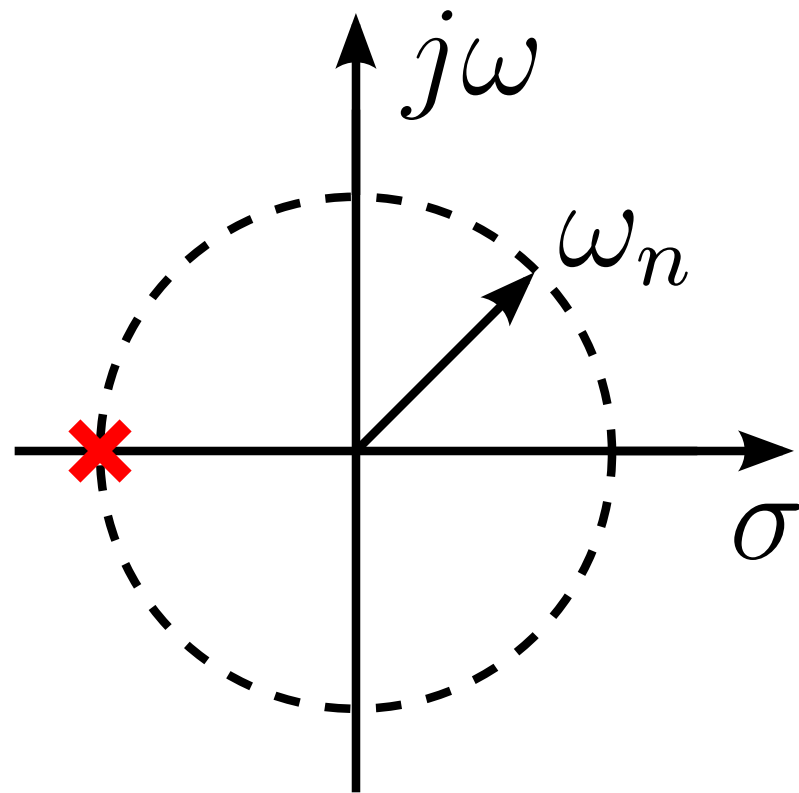


Structured Electronic Design

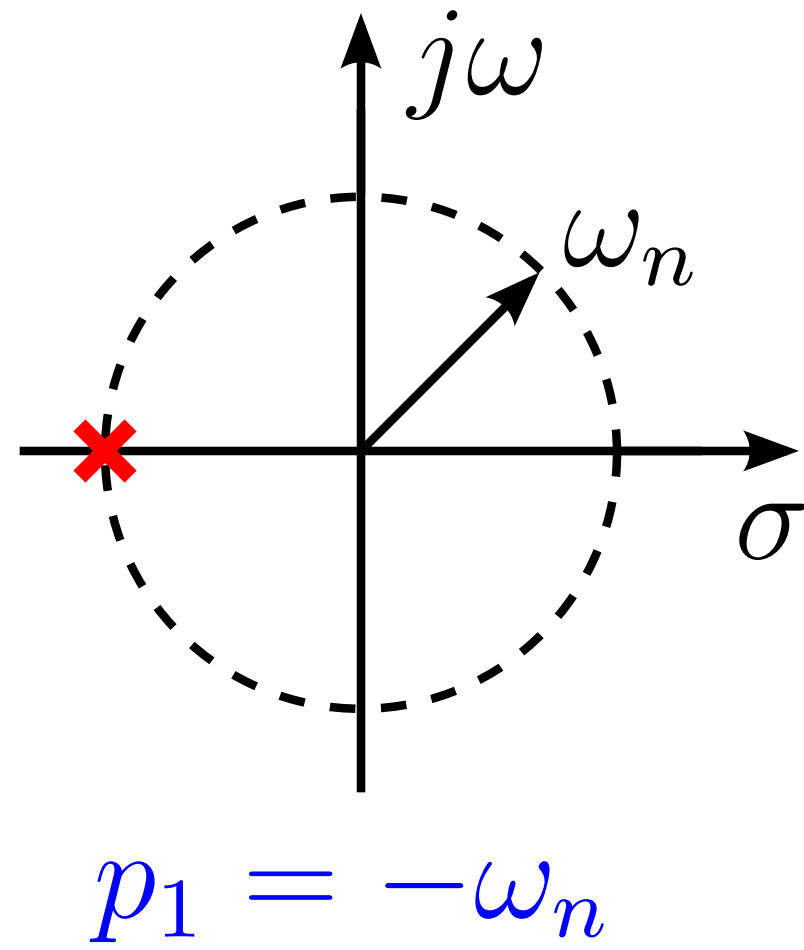
Butterworth, or Maximally Flat Magnitude Frequency Responses

