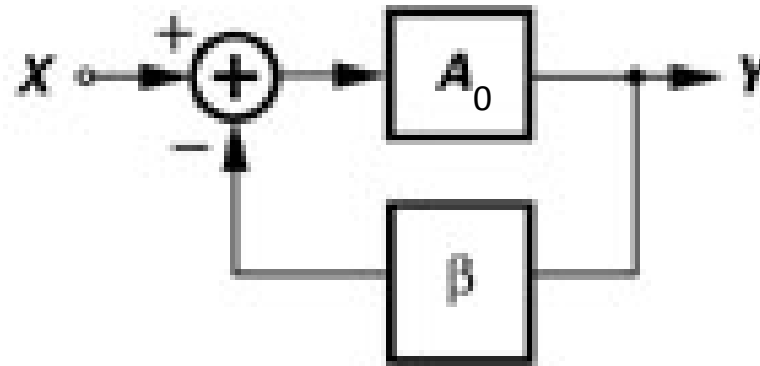


Lecture 8

IL2218 Analog electronics, advanced course

- Feedback, why feedback?
- Sense and return mechanisms
- Four different feedback models
- Gain, input and output resistance
- Effect of loading
- Example

Feedback system



$$A = \frac{Y}{X} = \frac{A_0}{1 + \beta A_0} = \frac{1}{\beta} \cdot \frac{\beta A_0}{1 + \beta A_0} = \frac{1}{\beta} \cdot \left(1 - \frac{1}{1 + \beta A_0} \right)$$

Closed loop gain determined, to the first order, by feedback factor β

The advantages of feedback

Gain desensitization

Closed loop gain will be less sensitive to changes in open loop gain

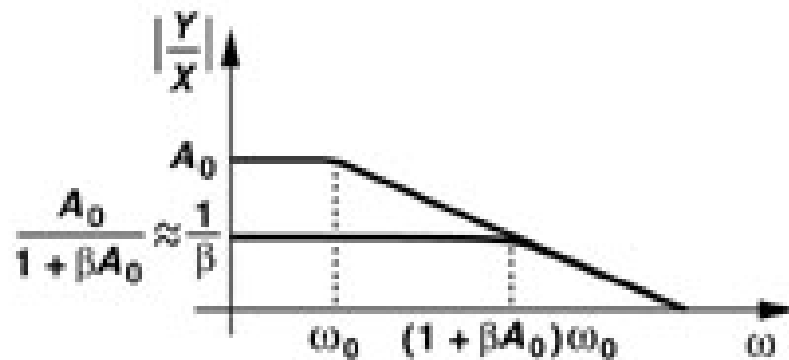
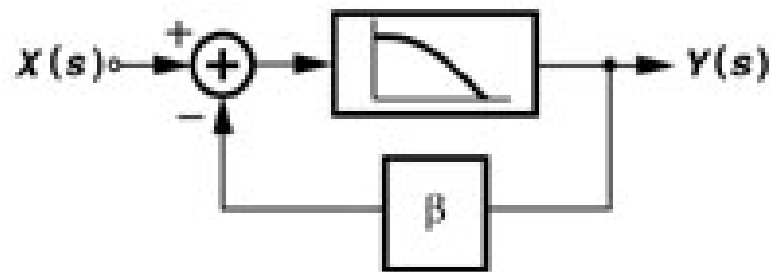
⇒ Increasing linearity

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

$$\frac{dA}{dA_o} = \dots = \frac{A}{A_o} \cdot \frac{1}{1 + \beta A_o}$$

$$\frac{dA}{A} = \frac{dA_o}{A_o} \cdot \frac{1}{1 + \beta A_o}$$

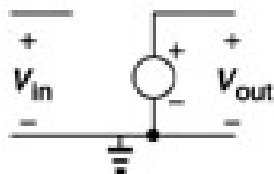
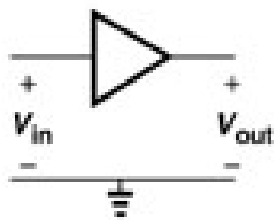
Increasing bandwidth



Increasing bandwidth
Decreasing gain

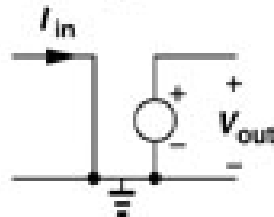
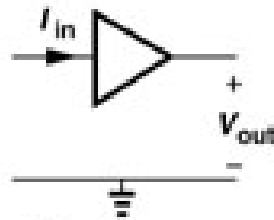
Amplifier types

Voltage Amp.



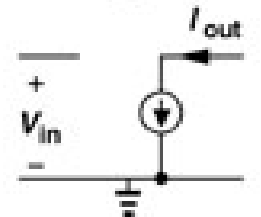
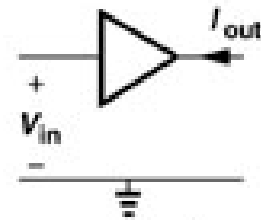
(a)

Transimpedance Amp.



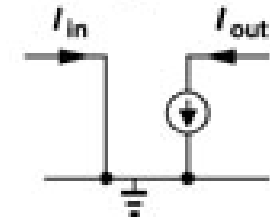
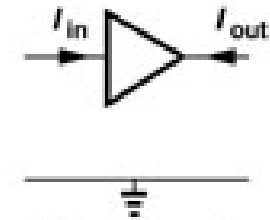
(b)

Transconductance Amp.

