EECS 16B
Designing Information Devices and Systems II

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Department of Electrical Engineering and Computer Science

Announcements:

- Midterm #1
  - Monday, February 26, 8-10pm
  - Scope is through material covered on today's lecture (end of circuits module)
- Systems and Controls starts next week (lots of linear algebra)

Today:

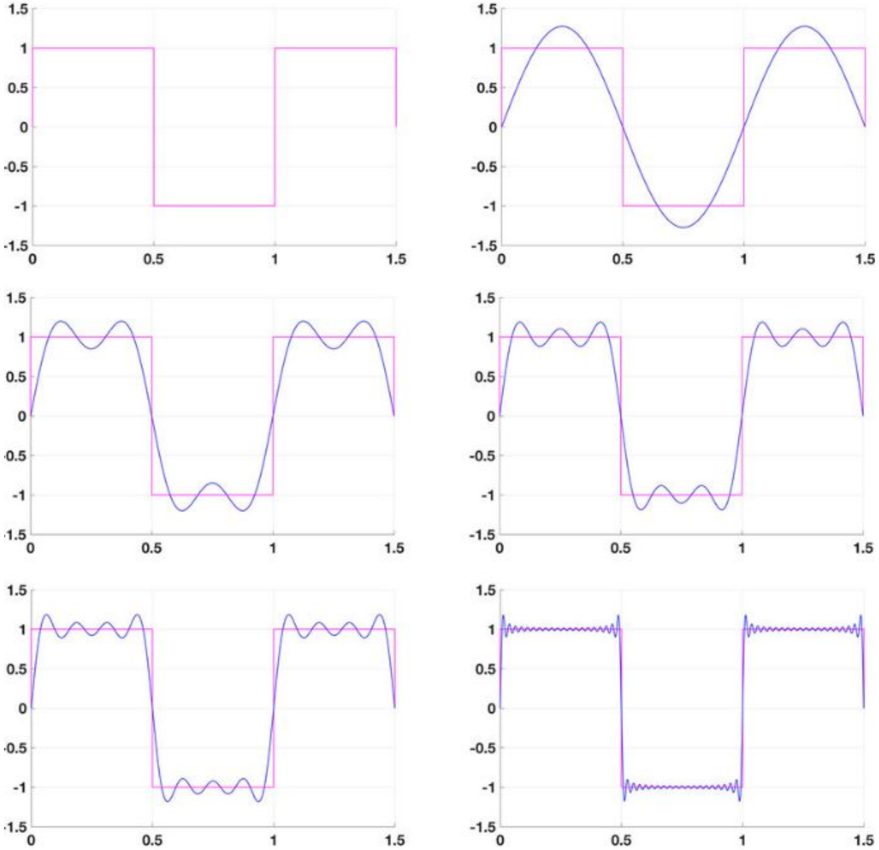
- Review/context
- Bode Plots
- Quality Factor (aka Q) for resonant circuits

Why sine waves?

Why sine waves?

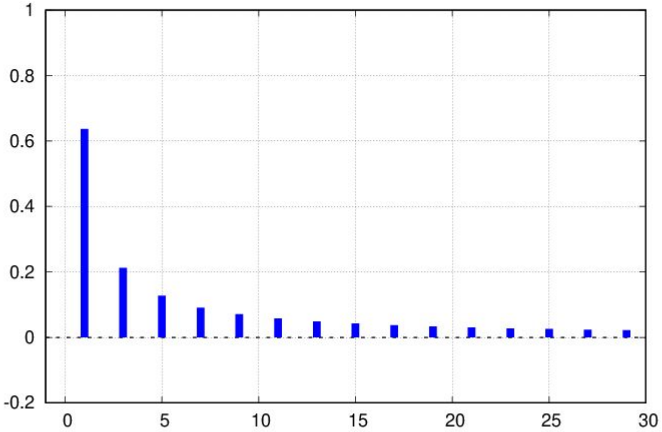
Joseph Fourier

Why sine waves?

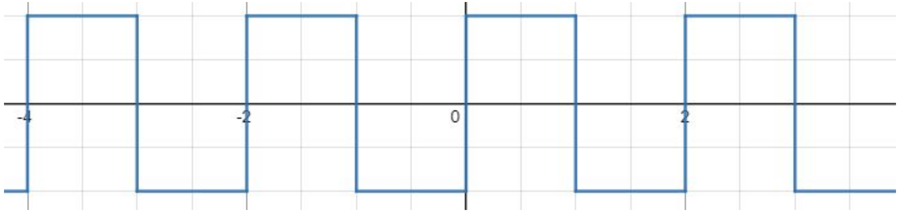


Joseph Fourier

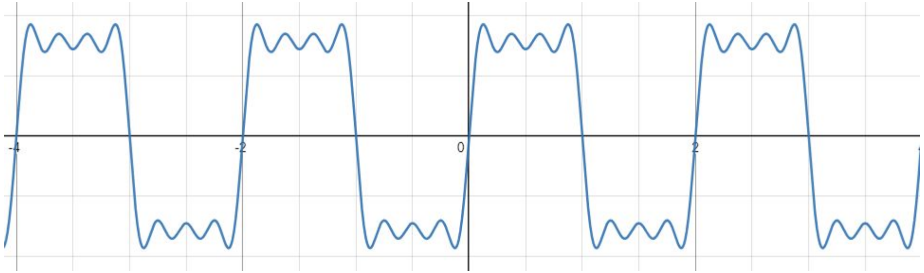
Fourier Series (periodic signals):



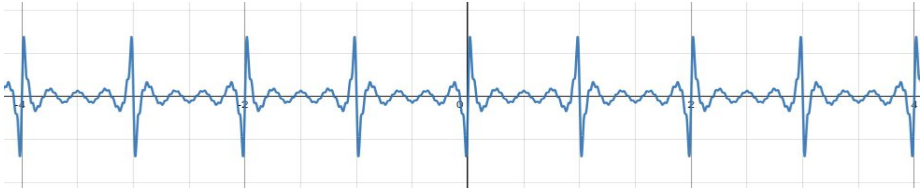
What do filters do?



