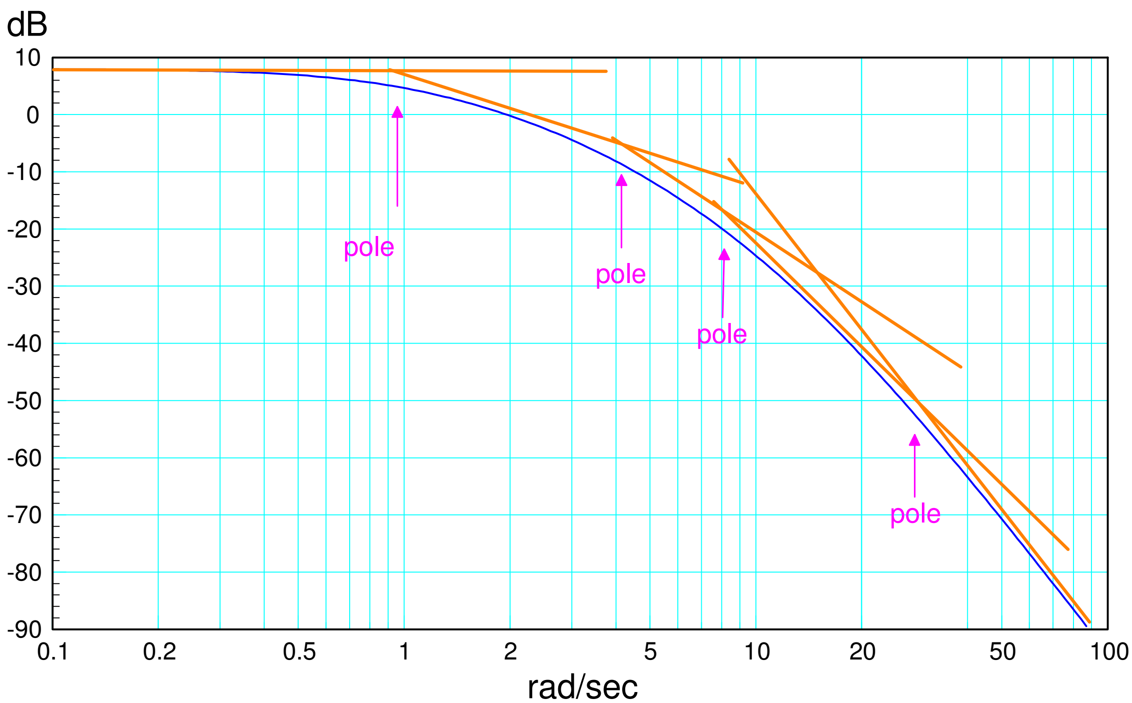
Homework #11: ECE 461/661

Bode Plots. Nichols charts and gain compensation. Due Monday, November 23rd

Bode Plots

1) Determine the system, G(s), with the following gain vs. frequency



Draw in the asymptotes at multiples of 20dB/decade (shown in orange)

