AUTONOMOUS INDYCAR CONTROLLER

ALEC HUDSON, SETH PEEBLES, DALTON ROBINSON

OBJECTIVES

- Develop Controller to Manipulate Autonomous Vehicle's Steer Angle
  - Obtain transfer function for Steering Dynamics
  - Obtain transfer function for Lateral Steering Dynamics
  - Simulate developed Model and run_car.p in MATLAB with Given Parameters
  - Develop controller for Indy Car
  - Simulate Model and run_car.p with controller
  - Simulate controller response at the Indianapolis Motor Speedway
  - Analyze results

THE MODEL (A)

System Identification Approach

- **Bicycle Model**

$$\sum F_y = F_{R,y} + F_{F,y}\cos\delta = m * V_{car} * \dot{\psi} + m * \dot{V}_{y,car}$$

$$\sum M_c = I_z * \ddot{\psi} = -F_{R,y} * b + F_{F,a} * a$$

$$\frac{\delta}{\delta_{com}} = \frac{1}{Fs + G}$$

$$\frac{\dot{\psi}_{(s)}}{\delta_{(s)}} = \frac{Ds + E}{As^2 + Bs + C}$$

$$A = I_z m$$

$$B = \frac{(I_z c_0 + c_2 m)}{V_{car}}$$

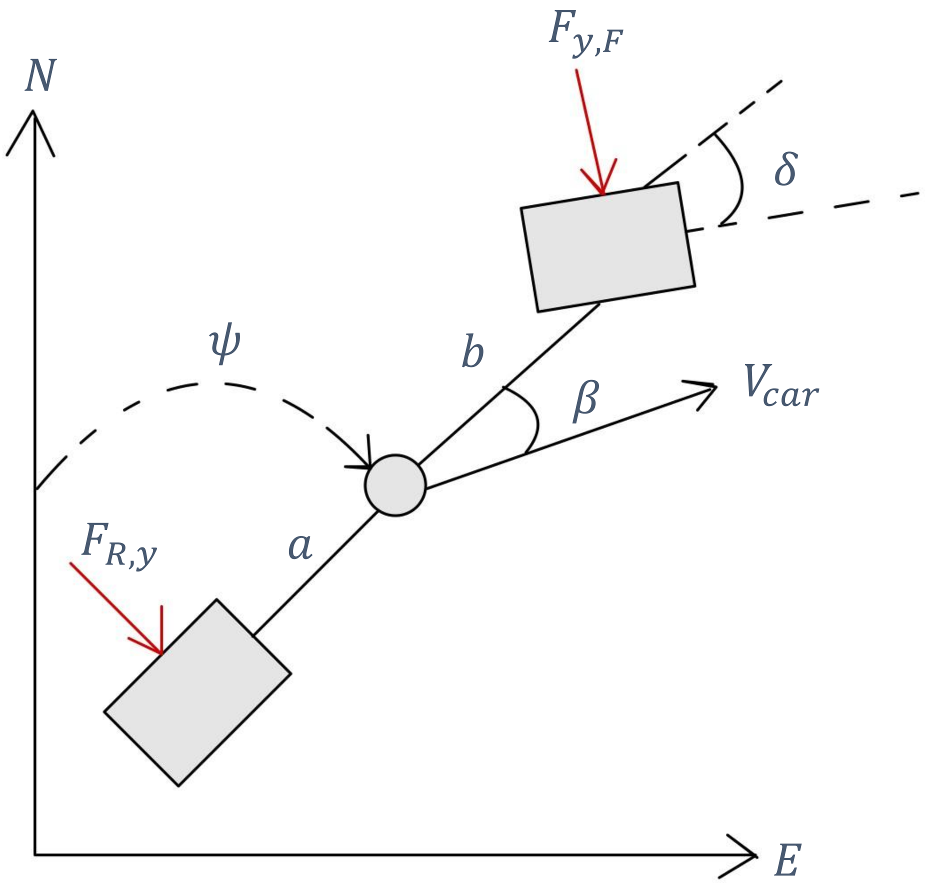
$$C = \frac{\left(c_2 c_0 - c_1 m {V_{car}}^2 - {c_1}^2\right)}{{V_{car}}^2}$$

$$D = c_f a m$$

$$E = \frac{\left(c_f c_0 a - c_1 c_f\right)}{V_{car}}$$

$$F = 0.1$$

$$G = 1$$

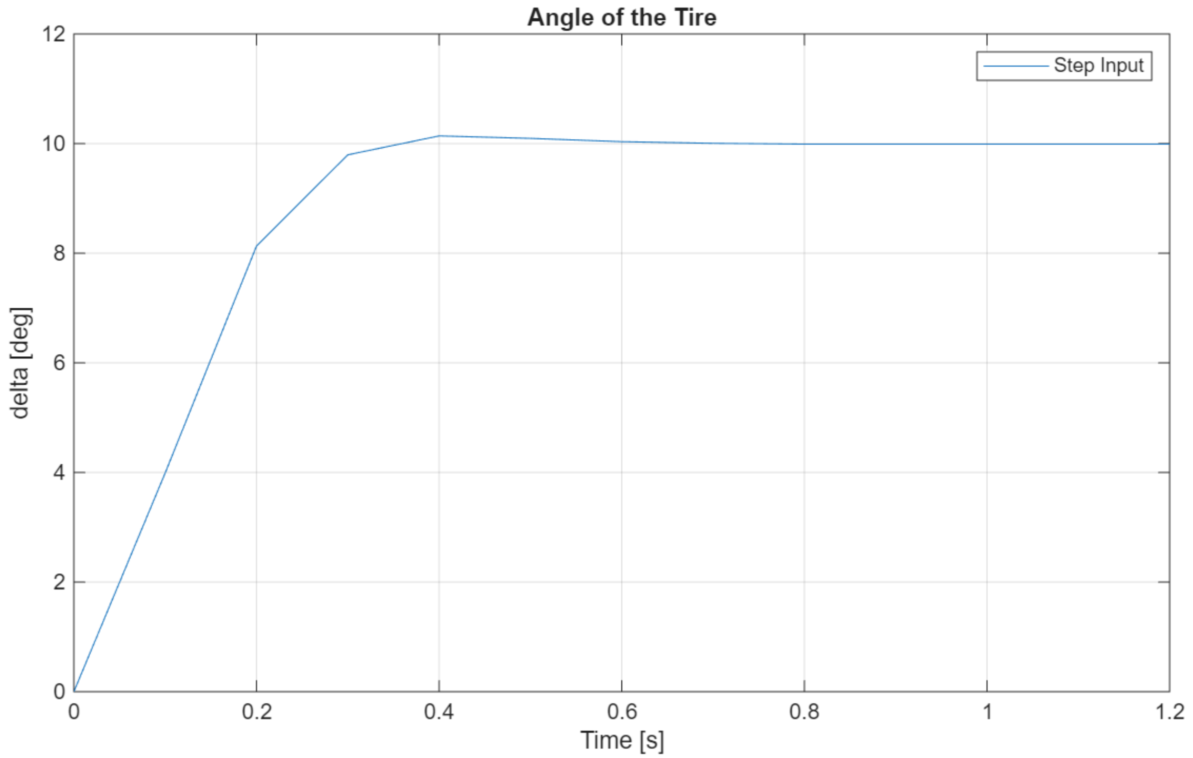


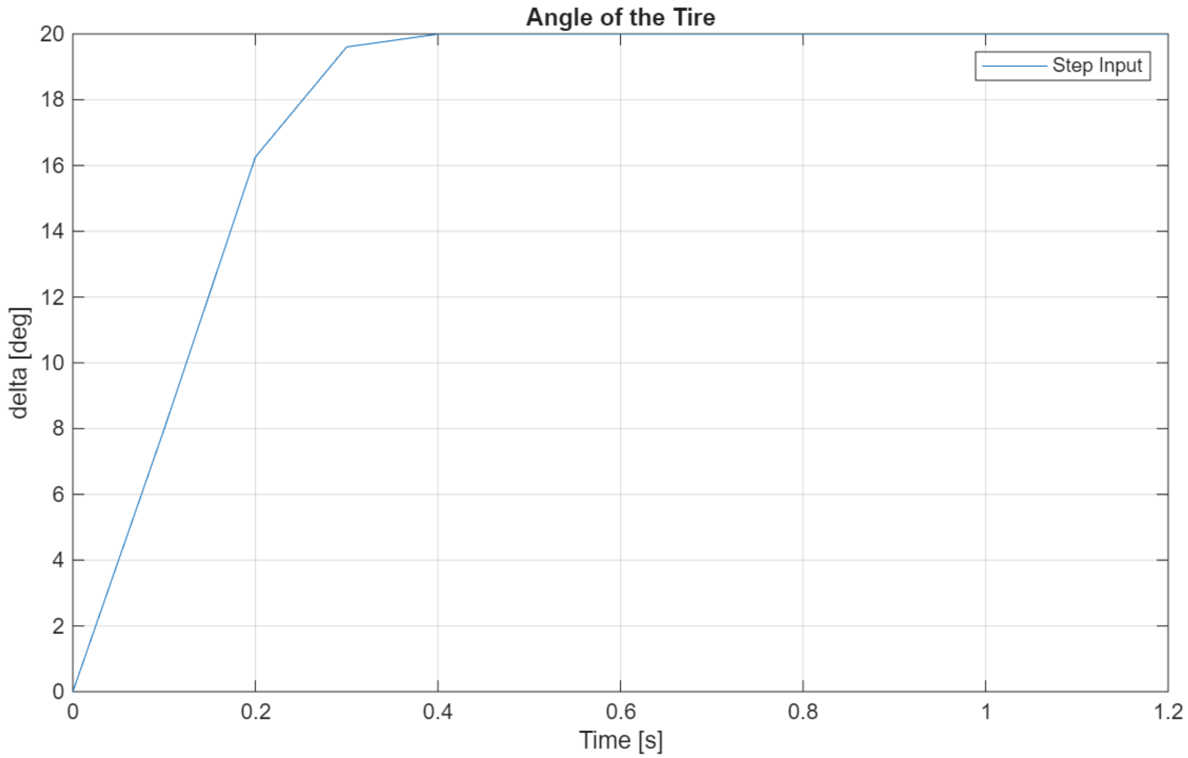
$$c_0 = c_f + c_r$$

$$c_1 = c_f a - c_r b$$

$$c_2 = c_f a^2 + c_r b^2$$

STEERING DYNAMIC MODEL IDENTIFICATION (A)





