Lab 4

Transient Response and Time-Domain Performance Measures

Objective

The lab aims to teach the students to plot the step response of control systems using MATLAB and to determine the time-domain performance measures.

Background Materials

1) Lecture notes for the course Control Theory 1, Theme 4. Performance of Control Systems, pp. 1 – 12.

2) MATLAB function `step`.

The step response of linear systems can be evaluated and drawn using the MATLAB function `step`. This function can be called with a variety of syntaxes:

```
step(sys)
step(sys,tfinal)
step(sys,t)
[y,t] = step(sys)
[y,t] = step(sys,tfinal)
y = step(sys,t)
```

In the function call, `sys` is an LTI model object, which can be a transfer function, state space, or pole-zero-gain model. This function applies to continuous systems and discrete-time systems. It can also be used for SISO and MIMO systems and systems with or without time delays. Thus the function provides a unified way of finding the step response of linear systems.

If no argument is returned in the function call, the step response will be drawn automatically.

`step(sys)` evaluates and plots the step response of the dynamic system `sys`. The time range and number of points are chosen automatically.

`step(sys,tfinal)` evaluates and plots the step response from $t = 0$ to the final time $t =$ `tfinal`.

`step(sys,t)` evaluates and plots the step response on user defined time vector `t`.

If the response data are returned as output arguments, there will be no response drawn. The data can be drawn later with the MATLAB `plot` function. However, the plain curves drawn by `plot` may lose many useful properties, such as the shortcut menu shown in Figure 1.

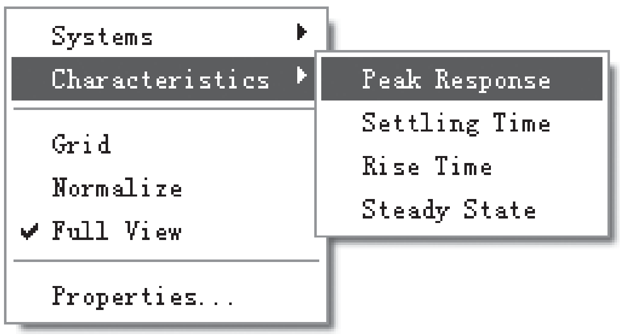

Figure 1 Shortcut menu.

The step response of more than one system model, for instance, `sys1`, `sys2`, and `sys3`, can be drawn on a single figure if the function is called as follows:

```
step(sys1,'r',sys2,'b--',sys3,'g:')
```

where the options are the same as the conventional `plot` function options. In the curves, the step response for `sys1` is shown by the red solid line, for `sys2` by the blue dashed-dotted line, and for `sys3` by the green dotted line.

Tasks

Task 1

Consider the temperature control system model shown in Figure 2. The values of the parameters are $k_1 = 1\ \%/{}^\circ\mathrm{C}$, $T_1 = 75\ \mathrm{s}$, $k_2 = 1.2\ {}^\circ\mathrm{C}/\%$, $c_0 = 85000\ \mathrm{s}^3$, $c_1 = 5700\ \mathrm{s}^2$, $c_2 = 150\ \mathrm{s}$.

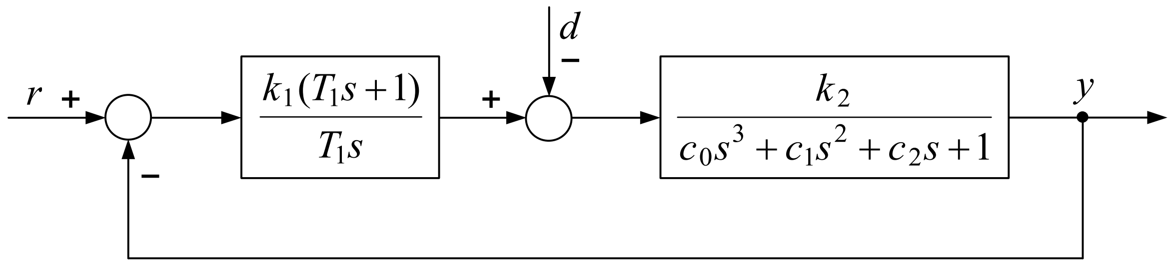

Figure 2 Block diagram of the control system for Task 1.

(a) Develop an M-file to plot the response $y(t)$ for a unit step reference input $R(s)=1/s$ and a unit step disturbance input $D(s)=1/s$.