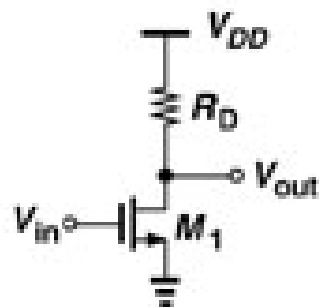


(c)

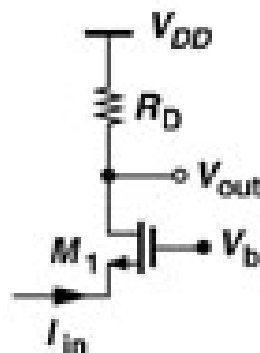
Current Amp.



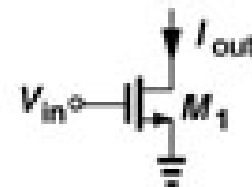
(d)



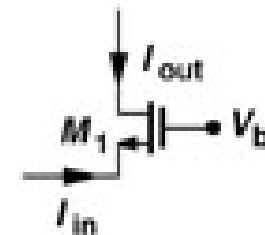
(a)



(b)

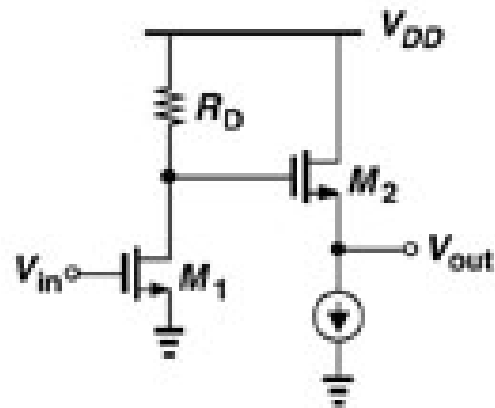


(c)

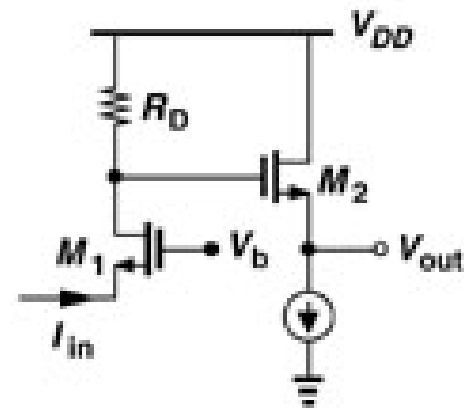


(d)

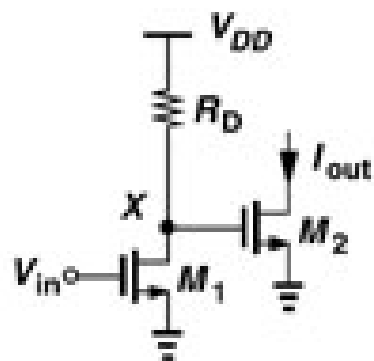
Improved examples of amplifier types



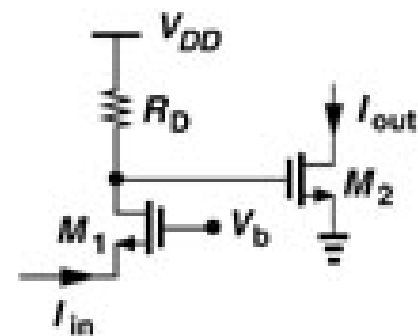
(a)



(b)