$\delta_{com} = 10°$

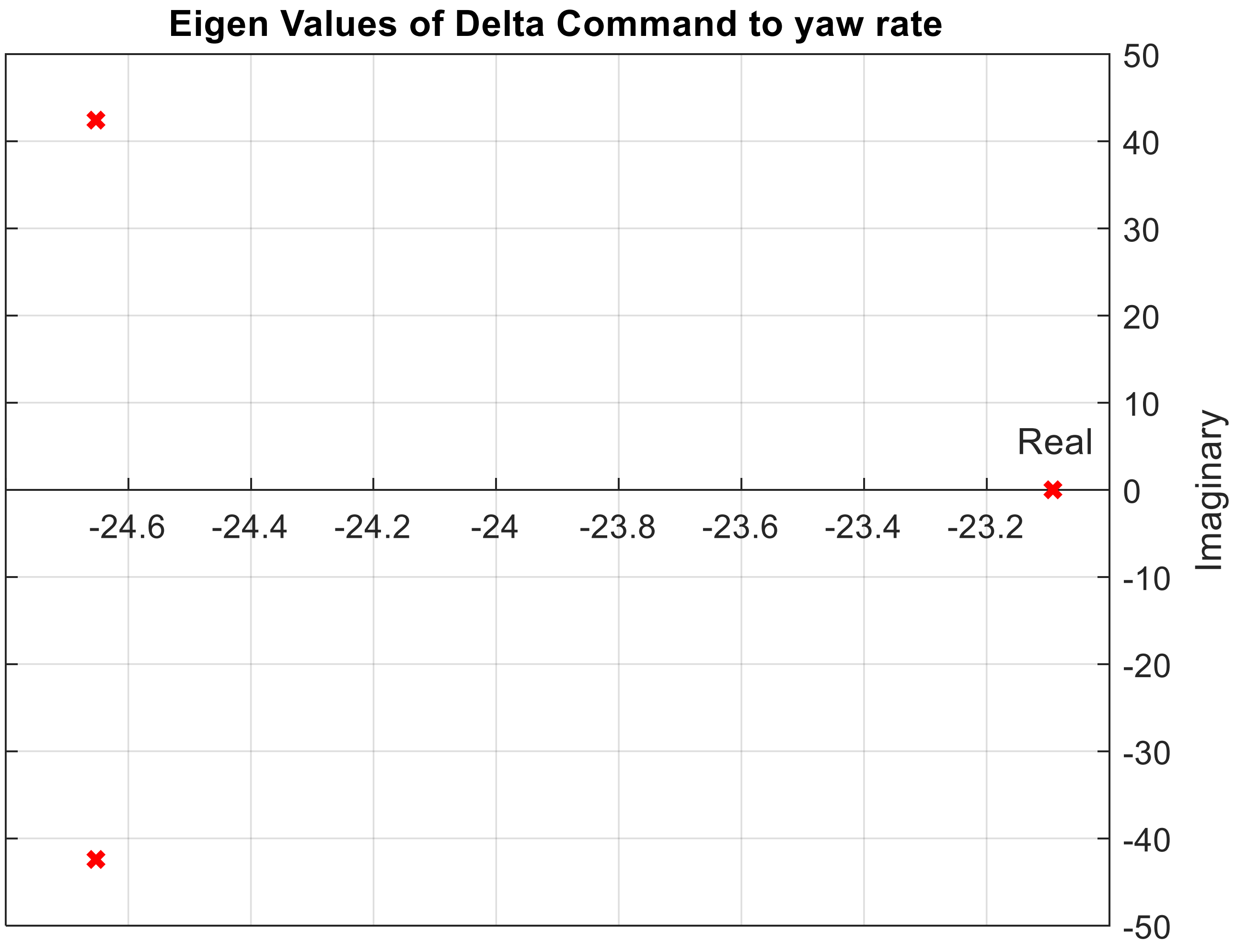
$\delta_{com} = 30°$

OPEN LOOP BLOCK DIAGRAM (A)

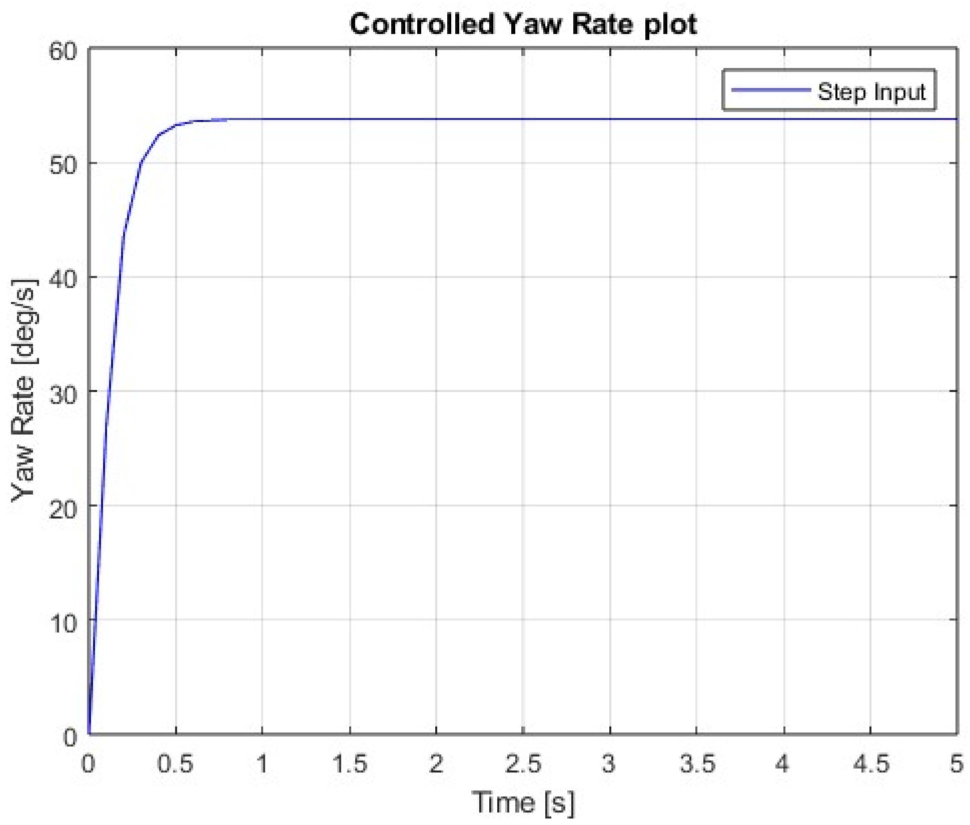
$$\delta_{com} \longrightarrow \boxed{\frac{1}{Fs+G}} \longrightarrow \boxed{\frac{Ds+E}{As^2+Bs+C}} \longrightarrow \dot{\psi}$$

$$\frac{\dot{\psi}}{\delta_{com}} = \frac{Ds+E}{(AF)s^3+(AG+BF)s^2+(BG+CF)s+CG}$$

EIGEN VALUE PLOT FOR DELTA COMMAND TO YAW RATE (A)



