Bode Plots by hand and by MatLab

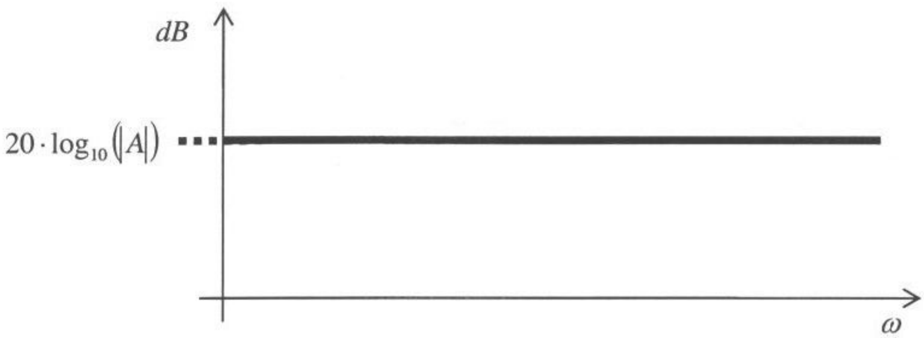
1. Bode Plots by Hand

Bode Diagrams

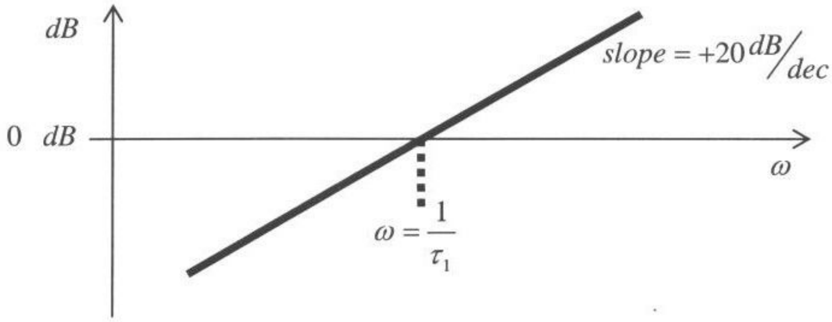
Bode magnitude plots

For Bode magnitude plots, the y-axis is typically expressed in terms of dB. Also, the x-axis is frequency on a logarithmic scale.

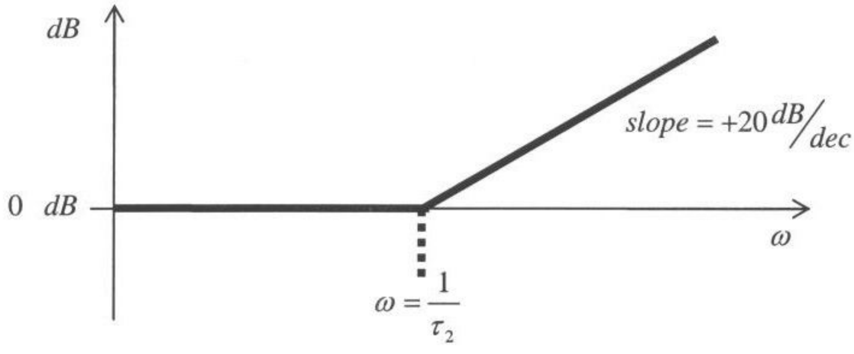
1. $20 \cdot \log_{10}(|A|)$, *where A is a real number*



2. $20 \cdot \log_{10}(|j \cdot \omega \cdot \tau_1|)$, *where τ_1 is a real number*



