ECE 342
Electronic Circuits

Lecture 28
Feedback Topologies

Jose E. Schutt-Aine
Electrical & Computer Engineering
University of Illinois
jesa@illinois.edu
Series-Shunt Feedback

Voltage mixing-voltage sampling feedback
Shunt- Series Feedback

Current mixing-current sampling feedback
Series-Series Feedback

Voltage mixing-current sampling feedback
Shunt-Shunt Feedback

Current mixing-voltage sampling feedback
Transfer Function Representation

Use a two-terminal representation of system for input and output
Y-parameter Representation

\[ I_1 = y_{11} V_1 + y_{12} V_2 \]
\[ I_2 = y_{21} V_1 + y_{22} V_2 \]
Y Parameter Calculations

To make $V_2 = 0$, place a short at port 2

$$y_{11} = \left. \frac{I_1}{V_1} \right|_{V_2=0}$$

$$y_{21} = \left. \frac{I_2}{V_1} \right|_{V_2=0}$$
Z Parameters

\[ V_1 = z_{11}I_1 + z_{12}I_2 \]

\[ V_2 = z_{21}I_1 + z_{22}I_2 \]
Z-parameter Calculations

\[ Z_{11} = \left. \frac{V_1}{I_1} \right|_{I_2=0} \quad Z_{21} = \left. \frac{V_2}{I_1} \right|_{I_2=0} \]

To make \( I_2 = 0 \), place an open at port 2
H Parameters

\[ V_1 = h_{11} I_1 + h_{12} V_2 \]
\[ I_2 = h_{21} I_1 + h_{22} V_2 \]
H Parameter Calculations

To make $V_2 = 0$, place a short at port 2

$$h_{11} = \left. \frac{V_1}{I_1} \right|_{V_2=0}$$

$$h_{21} = \left. \frac{I_2}{I_1} \right|_{V_2=0}$$
\[ I_1 = g_{11} V_1 + g_{12} I_2 \]
\[ V_2 = g_{21} V_1 + g_{22} I_2 \]
G-Parameter Calculations

\[ g_{11} = \left. \frac{I_1}{V_1} \right|_{I_2=0} \quad g_{21} = \left. \frac{V_2}{V_1} \right|_{I_2=0} \]

To make \( I_2 = 0 \), place an open at port 2
Series-Shunt Feedback - Ideal

\[ A \equiv \frac{V_o}{V_i} \]

\[ A_f \equiv \frac{V_o}{V_s} = \frac{A}{1 + A\beta} \]

Negative feedback decreases the gain
Series-Shunt Feedback – Equivalent Circuit

\[ R_{if} = R_i \left( 1 + A\beta \right) \]
\[ R_{of} = R_o / \left( 1 + A\beta \right) \]

Negative feedback increases the input resistance and decreases the output resistance by a factor equal to the feedback.
Series-Shunt Feedback - Actual

![Series-Shunt Feedback Diagram]
Series-Shunt Feedback: h-Parameters

Account for all 4 h parameters
Series-Shunt Feedback : $h$-Parameters

\[ h_{12}^{\text{basic amplifier}} \ll h_{12}^{\text{feedback network}} \]
\[ h_{21}^{\text{feedback network}} \ll h_{21}^{\text{basic amplifier}} \]
Series-Series Feedback - Ideal

\[ A \equiv \frac{I_o}{V_i} \]

\[ A_f \equiv \frac{I_o}{V_s} = \frac{A}{1 + A\beta} \]

Negative feedback decreases the gain
Series-Series Feedback – Equivalent Circuit

\[ R_{if} = R_i \left(1 + A\beta \right) \quad \quad \quad \quad R_{of} = R_o \left(1 + A\beta \right) \]

Negative feedback increases the input resistance and increases the output resistance by a factor equal to the feedback.
Series-Series Feedback - Actual

Series-Series Feedback Circuit Diagram:

- **R_s**
- **R_in**
- **R_L**
- **R_out**
- **V_s**
- **I_o**
- Basic Amplifier
- Feedback Network

Diagram Showing Components and Connections.
Series-Series Feedback: Z Parameters

Account for all 4 z parameters
Series-Series Feedback: Z Parameters

\[ Z_{12} \text{ basic amplifier} \ll Z_{12} \text{ feedback network} \]

\[ Z_{21} \text{ feedback network} \ll Z_{21} \text{ basic amplifier} \]
Shunt-Shunt Feedback - Ideal

\[ A \equiv \frac{V_o}{I_i} \]
Shunt-Shunt Feedback

\[ A_f \equiv \frac{V_o}{I_s} = \frac{A}{1 + A\beta} \]

Negative feedback decreases the gain

\[ R_{if} = R_i / (1 + A\beta) \quad R_{of} = R_o / (1 + A\beta) \]