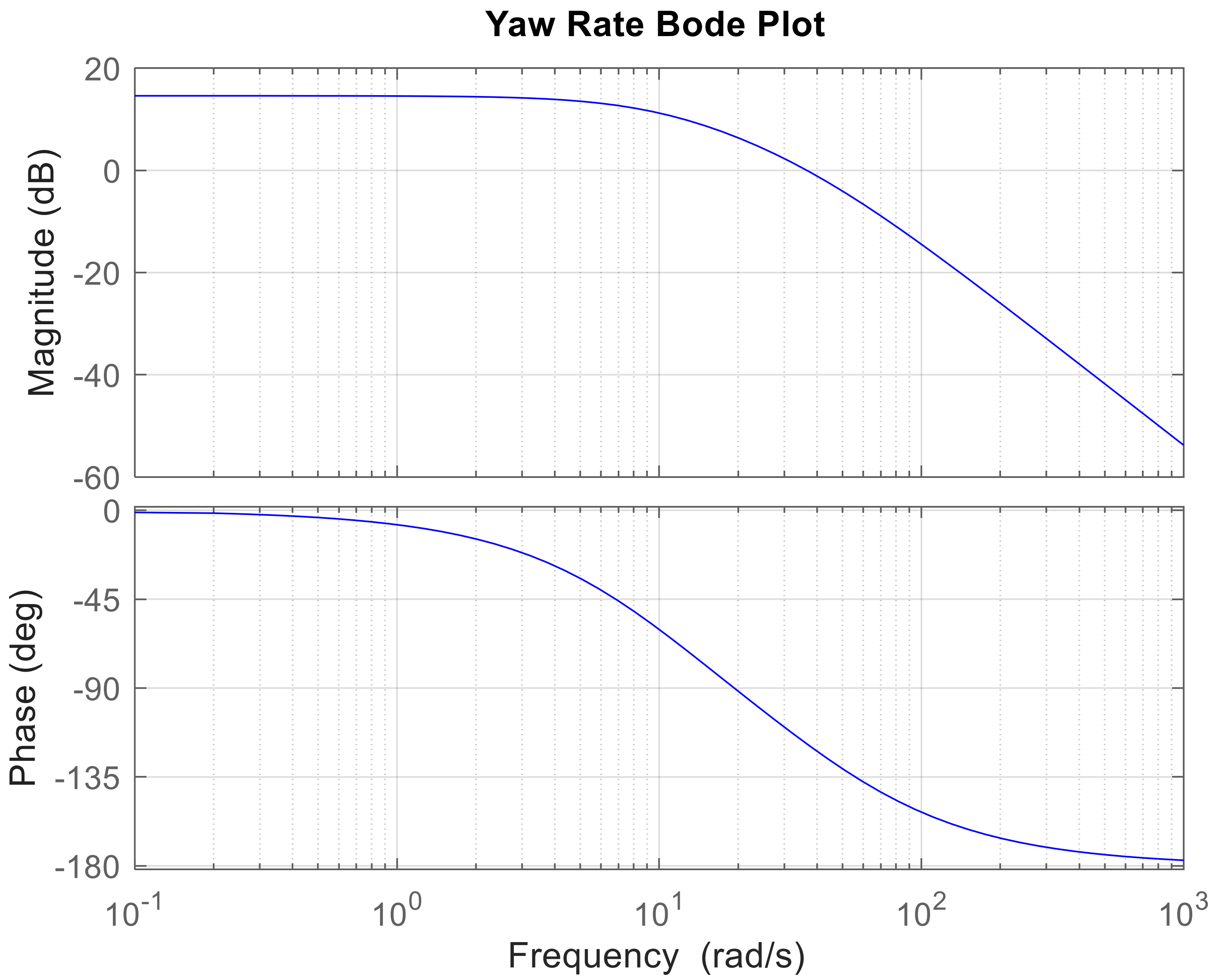
THE STEP RESPONSE GIVEN DELTA COMMAND (A)



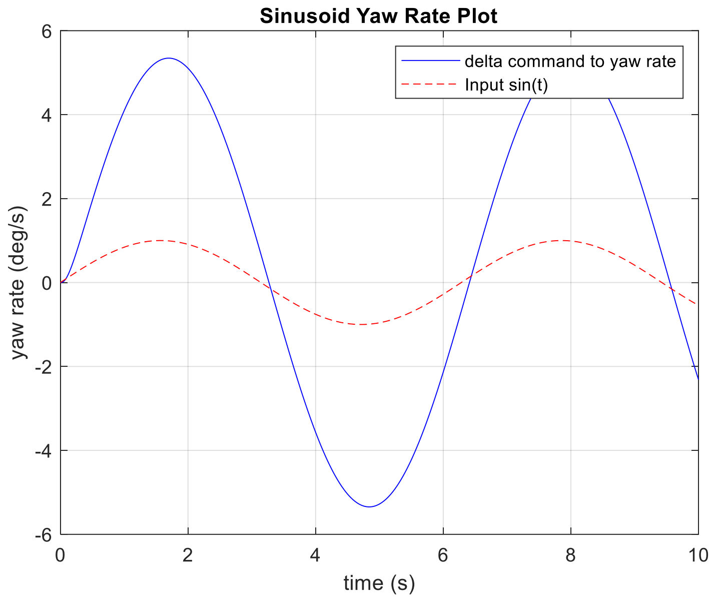
Input Steer Angle $\delta_{com} = 10°$

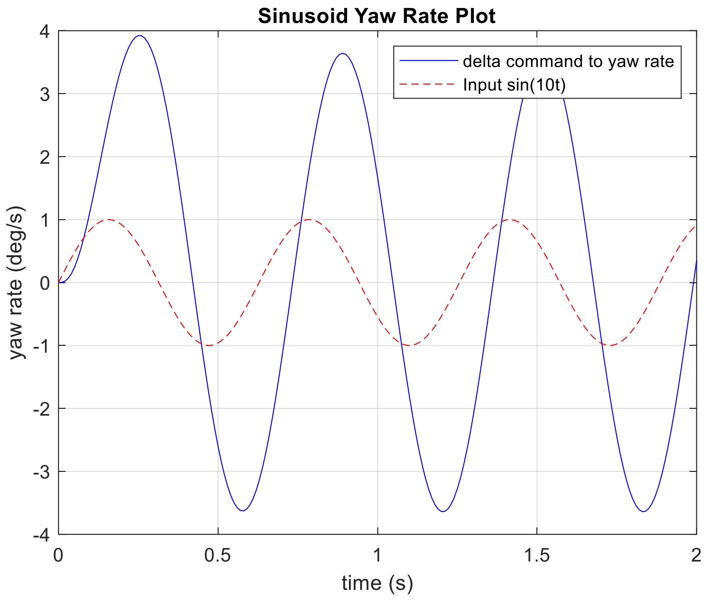
$$\frac{\dot{\psi}}{\delta_{com}} = \frac{Ds + E}{(AF)s^3 + (AG + BF)s^2 + (BG + CF)s + CG}$$

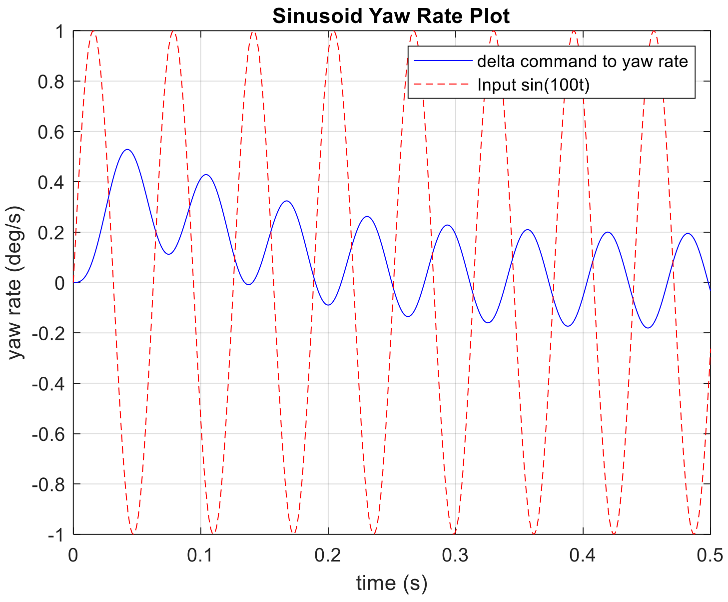
THE BODE PLOTS (A)



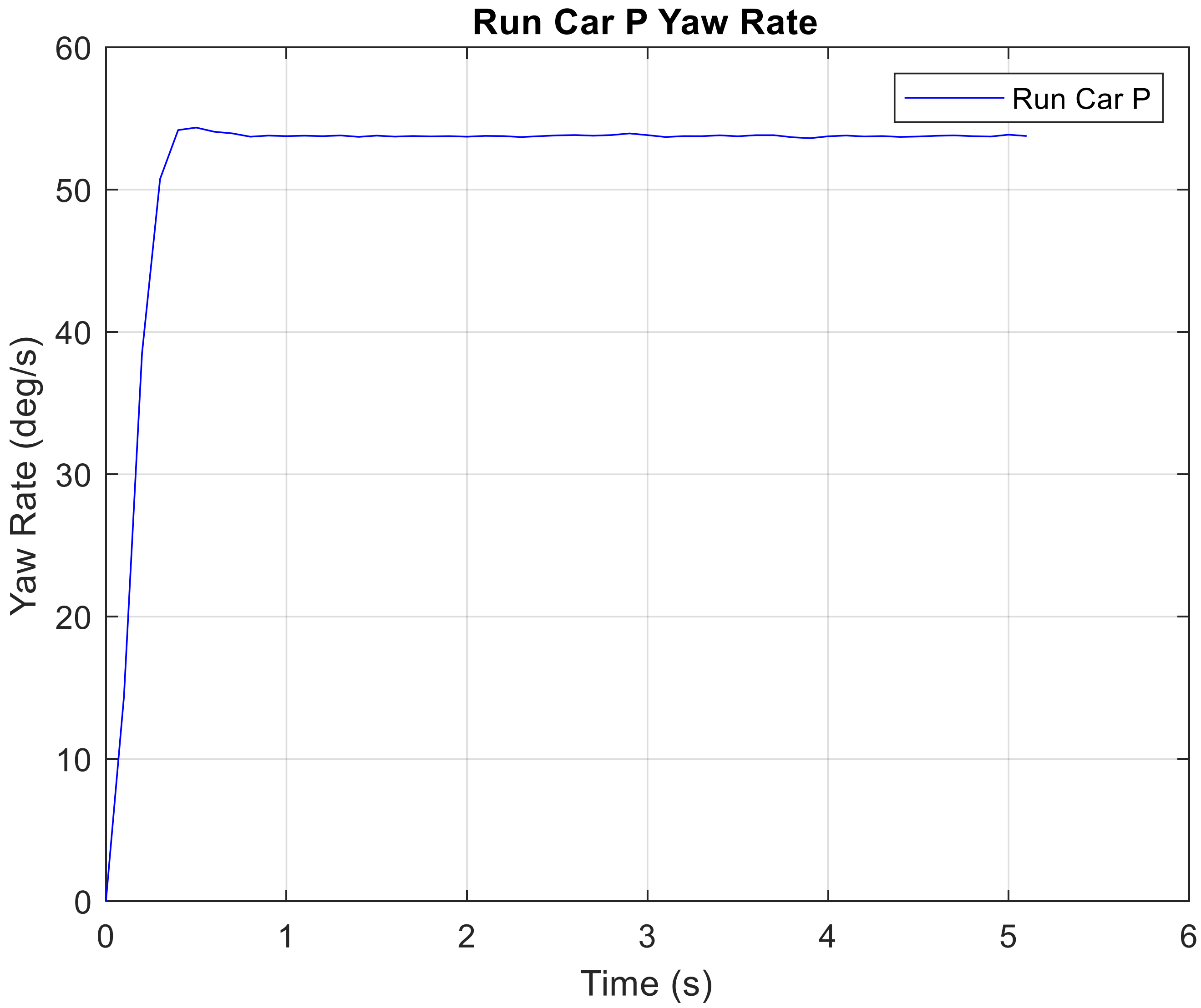
SINUSOID INPUT GIVEN DELTA COMMAND (A)