Each corner is a pole

$$G(s) \approx \left(\frac{k}{(s+0.9)(s+4.2)(s+8)(s+25)} \right)$$

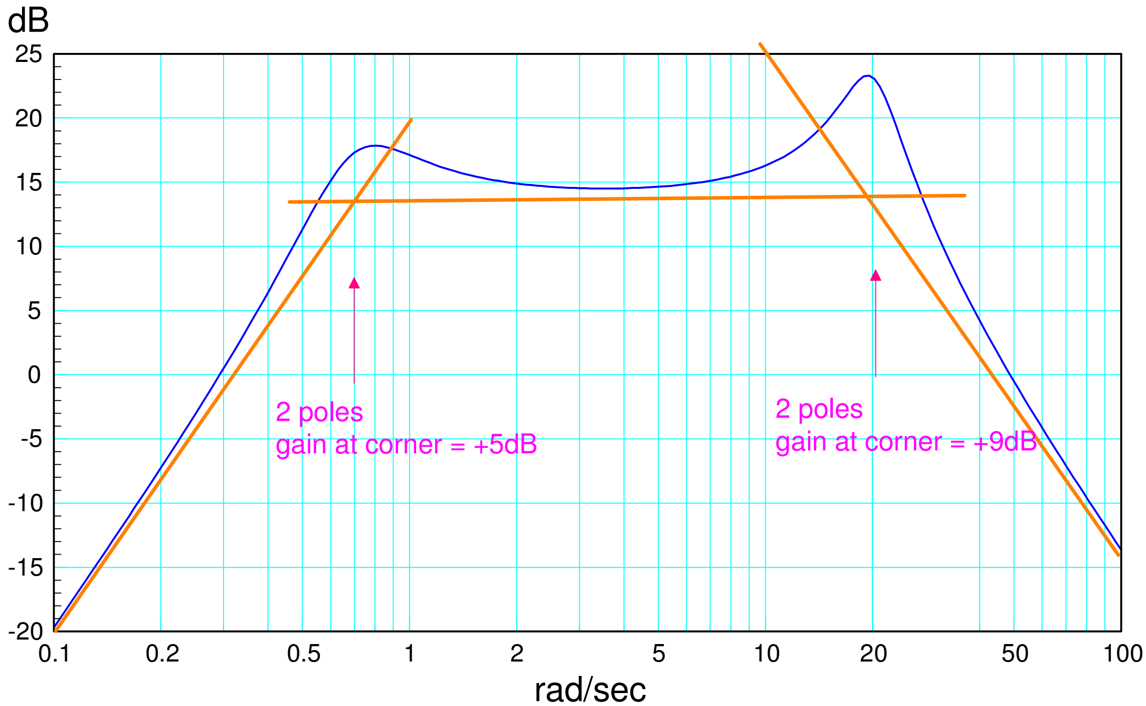
Pick k to match the gain at one point (DC)

$$\left(\frac{k}{(s+0.9)(s+4.2)(s+8)(s+25)} \right)_{s=0} = 9dB = 2.51$$

$$k = 1899$$

$$G(s) \approx \left(\frac{1899}{(s+0.9)(s+4.2)(s+8)(s+25)} \right)$$

2) Determine the system, G(s), with the following gain vs. frequency



Draw in the straight line approximations

- There are two zeros at s = 0 (someplace left of 0.1)
- There are two poles at s = 0.7
- There are two poles at s = 20

The gain at the corner tells you the damping ratio

$$\frac{1}{2\zeta} = +5dB = 1.778 \qquad \zeta = 0.281 \qquad \theta = 73.67^0$$

$$\frac{1}{2\zeta} = +9dB = 2.818 \qquad \zeta = 0.177 \qquad \theta = 79.78^0$$

$$G(s) \approx \left(\frac{ks^2}{(s+0.7\angle\pm 73.67^0)(s+20\angle\pm 79.78^0)} \right)$$

Pick k to match the gain at a point. As s = 0.1, the gain is -20dB

$$\left(\frac{ks^2}{(s+0.7\angle\pm 73.67^0)(s+20\angle\pm 79.78^0)} \right)_{s=0.1} = -20dB = 0.1$$

$$k = 1960$$

$$G(s) \approx \left(\frac{1960s^2}{(s+0.7\angle\pm 73.67^0)(s+20\angle\pm 79.78^0)} \right)$$

Nichols Charts

3) The gain vs. frequency of a system is measured

w (rad/sec)	1	2	3	4	5	6
Gain (dB)	4.63	-0.21	-4.45	-8.17	-11.51	-14.55
Phase (deg)	-67.6	-107.0	-133.67	-154.08	-170.63	-184.51