All-pole Butterworth (MFM) responses

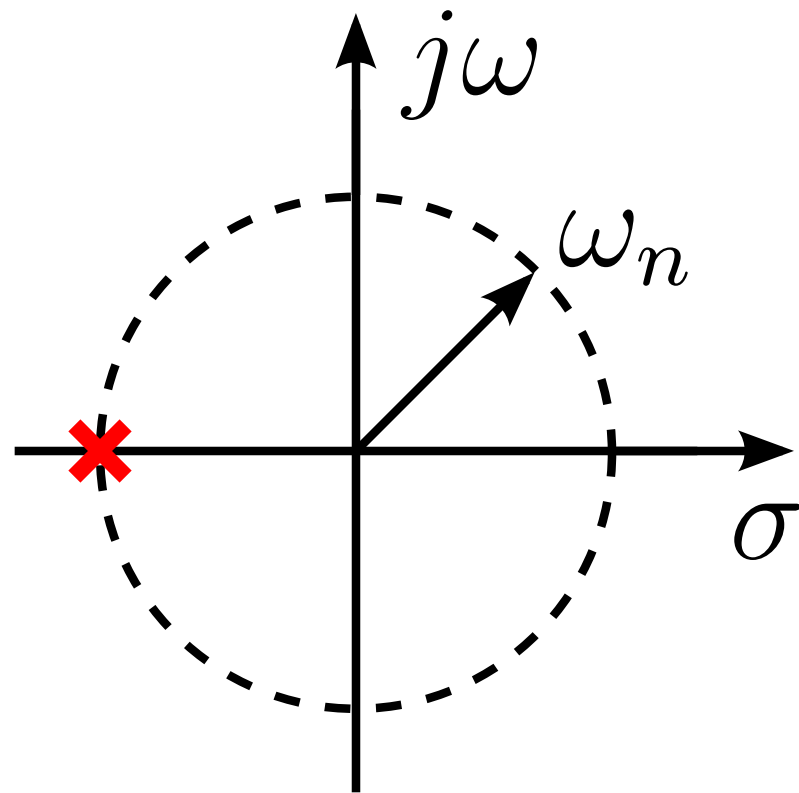
All-pole Butterworth (MFM) reponses



All-pole Butterworth (MFM) responses



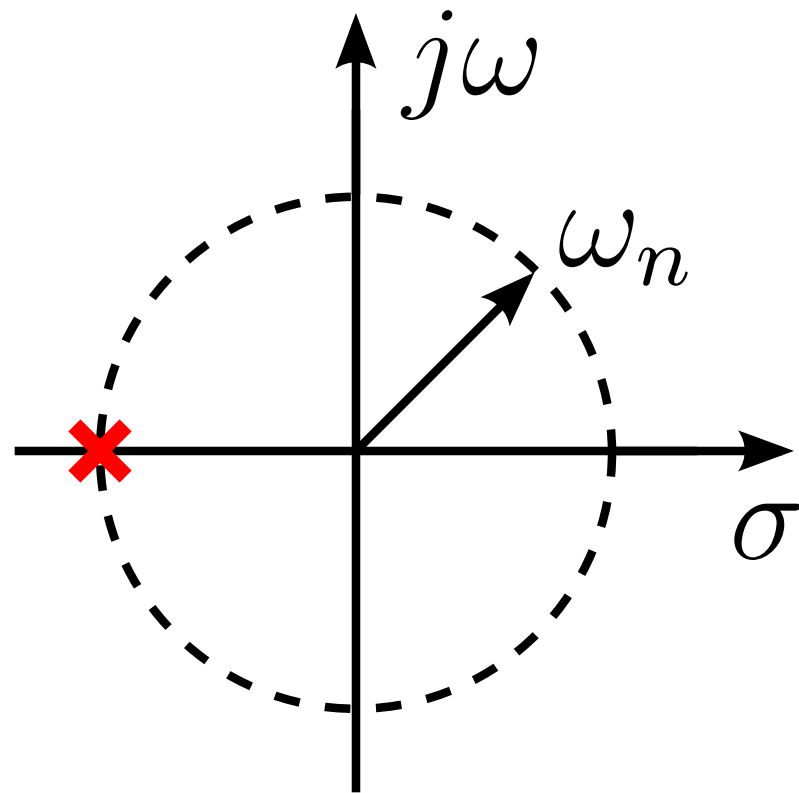
All-pole Butterworth (MFM) responses



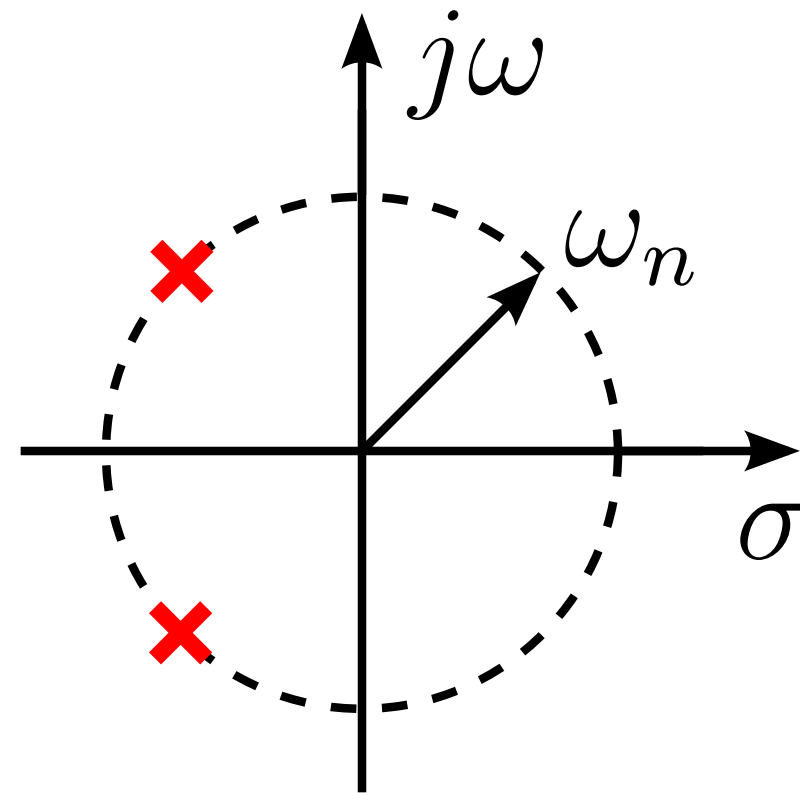
$$p_1 = -\omega_n$$

$$H_1(s) = \frac{1}{1 + s \frac{1}{\omega_n}}$$

All-pole Butterworth (MFM) responses

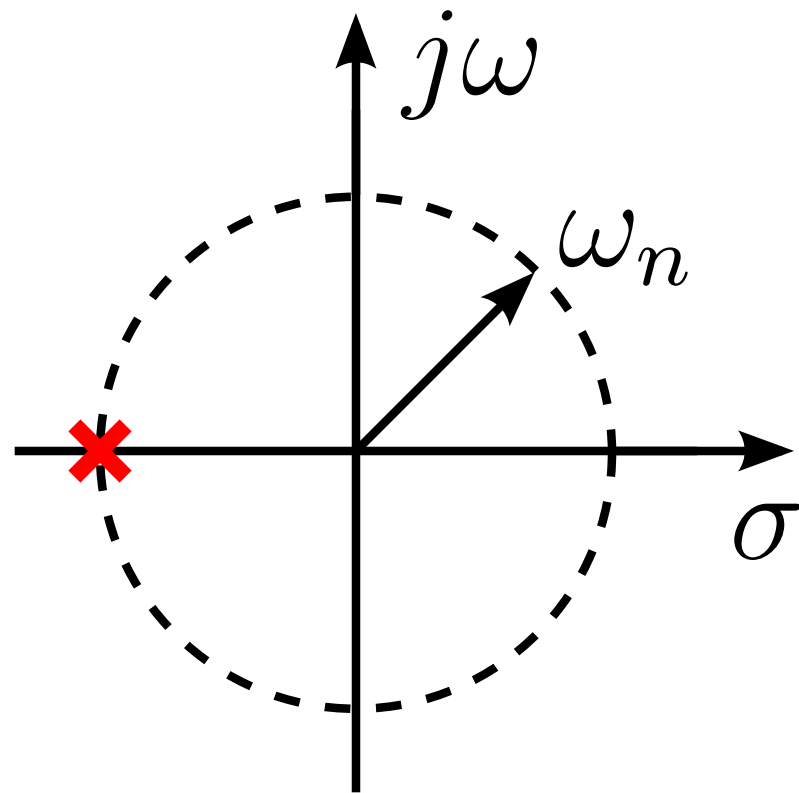


$$p_1 = -\omega_n$$

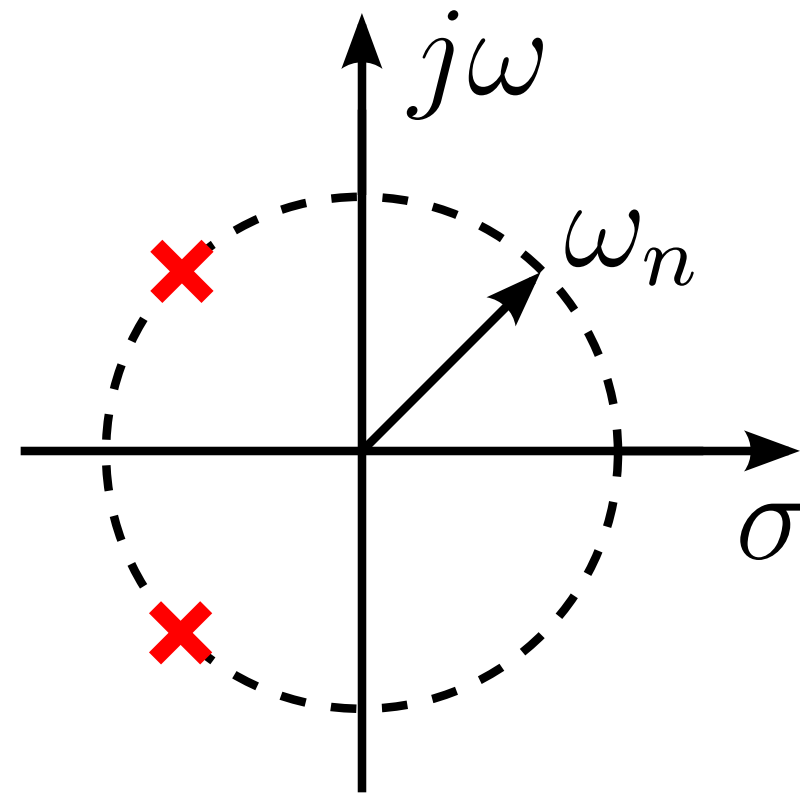


$$H_1(s) = \frac{1}{1 + s \frac{1}{\omega_n}}$$

All-pole Butterworth (MFM) responses



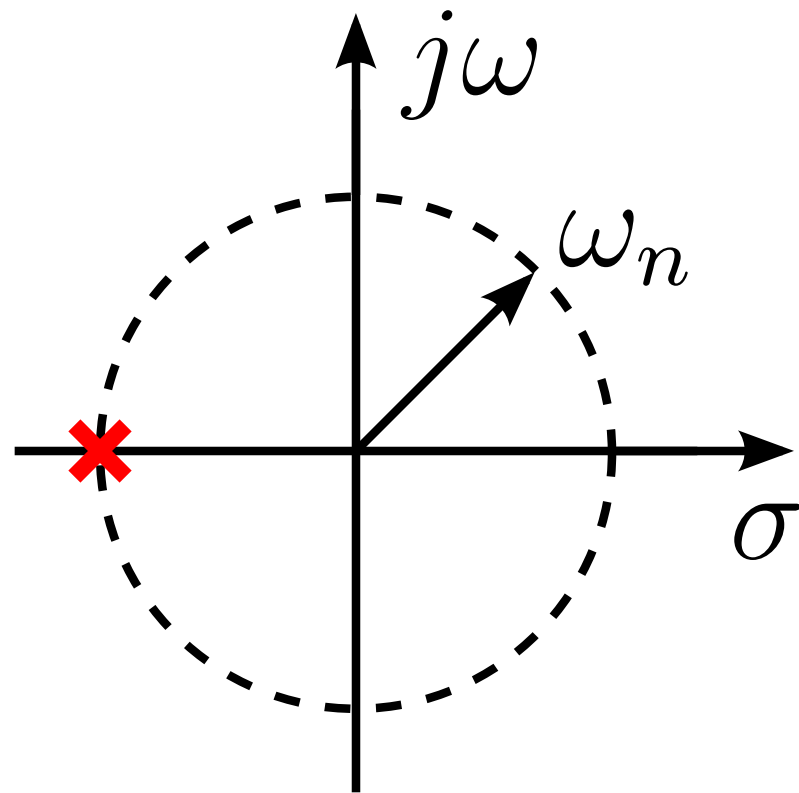
$$p_1 = -\omega_n$$



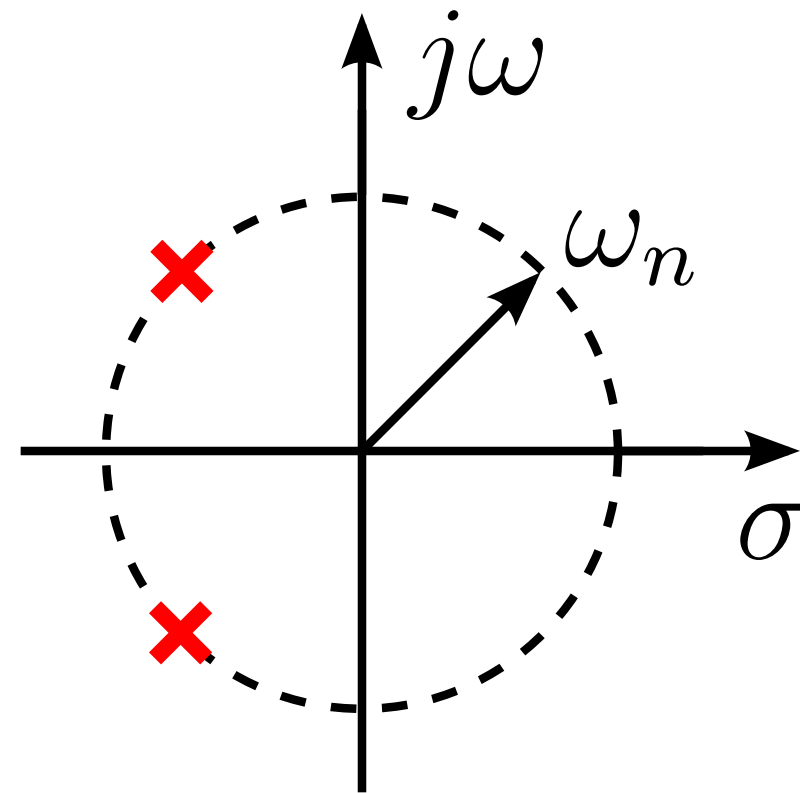
$$p_{1,2} = -\frac{1}{2}\sqrt{2}\omega_n(1\pm j)$$

