IIT ROORKEE

NPTEL ONLINE CERTIFICATION COURSE

Microelectronics: Devices to Circuits

Bode Plots and Frequency Response

SUDEB DASGUPTA

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING



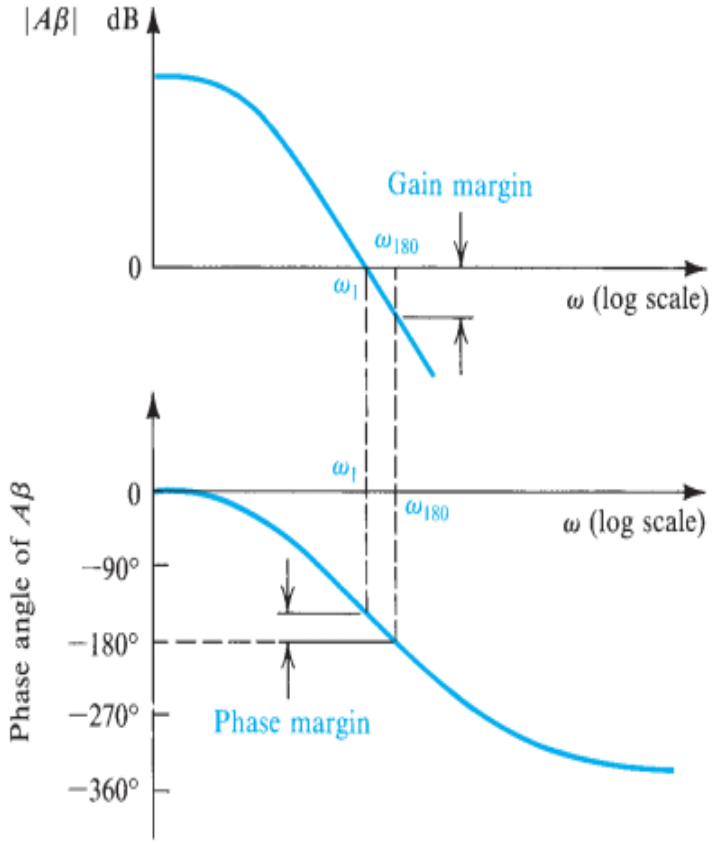
Outline

- Gain and Phase Margins
- Effect of Phase Margin on Closed-Loop Response
- Bode Plot
- Frequency Compensation
- Miller Compensation and Pole Splitting
- Recapitulation

Gain and Phase Margins

- The difference between the value of at ω_{180} and unity, called the gain margin, is usually expressed in decibels.
- The gain margin represents the amount by which the loop gain can be increased while stability is maintained.
- Feedback amplifiers are usually designed to have sufficient gain margin to allow for the inevitable changes in loop gain with temperature, time.
- To investigate the stability and to express its degree is to examine the Bode plot at the frequency for which |AB| = 1, which is the point at which the magnitude plot crosses the 0-dB line.

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition



- If at this frequency the phase angle is less (in magnitude) than 180°, then the amplifier is stable.
- The difference between the phase angle at this frequency and 180° is termed the phase margin.
- if at the frequency of unity loop-gain magnitude, the phase lag is in excess of 180°,the amplifier will be unstable.

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Effect of Phase Margin on Closed-Loop Response

- Feedback amplifiers are normally designed with a phase margin of at least 45°.

$$A_f(jw_1) = \frac{(1/\beta)e^{j\theta}}{1+e^{-j\theta}}$$

$$|A_f(jw_1)| = \frac{(1/\beta)}{|1+e^{-j\theta}|}$$

$$A(jw_1)\beta = 1\times e^{-j\theta}$$

θ= 180°-Phase margin

$$A_f(jw_1) = \frac{A(jw_1)}{1+A(jw_1)\beta}$$

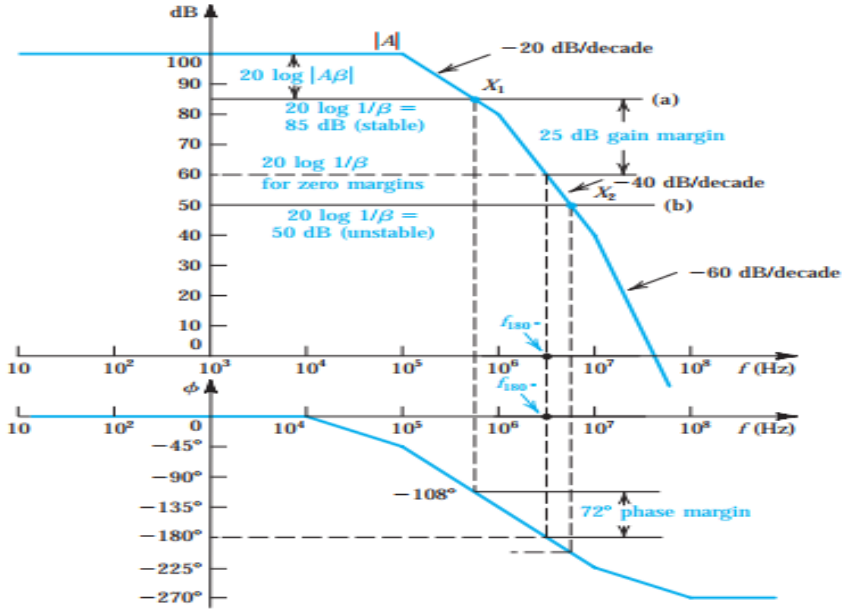
For Phase Margin 45°, θ=135°

$$|A_f(jw_1)| = 1.3\frac{1}{\beta}$$

- The gain peaks by a factor of 1.3 above the low-frequency value of 1/β.
- This peaking increases as the phase margin is reduced, eventually reaching ∞ when the phase margin is zero.
- Zero phase margin, of course, implies that the amplifier can sustain oscillations [poles on the *j*ω axis; Nyquist plot passing through (-1, 0)]

