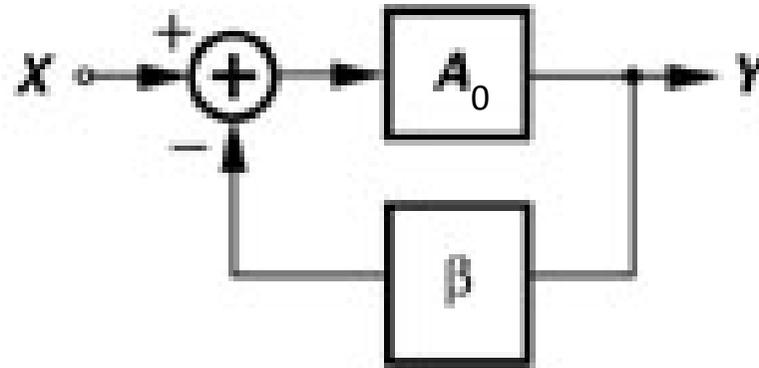


## Lecture 8

# 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  $\beta$

# The advantages of feedback

## Gain desensitization

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

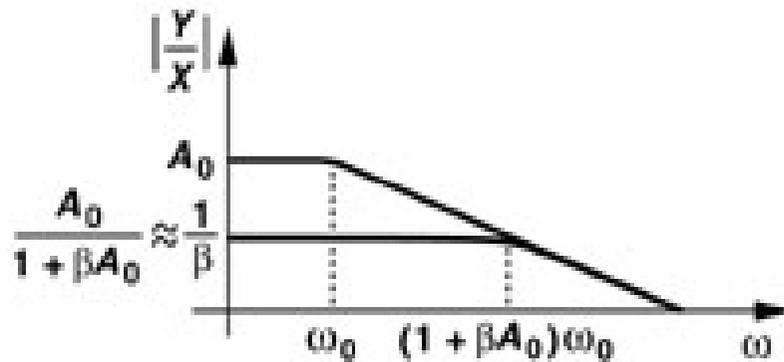
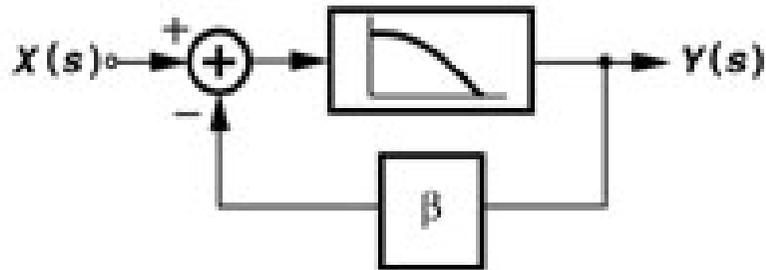
⇒ Increasing linearity

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

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

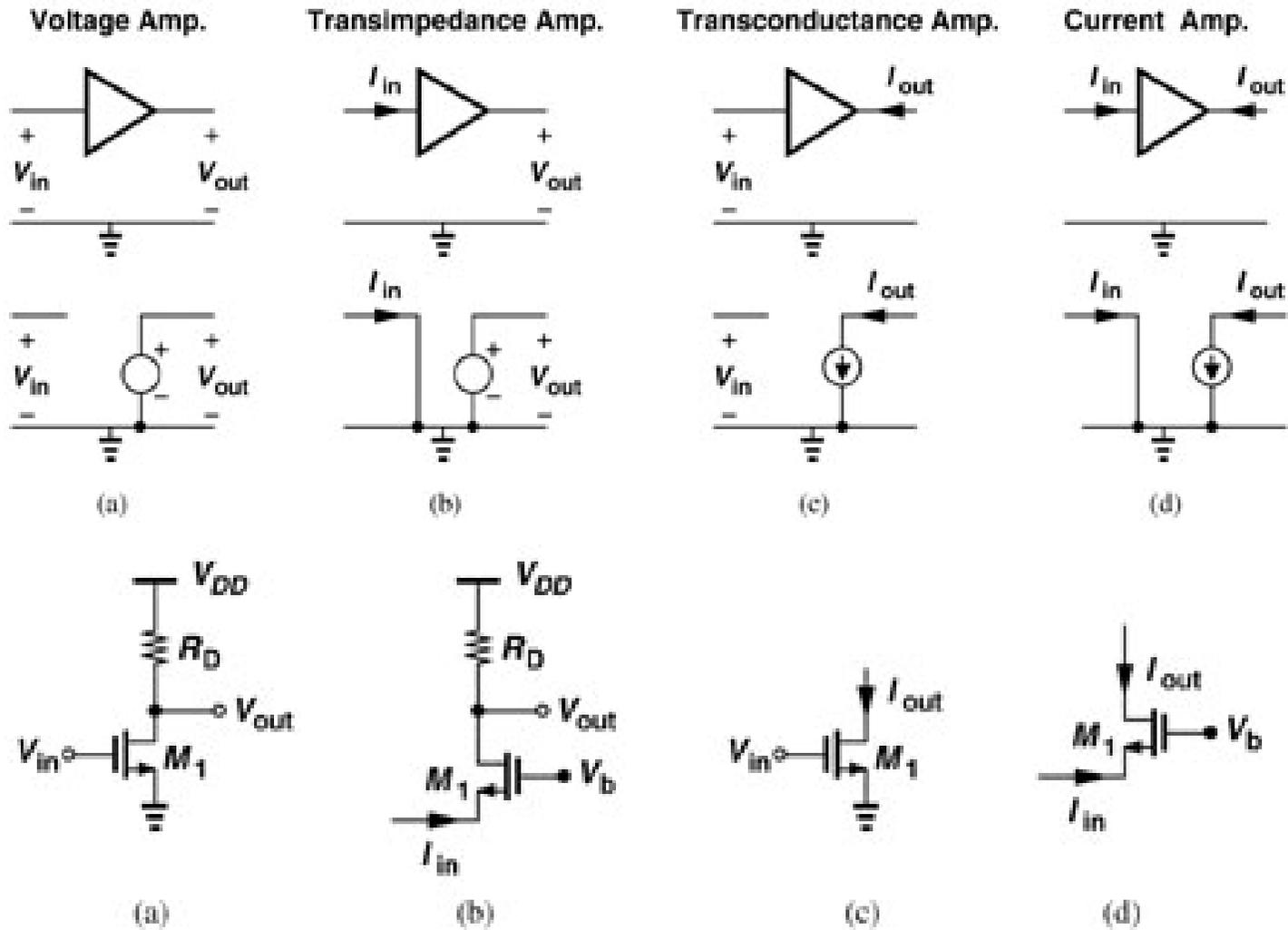
$$\frac{dA}{A} = \frac{dA_o}{A_o} \cdot \frac{1}{1 + \beta A_o}$$

