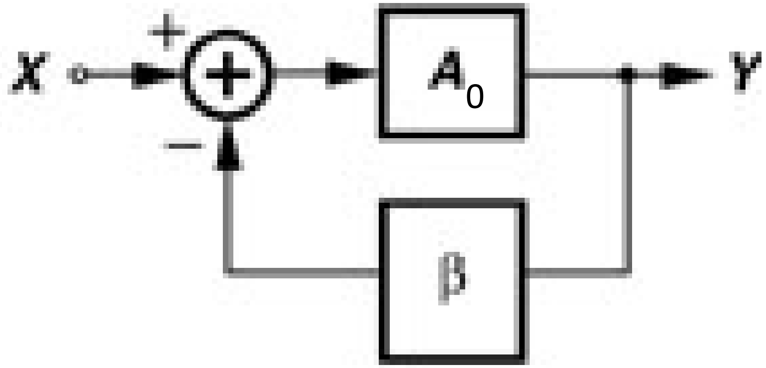
Lecture 8
IL2218 Analog electronics, advanced course

- 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

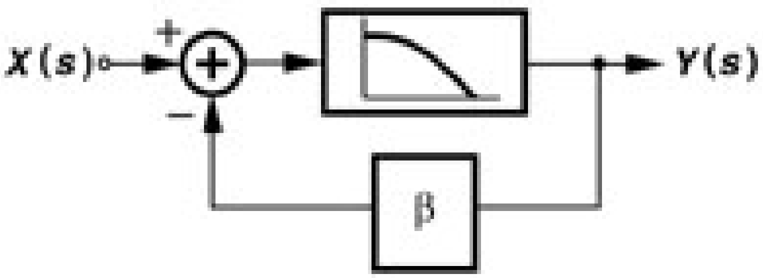
$$A = \frac{A_o}{1+\beta A_o}$$

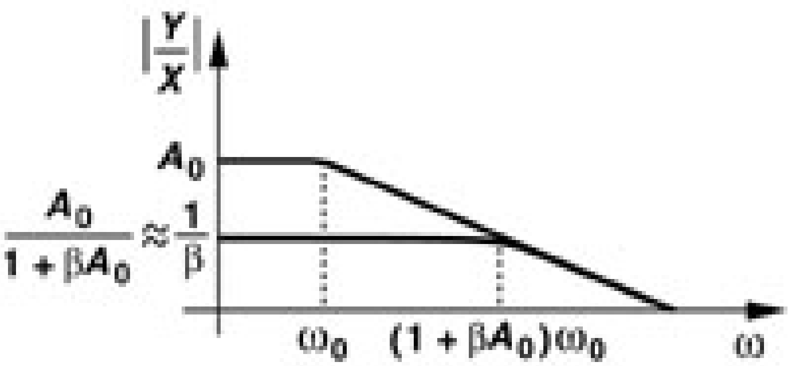
Closed loop gain will be less sensitive to changes in open loop gain
$\Rightarrow$ Increasing linearity