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

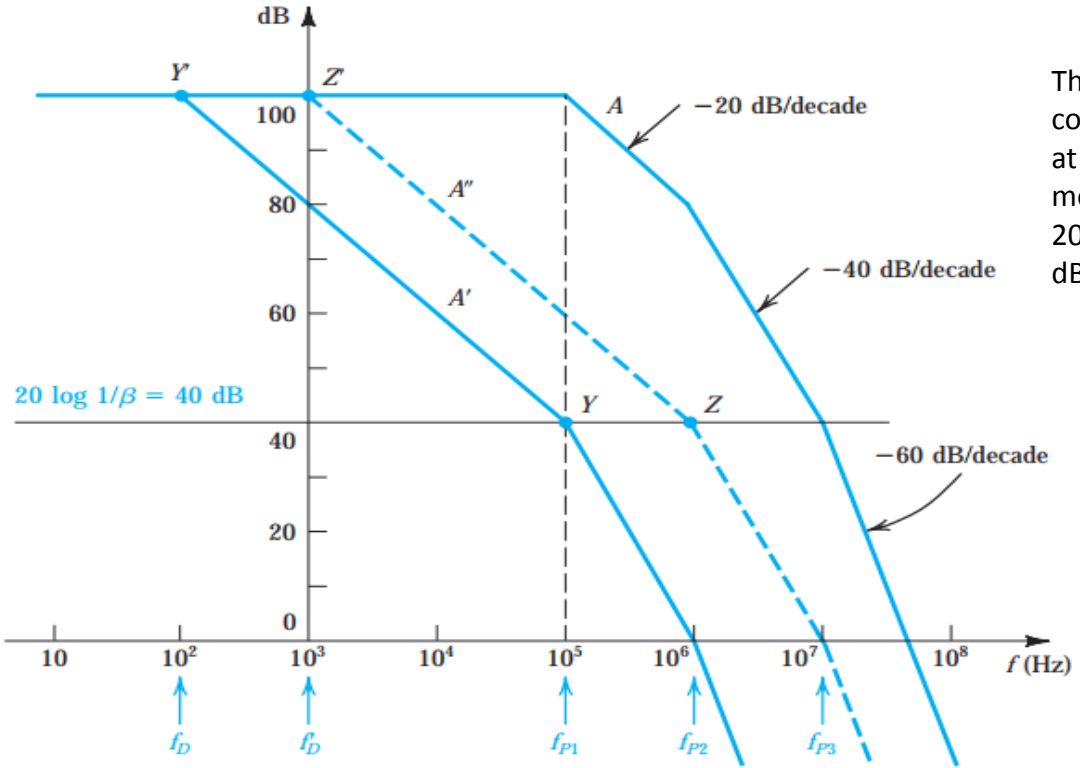
Bode Plot



$$20\log|A(iw)| - 20\log\frac{1}{\beta} = 20\log|A\beta|$$

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

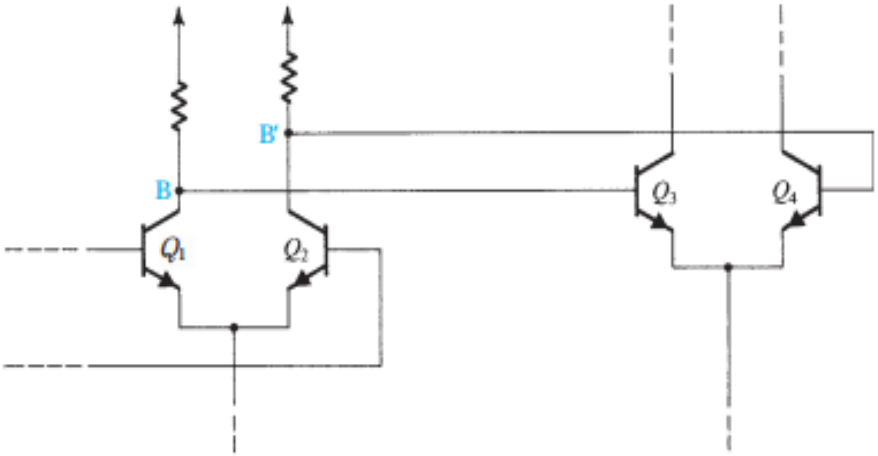
Frequency Compensation



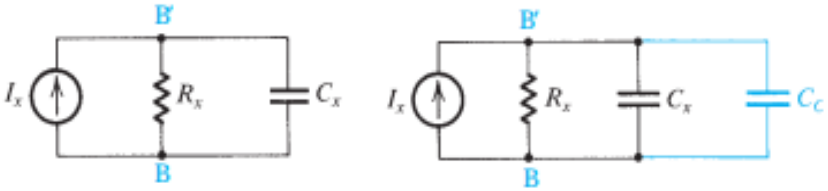
The simplest method of frequency compensation consists of introducing a new pole in the function $A(s)$ at a sufficiently low frequency, f_D, such that the modified open-loop gain, A'(S) intersects the 20log(1/|β| curve with a slope difference of 20 dB/decade.

β=0.01

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition



(a)



$$f_{P1} = \frac{1}{2\pi C_x R_x}$$

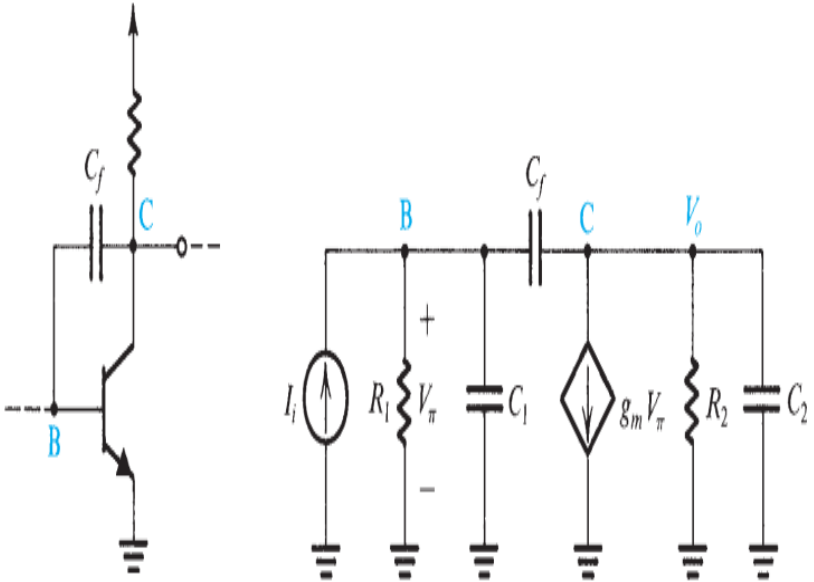
$$f_D' = \frac{1}{2\pi (C_x + C_c) R_x}$$

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Miller Compensation and Pole Splitting

$$f'_{P1} = \frac{1}{2\pi R_1 C_1} \qquad f'_{P2} = \frac{1}{2\pi R_2 C_2}$$

$$D(S) = \left(1 + \frac{S}{w_{p1}}\right)\left(1 + \frac{S}{w_{p2}}\right) = 1 + S\left(\frac{1}{w_{p1}} + \frac{1}{w_{p2}}\right) + \frac{S^2}{w_{p1} w_{p2}}$$



$$D(S) = 1 + \frac{S}{w_{p1}} + \frac{S^2}{w_{p1} w_{p2}}$$

$$w'_{p1} = \frac{1}{g_m R_2 C_f R_1}$$

$$w'_{p2} = \frac{g_m C_f}{C_1 C_2 + C_f (C_1 + C_2)}$$

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Recapitulation

- Negative feedback is employed to make the amplifier gain less sensitive to component variations; to control input and output impedances; to extend bandwidth; to reduce nonlinear distortion; and to enhance signal-to interference ratio.
- For the feedback amplifier to be stable, its poles must all be in the left half of the *s* plane.
- The stability of a feedback amplifier can be analyzed by constructing a Bode plot for and superimposing on it a plot for Stability is guaranteed if the two plots intersect with a difference in slope no greater than 6 dB/octave.

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

- To make a given amplifier stable for a given feedback factor β, the open-loop frequency response is suitably modified by a process known as frequency compensation.

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Thank You