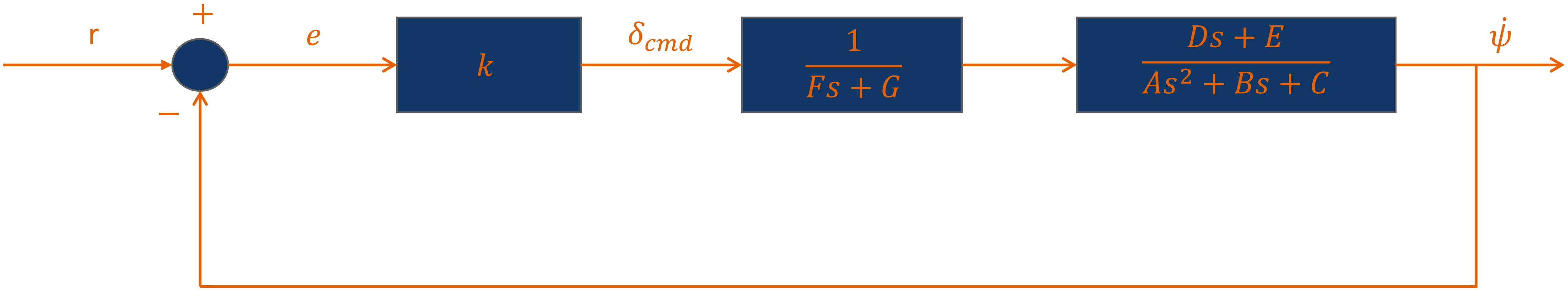




RUN_CAR.P RESPONSE (A)



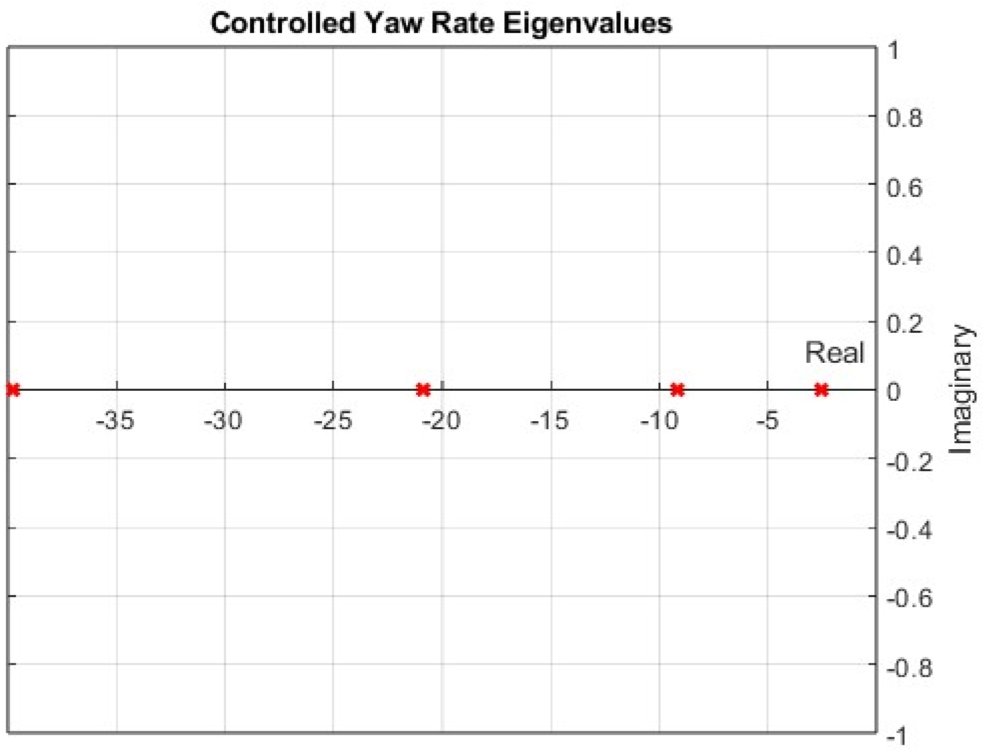
CONTROL LOOP BLOCK DIAGRAM (B)

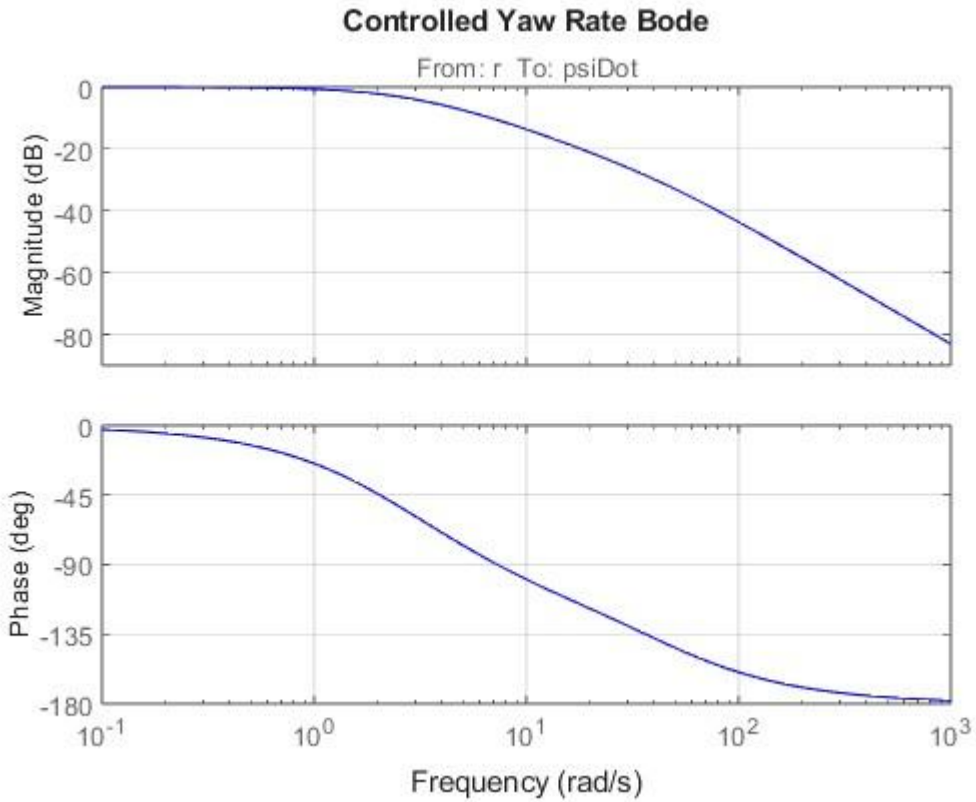


$$\frac{\dot{\psi}}{\delta_{com}} = \frac{K_pDs^2 + (K_pE + K_ID)s + K_IE}{AFs^4 + (BF + AG)s^3 + \left(CF + BG + K_pD\right)s^2 + \left(CG + K_pE + K_ID\right)s + K_IE}$$

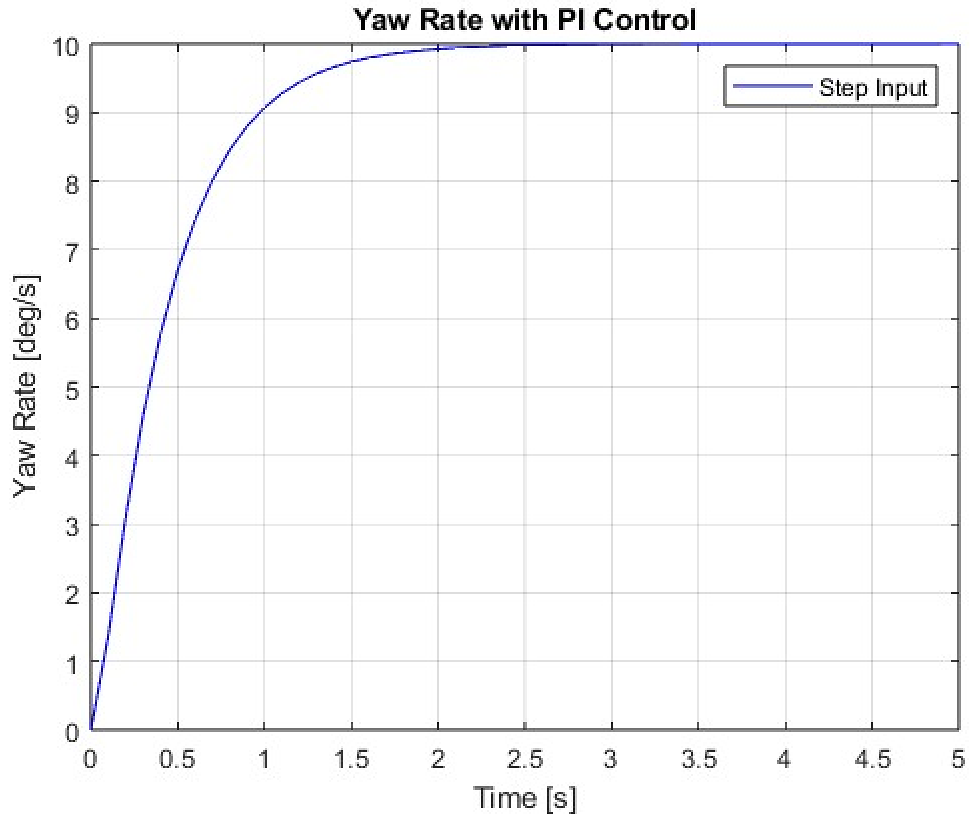
$$\delta_{cmd} = 0.0343 * e + 0.415 \int edt$$