$$H_1(s) = \frac{1}{1+s\frac{1}{\omega_n}}$$

All-pole Butterworth (MFM) responses



$$p_1 = -\omega_n$$

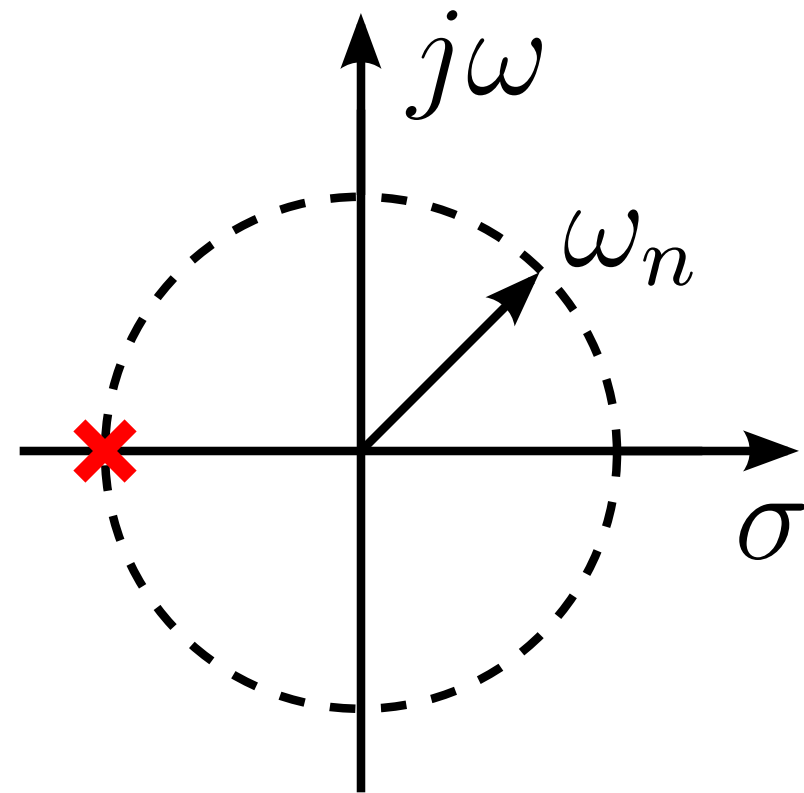


$$p_{1,2} = -\frac{1}{2}\sqrt{2}\omega_n(1\pm j)$$

$$H_1(s) = \frac{1}{1+s\frac{1}{\omega_n}}$$

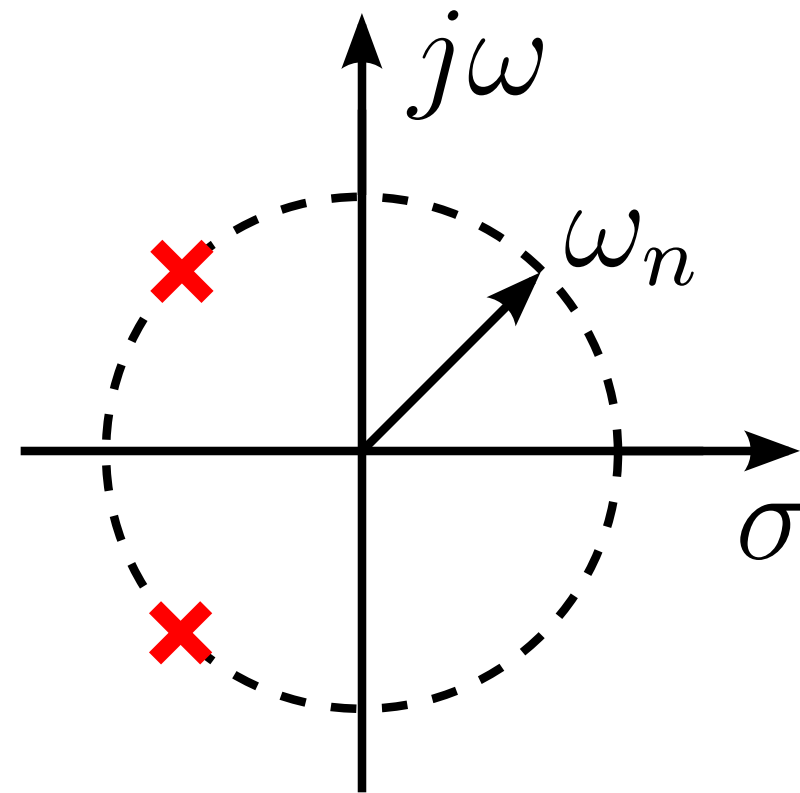
$$H_2(s) = \frac{1}{1+s\frac{\sqrt{2}}{\omega_n}+s^2\frac{1}{\omega_n^2}}$$

All-pole Butterworth (MFM) responses



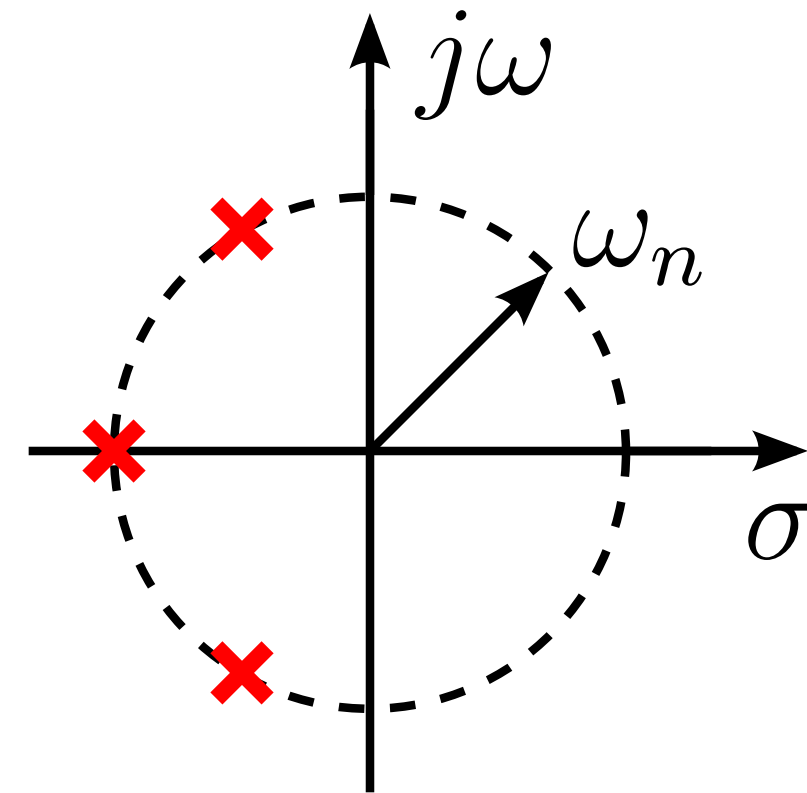
$$p_1 = -\omega_n$$

$$H_1(s) = \frac{1}{1 + s \frac{1}{\omega_n}}$$

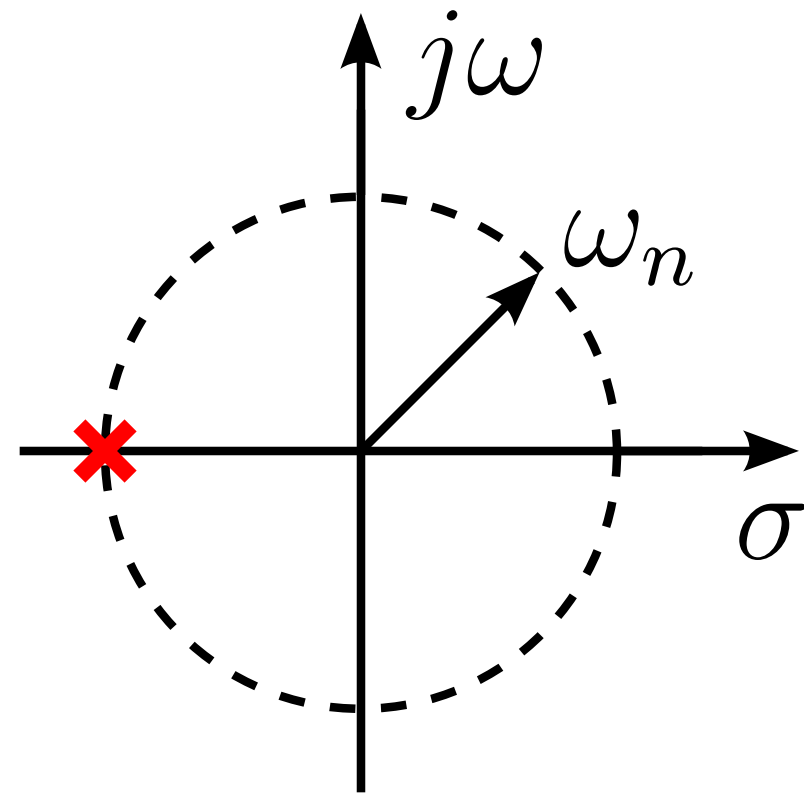


$$p_{1,2} = -\frac{1}{2}\sqrt{2}\omega_n(1 \pm j)$$

$$H_2(s) = \frac{1}{1 + s \frac{\sqrt{2}}{\omega_n} + s^2 \frac{1}{\omega_n^2}}$$

