

# FREQUENCY RESPONSES OF SOME TYPICAL SYSTEMS

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## INTRODUCTION

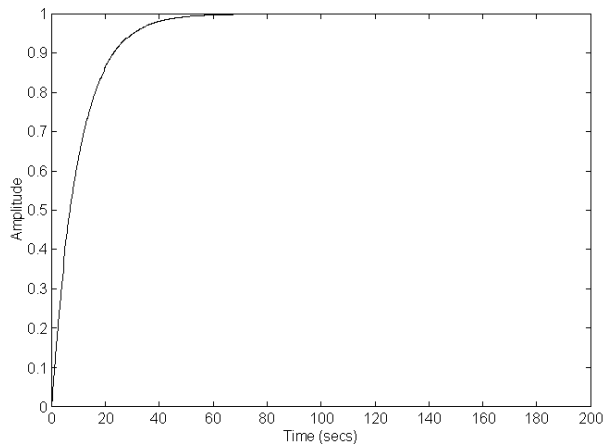
The next few pages of notes show the frequency responses of some common system components, drawn as Bode diagrams and Nyquist plots. Where appropriate, the corresponding time responses are also included to provide a reference to more familiar time domain characteristics.

You should note and compare the various features of the frequency response plots. The ability to recognise these features is very important and will help enormously with preliminary interpretations of frequency responses.

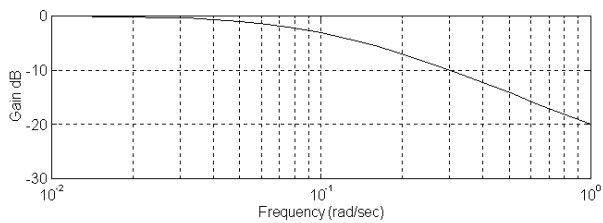
After studying these plots, you should be able to recognise the types of systems that give rise to a particular frequency response.



**Case A: Frequency response of a 1<sup>st</sup>-order lag with unit gain**



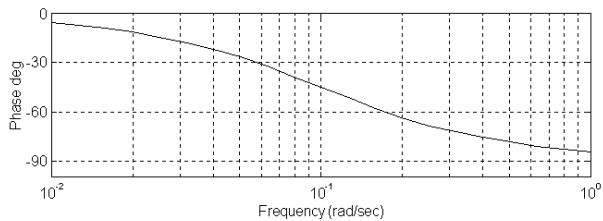
Step response of  $\frac{1}{1+10s}$



Bode plot of  $\frac{1}{1+10j\omega}$

Note:

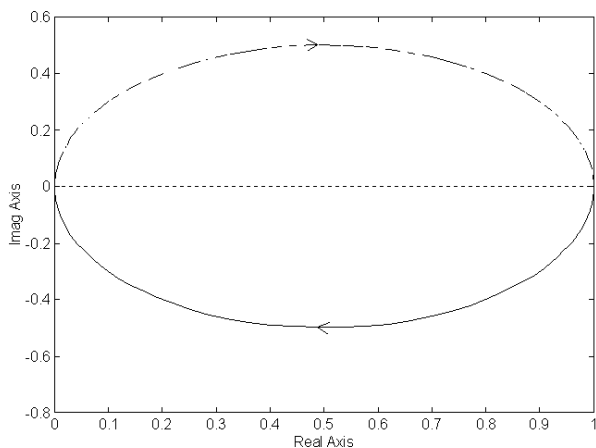
- maximum AR (dB);
- maximum and minimum phase shift
- the characteristics at 0.1 rad/sec