LPF:

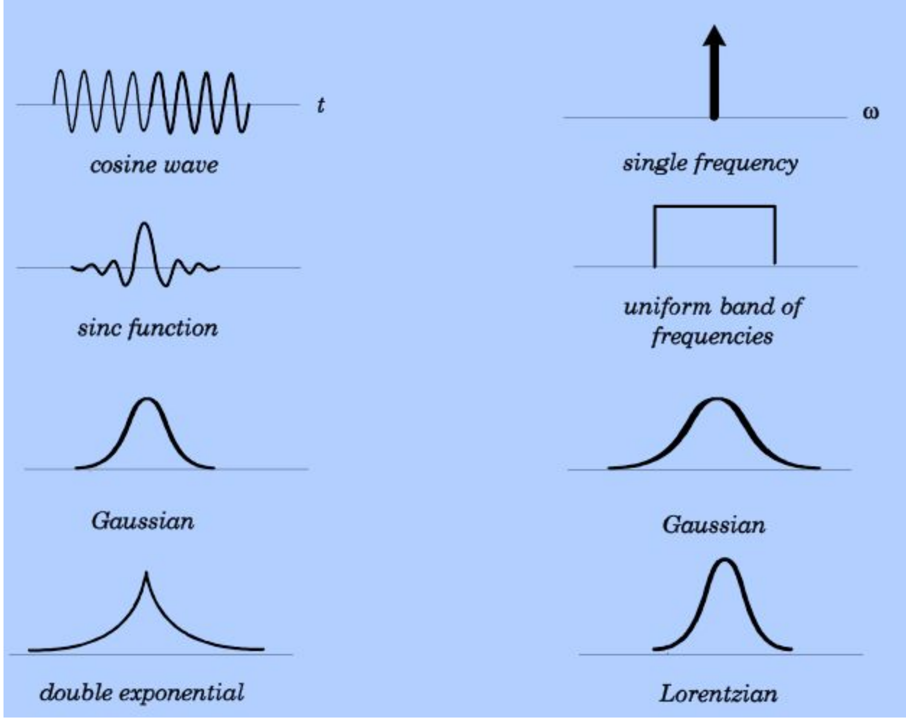


HPF:



Joseph Fourier

What about aperiodic signals?

