

Bode Plots by hand and by MatLab

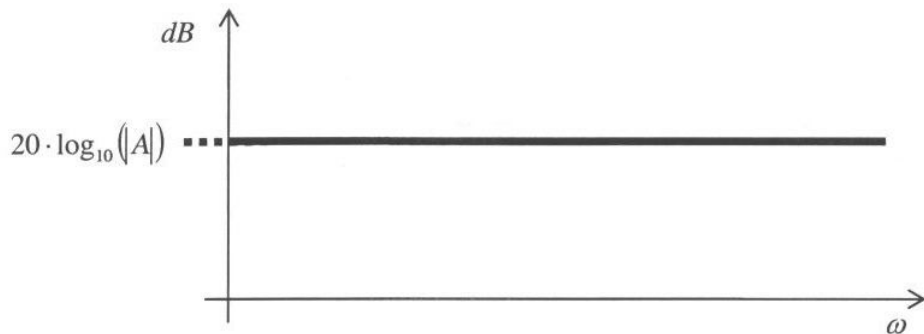
1. Bode Plots by Hand

Bode Diagrams

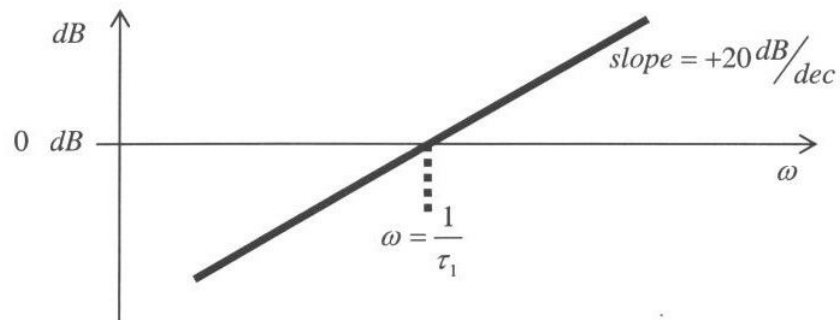
Bode magnitude plots

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

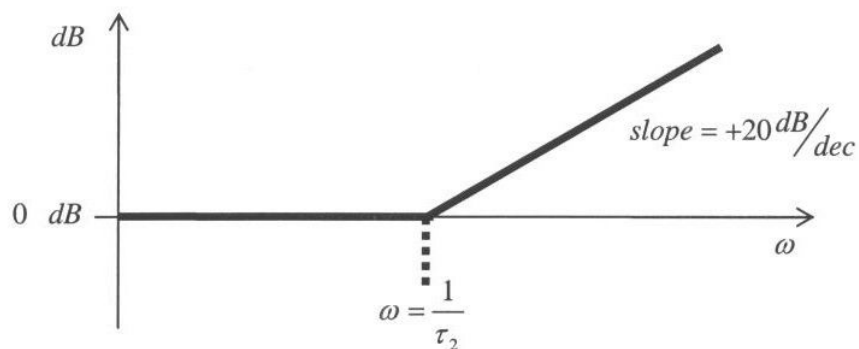
1. $20 \cdot \log_{10}(|A|)$, where A is a real number



