EXPERIMENT KW9: CONTROL SYSTEM PERFORMANCE AND STABILITY (OPEN-ENDED)

Related course: KIE3006 (Control System)

OBJECTIVES:
1. To compare the performance of control system using different controller type.
2. To analyze the stability of control systems using Bode plots, Nyquist plots and root locus techniques.

EQUIPMENT:
PC with MATLAB and Simulink

INSTRUCTIONS:
1. Save your results in a pendrive
2. Follow the demonstrator's instructions throughout the experiment

REFERENCE(S):
Refer to the main references of KIE3006

TESTS:
TEST 1: Control system model in Simulink
TEST 2: System stability using MATLAB

INTRODUCTION:

Controllers play a crucial role in control systems, enabling the regulation of dynamic processes to achieve desired performance and stability. The choice of controller significantly impacts how well a system responds to changes in input or disturbances. A proportional–integral–derivative controller (PID controller) is a control loop feedback mechanism widely used in industrial control systems and a variety of other applications requiring continuously modulated control. A PID controller continuously calculates an error value as the difference between a desired setpoint and a measured process variable and applies a correction based on proportional P, integral I, and derivative D terms.

System stability is a fundamental concept in control theory that determines whether a system will return to equilibrium after a disturbance or maintain its performance under varying conditions. Nyquist and Bode plots are graphical methods that visualize how the system's gain and phase margins affect stability, while the Root Locus method offers insights into how the location of poles changes with varying system gain. Understanding stability is crucial for designing control systems that can handle real-world uncertainties, disturbances, and nonlinearities. A stable system not only meets performance specifications but also ensures safety and reliability in applications.

TEST 1: Control system model in Simulink

1. Construct Figure 1 using Simulink and then, simulate the model to obtain its step response curve.
2. From the step response curve, determine the peak amplitude, rise time, settling time, percentage overshoot and steady state error.
3. Copy the results and paste in a Word document. Save the model.

4. Continued from the Simulink model in Figure 1, insert a controller block (called stabiliser) as shown in Figure 2. Then, obtain its step response curve.
5. From the step response curve, determine the peak amplitude, rise time, settling time, percentage overshoot and steady state error.
6. Copy the results and paste in a Word document. Save the model.