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

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

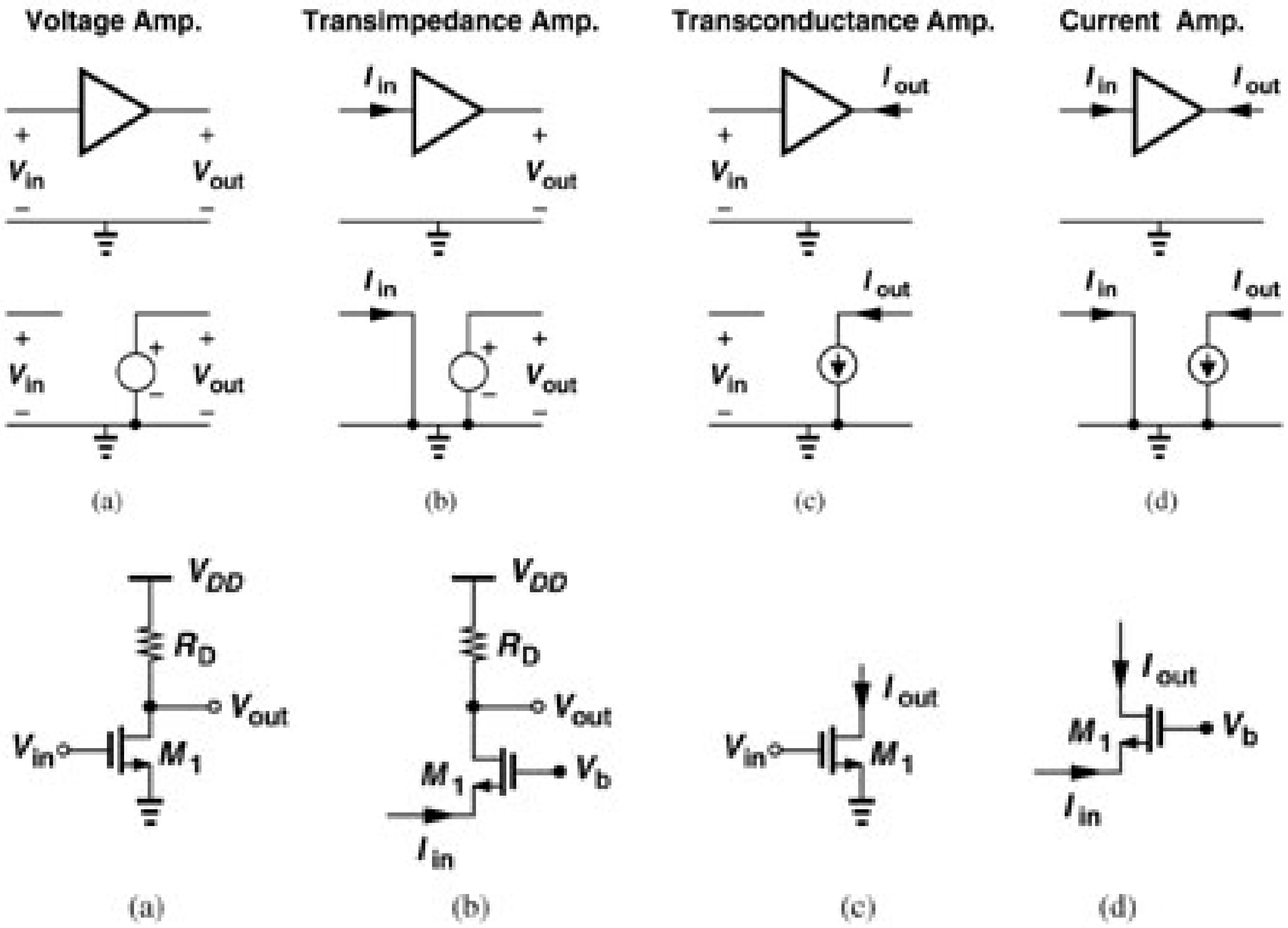
Increasing bandwidth



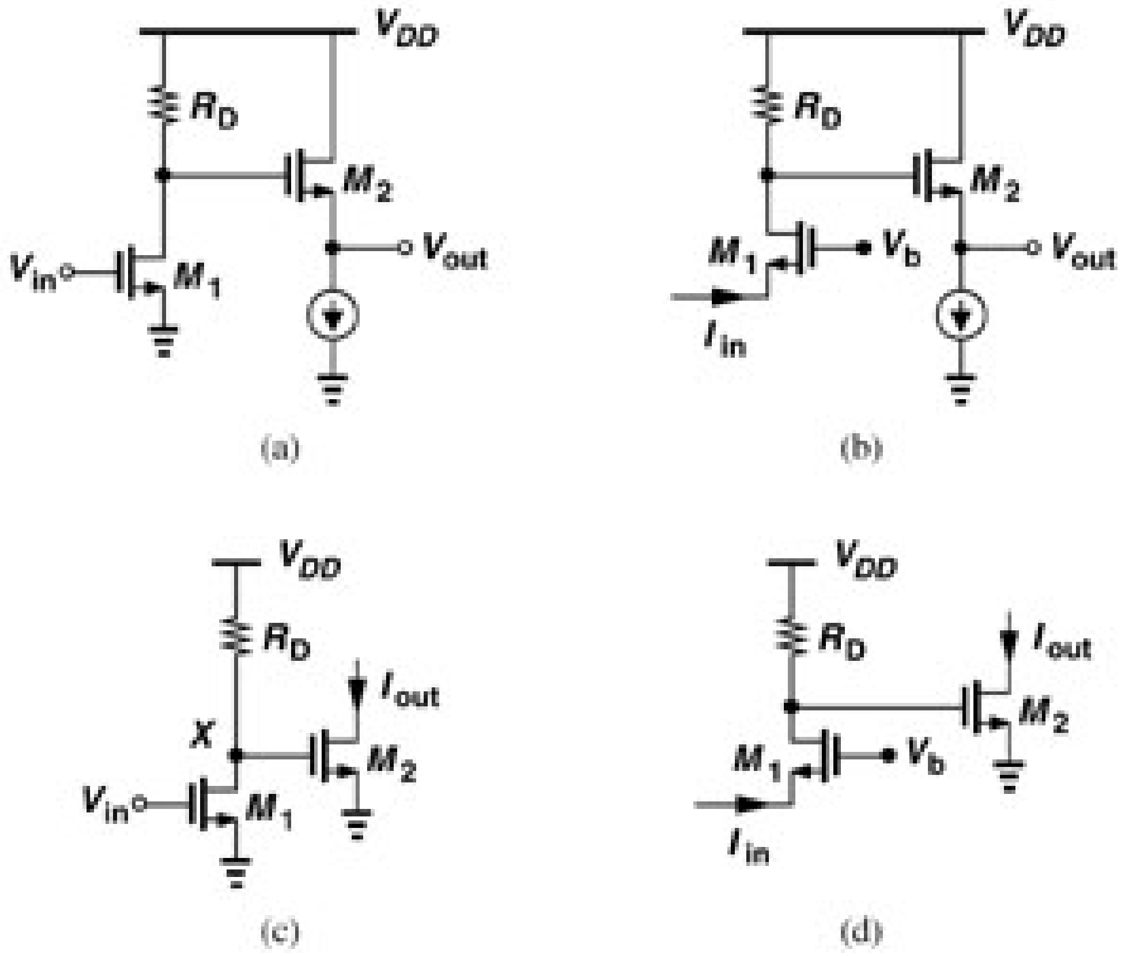


Increasing bandwidth
Decreasing gain

