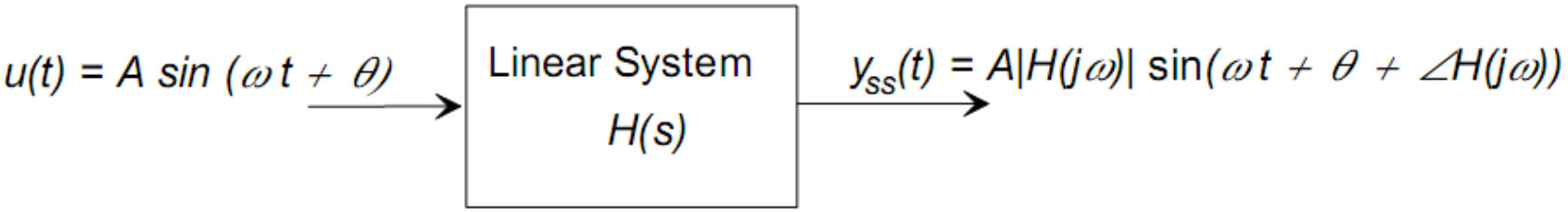
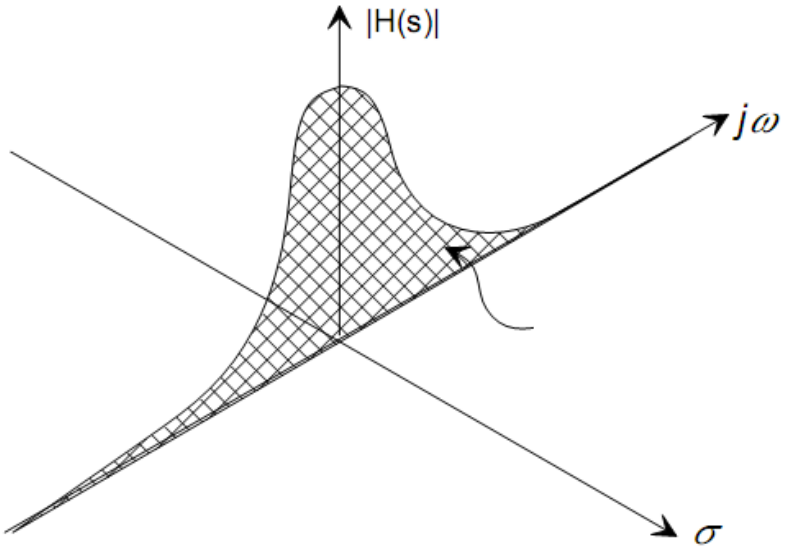
# Frequency Response III