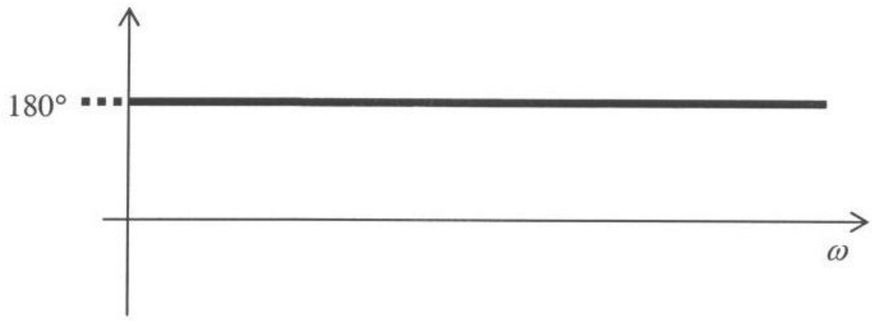
3. $20 \cdot \log_{10}(|(1 \pm j \cdot \omega \cdot \tau_2)|)$, *where τ_2 is a real number*



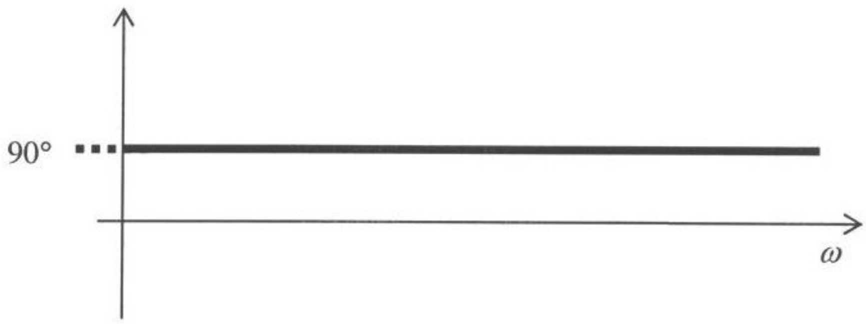
Bode Phase Plots

1. $\angle\ A$, *where* A *is a positive real number*

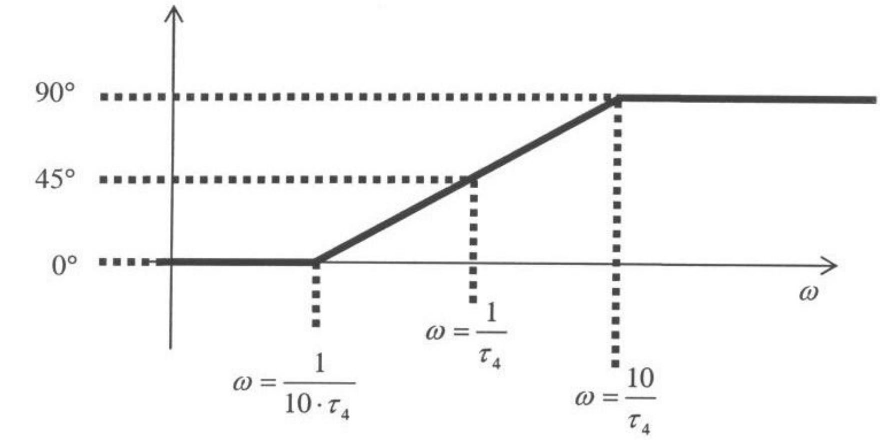
2. $\angle\ B$, *where* B *is a negative real number*



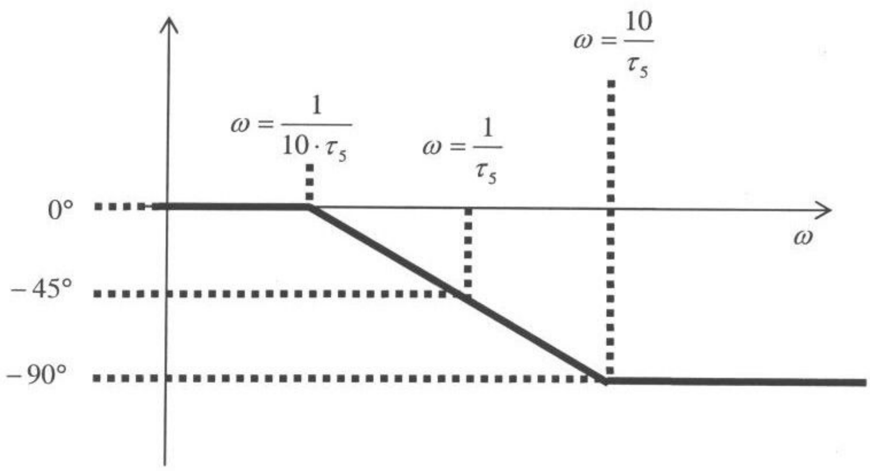
3. $\angle\ (j \cdot \omega \cdot \tau_3)$, *where* τ_3 *is a real number*



