EXPERIMENT 06

Aim: To determine the Impulse, Ramp and Step response of the block diagram shown below using MATLAB and SIMULINK.

Theory:

The impulse, step, and ramp responses are essential tools for analyzing the time-domain behavior of Linear Time-Invariant (LTI) systems.

1. Impulse Response:
   The impulse response shows how a system reacts to an instantaneous unit impulse input, δ(t). It reflects the system's natural behavior and provides insights into its stability, transient dynamics, and natural modes.

2. Step Response:
   The step response illustrates how the system responds to a sudden change in input from 0 to 1 (unit step). It helps determine key performance measures such as rise time, settling time, peak overshoot, and steady-state error.

3. Ramp Response:
   The ramp response indicates the system's ability to follow a linearly increasing input. It is useful for evaluating steady-state tracking performance and error characteristics under continuously changing inputs.

For the given system, the closed-loop transfer function is formed as:

$$T(s) = \frac{G_4(G_1 + G_2)}{1 + G_4 G_2 G_3}$$

where

$G_1 = \frac{1}{s+1}, \quad G_2 = \frac{2}{s^2+5s+100}, \quad G_3 = \frac{10}{2s+1}, \quad G_4 = \frac{100}{s+1}$

For the given system, the closed-loop transfer function was derived and simulated using MATLAB and Simulink to obtain and analyze the impulse, step, and ramp responses.

USING MATLAB

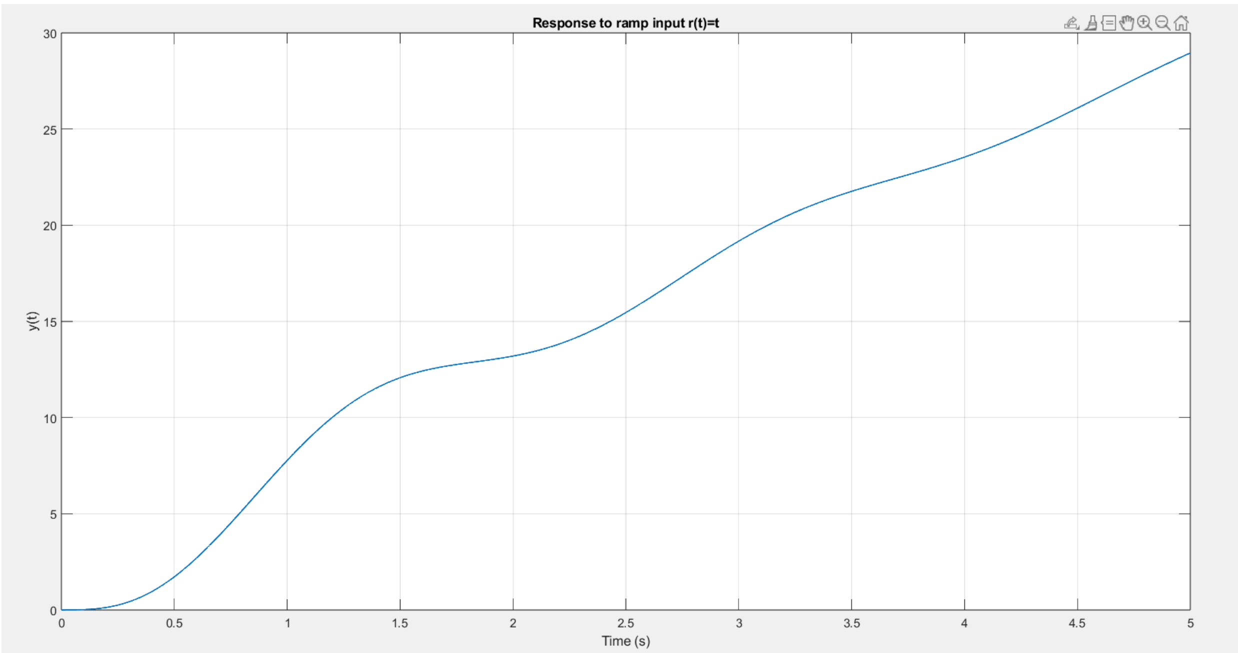
Code:

```
clear; close all; clc;

s = tf('s');

G1 = 1/(s+1);
G2 = 2/(s^2 + 5*s + 100);
G3 = 10/(2*s + 1);
G4 = 100/(s+1);

T = G4*(G1 + G2) / (1 + G4*G2*G3);

[num, den] = tfdata(T,'v');
fprintf('Closed-loop TF numerator coeffs: [%s]\n', num2str(num));
fprintf('Closed-loop TF denominator coeffs: [%s]\n\n', num2str(den));
disp('Closed-loop transfer function T(s):'); T

t = 0:0.001:5;

figure('Name','Impulse Response');
impulse(T, t);
grid on;
title('Impulse response y(t)');

figure('Name','Step Response');
step(T, t);
grid on;
title('Step response y(t)');

SI = stepinfo(T);
disp('Step info:'); disp(SI);

u = t;
y_ramp = lsim(T, u, t);
figure('Name','Ramp Response');
plot(t, y_ramp, 'LineWidth', 1.2);
grid on;
xlabel('Time (s)');
ylabel('y(t)');
title('Response to ramp input r(t)=t');
```