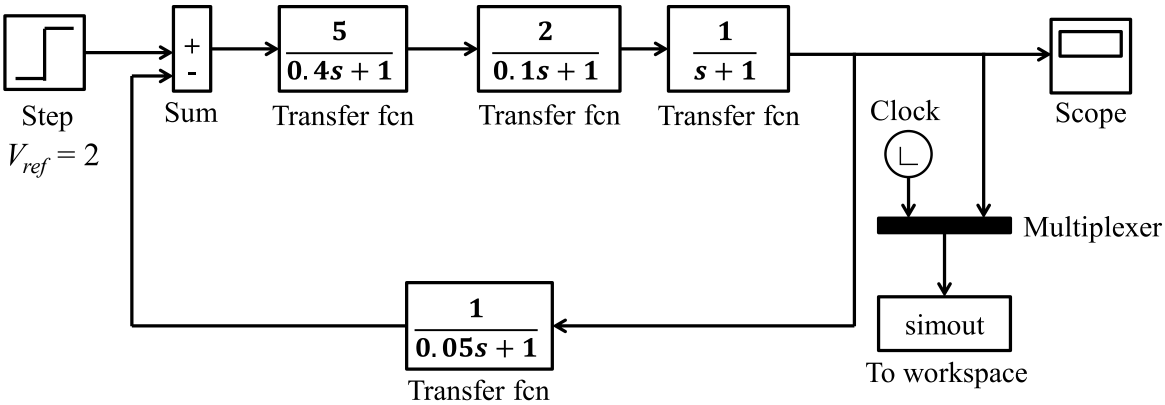


Figure 1: Control system model in Simulink

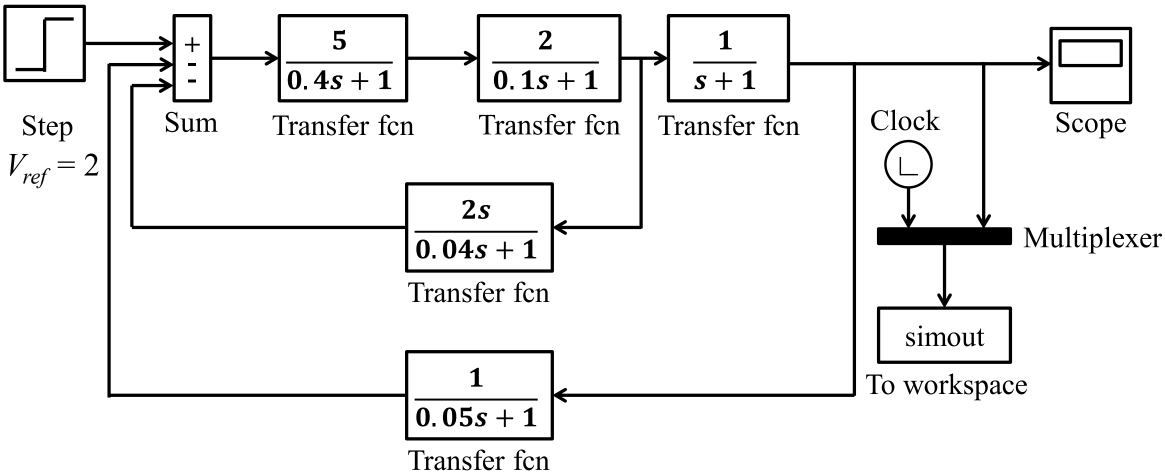


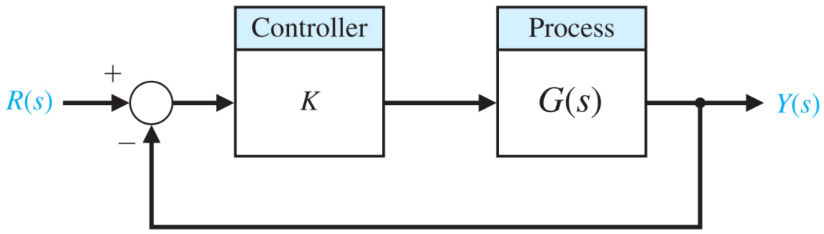
Figure 2: Control system model with a stabiliser in Simulink

Open-ended tasks (do this task during laboratory session):

Q1. Back to the Simulink model in Figure 1, insert a 'PID controller' block in the system at appropriate location. Configure the PID parameters (Proportional, Integral and Derivative) by trial-and-error method. Write down the values of the PID parameters that gives the best system performance. Compare and discuss the step response of this control system (PID controller) with the system in Figure 1 and Figure 2.

TEST 3: System Stability Using MATLAB

1. Consider the system given in Figure 3.



$$G(s) = \frac{10}{s^2 + 2s + 10}$$

Figure 3

2. Open MATLAB and enter the following commands to generate Bode Plots.

```
num = [10];
den = [1, 2, 10];
sys = tf(num, den);
bode(sys);
grid on;
```

   Print screen the Bode Plot and paste in a Word document.

3. Using the same transfer function, plot the Nyquist diagram:

```
nyquist(sys);
grid on;
```

   Print screen the Nyquist diagram and paste in a Word document.

4. Create a root locus plot for the same transfer function

```
rlocus(sys);
grid on;
```

   Print screen the root locus plot and paste in a Word document.

Analysis and discussion:

Q2. From the Bode plot, identify the gain and phase margins and note the frequencies at which these occur. Discuss how gain and phase margins relate to system stability.

Q3. From the Nyquist diagram, determine the number of encirclements of the critical point (-1, 0). Apply the Nyquist stability criterion to assess stability.

Q4. From the root locus plot, identify the locations of the poles as the gain varies. Discuss how the pole locations affect system stability.