4. $\angle\ (1 + j \cdot \omega \cdot \tau_4)$, *where* τ_4 *is a real number*

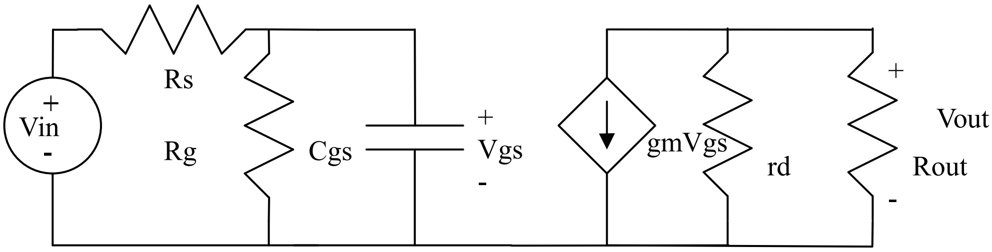


5. $\angle\ (1 - j \cdot \omega \cdot \tau_5)$, *where* τ_5 *is a real number*



2. Bode Plots by MatLab

Here is an example of doing Bode Plots with Matlab.



Assume you have a small signal circuit like this.

2.1. Find Vout/Vin

Assume you have the following parameters and try to draw the bode plots. First, you need to find out Vout/Vin.

$$V_{GSQ} = 3V, V_{th} = 1V, \mu_n C_{ox} = 100\frac{\mu A}{V^2}, \frac{W}{L} = 20, \lambda = 0,$$

$$Rs = 10k\Omega, Rg = 8x10^5\Omega, Rout = 1.82k\Omega, Cgs = 5fF$$

$$\frac{Vgs}{Vin} = \frac{Rg // \frac{1}{jwCgs}}{Rs + Rg // \frac{1}{jwCgs}} = \frac{Rg // \frac{1}{jwCgs}}{Rs + Rg // \frac{1}{jwCgs}} = \frac{8x10^5}{8.1x10^5 + jw(4x10^{-5})}$$

$$gm = \mu_n C_{ox}(\frac{W}{L})(V_{GSQ} - V_{th}) = 4m\Omega^{-1}$$

$$rd = \frac{1}{\lambda I_{DS}} = \infty$$

$$\frac{Vout}{Vin} = -gm \cdot Vgs(rd // Rout) = -4m \cdot (\frac{8x10^5}{8.1x10^5 + jw(4x10^{-5})})(\infty // 1.82k)$$

$$\left|\frac{Vout}{Vin}\right| = \frac{5.82x10^6}{8.1x10^5 + jw(4x10^{-5})}$$

2.2. Plot the Bode Plot with MatLab

Assume that you wanted to use Matlab in order to obtain Bode magnitude and phase plots for the following transfer function. The s is jw (j omega).

H(s) = Z(s)/P(s), where

Z(s) = [2.5329e-14*s^2 + 1.5915e-4*s + 1]