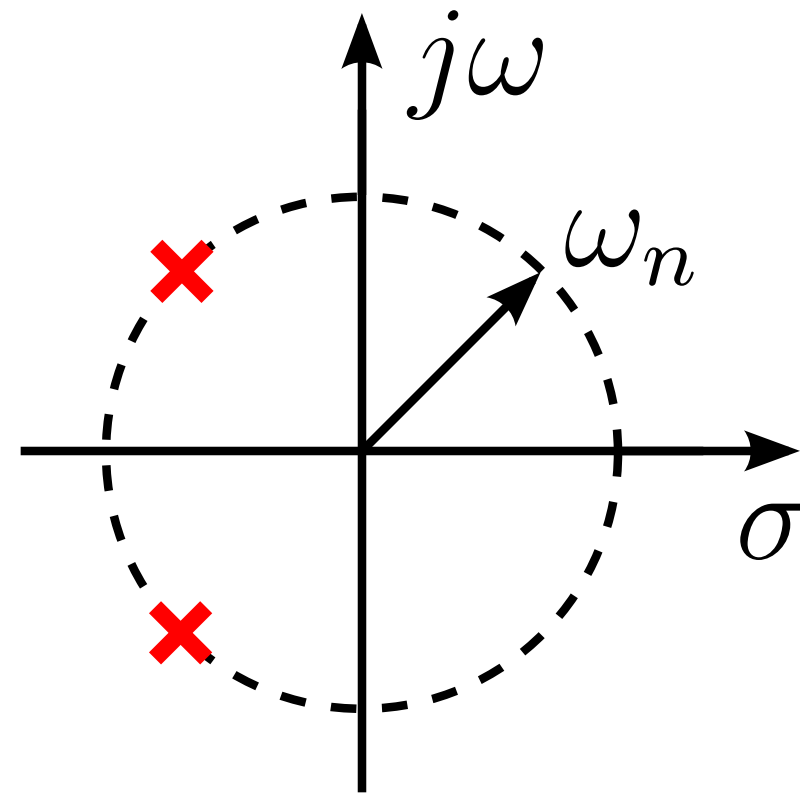


All-pole Butterworth (MFM) responses



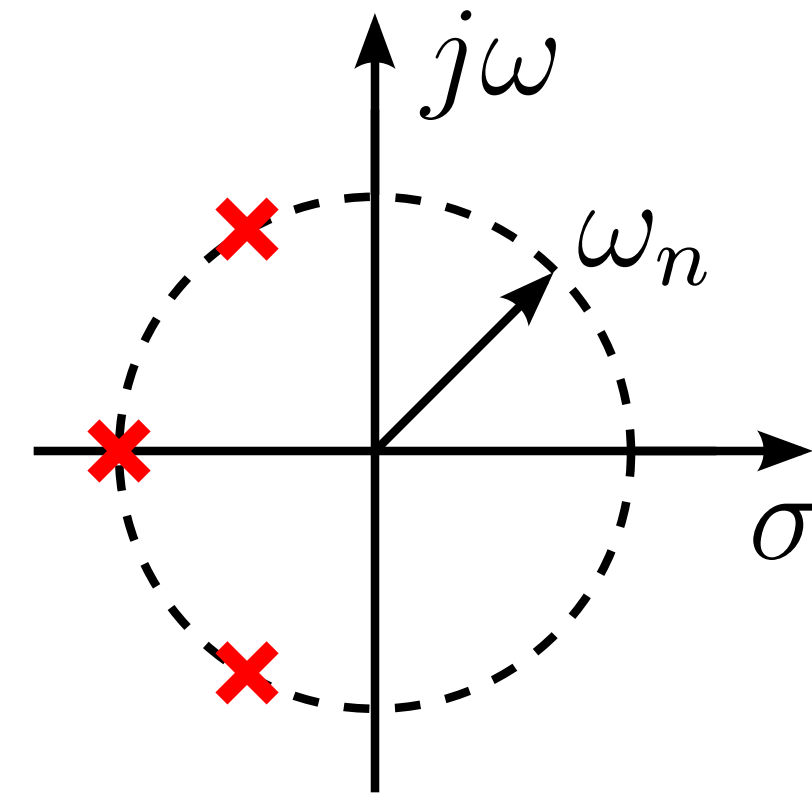
$$p_1 = -\omega_n$$

$$H_1(s) = \frac{1}{1 + s \frac{1}{\omega_n}}$$



$$p_{1,2} = -\frac{1}{2}\sqrt{2}\omega_n(1 \pm j)$$

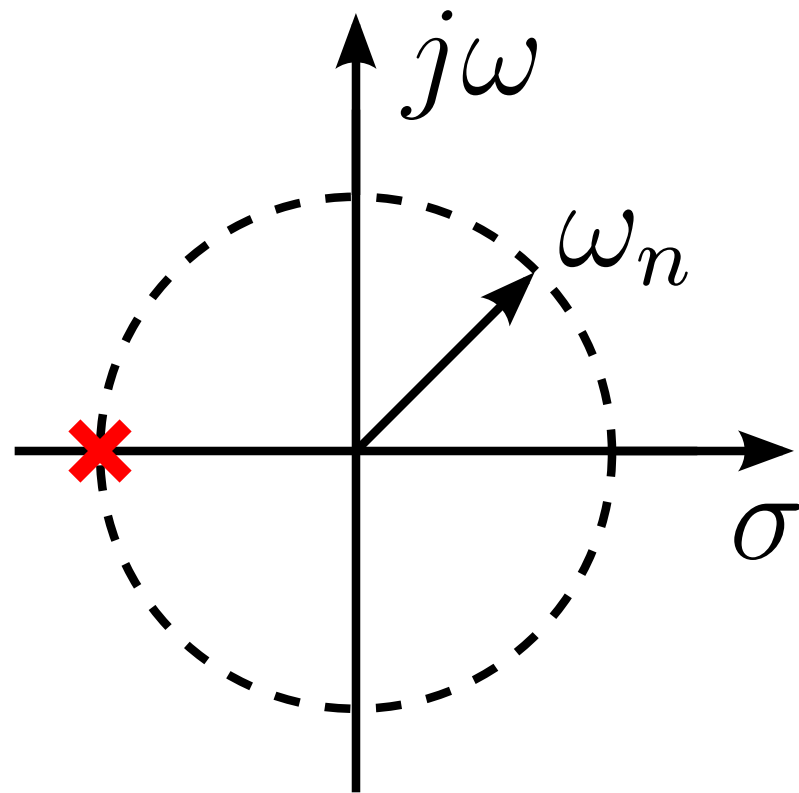
$$H_2(s) = \frac{1}{1 + s \frac{\sqrt{2}}{\omega_n} + s^2 \frac{1}{\omega_n^2}}$$



$$p_1 = -\omega_n$$

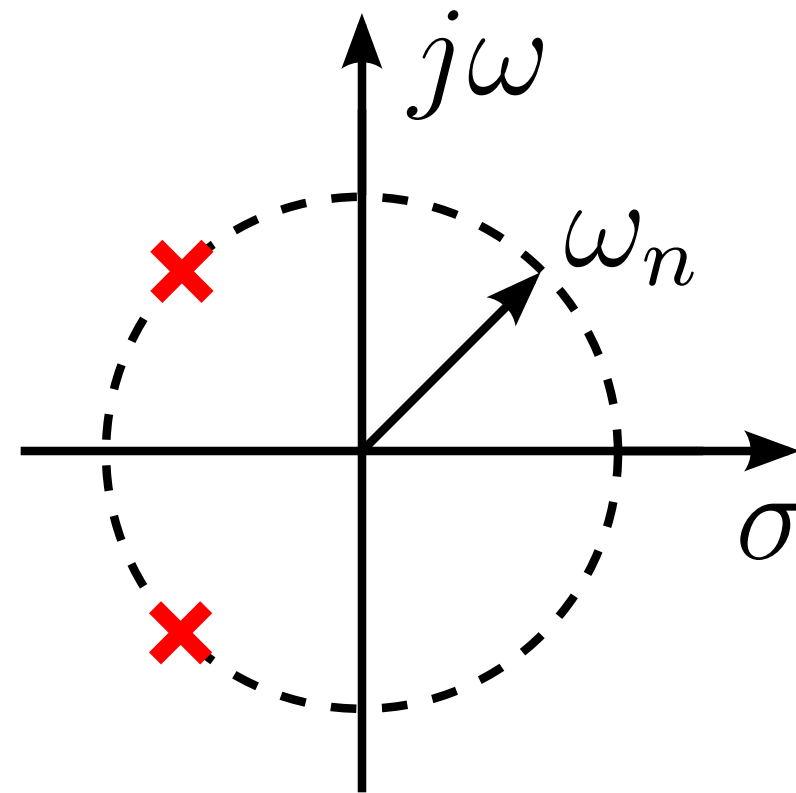
$$p_{2,3} = -\frac{1}{2}\omega_n \pm j \frac{1}{2}\sqrt{3}\omega_n$$

All-pole Butterworth (MFM) responses



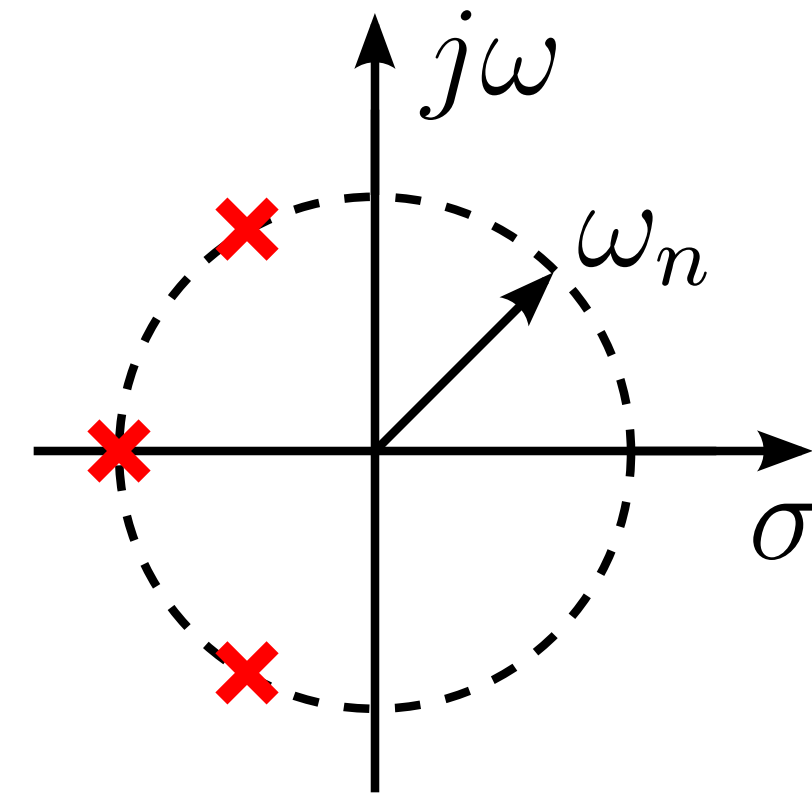
$$p_1 = -\omega_n$$

$$H_1(s) = \frac{1}{1 + s \frac{1}{\omega_n}}$$



$$p_{1,2} = -\frac{1}{2}\sqrt{2}\omega_n(1 \pm j)$$

$$H_2(s) = \frac{1}{1 + s \frac{\sqrt{2}}{\omega_n} + s^2 \frac{1}{\omega_n^2}}$$