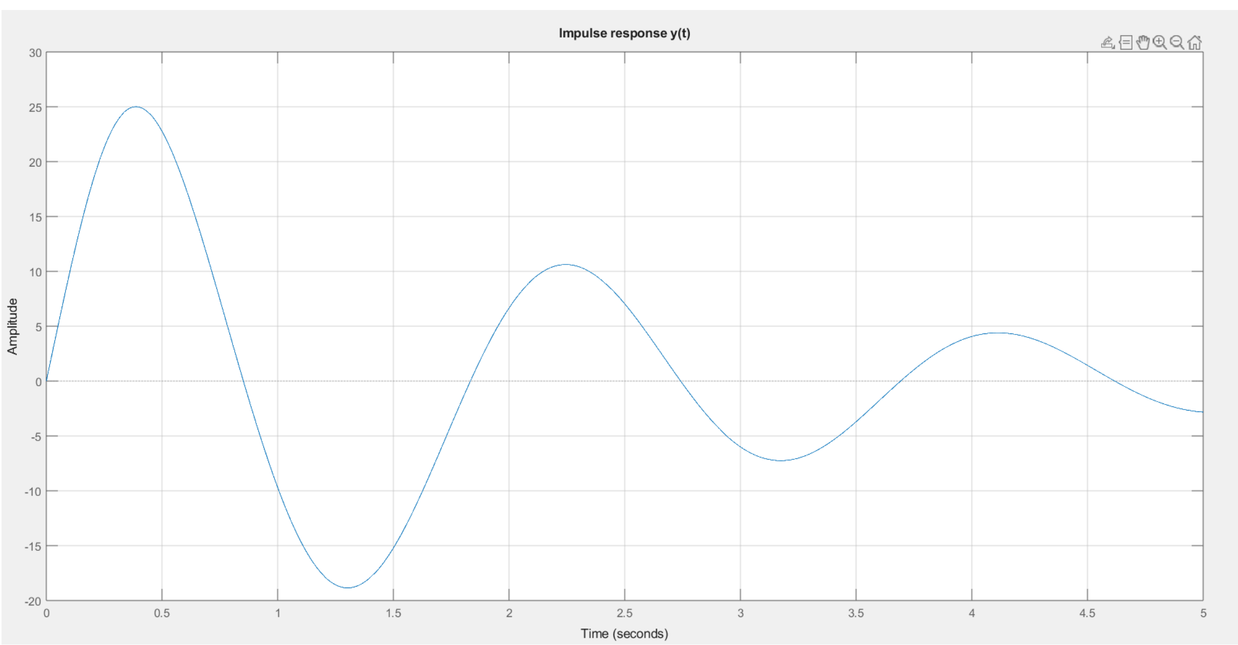
```
ess_ramp = u(end) - y_ramp(end);
fprintf('Approx steady-state error for ramp (t_end = %.3g s):
%.5g\n', t(end), ess_ramp);
```

<u>Output</u>:

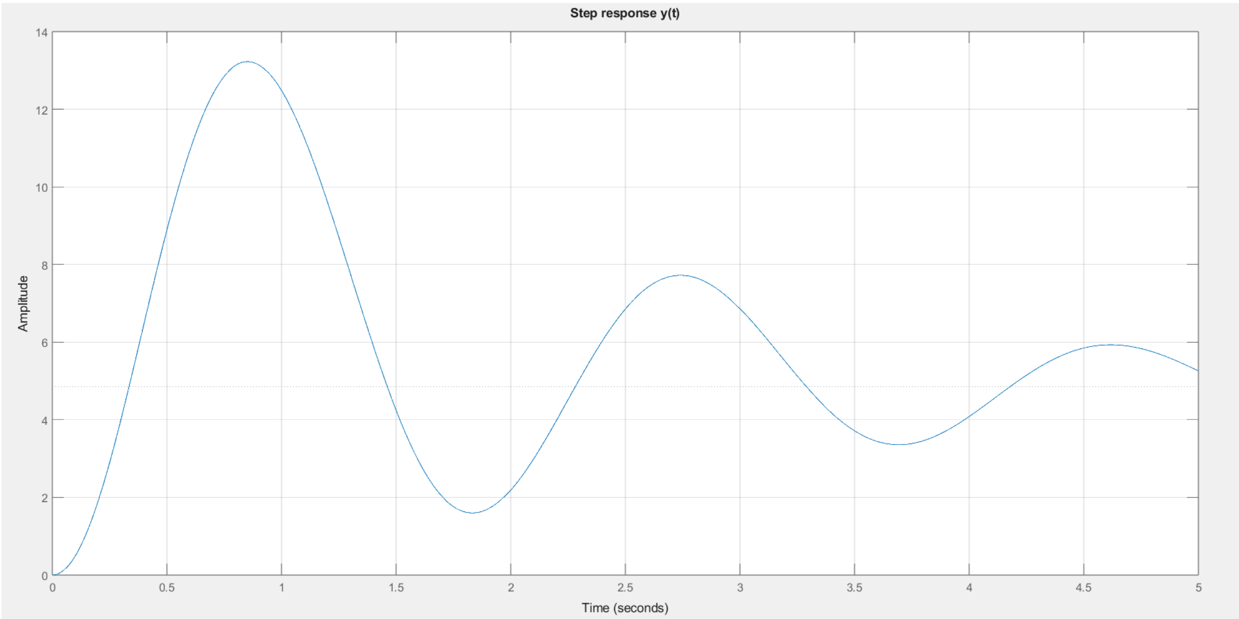
Ramp Response



Impulse Response



Step Response



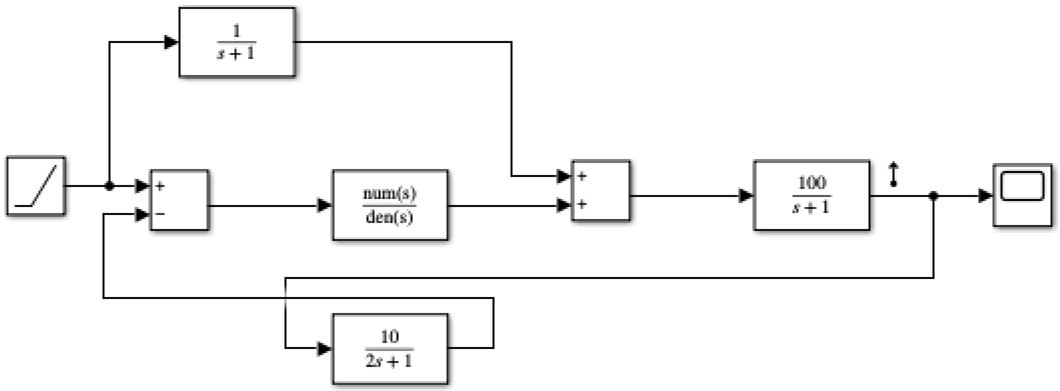
Command Window

```
Closed-loop TF numerator coeffs: [0        0      200      2700      51100    314300   2426700   3181000   1020000]
Closed-loop TF denominator coeffs: [2       27      529     3670     31076     94135    317225    461000   210000]

Closed-loop transfer function T(s):

T =

       200 s^6 + 2700 s^5 + 51100 s^4 + 314300 s^3 + 2.427e06 s^2 + 3.181e06 s + 1.02e06
  ---------------------------------------------------------------------------------------------
  2 s^8 + 27 s^7 + 529 s^6 + 3670 s^5 + 31076 s^4 + 94135 s^3 + 317225 s^2 + 461000 s + 210000

Continuous-time transfer function.
Model Properties
Step info:
         RiseTime: 0.2164
    TransientTime: 7.6912
     SettlingTime: 9.4074
      SettlingMin: 1.6014
      SettlingMax: 13.2085
        Overshoot: 171.9397
       Undershoot: 0
             Peak: 13.2085
         PeakTime: 0.8289

Approx steady-state error for ramp (t_end = 5 s): -23.95
fx >>
```