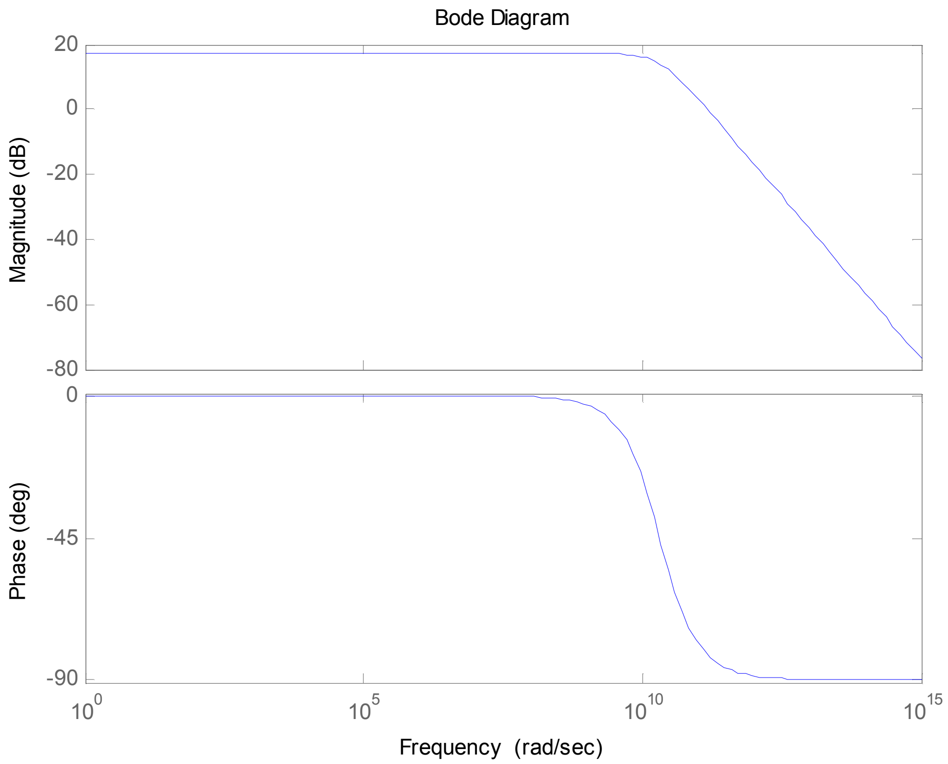
P(s) = [2.5329e-20*s^2 + 1.5915e-7*s + 1]

You would need to type the following:

```
>> num = [2.5329e-14 1.5915e-4 1];
>> den = [2.5329e-20 1.5915e-7 1];
>> sys = tf(num,den)
>> bode(sys,{1,1e15})
```

```
>> num = 5.82e6;             %%the numerator
den = [4e-5 8.1e5];          %%the denominator
sys = tf(num, den)           %%the transfer function
bode(sys,{1,1e15})            %%plot the magnitude and phase of the transfer function
                             %% The frequency range is 1 rad/s to 1e15 rad/s

Transfer function:            %Output
      5.82e006
-------------------------
4e-005 s + 810000
```



3. Bode Plot by Hand Example

3.1 The Transfer Function

Say we want to plot the following transfer function by hand.

$$\frac{Vout}{Vin} = \frac{5.82x10^6}{8.1x10^5 + jw(4x10^{-5})}$$

First, we rearrange the numbers

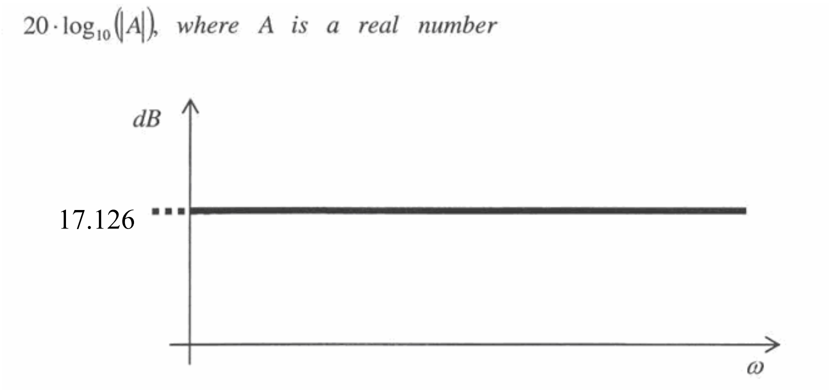
$$\frac{Vout}{Vin} = \frac{7.185}{1 + \frac{jw}{4.938x10^{11}}}$$

Notice when omega w equals to 4.938 x 10^{11} , it becomes a corner in the bode plot. Also, if w is close to zero, $\frac{Vout}{Vin}$ is just 7.185.