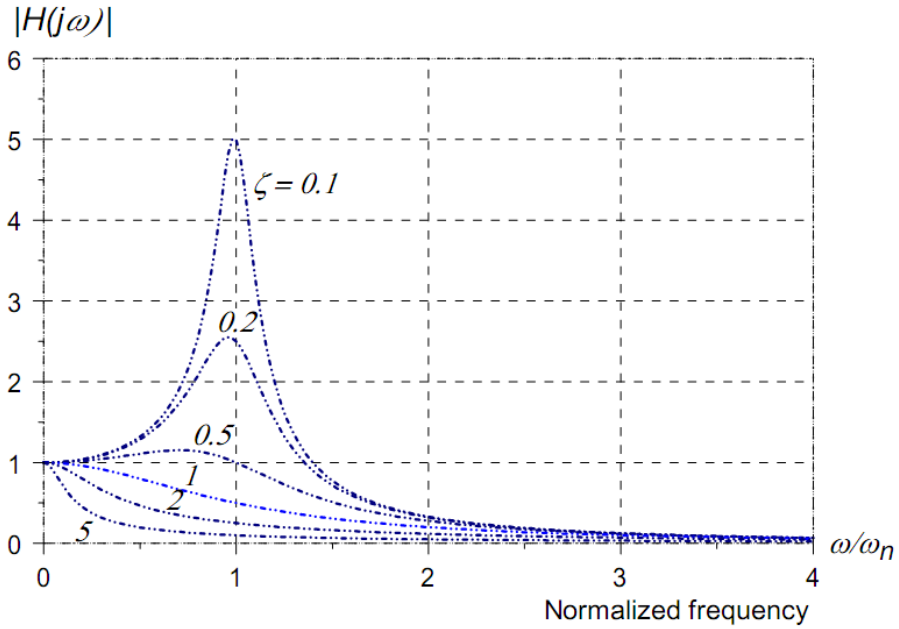
# Frequency Response

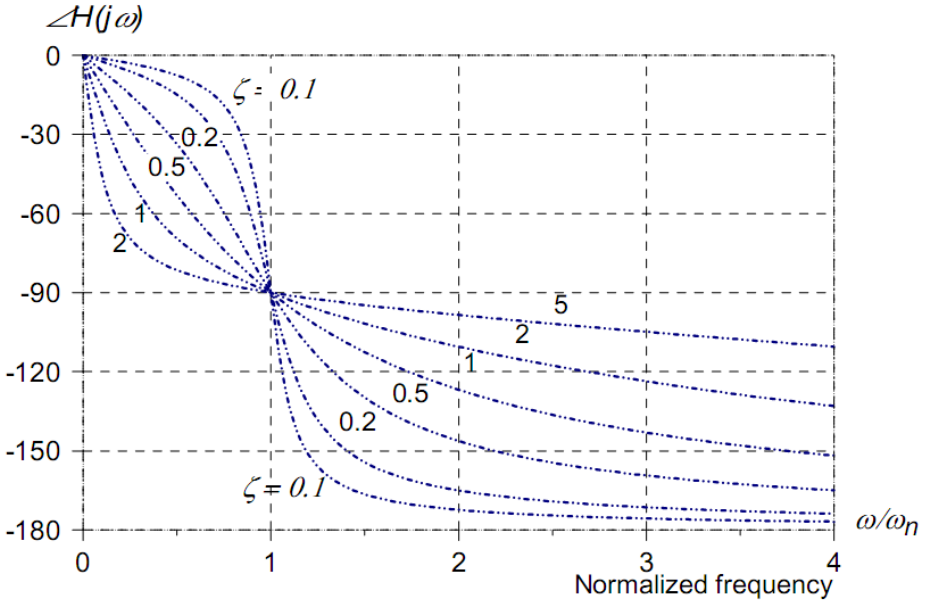



$$H(j\omega) = H(s)\big|_{s=j\omega}$$



# Frequency Response and Damping ratio



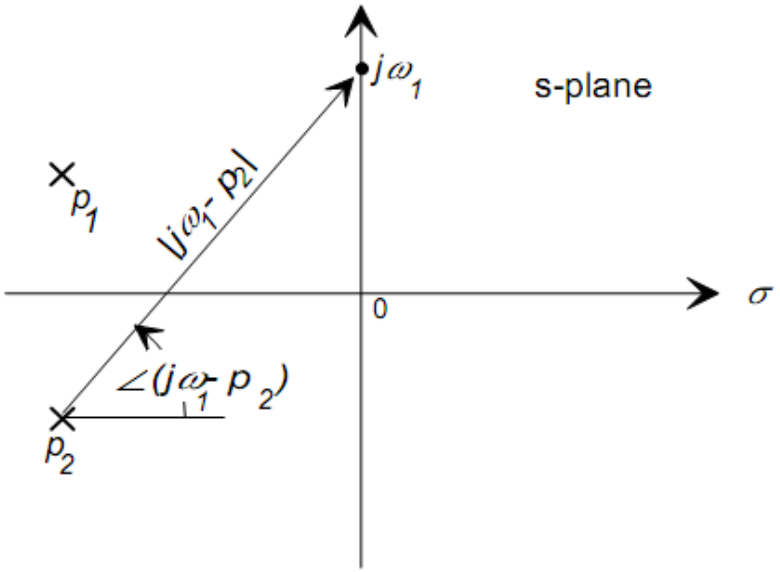