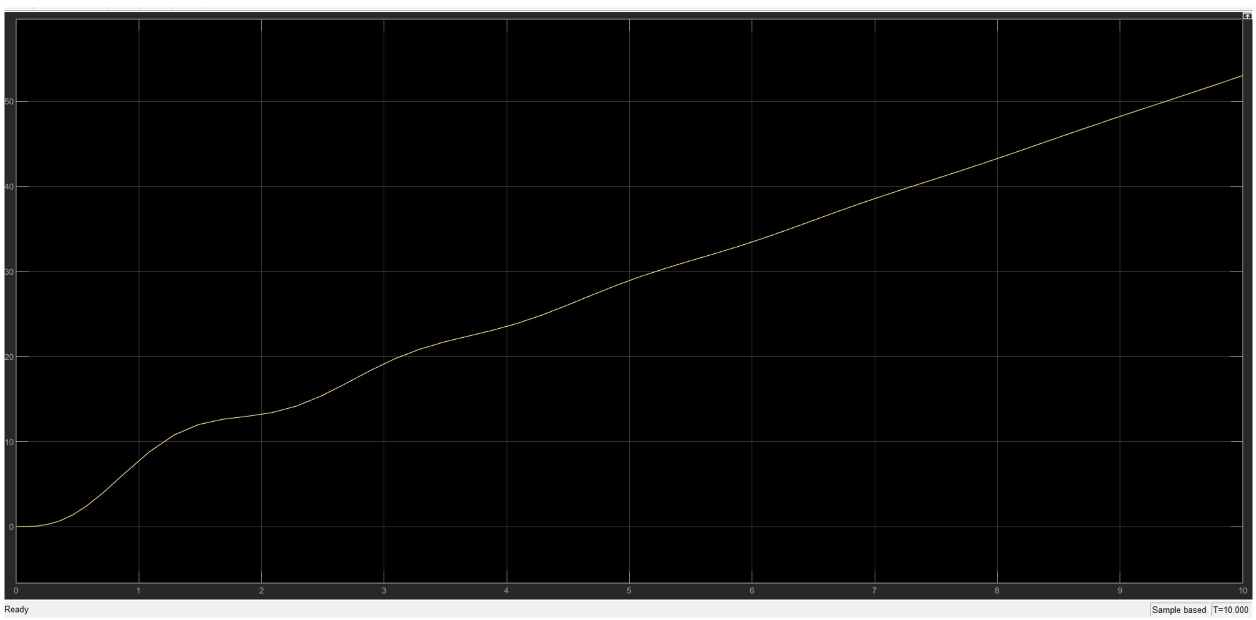
USING SIMULINK

Ramp Response

Circuit Diagram

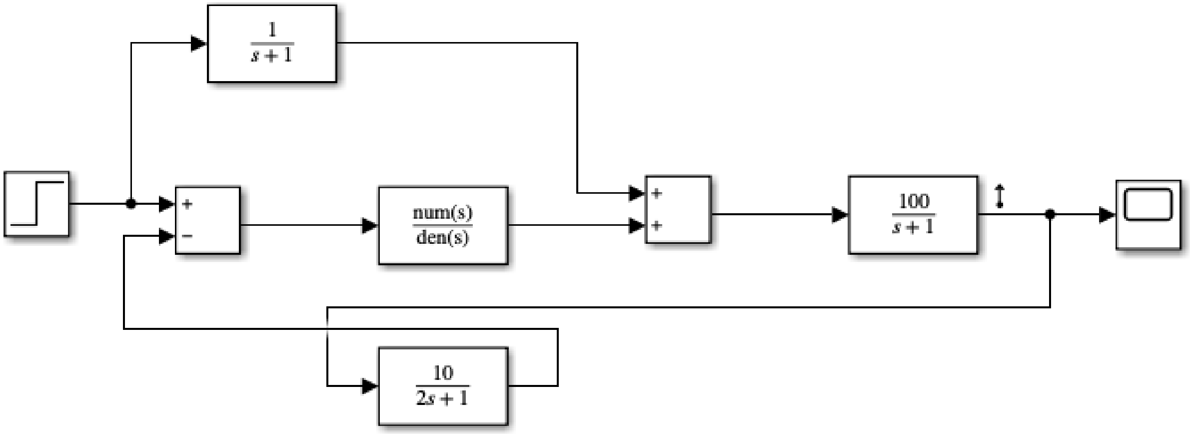


Output Waveform

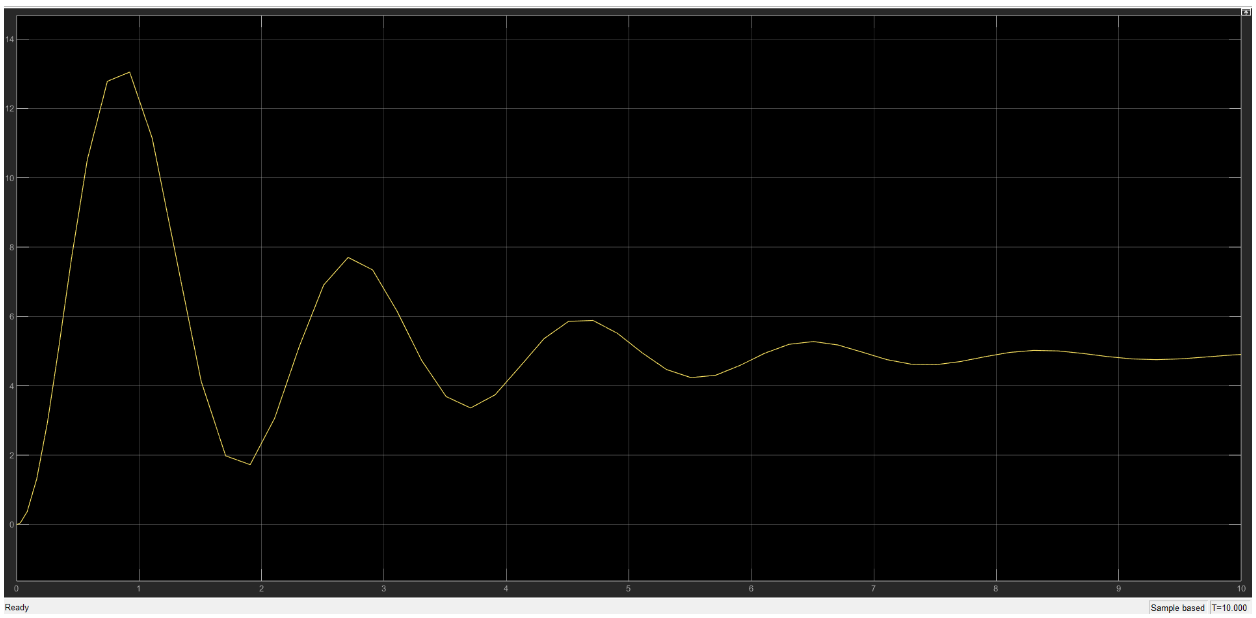


<u>Step Response</u>

Circuit Diagram

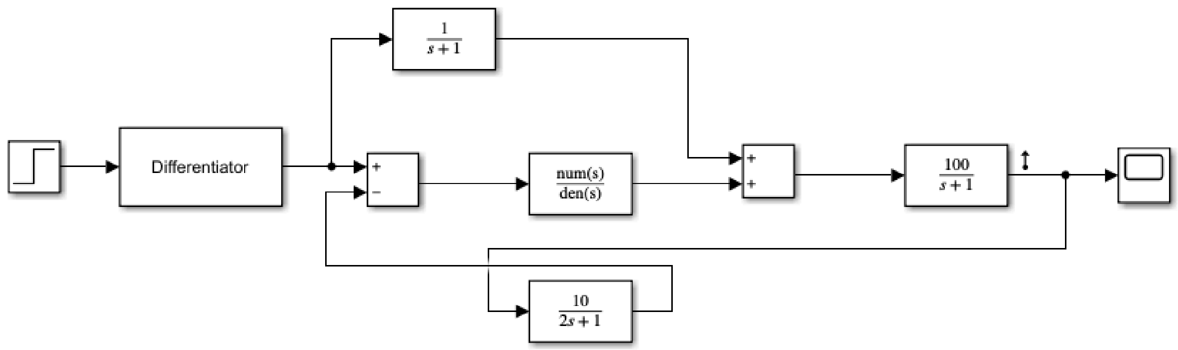


Output Waveform

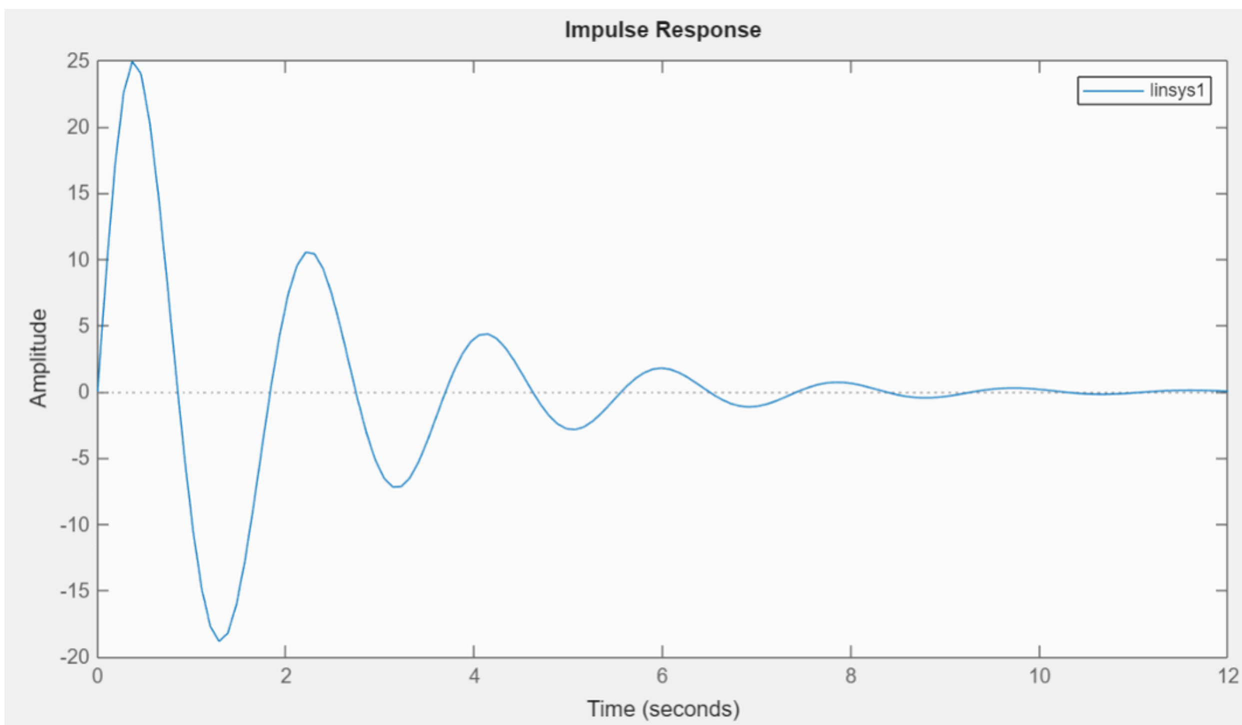


<u>Impulse Response</u>

Circuit Diagram



Output Waveform



<u>Discussion</u>:
From the MATLAB and Simulink simulations, the system's time-domain responses to standard test inputs—impulse, step, and ramp—were analyzed to evaluate its performance and stability. The impulse response revealed the transient behavior of the system, showing a smooth decay over time, which confirms stability and highlights the presence of damping and natural oscillations. The step response demonstrated a rapid rise with a minor overshoot before settling to a steady-state value, with parameters such as rise time, settling time, and overshoot (obtained from stepinfo()) further validating the system's stability and responsiveness. The ramp response showed that

the output closely followed the input ramp with a small steady-state error, indicating good but limited tracking capability for continuously changing inputs. Overall, the MATLAB and Simulink results closely matched, confirming the accuracy of the derived mathematical model and the reliability of the system’s dynamic performance.

Conclusion:

The experiment confirms that the given control system is stable with good transient performance. The impulse response shows a decaying transient, the step response indicates fast rise and minimal steady-state error, and the ramp response shows a finite steady-state error typical of a Type-1 system. MATLAB and Simulink effectively validated the system’s behavior through these standard test inputs.