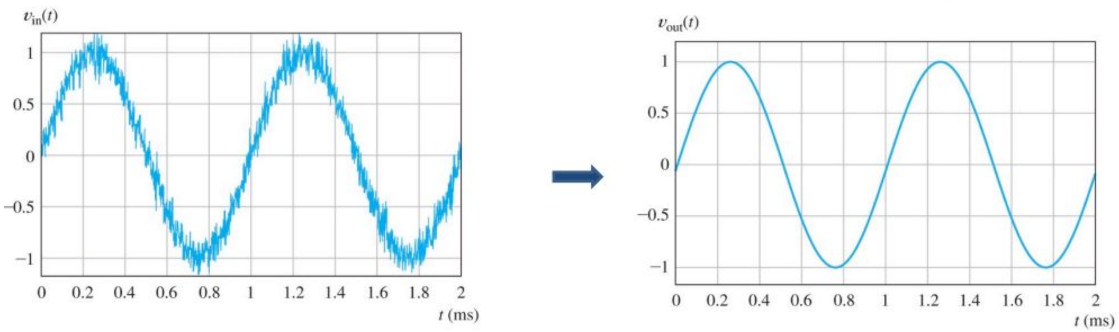


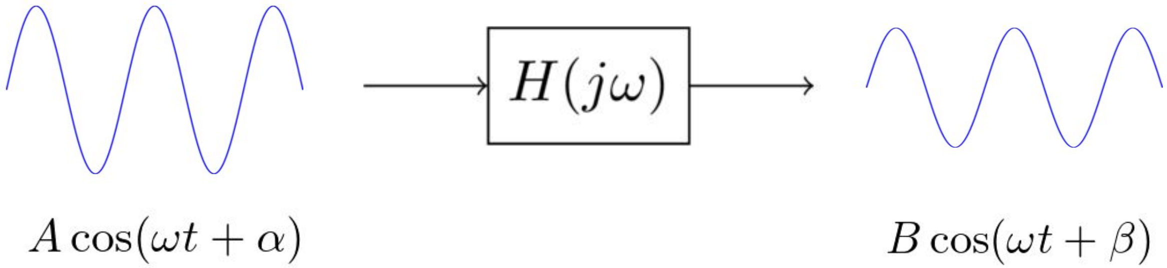
Joseph Fourier

Fourier Transform

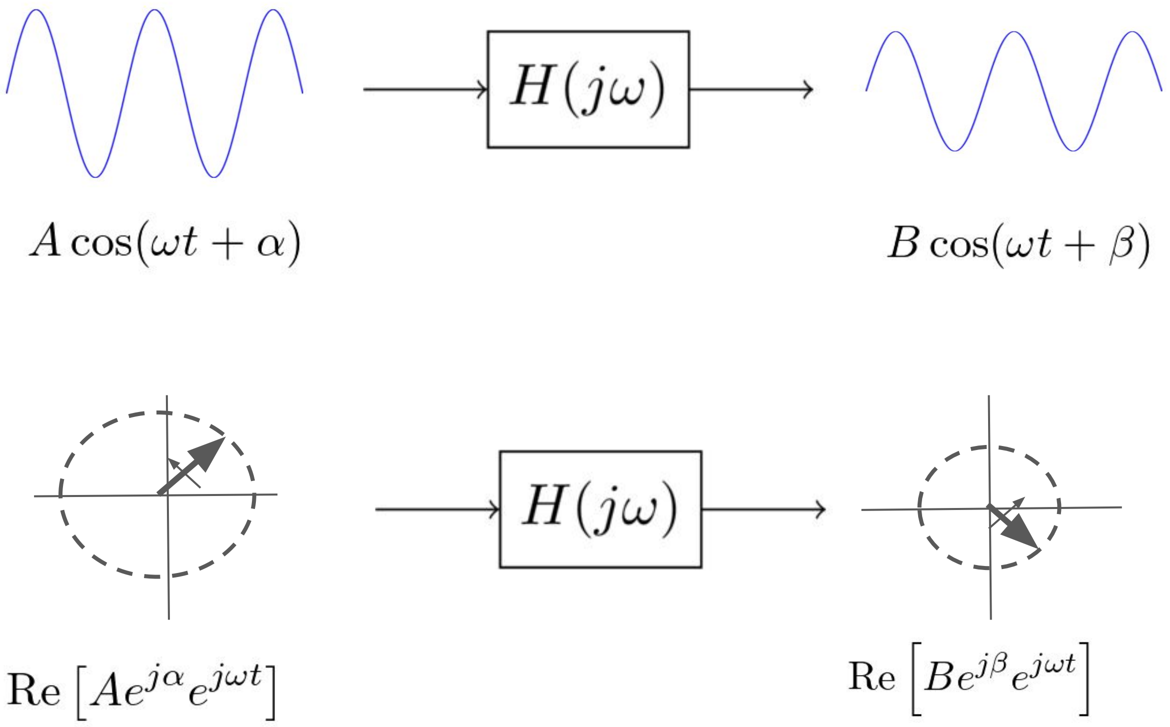
What type of filter was used to process the below signal?

1. Low Pass Filter
2. High Pass Filter
3. Band Pass Filter
4. Either 2 or 3
5. None of the above





$H(j\omega)$
$A\cos(\omega t + \alpha)$
$B\cos(\omega t + \beta)$


$H(j\omega)$
$A\cos(\omega t+\alpha)$
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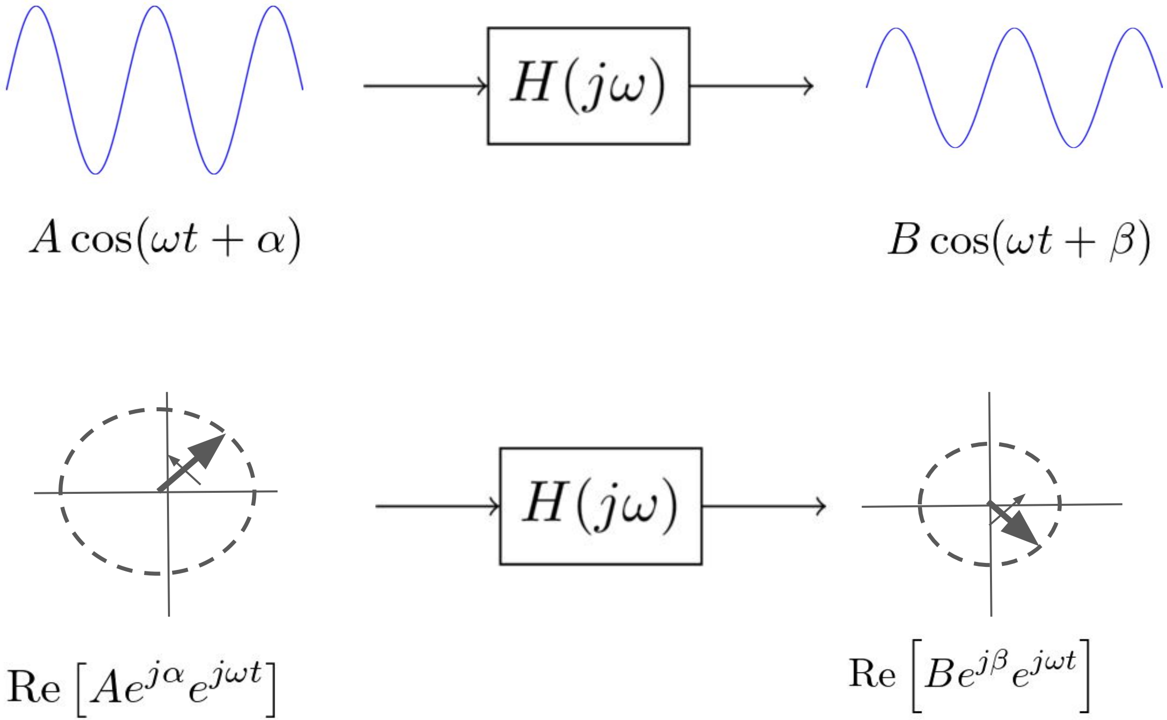
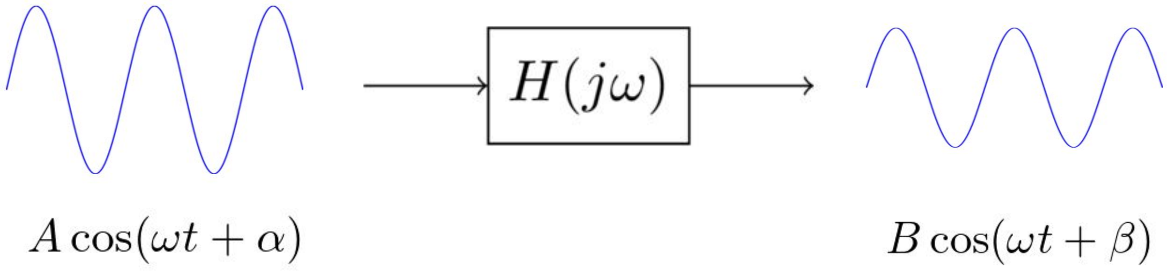
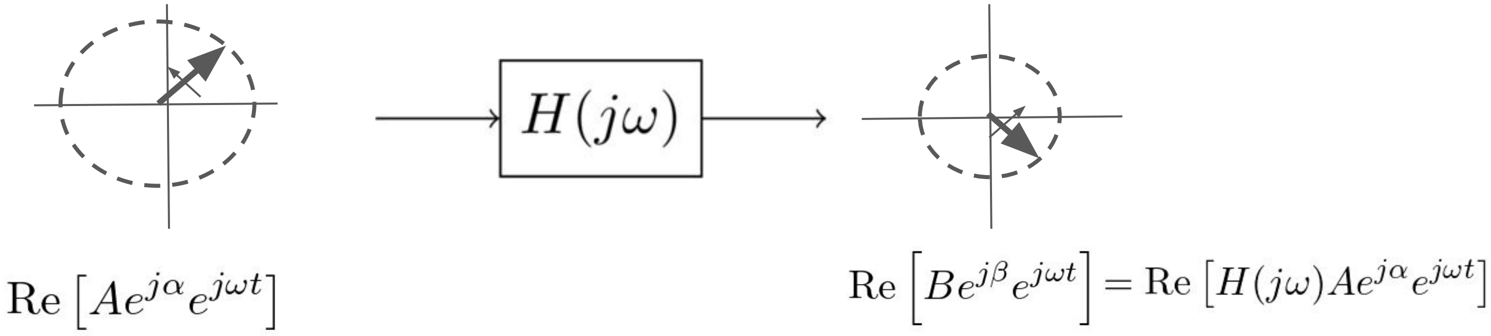
$H(j\omega)$
$\mathrm{Re}\left[Ae^{j\alpha}e^{j\omega t}\right]$
$\mathrm{Re}\left[Be^{j\beta}e^{j\omega t}\right]$