PI CONTROLLER RESPONSE GIVEN STEP INPUT (B)



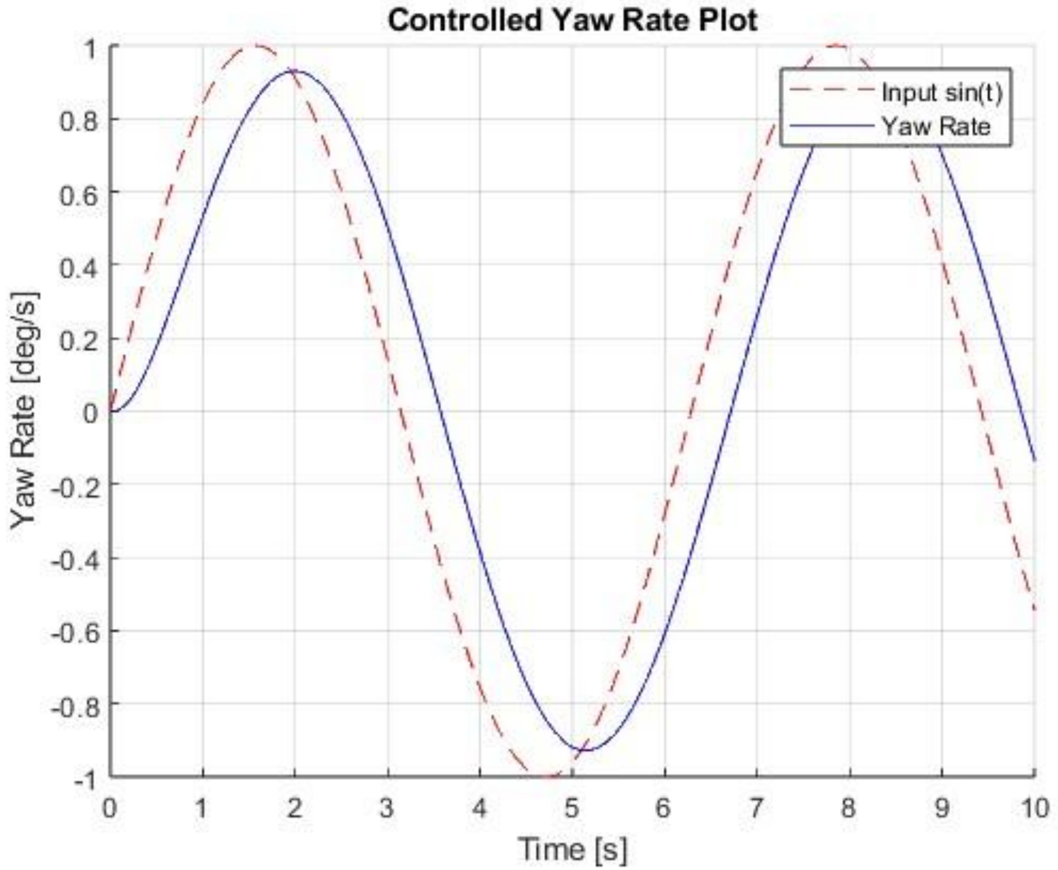


PI CONTROLLER RESPONSE GIVEN STEP INPUT (B)



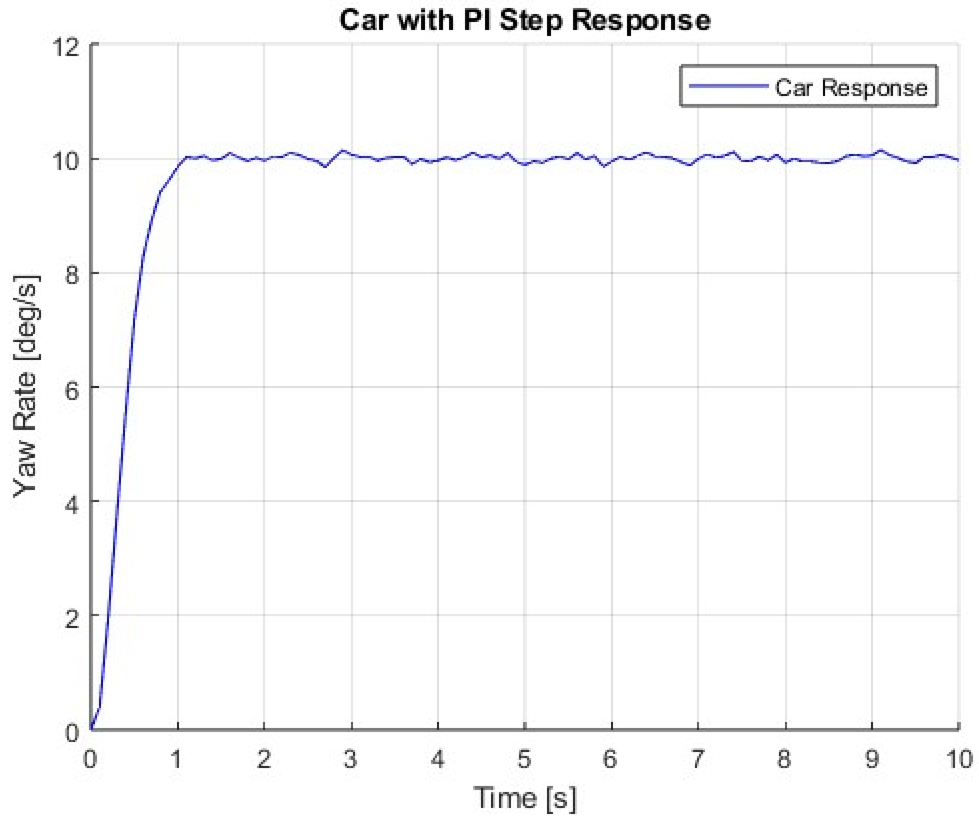
$\dot{\psi}_{cmd} = 10°$

PI CONTROLLER RESPONSE GIVEN SINUSOID INPUT (B)



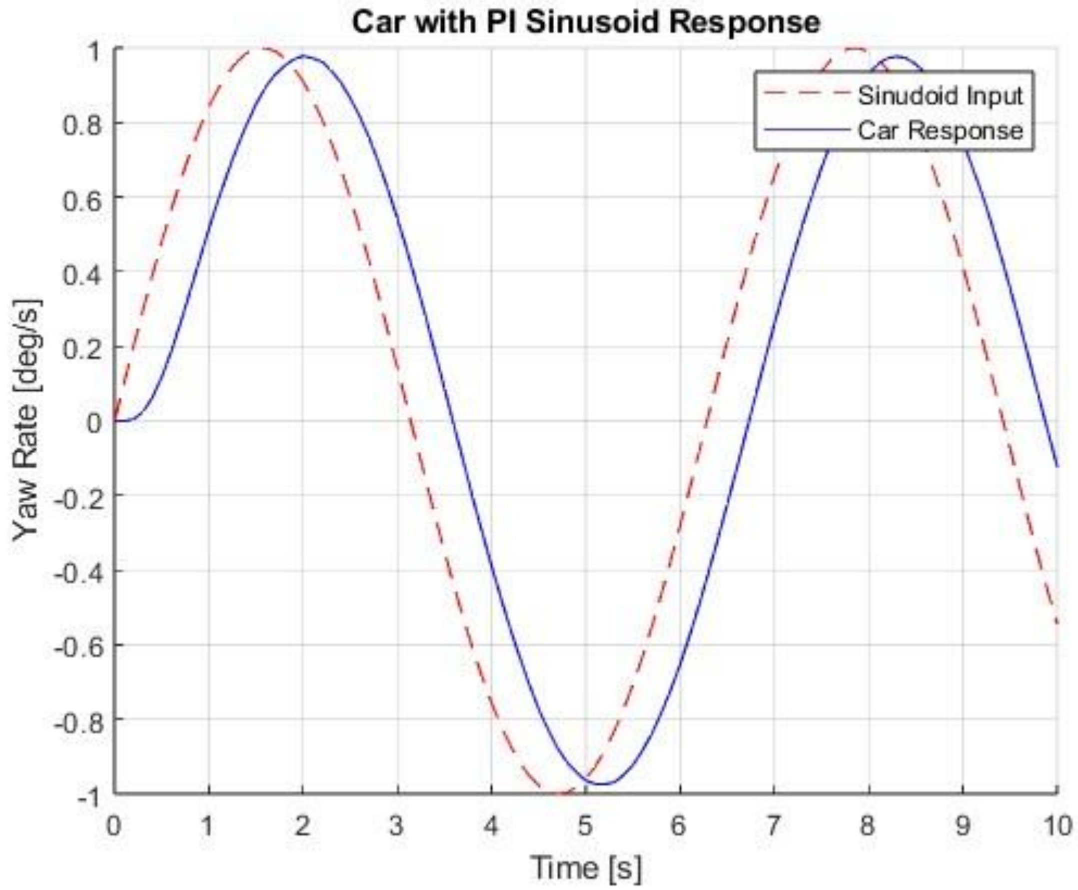
$$\dot{\psi}_{cmd} = \sin(t)$$

CAR STEP RESPONSE (B)