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

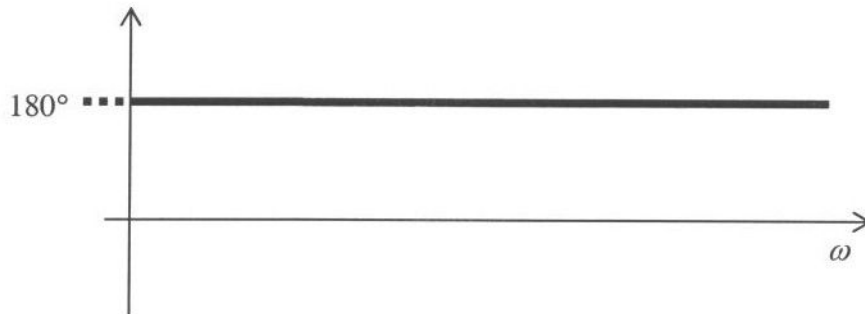


Bode Phase Plots

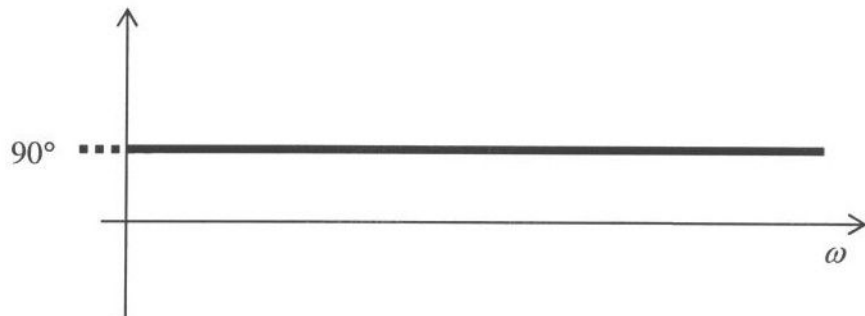
1. $\angle A$, where A is a positive real number



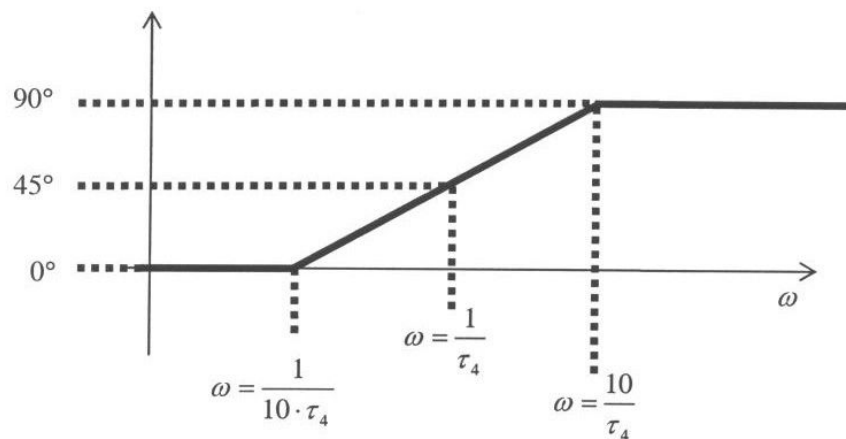
2. $\angle B$, where B is a negative real number



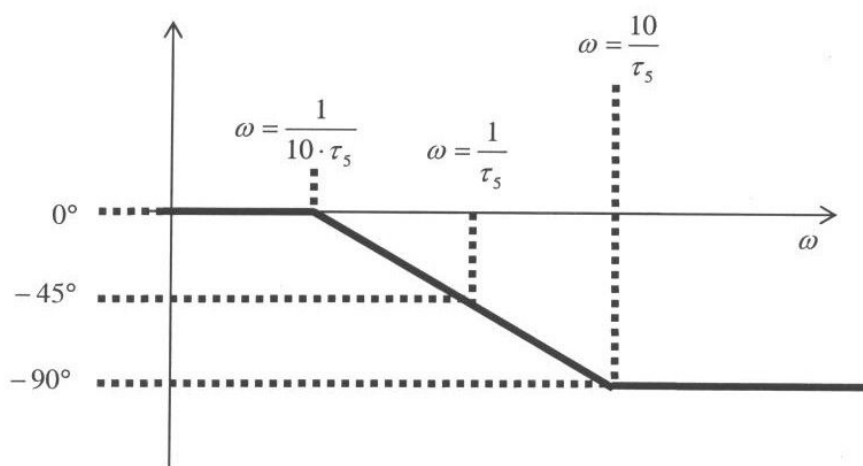
3. $\angle (j \cdot \omega \cdot \tau_3)$, where τ_3 is a real number



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.

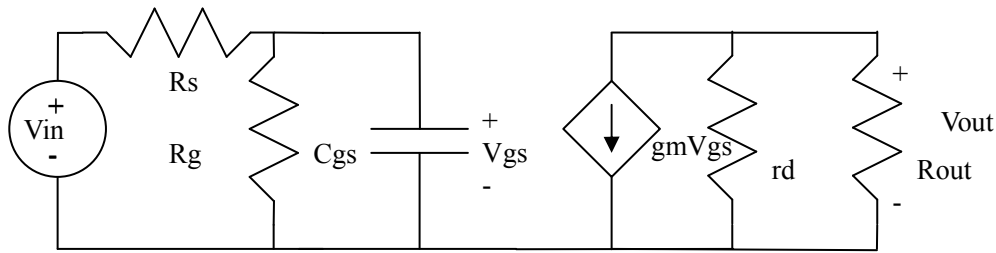


Figure 1. Assume you have a small signal circuit like this.