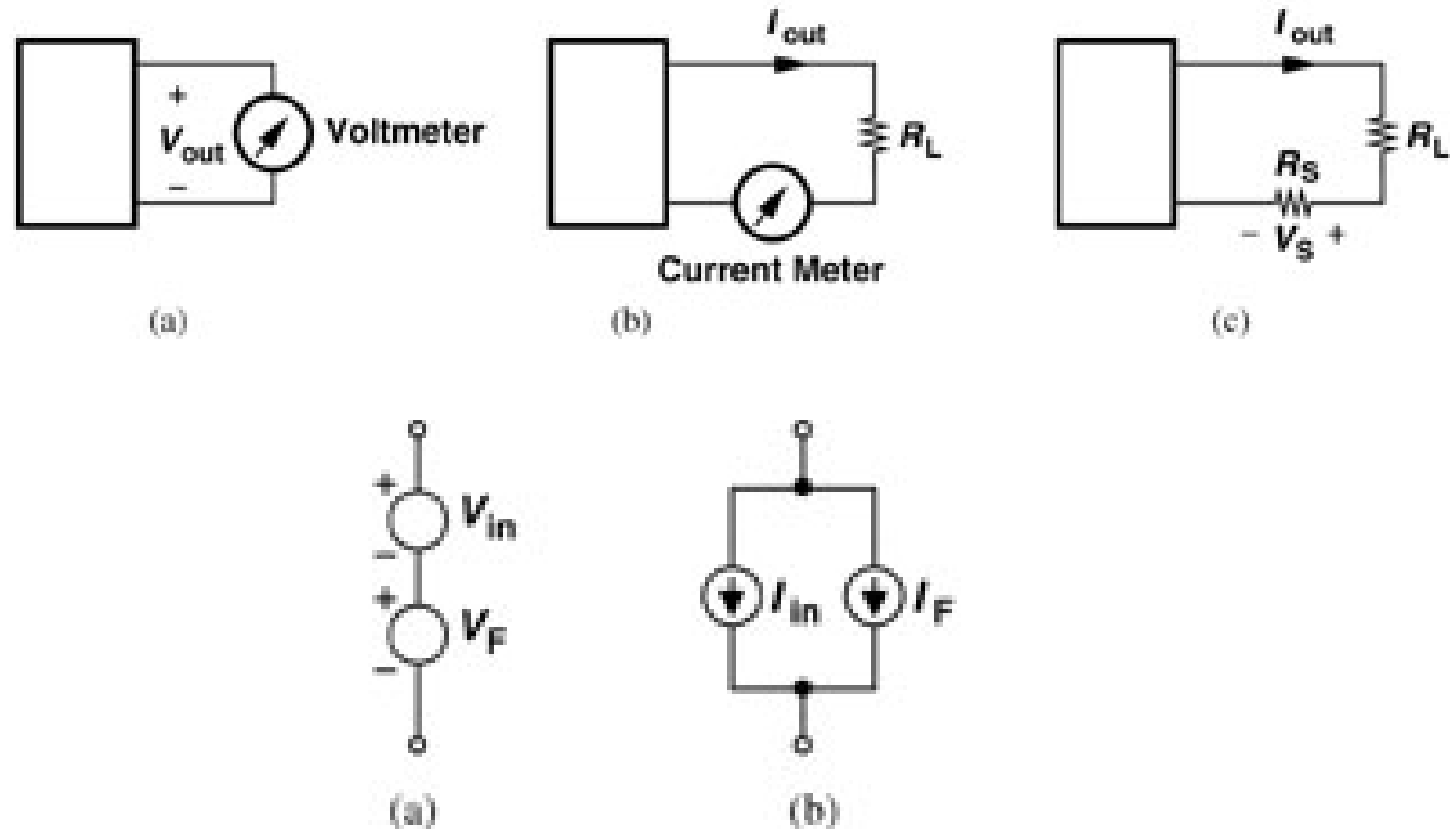


(c)

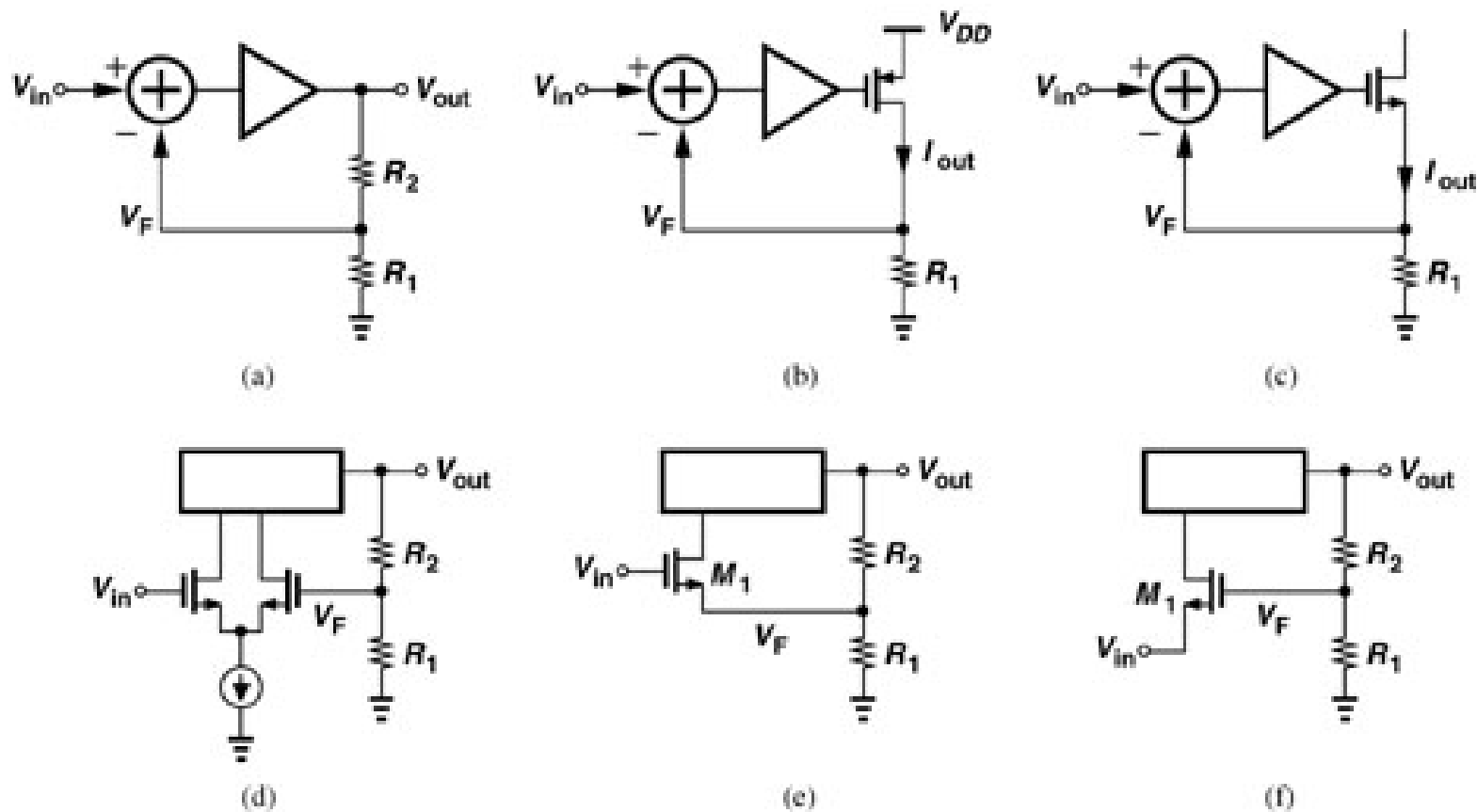


(d)

