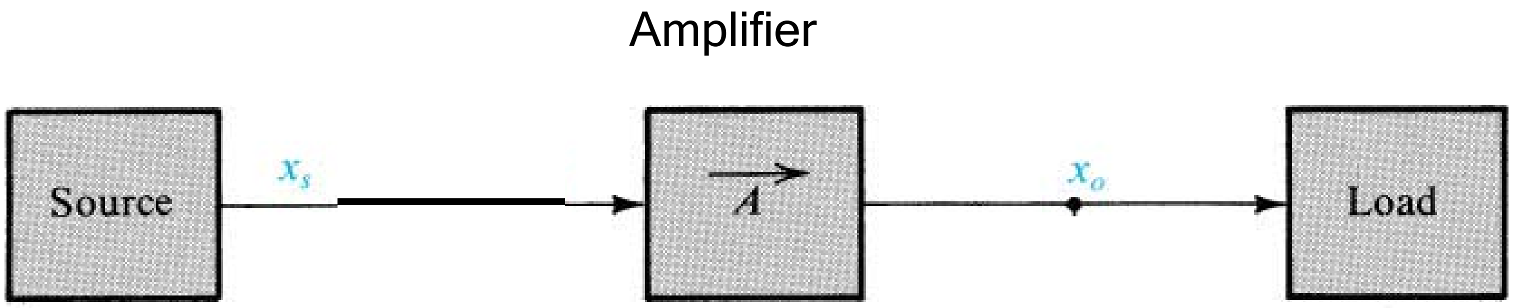
Lect. 13: Feedback (12.1, 12.2 in Razavi)

Feedback



$$x_o = Ax_s$$

$$x_f = \beta x_o$$ (Assume β is positive)

$$x_i = x_s - x_f = x_s - \beta x_o$$

$$x_o = Ax_i = A(x_s - \beta x_o)$$

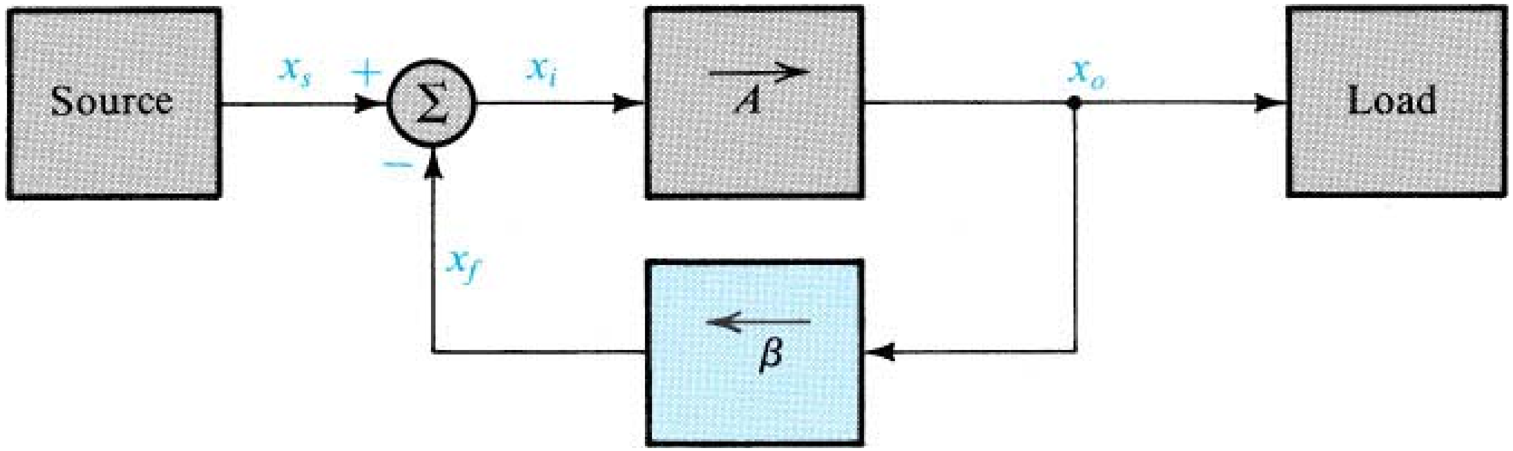
$$x_o(1 + A\beta) = Ax_s$$

$$\therefore A_f = \frac{x_o}{x_s} = \frac{A}{1 + A\beta}$$

(Closed loop gain)

$A\beta$ (loop gain)

Lect. 13: Feedback



$$A_f = \frac{x_o}{x_s} = \frac{A}{1 + A\beta} \sim \frac{1}{\beta} \text{ (If } A\beta >> 1\text{)}$$

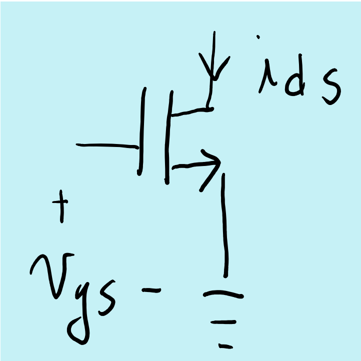
What good is it?

