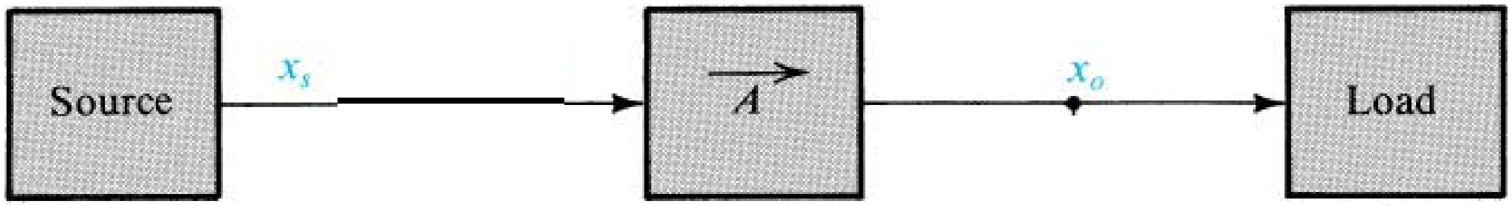
Lect. 9: Feedback (S&S 8.1-8.2, 8-10, 8-11)

Feedback

Amplifier



$$x_o = Ax_s$$

$$x_f = \beta x_o$$

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

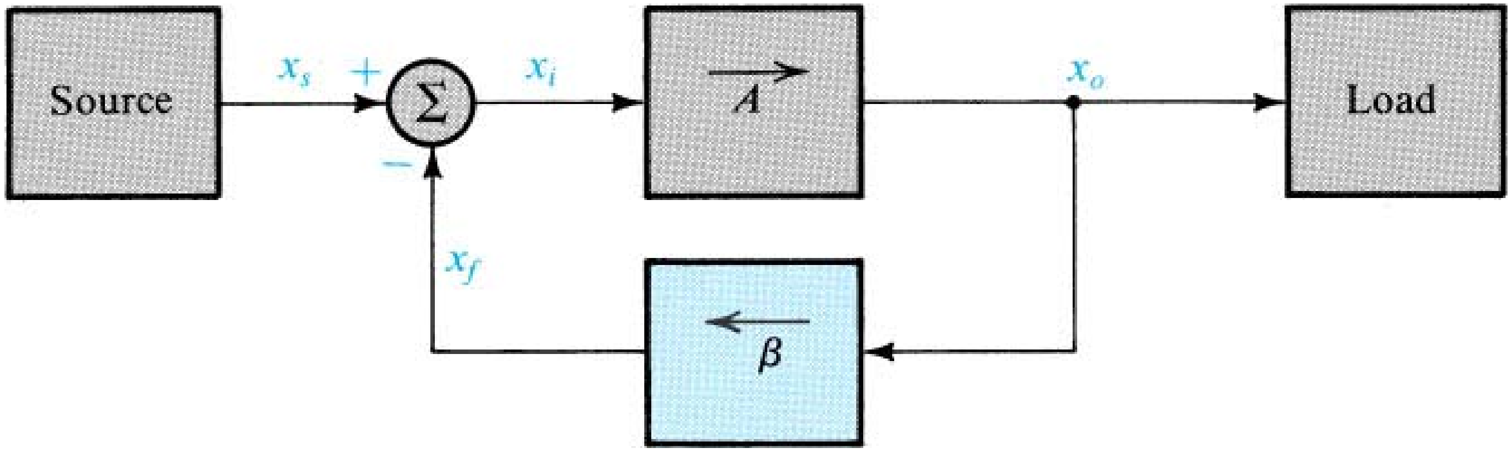
$$x_o = Ax_i = A(x_s - \beta x_o)$$

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

$$\therefore A_f = \frac{x_o}{x_s} = \frac{A}{1 + A\beta}$$ (Close loop gain)

($A\beta$: loop gain)

Lect. 9: Feedback



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

What good is it?