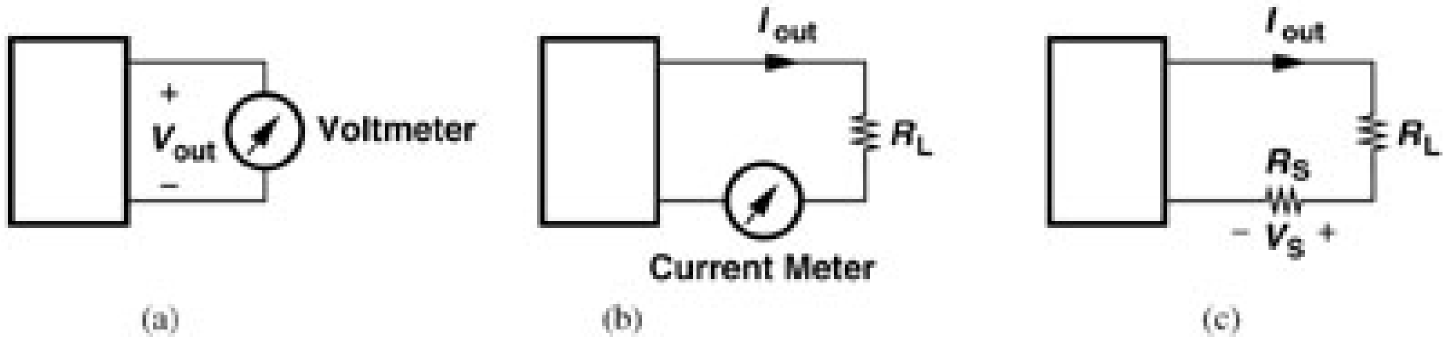
Amplifier types

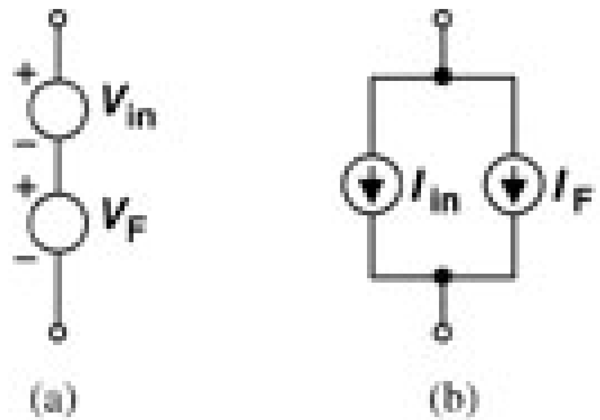


Improved examples of amplifier types

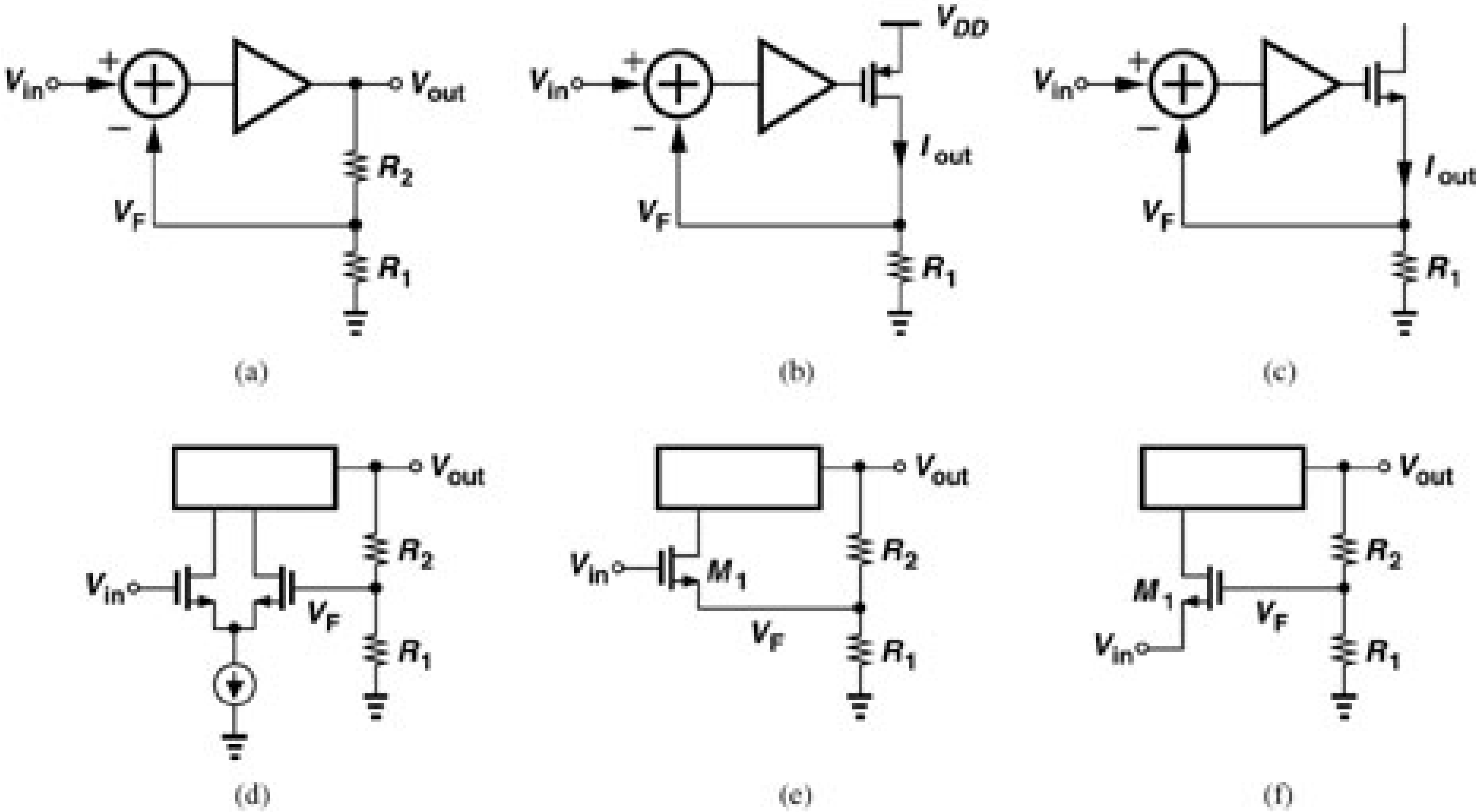


Sense and feedback mechanisms

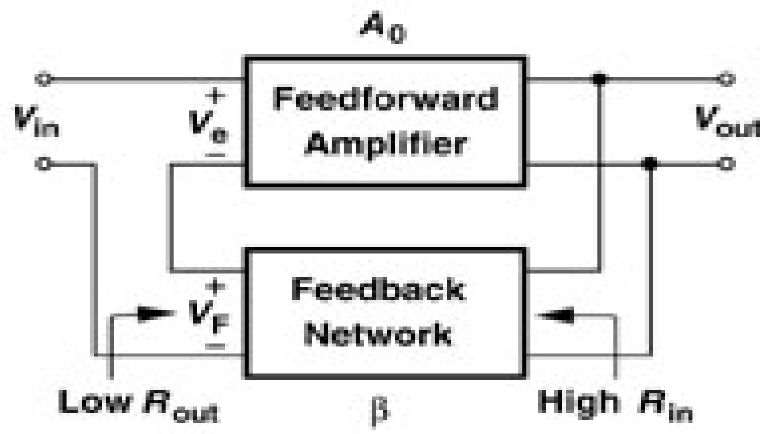


