Feedback and Oscillators

Lesson #14

Impedances

Section 9.3-5

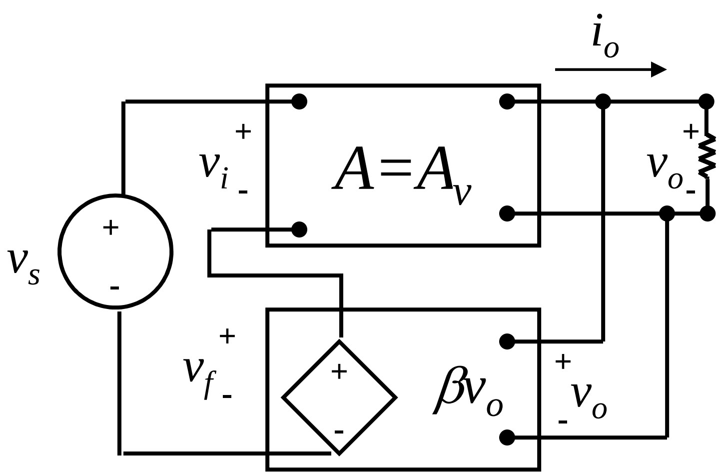
Types of Feedback

- Type of feedback (the output entity fed back):
  - Voltage Feedback vs. Current Feedback
  - βv_o vs. βi_o
- How it is achieved (the means to fed back the output to the input):
  - Series (input voltage) Feedback vs. Parallel (input current) Feedback
  - $v_i = v_s - v_f$ vs. $i_i = i_s - i_f$

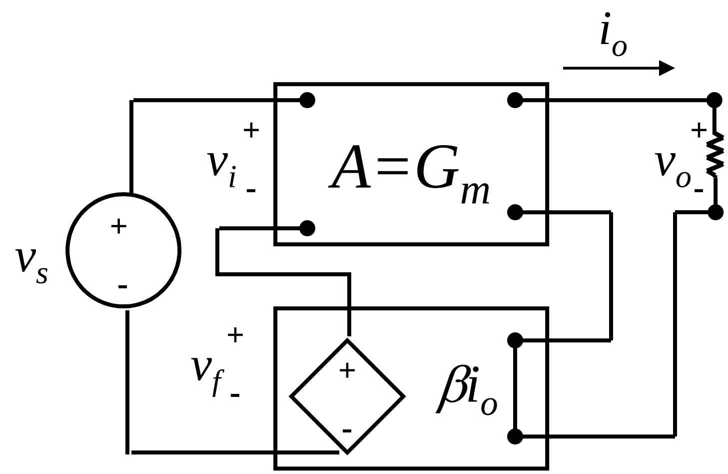
Types of Feedback (Continued)

- Four Combinations
  - Series Voltage: where amplifier input and output are voltages and, therefore, the gain parameter is a voltage gain, A_v and the feedback is a voltage, βv_o ,which is proportional to the output voltage
  - Series Current : where amplifier input is a voltage and its output is a current and, therefore, the gain parameter is a transconductance, G_m, and the feedback is a voltage βi_o, which is proportional to the output current
  - Parallel Voltage: where amplifier input is a current and its output is a voltage and, therefore, the gain parameter is a transresistance gain, R_m and the feedback is a current, βv_o ,which is proportional to the output voltage
  - Parallel current: where amplifier input and output are currents and, therefore, the gain parameter is a current gain, A_i and the feedback is a current, βi_o ,which is proportional to the output current.