Nyquist/Polar plot of  $\frac{1}{1+10j\omega}$

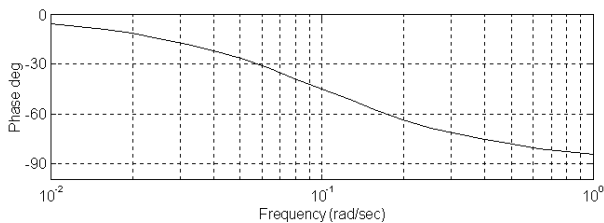
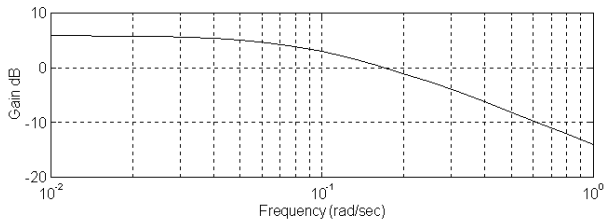
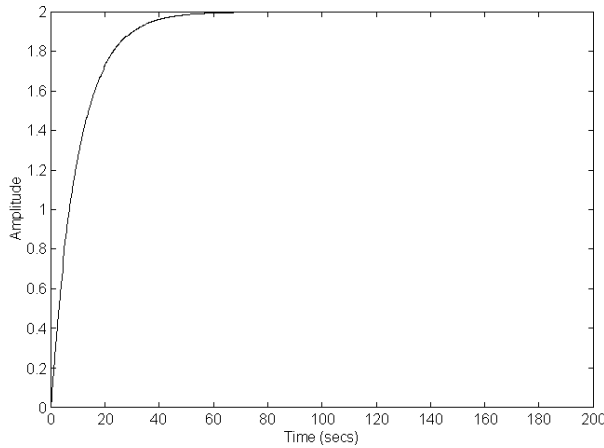
Note:

- shape of plot
- start and end points of plot



**Case B: Frequency response of a 1<sup>st</sup>-order lag with a gain of 2**

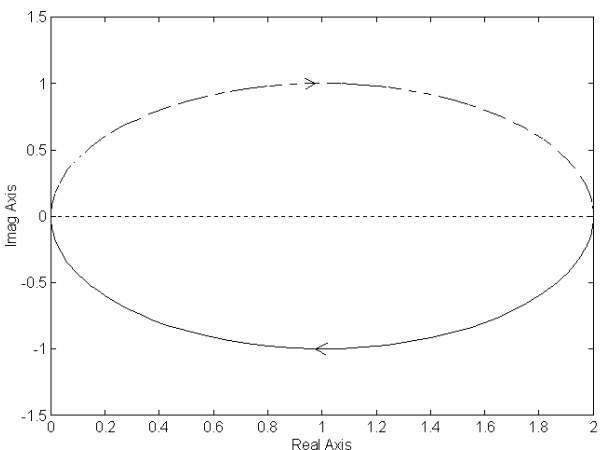
Step response of  $\frac{2}{1+10s}$



Bode plot of  $\frac{2}{1+10j\omega}$

Note and compare with Case A:

- maximum AR (dB);
- maximum and minimum phase shift
- the characteristics at 0.1 rad/sec



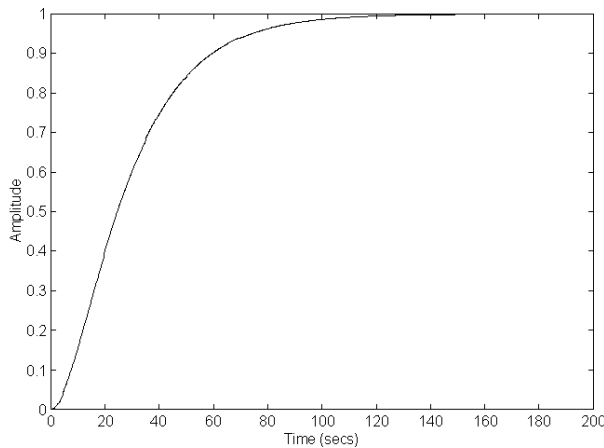
Nyquist/Polar plot of  $\frac{2}{1+10j\omega}$

Note and compare with Case A:

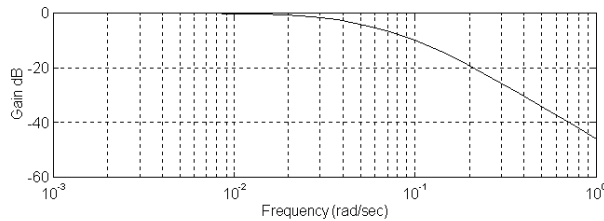
- shape of plot
- start and end points of plot