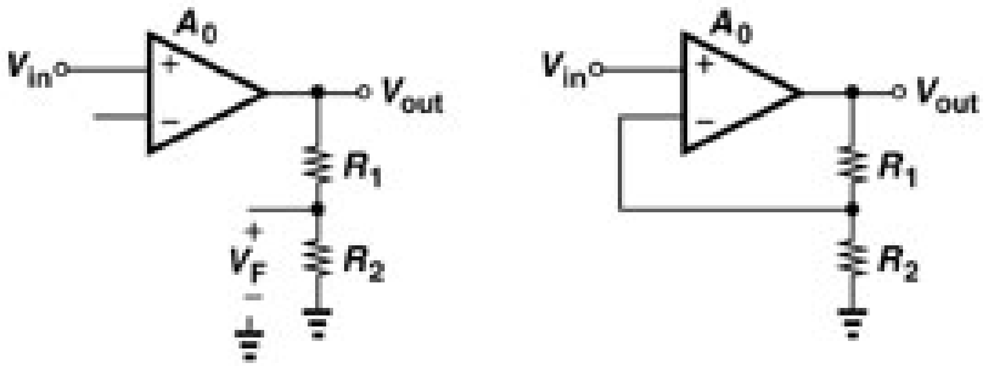


Example feedback mechanisms

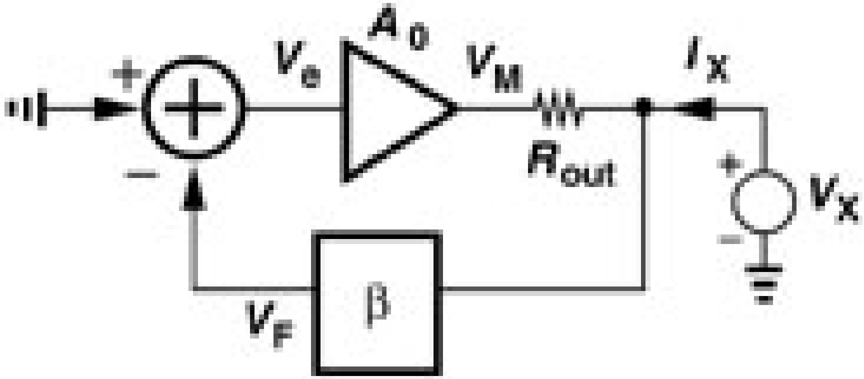


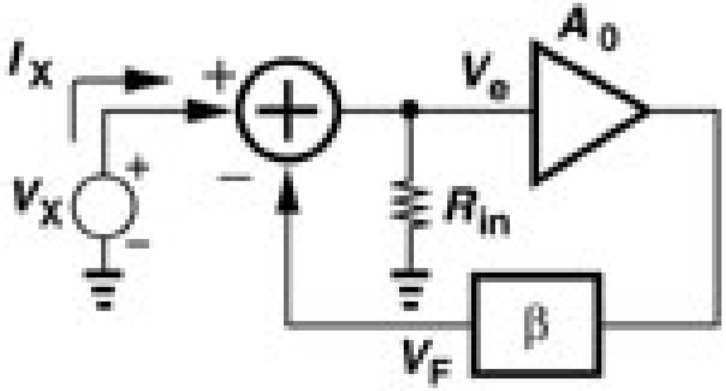
Voltage-voltage feedback





Output and input resistance



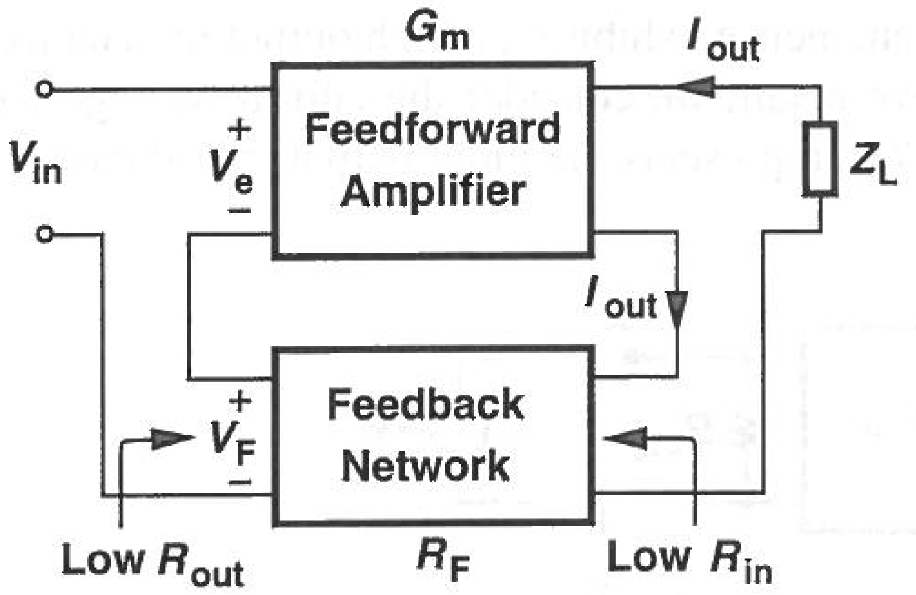


$$I_X = \frac{V_X - V_M}{R_{out}} = \frac{V_X - (-\beta A_0 V_X)}{R_{out}}$$

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

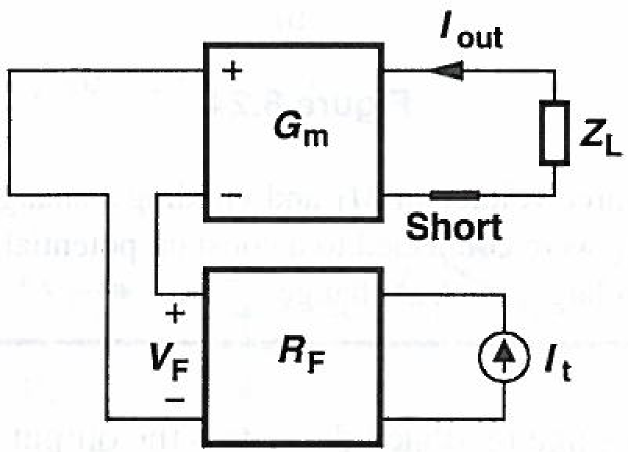
$$\frac{V_X}{I_X} = R_{in,CL} = R_{in}(1+\beta A_0)$$