Consider $\dfrac{dA_f}{A_f} = \dfrac{1}{(1+A\beta)}\dfrac{dA}{A} << \dfrac{dA}{A}$ ➔ A_f is not influenced by changes in A

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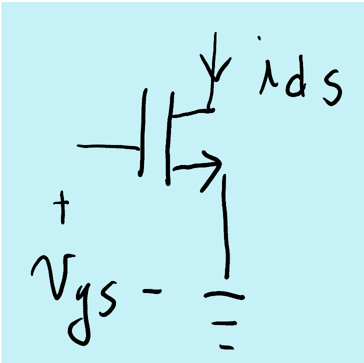
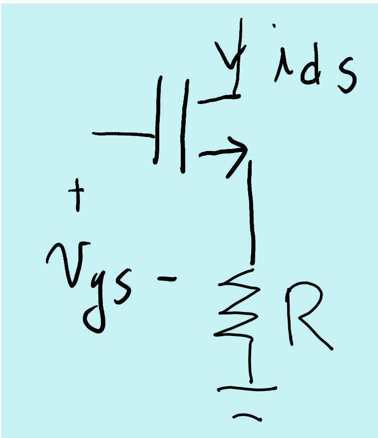
Lect. 9: Feedback

Example: Consider CS transconductance amplifier

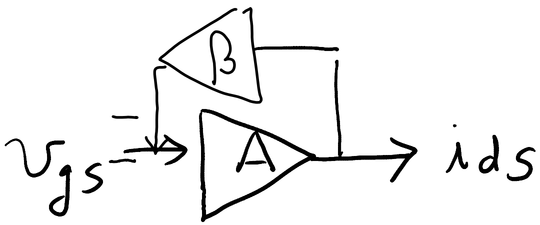


$G_m = i_{ds}/v_{gs} = g_m$

Assume g_m is not very predictable
➔ Amplifier performance is not predictable



CS with source resistance



$A = g_m$ $\beta = R$

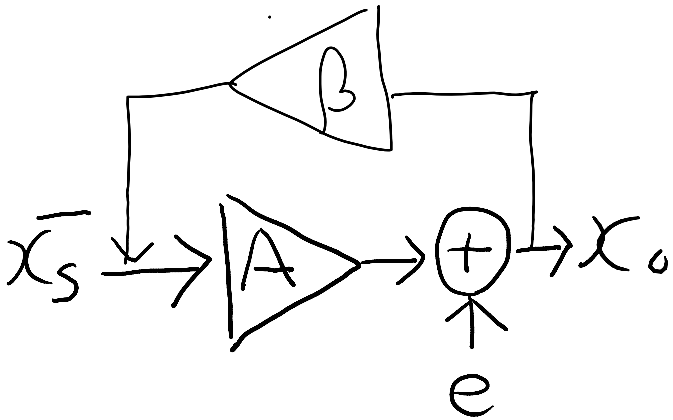
$$A_f = \frac{A}{1 + A\beta}$$

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

G_m is controlled by R!

Lect. 9: Feedback

Consider a case in which noises are added to an amplifier



Without feedback $x_o = Ax_s + e$

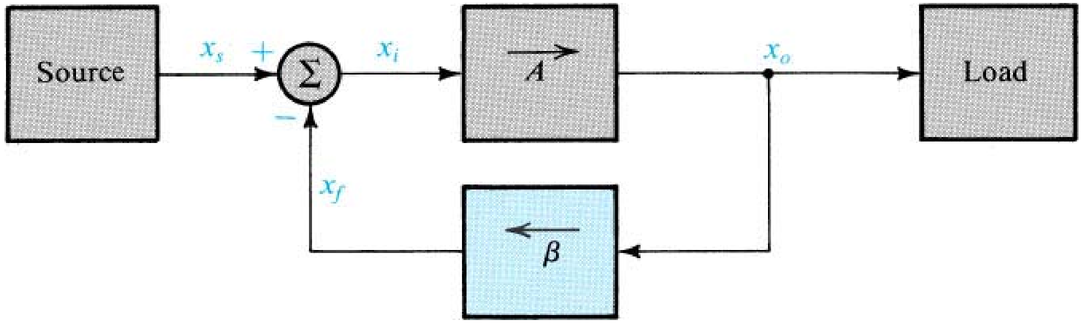
With feedback $x_o = A(x_s - \beta x_o) + e$ $\quad x_o(1 + A\beta) = Ax_s + e$

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

➔ Output not influenced by noises

Lect. 9: Feedback

Frequency Response of Feedback System



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

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

(β is frequency independent)