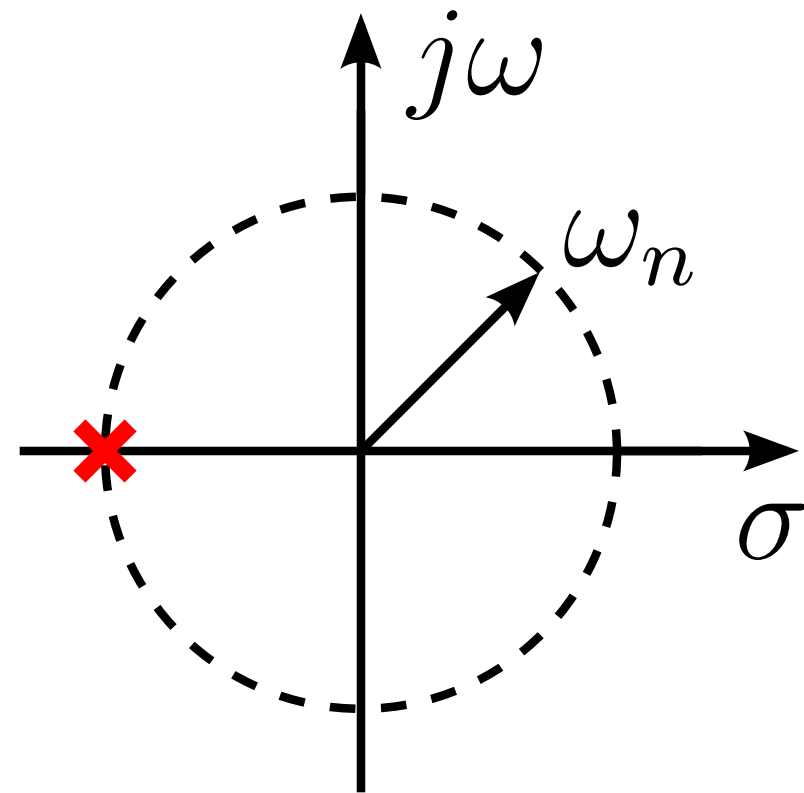


$$p_1 = -\omega_n$$

$$p_{2,3} = -\frac{1}{2}\omega_n \pm j \frac{1}{2}\sqrt{3}\omega_n$$

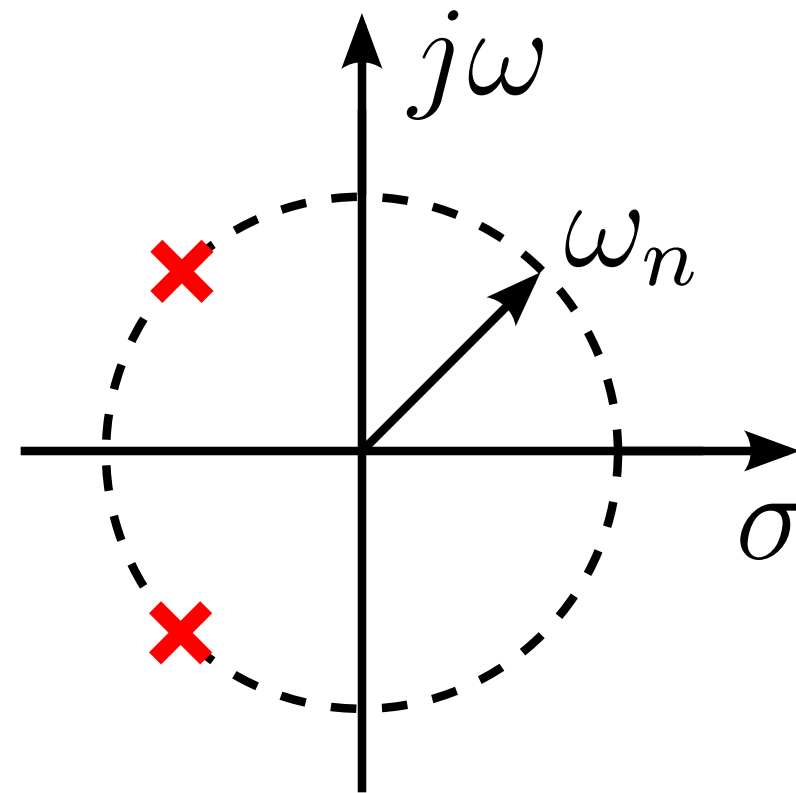
$$H_3(s) = \frac{1}{1 + s \frac{2}{\omega_n} + s^2 \frac{2}{\omega_n^2} + s^3 \frac{1}{\omega_n^3}}$$

All-pole Butterworth (MFM) responses



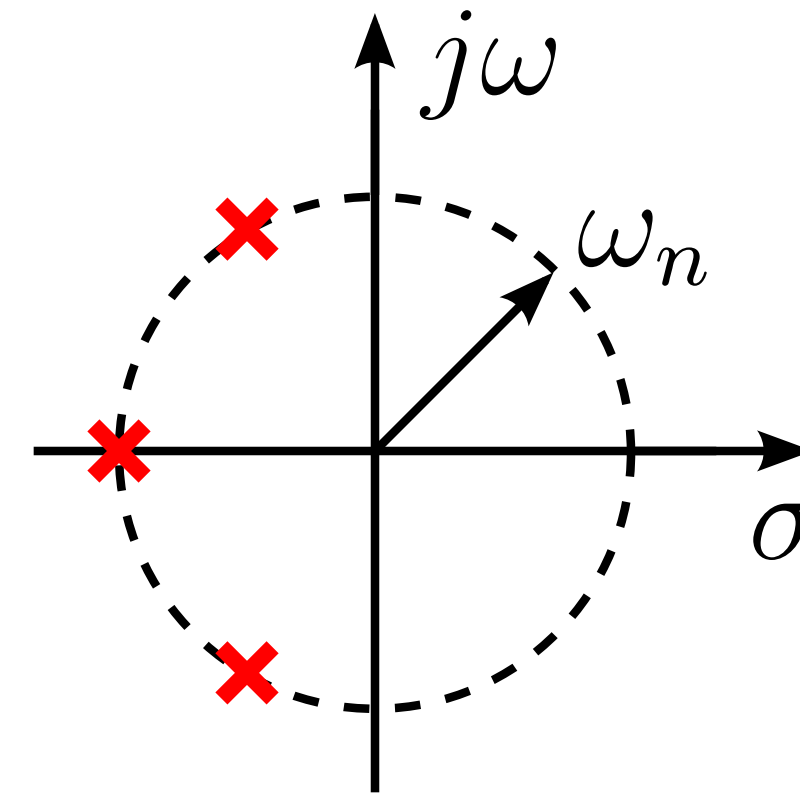
$$p_1 = -\omega_n$$

$$H_1(s) = \frac{1}{1 + s \frac{1}{\omega_n}}$$



$$p_{1,2} = -\frac{1}{2}\sqrt{2}\omega_n(1 \pm j)$$

$$H_2(s) = \frac{1}{1 + s \frac{\sqrt{2}}{\omega_n} + s^2 \frac{1}{\omega_n^2}}$$



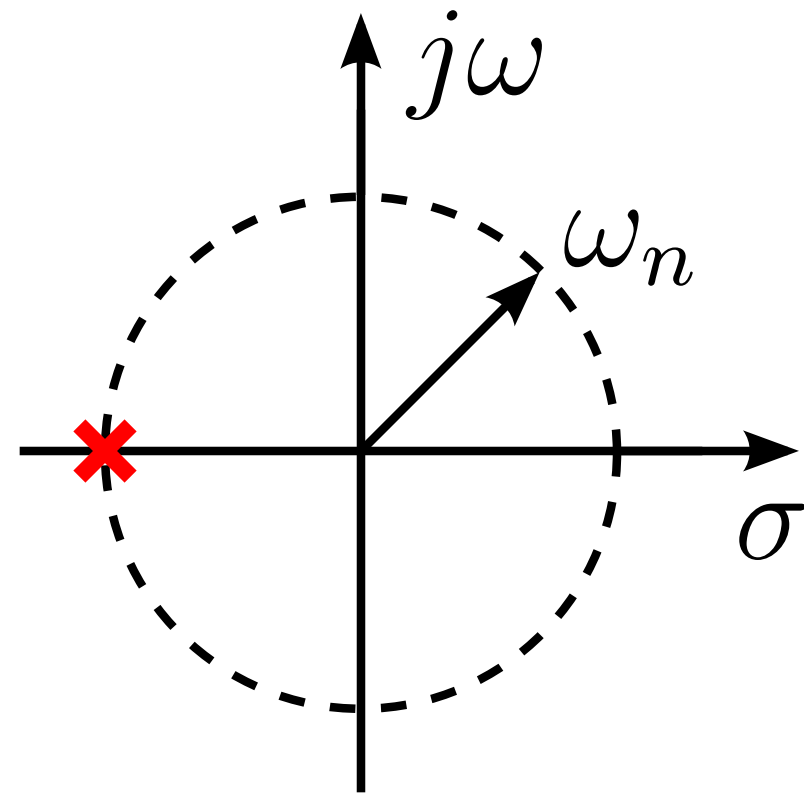
$$p_1 = -\omega_n$$

$$p_{2,3} = -\frac{1}{2}\omega_n \pm j \frac{1}{2}\sqrt{3}\omega_n$$

$$H_3(s) = \frac{1}{1 + s \frac{2}{\omega_n} + s^2 \frac{2}{\omega_n^2} + s^3 \frac{1}{\omega_n^3}}$$

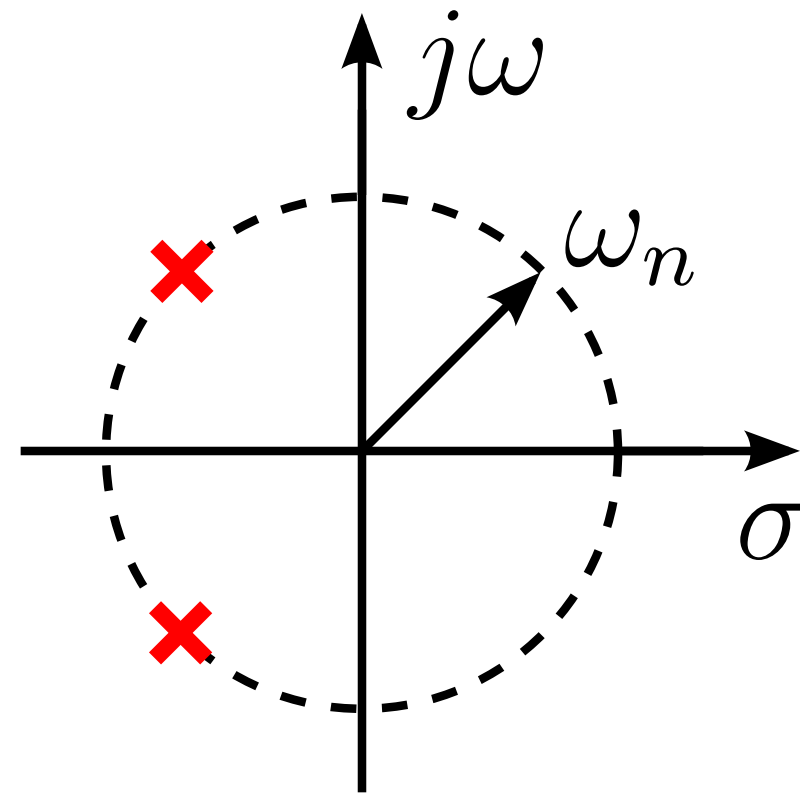
Denominator coefficient of highest order of s determines the bandwidth