Current-voltage feedback

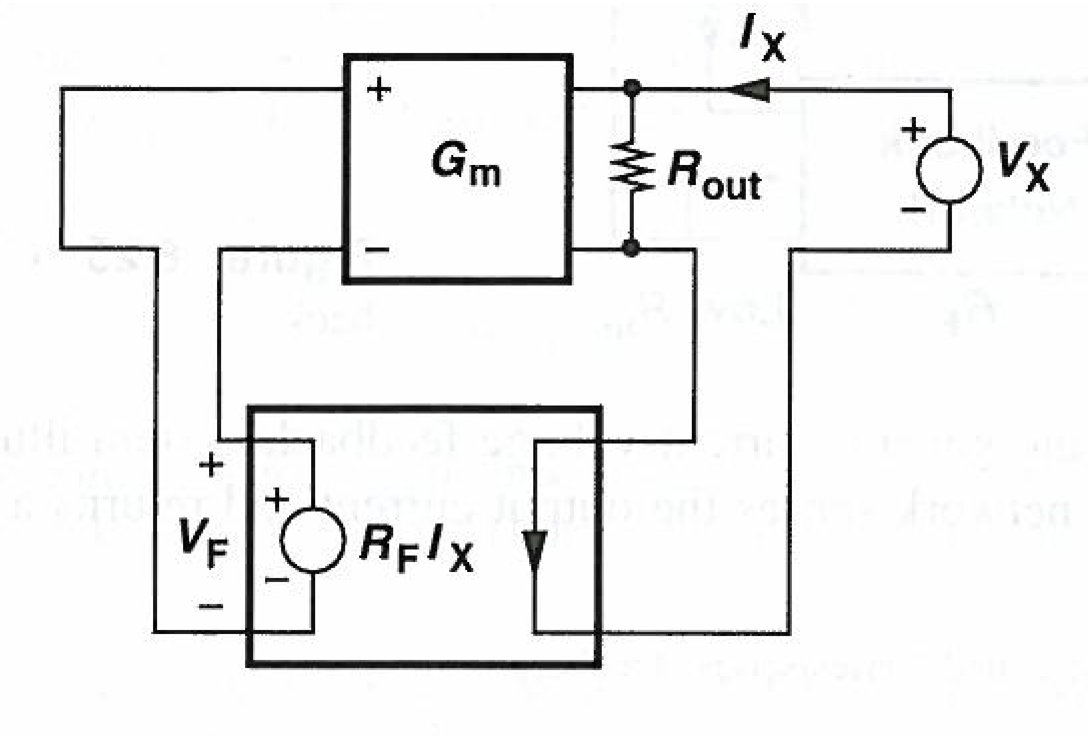


$$\frac{I_{out}}{V_{in}} = \frac{G_m}{1 + G_m R_F}.$$

Loop gain

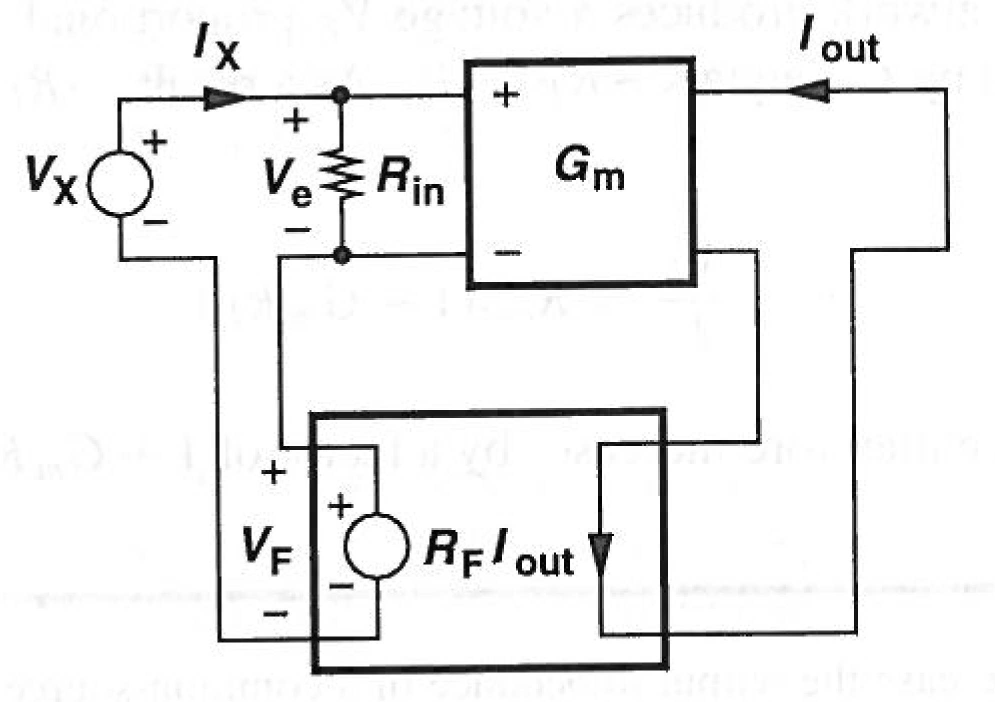


Current-voltage feedback, output resistance



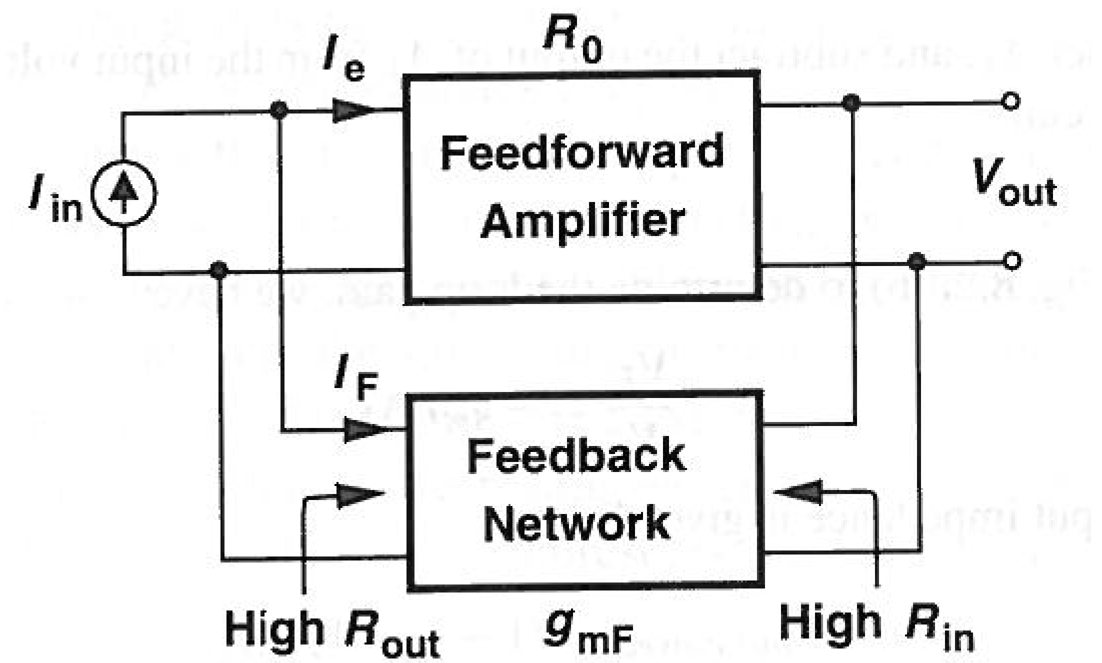
$$\frac{V_X}{I_X} = R_{out}(1 + G_m R_F).$$

