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ECE Lab 2 – Lecture 3c: Stability of Negative Feedback Systems

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Focus

- Evaluating stability of negative feedback systems using Gain and Phase margins.
- How is the response effected (in both time domain and frequency domain) when the feedback system has a small phase margin?
  - How does the pole positions of the system relate to this occurrence?

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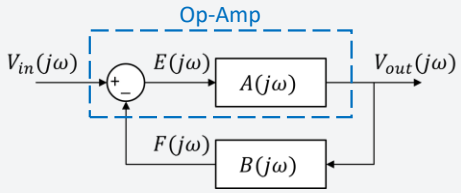
Previously…

- We reviewed some characteristics of negative feedback op-amp circuits and their stability.
- We observed that if $A(j\omega)B(j\omega) = -1$, then there will be some stability issues.

$$H_{closed}(j\omega) = \frac{A(j\omega)}{1 + A(j\omega)B(j\omega)}$$

$$= \frac{A(j\omega)}{1 - 1} = \infty$$



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Stability in the Frequency Domain

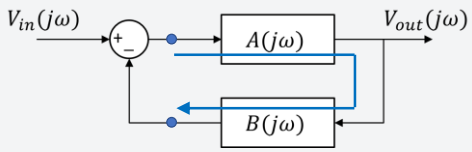
- With respect to,

$$H_{closed}(j\omega) = \frac{A(j\omega)}{1 + A(j\omega)B(j\omega)}$$

- The **Loop Gain** is defined as:

$$\text{Loop Gain} = A(j\omega)B(j\omega) = H_{AB}(j\omega)$$

- We assume $A(j\omega)B(j\omega) = H_{AB}(j\omega)$ is stable by itself (without feedback).



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Stability in the Frequency Domain (cont.)

Question: How stable is the system?

- We measure stability with **gain margin** and **phase margin**.
- **Gain Margin** – (always a positive dB value) is the distance from $0\ dB$ to the magnitude associated with the frequency $f_{\pm 180}$.
- **Phase Margin** – (always a positive value) is the distance from $\pm 180°$ to the point associated with the frequency where the gain crosses the $0\ dB$ axis. [We will call this frequency f_{0dB}.]
- A good rule of thumb for stability is that **you want G.M. $\geq 10dB$ and you want P.M. $\geq 45°$**.

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Stability in the Frequency Domain

- Stability may be analyzed in the frequency domain using the concepts of **gain margin** and **phase margin**.
- This procedure is described as follows:
  1) Plot the log magnitude and phase of $H_{AB}(j\omega)$ with respect to frequency (i.e., $20\log_{10}|H_{AB}(j\omega)|$ and $\angle H_{AB}(j\omega)$).
  2) Find, if any, a frequency $f_{\pm 180} \rightarrow \omega_{\pm 180}$ where $\angle H_{AB}(j\omega) = \pm 180°$.
  3) Evaluate $20\log_{10}|H_{AB}(j\omega)|$. If this value is $< 0dB$, then the closed loop system is stable, otherwise it is not stable.

  [Note that of if it is exactly $0dB$, then $H_{AB}(j\omega) = -1$ and there are self-sustaining oscillations.]

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Example - Stability in the Frequency Domain

- See Example.

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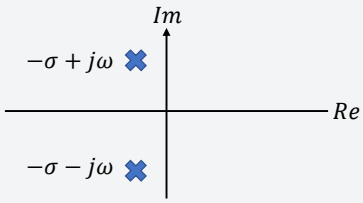
Gain Peaking, Ringing and Overshoot

- A small phase margin is associated with undesirable effects…
- A small phase margin signifies that there are a pair of complex poles in the s-plane that are significantly close to the Im axis.
- Left-hand plane poles close to the Im axis are associated with,
  - "Gain Peaking" in the frequency-domain.
  - "Ringing" in the time-domain.



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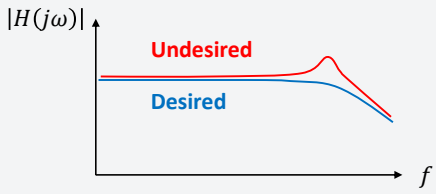
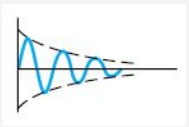
Gain Peaking, Ringing and Overshoot (cont.)

- These poles cause the closed-loop gain to rise near their associated frequency $f_o = {\omega_o}/{2\pi}$.
- The gain response (not in dB, i.e., not in log magnitude) would be…
- Recall the output response associated with $\sigma < 0$ for a pair of complex poles is…

[Slower decay with smaller $|\sigma|$.]



$$Ae^{-\sigma t}\cos(\omega t)$$



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Questions