Assignment 1

AV224 – Control Systems

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Objective: Design of Proportional + Rate feedback, and Proportional + Derivative (PD) type of compensators for a typical electromechanical engine gimbal control system of launch vehicles and linear system performance assessment using SIMULINK model.

1) Find out the values of undamped natural frequency (ωn), proportional controller gain (K1) and rate feedback controller gain (K2) using a MATLAB program which use the parameter values of the plant dynamics, sensor scale factors and closed specifications. Write down the values below:

MATLAB Code:

Declaring Variables

```
% Motor torque constant
KT = 0.181; % (N-m/A)
% Motor back emf constant
KB = 0.181; % (V/(rad/sec))
% MI of motor rotating assembly
Jm = 1.1694e-4; % (Kg-m2)
% MI of Engine gimbal
JL = 12.753; % (Kg-m2)
% Ball screw gear ratio : pitch of ball screw/actuator moment arm x
2pie rad
N = 1/398; % = Nm/NL = 0.005 m/(0.3166 mx 2pie rad)
% Viscous damping coefficient of motor shaft
Bm = 2.943e-4; % (N-m/(rad/sec))
% Viscous damping coefficient of the Engine gimbal
BL = 58.86; % (N-m/(rad/sec))
% Armature resistance
Ra = 8.6; % ohms
% Position sensor scale factor
Kp = 0.36; % V/rad (10V corresponds to 4*398 deg deflection of
motor shaft)
% Tacho generator scale factor
KTG = 0.1; % (V/(rad/sec))
% -3 dB Bandwidth
wb = 2*pi*5; % (rad/2) for fb=5Hz
% damping factor
zeta = 0.6;
```

Parameter Values

```
J = Jm + (N^2)*JL;
B = Bm + KT*KB/Ra + (N^2)*BL;
K = KT/Ra;
wn=wb/(sqrt((1-2*((zeta).^2)) + sqrt(4*((zeta).^4) - 4*((zeta).^2)
+ 2)))
```

```
wn = 27.3600
```

```
K1=((wn.^2)*J)/(Kp*K)
```

```
K1 = 19.5077
```

```
K2=(2*zeta*wn*J-B)/(K*KTG)
```

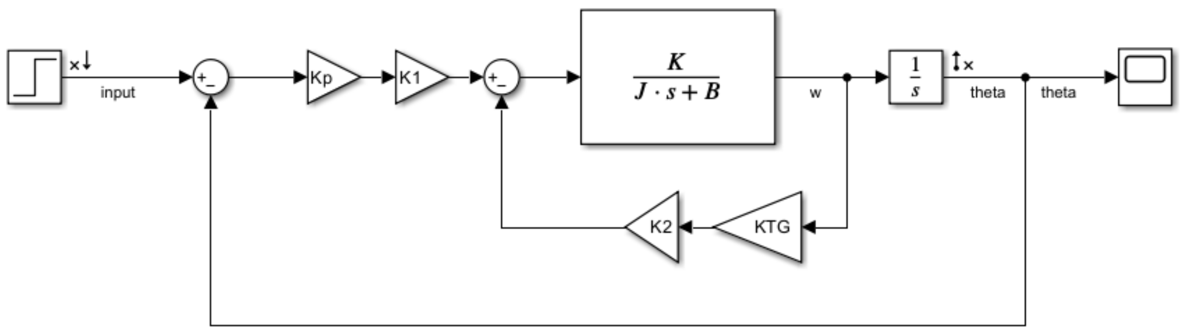
```
K2 = 0.9538
```

```
Kd=K2*KTG/Kp;
```