2.1. Find V_{out}/V_{in}

Assume you have the following parameters and try to draw the bode plots. First, you need to find out V_{out}/V_{in} .

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

$$R_s = 10k\Omega, R_g = 8 \times 10^5 \Omega, R_{out} = 1.82k\Omega, C_{gs} = 5fF$$

$$\frac{V_{gs}}{V_{in}} = \frac{R_g // \frac{1}{j\omega C_{gs}}}{R_s + R_g // \frac{1}{j\omega C_{gs}}} = \frac{R_g // \frac{1}{j\omega C_{gs}}}{R_s + R_g // \frac{1}{j\omega C_{gs}}} = \frac{8 \times 10^5}{8.1 \times 10^5 + j\omega(4 \times 10^{-5})}$$

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

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

$$\frac{V_{out}}{V_{in}} = -g_m \cdot V_{gs} (r_d // R_{out}) = -4m \cdot \left(\frac{8 \times 10^5}{8.1 \times 10^5 + j\omega(4 \times 10^{-5})} \right) (\infty // 1.82k)$$

$$\frac{V_{out}}{V_{in}} = \frac{5.82 \times 10^6}{8.1 \times 10^5 + j\omega(4 \times 10^{-5})}$$

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 $j\omega$ (j omega).

$$H(s) = P(s)/Z(s), \text{ where}$$

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

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

You would need to type the following:

```
>> num = [2.5329e-14 1.5915e-4 1];
```