# Increasing bandwidth

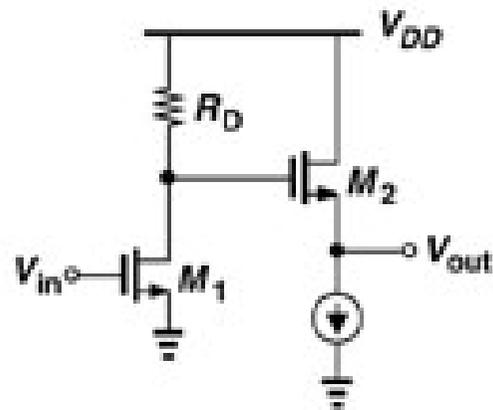


Increasing bandwidth  
Decreasing gain

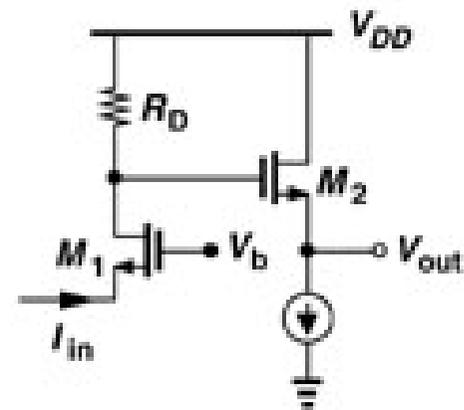
# Amplifier types



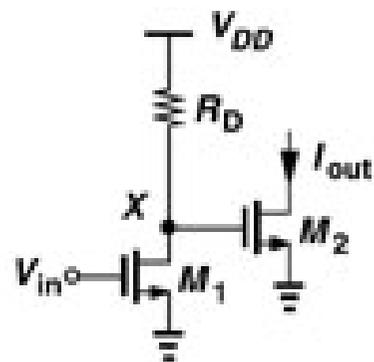
# Improved examples of amplifier types



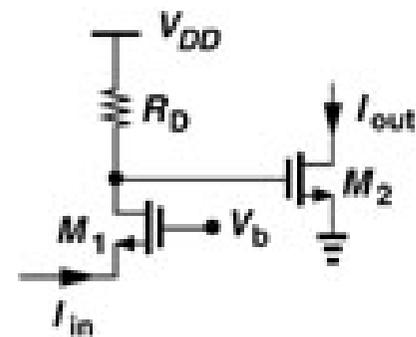
(a)



(b)

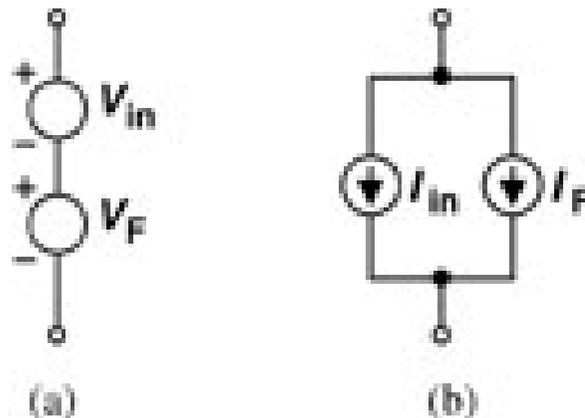
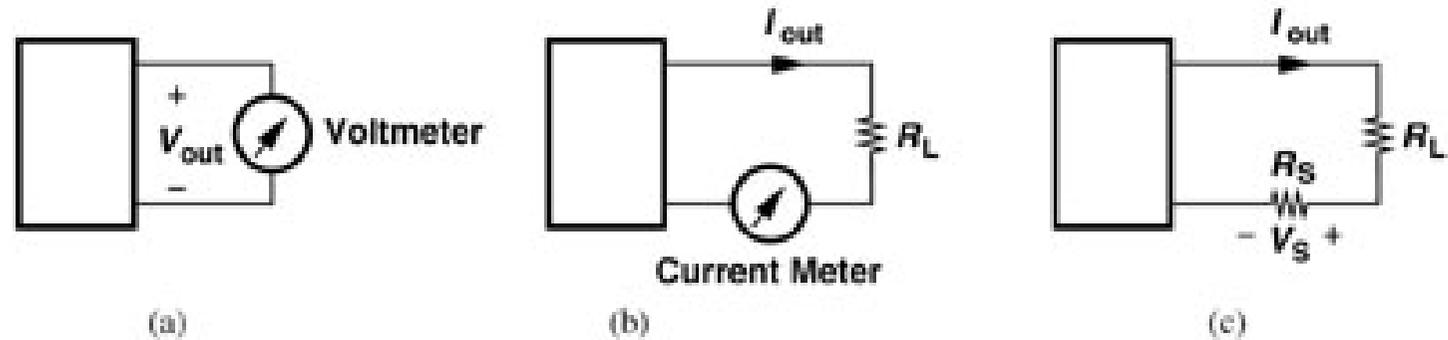


