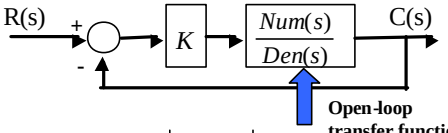
Definitions - Unity Feedback



Open-loop transfer function

Magnitude criterion: $K\left|\frac{Num(s)}{Den(s)}\right| = 1 = 0dB$

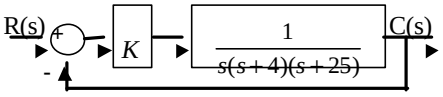
Phase criterion: $angle\left(\frac{Num(s)}{Den(s)}\right) = -180^{\circ}$

Stability in Frequency Domain

- **Gain Margin, G_M - How much open-loop gain K can we add such that the 0 db crossover occurs at -180° phase?**
- **Phase Margin, F_M - How much phase angle could we subtract at 0 dB cross-over (unity gain) to reach -180° phase?**

Both gain and phase margin computed from the open-loop transfer function's frequency response

Root Locus Example #7

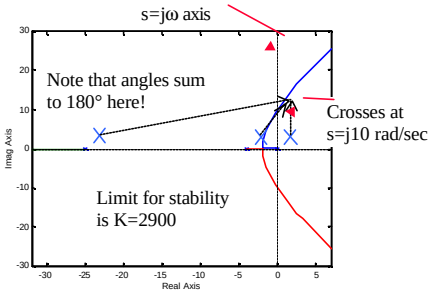


Closed-Loop Transfer Function is:

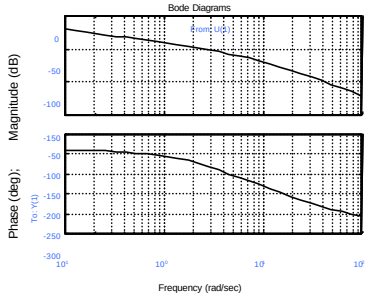
$$\frac{C(s)}{R(s)} = \frac{K}{s(s+4)(s+25)+K}$$

Root locus shown on next slide

Root Locus #7

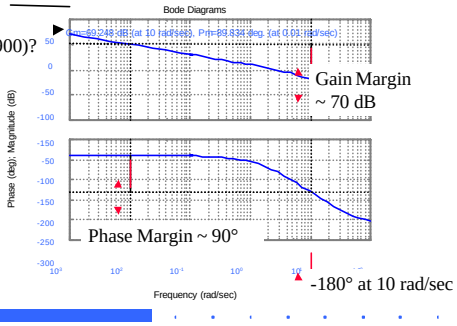


Bode(num,den)

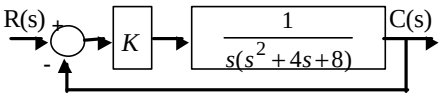


Margin(num,den)

What is $20\log_{10}(2900)$?



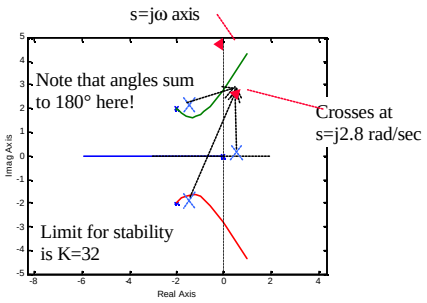
Example #9



Closed-Loop Transfer Function is:

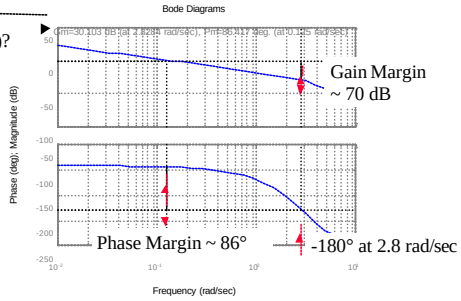
$$\frac{C(s)}{R(s)} = \frac{K}{s(s^2+4s+8)+K}$$

Root Locus #9



Margin(num,den)

What is $20\log_{10}(32)$?



System Identification

- **Use the experimentally determined frequency response to estimate the transfer function**
  - apply sine wave inputs at known frequencies
  - measure the system output amplitude and phase angle
  - plot magnitude and phase as functions of frequency

$$20\log_{10}\left(\frac{outputamplitude}{inputamplitude}\right)$$

Step #1 in System ID

- **Low frequency slope**
  - if zero then no poles or zeros at origin
  - if +20 dB/decade, then a zero at origin
    - low frequency phase shift of +90°
  - if -20 dB/decade, then a pole at origin
    - low frequency phase shift of -90°

Step #2 in System ID

- **High frequency characteristics**
  - tells n-m (order of denominator- order of numerator)

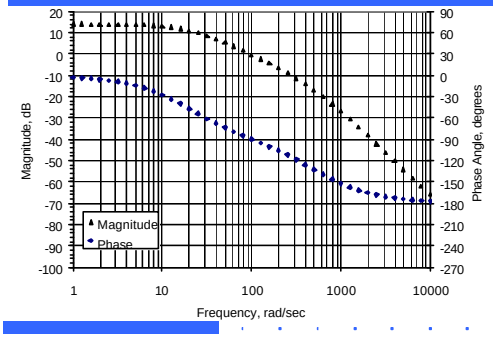
$$high\ frequency slope = -20(n-m) = 20(m-n)$$

$$high\ frequency\ phase = -90(n-m) = 90(m-n)$$

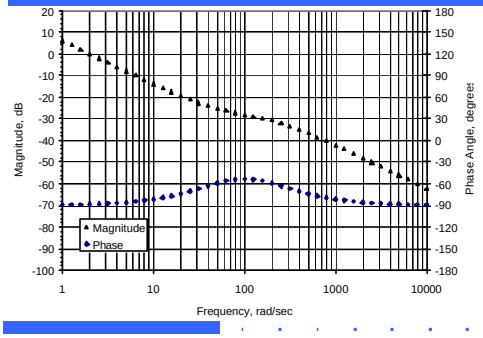
Step #3 in System ID

- **Mid frequency characteristics**
  - look for breaks in either magnitude or phase
  - remember the characteristics of the remaining building blocks
    - 1st order pole
    - 1st order zero
    - 2nd order pole
    - 2nd order zero

Example #1



Example #2



Example #3