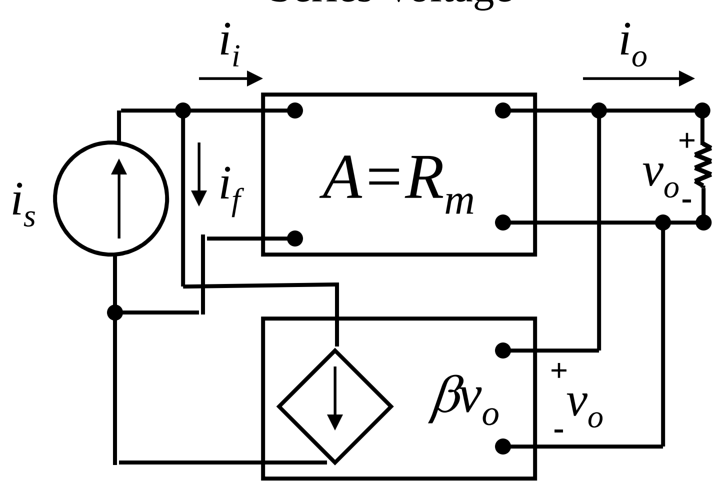
Types of Feedback Circuits



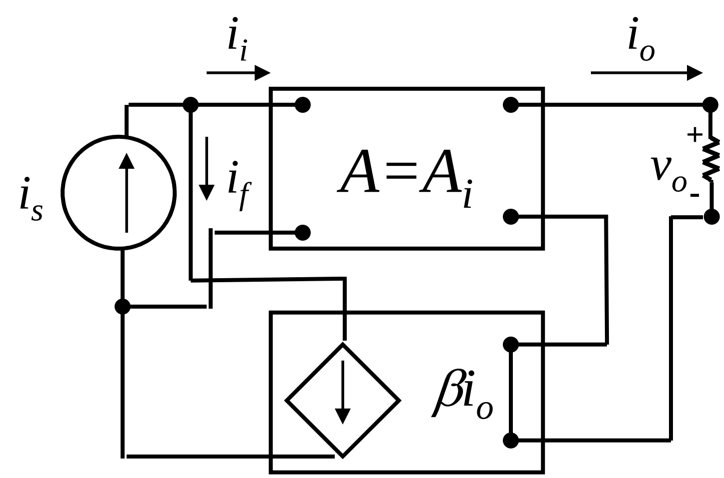
Series Voltage



Series Current



Parallel Voltage

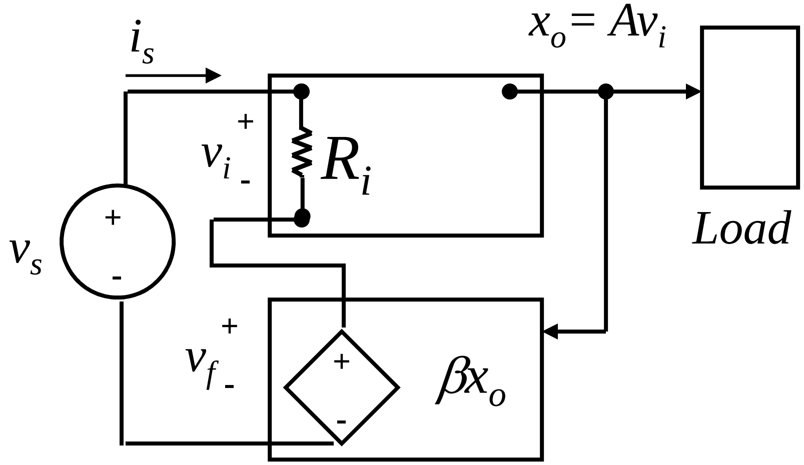


Parallel Current

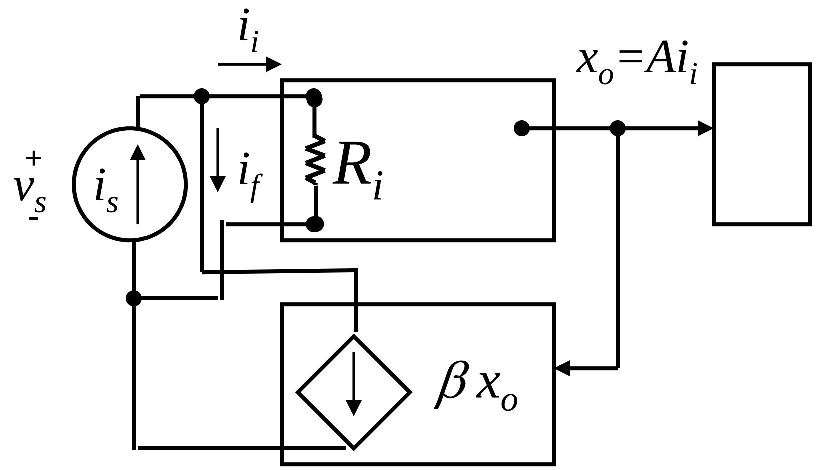
Feedback Relations for the 4 Types

- Since we derived the the feedback gain independent of whether the a current or voltage is fed back, then for each type:
- Series Voltage: $$A_{vf} = \frac{v_o}{v_s} = \frac{A_v}{1 + A_v \beta}$$
- Series Current: $$G_{mf} = \frac{i_o}{v_s} = \frac{G_m}{1 + G_m \beta}$$
- Parallel Voltage: $$R_{mf} = \frac{v_o}{i_s} = \frac{R_m}{1 + R_m \beta}$$
- Parallel Current $$A_{if} = \frac{i_o}{i_s} = \frac{A_i}{1 + A_i \beta}$$

Input Impedance



Series



Parallel

$$R_{if} = \frac{v_s}{i_s}$$

$$v_s = R_i i_s + v_f = R_i i_s + \beta x_o$$

$$x_o = Av_i$$

$$v_i = R_i i_s$$

$$\therefore x_o = AR_i i_s$$

$$v_s = R_i i_s + \beta AR_i i_s$$

$$R_{if} = \frac{v_s}{i_s} = R_i(1+\beta A)$$

$$R_{if} = \frac{v_s}{i_s}$$

$$i_f = \beta x_o$$

$$i_i = i_s - i_f = i_s - \beta x_o$$

$$x_o = Ai_i$$

$$\therefore i_i = i_s - \beta Ai_i$$

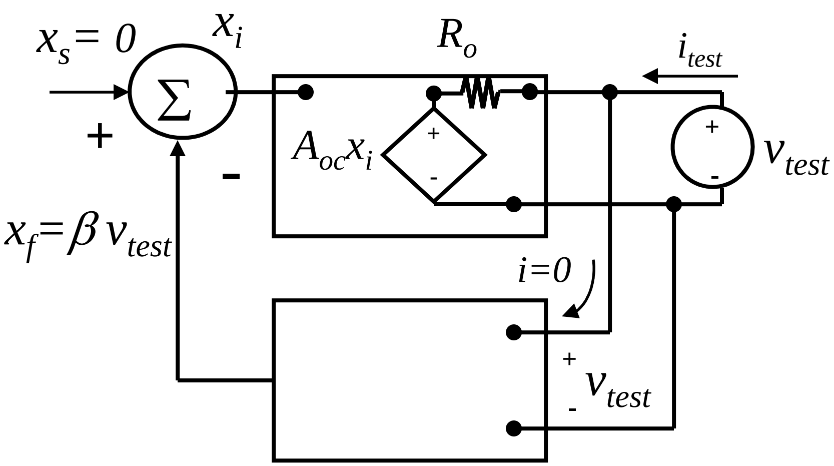
$$i_i = \frac{i_s}{(1+\beta A)}$$

$$v_s = R_i i_i$$

$$\therefore v_s = \frac{R_i}{(1+\beta A)} i_s$$

$$\therefore R_{if} = \frac{v_s}{i_s} = \frac{R_i}{1+A\beta}$$

Output Impedance



Voltage

$$R_{of} = \frac{v_{test}}{i_{test}}$$

$$v_{test} = R_o i_{test} + A_{oc} x_i$$

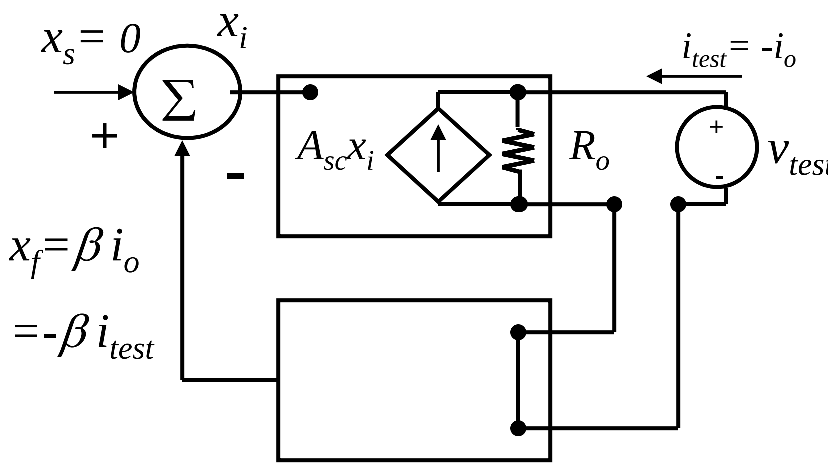
$$x_i = x_s - x_f = x_s - \beta\, v_{test}$$

