

Tutorial on Using Excel Spreadsheet to Obtain Bode Plots and Nyquist Plots

(by Tom Co, tbco@mtu.edu , last revision 1/11/2010)

I. Preliminaries:

Given: $G(s)$, a transfer function in Laplace domain

Required: Frequency response plots corresponding to $G(s)$

A. Bode Plots.

- These consist of two plots. The first plot is a plot of log modulus (in decibels) versus frequency. The second plot is the phase shift (in degrees) versus frequency. Both plots usually have the frequency in logarithmic scale.
- Using the given transfer function $G(s)$,

$$\text{Log Modulus} = 20 \log \left(\left| G(i\omega) \right| \right)$$
$$\text{Phase Shift} = \phi = \arg \left(G(i\omega) \right) \frac{180^\circ}{\pi}$$

B. Nyquist Plots.

- The Nyquist plots is obtained by simply plotting
Imaginary $\left(G(i\omega) \right)$ vs. Real $\left(G(i\omega) \right)$

II. Spreadsheet Implementation:

For discussion purposes, consider a second order transfer function,

$$G(s) = \frac{K}{\tau_n s^2 + 2\zeta \tau_n s + 1}$$

1. Set up some cells for the various parameters in the transfer function.

| | B | C | D |
|---|---|----------|-----|
| 1 | | | |
| 2 | | τ_n | 1 |
| 3 | | ζ | 0.1 |
| 4 | | K | 1 |
| 5 | | | |

2. Next, determine the range of frequencies that are of interest. For example, let $10^{-1} < \omega < 10^1$. Since the frequency will be plotted in logarithmic scale, you can use a column to include numbers ranging linearly from -1 to 1 e.g. $-1, -0.99, \dots, 0.98, 0.99, 1$. Then use another column to evaluate the frequency, e.g. $\omega = 10^{-1}, 10^{-0.99}, \dots, 10^{0.98}, 10^{0.99}, 10^1$.

| | C | D |
|----|-------|----------|
| 5 | | |
| 6 | | |
| 7 | | ω |
| 8 | -1 | 0.1 |
| 9 | -0.99 | 0.102329 |
| 10 | -0.98 | 0.104713 |
| 11 | -0.97 | 0.107152 |
| 12 | -0.96 | 0.109648 |
| 13 | -0.95 | 0.112202 |
| 14 | -0.94 | 0.114815 |
| 15 | -0.93 | 0.11749 |
| 16 | -0.92 | 0.120226 |
| 17 | -0.91 | 0.123027 |
| 18 | -0.9 | 0.125893 |
| 19 | -0.89 | 0.128825 |

$=10^{\wedge} C12$

3. In the next column, build cells containing complex numbers, $s=i\omega$. This can be done by using the **COMPLEX(,)** function provided in Excel.

| | C | D | E |
|----|-------|----------|--------------------|
| 6 | | | |
| 7 | | ω | $s=i\omega$ |
| 8 | -1 | 0.1 | 0.1i |
| 9 | -0.99 | 0.102329 | 0.102329299228075i |
| 10 | -0.98 | 0.104713 | 0.10471285480509i |
| 11 | -0.97 | 0.107152 | 0.10715193823761i |
| 12 | -0.96 | 0.109591 | 0.109590823761i |
| 13 | -0.95 | 0.112030 | 0.11202970823761i |
| 14 | -0.94 | 0.114469 | 0.114468592761i |

(Note: you may need to change the width of the column in order to see the numbers)

4. Now evaluate the transfer function, $G(s)$, with $s = i\omega$, using the built-in functions, **IMDIV(a,b)**, **IMSUM(a,b)**, **IMPRODUCT(a,b)**, **IMPOWER(a,n)** to perform complex division, sum, product and power operations on complex numbers **a** and **b**, with **n** as integer.

| | C | D | E | F |
|----|----------|----------|--|----------------------------------|
| 1 | | | | |
| 2 | τ_n | 1 | =IMDIV(\$D\$4, IMSUM(IMSUM(IMSUM(1, IMPRODUCT(E9, 2*\$D\$2*\$D\$3)), IMPRODUCT(IMPOWER(E9,2), \$D\$2^2)))) | |
| 3 | ξ | 0.1 | | |
| 4 | K | 1 | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | ω | $s=i\omega$ | $G(i\omega)$ |
| 8 | -1 | 0.1 | 0.1i | 1.009688893421724-0.03977562468i |
| 9 | -0.99 | 0.102329 | 0.102329299228075i | 1.01014998884187-2.08923579390i |
| 10 | -0.98 | 0.104713 | 0.10471285480509i | 1.0106322037379-2.1200998203362i |
| 11 | -0.97 | 0.107152 | 0.10715193823761i | 1.01113966552599-2.19207978728i |