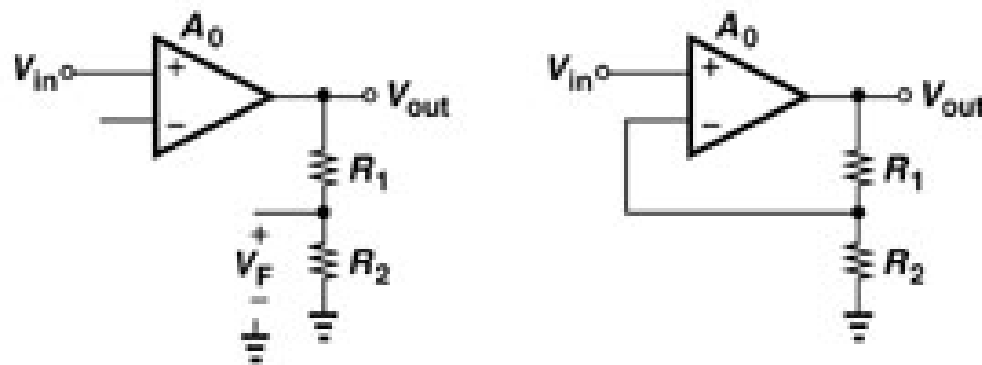
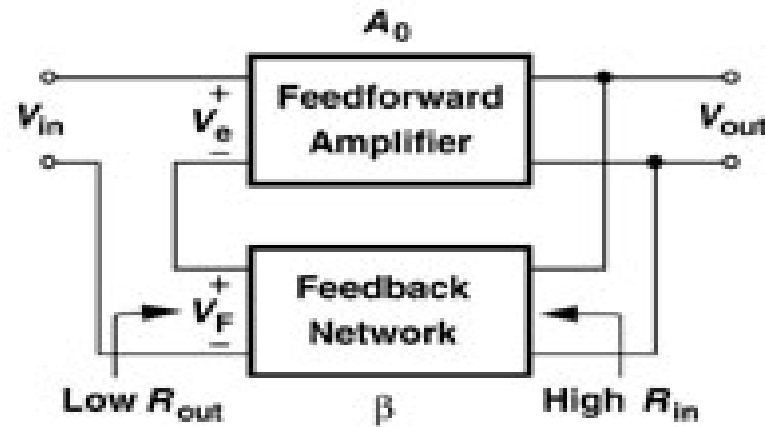
Sense and feedback mechanisms