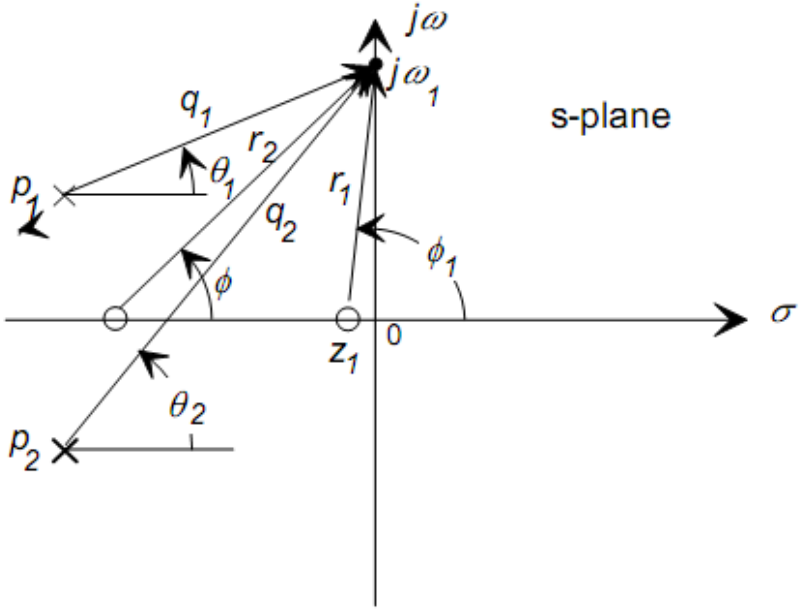
# Frequency Response and Pole Zero Plot

$$H(j\omega) = K\frac{(j\omega - z_1)(j\omega - z_2)\ldots(j\omega - z_{m-1})(j\omega - z_m)}{(j\omega - p_1)(j\omega - p_2)\ldots(j\omega - p_{n-1})(j\omega - p_n)}$$