But… by definition, $Be^{j\beta} = H(j\omega)Ae^{j\alpha}$





But… by definition, $Be^{j\beta} = H(j\omega)Ae^{j\alpha}$

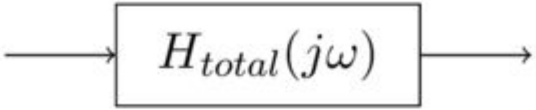
True or False: A phasor is a rotating vector on the complex plane.

1. True
2. False

Cascaded systems => transfer functions multiply

Cascaded systems => transfer functions multiply

This is equivalent to:



$$H_{total}(j\omega) = H_1(j\omega)H_2(j\omega)$$

Why $H(j\omega)$? Why not just $H(\omega)$?

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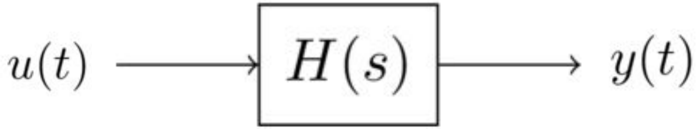
Pierre-Simon Laplace

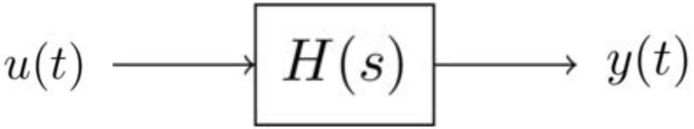
Why $H(j\omega)$? Why not just $H(\omega)$?



$$s = \sigma + j\omega$$

Pierre-Simon Laplace

Why $H(j\omega)$? Why not just $H(\omega)$?

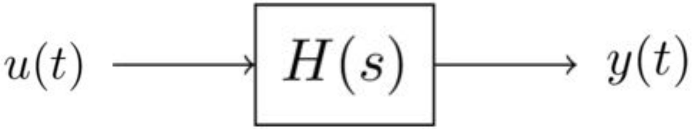


$$s = \sigma + j\omega$$

$$e^{st} = e^{(\sigma + j\omega)t} = e^{\sigma t} e^{j\omega t}$$

Pierre-Simon Laplace

Why $H(j\omega)$? Why not just $H(\omega)$?



Pierre-Simon Laplace

$$s = \sigma + j\omega$$

$$e^{st} = e^{(\sigma + j\omega)t} = e^{\sigma t} e^{j\omega t}$$

$$H(s) = \frac{N(s)}{D(s)}$$

Zeros are values of s such that $N(s) = 0$

Poles are values of s such that $D(s) = 0$

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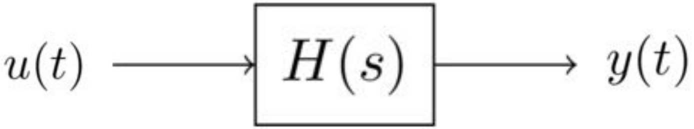

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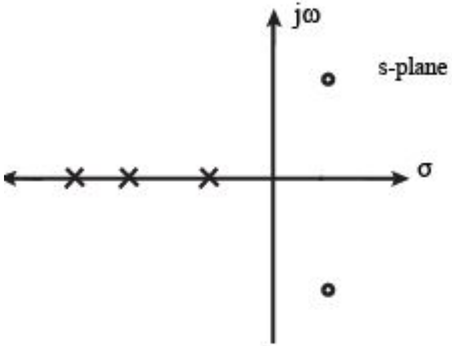