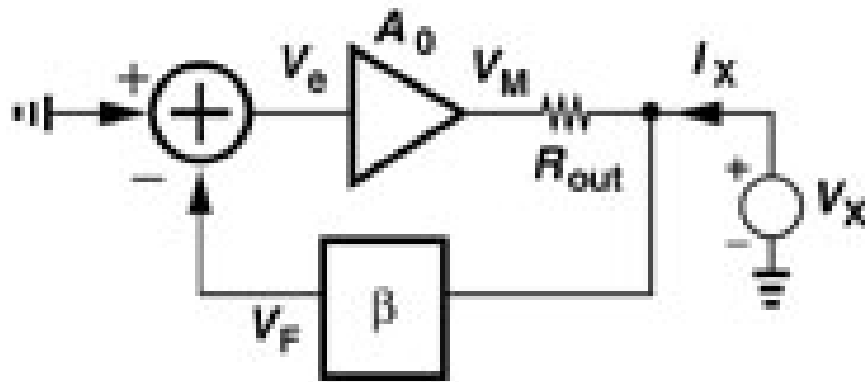
Example feedback mechanisms



Voltage-voltage feedback

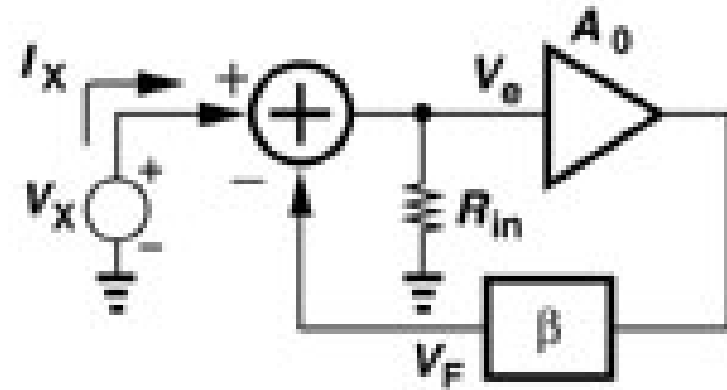


Output and input resistance



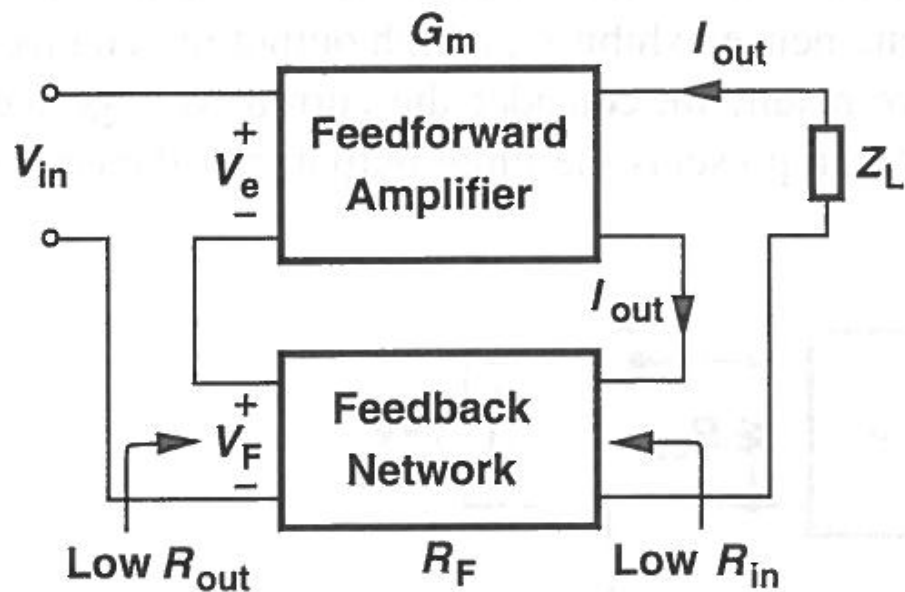
$$I_X = \frac{V_X - V_M}{R_{out}} = \frac{V_X - (-\beta A_0 V_X)}{R_{out}}$$

$$\frac{V_X}{I_X} = R_{out,CL} = \frac{R_{out}}{1 + \beta A_0}$$



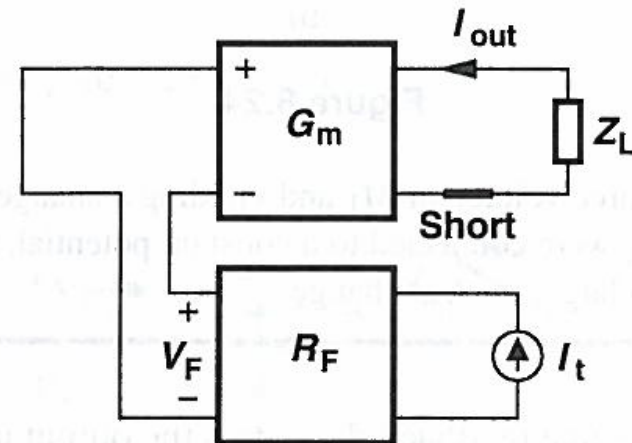
$$\frac{V_X}{I_X} = R_{in,CL} = R_{in}(1 + \beta A_0)$$