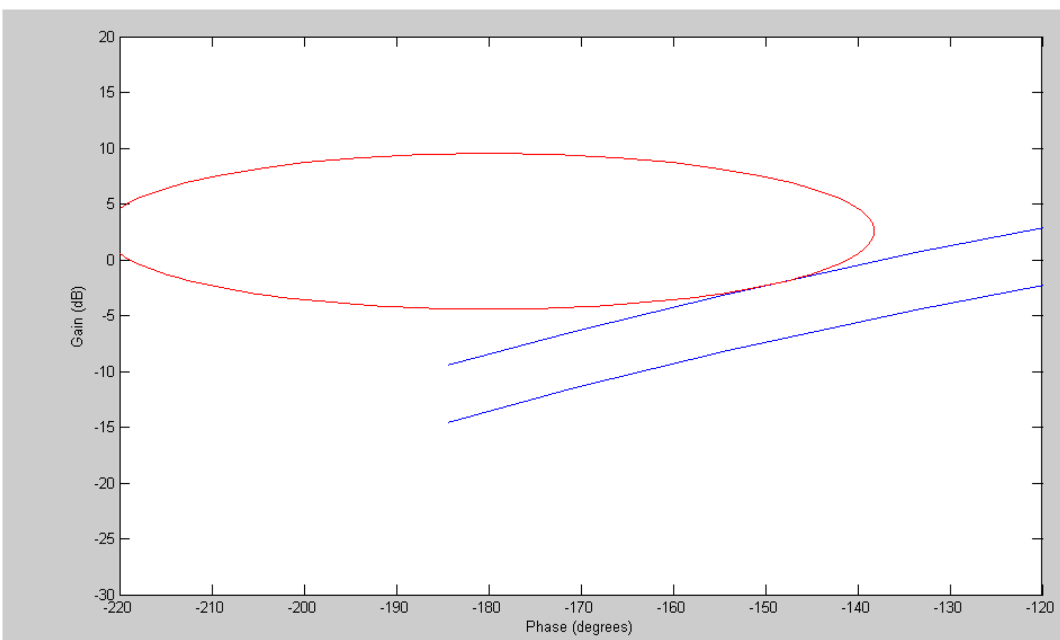
Using this data

- Transfer it to a Nichols chart
- Determine the maximum gain that results in a stable system **k = +14dB**
- Determine the gain, k, that results in a maximum closed-loop gain of Mm = 1.5 **k = 1.8**

```
>> w = [1,2,3,4,5,6]';
>> GdB = [4.63,-0.21,-4.45,-8.17,-11.51,-14.55]';
>> Gdeg = [-67.6,-107,-133.67,-154.08,-170.63,-184.51]';
>> Gw = 10.^(GdB/20)  .*  exp(j*Gdeg*pi/180)

   0.6494 - 1.5755i
  -0.2854 - 0.9335i
  -0.4137 - 0.4333i
  -0.3511 - 0.1706i
  -0.2622 - 0.0433i
  -0.1867 + 0.0147i

>> Nichols2(Gw*[1,2],1.5);
>> Nichols2(Gw*[1,1.8],1.5);
>> Nichols2(Gw*[1,1.8],1.5);
```