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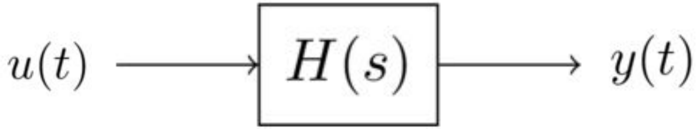

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Zeros are values of s such that $N(s) = 0$

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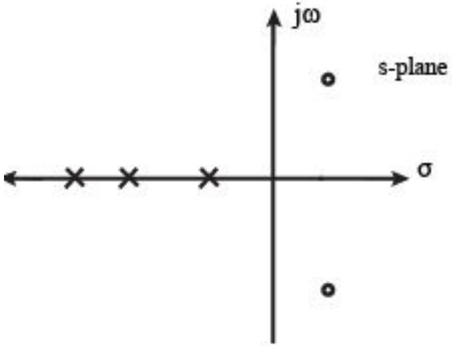
$H(\cdot)$ is the **transfer function.**

$H(j\omega)$ is the **frequency response.**



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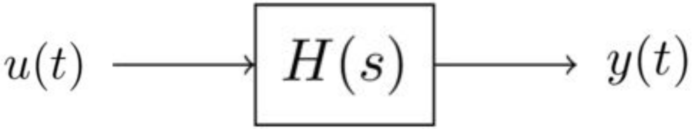

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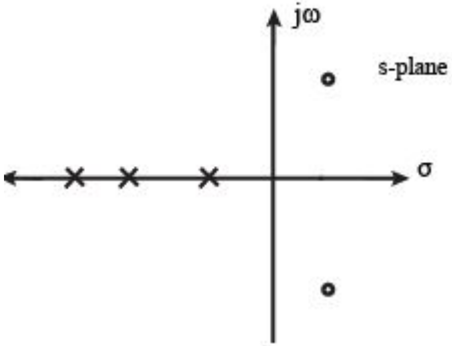
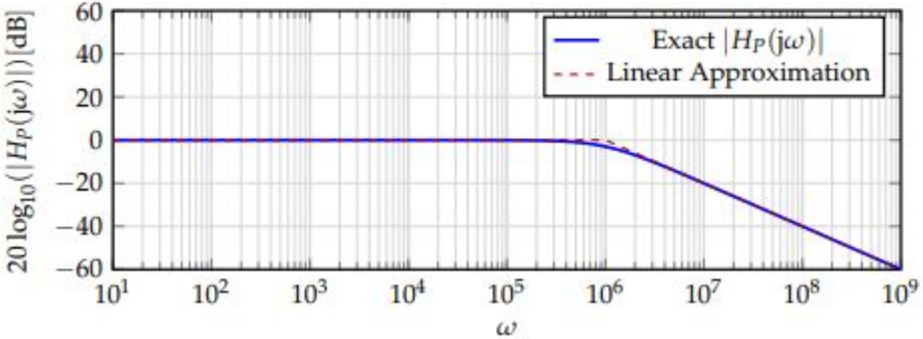


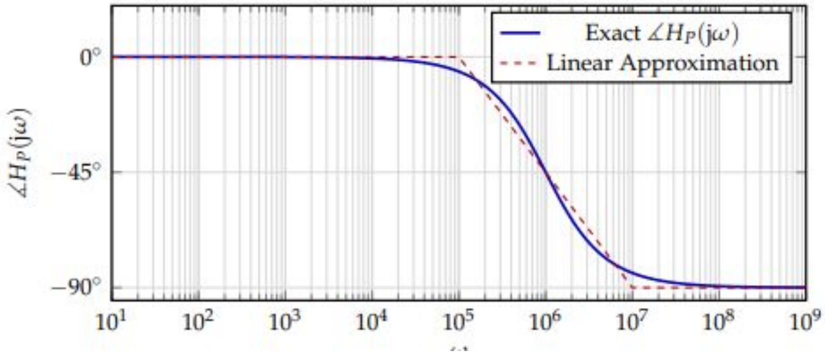
$H(\cdot)$ is the **transfer function.**

$H(j\omega)$ is the **frequency response.**

Laplace and s-domain will not be covered on the exam.