Current-voltage feedback

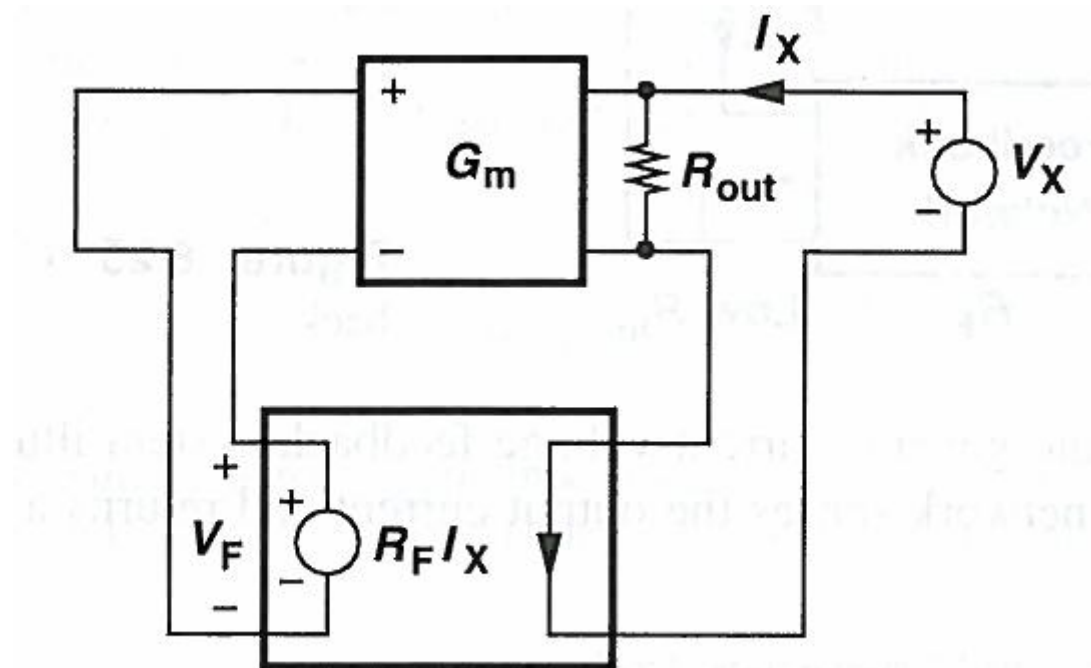


$$\frac{I_{out}}{V_{in}} = \frac{G_m}{1 + G_m R_F}$$

Loop gain

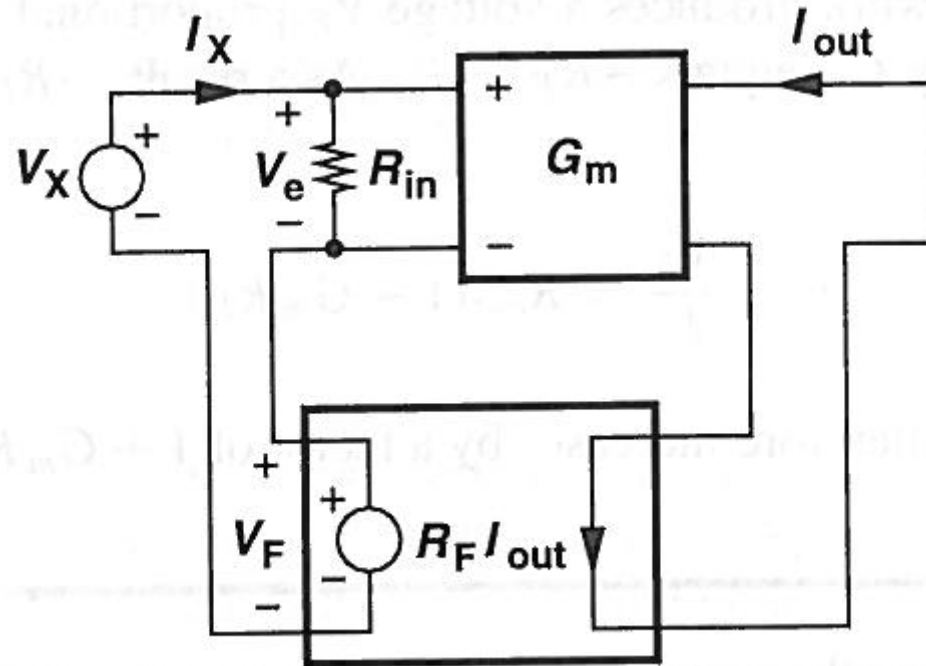


Current-voltage feedback, output resistance



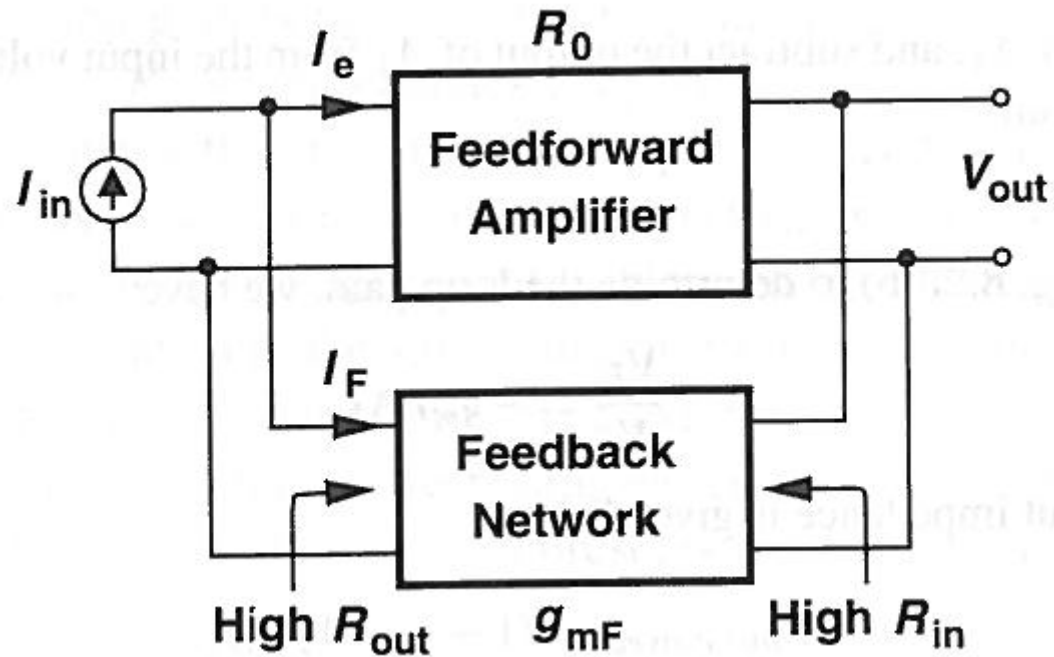
$$\frac{V_X}{I_X} = R_{out}(1 + G_m R_F).$$