A_f is not influenced by changes in A

➔Gain Desensitivity

Lect. 13: Feedback

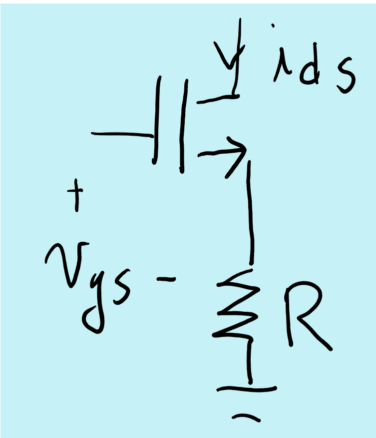
Example: Consider CS transconductance amplifier



$G_m = i_{ds}/v_{gs} = g_m = \sqrt{2\mu_n C_{ox} \cdot \frac{W}{L} \cdot I_D}$

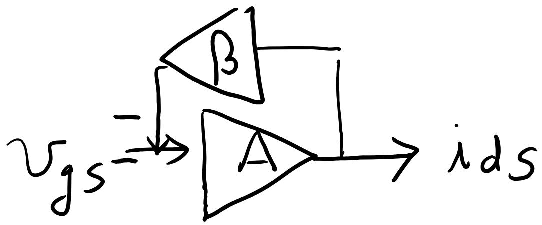
If g_m cannot be controlled very well
(bias conditions, process variations, temp., etc)

➔ Amplifier performance is not predictable



Feedback: source resistance

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



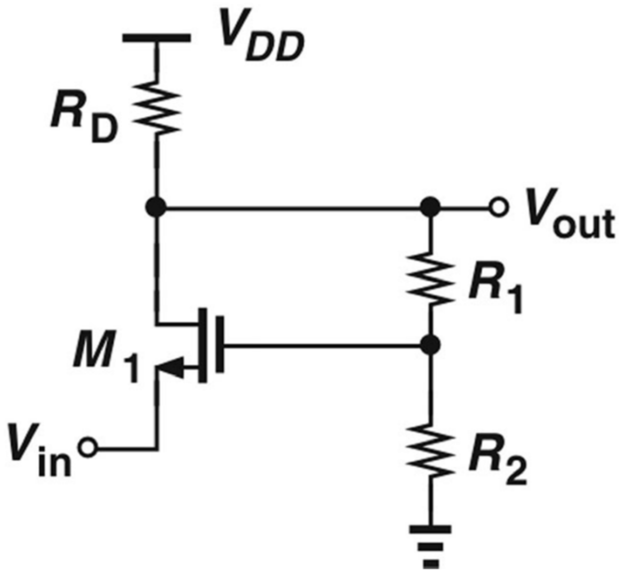
$$G_m = \frac{i_{ds}}{v_{gs}} = \frac{g_m}{1 + g_m R} \sim \frac{1}{R}$$

G_m is controlled by R!

$A = g_m$ $\beta = R$

(Assuming R is well controlled ➔ design using discrete components)

Example 12.7 : CG with feedback
(Assume $R_1+R_2 >> R_D$, $\lambda = 0$)