(c)

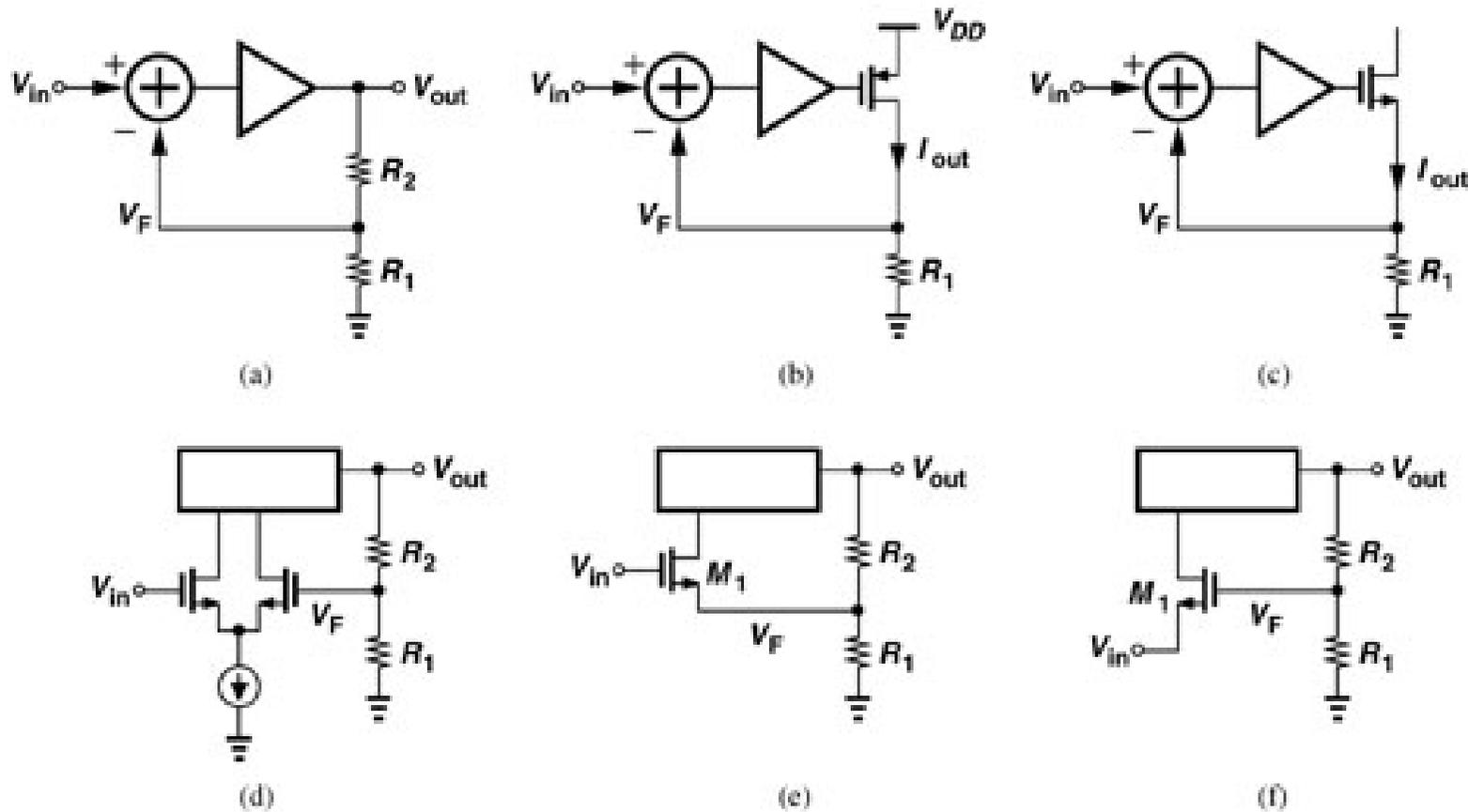


(d)