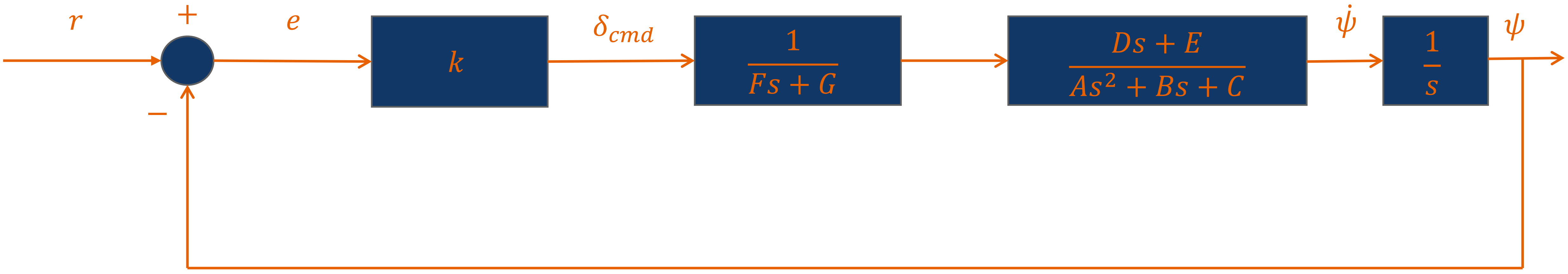
$$\dot{\psi}_{cmd} = 10°$$

CAR SINUSOID RESPONSE (B)



$$\dot{\psi}_{cmd} = \sin(t)$$

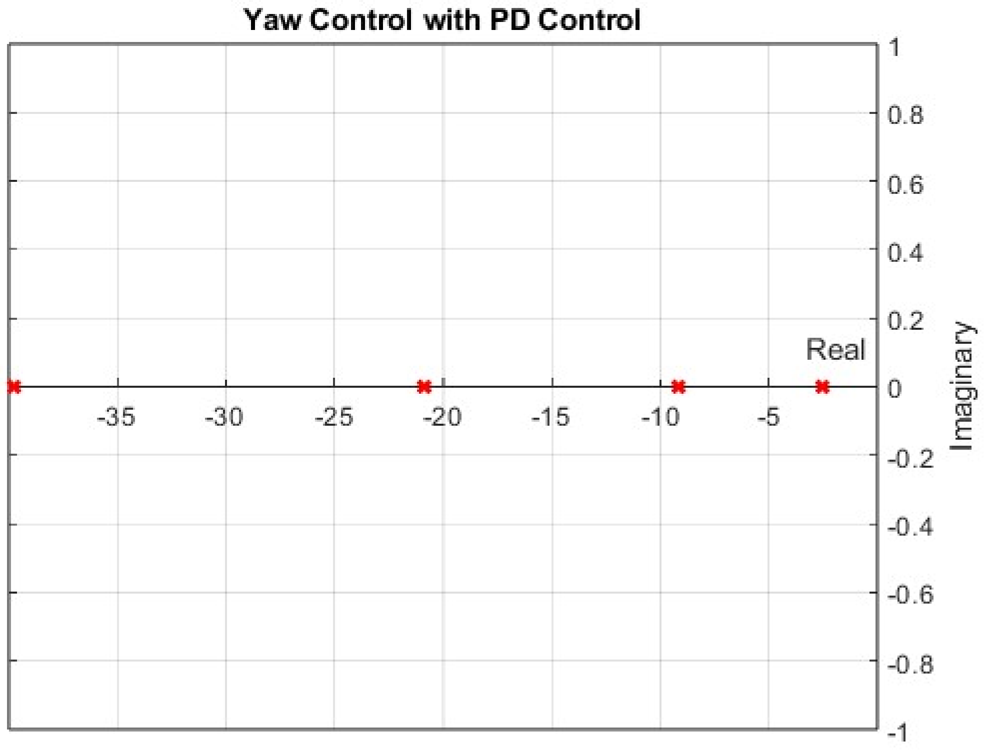
AUGMENTED PART A MODEL (C)

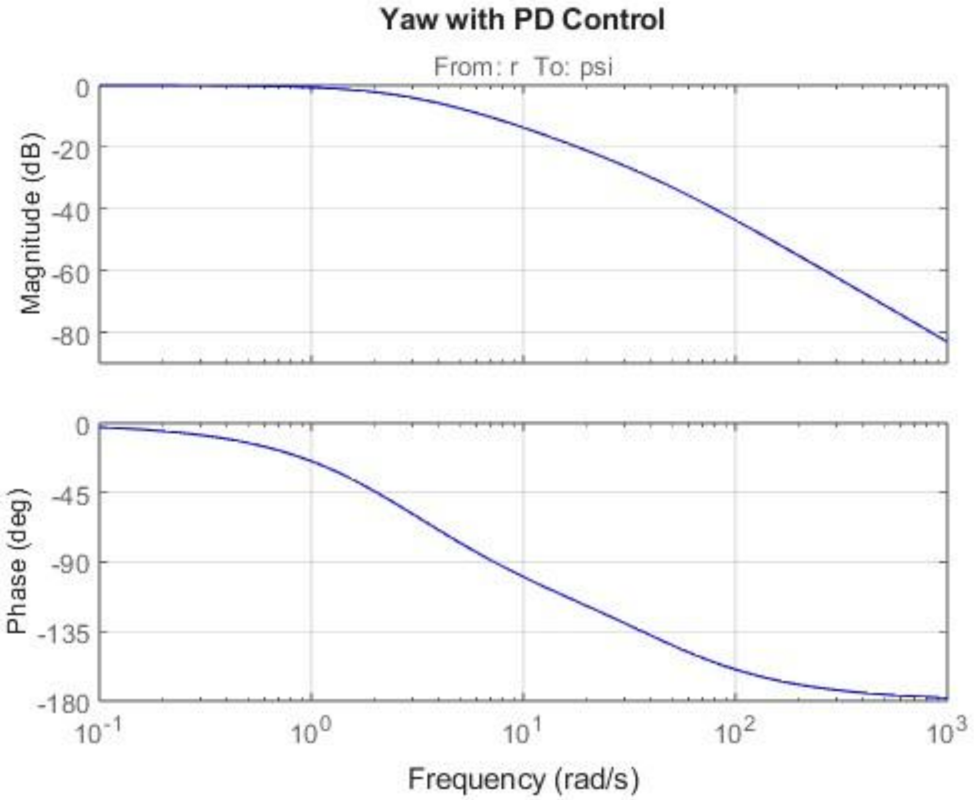


$$\frac{\psi}{\delta_{com}} = \frac{K_d D s^2 + (K_d E + K_p D)s + K_p E}{AFs^4 + (BF + AG)s^3 + (CF + BG + K_d D)s^2 + \left(CG + K_d E + K_p D\right)s + K_p E}$$

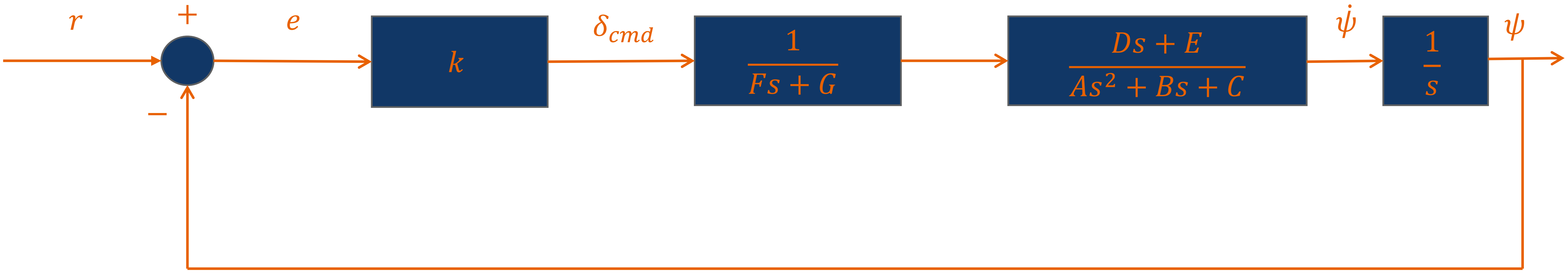
$$\delta_{cmd} = 0.415 * e + 0.0343 * \dot{e}$$

AUGMENTED MODEL EIGENVALUES AND BODE (C)