Negative feedback decreases the input resistance and decreases the output resistance by a factor equal to the feedback

\[
\begin{align*}
|Y_{12}|_{\text{basic amplifier}} & \ll |Y_{12}|_{\text{feedback network}} \\
|Y_{21}|_{\text{feedback network}} & \ll |Y_{21}|_{\text{basic amplifier}}
\end{align*}
\]
Shunt-Series Feedback - Ideal

\[ A \equiv \frac{I_o}{I_i} \]
Shunt-Series Feedback

\[ A_f = \frac{I_o}{I_s} = \frac{A}{1 + A\beta} \]

Negative feedback decreases the gain

\[ R_{if} = R_i / (1 + A\beta) \quad \quad \quad R_{of} = R_o \left(1 + A\beta\right) \]

Negative feedback decreases the input resistance and increases the output resistance by a factor equal to the feedback

\[
\begin{align*}
|g_{12}|_{\text{basic amplifier}} & \ll |g_{12}|_{\text{feedback network}} \\
|g_{21}|_{\text{feedback network}} & \ll |g_{21}|_{\text{basic amplifier}}
\end{align*}
\]
Rules for Series-Shunt Feedback

\[ V_1 = h_{11} I_1 + h_{12} V_2 \]
\[ I_2 = h_{21} I_1 + h_{22} V_2 \]

\[ h_{11} = \left. \frac{V_1}{I_1} \right|_{V_2=0} \quad h_{21} = \left. \frac{I_2}{I_1} \right|_{V_2=0} \]

\[ h_{12} = \left. \frac{V_1}{V_2} \right|_{I_1=0} \quad h_{22} = \left. \frac{I_2}{V_2} \right|_{I_1=0} \]

where \( R_{11} \) is obtained from

and \( R_{22} \) is obtained from

and the gain \( A \) is defined

\[ A = \frac{V_o}{V_i} \]

(b) \( \beta \) is obtained from

\[ \beta = \left. \frac{V_f}{V_o} \right|_{I_1 = 0} \]
Rules for Series-Series Feedback

\[ V_1 = z_{11} I_1 + z_{12} I_2 \]
\[ V_2 = z_{21} I_1 + z_{22} I_2 \]

\[ z_{11} = \frac{V_1}{I_1} \bigg|_{I_2=0} \quad z_{21} = \frac{V_2}{I_1} \bigg|_{I_2=0} \]
\[ z_{12} = \frac{V_1}{I_2} \bigg|_{I_1=0} \quad z_{22} = \frac{V_2}{I_2} \bigg|_{I_1=0} \]

where \( R_{11} \) is obtained from

and \( R_{22} \) is obtained from

and the gain \( A \) is defined

\[ A = \frac{I_o}{V_i} \]

(b) \( \beta \) is obtained from

\[ \beta = \frac{V_f}{I_o} \bigg|_{I_i=0} \]
Rules for Shunt-Shunt Feedback

\[ I_1 = y_{11} V_1 + y_{12} V_2 \]
\[ I_2 = y_{21} V_1 + y_{22} V_2 \]

\[ y_{11} = \frac{I_1}{V_1} \bigg|_{V_2 = 0} \quad y_{21} = \frac{I_2}{V_1} \bigg|_{V_2 = 0} \]
\[ y_{12} = \frac{I_1}{V_2} \bigg|_{V_1 = 0} \quad y_{22} = \frac{I_2}{V_2} \bigg|_{V_1 = 0} \]

(a) The A circuit is

\[ I_j \]
\[ R_i \]
\[ R_{11} \]
\[ R_{22} \]
\[ V_o \]

where \( R_{11} \) is obtained from

(b) \( \beta \) is obtained from

\[ \beta = \frac{I_f}{V_o} \bigg|_{V_1 = 0} \]
Rules for Shunt-Series Feedback

\[ I_1 = g_{11} V_1 + g_{12} I_2 \]
\[ V_2 = g_{21} V_1 + g_{22} I_2 \]

\[ g_{11} = \left. \frac{I_1}{V_1} \right|_{I_2=0} \quad g_{21} = \left. \frac{V_2}{V_1} \right|_{I_2=0} \]

\[ g_{12} = \left. \frac{I_1}{I_2} \right|_{V_1=0} \quad g_{22} = \left. \frac{V_2}{I_2} \right|_{V_1=0} \]

(a) The circuit is

\[ I_2 = \frac{I_0}{R_{22}} \]

where \( R_{11} \) is obtained from

\[ R_{11} = \left. \frac{V_{Y}}{I_{2}} \right|_{V_1=0} \]

and \( R_{22} \) is obtained from

\[ R_{22} = \left. \frac{V_{Y'}}{I_{2}} \right|_{V_1=0} \]

(b) \( \beta \) is obtained from

\[ \beta = \left. \frac{I_2}{I_o} \right|_{V_1=0} \]