$$x_s = 0$$

$$x_i = -\beta\, v_{test}$$

$$v_{test} = R_o i_{test} - A_{oc}\ \beta\, v_{test}$$

$$R_{of} = \frac{v_{test}}{i_{test}} = \frac{R_0}{(1+\beta A_{oc})}$$



Current

$$R_{of} = \frac{v_{test}}{i_{test}}$$

$$v_{test} = R_o(i_{test} + A_{sc} x_i) + 0$$

$$x_i = x_s - x_f = 0 - \beta i_o$$

$$x_i = -\beta i_o = \beta i_{test}$$

$$v_{test} = R_o(i_{test} + A_{sc}\beta i_{test})$$

$$R_{of} = \frac{v_{test}}{i_{test}} = R_0(1+\beta A_{sc})$$

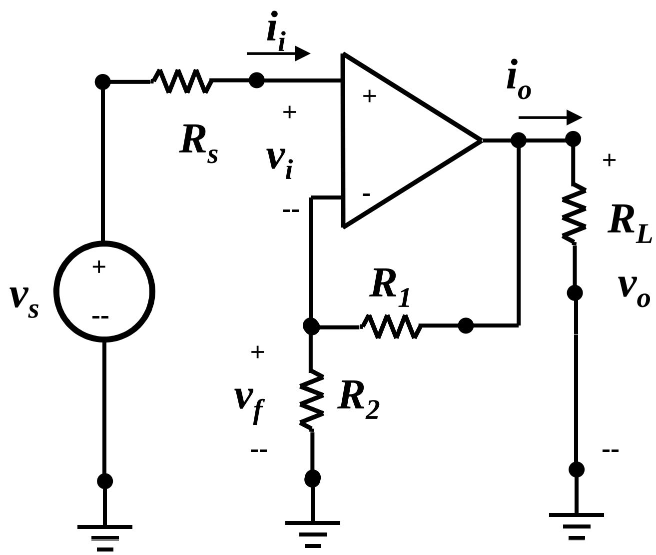
Identifying Negative Feedback

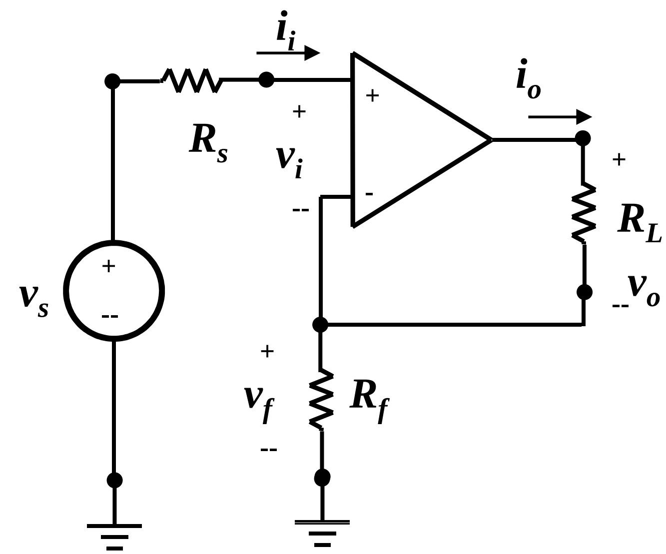
- Determine the type of feedback: Voltage vs Current
- Determine how the feedback is applied: Series or Parallel
- Determine if the feedback is in opposition to how the input is applied.
  - See if the feedback is applied to the inverting (subtractive) input of the amplifier.

Identifying Negative Feedback
See the column on page 571

- Output
  - In voltage feedback, the input terminals of the feedback network are in parallel with the load
  - In current feedback, the input terminals of the feedback network are in series with the load
- Input
  - If the feedback signal vanishes for a open circuit load, then current feedback
  - If the feedback signal vanishes for a short circuit load, then voltage feedback

Identifying Negative Feedback (Continued)