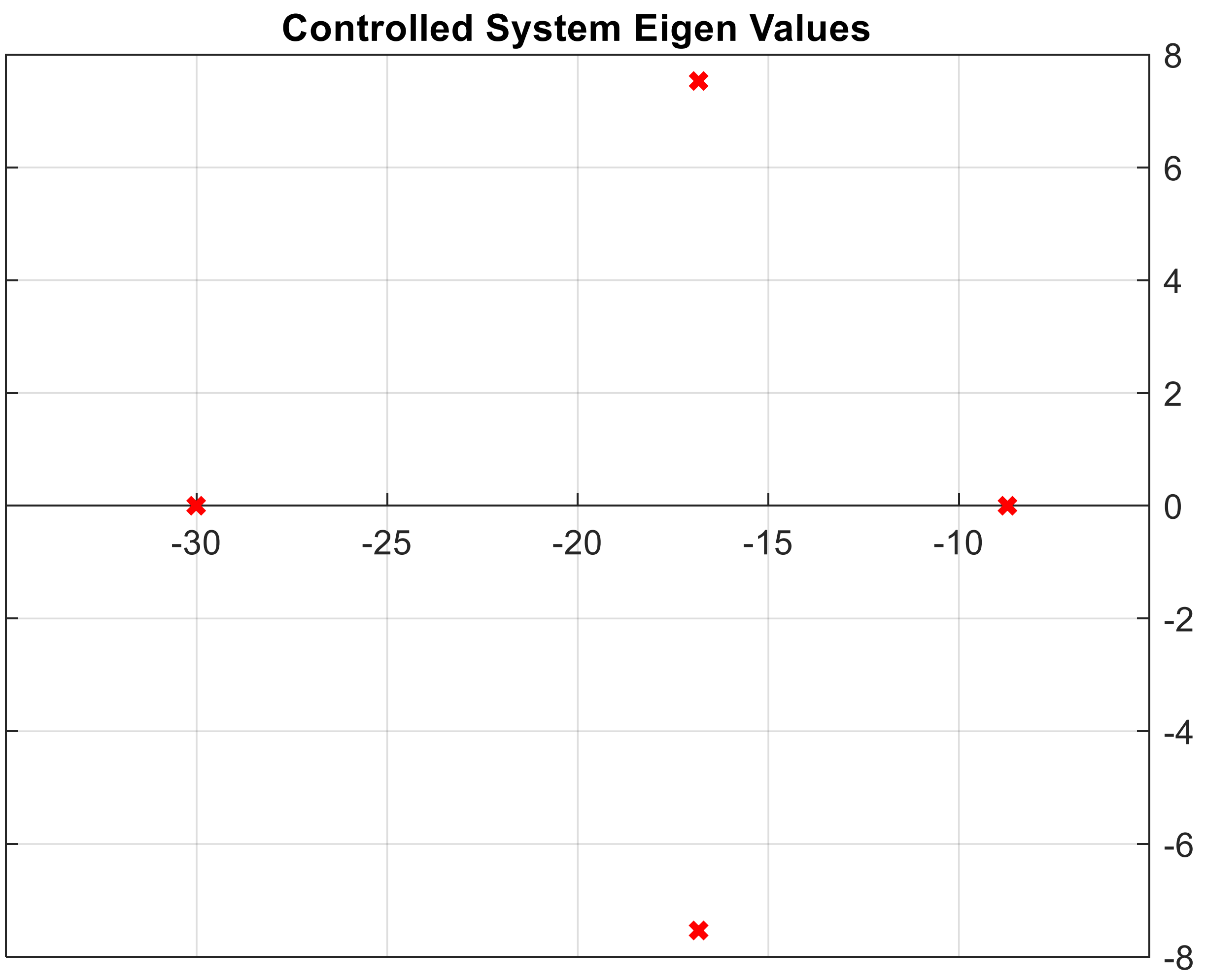
AUGMENTED PART A MODEL (C)



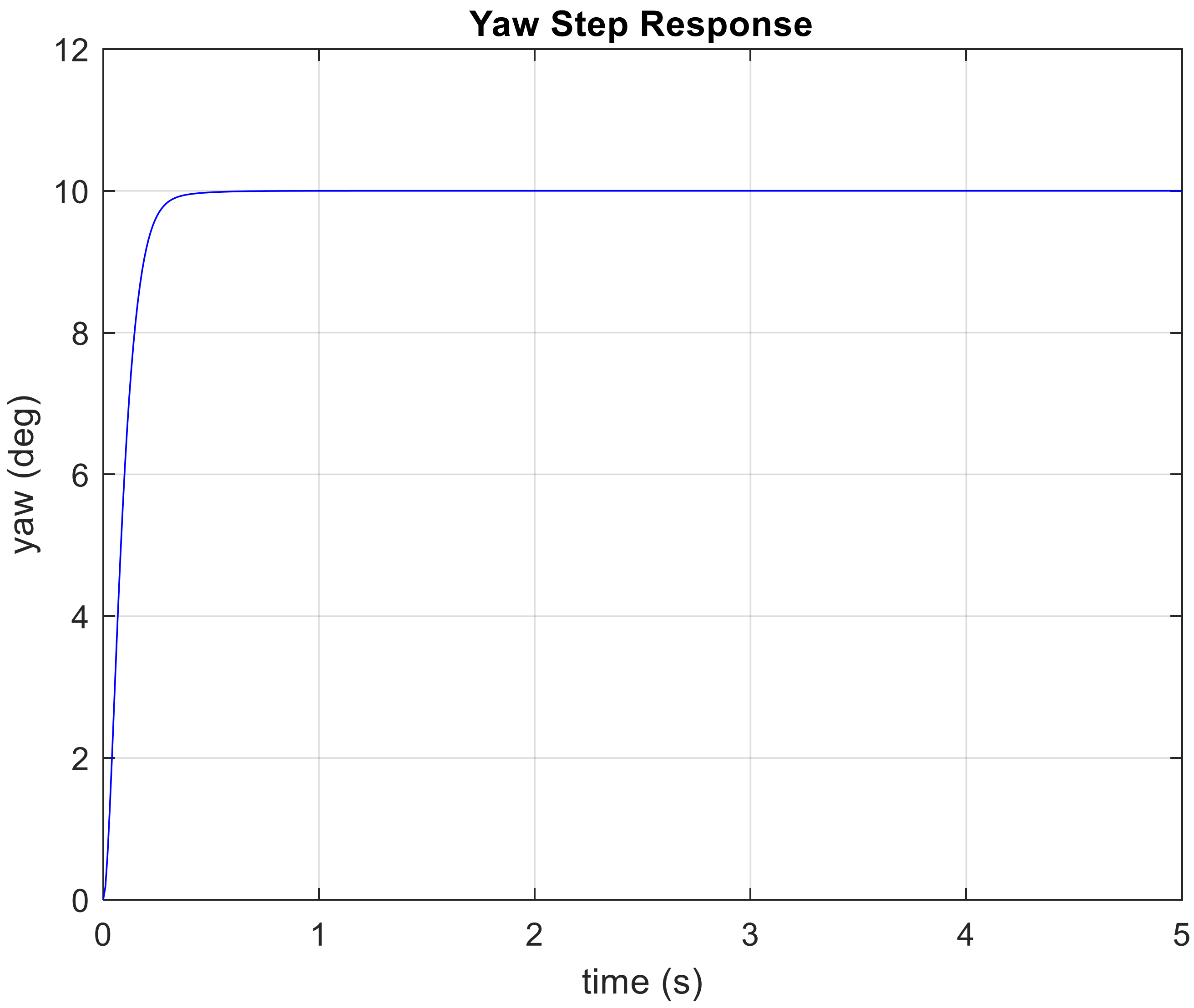
$$\frac{\psi}{\delta_{com}} = \frac{K_d D s^2 + (K_d E + K_p D)s + K_p E}{AFs^4 + (BF + AG)s^3 + (CF + BG + K_d D)s^2 + \left(CG + K_d E + K_p D\right)s + K_p E}$$

$$\delta_{cmd} = 1.9 * e + 0.2 * \dot{e}$$

PD CONTROL EIGEN VALUES (D)



CONTROLLER DESIGN (D)