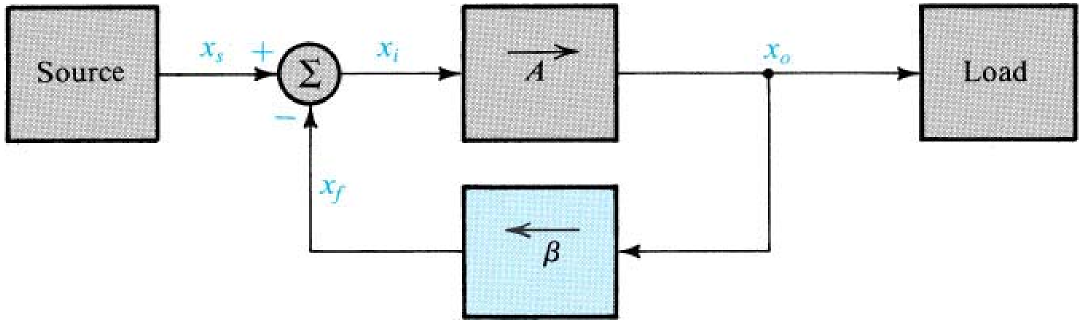
$$A_f(s) = \frac{\dfrac{A_M}{1+s/\omega_H}}{1+\beta\dfrac{A_M}{1+s/\omega_H}} = \frac{A_M}{1+\beta A_M + s/\omega_H} = \frac{A_M/(1+A_M\beta)}{1+s/\omega_H(1+A_M\beta)}$$

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

Bandwidth extension!

