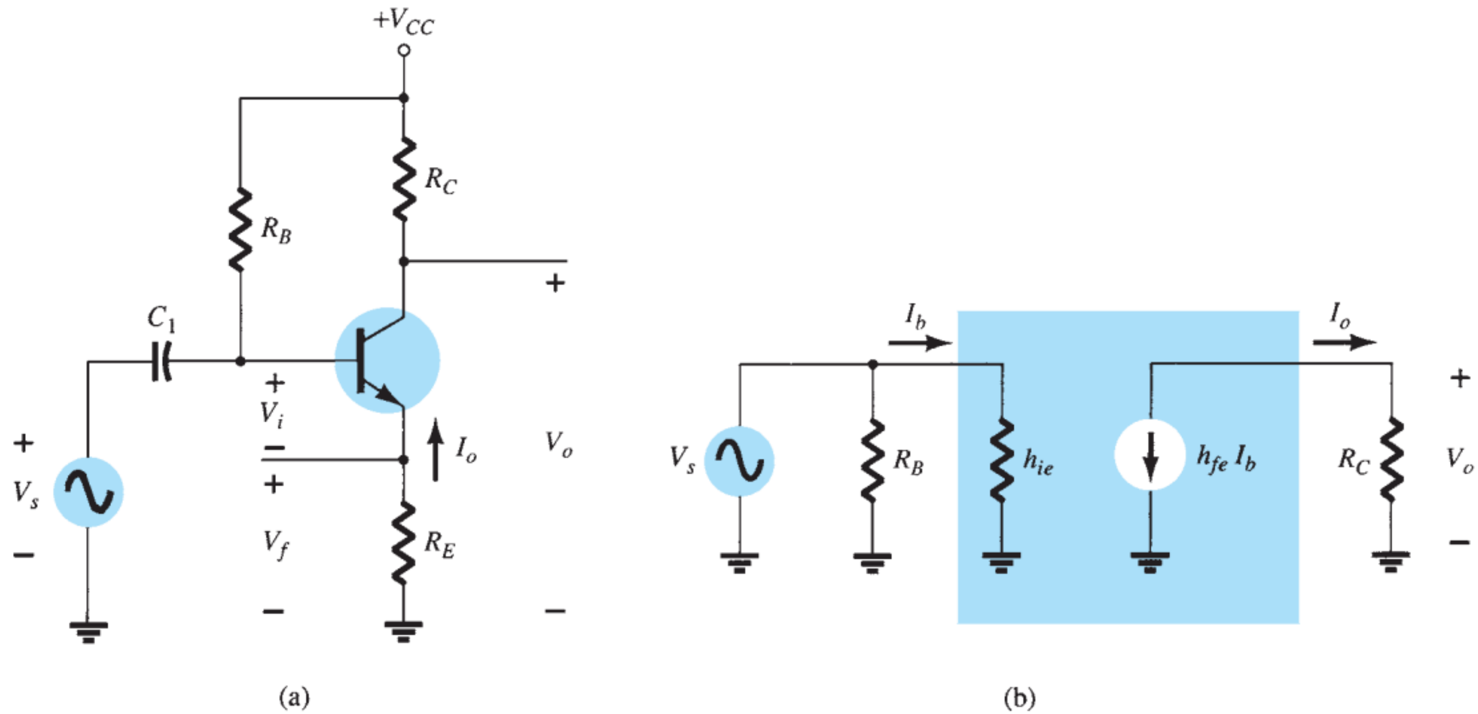



**FIG. 14.10**

*Transistor amplifier with unbypassed emitter resistor ($R_E$) for current-series feedback: (a) amplifier circuit; (b) ac equivalent circuit without feedback.*

# Current-Series Feedback circuit

**Without Feedback** Referring to the basic format of Fig. 14.2a and summarized in Table 14.1, we have

$$A = \frac{I_o}{V_i} = \frac{-I_b h_{fe}}{I_b h_{ie} + R_E} = \frac{-h_{fe}}{h_{ie} + R_E} \quad (14.16)$$

$$\beta = \frac{V_f}{I_o} = \frac{-I_o R_E}{I_o} = -R_E \quad (14.17)$$

The input and output impedances are, respectively,

$$Z_i = R_B \| (h_{ie} + R_E) \cong h_{ie} + R_E \quad (14.18)$$

$$Z_o = R_C \quad (14.19)$$

**With Feedback**

$$A_f = \frac{I_o}{V_s} = \frac{A}{1 + \beta A} = \frac{-h_{fe}/h_{ie}}{1 + (-R_E)\left(\frac{-h_{fe}}{h_{ie} + R_E}\right)} \cong \frac{-h_{fe}}{h_{ie} + h_{fe}R_E} \quad (14.20)$$

