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
  – $\beta v_o$ vs. $\beta i_o$

• 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, $\beta v_o$, 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 $\beta i_o$, 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, $\beta v_o$, 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, $\beta i_o$, which is proportional to the output current.
Types of Feedback Circuits

Series Voltage

\[ A = A_v \]

Series Current

\[ A = G_m \]

Parallel Voltage

\[ A = R_m \]

Parallel Current

\[ A = A_i \]
Feedback Relations for the 4 Types

- Since we derived 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: \( A_{ij} = \frac{i_o}{i_s} = \frac{A_i}{1 + A_i \beta} \)
Input Impedance

Series

\[ R_f = \frac{v_s}{i_s} \]
\[ v_s = R_i i_s + v_f = R_i i_s + \beta x_o \]
\[ x_o = A v_i \]
\[ v_i = R_i i_s \]
\[ \therefore x_o = A R_i i_s \]
\[ v_s = R_i i_s + \beta A R_i i_s \]
\[ R_f = \frac{v_s}{i_s} = R_i (1 + \beta A) \]

Parallel

\[ R_f = \frac{v_s}{i_s} \]
\[ i_f = \beta x_o \]
\[ i_i = i_s - i_f = i_s - \beta x_o \]
\[ x_o = A i_i \]
\[ \therefore i_i = i_s - \beta A i_i \]
\[ v_s = \frac{R_i}{1 + \beta A} i_s \]
\[ \therefore R_f = \frac{v_s}{i_s} = \frac{R_i}{1 + A \beta} \]
Output Impedance

\[ R_{of} = \frac{v_{test}}{i_{test}} \]

\[ v_{test} = R_{o} i_{test} + A_{oc} x_{i} \]

\[ x_{i} = x_{s} - x_{f} = x_{s} - \beta v_{test} \]

\[ x_{s} = 0 \]

\[ x_{i} = -\beta v_{test} \]

\[ v_{test} = R_{o} i_{test} - A_{oc} \beta v_{test} \]

\[ R_{of} = \frac{v_{test}}{i_{test}} = \frac{R_{o}}{1 + \beta A_{oc}} \]

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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)

\[ i_f = \frac{v_o}{R_f} \]

\[ \beta = \frac{1}{R_f} \]

\[ i_f = -i_o \frac{R_l}{R_f + R_l} \; \text{; since } v_i \approx 0 \]

\[ \beta = -\frac{R_l}{R_f + R_l} \]

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Design of Feedback Amplifiers

• Determine what type of feedback is required and the value of $\beta$
• 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 $2 \, k\Omega$ and the differential amplifier has an open circuit gain of $10^4$ with an input resistance of $5 \, k\Omega$ and an output resistance of $R_o = 100 \, \Omega$

\[ A_{vf} = A_f \approx \frac{1}{\beta} = 10 \]

\[ \beta = 0.1 \]

\[ A = A_{vo} = 10^4 \]

\[ A\beta = 10^4 \times 0.1 = 1000 \]

\[ \beta = \frac{R_2}{R_1 + R_2} = .1 \]

\[ R_1/R_2 = 9 \]

Choose $R_1 + R_2 > R_o$ to reduce any loss of gain due to loading.
Homework

• Impedances

• Practical Networks
  – Problems: 9.38