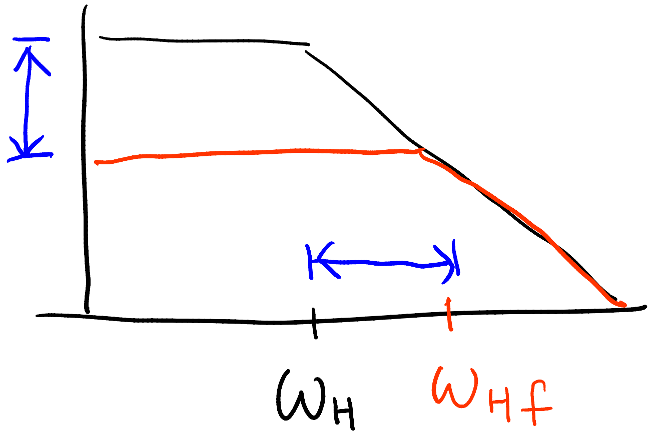
Reduction in LF gain

Lect. 9: Feedback



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

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



Is feedback always possible? ➔ Stability of feedback system

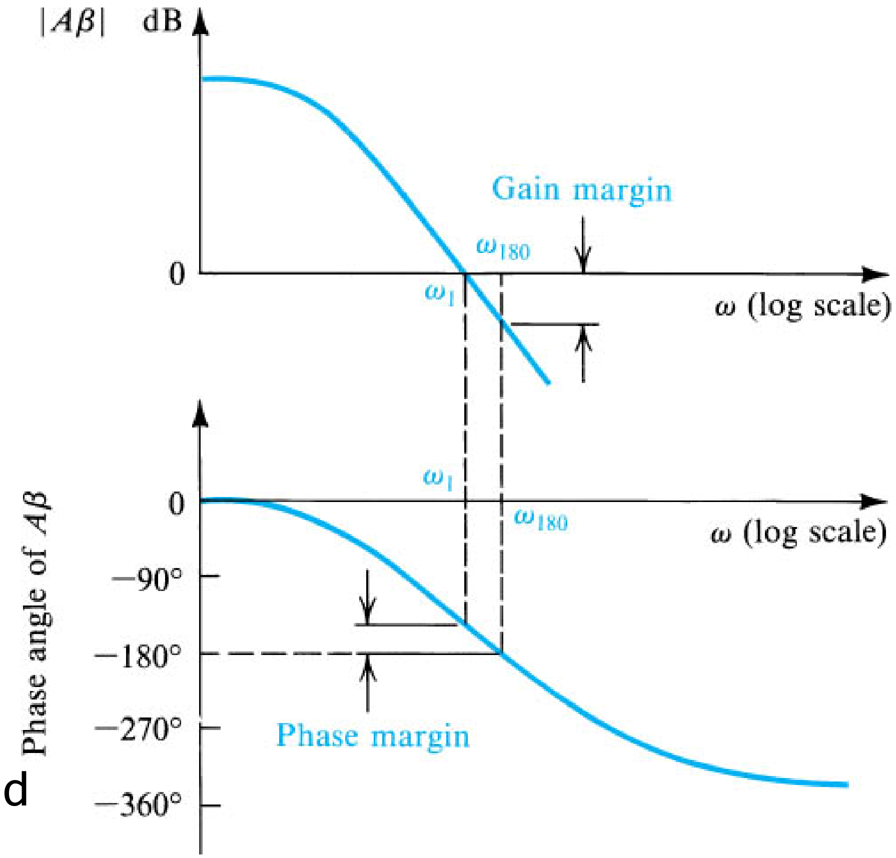
$$A_f(s) = \frac{A(s)}{1+\beta A(s)}$$

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

For stable feedback system design,

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

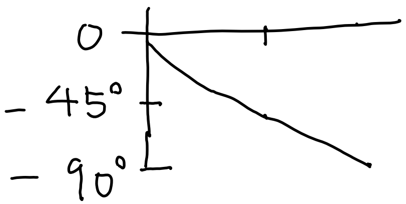
Design $A(s)$ with feedback application in mind
➔ Provide sufficient phase margin



Lect. 9: Feedback

Consider CS

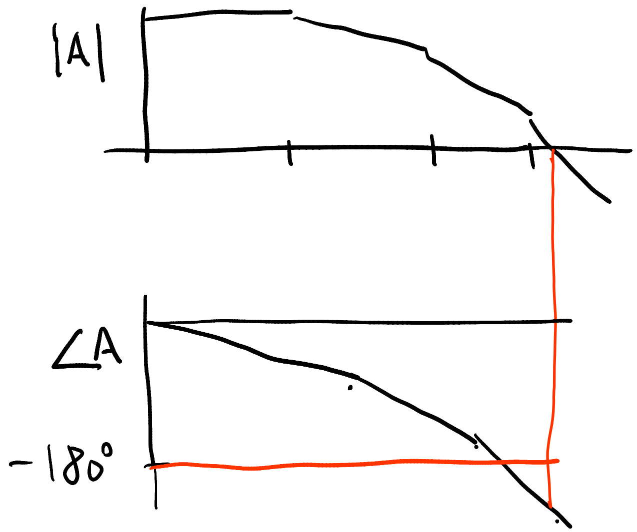
$$A_v(\omega) = \frac{A_{v,LF}}{1 + j\frac{\omega}{\omega_H}}$$



βA(s) will never reach -1

-Single-stage CS has no problem for feedback stability

- For most applications, multi-stage amplifiers are used
  ➔ Multi-pole system



Very careful consideration for phase margin is required!

For a given amplifier,
can we tell from its Bode plot
if it is OK for a given β?

Plot 20 log(1/β) = 85 dB

(β = 5.6x10-5)