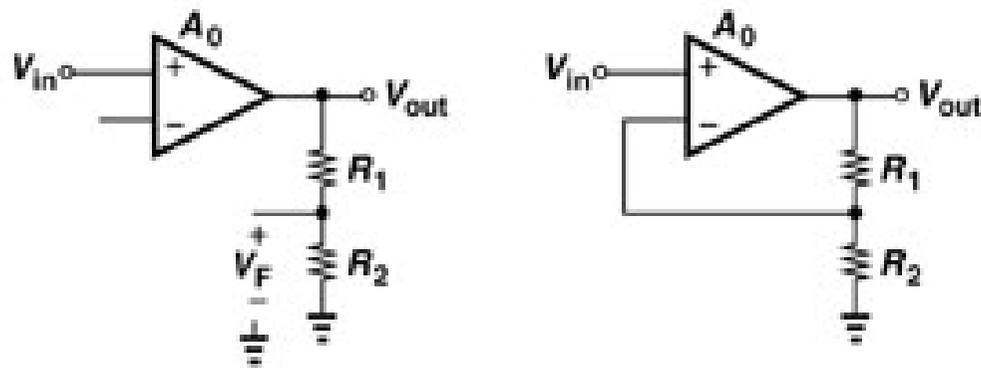
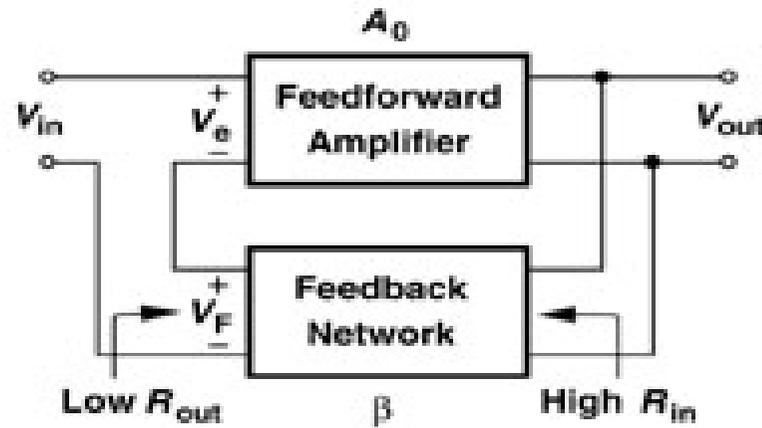
# Sense and feedback mechanisms



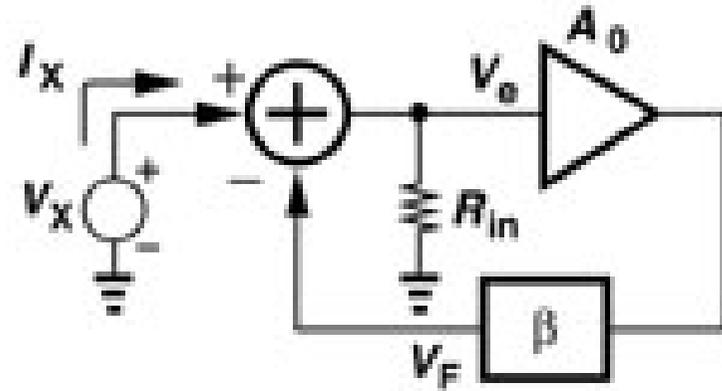
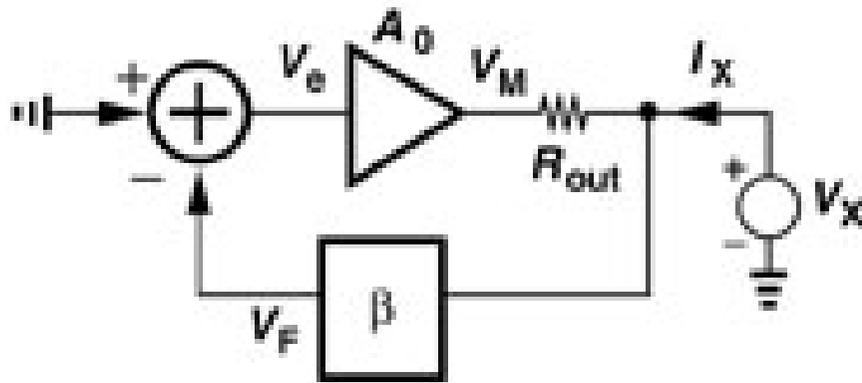
# Example feedback mechanisms