All-pole Butterworth (MFM) responses



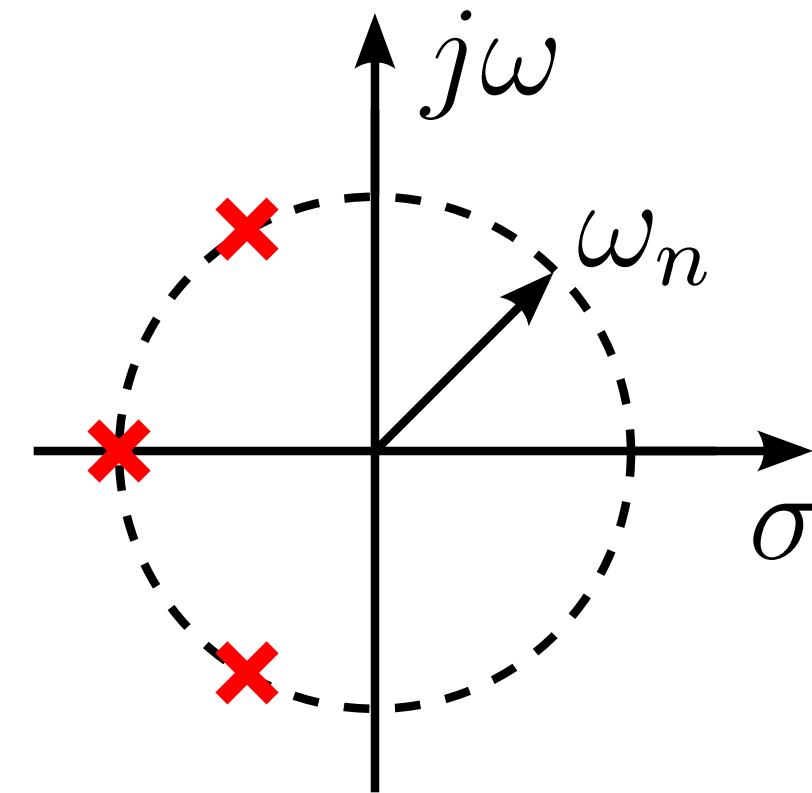
$$p_1 = -\omega_n$$

$$H_1(s) = \frac{1}{1 + s \frac{1}{\omega_n}}$$



$$p_{1,2} = -\frac{1}{2}\sqrt{2}\omega_n(1 \pm j)$$

$$H_2(s) = \frac{1}{1 + s \frac{\sqrt{2}}{\omega_n} + s^2 \frac{1}{\omega_n^2}}$$



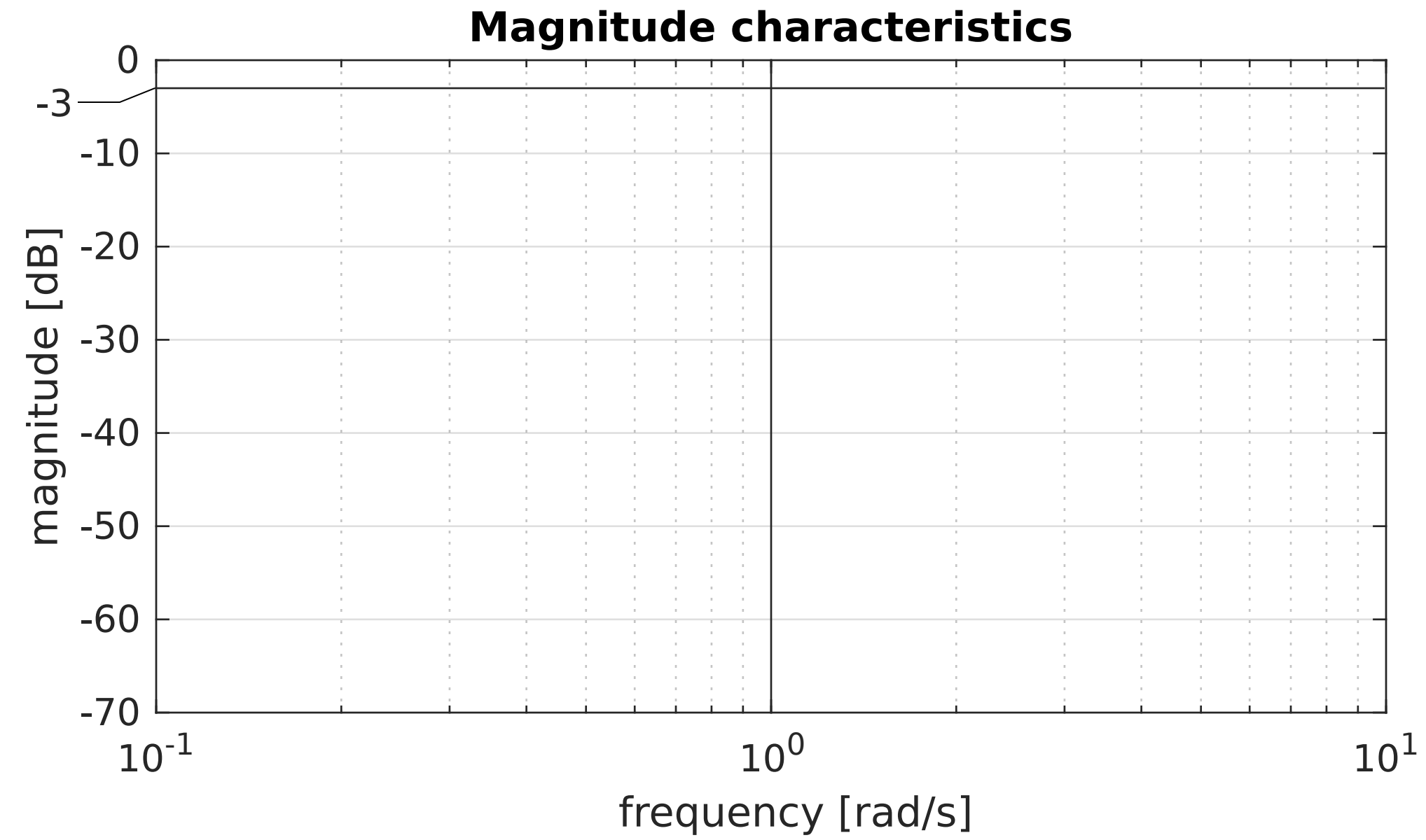
$$p_1 = -\omega_n$$

$$p_{2,3} = -\frac{1}{2}\omega_n \pm j \frac{1}{2}\sqrt{3}\omega_n$$

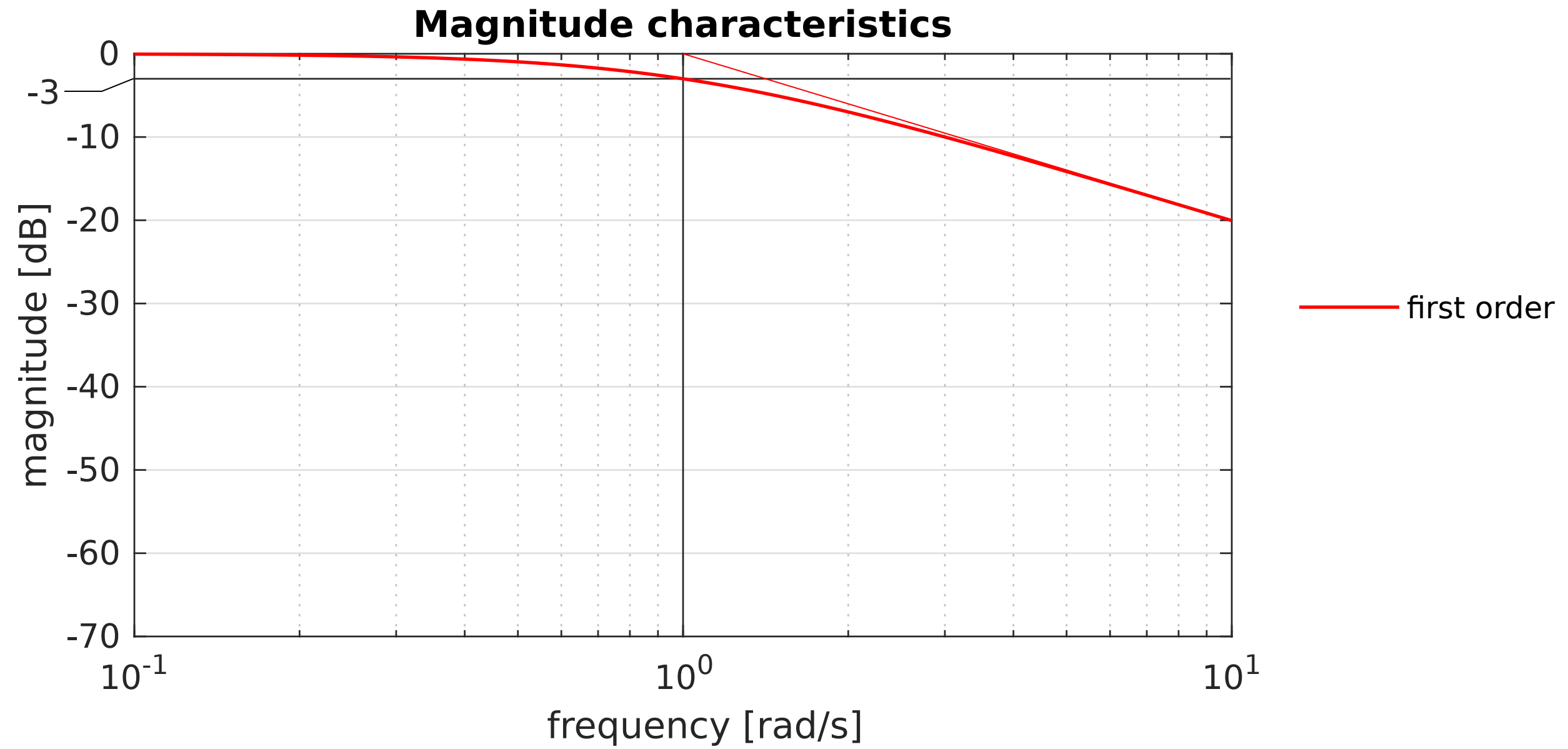
$$H_3(s) = \frac{1}{1 + s \frac{2}{\omega_n} + s^2 \frac{2}{\omega_n^2} + s^3 \frac{1}{\omega_n^3}}$$