**Case C: Frequency response of a 2<sup>nd</sup>-order lag with unit gain**



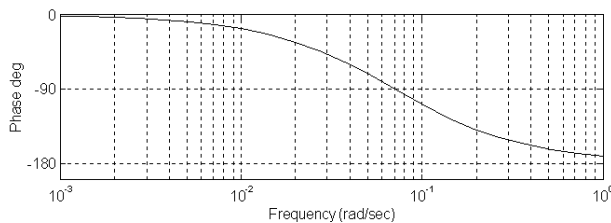
Step response of  $\frac{1}{(1+10s)(1+20s)}$



Bode plot of  $\frac{1}{(1+10j\omega)(1+20j\omega)}$

Note and compare with Case A:

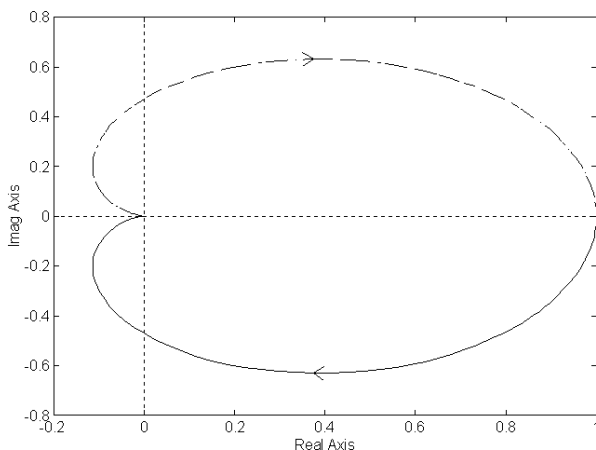
- maximum AR (dB);
- maximum and minimum phase shift
- point of inflection of phase plot



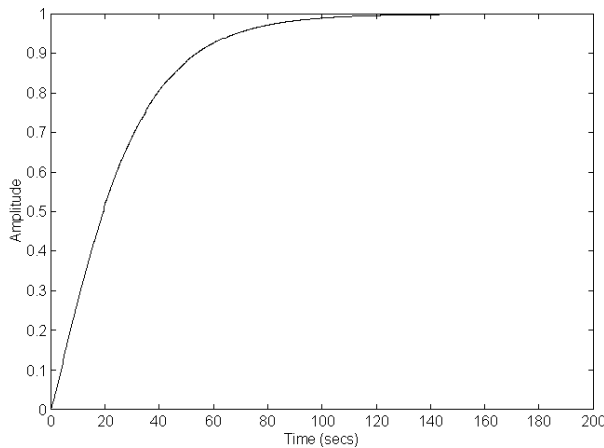
Nyquist/Polar plot of  $\frac{1}{(1+10j\omega)(1+20j\omega)}$

Note and compare with Case A:

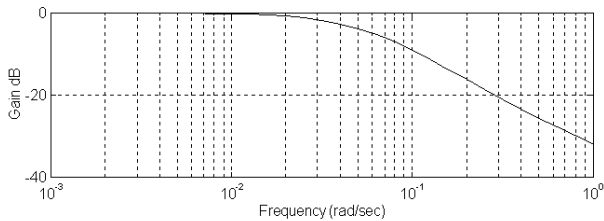
- shape of plot
- start and end points of plot



**Case D: Frequency response of a 2<sup>nd</sup>-order lag with a 1<sup>st</sup>-order lead term**



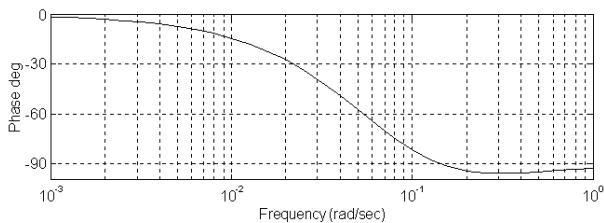
Step response of  $\frac{1 + 5s}{(1 + 10s)(1 + 20s)}$



