MENG366 SYSTEM DYNAMICS AND CONTROL LABORATORY

LABORATORY 3: TRANSFER FUNCTION SIMPLIFICATION AND SOLUTION

1. OBJECTIVE

In this laboratory exercise, you will practice block diagram reduction and simulating response for various inputs for a transfer function using MATLAB.

2. COMPONENTS & EQUIPMENT

PC with MATLAB and Simulink toolbox installed.

3. BACKGROUND

In engineering, a transfer function (also known as system function or network function) of an electronic or control system component is a mathematical function which theoretically models the device's output for each possible input.

The term "transfer function" is also used in the frequency domain analysis of systems using transform methods such as the Laplace transform; here it means the amplitude of the output as a function of the frequency of the input signal. For example, the transfer function of an electronic filter is the voltage amplitude at the output as a function of the frequency of a constant amplitude sine wave applied to the input. For optical imaging devices, the optical transfer function is the Fourier transform of the point spread function (hence a function of spatial frequency)

Example 1: Check responses of the following system when k = 1, 2, 2.25, 3, respectively.

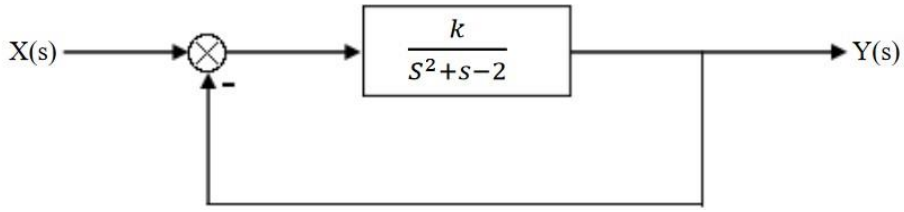


Figure 1 System 1

Close-loop transfer function:

$$G(s) = \frac{\frac{k}{s^2+s-2}}{1+\frac{k}{s^2+s-2}} = \frac{k}{s^2+s+(k-2)}$$

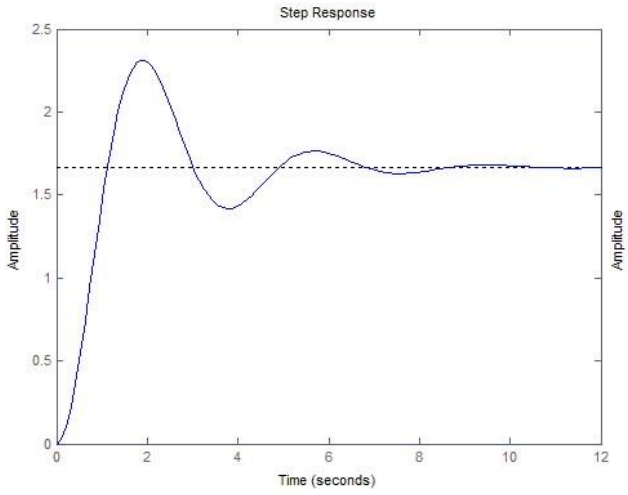
MATLAB code example:

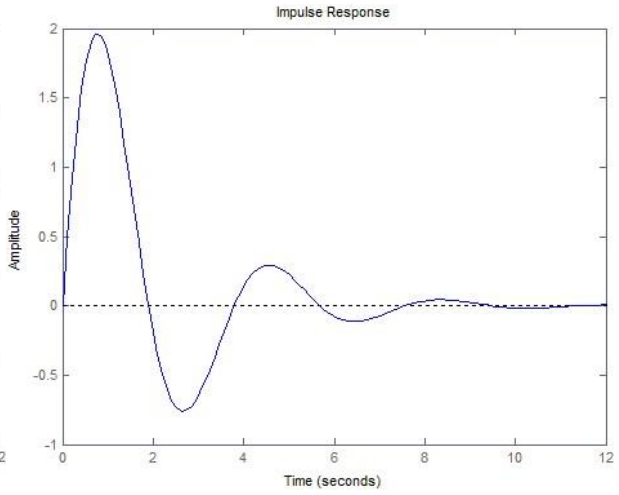
```
k = 5; num = [k];
den = [1, 1, k-2];
sys = tf(num,
den);

z = zero(sys)
p = pole(sys)  r
= roots(den)

figure(1), step(sys)
figure(2), impulse(sys)
```

Results:

```
z =

  0×1 empty double column vector


p =

  -0.5000 + 1.6583i
  -0.5000 - 1.6583i


r =

  -0.5000 + 1.6583i
  -0.5000 - 1.6583i
```

System Response:





Example 2. Check the system responses when [a,b] = [0,1], [1,0], [0,0].