# Voltage-voltage feedback



# Output and input resistance

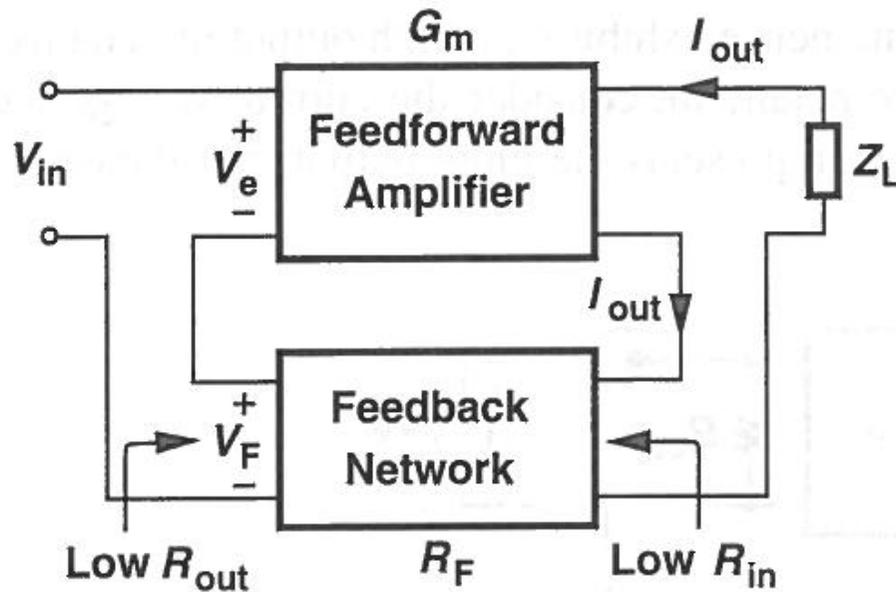


$$I_X = \frac{V_X - V_M}{R_{out}} = \frac{V_X - (-\beta A_0 V_X)}{R_{out}}$$

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

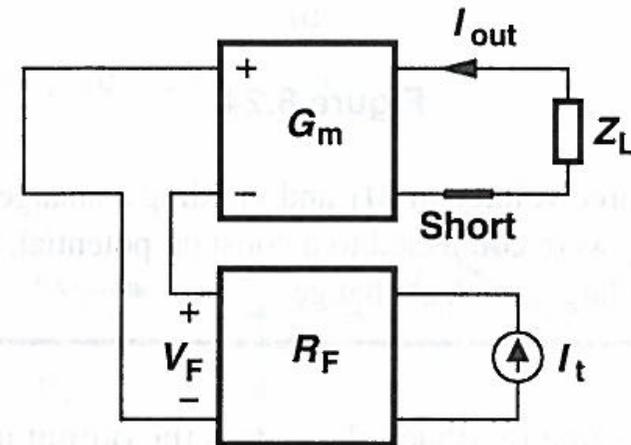
$$\frac{V_X}{I_X} = R_{out,CL} = \frac{R_{out}}{1 + \beta A_0}$$