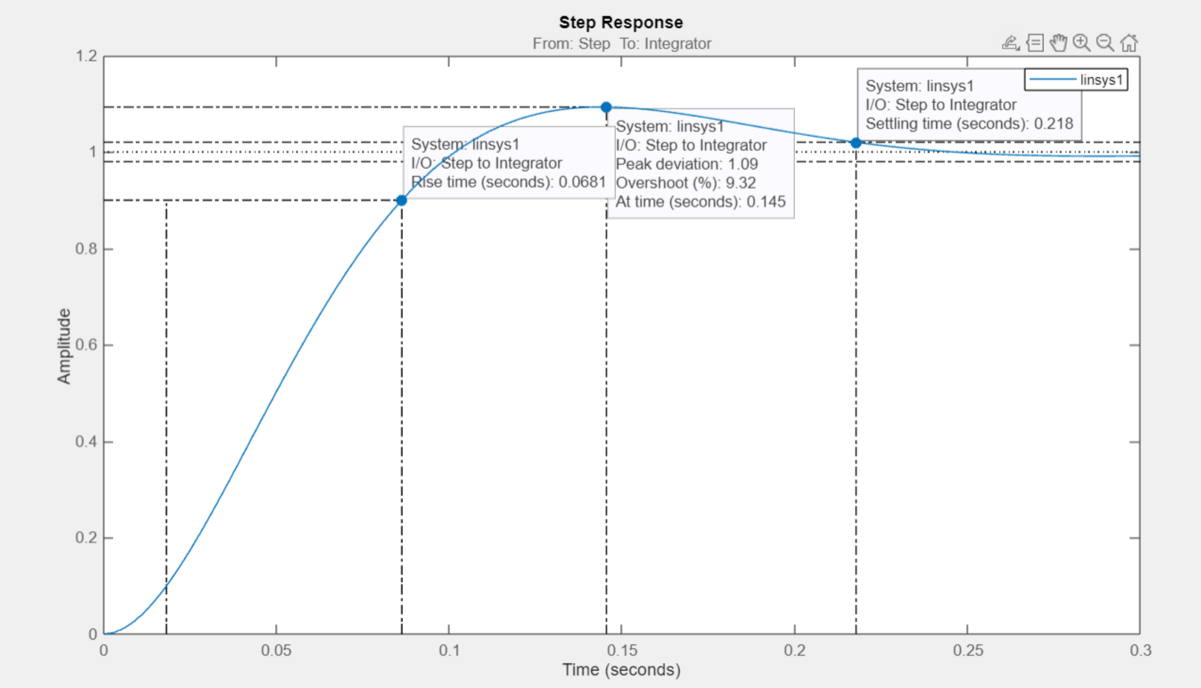
ωn = 27.36 rad/sec , K1= 19.5077 , K2 = 0.9538

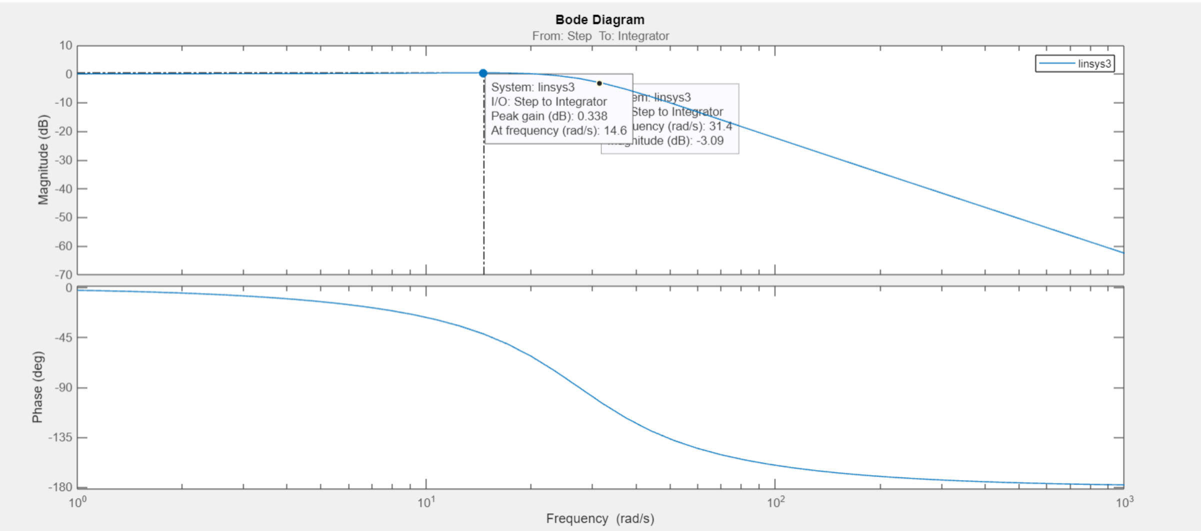
2) Build up a Simulink model for the closed loop system and find out the following performances using SIMULINK LTI Viewer a) – 3 dB bandwidth b) M –peak c) Peak Overshoot for step response d) Rise time e) Settling time