$$|j\omega - p_i| \quad =$$

$$\angle(s - p_i) \quad =$$



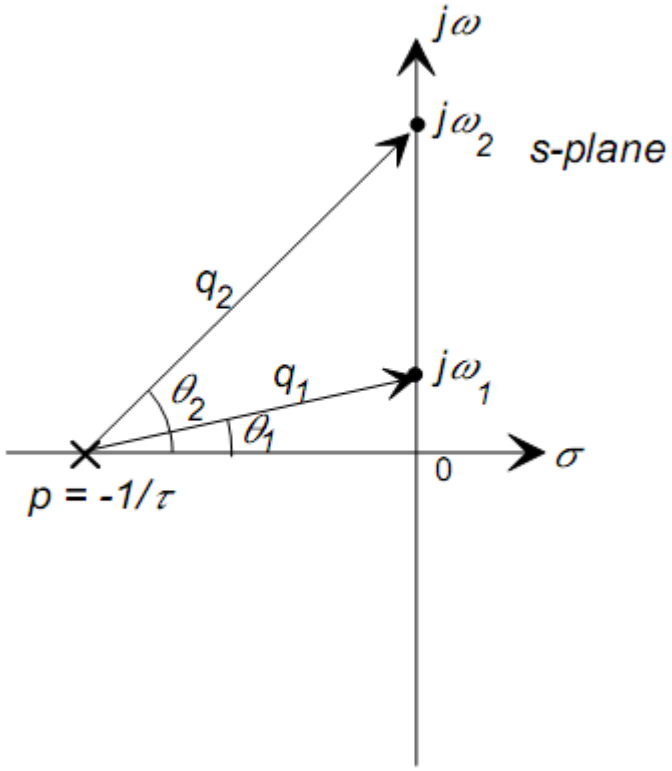
# Frequency Response and Pole Zero Plot

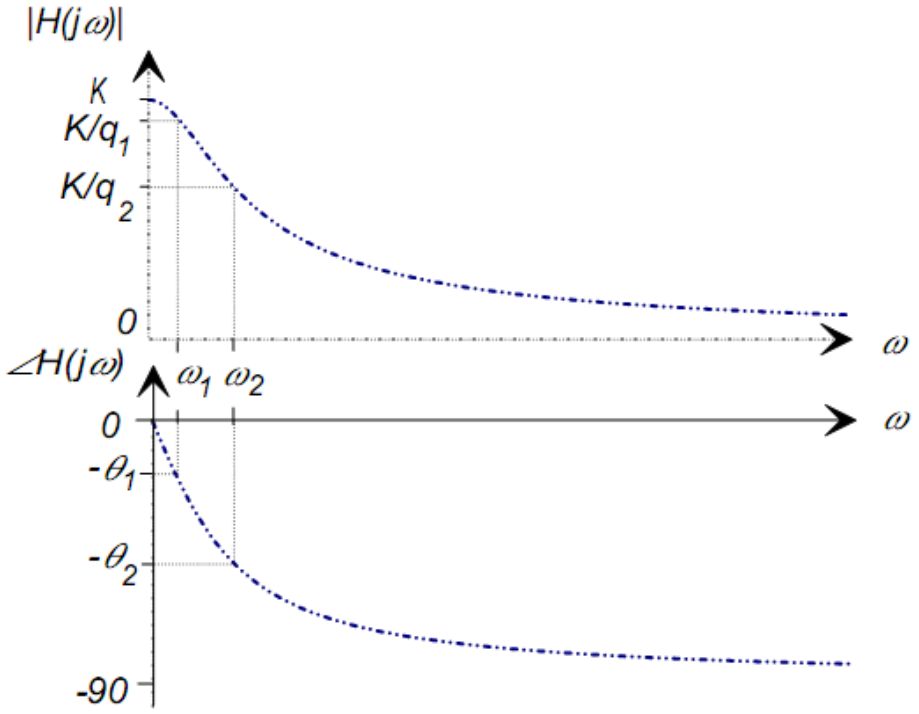
$$|H(j\omega)| = K\frac{\prod_{i=1}^{m}|(j\omega - z_i)|}{\prod_{i=1}^{n}|(j\omega - p_i)|} \qquad |H(j\omega)| =$$

$$\angle H(j\omega) = \sum_{i=1}^{m}\angle(j\omega - z_i) - \sum_{i=1}^{n}\angle(j\omega - p_i)$$

