ABDULLAH ALMOSALAMI ECE461 (SUPER LATE) 12/16/2020 Wednesday

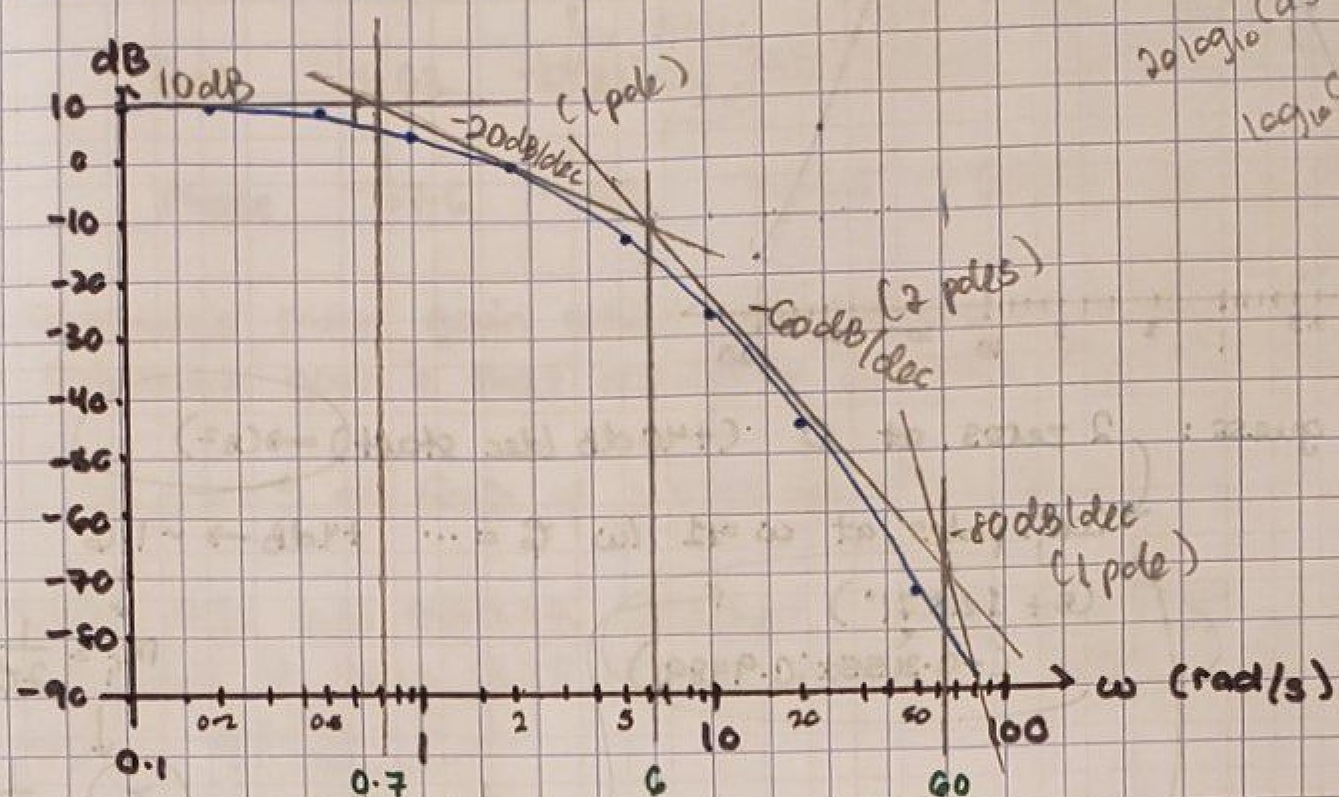
BODE PLOTS

1) Determine $G(s)$:

$20\log_{10}(a) = 10$

$\log_{10}(a) = 1/2$

$a = 10^{1/2}$



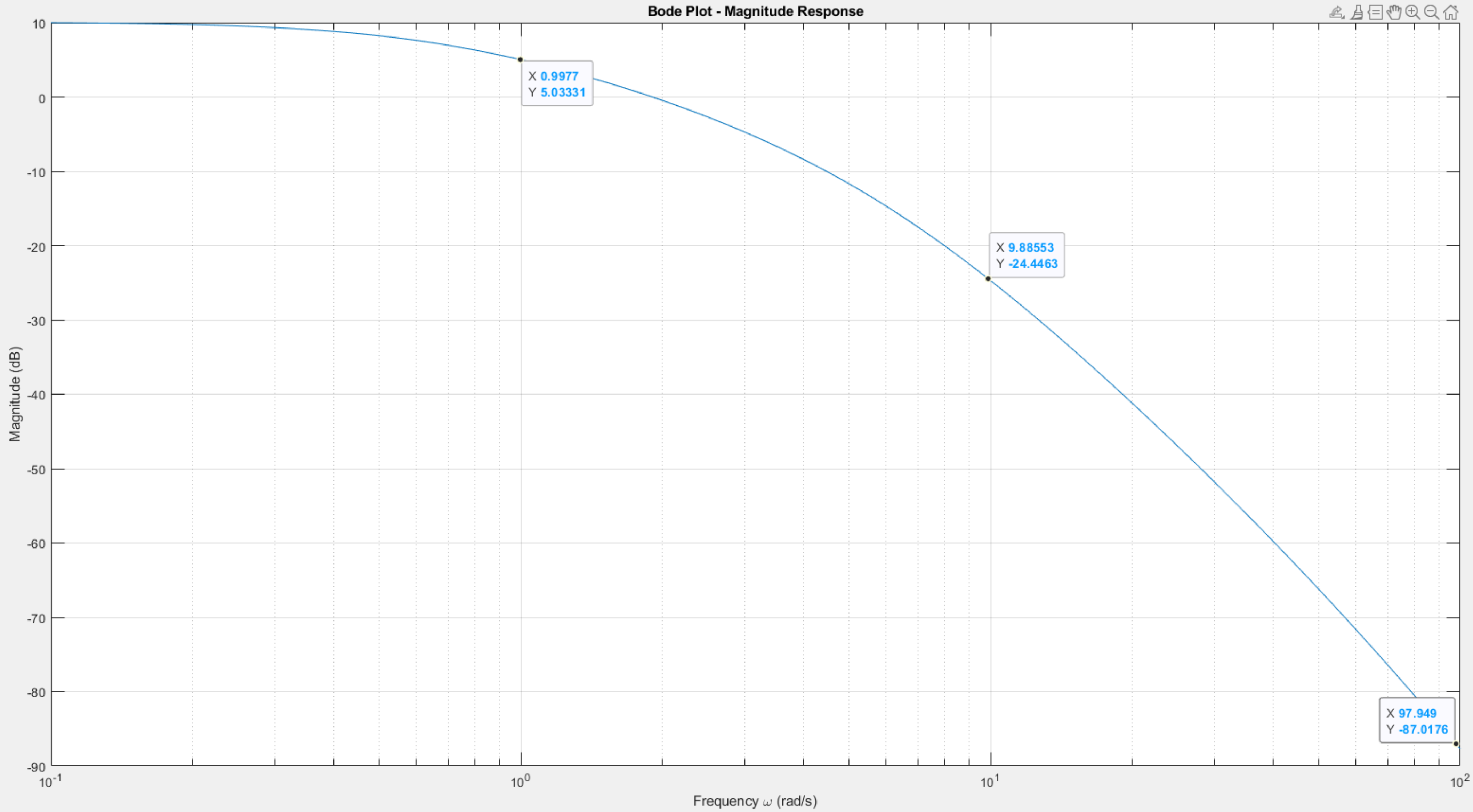
Based on my asymptote approximation,

$$G(s) \simeq \frac{k}{(s+0.7)(s+6)^2(s+60)}$$

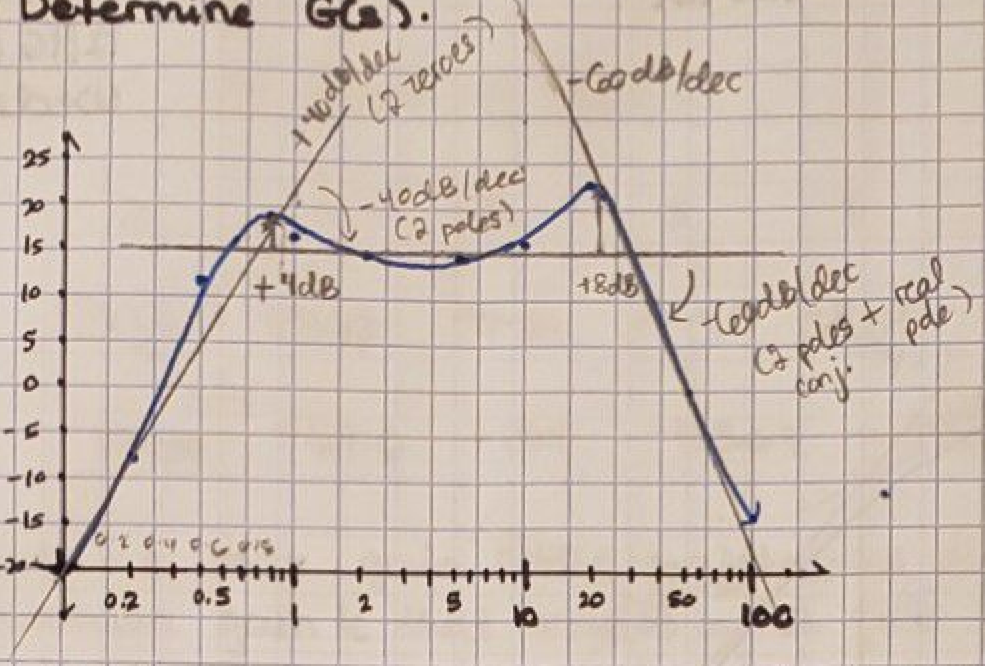
$$G(j\omega)\Big|_{\omega=0.1} = \sqrt{10} \Rightarrow \boxed{k = 4830}$$

Testing out my approximation … (next page)

Pretty good actually! :)


Bode Plot - Magnitude Response
X 0.9977
Y 5.03331
X 9.88553
Y -24.4463
X 97.949
Y -87.0176
Magnitude (dB)
Frequency ω (rad/s)
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
10^-1
10^0
10^1
10^2

2) Determine G(s).



Rough guess: 2 zeros at 0 (+40 dB/dec start) $\Rightarrow (s^2)$

Conj. poles at $\omega \approx 1$ w $\zeta = \dots$ +4dB $\rightarrow \sim 1.6$ $\rightarrow$ $M_{r_1} = \frac{1}{2\zeta}$ $\rightarrow$ $\zeta_1 = \frac{1}{2M_r} = 0.3155$

$\phi_1 = \cos^{-1}\zeta \Leftarrow$

$\phi_1 = 71°$

$(s + 1\angle \pm 71°)$

$(-0.3155 \pm j0.9489)$

Conj. poles AND real pole at $\omega \approx 20$

+8dB $\rightarrow M_{r_2} = 2.5119 \rightarrow \zeta_2 = 0.1991 \rightarrow \phi_2 = 78°$

$\Rightarrow (s \pm 20\angle \pm 78°)(s+20)$

$(-3.9811 \pm j19.6)$

So overall,

$$G(s) = \frac{ks^2}{(s+1\angle \pm 71°)(s+20\angle \pm 78°)(s+20)}$$

To match gain at 0.1 $\Rightarrow$ $\boxed{k = 79{,}360}$

Checking... Gain is a little too high but shape is right.

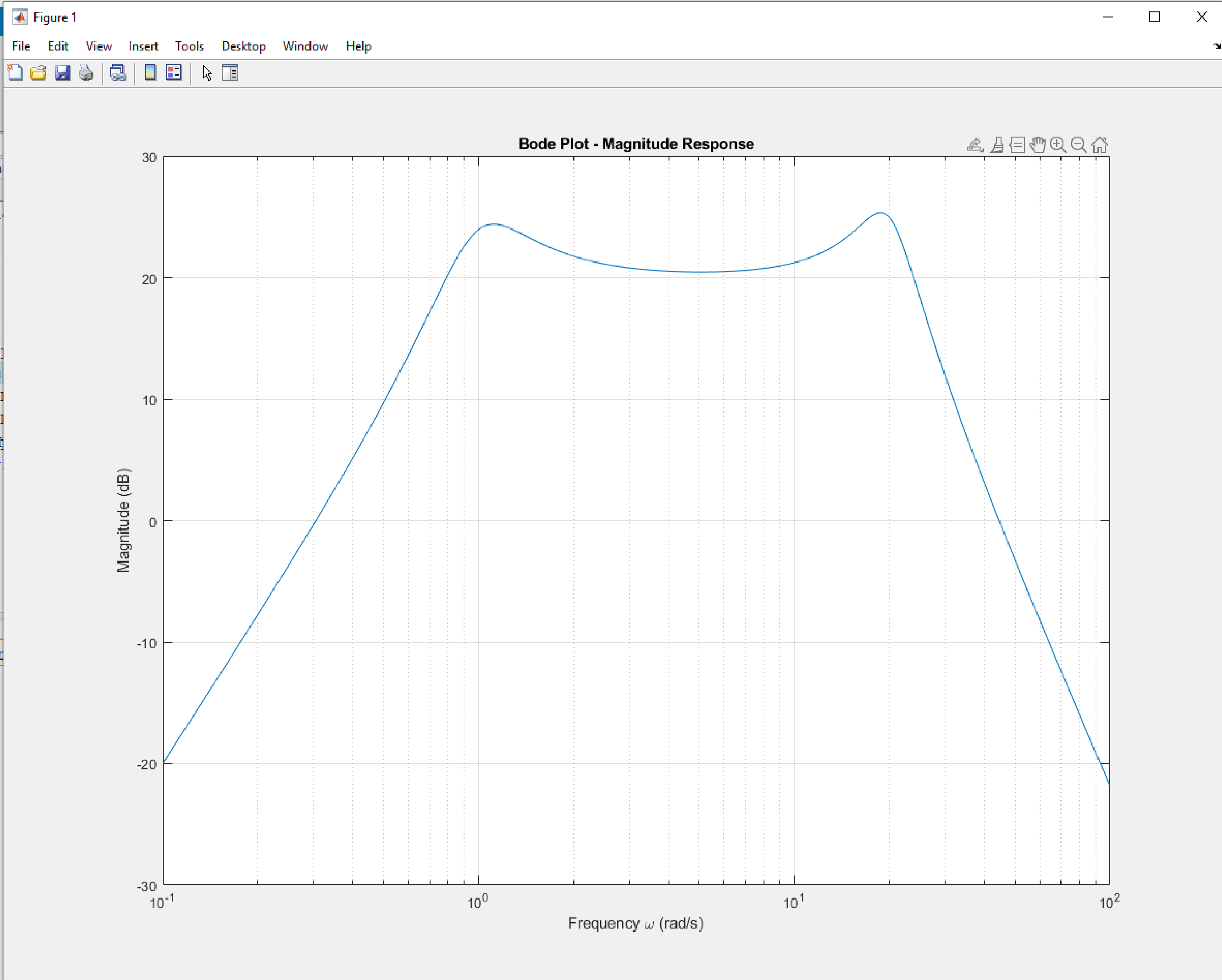


Figure 1
File Edit View Insert Tools Desktop Window Help
Bode Plot - Magnitude Response
30
20
10
0
-10
-20
-30
Magnitude (dB)
10^-1
10^0
10^1
10^2
Frequency ω (rad/s)

NICHOLS CHART

3) Using the following data:

ω	1	2	3	4	5	6
Gain	4.63	-0.21	-4.45	-8.17	-11.61	-14.55
Phase	-67.6	-107	-133.67	-154.08	-170.63	184.81

- Determine max gain while maintaining stability
- Determine gain k that results in CL gain M_m of 1.5 ⇒ i.e., $\zeta \approx 0.33$

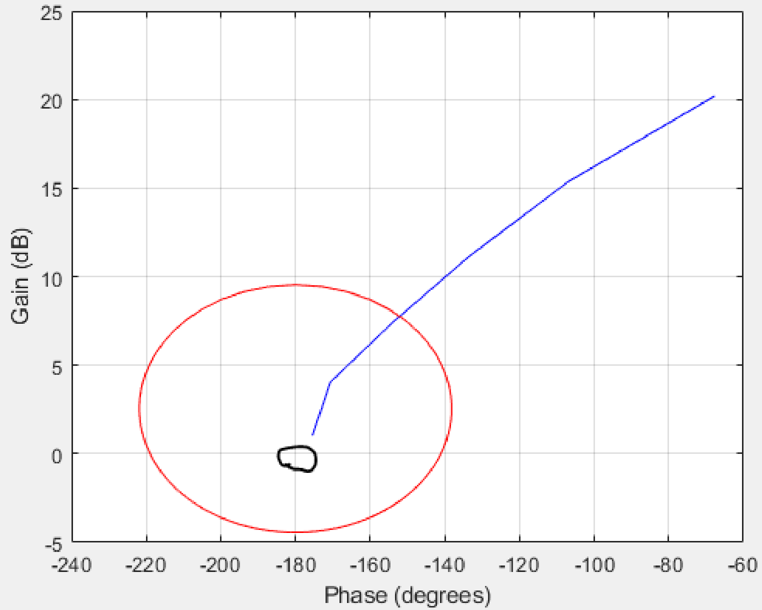
%OS = 33%

$M_m = 1.5 \Rightarrow$ Gain of 3.5218 dB ← M-Circle

Putting this onto MATLAB (attached) using your code, and increasing gain until it looks OLTF Nichols chart at (0dB, 180°) is just under, and I get k = 6.

To get a CL gain resonance of 1.5, at k = 1.8, I get the Nichols curve for OLTF tangent to M-circle.

Figure 1



MATLAB R2020b - academic use

Editor - C:\Users\almos\OneDrive\Documents\Control Systems\nichols_on_data.m

Bode2.m | Nichols2.m | transient_specs.m | nichols_on_data.m

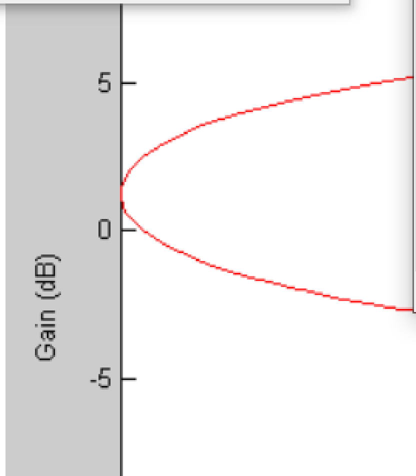
```
Gdb = [4.63,-0.21,-4.45,-8.17,-11.51,-14.55];
P = deg2rad([-67.7,-107,-133.67,-154.08,-170.63,184.51]);
Gw = 10.^(Gdb/20) .* exp(1j*P);

Nichols2(Gw,1.5);
```

Command Window

New to MATLAB? See resources for Getting Started.

```
>> Nichols2(3*Gw,1.5);
>> Nichols2(3.5*Gw,1.5);
>> Nichols2(5*Gw,1.5);
>> Nichols2(6*Gw,1.5);
>> Nichols2(7*Gw,1.5);
>> Nichols2(6*Gw,1.5);
>>
```



4)

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

- Draw Nichols
- Max gain
- $M_m = 1.5 \Rightarrow \zeta = 1/3 \Rightarrow OS = 33\%$

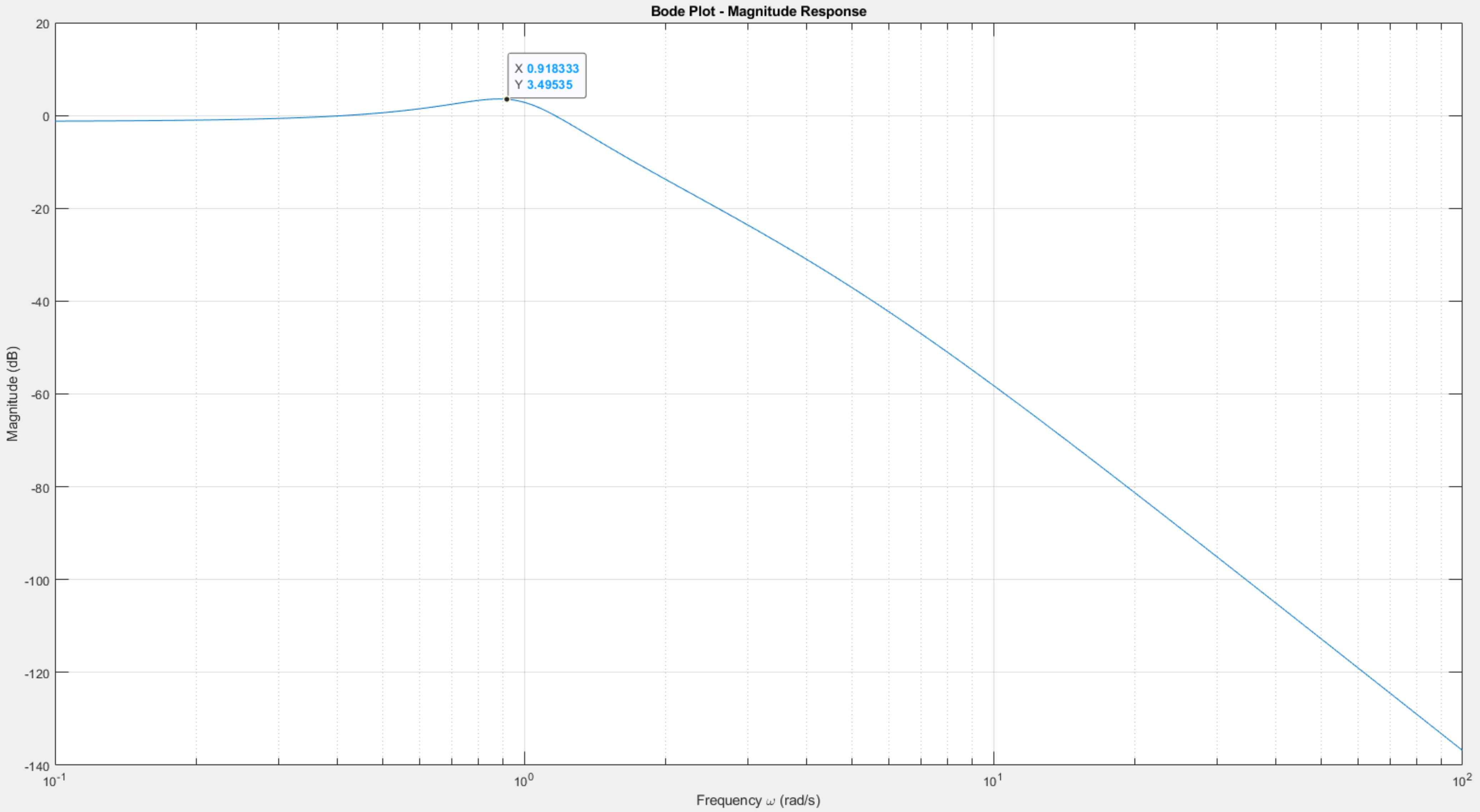
$\approx 4dB$

Using attached code,

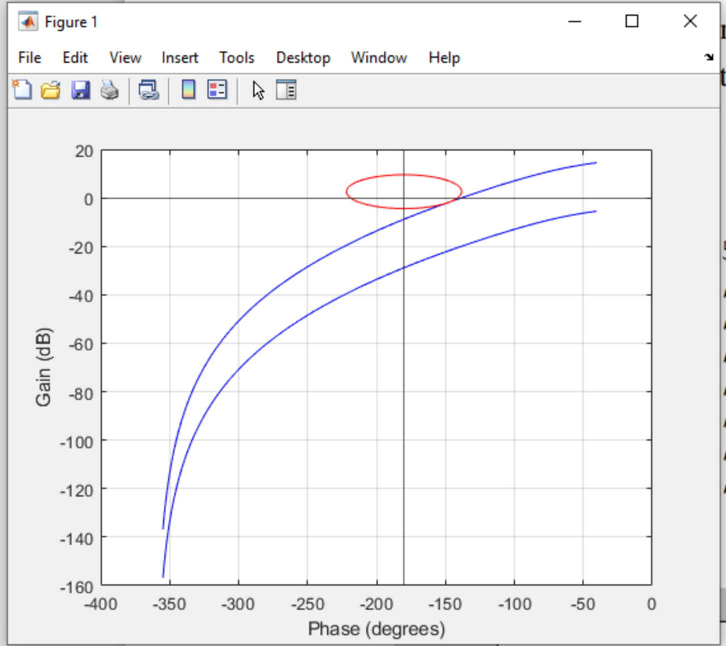
- Max gain $k = 27 \Rightarrow -28dB$

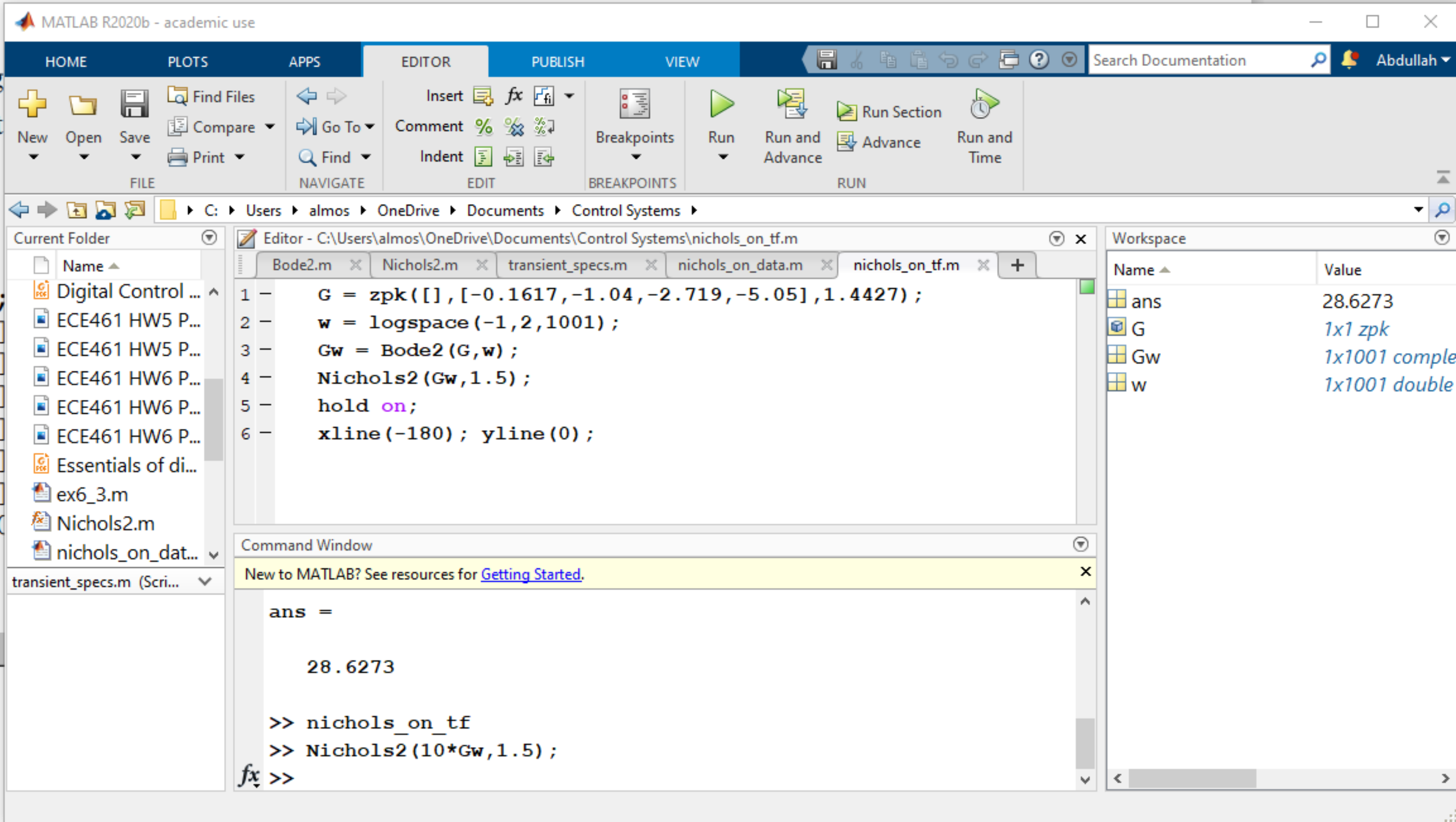
- Gain for $M_m = 1.5 \ldots \Rightarrow k = 10 \Rightarrow 20dB$

Testing this out... (first Bode, then step response OS...)

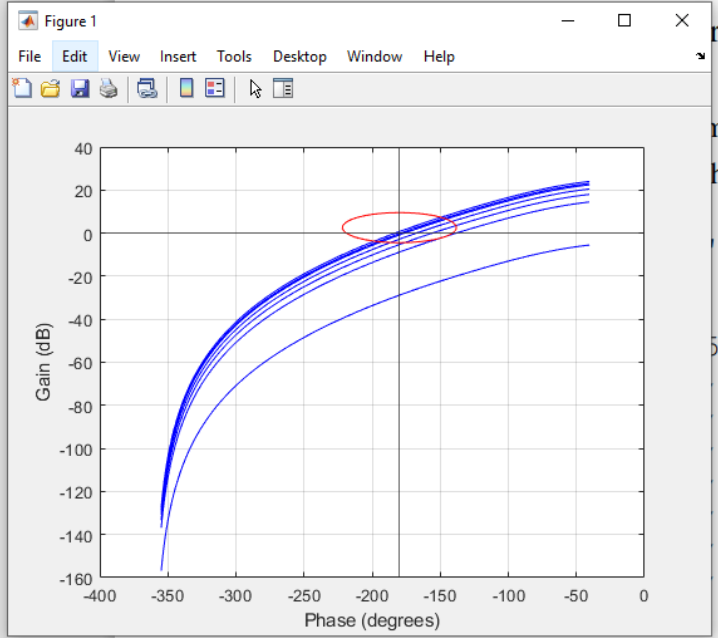

Bode Plot - Magnitude Response
X 0.918333
Y 3.49535
20
0
-20
-40
-60
-80
-100
-120
-140
Magnitude (dB)
10^{-1}
10^{0}
10^{1}
10^{2}
Frequency ω (rad/s)

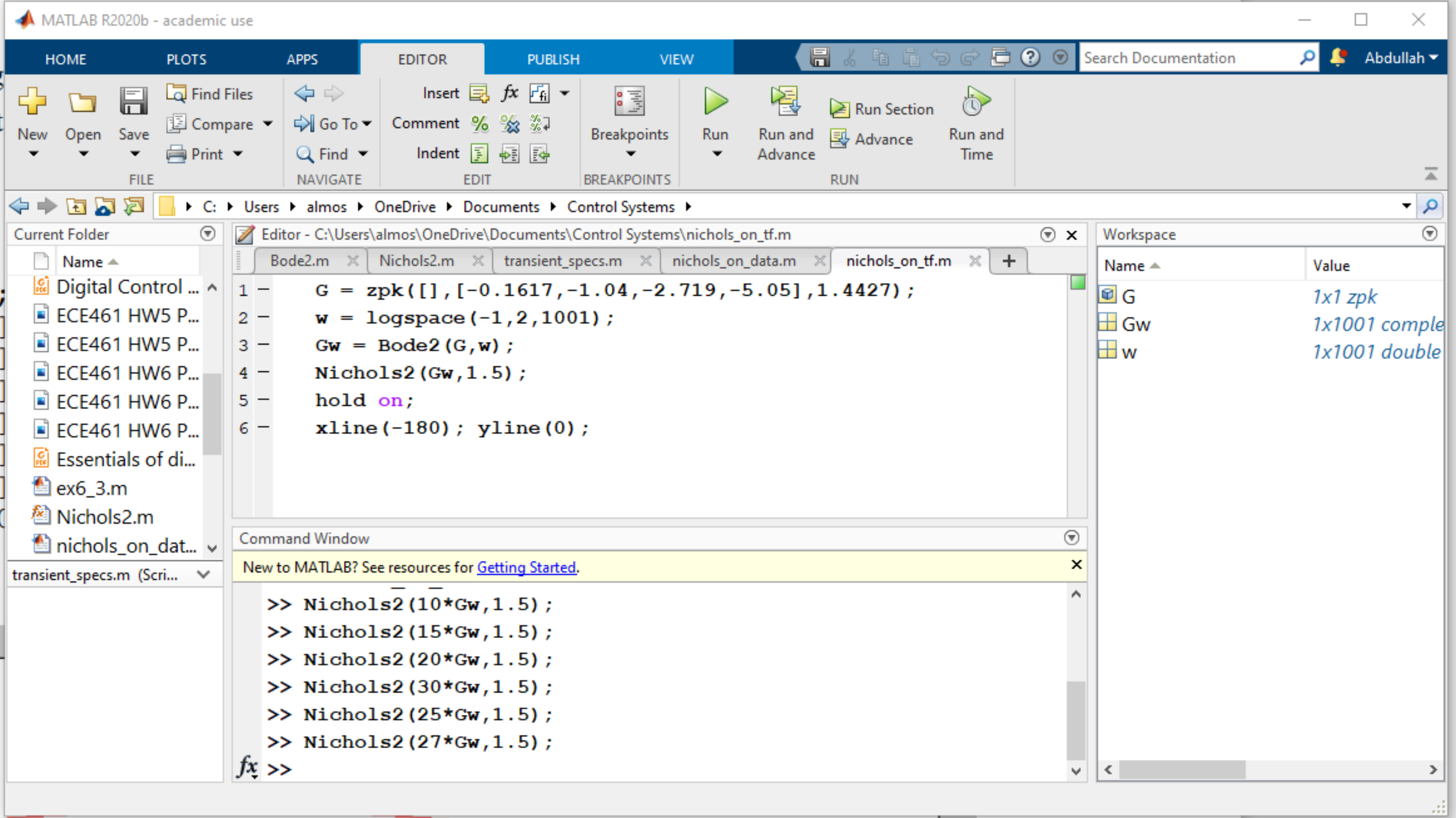
- Draw a Nichols chart

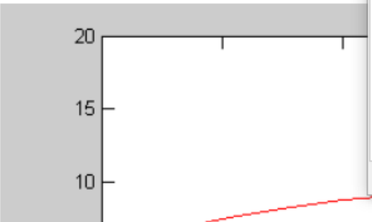




r similar program). With ths data,







Command Window

New to MATLAB? See resources for Getting Started.

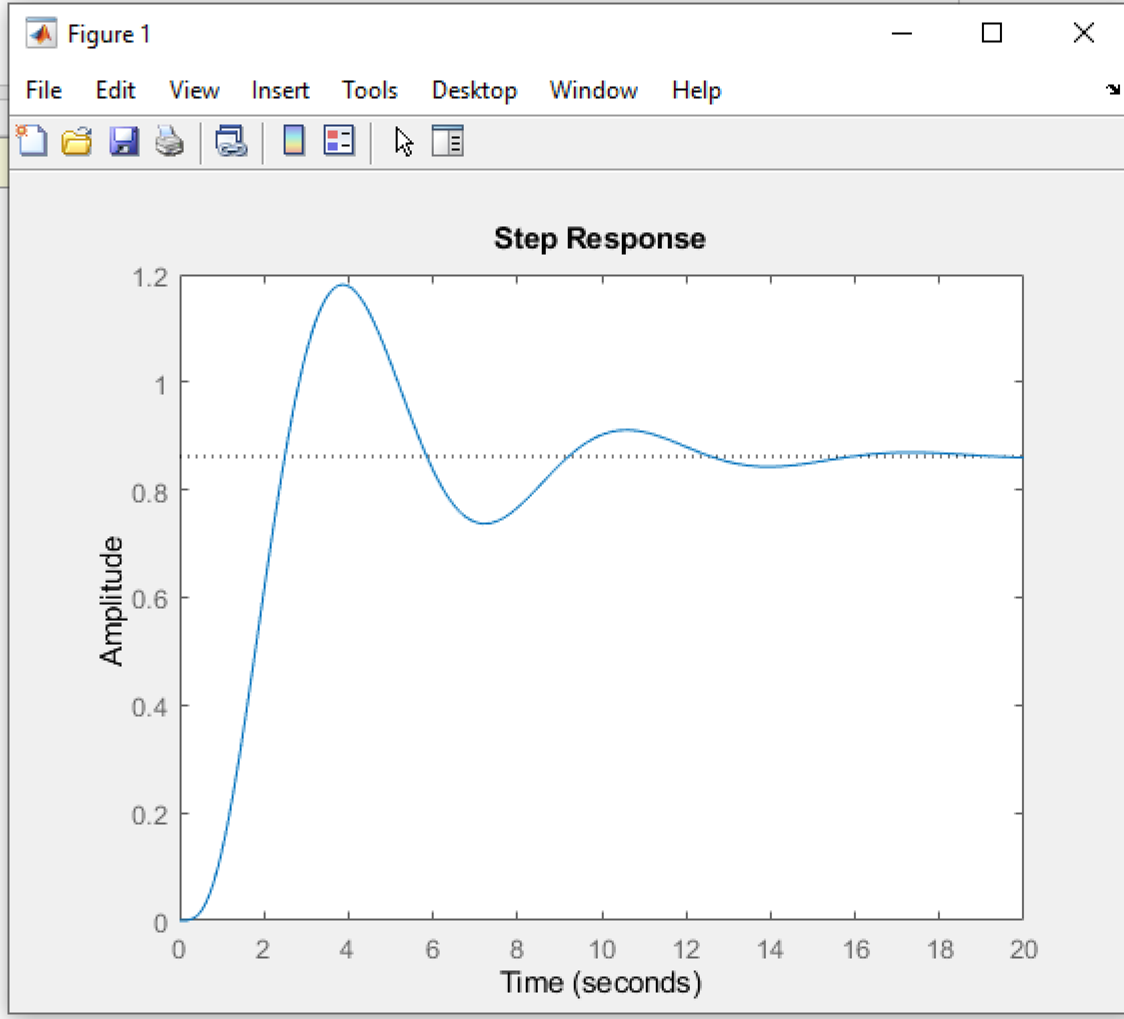
```
>> step(CLTF)
>> stepinfo(CLTF)

ans =

  struct with fields:

        RiseTime: 1.4492
    SettlingTime: 14.4373
     SettlingMin: 0.7371
     SettlingMax: 1.1808
       Overshoot: 36.9800
      Undershoot: 0
            Peak: 1.1808
        PeakTime: 3.8680

fx >>
```



5) Now add 500ms delay...

Doing the same code... (see attached)

$k_{max} = 14 \Rightarrow -23dB$

k for $m_m = 6$

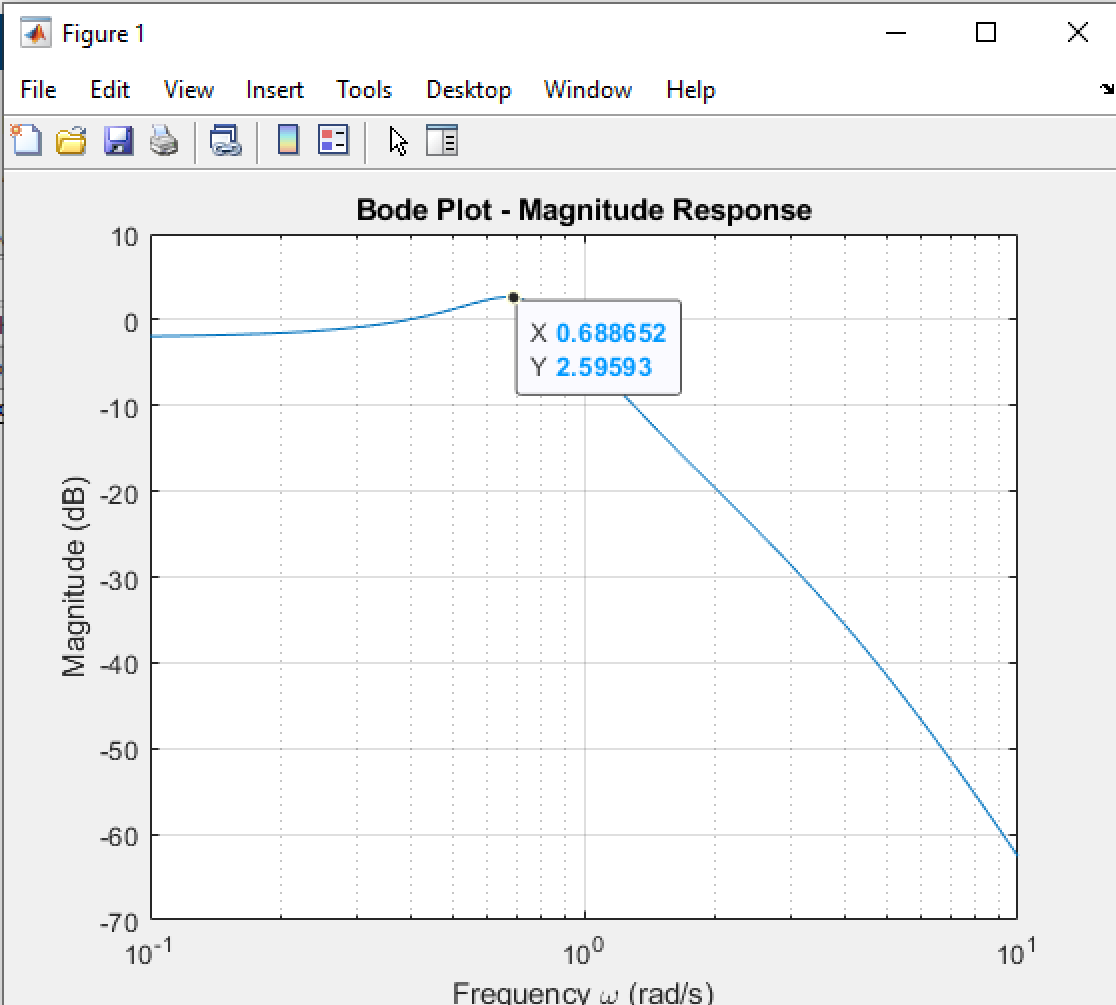


Figure 1
File Edit View Insert Tools Desktop Window Help
Bode Plot - Magnitude Response
X 0.688652
Y 2.59593
10
0
-10
-20
-30
-40
-50
-60
-70
Magnitude (dB)
10^{-1}
10^{0}
10^{1}
Frequency ω (rad/s)

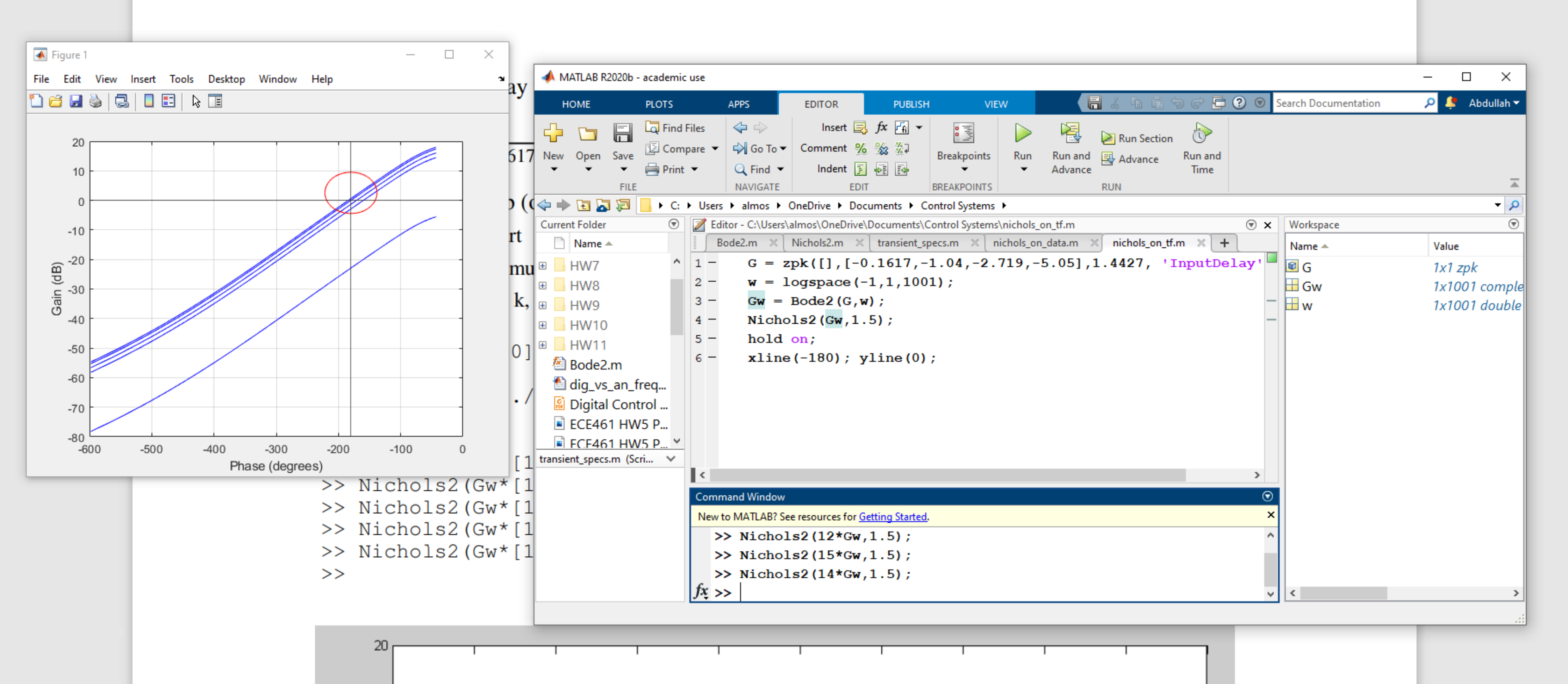


Figure 1
Gain (dB)
Phase (degrees)
MATLAB R2020b - academic use
Editor - C:\Users\almos\OneDrive\Documents\Control Systems\nichols_on_tf.m
G = zpk([],[-0.1617,-1.04,-2.719,-5.05],1.4427, 'InputDelay'
w = logspace(-1,1,1001);
Gw = Bode2(G,w);
Nichols2(Gw,1.5);
hold on;
xline(-180); yline(0);
Command Window
>> Nichols2(12*Gw,1.5);
>> Nichols2(15*Gw,1.5);
>> Nichols2(14*Gw,1.5);
>> Nichols2(Gw*[1
>> Nichols2(Gw*[1
>> Nichols2(Gw*[1
>> Nichols2(Gw*[1
Workspace
G 1x1 zpk
Gw 1x1001 comple
w 1x1001 double

Command Window

New to MATLAB? See resources for Getting Started.

```
>> step(CLTF)
>> stepinfo(CLTF)

ans =

  struct with fields:

        RiseTime: 1.8512
    SettlingTime: 16.1014
     SettlingMin: 0.6828
     SettlingMax: 1.0764
       Overshoot: 36.3585
      Undershoot: 1.0144e-12
            Peak: 1.0764
        PeakTime: 5.4448

fx >>
```