# Current-voltage feedback

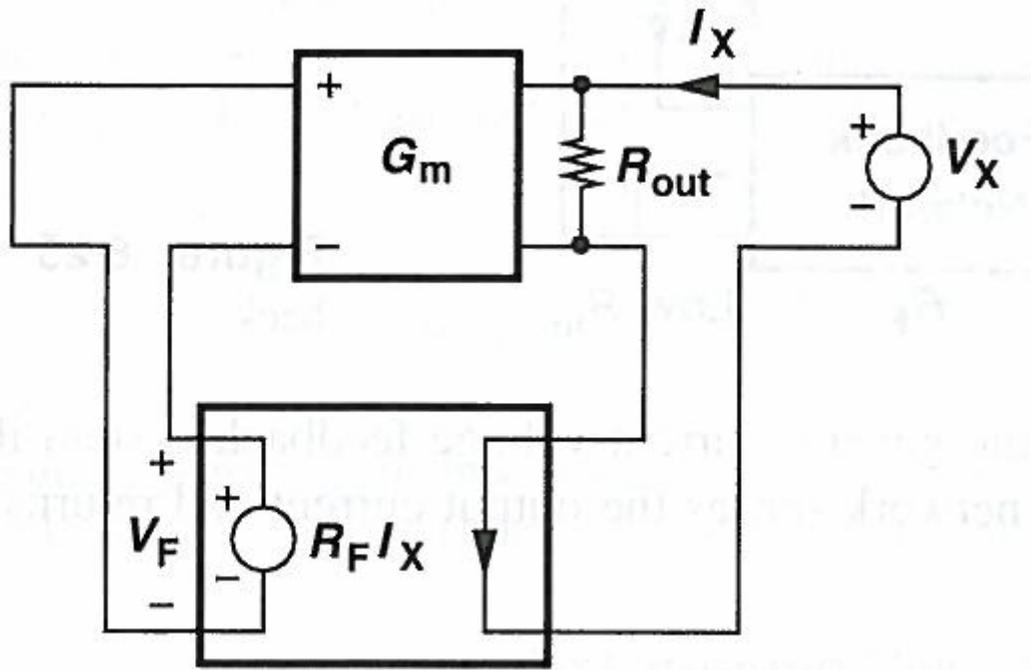


$$\frac{I_{out}}{V_{in}} = \frac{G_m}{1 + G_m R_F}$$

Loop gain

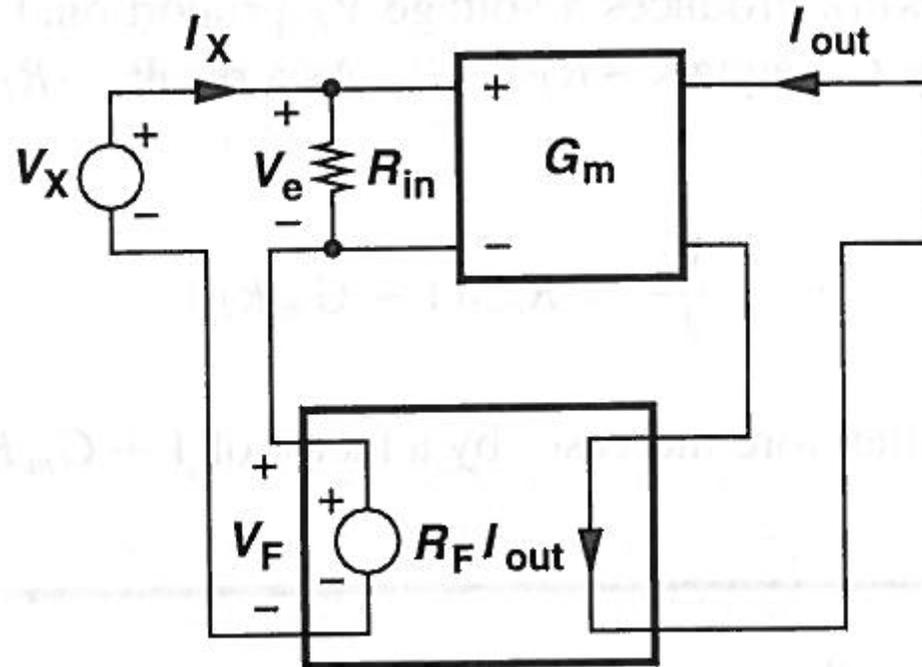


# Current-voltage feedback, output resistance



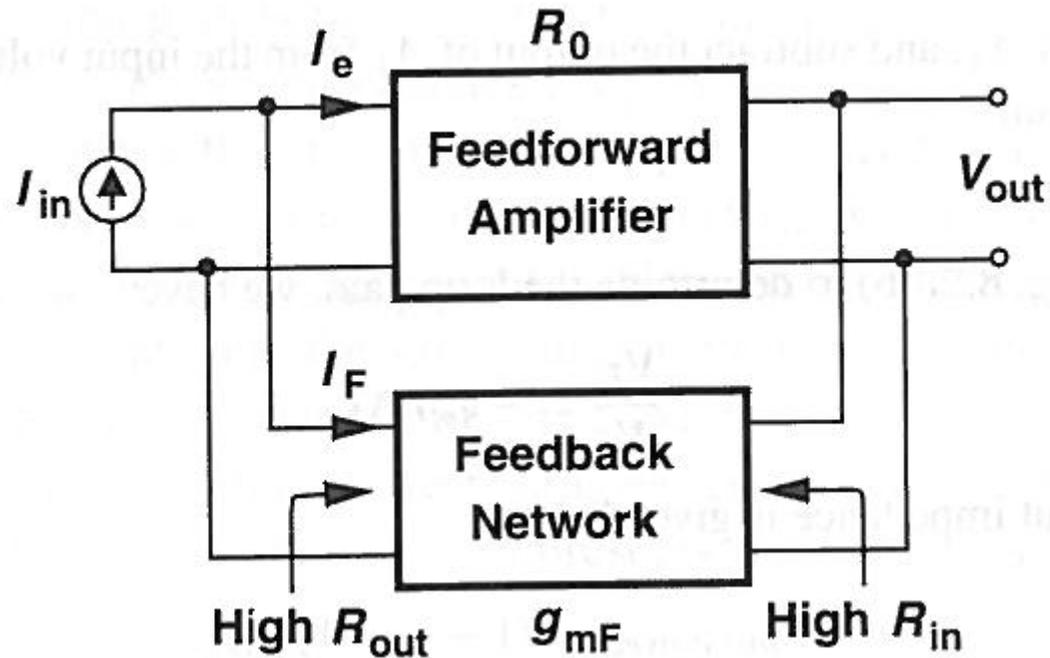
$$\frac{V_X}{I_X} = R_{out}(1 + G_m R_F).$$