Current-voltage feedback, input resistance

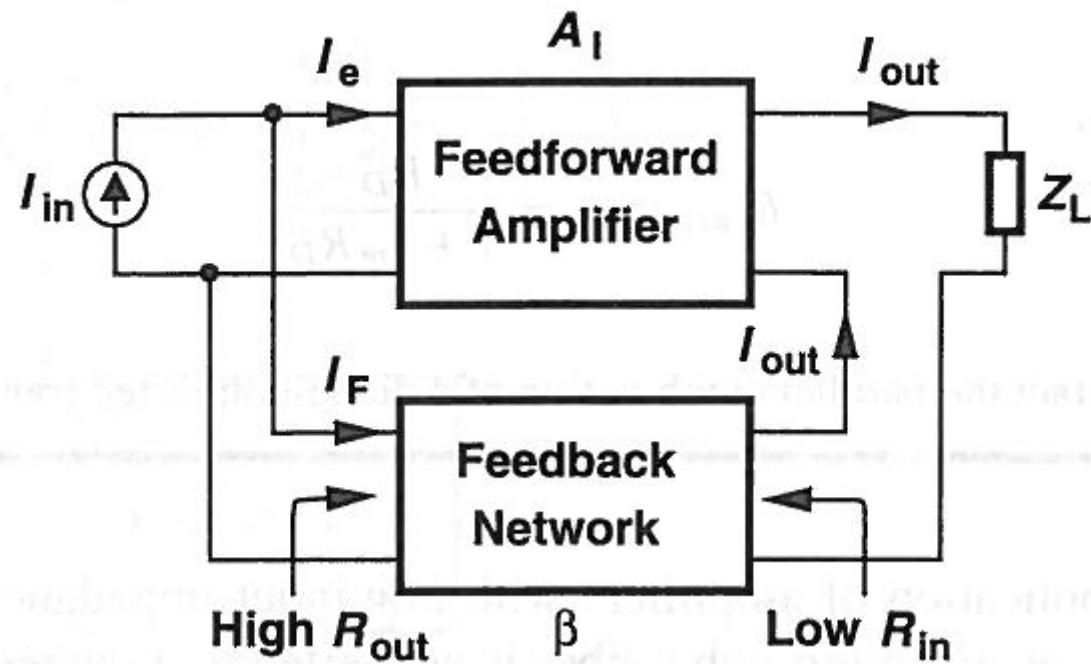


$$\frac{V_X}{I_X} = R_{in}(1 + G_m R_F).$$

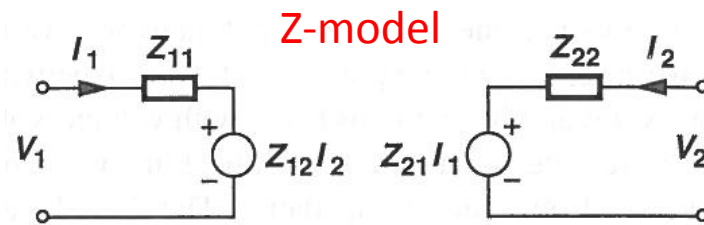
Voltage-current feedback



Current-current feedback

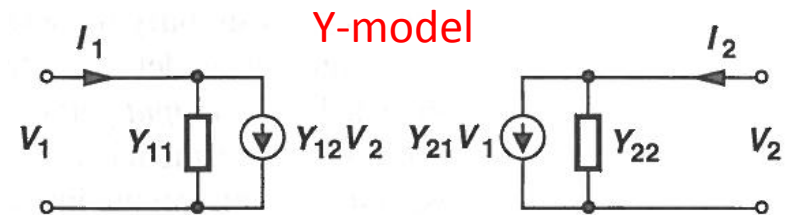


Two port models



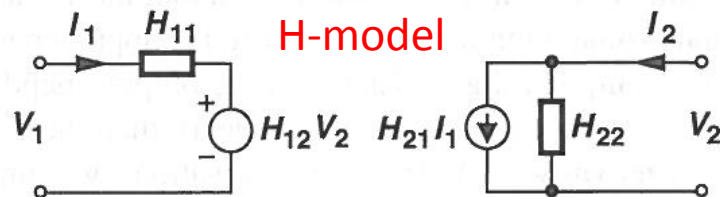
$$V_1 = Z_{11}I_1 + Z_{12}I_2$$

$$V_2 = Z_{21}I_1 + Z_{22}I_2.$$



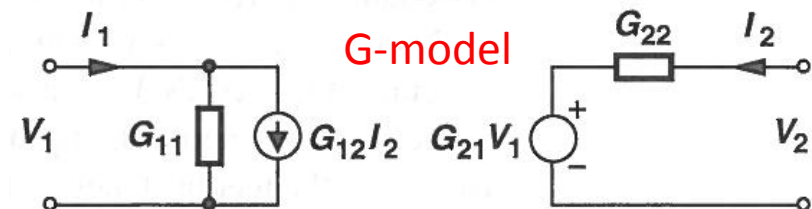
$$I_1 = Y_{11}V_1 + Y_{12}V_2$$

$$I_2 = Y_{21}V_1 + Y_{22}V_2,$$



$$V_1 = H_{11}I_1 + H_{12}V_2$$

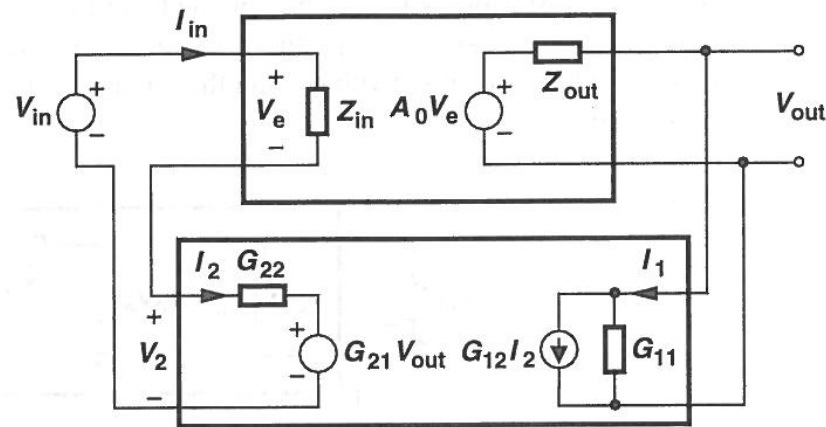
$$I_2 = H_{21}I_1 + H_{22}V_2,$$



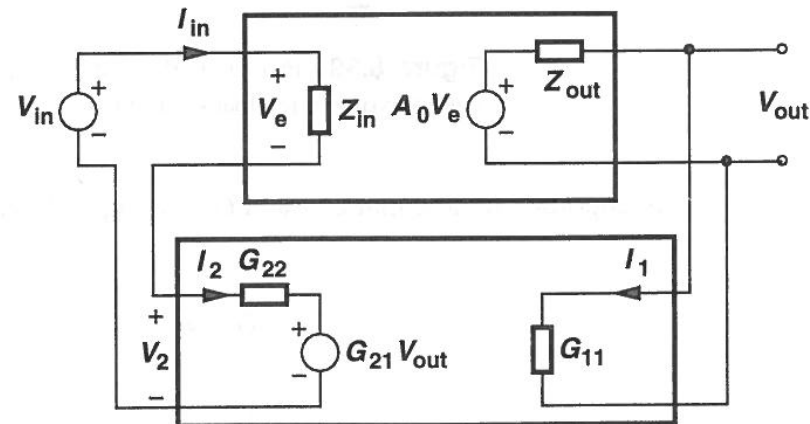
$$I_1 = G_{11}V_1 + G_{12}I_2$$

$$V_2 = G_{21}V_1 + G_{22}I_2.$$

Effect of loading in voltage-voltage feedback



(a)



(b)

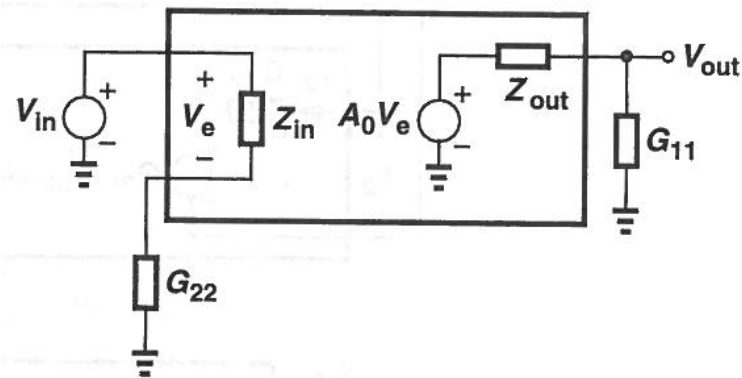
$$V_e = (V_{in} - G_{21} V_{out}) \frac{Z_{in}}{Z_{in} + G_{22}},$$

$$(V_{in} - G_{21} V_{out}) \frac{Z_{in}}{Z_{in} + G_{22}} A_0 \frac{G_{11}^{-1}}{G_{11}^{-1} + Z_{out}} = V_{out}.$$

$$\frac{V_{out}}{V_{in}} = \frac{A_0 \frac{Z_{in}}{Z_{in} + G_{22}} \frac{G_{11}^{-1}}{G_{11}^{-1} + Z_{out}}}{1 + \frac{Z_{in}}{Z_{in} + G_{22}} \frac{G_{11}^{-1}}{G_{11}^{-1} + Z_{out}} G_{21} A_0}.$$

Including loading in voltage-voltage feedback

Proper method of including loading



Conceptual view of including loading

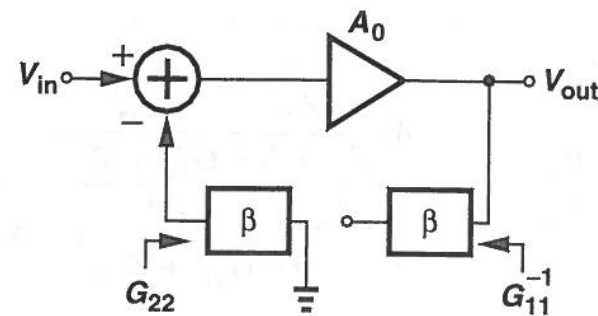