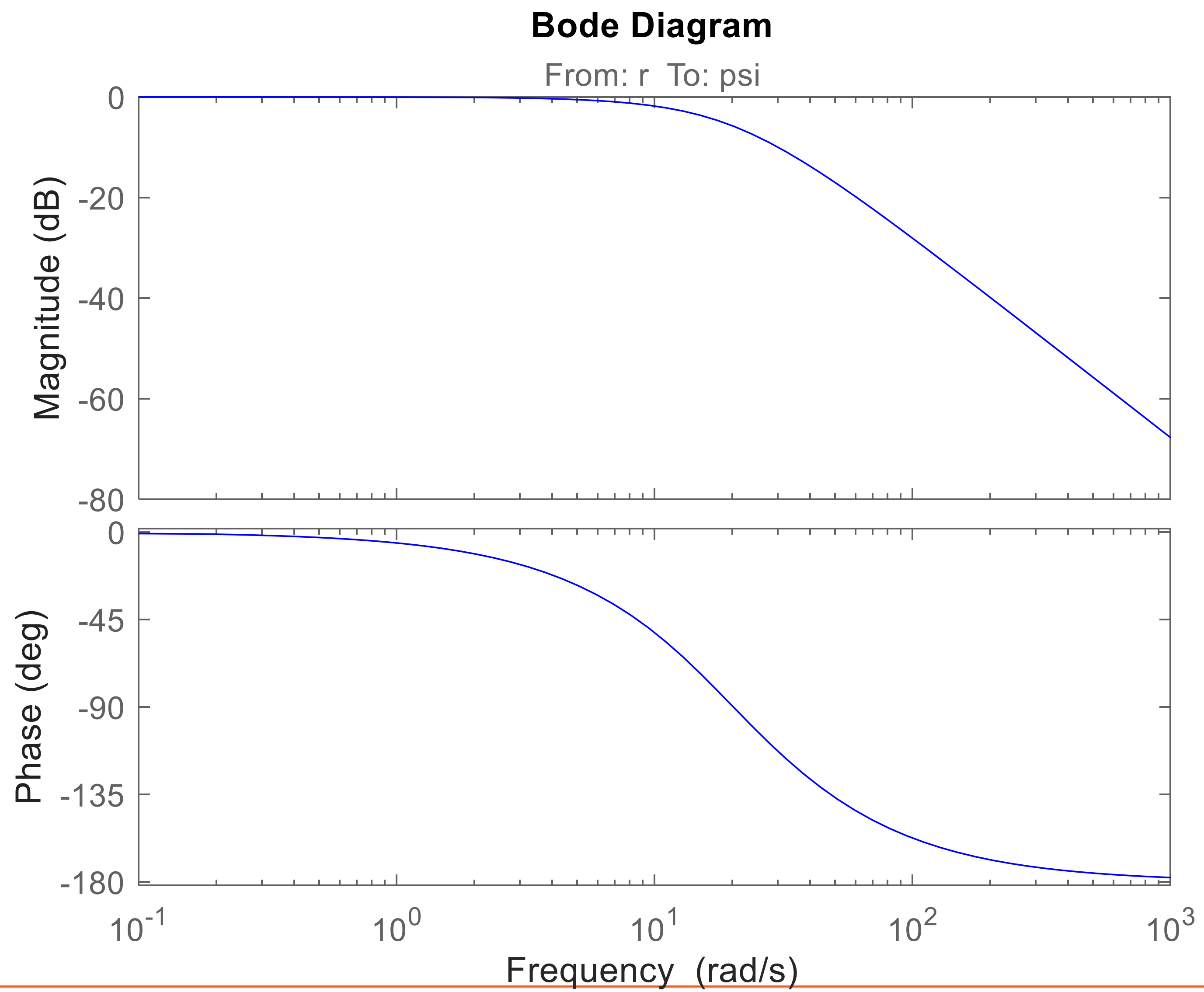


$\psi_{des} = 10°$

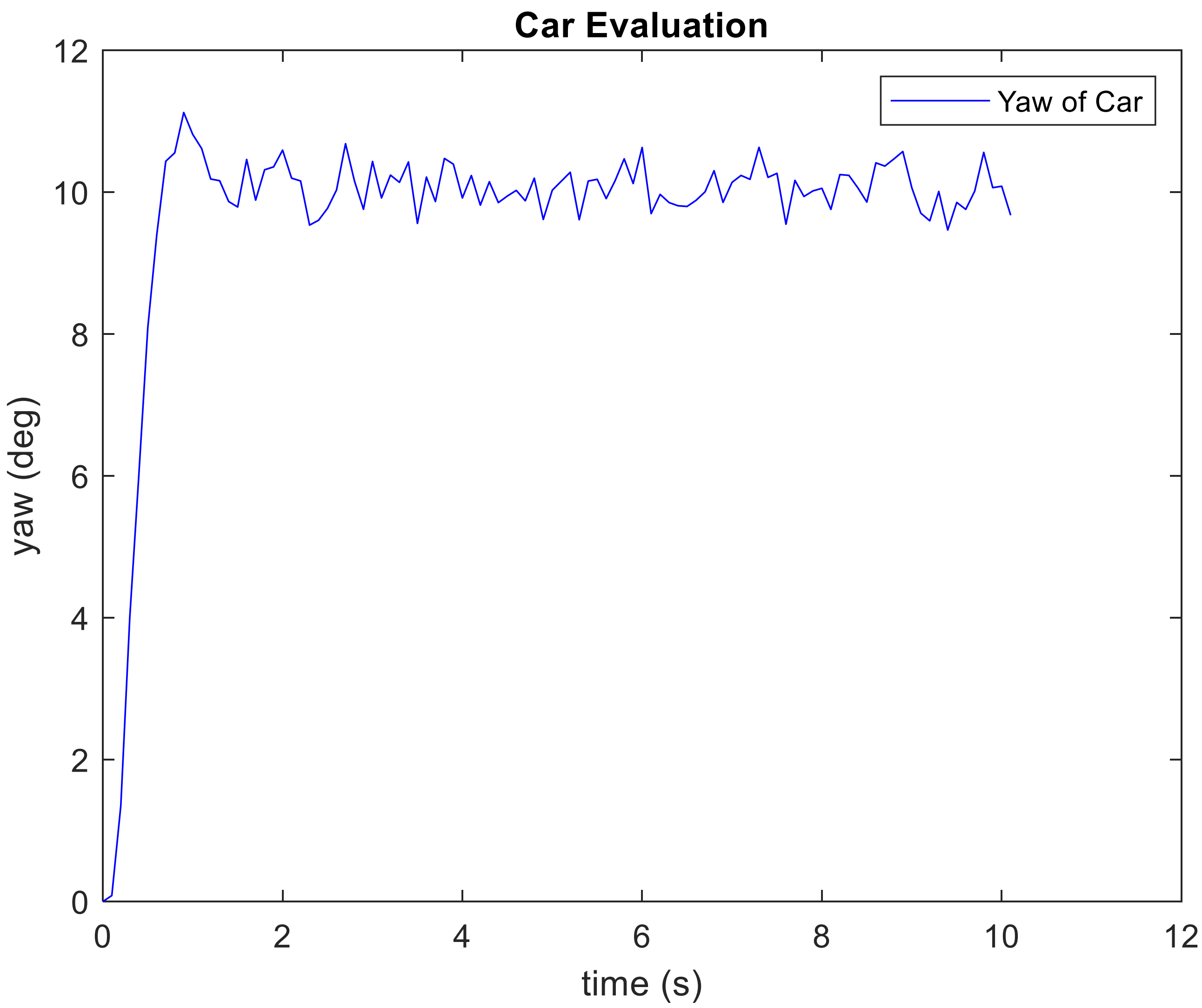
$t_{s,1\%} = 0.2848\ s$

$\mathrm{MP} = 0\%$

BODE PLOT FOR THE CONTROLLER (D)



EVALUATING THE STEP RESPONSE OF THE SYSTEM (E)

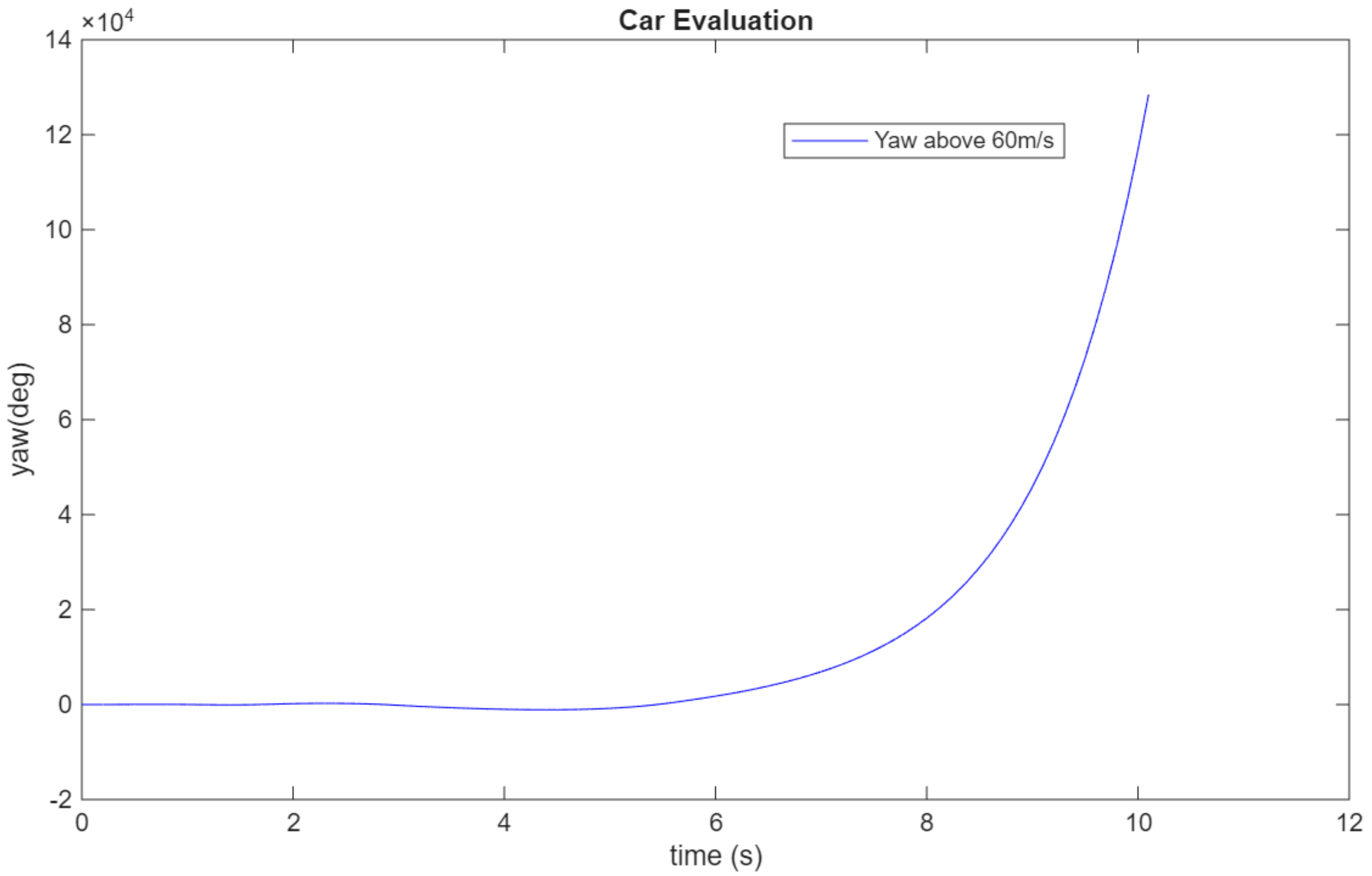


$K_p = 0.5$

$K_d = 0.02$

$K_i = 0.1$

CAR ABOVE 60 M/S



EVALUATING THE PERFORMANCE OF THE CAR (F)

Velocity = 15 $\frac{m}{s}$

Velocity = 15 $\frac{m}{s}$

THANK YOU!