# Current-voltage feedback, input resistance

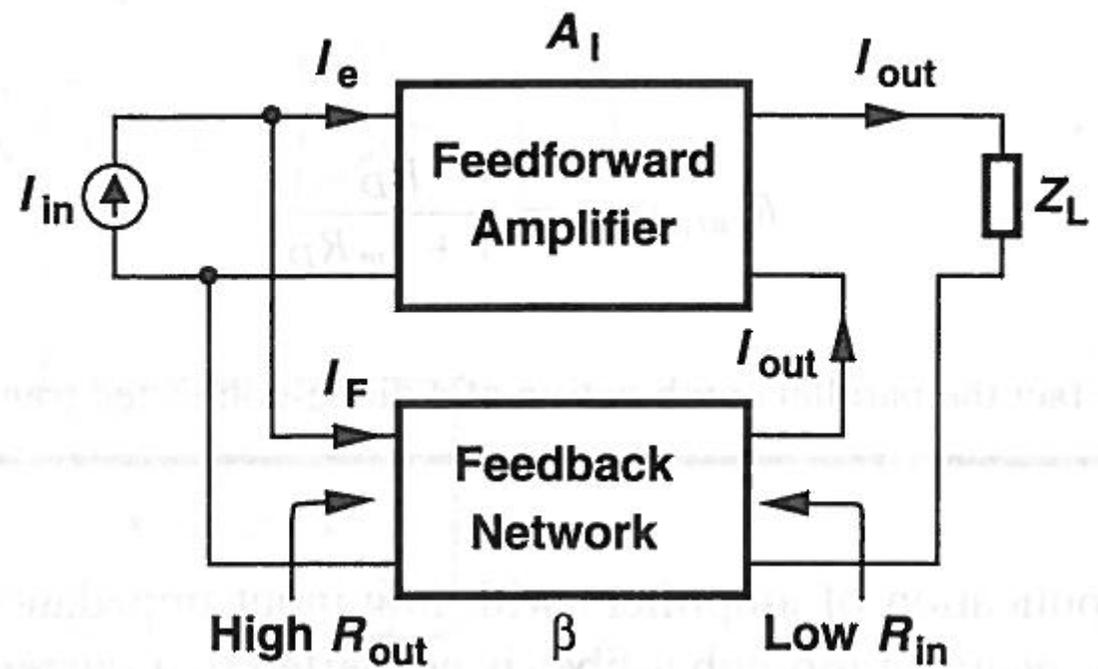


$$\frac{V_X}{I_X} = R_{in}(1 + G_m R_F).$$

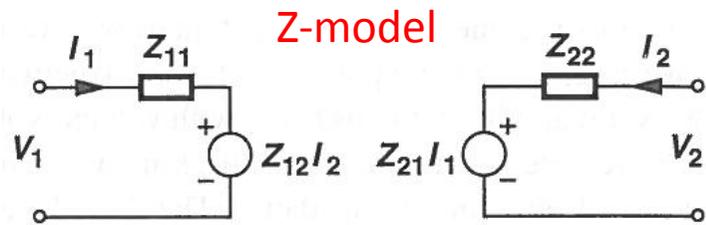
# Voltage-current feedback



# Current-current feedback

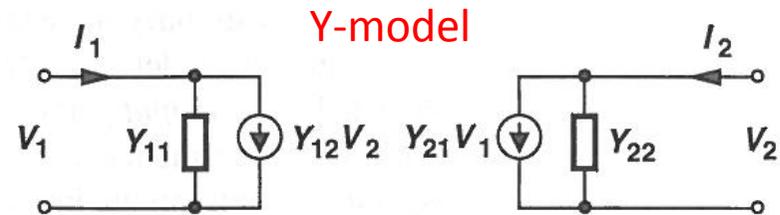


# Two port models



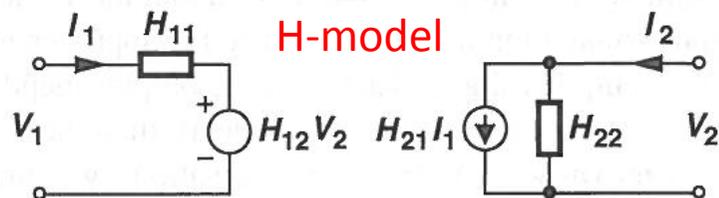
$$V_1 = Z_{11}I_1 + Z_{12}I_2$$

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



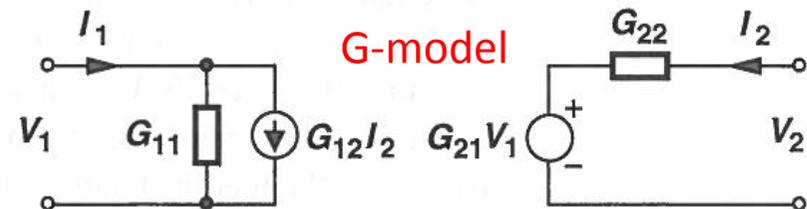
$$I_1 = Y_{11}V_1 + Y_{12}V_2$$

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



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

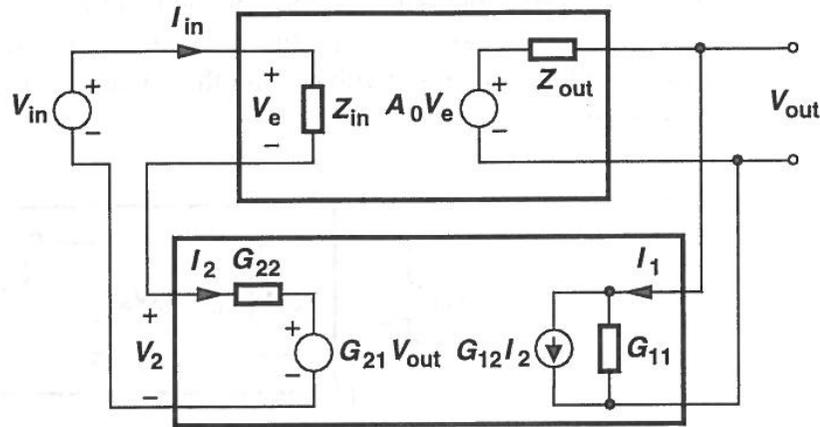
$$I_2 = H_{21}I_1 + H_{22}V_2,$$



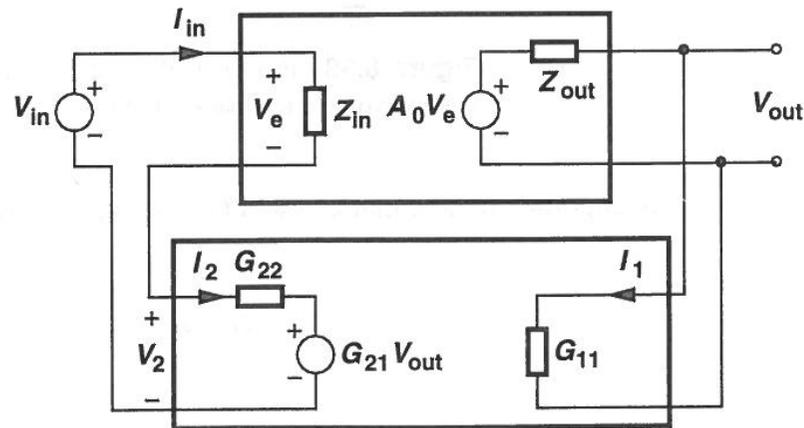
$$I_1 = G_{11}V_1 + G_{12}I_2$$

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

# Effect of loading in voltage-voltage feedback



(a)



(b)

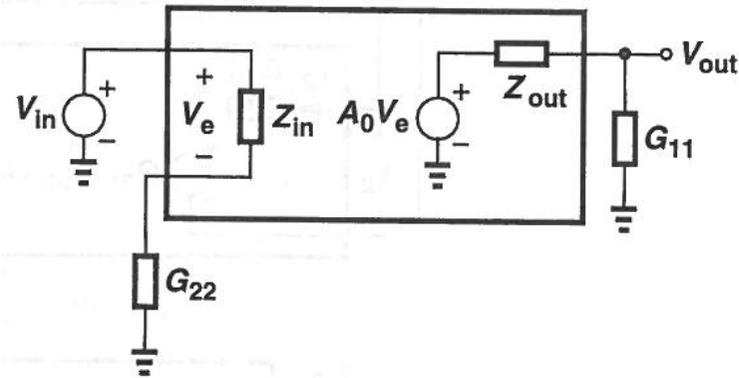
$$V_e = (V_{in} - G_{21} V_{out}) \frac{Z_{in}}{Z_{in} + G_{22}},$$