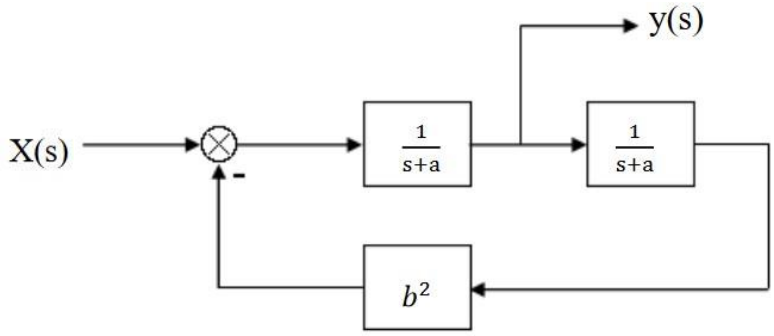


Figure 2 System 2

Transfer function:

$$G(s) = \frac{\frac{1}{s+a}}{1 + \left(\frac{1}{s+a}\right) \times \left(\frac{b^2}{s+a}\right)}$$

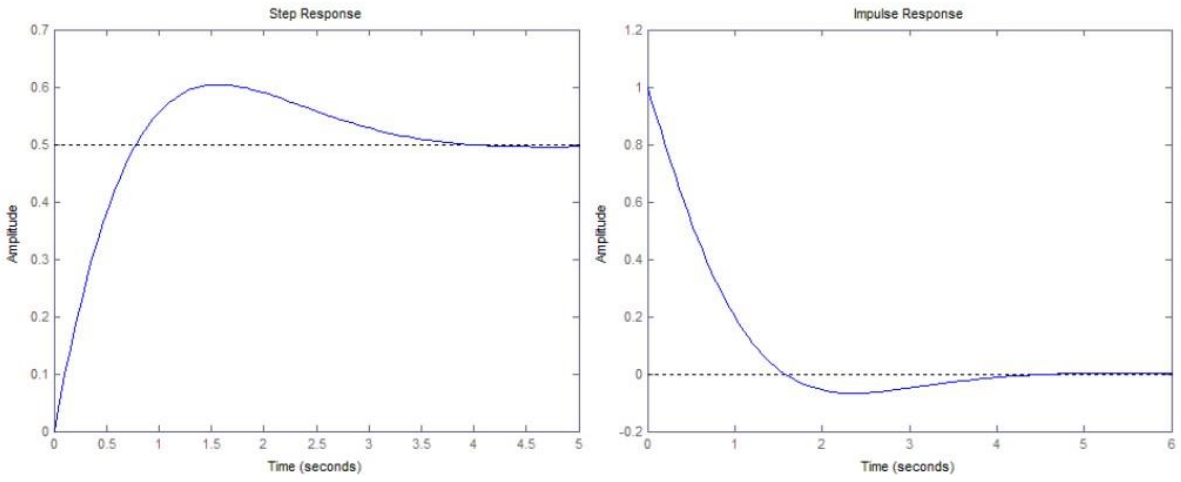
MATLAB code example:

```
a=1; b=1;
num=[1,a];
den=[1,2*a,a^2+b^2];

sys=tf(num,den);
z=zero(sys)

p=pole(sys)
r=roots(den)  figure(1),
step(sys)
figure(2),impulse(sys)
```

Results:

```
z =

    -1


p =

  -1.0000 + 1.0000i
  -1.0000 - 1.0000i


r =

  -1.0000 + 1.0000i
  -1.0000 - 1.0000i
```

System Response:



4. LAB DELIVERIES

PRELAB:

1. **Review the knowledge of transfer function.**

2. **Learn, exercise and understand the MATLAB code examples for the two system in Figure 1 and Figure 2.**

3. **Derive the transfer functions for the System 3 and System 4 as follows, respectively.**