Bode plot of  $\frac{1 + 5j\omega}{(1 + 10j\omega)(1 + 20j\omega)}$

Note and compare with Case C:

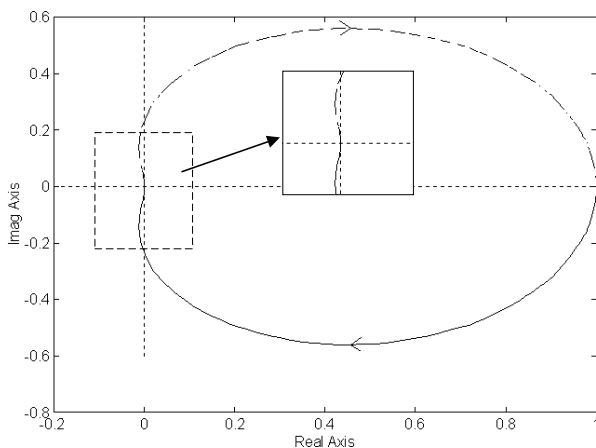
- the maximum amplitude ratio
- the minimum and maximum phase shift



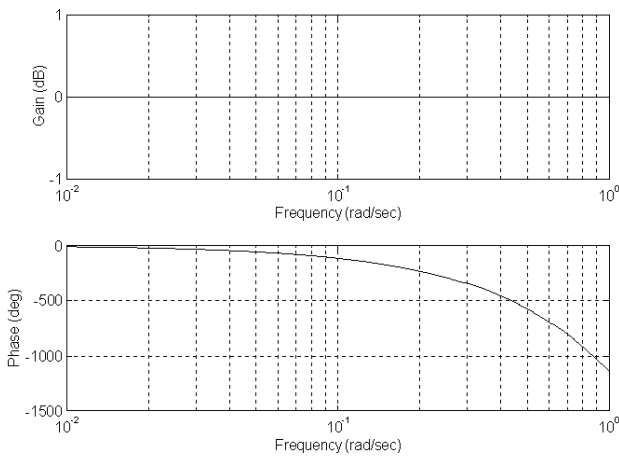
Nyquist/Polar plot of  $\frac{1 + 5j\omega}{(1 + 10j\omega)(1 + 20j\omega)}$

Note and compare with Case C:

- shape of plot
- start and end points of plot
- the manner in which the plot moves towards the origin



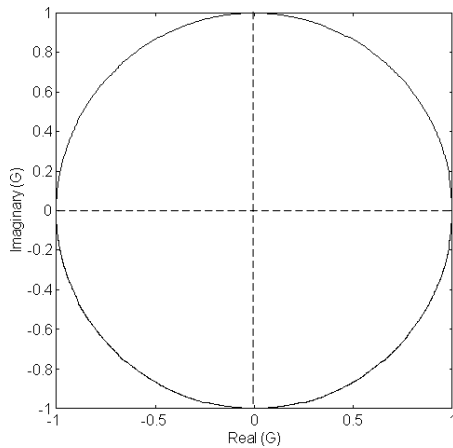
**Case E: Pure time delay process**



This is a Bode plot of a pure time delay of magnitude 20 seconds.

Note:

- the AR plot
- the minimum and maximum phase shift
- shape of phase plot compared to previous cases



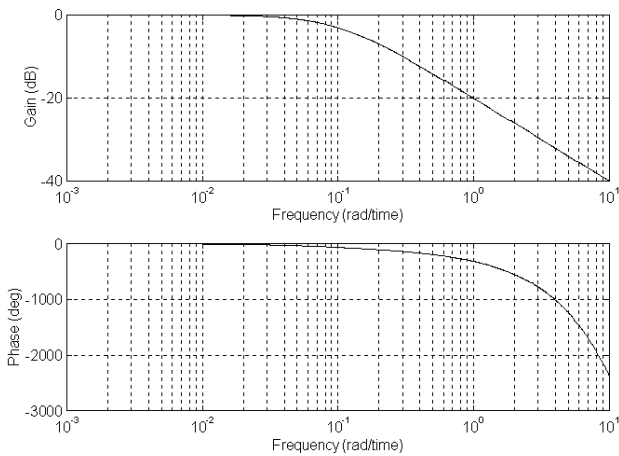
Nyquist/Polar plot of a pure time delay of magnitude 20s

