freq.bodesimp Bode plots for simple transfer functions

1 Although we have defined Bode plots in terms of the frequency response function $H(j\omega)$, it turns out that, due to its similarity, we can just as easily talk about the Bode plot of a transfer function. Since this is common convention, we proceed in kind.

2 It turns out that bode plots, both magnitude and phase, given their logarithmic scale (recall that the ω-axes are also plotted logarithmically), are quite asymptotic to straight-lines for first- and second-order systems. Furthermore, higher-order system transfer functions can be re-written as the product of those of first-and second-order. For instance,

$$H(s) = \frac{\_\_s + \_\_}{s^3 + \_\_s^2 + \_\_s + \_\_} \tag{1a}$$

$$= \_\_ \cdot (\_\_s + 1) \cdot \frac{1}{\_\_s + 1} \cdot \frac{1}{s^2 + \_\_s + \_\_} \tag{1b}$$

3 Recall (from, for instance, phasor representation) that for products of complex numbers, phases ϕ_i add and magnitudes M_i multiply. For instance,

$$M_1\angle\phi_1 \cdot \frac{1}{M_2\angle\phi_2} \cdot \frac{1}{M_3\angle\phi_3} = \frac{M_1}{M_2M_3}\angle(\phi_1 - \phi_2 - \phi_3). \tag{2}$$

And if one takes the logarithm of the magnitudes, they add; for instance,

$$\log \frac{M_1}{M_2M_3} = \log M_1 - \log M_2 - \log M_3. \tag{3}$$

There is only one more link in the chain: first- and second-order Bode plots depend on a handful of parameters that can be found directly from transfer functions. There is no need to compute $|H(j\omega_0)|$ and $\angle H(j\omega_0)$!

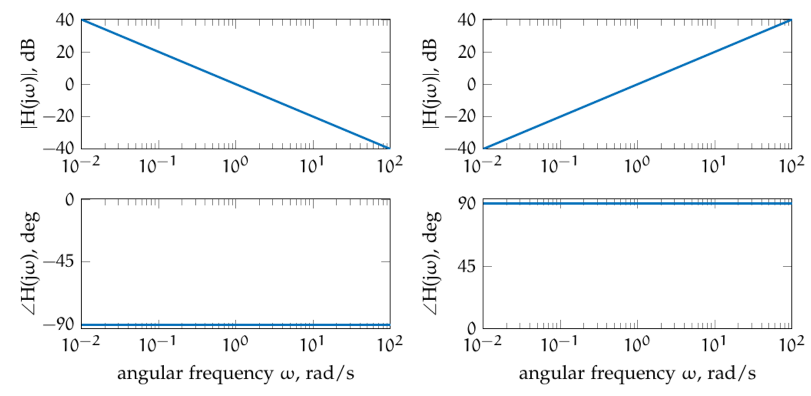
4 In a manner similar to Example freq.bode-1, we construct Bode plots for several simple transfer functions in this lecture. Once we have these simple "building blocks," we will be able to construct sketches of higher-order systems by graphical addition because logarithmic magnitudes and phases combine by summation, as shown in Lec. freq.bodesketch.

Constant gain

5 For a transfer function that is simply a constant real gain $H(s) = K$, the frequency response function is trivially $H(j\omega) = K$. Its magnitude $|H(j\omega)| = |K|$. For positive gain K, the phase is $\angle H(j\omega) = 0$, and for negative K, the phase is $\angle H(j\omega) = 180$ deg.

Pole and zero at the origin

6 In Example freq.bode-1, we have already demonstrated how to derive from the transfer function $H(s) = s$, a zero at the origin, the frequency response function plotted in Fig. bodesimp.1. Similarly, for $H(s) = 1/s$, a pole at the origin, the frequency response function plotted in Fig. bodesimp.1.

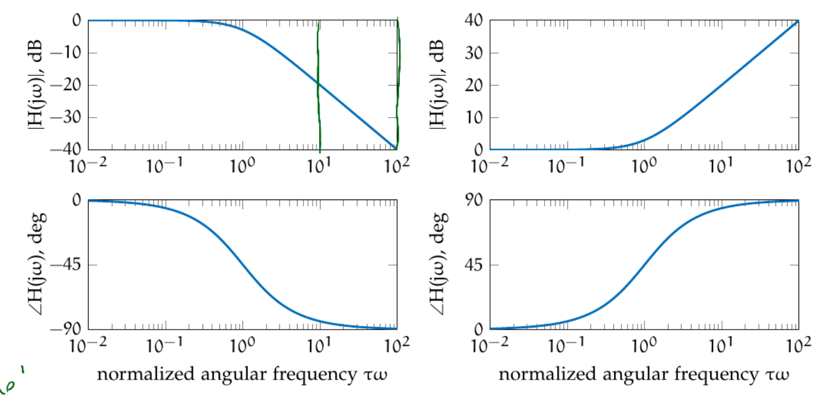


(a) $H(s) = 1/s$. (b) $H(s) = s$.

Figure bodesimp.1: Bode plots for (a) a pole at the origin and (b) a zero at the origin.

Real pole and real zero

7 The derivations for real poles and zeros are not included, but the resulting Bode plots are shown in Fig. bodesimp.2.

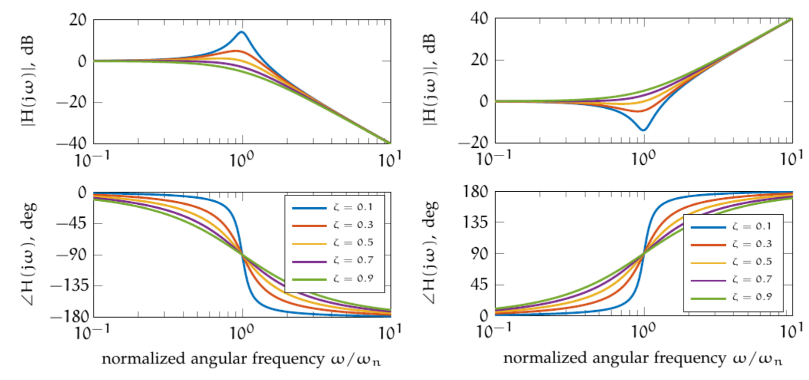


(a) $H(s) = 1/(\tau s + 1)$. (b) $H(s) = \tau s + 1$.

Figure bodesimp.2: Bode plots for (a) a single real pole and (b) a single real zero.

Complex conjugate pole pairs and zero pairs

8 The derivations for complex conjugate pole pairs and zero pairs are not included, but the resulting Bode plots are shown in Fig. bodesimp.3.



(a) $H(s) = \omega_n^2/(s^2 + 2\zeta\omega_n s + \omega_n^2)$. (b) $H(s) = (s^2 + 2\zeta\omega_n s + \omega_n^2)/\omega_n^2$.

Figure bodesimp.3: Bode plots for (a) a complex conjugate pole pair and (b) a complex conjugate zero pair.