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

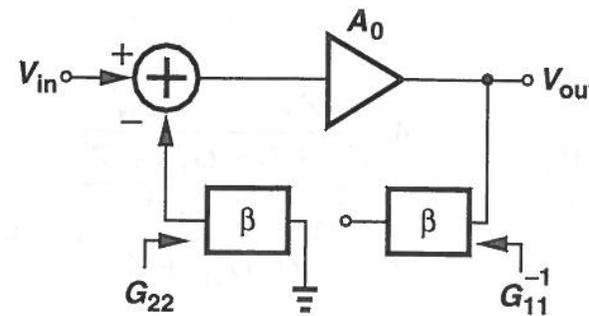
$$\frac{V_{out}}{V_{in}} = \frac{A_0 \frac{Z_{in}}{Z_{in} + G_{22}} \frac{G_{11}^{-1}}{G_{11}^{-1} + Z_{out}}}{1 + \frac{Z_{in}}{Z_{in} + G_{22}} \frac{G_{11}^{-1}}{G_{11}^{-1} + Z_{out}} G_{21} A_0}.$$

# Including loading in voltage-voltage feedback

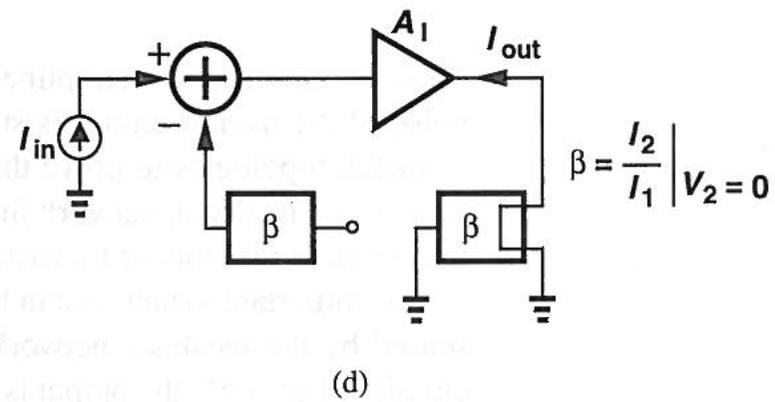
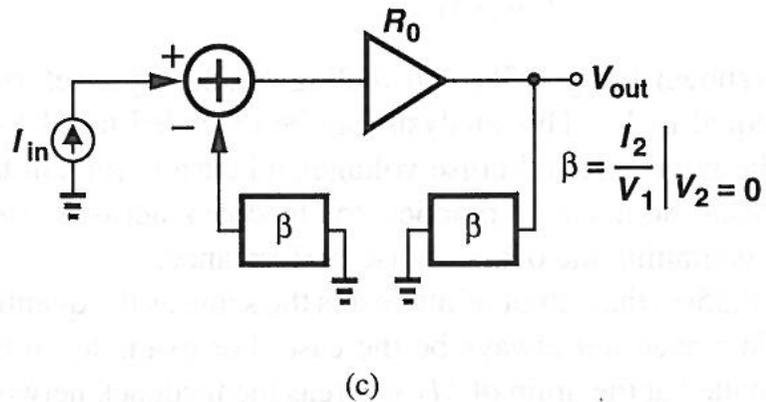
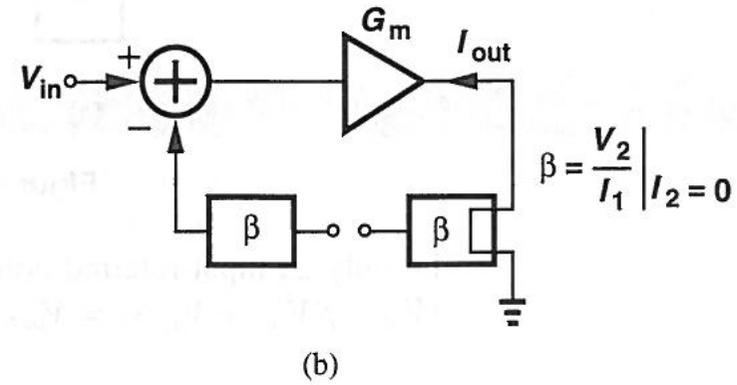
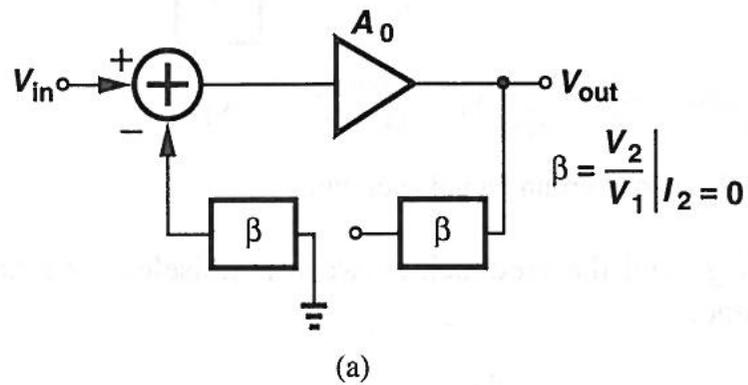
Proper method of including loading



Conceptual view of including loading



# 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.