Current-voltage feedback, input resistance

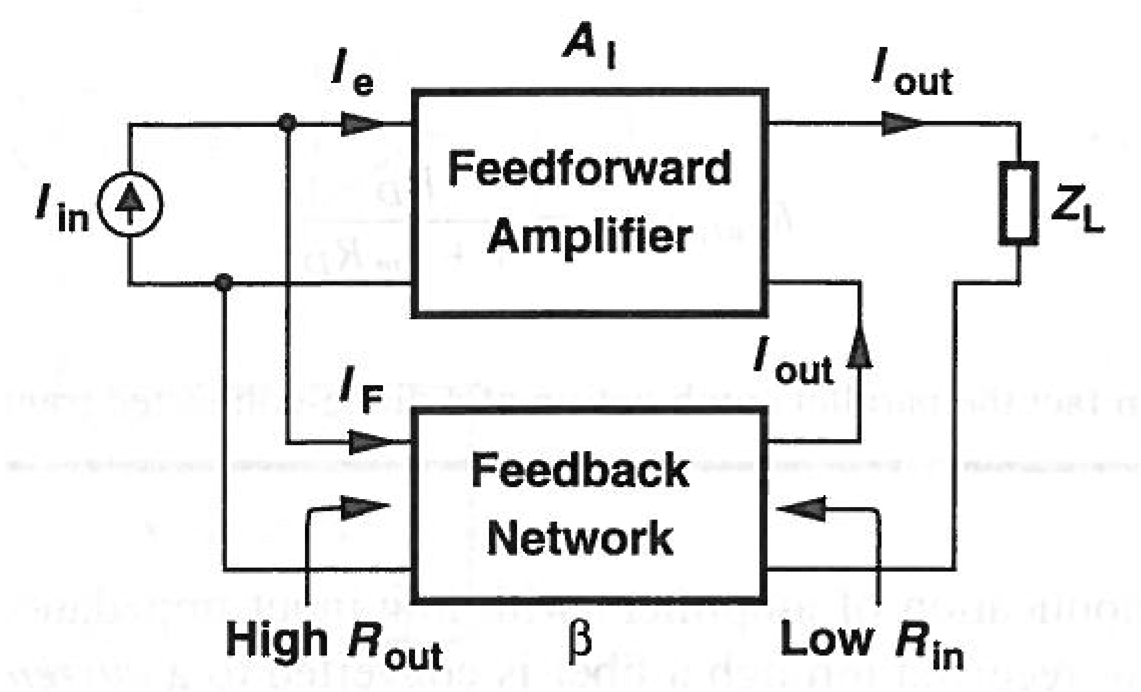


$$\frac{V_X}{I_X} = R_{in}(1 + G_m R_F).$$

Voltage-current feedback

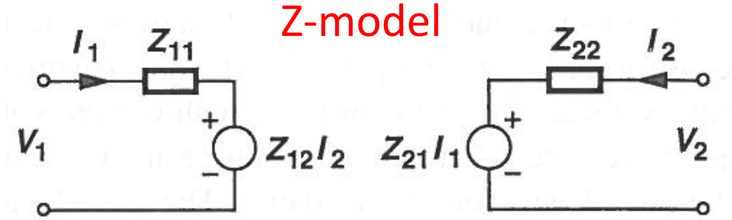


Current-current feedback



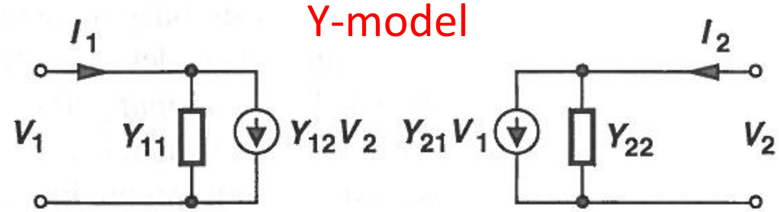
Two port models

Z-model



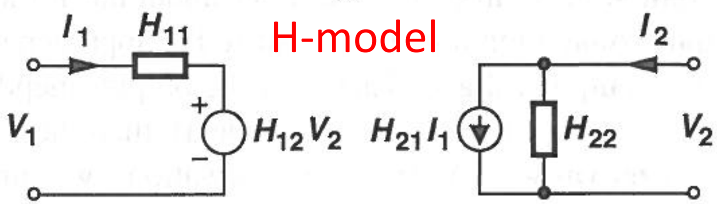
$$V_1 = Z_{11}I_1 + Z_{12}I_2$$
$$V_2 = Z_{21}I_1 + Z_{22}I_2.$$

Y-model



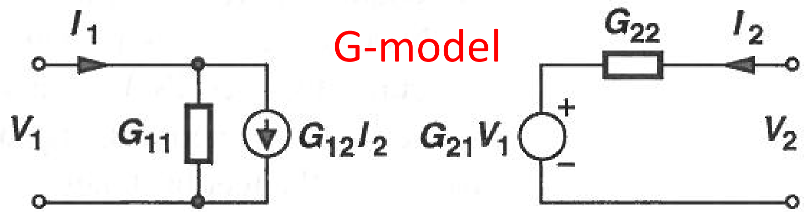
$$I_1 = Y_{11}V_1 + Y_{12}V_2$$
$$I_2 = Y_{21}V_1 + Y_{22}V_2,$$

H-model



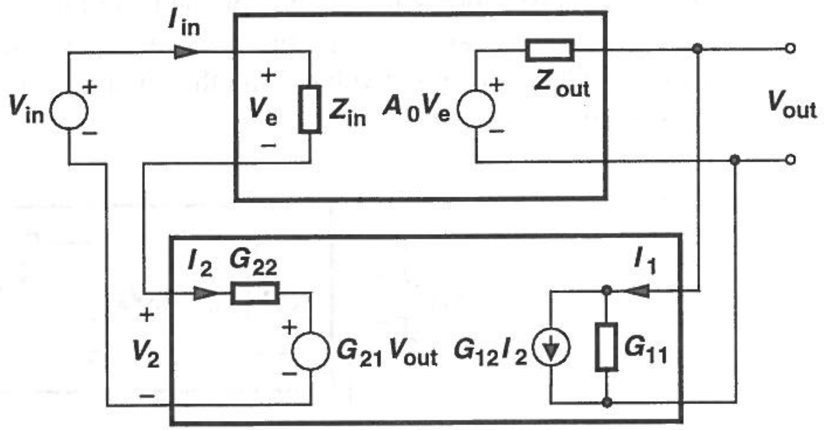
$$V_1 = H_{11}I_1 + H_{12}V_2$$
$$I_2 = H_{21}I_1 + H_{22}V_2,$$

G-model



$$I_1 = G_{11}V_1 + G_{12}I_2$$
$$V_2 = G_{21}V_1 + G_{22}I_2.$$

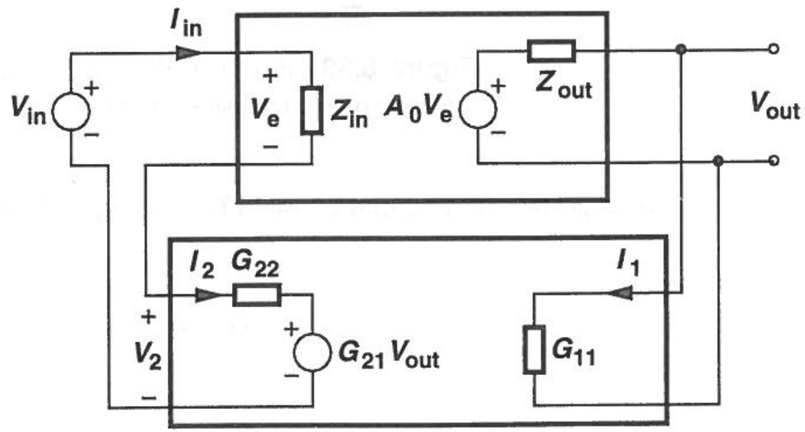
Effect of loading in voltage-voltage feedback



(a)