Figure 10.10 consists of four circuit diagrams labeled (a), (b), (c), and (d), each illustrating a different feedback topology and the method to calculate the beta factor.

- (a) Voltage-series feedback:** The input is a voltage V_{in} . The feedback network is a voltage divider with gain β . The forward path has a gain A_0 . The output is V_{out} . The beta factor is calculated as $\beta = \frac{V_2}{V_1} \Big|_{I_2=0}$.
- (b) Current-series feedback:** The input is a voltage V_{in} . The feedback network is a current divider with gain β . The forward path has a transconductance G_m . The output is a current I_{out} . The beta factor is calculated as $\beta = \frac{V_2}{I_1} \Big|_{I_2=0}$.
- (c) Voltage-shunt feedback:** The input is a current I_{in} . The feedback network is a current divider with gain β . The forward path has a resistance R_0 . The output is a voltage V_{out} . The beta factor is calculated as $\beta = \frac{I_2}{V_1} \Big|_{V_2=0}$.
- (d) Current-shunt feedback:** The input is a current I_{in} . The feedback network is a current divider with gain β . The forward path has a transconductance A_1 . The output is a current I_{out} . The beta factor is calculated as $\beta = \frac{I_2}{I_1} \Big|_{V_2=0}$.

Problem 8.10

8.10. Using feedback techniques, calculate the input and output impedance and voltage gain of each circuit in Fig. 8.57.