$V_{out} / V_{in} = ?$

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

$$A \sim g_m R_D$$

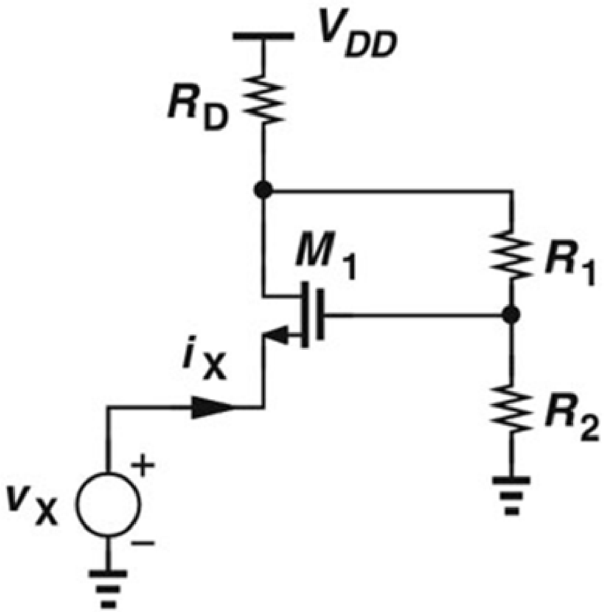
$$\beta = \frac{R_2}{R_1 + R_2}$$

$$V_{out} / V_{in} = \frac{g_m R_D}{1 + \frac{R_2}{R_1 + R_2} g_m R_D}$$

W.-Y. Choi

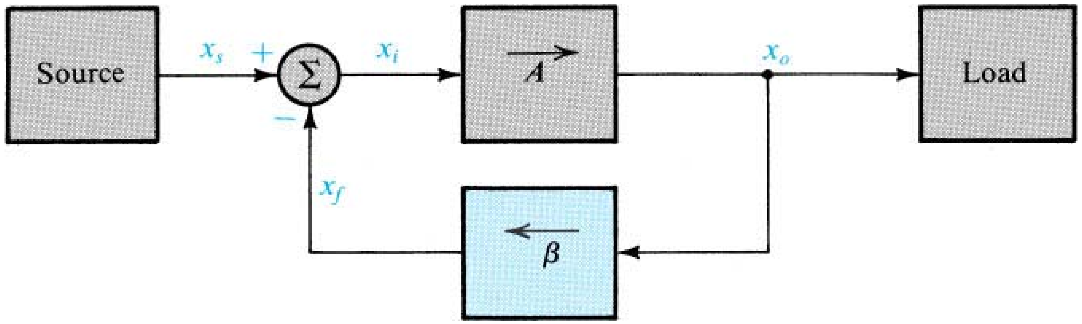
Example 12.7 : CG with feedback
(Assume $R_1+R_2 >> R_D$, $\lambda = 0$)

$R_{in} = ?$



Lect. 13: Feedback

Frequency Response of Feedback System



Assume $A(s) = \dfrac{A_M}{1+s/\omega_H}$

Then $A_f(s) = \dfrac{A(s)}{1+\beta A(s)}$

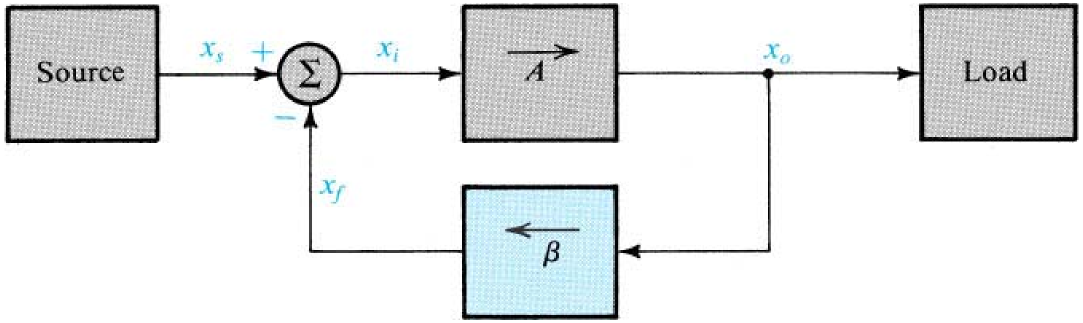
$$A_f(s) = \frac{\dfrac{A_M}{1+s/\omega_H}}{1+\beta\dfrac{A_M}{1+s/\omega_H}} = \frac{A_M}{1+A_M\beta+s/\omega_H} = \frac{A_M/(1+A_M\beta)}{1+s/\omega_H(1+A_M\beta)}$$

$$\omega_{Hf} = \omega_H(1+A_M\beta)$$

Bandwidth extension!