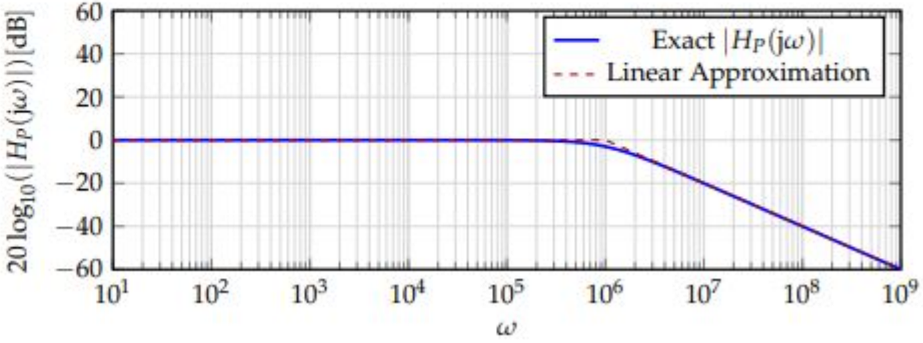
Bode Plots - Key Points

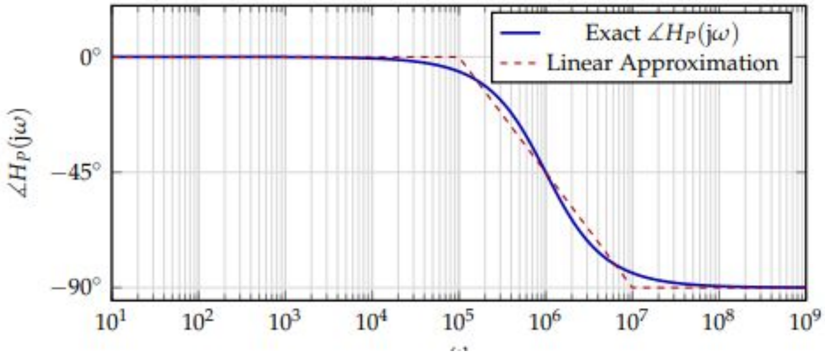




Bode Plots - Key Points

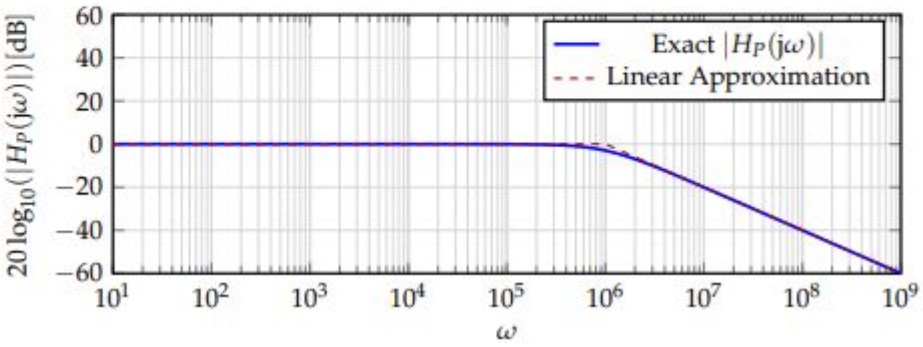
- Piecewise linear approximations of frequency response

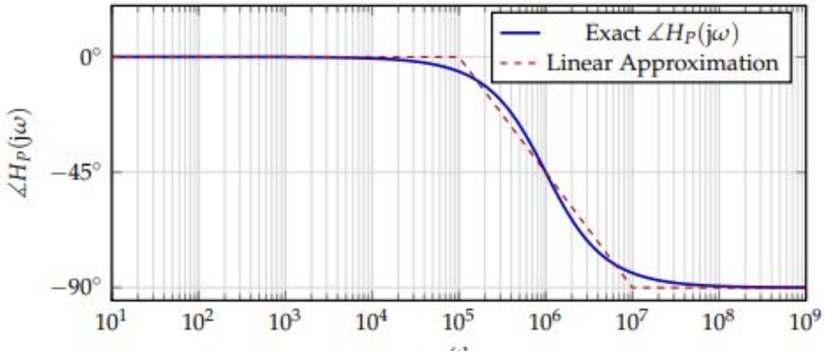




Bode Plots - Key Points

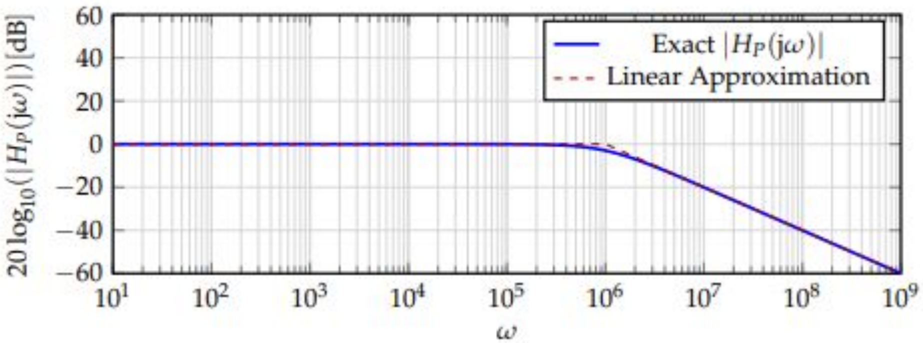
- Piecewise linear approximations of frequency response
- Two graphs (magnitude and phase)

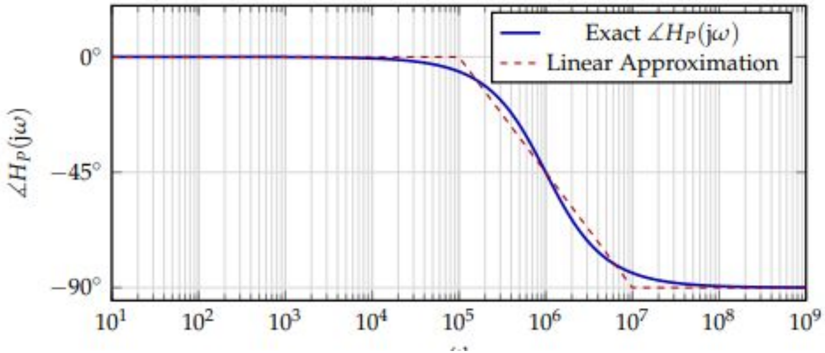




Bode Plots - Key Points

- Piecewise linear approximations of frequency response
- Two graphs (magnitude and phase)
- Horizontal axis (ω) is always logarithmic





