IIT ROORKEE

NPTEL ONLINE CERTIFICATION COURSE

Microelectronics: Devices to Circuits

Stability and Amplifier Poles

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Outline

- Stability of feedback system
- Stability and Pole Location
- Amplifier with a Single-Pole Response
- Amplifier with Two-Pole Response
- Amplifiers with Three or More Poles
- Recapitulation

Stability of feedback system

- In negative feedback, a portion of the output signal is subtracted from the input signal to produce the error signal.
- Subtraction property, or the loop gain, may change as a function of frequency.
- At some frequencies, the subtraction may actually be addition; that is, the negative feedback may become positive, producing an unstable system.

$$T(iw) = |T(jw)| \angle \phi \qquad A_f(jw) = \frac{A(jw)}{1 + T(jw)}$$

$$A_f = \frac{S_0}{S_i} = \frac{A}{1 + A\beta} \qquad A_f(S) = \frac{S_0(S)}{S_i(S)} = \frac{A(S)}{1 + A(S)\beta} = \frac{A(S)}{1 + T(S)}$$

T(S) is the loop gain S=jw

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

- The stability of the feedback circuit is a function of the loop gain $T(j\omega)$.
- If the loop gain magnitude is unity when the phase is 180 degrees, then $T(j\omega) = -1$ and the closed-loop gain goes to infinity.
- An output will exist for a zero input, which means that the circuit will oscillate.
- If we are trying to build a linear amplifier, an oscillator is considered an unstable circuit.
- If $|T(j\omega)| < 1$ when the phase is 180 degrees, the system is stable.
- if $|T(j\omega)| \geq 1$ when the phase is 180 degrees, the system is unstable.

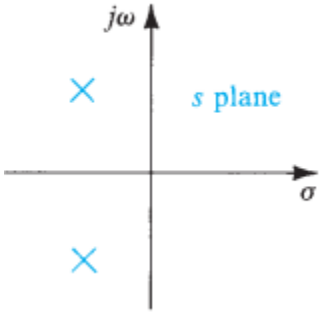
Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

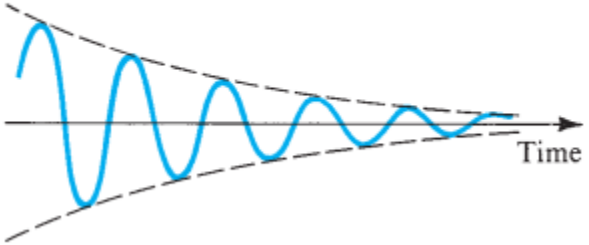
Stability and Pole Location

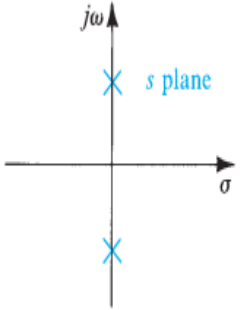
- For an amplifier or any other system to be stable, its poles should lie in the left half of the *s* plane.
- A pair of complex-conjugate poles on the *jω* axis gives rise to sustained sinusoidal oscillation.
- Poles in the right half of the *s* plane give rise to growing oscillation.

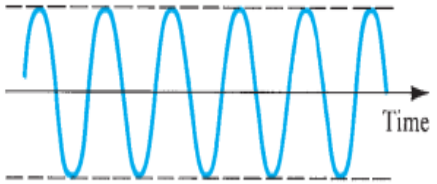
$$S = \sigma_0 \pm j w_n \qquad v(t) = e^{\sigma_0 t}\left[e^{+j w_n t} + e^{-j w_n t}\right] = 2e^{\sigma_0 t}\cos(w_n t)$$

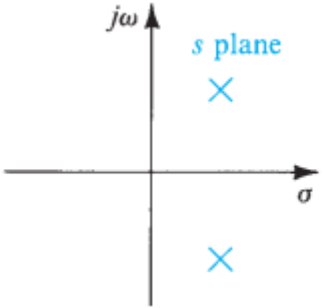
Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

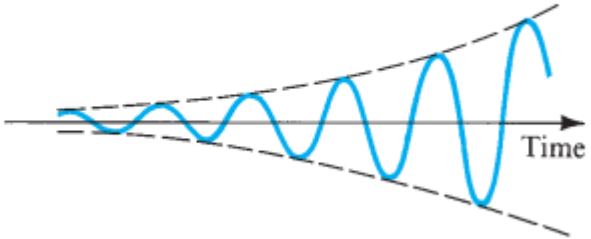












Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Amplifier with a Single-Pole Response

$$A(S) = \frac{A_0}{1 + \frac{S}{w_p}} \qquad A_f(S) = \frac{A_0/(1 + A\beta)}{1 + \frac{S}{w_p(1 + A_0\beta)}} \qquad w_{pf} = w_p(1 + A_p\beta) \qquad A_f(S) \approx \frac{A_0 w_p}{S} \approx A(S)$$