END OF EXPERIMENT

APPENDIX: STEP RESPONSE

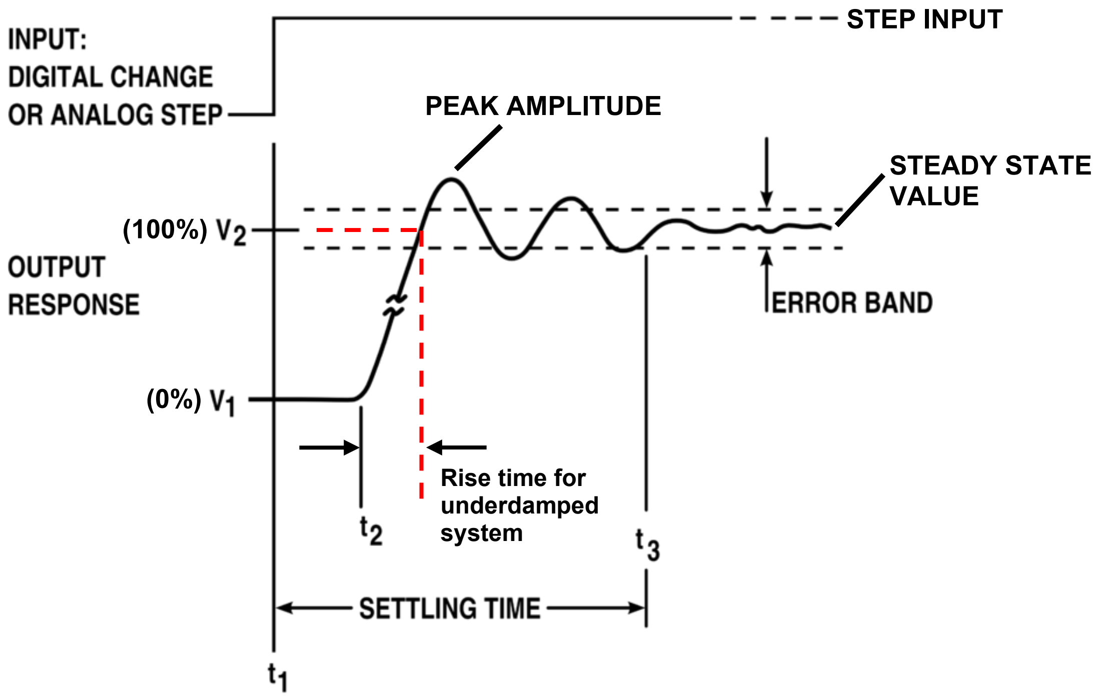


Figure A: Step response of a system

Parameter	Definition
Steady state value	The final value of the response (V_2)
Steady state error	The difference between the step input and the steady state value
Settling time	The time required for the response curve to reach and stay within a range of certain percentage or error band (usually 2 to 5%) of the steady state value ($t_3 – t_1$)
Peak amplitude	The maximum peak value of the response
Percentage overshoot	Peak amplitude relative to the step input [Peak amplitude minus the step input divided by the step input]
Rise time	The time required for the response to rise from x% to y% of its steady state value [0%-100% rise time for underdamped, 5%-95% for critically damped and 10%-90% for overdamped]
Root locus	Shows how the root of a system changes with variation of certain system parameters
Zero	The value of *s* on the numerator of a transfer function
Poles	The value of *s* on the denumerator of a transfer function

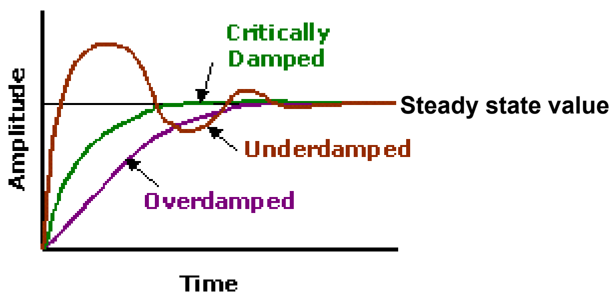


Figure B: Example of step response