SIMULINK Simulation:



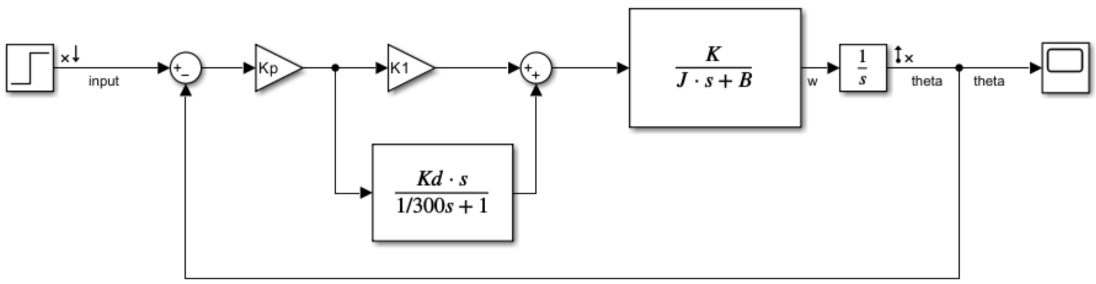
Linear Time Analysis:



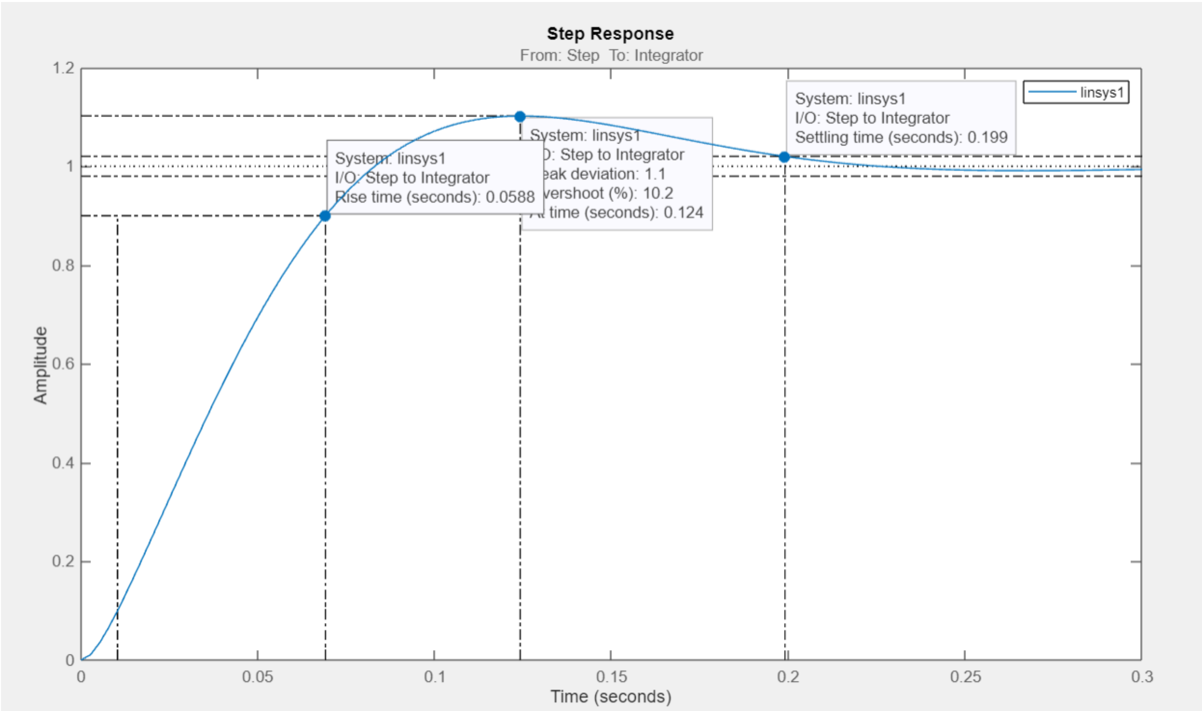


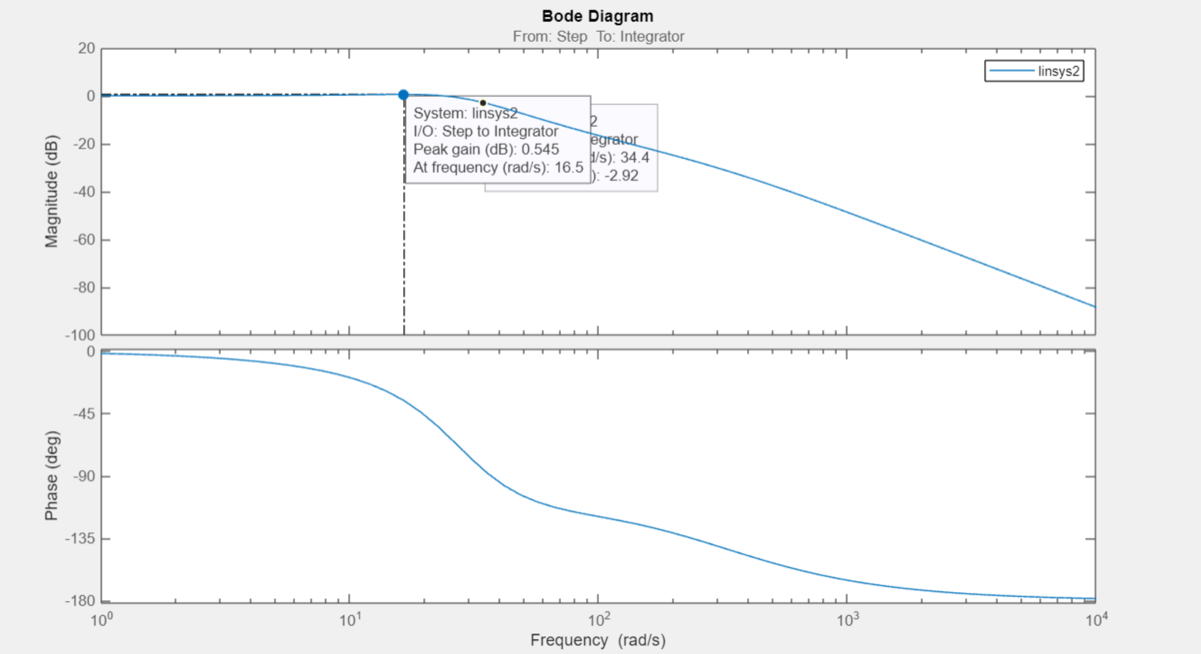
3) Add a derivative controller ` G(s) = Kd.s/(1+s/300)' where Kd = K2*KTG/Kp in parallel with the K1 and remove the rate feedback controller, K2. Repeat the exercise in section (2) for this PD controller.

SIMULINK Simulation:



Linear Time Analysis:





4) Make a performance comparison table as given below:

Performance Parameter	P + Rate feedback	PD Control
-3 dB Bandwidth (Hz)	4.99	5.47
M peak (dB)	0.338	0.545
Peak Overshoot (%)	9.32	10.2
Rise time (m.sec)	68.1	58.8
Settling time (m.sec)	218	199

5) Give your comments on the performance comparison.

Answer:
(i) In PD controller the speed of response is higher.
(ii) -3dB Bandwidth: Greater for PD.
(iii) M peak varies. It's less for PR and higher for PD.
(iv) %OS is almost the same . It is slightly less for PR controller.
(v) Rise time is lower for the PD controller.
(vi) Settling time is lower for PD controller.
(vii) PD controller performs differently in almost all aspects when compared to PR controller. PD controller reduces SS error at the same time improves transient response. (Lower Ts value).