Bode Plots - Key Points

- Piecewise linear approximations of frequency response
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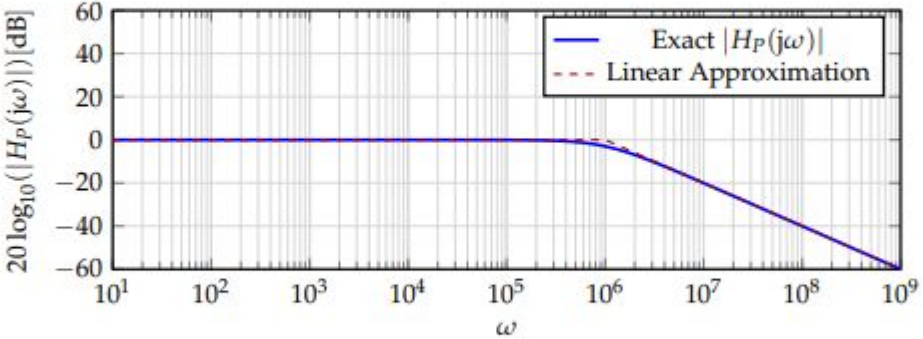
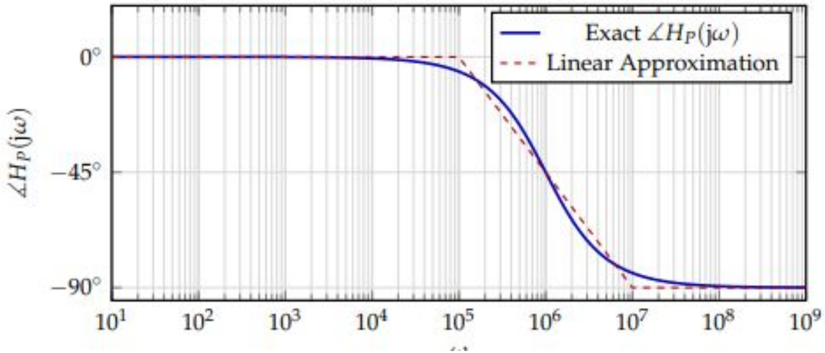
- Magnitude is in dB = 20 log (|H|)





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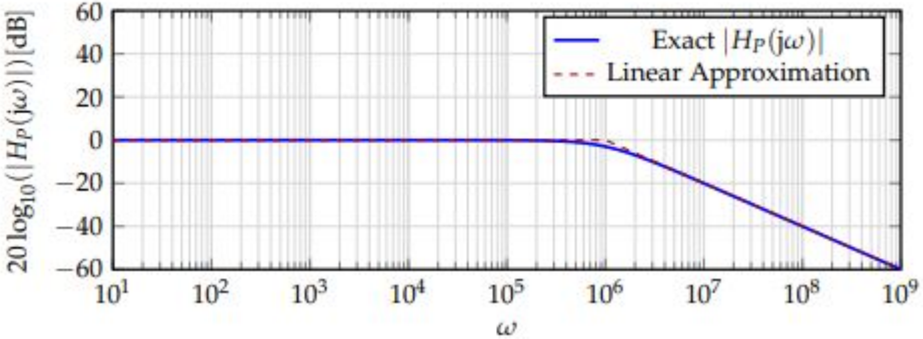

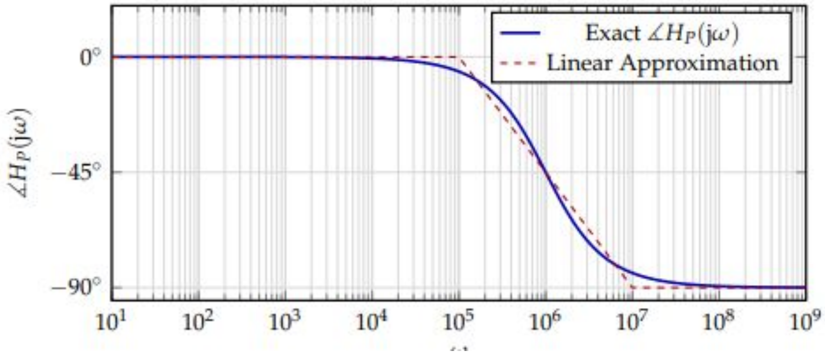

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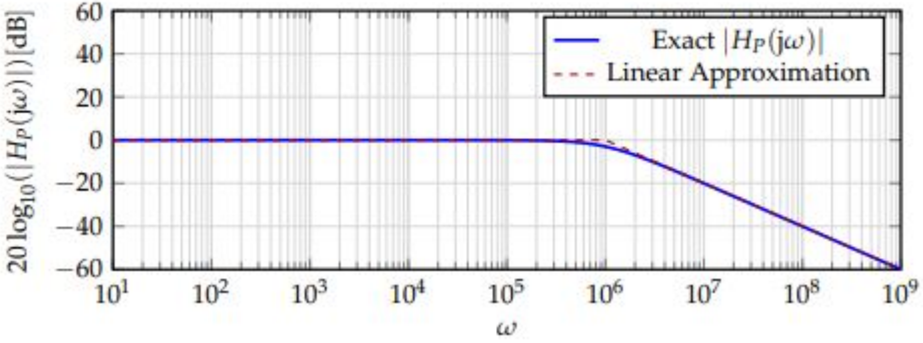
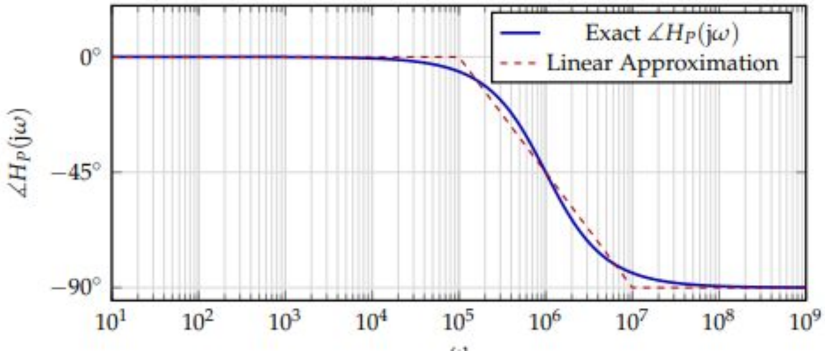
- Slope is +/- 20 db/decade per pole or zero, corner at ω_c (magnitude)