3.1 Magnitude Plot

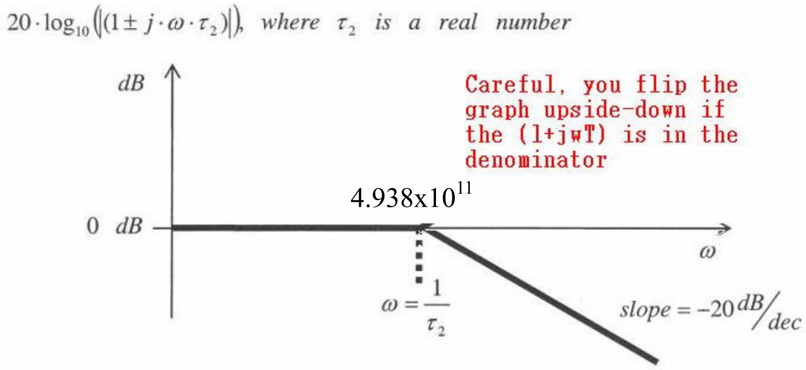
Just adding all the plots. 20 log(7.185) = 17.126.

For 7.185



+

For $1+\frac{jw}{4.938x10^{11}}$

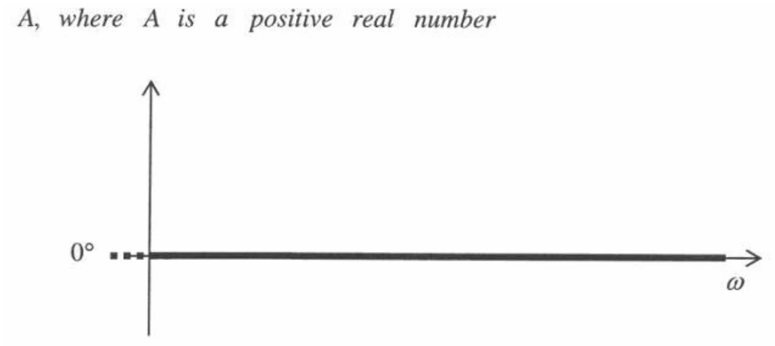


<u>3.2 Phase Plot</u>

Just adding all the plots.

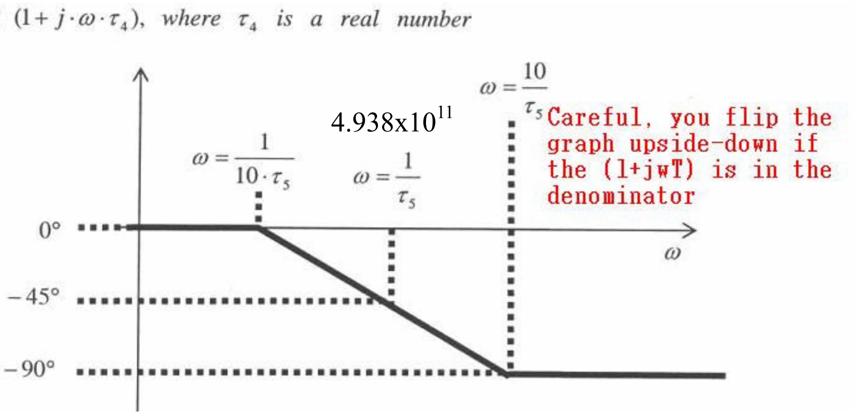
$$\frac{Vout}{Vin} = \frac{7.185}{1 + \frac{jw}{4.938x10^{11}}}$$

For 7.185



+

For $1 + \frac{jw}{4.938x10^{11}}$



<u>4. Reference</u>

Original EE 105 Discussion Notes from Meghdad Hajimorad ("Amin")

Last Modified by: Bill Hung

Date: 5 August 2006