Denominator coefficient of highest order of s determines the bandwidth

All-pole Butterworth (MFM) reponses

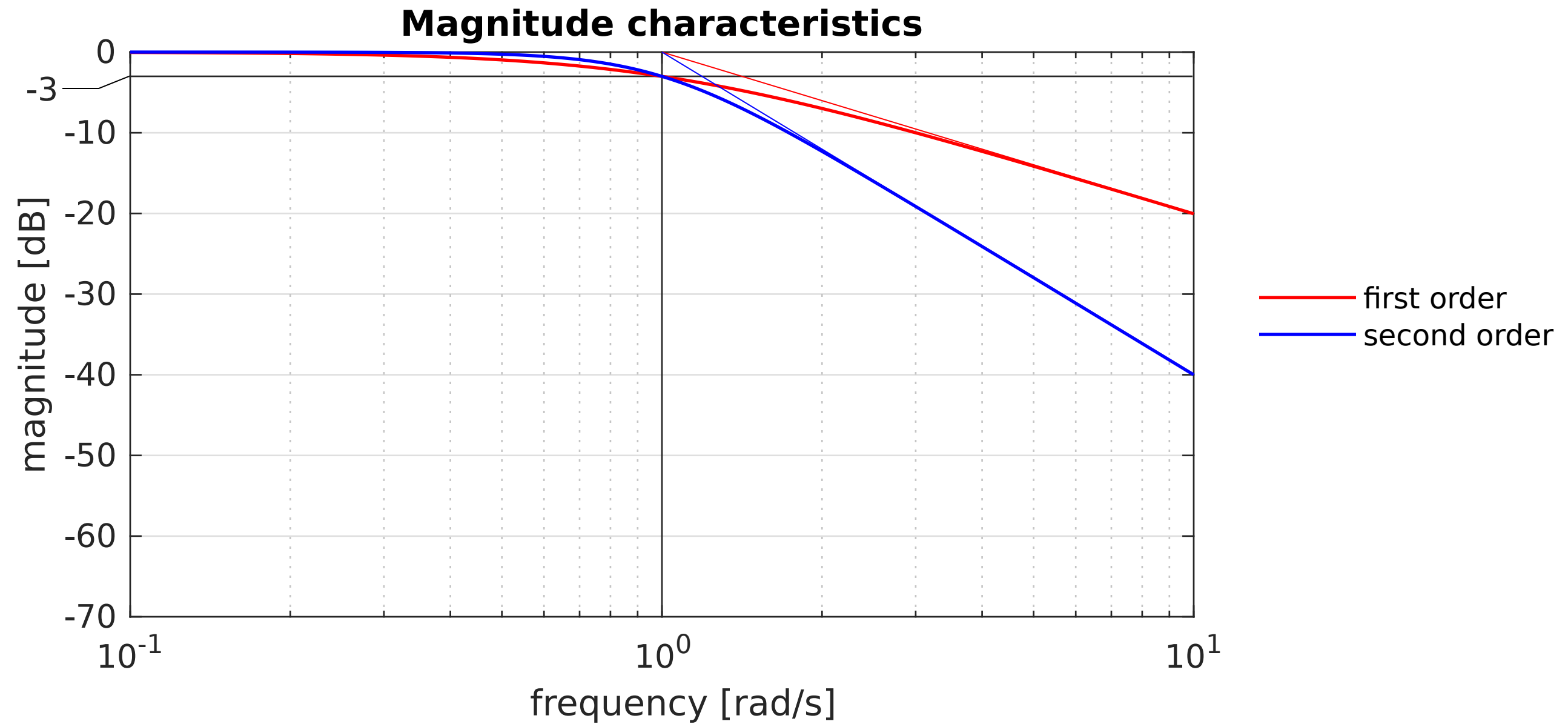


All-pole Butterworth (MFM) reponses



$$H_1(s) = \frac{1}{1 + s \frac{1}{\omega_n}}$$

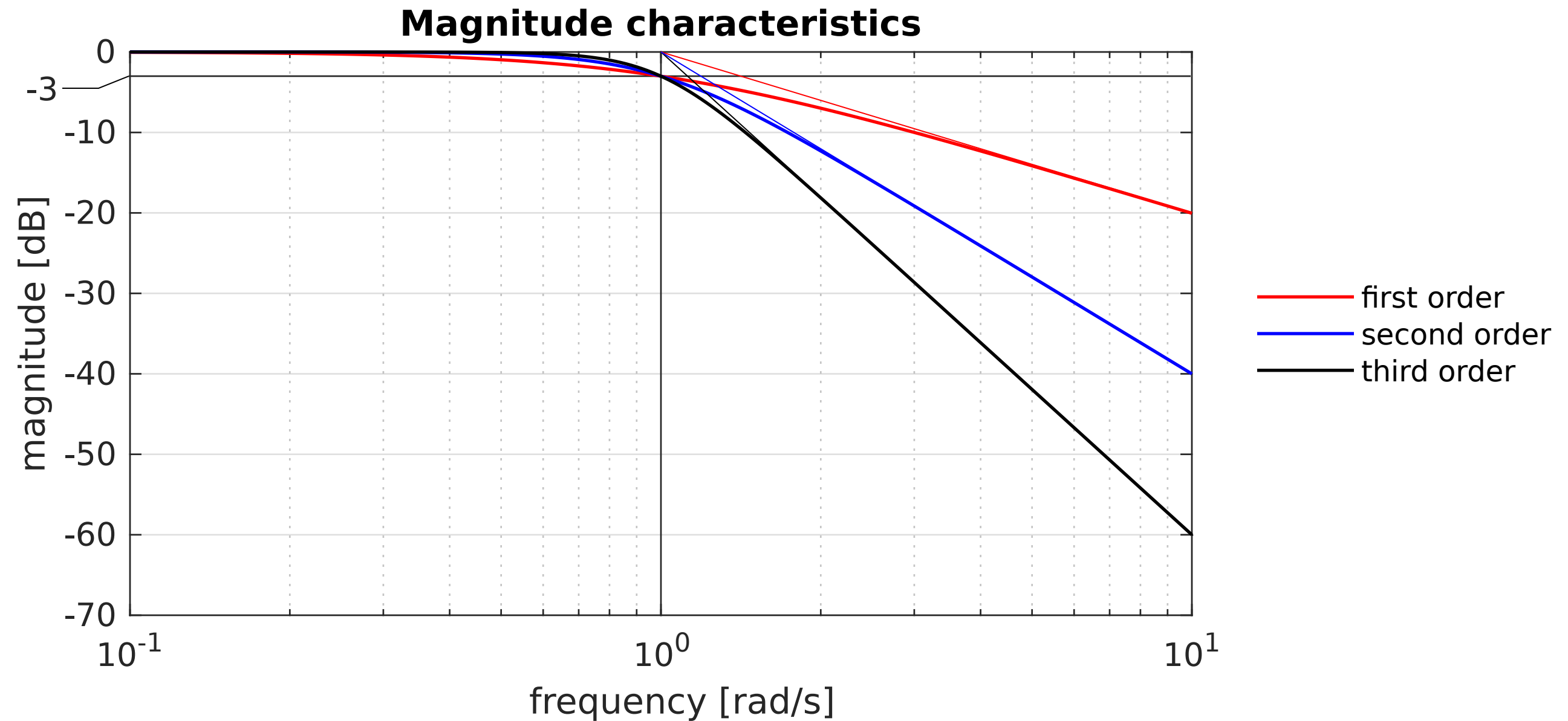
All-pole Butterworth (MFM) responses



$$H_1(s) = \frac{1}{1 + s \frac{1}{\omega_n}}$$

$$H_2(s) = \frac{1}{1 + s \frac{\sqrt{2}}{\omega_n} + s^2 \frac{1}{\omega_n^2}}$$

All-pole Butterworth (MFM) responses

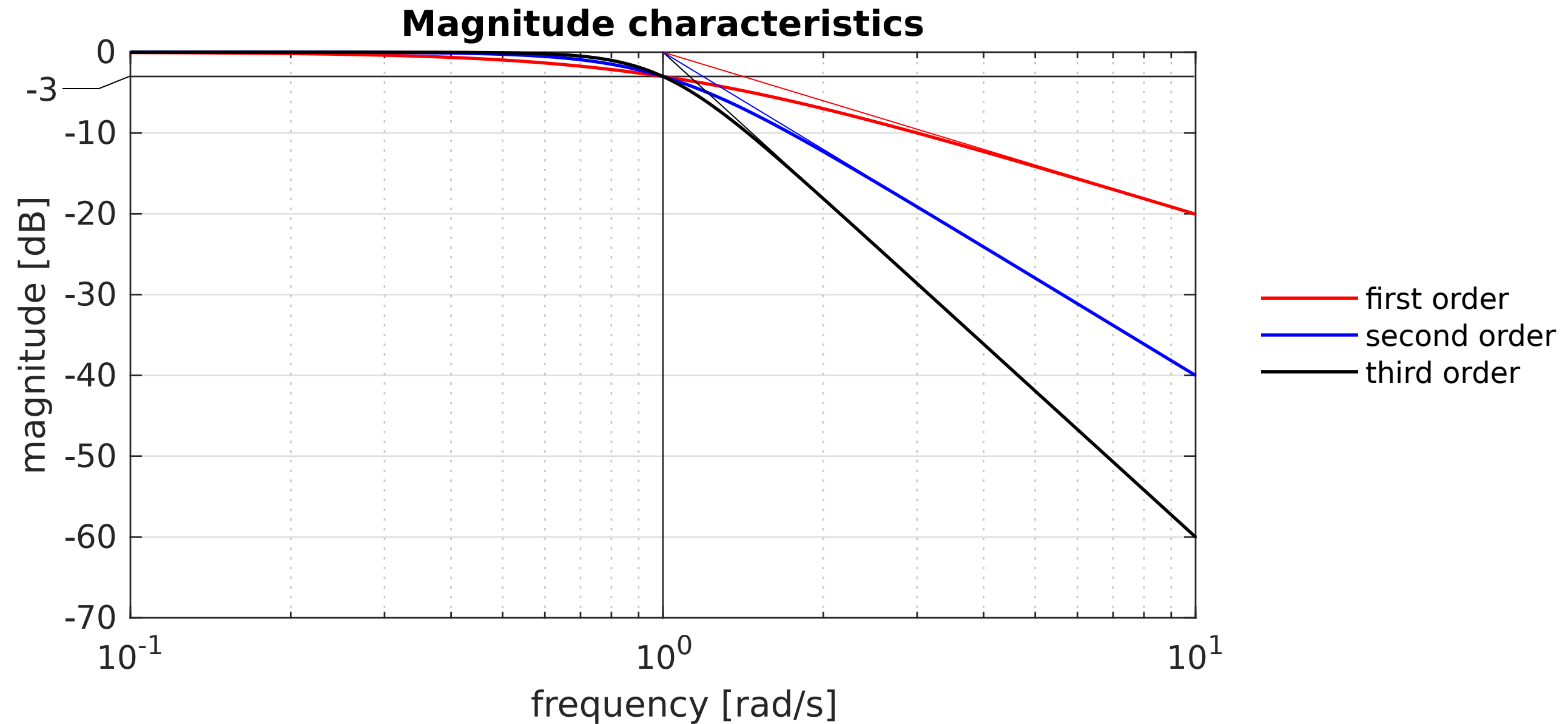


$$H_1(s) = \frac{1}{1 + s \frac{1}{\omega_n}}$$

$$H_2(s) = \frac{1}{1 + s \frac{\sqrt{2}}{\omega_n} + s^2 \frac{1}{\omega_n^2}}$$

$$H_3(s) = \frac{1}{1 + s \frac{2}{\omega_n} + s^2 \frac{2}{\omega_n^2} + s^3 \frac{1}{\omega_n^3}}$$

All-pole Butterworth (MFM) responses



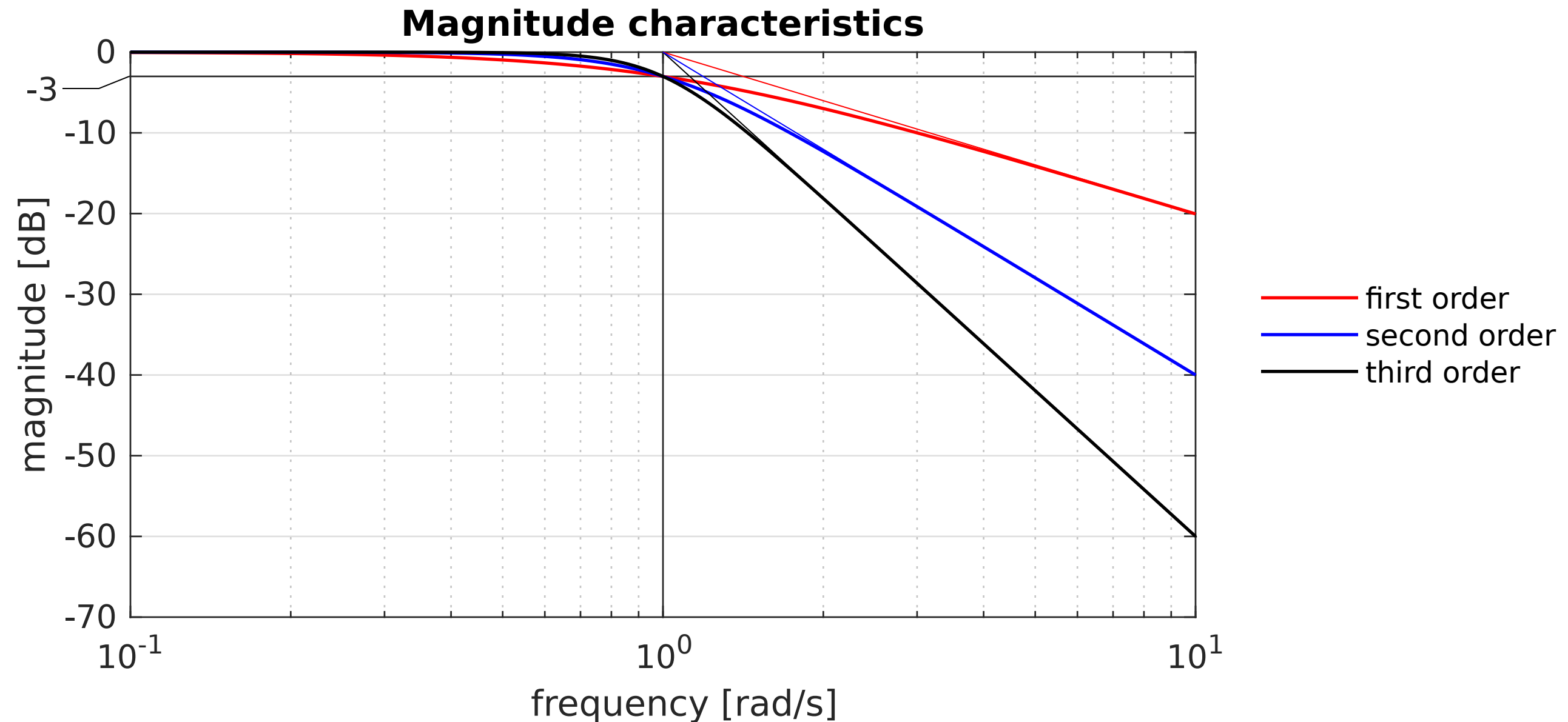
$$H_1(s) = \frac{1}{1 + s \frac{1}{\omega_n}}$$

$$H_2(s) = \frac{1}{1 + s \frac{\sqrt{2}}{\omega_n} + s^2 \frac{1}{\omega_n^2}}$$

$$H_3(s) = \frac{1}{1 + s \frac{2}{\omega_n} + s^2 \frac{2}{\omega_n^2} + s^3 \frac{1}{\omega_n^3}}$$

Butterworth or MFM: -3dB frequency at intersection of asymptotes:

All-pole Butterworth (MFM) responses



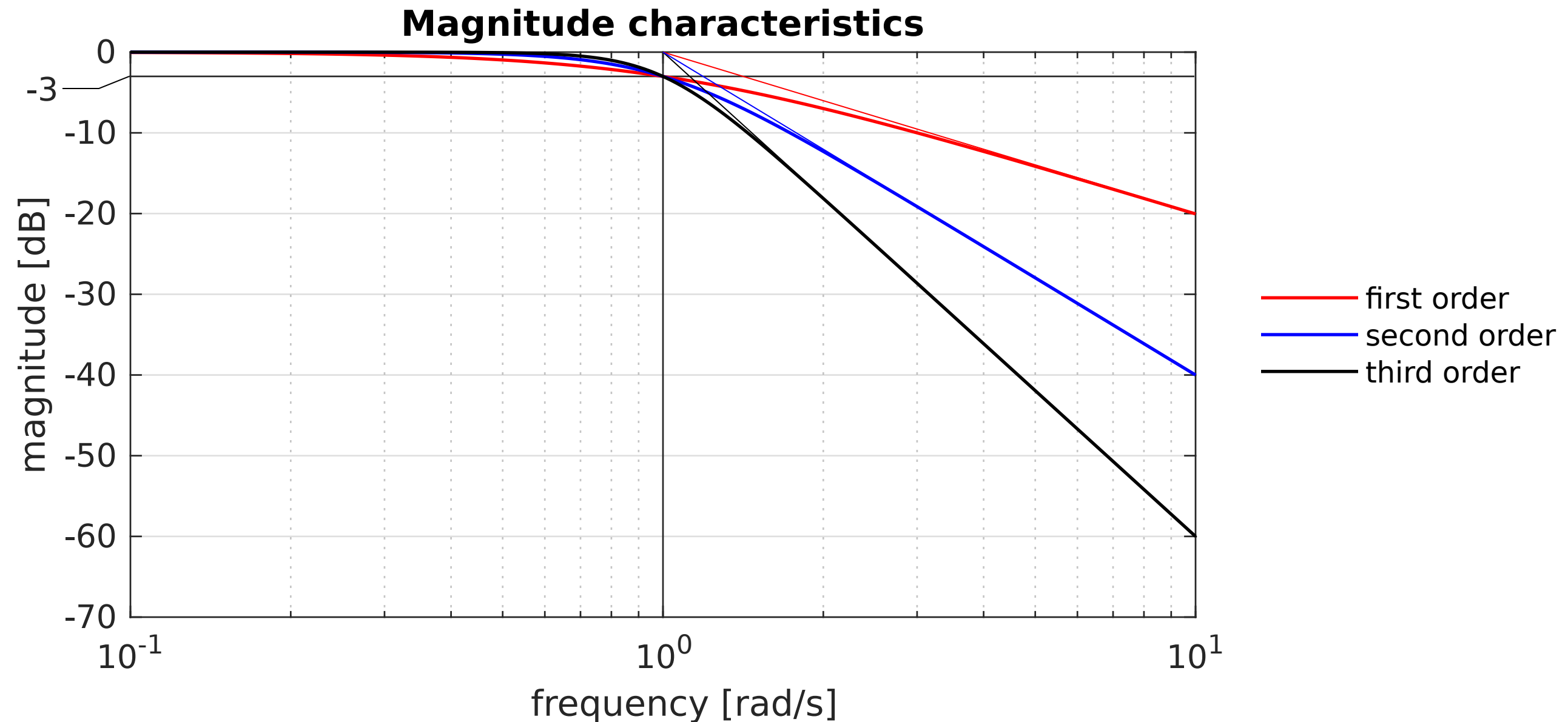
$$H_1(s) = \frac{1}{1 + s \frac{1}{\omega_n}}$$

$$H_2(s) = \frac{1}{1 + s \frac{\sqrt{2}}{\omega_n} + s^2 \frac{1}{\omega_n^2}}$$

$$H_3(s) = \frac{1}{1 + s \frac{2}{\omega_n} + s^2 \frac{2}{\omega_n^2} + s^3 \frac{1}{\omega_n^3}}$$

Butterworth or MFM: -3dB frequency at intersection of asymptotes: $\omega_{-3\text{dB}} = \omega_n$

All-pole Butterworth (MFM) responses



$$H_1(s) = \frac{1}{1 + s \frac{1}{\omega_n}}$$

$$H_2(s) = \frac{1}{1 + s \frac{\sqrt{2}}{\omega_n} + s^2 \frac{1}{\omega_n^2}}$$

$$H_3(s) = \frac{1}{1 + s \frac{2}{\omega_n} + s^2 \frac{2}{\omega_n^2} + s^3 \frac{1}{\omega_n^3}}$$

Butterworth or MFM: -3dB frequency at intersection of asymptotes: $\omega_{-3\text{dB}} = \omega_n$