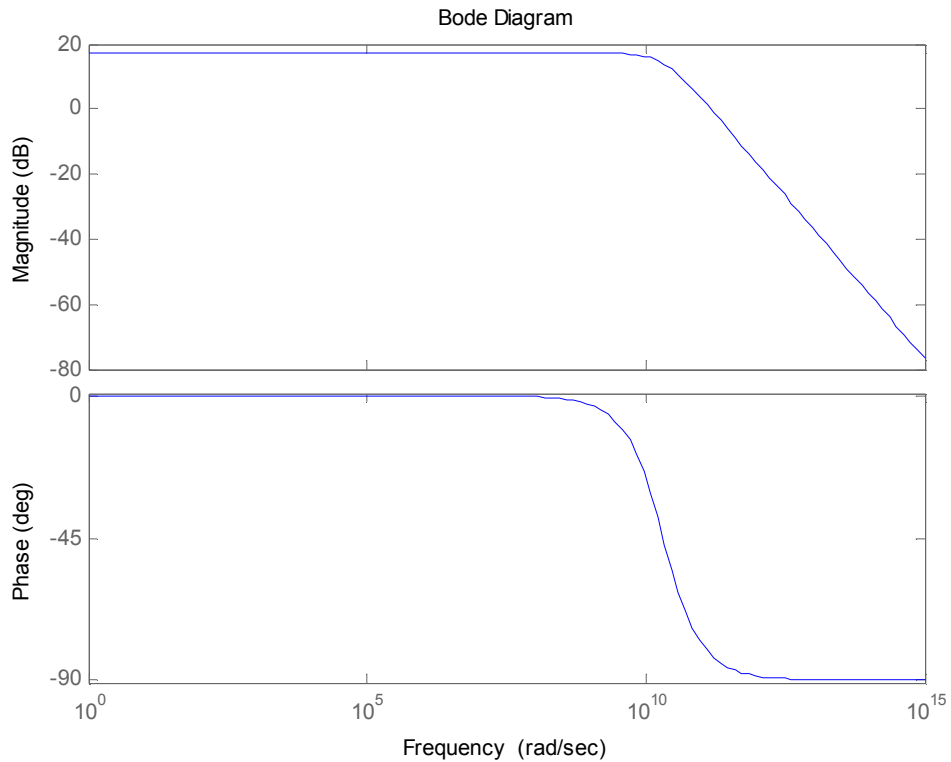
```
>> den = [2.5329e-20 1.5915e-7 1];
```

```
>> 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.

$$\frac{V_{out}}{V_{in}} = \frac{5.82 \times 10^6}{8.1 \times 10^5 + j\omega(4 \times 10^{-5})}$$

First, we rearrange the numbers

$$\frac{V_{out}}{V_{in}} = \frac{7.185}{1 + \frac{j\omega}{4.938 \times 10^{11}}}$$

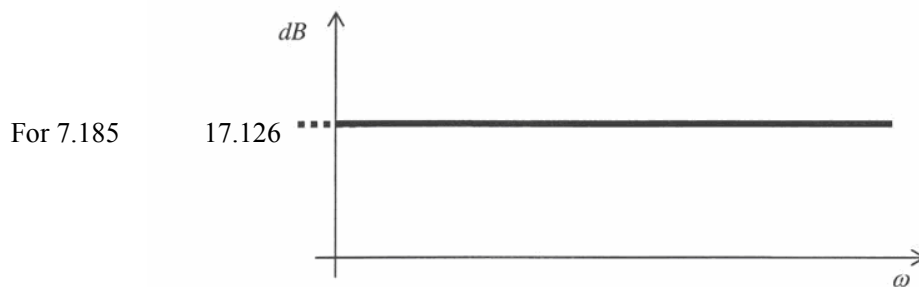
Notice when omega ω equals to 4.938×10^{11} , it becomes a corner in the bode plot. Also,

if ω is close to zero, $\frac{V_{out}}{V_{in}}$ is just 7.185.

3.1 Magnitude Plot

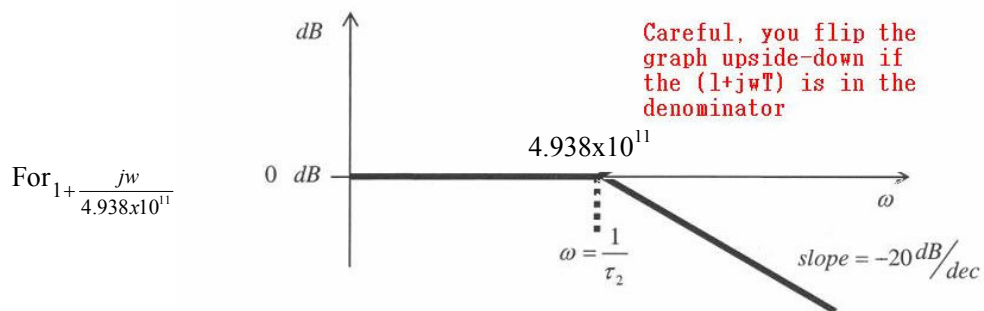
Just adding all the plots. $20 \log(7.185) = 17.126$.

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



+

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



3.2 Phase Plot

Just adding all the plots.

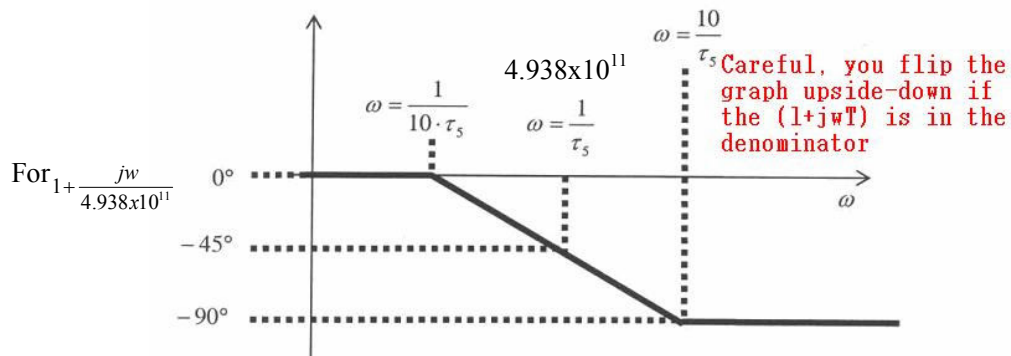
$$\frac{V_{out}}{V_{in}} = \frac{7.185}{1 + \frac{j\omega}{4.938 \times 10^{11}}}$$

A , where A is a positive real number



+

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



4. Reference

Original EE 105 Discussion Notes from Meghdad Hajimorad (“Amin”)

Last Modified by: Bill Hung

Date: 5 August 2006