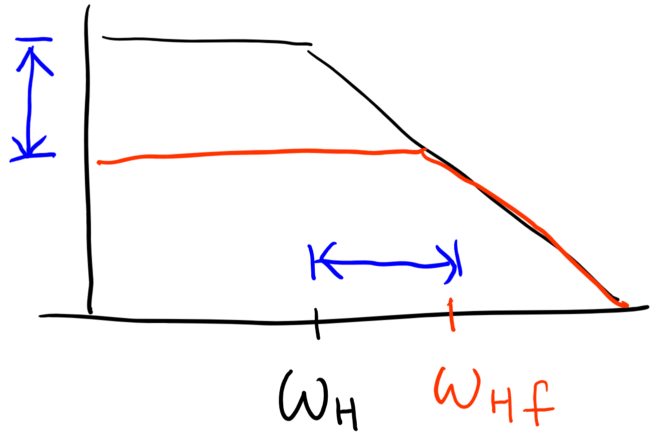
Reduction in LF gain

Lect. 13: Feedback



$$A(s) = \frac{A_M}{1 + s/\omega_H}$$

$$A_f(s) = \frac{A_M / (1 + A_M\beta)}{1 + s/\omega_H(1 + A_M\beta)}$$



Lect. 13: Feedback

Is feedback always possible? ➔ Stability of feedback system

$$A_f(s) = \frac{A(s)}{1+\beta A(s)}$$

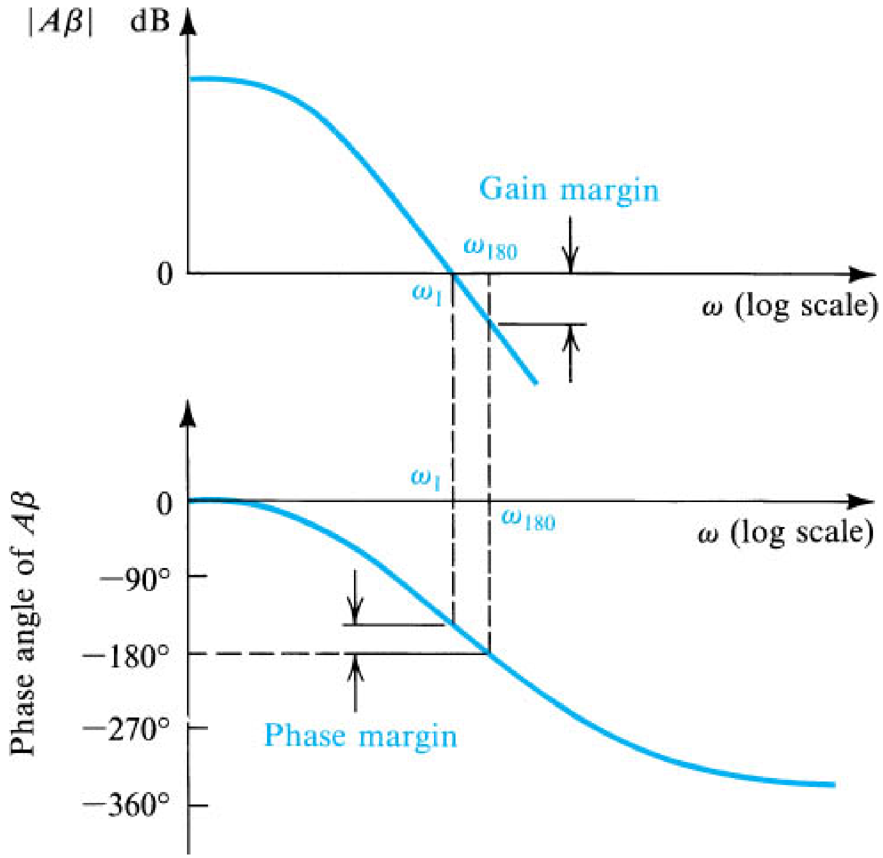
If $\beta A(s)$ = -1, system becomes unstable !

For stable feedback system design,

Phase [$\beta A(s)$] > -180 deg when $|\beta A(s)|$ = 1

➔ The larger β is, less phase margin

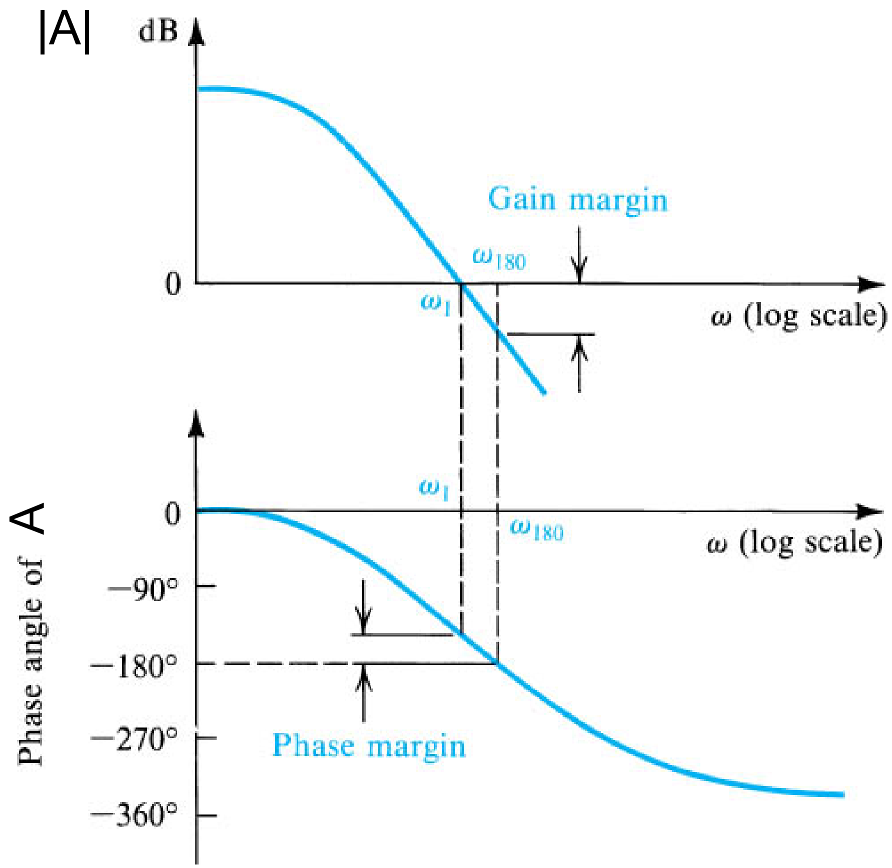
How should we design our amplifier
for feedback applications?