(b) Plot the step responses for $k_1 = 0.2\ \%/{}^\circ\mathrm{C}$ and $k_1 = 2\ \%/{}^\circ\mathrm{C}$. Compare the results obtained.

Task 2

Consider the control system model shown in Figure 3. The values of the parameters are $k_1 = 5\ \mathrm{Nm/(rad/s)}$, $T_1 = 0.06\ \mathrm{s}$, $c_0 = 0.00005\ \mathrm{s}^2$, $c_1 = 0.01\ \mathrm{s}$, and $J = 0.1\ \mathrm{kgm}^2$.

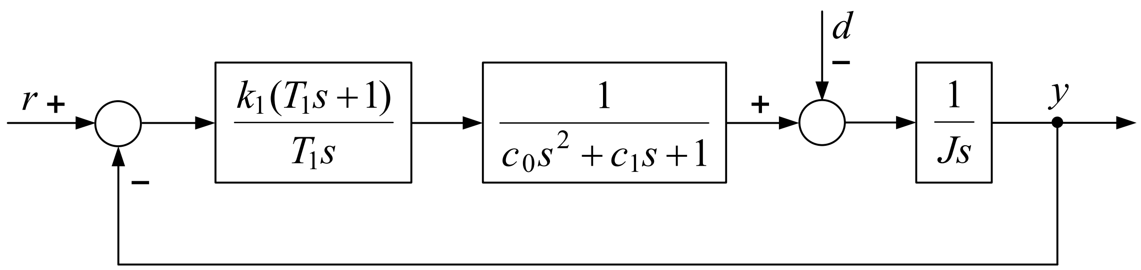

Figure 3 Block diagram of the control system for Task 2.

(a) Plot the response $y(t)$ for a unit step reference input $R(s)=1/s$ and a unit step disturbance input $D(s)=1/s$.

(b) Plot the step responses if in the control system P controller

$$G_c(s) = k_1, \qquad k_1 = 5\ \mathrm{Nm/(rad/s)}$$

is used. Compare the results obtained for PI and P controllers.

Task 3

Consider the second-order closed-loop system shown in Figure 4.

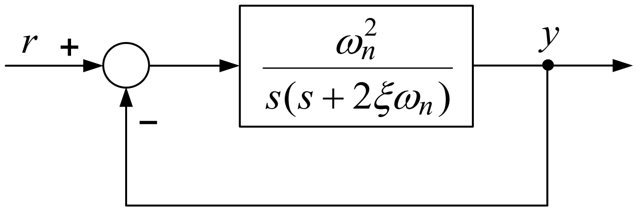

Figure 4 Block diagram of the closed-loop system for Task 3.

Plot the step response of the closed-loop system for $\omega_n = 1$ and $\xi = 0.1$, 0.4, 0.7, 1.0 and 2.0. Determine the values of rise time, settling time and percent overshoot and fill the following table.

ξ	Rise time	Settling time	Percent overshoot
0.1			
0.4			
0.7			
1.0			
2.0			

Task 4

Consider the control system model shown in Figure 5. The values of the parameters are $T_1 = 0.25$ s, $T_2 = 0.125$ s, $k_2 = 0.4$, $c_0 = 0.02\ \mathrm{s}^2$, $c_1 = 0.3$ s.

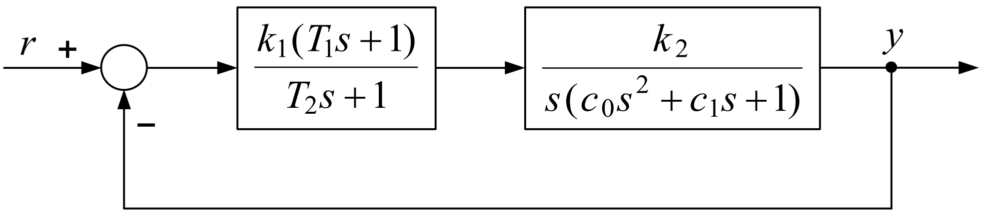

Figure 5 Block diagram of the control system for Task 4.

Plot the step response of the control system for $k_1 = 2.5$, $k_1 = 5$, $k_1 = 10$, and $k_1 = 20$. Determine the values of rise time, settling time and percent overshoot and fill the following table.

k_1	Rise time	Settling time	Percent overshoot
2.5			
5			
10			
20			

Report Content

The lab report should contain the following:

- The objective of the lab.
- Formulation of the tasks.
- Results, MATLAB script-files, and obtained plots.
- Discussion of the obtained results.
- Conclusion.