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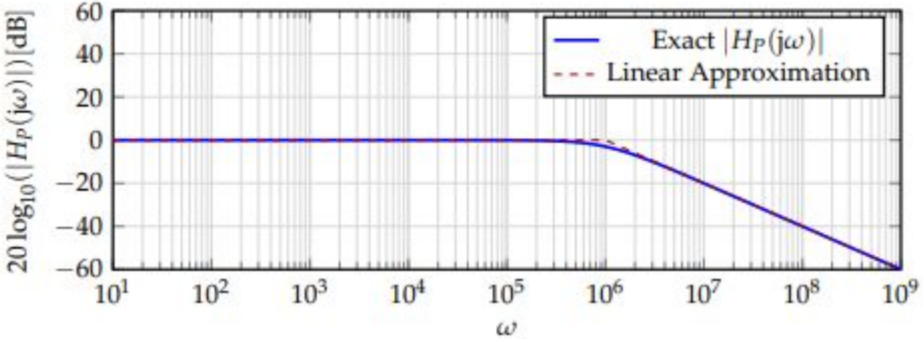
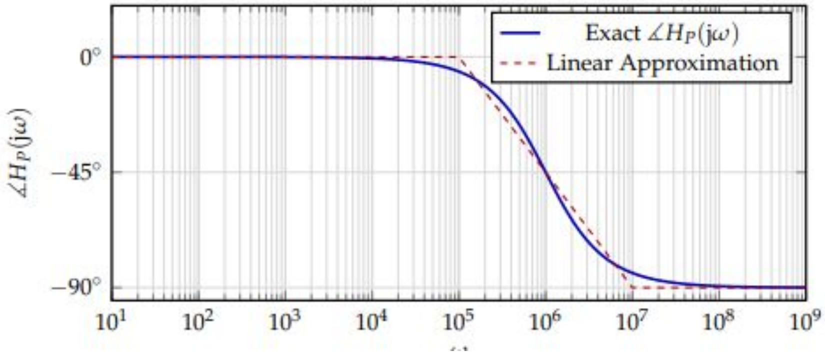
- Slope is +/- 45°/decade per pole or zero, corners at $\omega_c/10$, $10\omega_c$ (phase)





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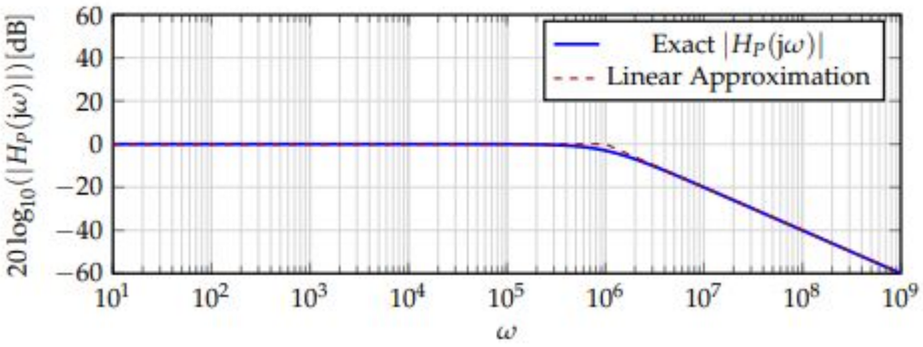
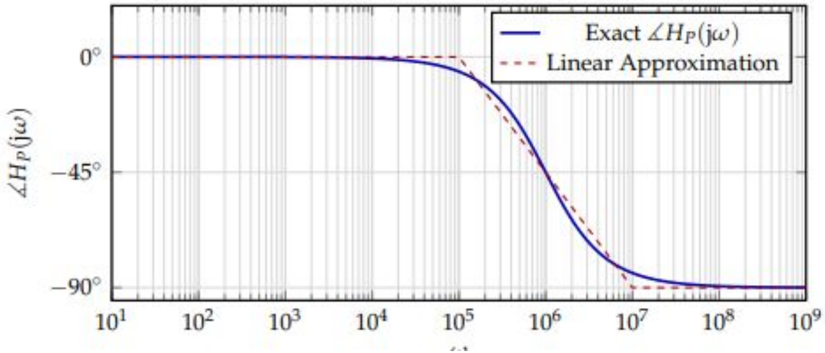
- Slope is +/- 45°/decade per pole or zero, corners at $\omega_c/10$, $10\omega_c$ (phase)
- Cascaded system => components add rather than multiply





Generic Form for Frequency Response

$$H(j\omega) = K \cdot \frac{N(j\omega)}{D(j\omega)} = K \frac{(j\omega)^{N_{z0}}\left(1 \pm j\frac{\omega}{\omega_{z1}}\right)\left(1 \pm j\frac{\omega}{\omega_{z2}}\right)\cdots\left(1 \pm j\frac{\omega}{\omega_{zn}}\right)}{(j\omega)^{N_{p0}}\left(1 \pm j\frac{\omega}{\omega_{p1}}\right)\left(1 \pm j\frac{\omega}{\omega_{p2}}\right)\cdots\left(1 \pm j\frac{\omega}{\omega_{pm}}\right)}$$

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What happens when ω is small?

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What happens when ω is small?
What happens when ω is large?

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What happens when ω is small?
What happens when ω is large?
Can zeros and poles at the origin coexist?

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What happens when ω is small?
What happens when ω is large?
Can zeros and poles at the origin coexist?
Why are there no cutoff frequencies for the zeros/poles at the origin?

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What happens when ω is small?
What happens when ω is large?
Can zeros and poles at the origin coexist?
Why are there no cutoff frequencies for the zeros/poles at the origin?
What happens when K is negative?

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What happens when ω is small?
What happens when ω is large?
Can zeros and poles at the origin coexist?
Why are there no cutoff frequencies for the zeros/poles at the origin?
What happens when K is negative?
What if I am interested in finding H(s)? (Just replace jw with s.)