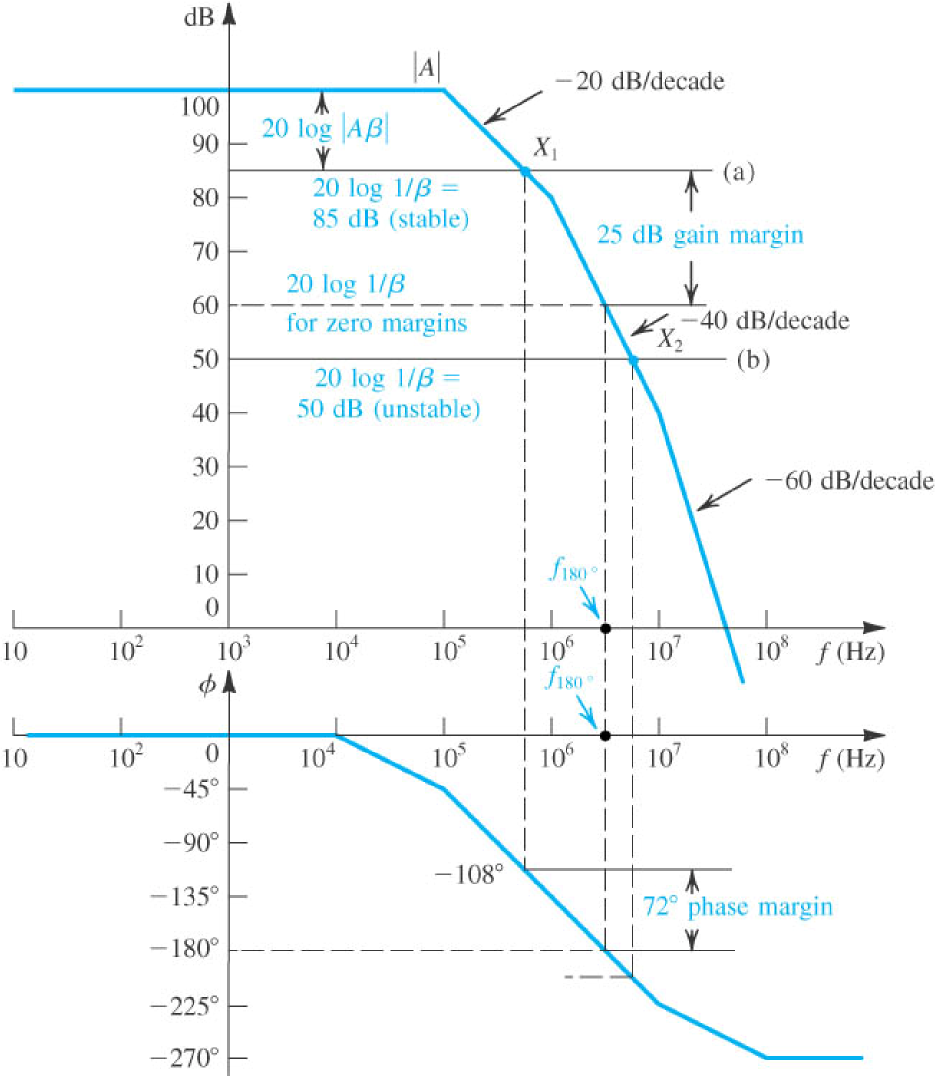
➔ Difference is 20log|Aβ|

➔ Determine the phase margin

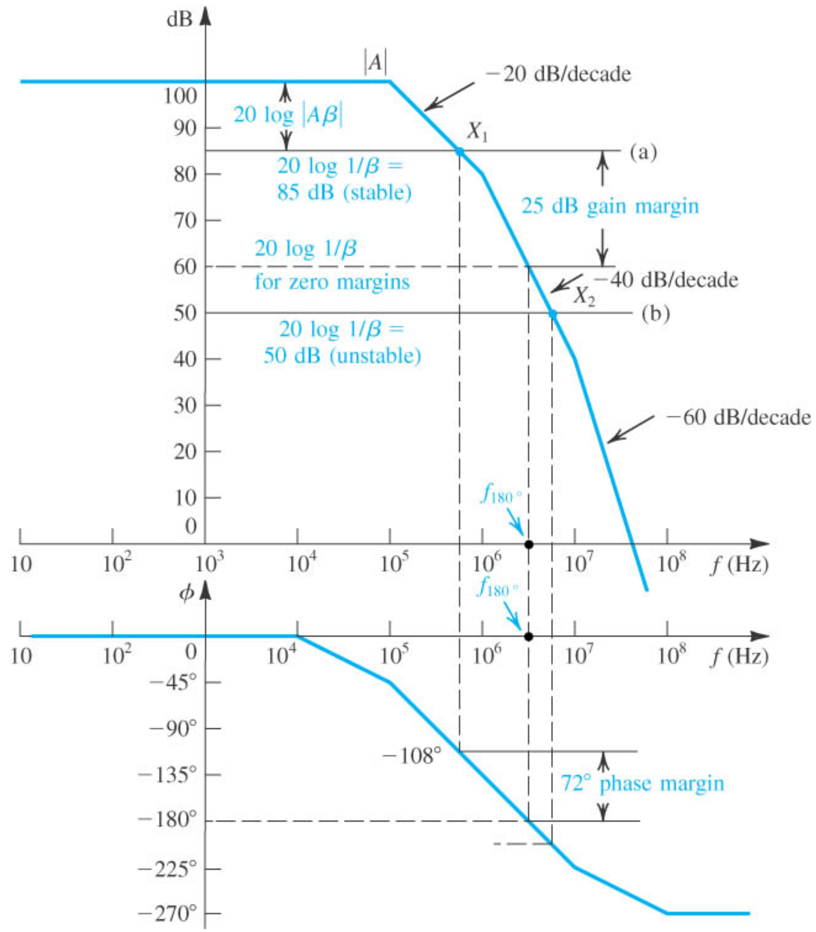
What is max. β?

20 log(1/β) = 60 dB

➔Max. β = 0.001



Bode plots for multi-pole amplifier



Observation:

-180 deg phase point always occurs on -40dB/decade segment of |A|

If |A| intersects 20 log(1/β) with -20dB/decade slope,

➔ Stable!