$$\angle H(j\omega) =$$

# Frequency Response of a First Order System



# High Frequency Response

## Magnitude Response

$$|H(j\omega)| = K\frac{r_1 \ldots r_m}{q_1 \ldots q_n}$$

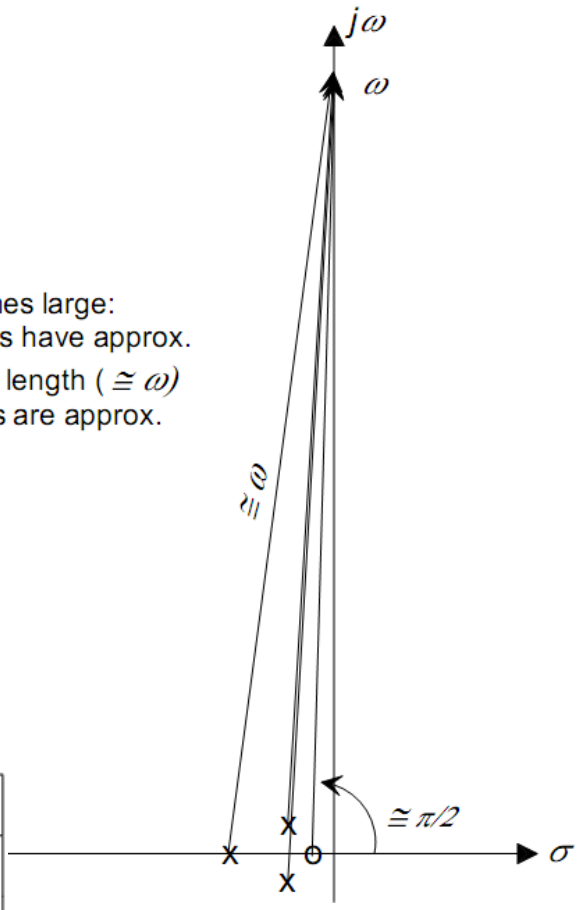
$$\lim_{\omega \to \infty} |H(j\omega)| =$$

## Phase Response

$$\angle H(j\omega) = (\phi_1 + \ldots + \phi_m) - (\theta_1 + \ldots + \theta_n)$$

$$\lim_{\omega \to \infty} \angle H(j\omega) =$$

As $\omega$ becomes large:
1) All vectors have approx. the same length ( $\cong \omega$)
2) All angles are approx. $\pi/2$




| | $n > m$ | $n = m$ | $n < m$ |
|---|---|---|---|
| $\lim_{\omega \to \infty} \lvert H(j\omega) \rvert$ | | | |
| $\lim_{\omega \to \infty} \angle H(j\omega)$ | | | |

# Low Frequency Response

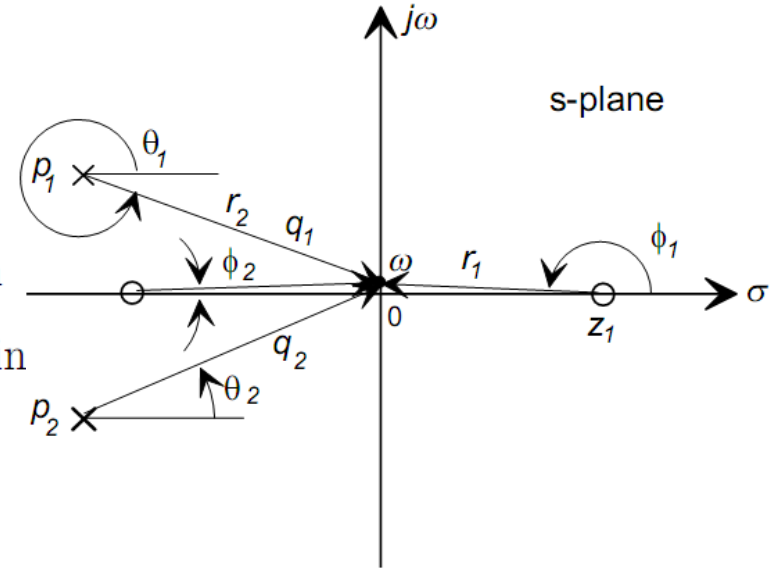
## Magnitude Response

$$|H(j\omega)| = K\frac{r_1 \cdots r_m}{q_1 \cdots q_n}$$

$$\lim_{\omega \to 0} |H(j\omega)| = \quad \text{if there are zeros at the origin}$$

$$\lim_{\omega \to 0} |H(j\omega)| = \quad \text{if there are poles at the origin}$$

$$\lim_{\omega \to 0} |H(j\omega)| = \quad \text{otherwise}$$




## Phase Response

$$\angle H(j\omega) = (\phi_1 + \ldots + \phi_m) - (\theta_1 + \ldots + \theta_n)$$

$$\lim_{\omega \to 0} \angle H(j\omega) =$$

# Frequency Response of poles and zeros close to imaginary axis

$$|H(j\omega)| = \qquad \angle H(j\omega) =$$