The input and output impedances are calculated as specified in Table 14.2:

$$Z_{if} = Z_i(1 + \beta A) \cong h_{ie}\left(1 + \frac{h_{fe}R_E}{h_{ie}}\right) = h_{ie} + h_{fe}R_E \quad (14.21)$$

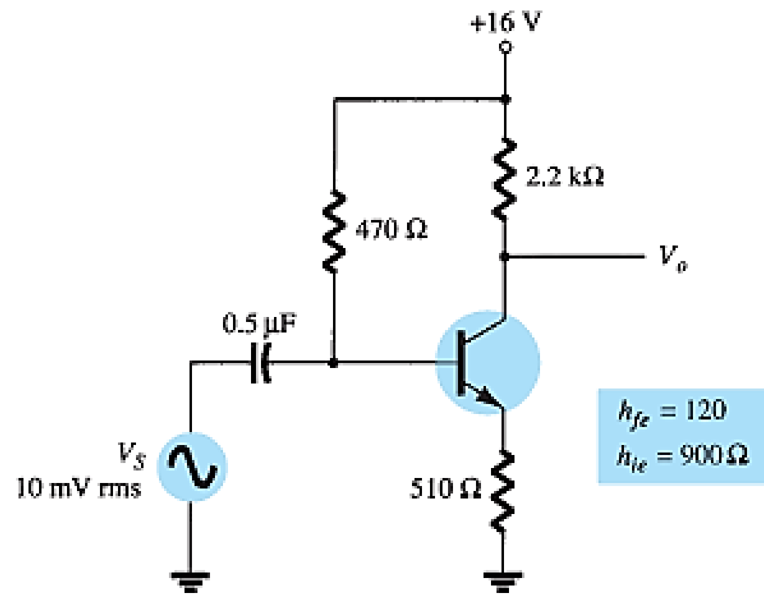
$$Z_{of} = Z_o(1 + \beta A) = R_C\left(1 + \frac{h_{fe}R_E}{h_{ie}}\right) \quad (14.22)$$

The voltage gain $A$ with feedback is

$$A_{vf} = \frac{V_o}{V_s} = \frac{I_o R_C}{V_s} = \left(\frac{I_o}{V_s}\right)R_C = A_f R_C \cong \frac{-h_{fe}R_C}{h_{ie} + h_{fe}R_E} \quad (14.23)$$

# Example

- **Calculate the voltage gain of the shown circuit.**




**Solution:** Without feedback,

$$A = \frac{I_o}{V_i} = \frac{-h_{fe}}{h_{ie} + R_E} = \frac{-120}{900 + 510} = -0.085$$

$$\beta = \frac{V_f}{I_o} = -R_E = -510$$

The factor $(1 + \beta A)$ is then

$$1 + \beta A = 1 + (-0.085)(-510) = 44.35$$

The gain with feedback is then

$$A_f = \frac{I_o}{V_s} = \frac{A}{1 + \beta A} = \frac{-0.085}{44.35} = -1.92 \times 10^{-3}$$

and the voltage gain with feedback $A_{vf}$ is

$$A_{vf} = \frac{V_o}{V_s} = A_f R_C = (-1.92 \times 10^{-3})(2.2 \times 10^3) = \mathbf{-4.2}$$

Without feedback ($R_E = 0$), the voltage gain is

$$A_v = \frac{-R_C}{r_e} = \frac{-2.2 \times 10^3}{7.5} = \mathbf{-293.3}$$

- For more details, refer to:
  - Chapter 14 at Boylestad, **Electronic Circuits and Devices**,11th edition.
- The lecture is available online at:
  - http://bu.edu.eg/staff/ahmad.elbanna-courses/11966
- For inquires, send to:
  - ahmad.elbanna@feng.bu.edu.eg