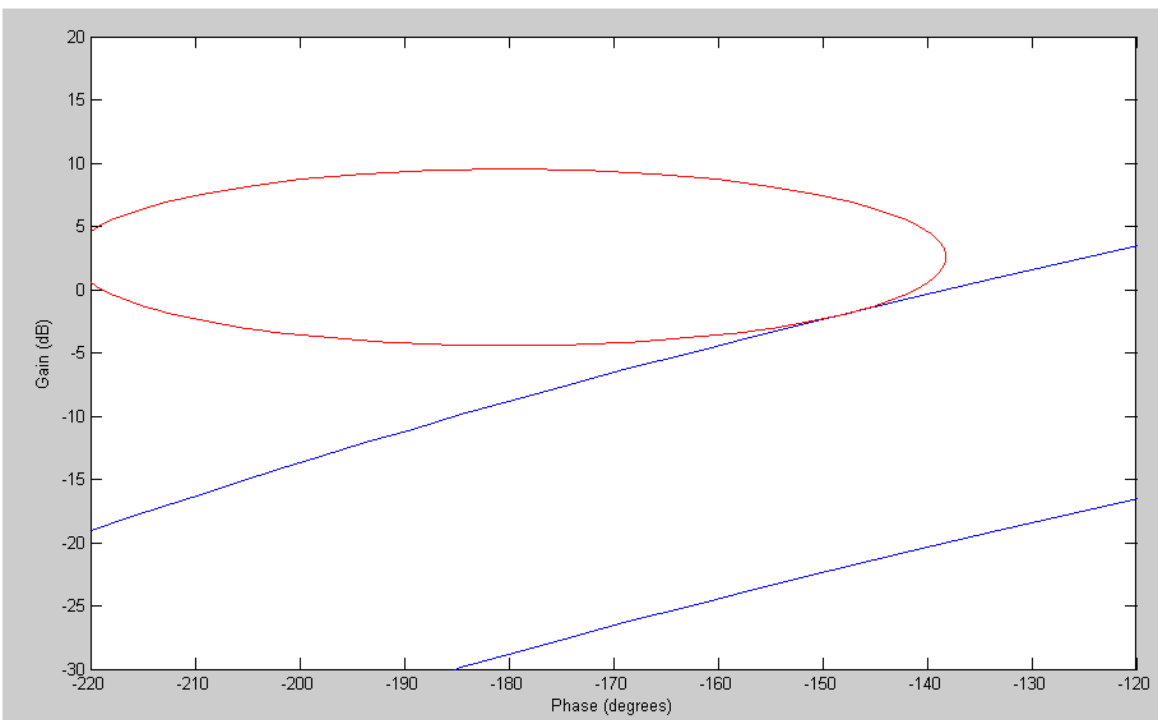
4) Assume

$$G(s) = \left(\frac{1.4427}{(s+0.1617)(s+1.04)(s+2.719)(s+5.05)} \right)$$

Find G(jw) using Matlab (or similar program). With ths data,

- Draw a Nichols chart
- Determine the maximum gain that results in a stable system **k = +28dB**
- Determine the gain, k, that results in a maximum closed-loop gain of Mm = 1.5 **k = 10**

```
>> w = [0:0.1:10]';
>> s = j*w;
>> Gw = 1.4427 ./ ( (s+0.1617).*(s+1.04).*(s+2.719).*(s+5.05) );
>> Nichols2(Gw,1.5);
>> Nichols2(Gw*[1,2],1.5);
>> Nichols2(Gw*[1,4],1.5);
>> Nichols2(Gw*[1,5],1.5);
>> Nichols2(Gw*[1,7],1.5);
>> Nichols2(Gw*[1,8],1.5);
>> Nichols2(Gw*[1,9],1.5);
>> Nichols2(Gw*[1,10],1.5);
>>
```



5) Assume a 500ms delay is added

$$G(s) = \left(\frac{1.4427}{(s+0.1617)(s+1.04)(s+2.719)(s+5.05)} \right) e^{-0.5s}$$

Find G(jw) using Matlab (or similar program). With ths data,

- Draw a Nichols chart
- Determine the maximum gain that results in a stable system **k = +23dB**
- Determine the gain, k, that results in a maximum closed-loop gain of Mm = 1.5 **k = 6.4**

```
>> w = [0:0.1:10]';
>> s = j*w;
>> Gw = 1.4427 ./ ( (s+0.1617).*(s+1.04).*(s+2.719).*(s+5.05) ) .*
exp(-0.5*s);

>> Nichols2(Gw*[1,10],1.5);
>> Nichols2(Gw*[1,6],1.5);
>> Nichols2(Gw*[1,6.2],1.5);
>> Nichols2(Gw*[1,6.3],1.5);
>> Nichols2(Gw*[1,6.4],1.5);
>>
```