Note and compare with other cases:

- shape of plot
- start and end points of plot



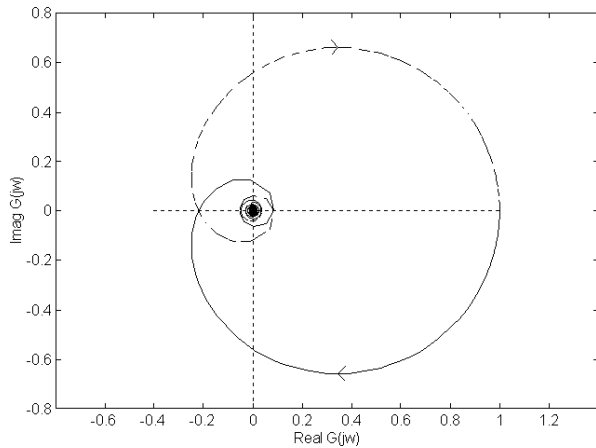
**Case F: 1<sup>st</sup>-order plus time delay process**



Bode plot of  $\frac{\exp(-4j\omega)}{1+10j\omega}$

Note and compare with Case A:

- details of AR plot
- minimum and maximum phase shift



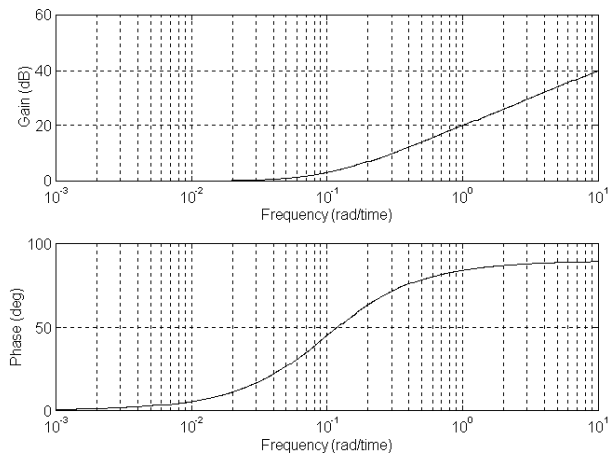
Nyquist/Polar plot of  $\frac{\exp(-4j\omega)}{1+10j\omega}$

Note and compare with Case A:

- shape of plot
- start and end points of plot



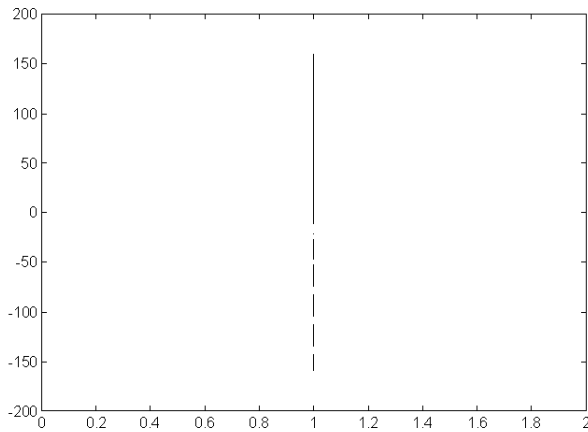
**Case G: 1<sup>st</sup>-order lead**



Bode plot of  $(1 + 10j\omega)$

Note and compare with Case A:

- shape of AR plot
- minimum and maximum phase shifts



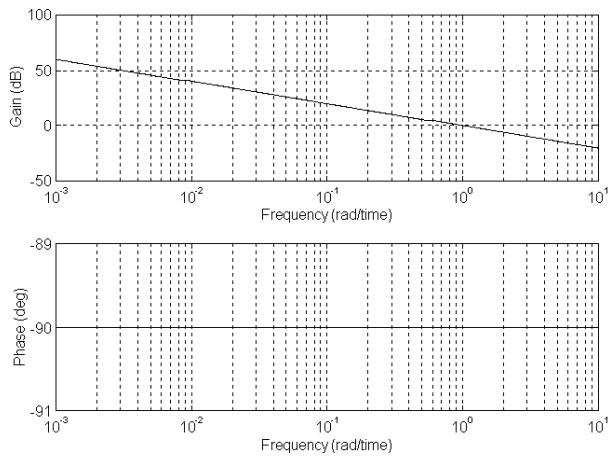
Nyquist/Polar plot of  $(1 + 10j\omega)$

Note and compare with Case A:

- shape of plot
- start and end points of plot



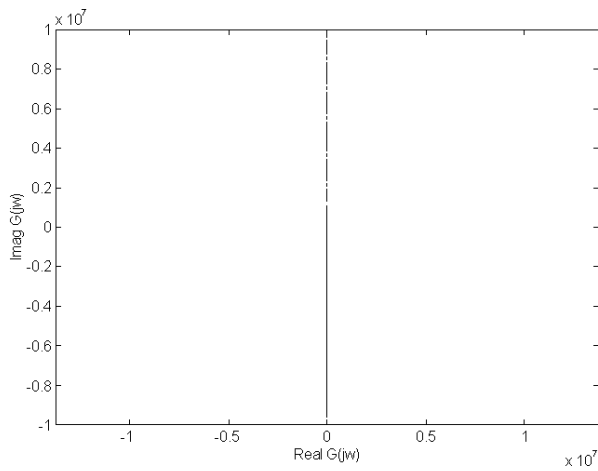
**Case H: Integrators**



Bode plot of  $\frac{1}{j\omega}$

Note:

- slope of AR plot
- minimum and maximum phase shift



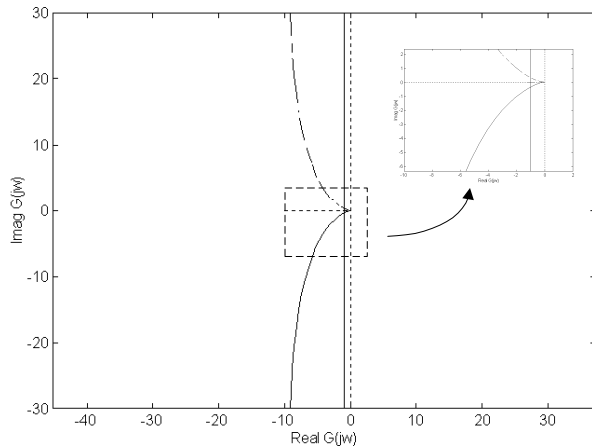
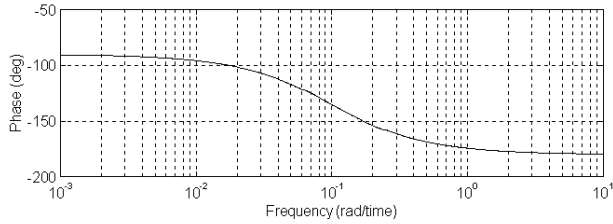
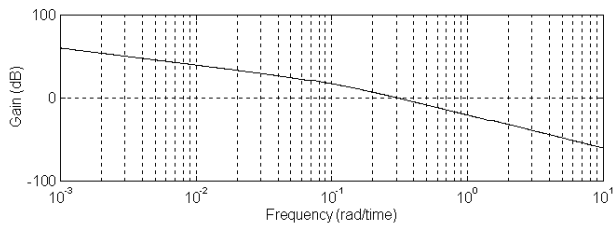
Nyquist/polar plot of  $\frac{1}{j\omega}$

Note:

- shape of plot



**Case I: 1<sup>st</sup>-order in series with an integrator**



Bode plot of  $\frac{1}{j\omega(1+10j\omega)}$

Note and compare with Case A:

- shape of AR plot
- minimum and maximum phase shifts

Nyquist/polar plot of  $\frac{1}{j\omega(1+10j\omega)}$

Note:

- starting and end points
- shape of plot