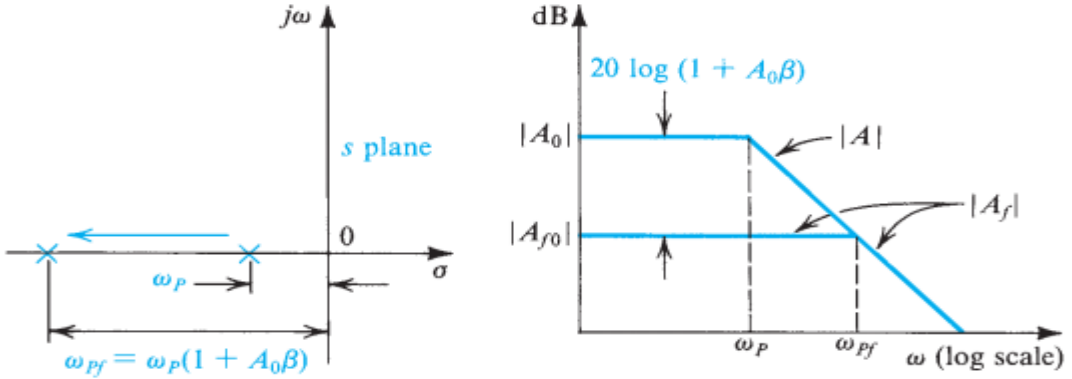
- Note that while at low frequencies the difference between the two plots is 20 log(1 + $A_0\beta$), the two curves coincide at high frequencies.
- Physically speaking, at such high frequencies the loop gain is much smaller than unity and the feedback is ineffective.

$$w >> w_p(1 + A_0\beta)$$

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

❑Applying negative feedback to an amplifier results in extending its bandwidth at the expense of a reduction in gain. Since the pole of the closed-loop amplifier never enters the right half of the *s* plane.

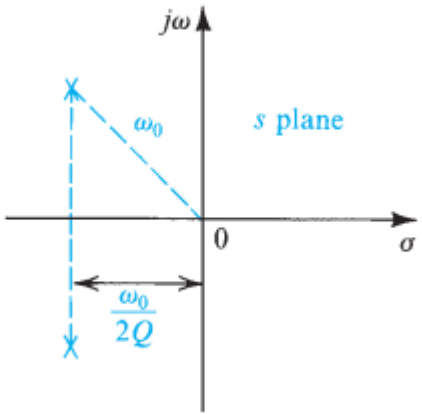
❑ The single-pole amplifier is stable for any value of β. Thus this amplifier is said to be unconditionally stable



Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

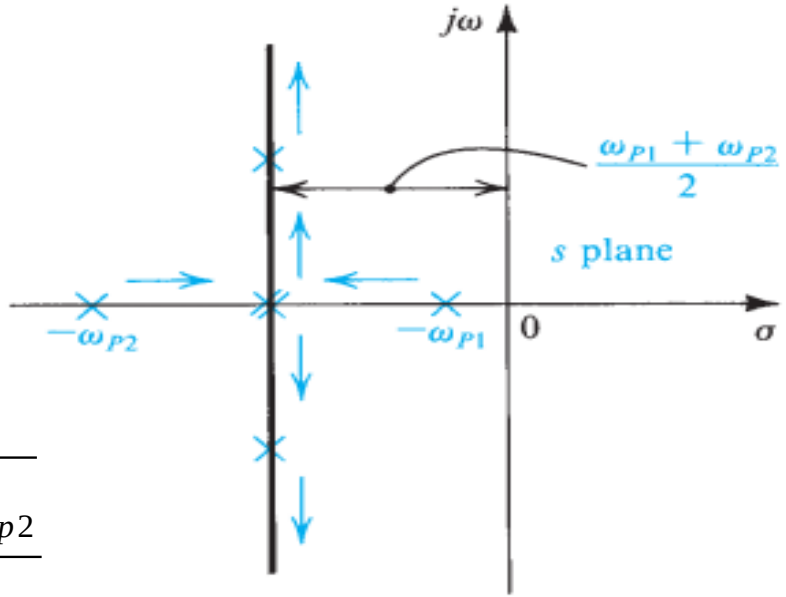
Amplifier with Two-Pole Response

$$A(S) = \frac{A_0}{\left(1 + S/w_{p1}\right)\left(1 + \frac{S}{w_{p2}}\right)}$$