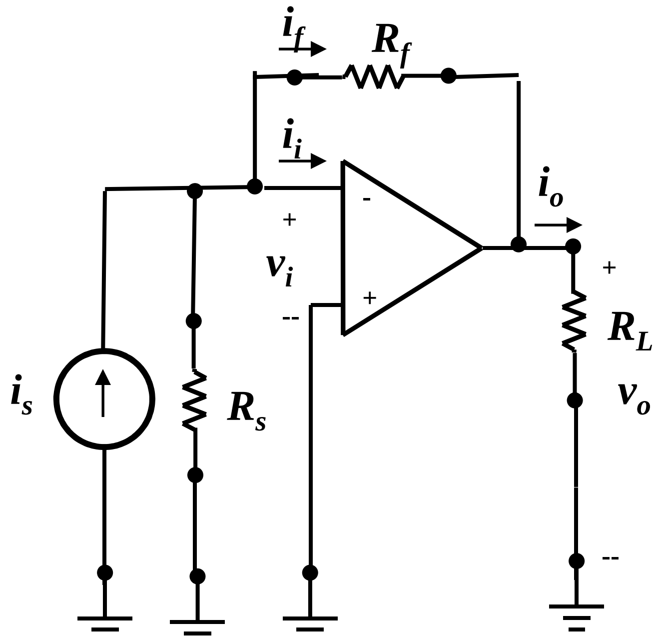
$$v_f = \frac{R_2}{R_1 + R_2} v_o$$

$$\beta = \frac{R_2}{R_1 + R_2}$$

$$v_f = R_f i_o$$

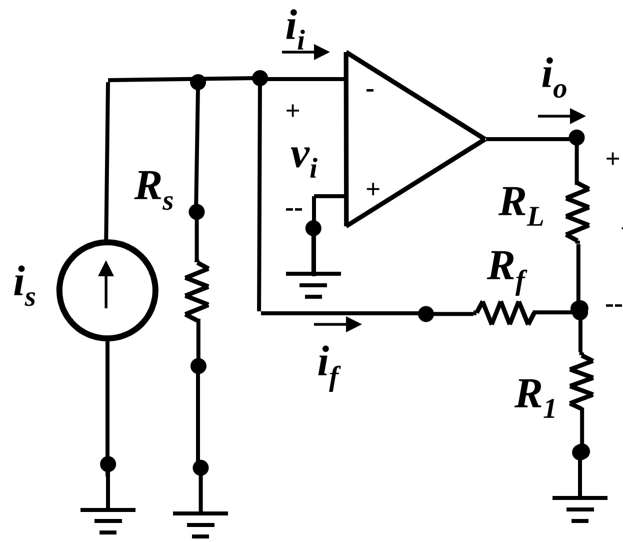
$$\beta = R_f$$

Identifying Negative Feedback (Continued)



$$i_f = \frac{v_o}{R_f}$$

$$\beta = \frac{1}{R_f}$$



$$i_f = -i_o \frac{R_1}{R_f + R_1}; \text{since } v_i \approx 0$$

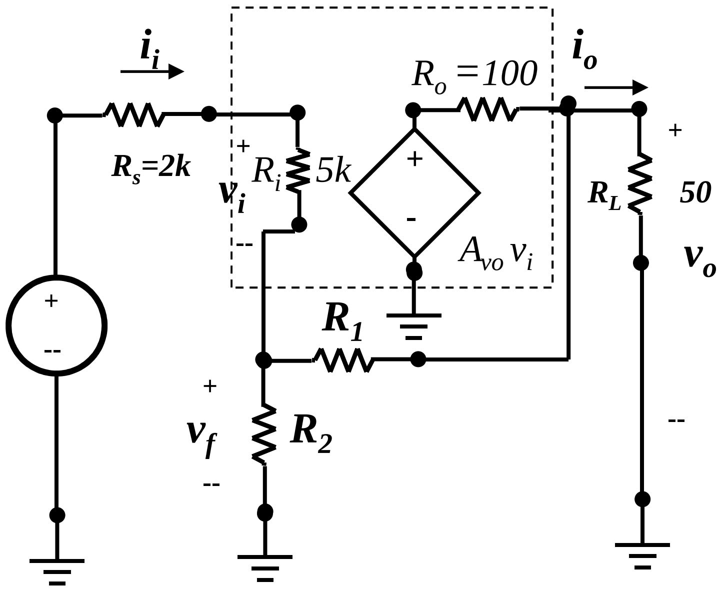
$$\beta = -\frac{R_1}{R_f + R_1}$$

Design of Feedback Amplifiers

- Determine what type of feedback is required and the value of β
- Select a circuit design
- Calculate the appropriate values of the circuit elements (i.e., resistors in the feedback network)

Design Example

- Design a feedback circuit which provides a voltage equal to 10 times the input source. Assume that the source has a resistance of *2 kΩ* and the differential amplifier has an open circuit gain of 10^4 with an input resistance of *5 kΩ* and an output resistance of $R_o = 100\ \Omega$



$$A_{vf} = A_f \cong 1/\beta = 10$$

$$\beta = 0.1$$

$$A = A_{vo} = 10^4$$

$$A\beta = 10^4 \times 0.1 = 1000$$

$$\beta = \frac{R_2}{R_1 + R_2} = .1$$

$$R_1/R_2 = 9$$

Choose $R_1 + R_2 > R_O$ to reduce any loss of gain due to loading

Homework

- Impedances
  - Problems: 9.22, 27-36
- Practical Networks
  - Problems: 9.38