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

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

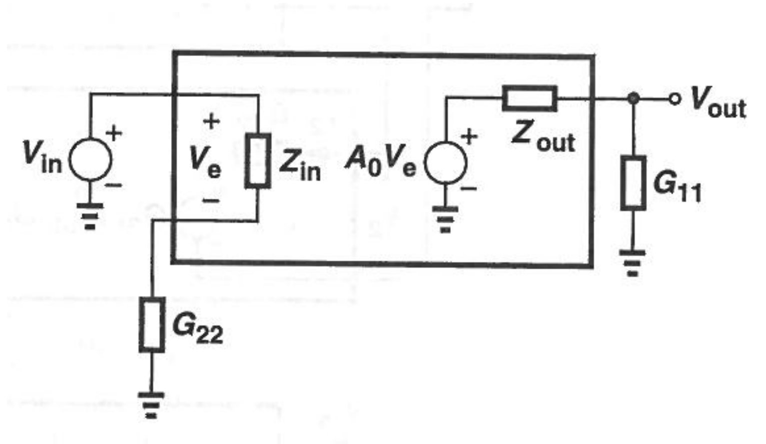


(b)

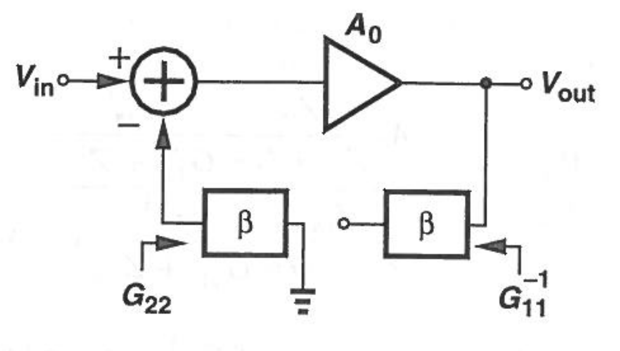
$$\frac{V_{out}}{V_{in}} = \frac{A_0\dfrac{Z_{in}}{Z_{in} + G_{22}}\dfrac{G_{11}^{-1}}{G_{11}^{-1} + Z_{out}}}{1 + \dfrac{Z_{in}}{Z_{in} + G_{22}}\dfrac{G_{11}^{-1}}{G_{11}^{-1} + Z_{out}}G_{21}A_0}.$$

Including loading in voltage-voltage feedback

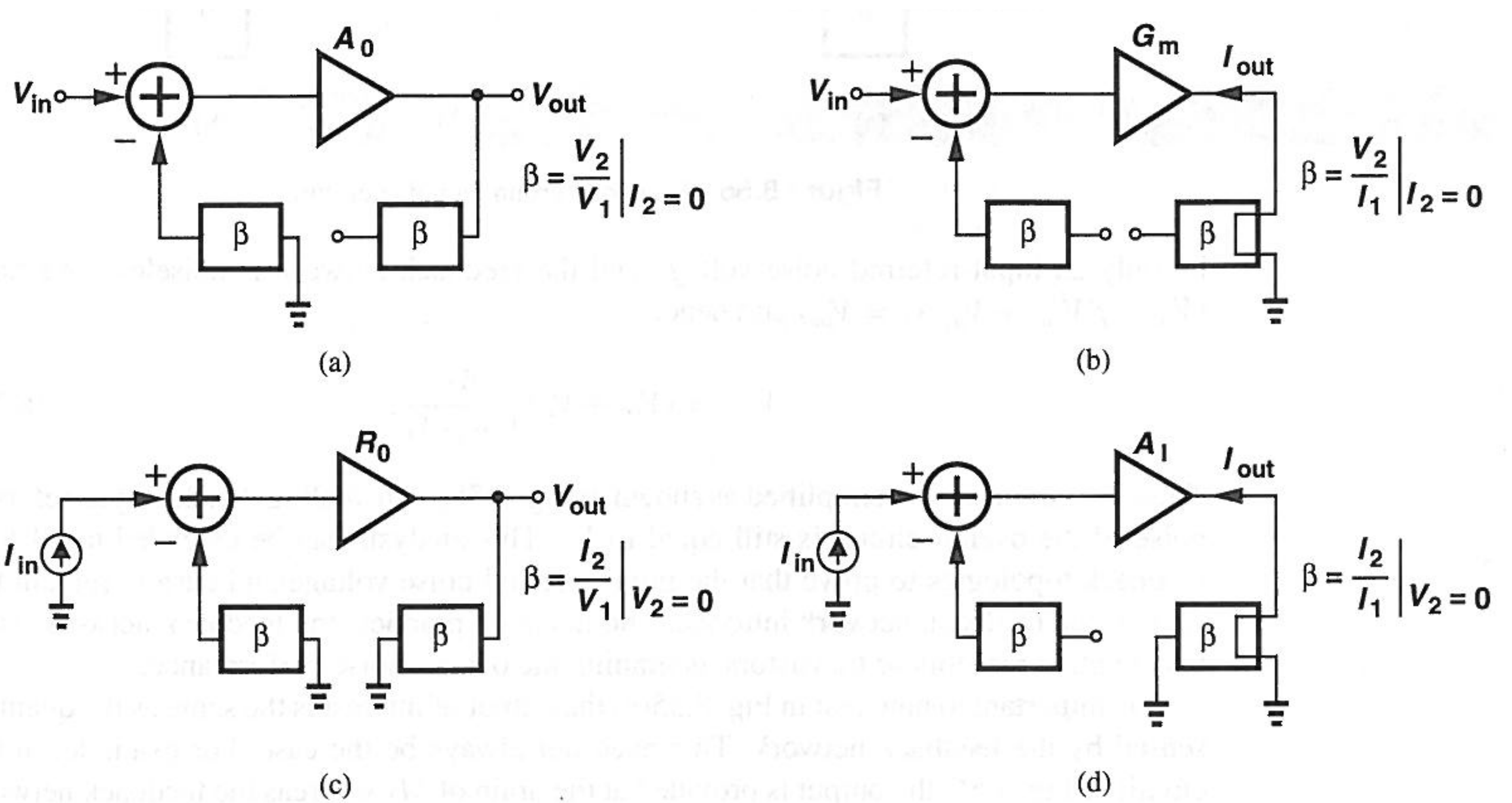
Proper method of including loading



Conceptual view of including loading



Summary of loading effects



Problem 8.10

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