$$S^2 + S\frac{w_0}{Q} + w_0^2 = 0$$

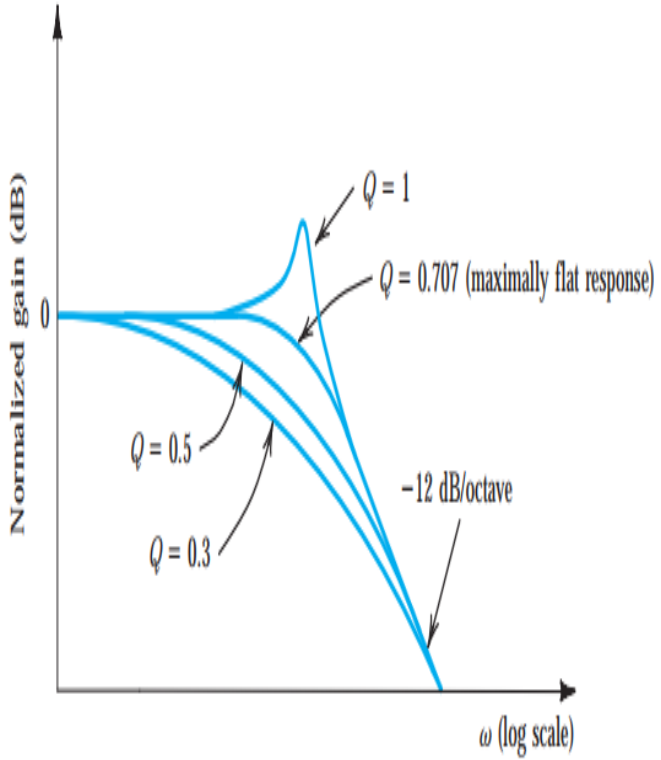
$$Q = \frac{\sqrt{\left(1 + A_0\beta\right)w_{p1}w_{p2}}}{w_{p1} + w_{p2}}$$



W_0 -pole frequency Q -pole Q factor

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

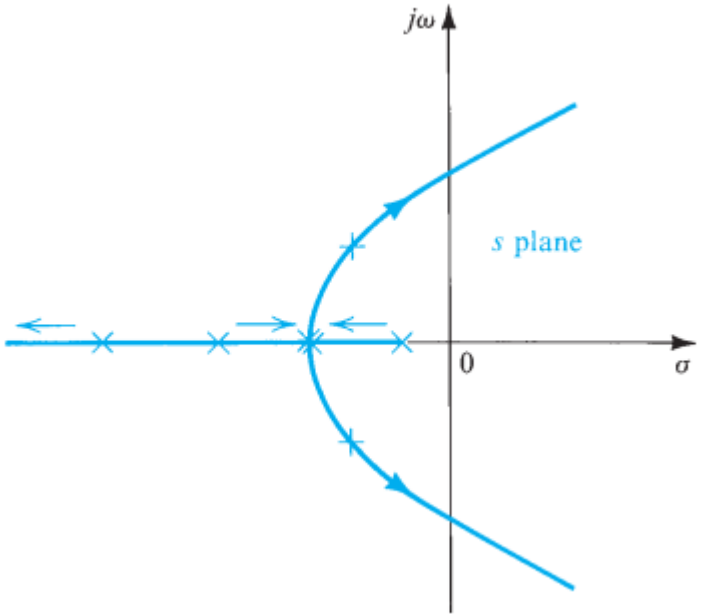
- Note that ω_0 is the radial distance of the poles from the origin and that Q indicates the distance of the poles from the $j\omega$ axis.
- Poles on the $j\omega$ axis have $Q = \infty$.
- The response of the feedback amplifier under consideration shows no peaking for $Q \leq 0.707$
- The boundary case corresponding to $Q = 0.707$ (poles at 45°angles) results in the maximally flat response.



Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Amplifiers with Three or More Poles

- The root-locus diagram for a feedback amplifier whose open-loop response is characterized by three poles.



Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Recapitulation

- The loop gain varies with frequency that determines the stability or instability of the feedback amplifier.
- The amplifier frequency response and stability are determined directly by its poles.
- Poles in the right half of the *s* plane give rise to growing oscillations.
- For an amplifier or any other system to be stable, its poles should lie in the left half of the *s* plane.
- A pair of complex-conjugate poles on the $j\omega$ axis gives rise to sustained sinusoidal oscillations.

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Thank You