Lect. 13: Feedback

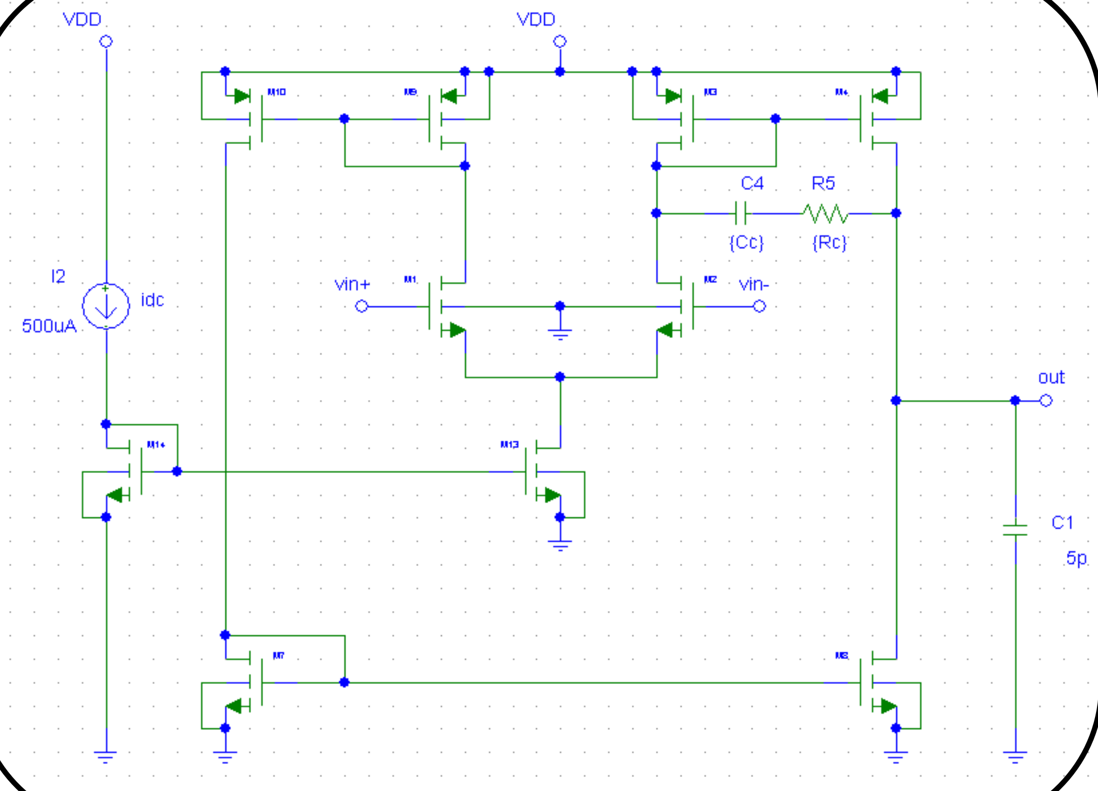
When designing amplifiers
for feedback applications
(Example, OTA for our design project)

➔Provide sufficient phase margin



Lect. 13: Feedback

Mirrored OTA for Design Project #1



- Mirrored OTA Specifications

Parameter	Value
A_V	>56dB
Bandwidth	>60KHz
Phase Margin	>65°
V_{p-p}	>1.5V
Slew Rate	>13MV/s
CMRR	>85dB
Power Consumption	<2.5mW