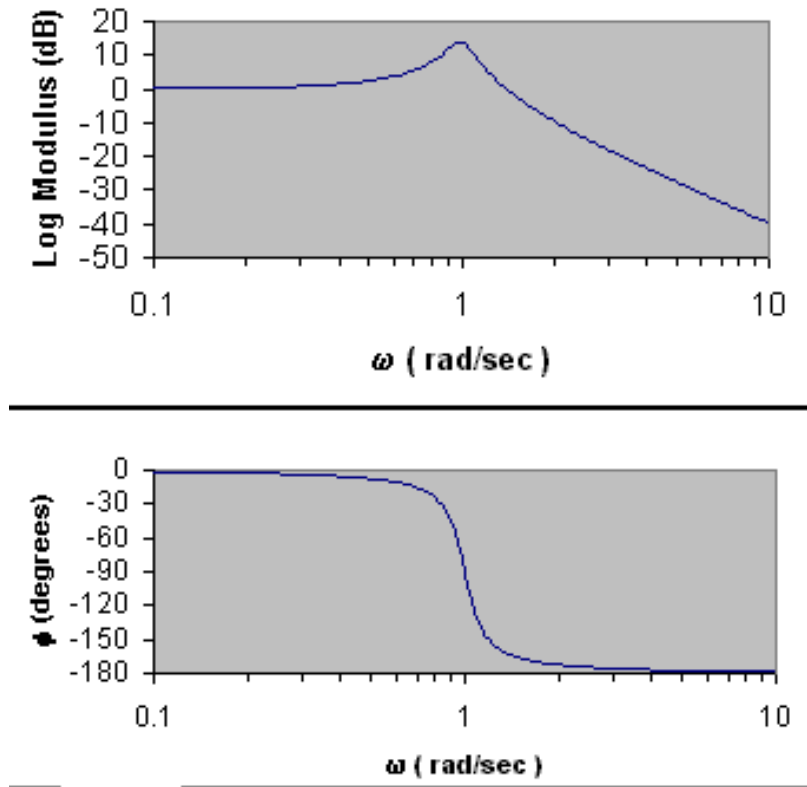
5. From the results in $G(i\omega)$, obtain the Log Modulus and Phase Shift columns:

| | F | G | H |
|----|---------------------------------|--------------------------------|----------------------------------|
| 4 | =20*LOG10(IMABS(F9)) | | |
| 5 | | | |
| 6 | | | |
| 7 | G(iω) | LM(ω) | $\phi(\omega)$ |
| 8 | 1.00968893421724-2.03977562468i | 0.085524 | -1.15733 |
| 9 | 1.01014998884187-2.08923579390i | 0.0895746 | -1.18485 |
| 10 | 1.0106332037379-2.139990285362i | 0.0938181 | -1.21304 |
| 11 | 1.01113966552599-2.19207978728i | 0.0982636 | -1.24194 |
| 12 | 1.01167051620514-2.24554673518i | 0.102821 | -1.27155 |
| 13 | 1.01222695617852-2.30043541557i | 0.10748005 | -1.30191 |
| 14 | 1.01281024746423-2.35679207740i | 0.1122427 | -1.33302 |
| 15 | 1.01342171710397-2.41466505151i | 0.1170269 | -1.36492 |

6. Also, from $G(i\omega)$, obtain columns that evaluate $Re[G]$ and $Im[G]$, respectively:

| | F | I | J |
|----|---------------------------------|----------------|----------------|
| 7 | G(iω) | Re[G] | Im[G] |
| 8 | 1.00968893421724-2.03977562468i | 1.00968893 | -0.02039776 |
| 9 | 1.01014998884187-2.08923579390i | 1.01014999 | -0.02089236 |
| 10 | 1.0106332037379-2.139990285362i | 1.0106332 | -0.0213999 |
| 11 | 1.01113966552599-2.19207978728i | 1.01113967 | -0.0219208 |
| 12 | 1.01167051620514-2.24554673518i | 1.01167052 | -0.02245547 |
| 13 | 1.01222695617852-2.30043541557i | 1.01222696 | -0.02300435 |
| 14 | 1.01281024746423-2.35679207740i | 1.01281025 | -0.02356792 |
| 15 | 1.01342171710397-2.41466505151i | 1.01342172 | -0.02414665 |
| 16 | 1.01406276078389-2.47410487941i | 1.01406276 | -0.02474105 |
| 17 | 1.01473484668299-2.53516445178i | 1.01473485 | -0.02535164 |
| 18 | 1.01543951956582-2.59789915753i | 1.01543952 | -0.02597899 |
| 19 | 1.01617840513754-2.66236704463i | 1.01617841 | -0.02662367 |

7. Using the Log modulus, Phase Shift and Frequency columns, obtains the Bode plots:



8. Using the columns for $Re[G]$ and $Im[G]$, obtain the Nyquist Plot:

