Massachusetts Institute of Technology
2.004 Dynamics and Control II

Lab Section: Tues 3-5pm

Name: Elissa Ito
Collaborators (if any):

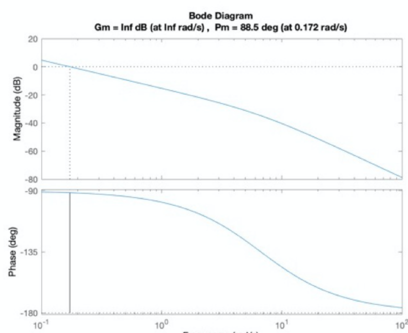
Lab 7 – Frequency Domain Control Design

Prelab

$\tau = 0.15\,s$ $\quad K_{dc} \approx 8.78 \quad K = 0.172$

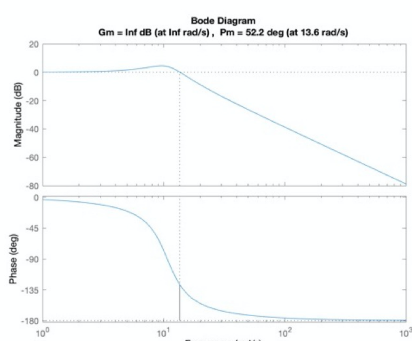
$$G(s) = \frac{\Theta(s)}{V_c(s)} = \frac{K}{\tau s^2 + s} = \frac{0.172}{0.15 s^2 + s}$$

a)



phase margin = 88.5 deg
crossover freq. = 0.172 rad/sec

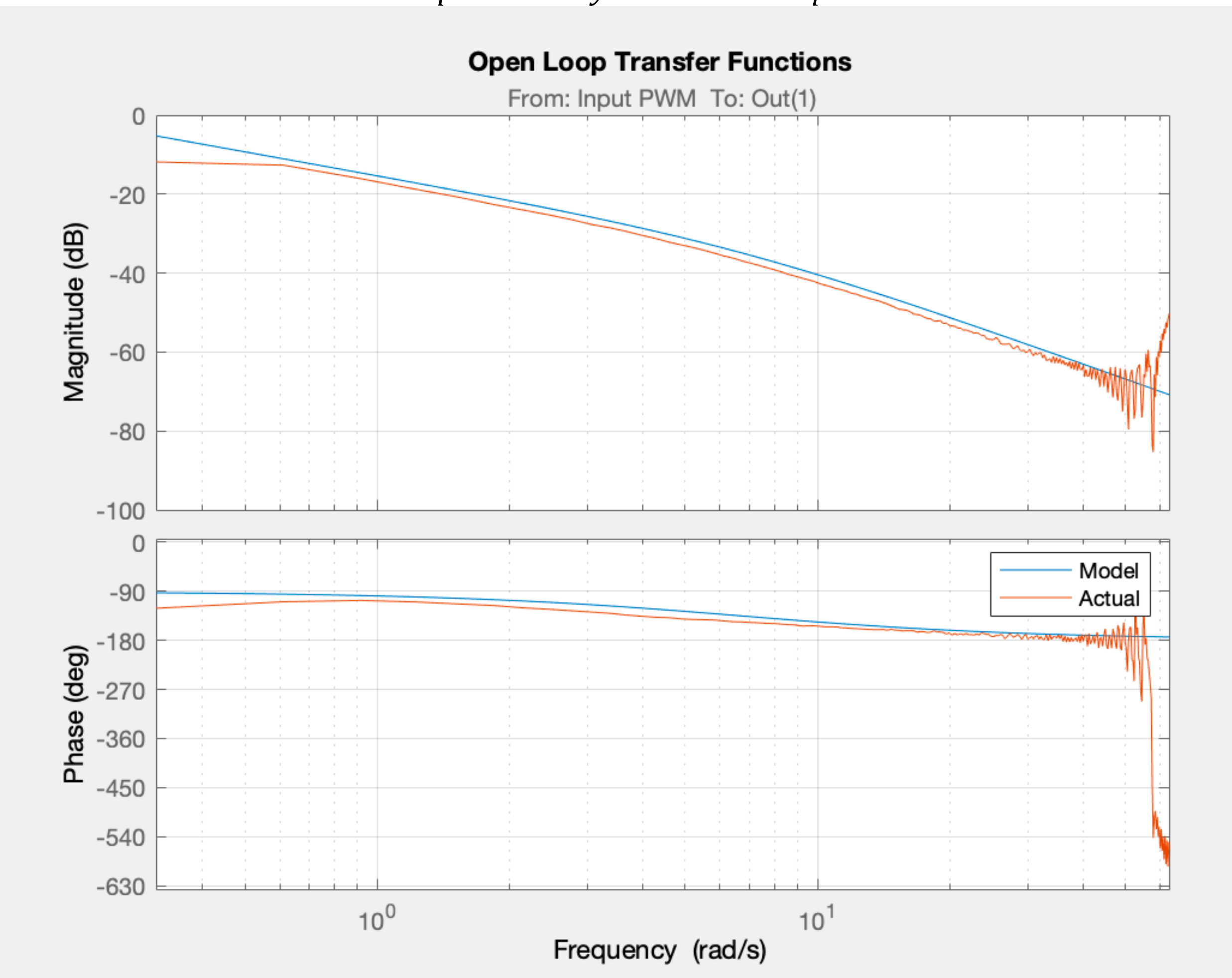
b) $$G_{CL}(s) = \frac{\frac{0.172}{0.15 s^2 + s} \cdot 100}{1 + \frac{0.172}{0.15 s^2 + s} \cdot 100} = \frac{17.2}{17.2 + 0.15 s^2 + s}$$



bandwidth = 15.4765

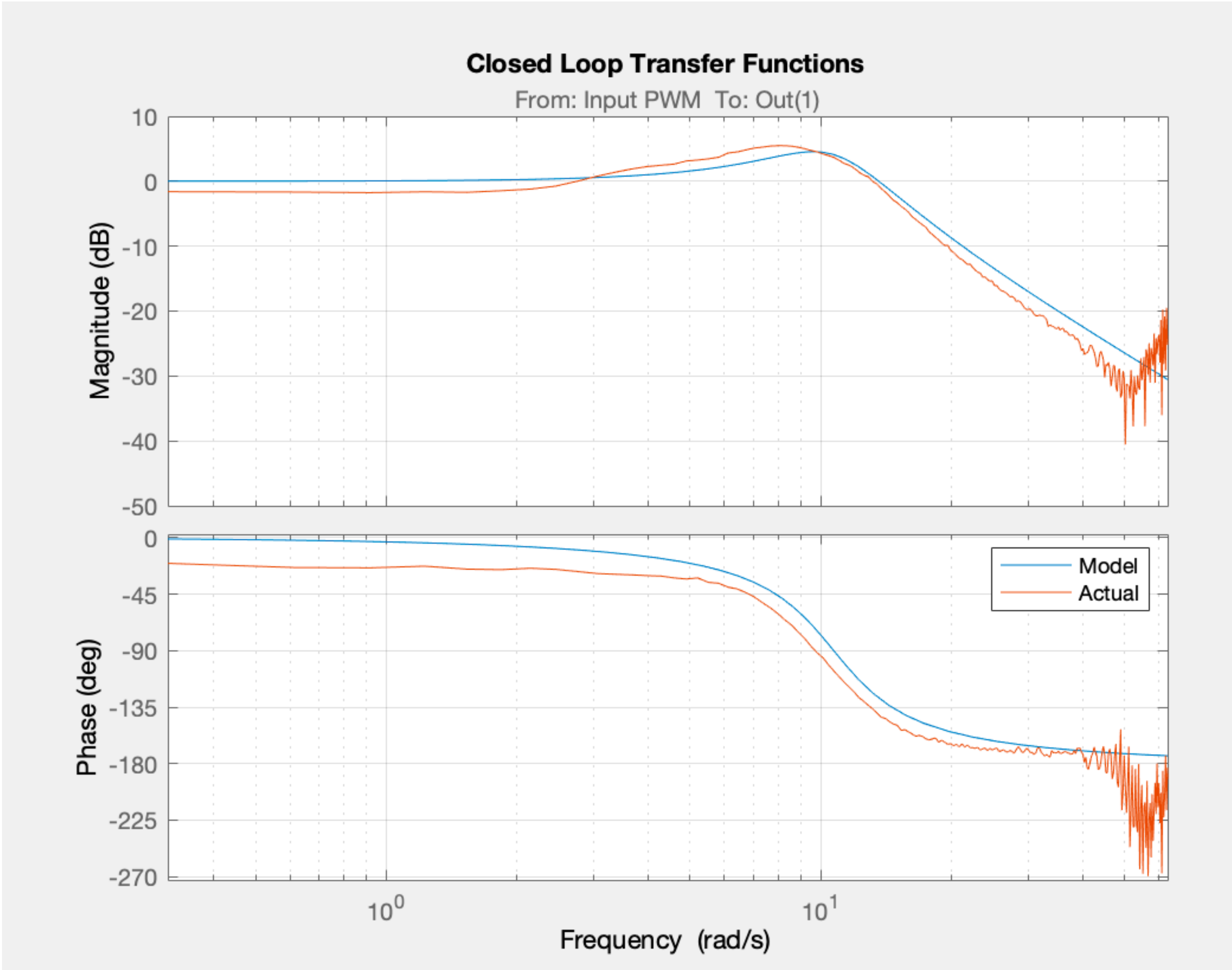
Experiment #1: Open and Closed Loop Bode Plots:

1. *Attach open loop Bode plots and locate the plant poles. Explain the discrepancies between the model and experimentally collected Bode plots.*



0.172/0.15s^2+s
Poles at s=0, -6.6667 (where phase @-90, @-135)
Discrepancy at high and low frequencies – low frequency is deadband and high frequency is oversaturated.

2. *Attach closed loop Bode plots with a proportional controller with* $K_p = 100$*. Explain the discrepancies between the model and measured bode plots.*



Discrepancy at high and low frequencies – low frequency is deadband and high frequency is oversaturated.

3. *When the experiment and model do not agree, is this due to model, or the way we collected data? Explain your reasoning.*

The way we collected data; the friction in the flywheel causes deadband and saturation and low and high frequencies respectively.

Experiment #2. Controller Design:

Time domain step response specifications: overshoot 7% or less, and 2% settling time of 0.4 seconds or less.

%OS<=7 => zeta >= 0.646
*PM ≈100*zeta = 64.6*
*0.4 = 4/(zeta*w_n) => w_n = 15.48*
w_c ≈w_n = 15.48
phi_max = 64.6-27.5 = 37.1

1. *What values of ϕ_m and ω_c should we use to achieve the required time domain performances?*

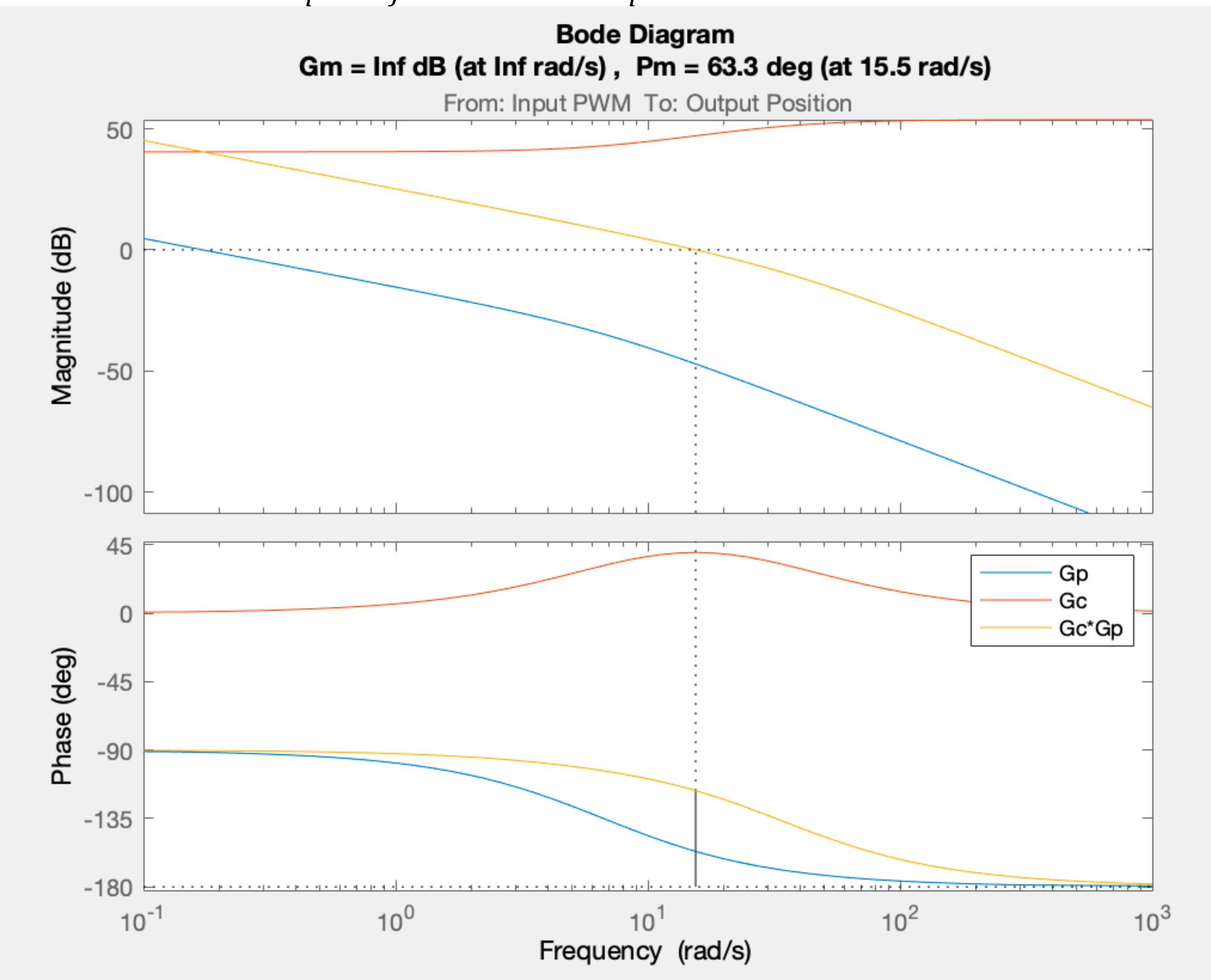
$$PM = 64.6$$

$$\omega_c = 15.48$$

2. *Transfer function of your lead controller:*

$G_c(s)$ =487.51(s+7.218)/(s+33.2)=106.01(0.14s+1)/(0.03s+1)

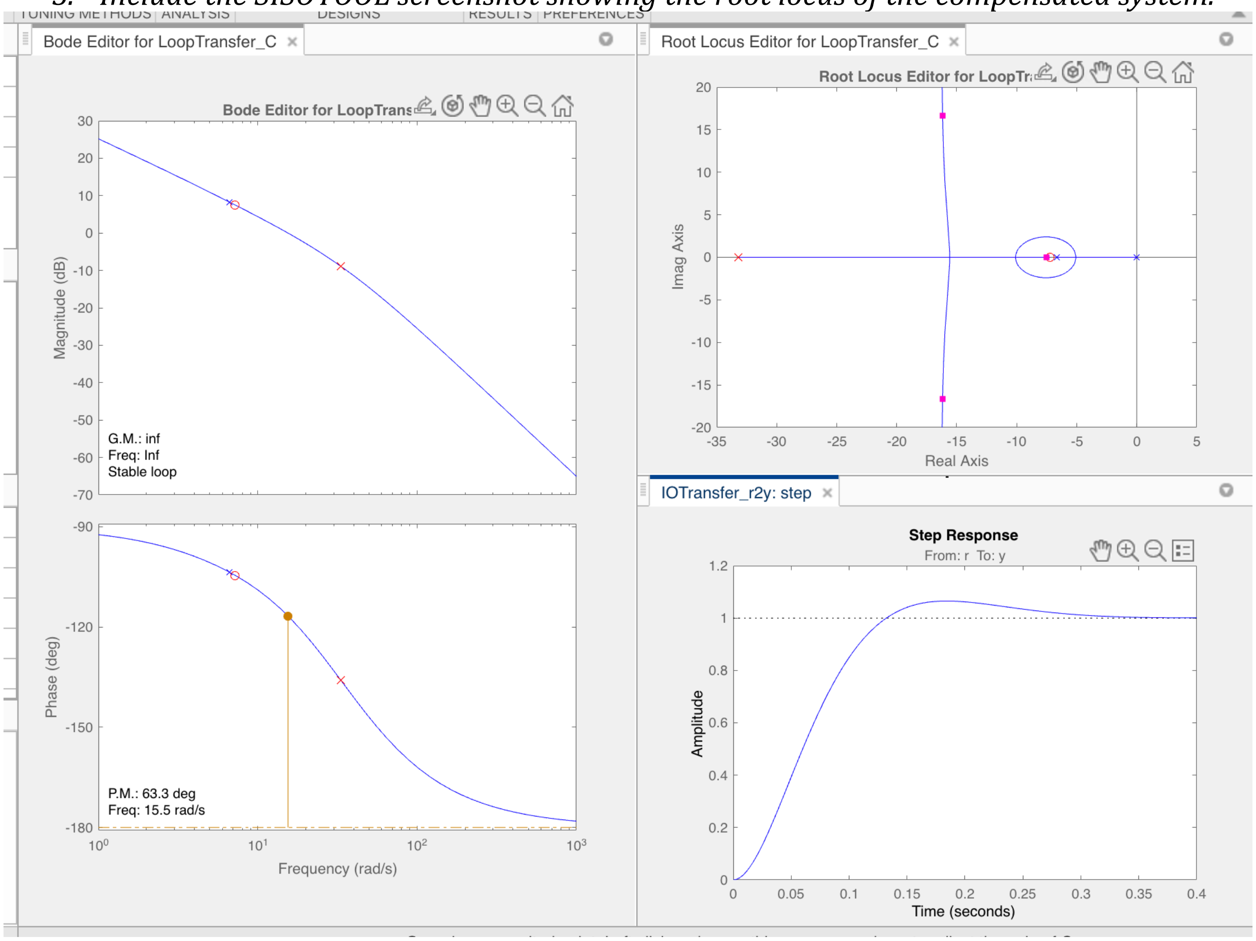
3. *Attach the Bode plots of the simulated responses with the new controller.*



4. *Find the closed-loop step response characteristics by running the MATLAB command:*

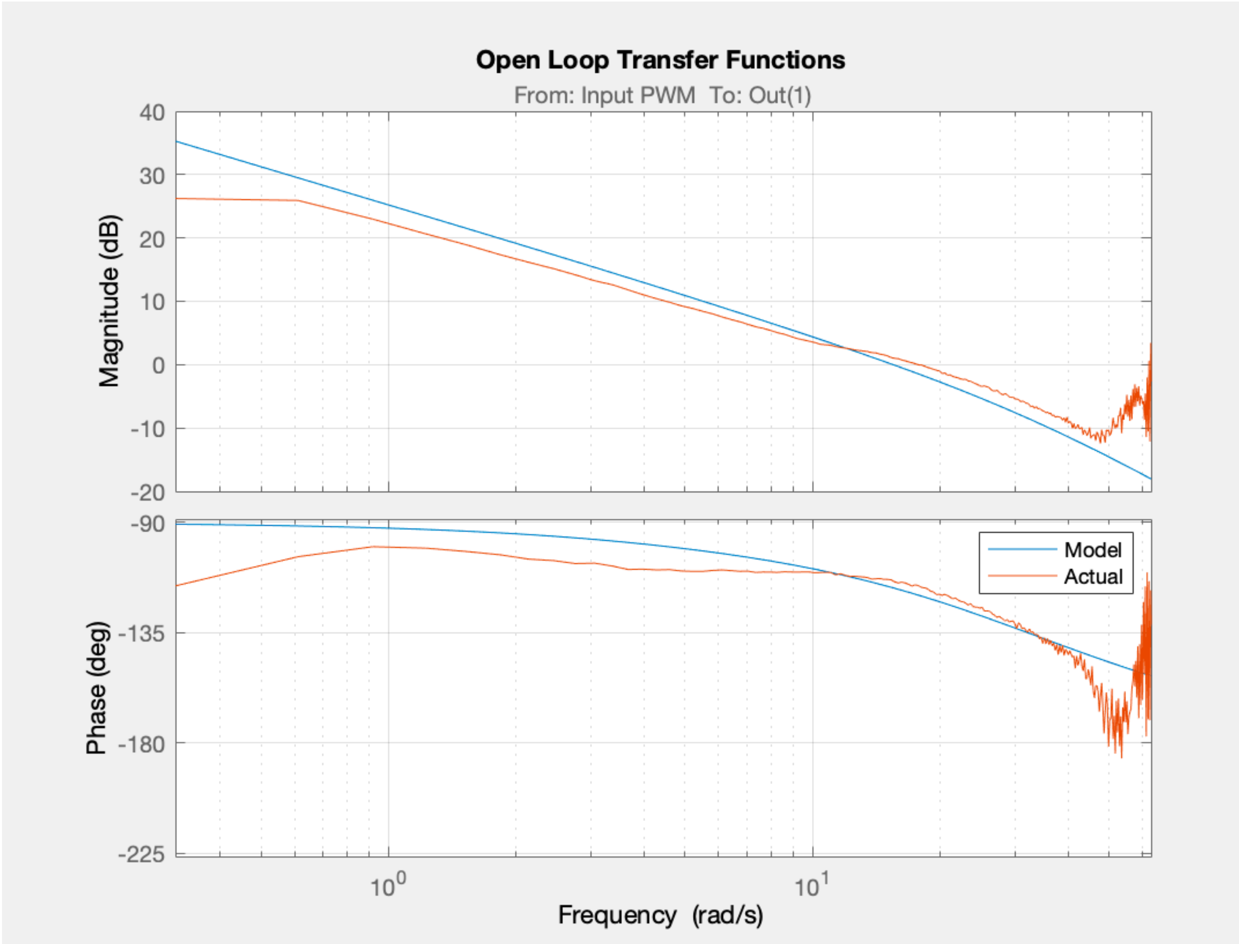
```
stepinfo(feedback(Gc*Gp,1))
        RiseTime: 0.0872
    SettlingTime: 0.2777
     SettlingMin: 0.9138
     SettlingMax: 1.0651
       Overshoot: 6.5078
      Undershoot: 0
            Peak: 1.0651
        PeakTime: 0.1850
```

5. *Include the SISOTOOL screenshot showing the root locus of the compensated system.*



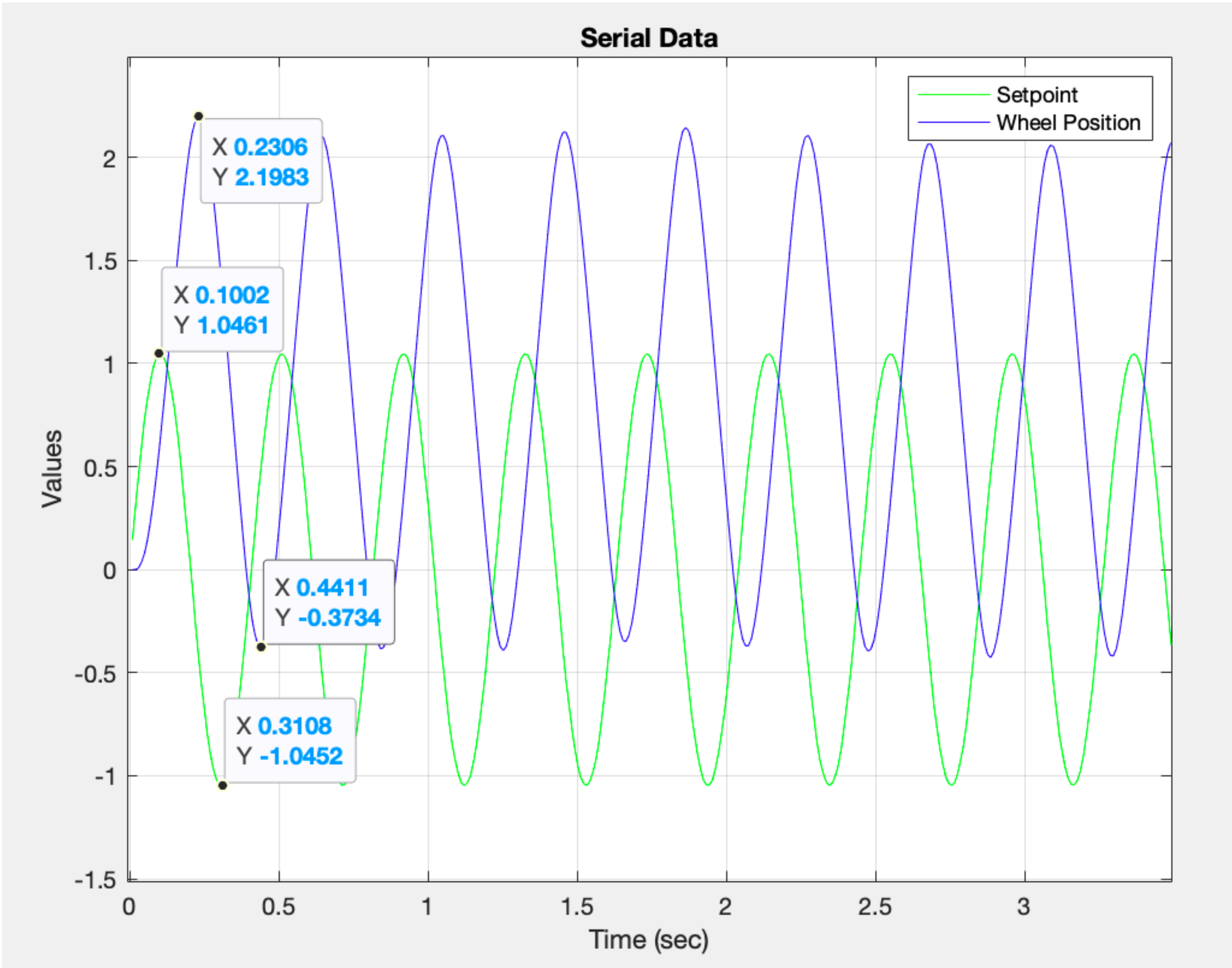
Experiment #3. Controller Testing:

1. *Attach open loop Bode plots for the compensated system, (G_cG_p) and determine the new crossover frequency and phase margin from the actual data.*



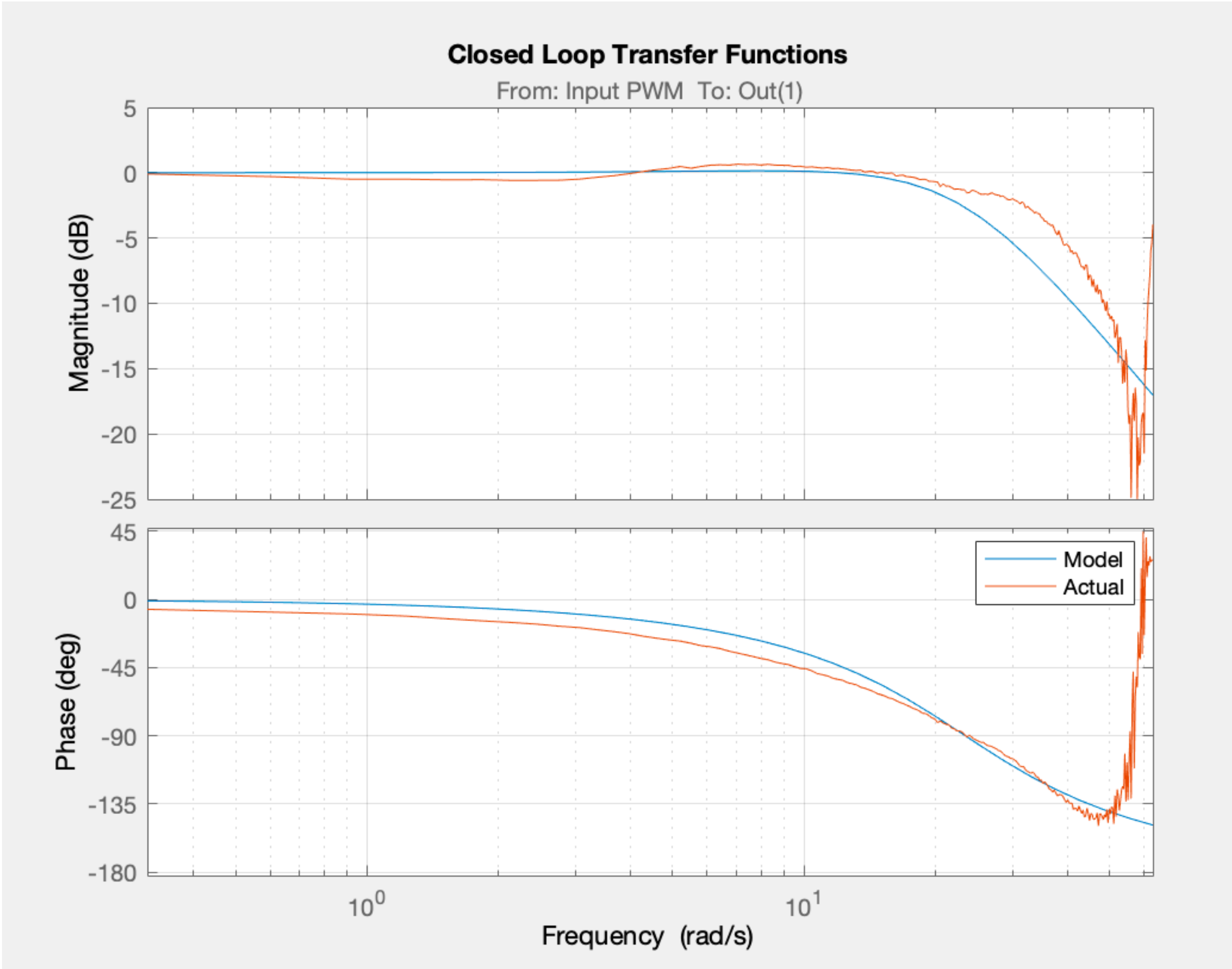
Crossover Freq = 15.4
Phase Margin = 64

2. *Attach the sine wave plot when driven by a frequency equals to the crossover frequency, and include the phase and magnitude information for the crossover frequency. Do they match with the values determined from the open loop Bode plots?*



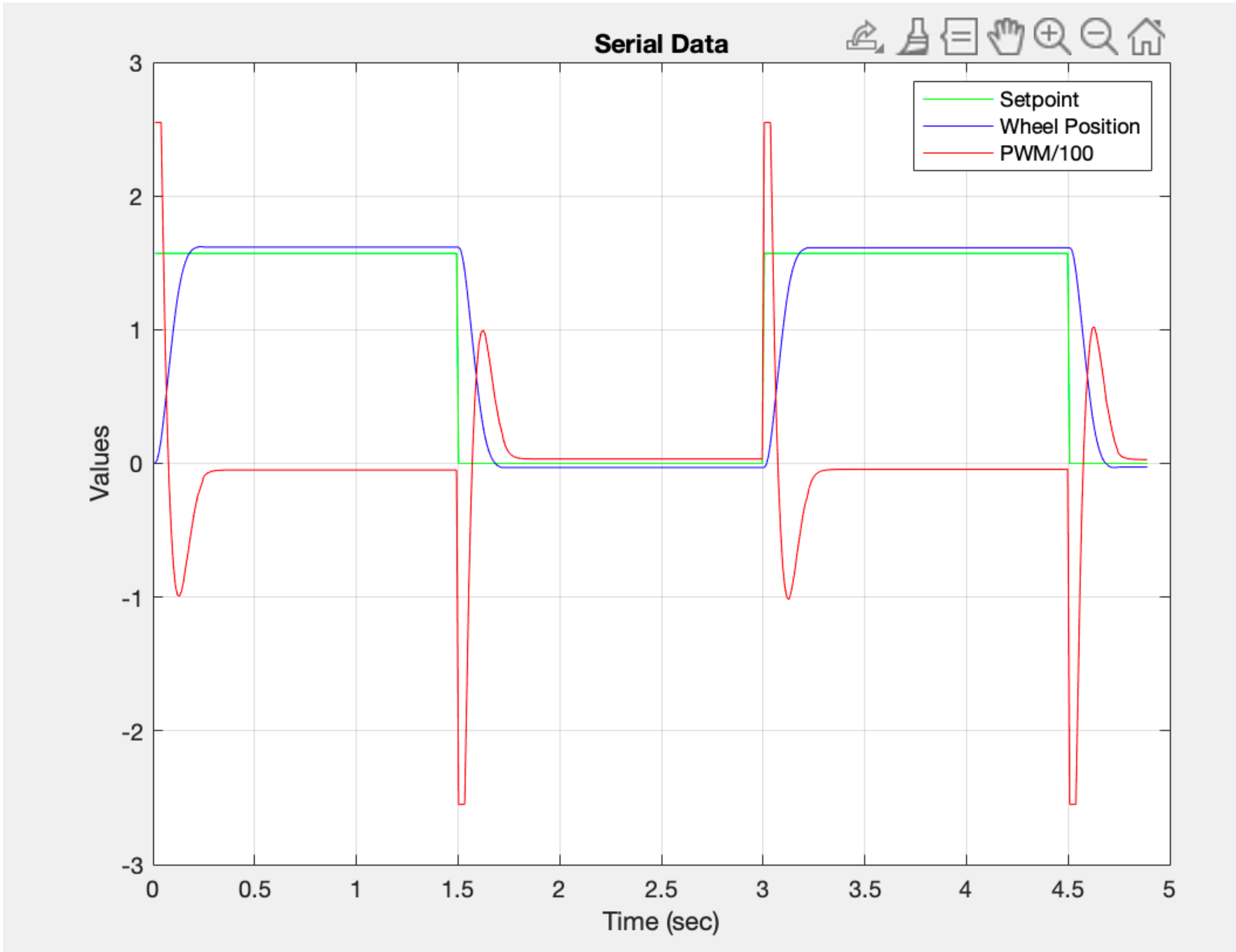
Gain = (2.1983+0.3734)/(1.0461+1.0452) = 1.23 = 1.798dB
Phase = 360(0.1002-0.2306)*2.451=-115.06deg*

3. *Attach the closed loop Bode plots and estimate the closed loop bandwidth.*



Bandwidth = 33.5

4. *Attach the step response of the actual closed loop system. Measure the actual percent overshoot and settling time.*



%OS = 3.7
Ts = 0.22s

5. *Describe the effects of incorporating the lead controller onto the system.*

Incorporating the lead controller caused the step response to reach the transient response a lot faster. It caused a greater overshoot.