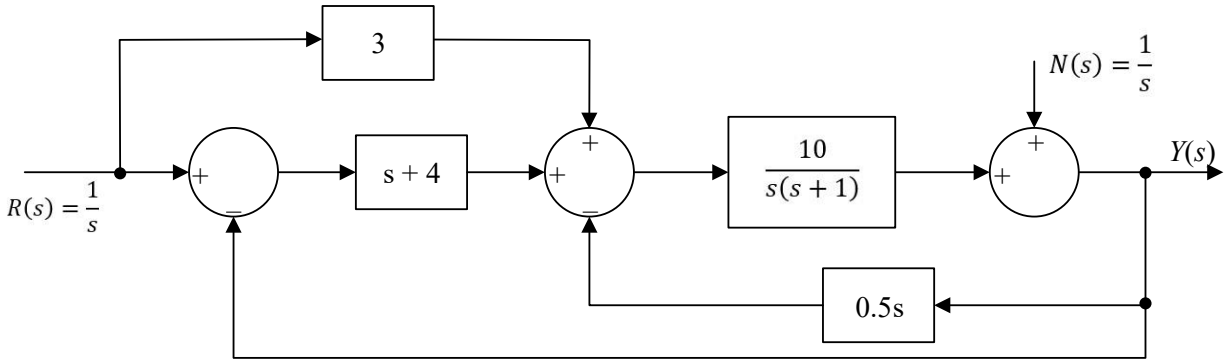


Figure 3. System 3

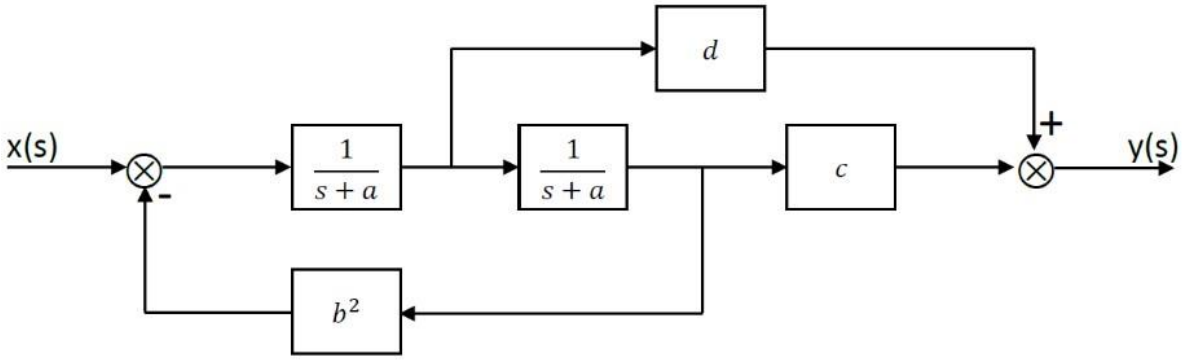


Figure 4. System 4

LAB EXPERIMENTS:

1. **Plot step and impulse response of System 3.**
   - Use both MATLAB coding to plot the responses with derived transfer function.
   - Use Simulink block diagram to run the simulations.
   - Compare the results.
2. **Use MATLAB to plot step and impulse response of System 4 with derived transfer function:**
   1) if [a, b, c, d] = [0, 1, 1, 1];
   2) if [a, b, c, d] = [1, 1, 0, 0].
   3) if [a, b, c, d] = [1, 1, 1, 1].
   4) Compare and explain why these results of the 3 sets of variables are different?
   5) Repeat Step 1) ~ 3) with Simulink block diagram and compare the results.

POSTLAB REPORT:

Include the following elements in the report document:

<table>
<tr><th>Section</th><th colspan="2">Element</th></tr>
<tr><td>1</td><td colspan="2">Theory of operation
Include a brief description of every element and phenomenon that appear during the experiments.</td></tr>
<tr><td>2</td><td colspan="2">Prelab report
Hand calculation results of prelab systems (3) and (4).</td></tr>
<tr><td rowspan="3">3</td><td colspan="2">Results of the experiments</td></tr>
<tr><td>Experiments</td><td>Experiment Results</td></tr>
<tr><td>1</td><td>MATLAB code and simulation results Experiment 1.</td></tr>
<tr><td rowspan="3">4</td><td colspan="2">Answer the questions</td></tr>
<tr><td>Questions</td><td>Questions</td></tr>
<tr><td>1</td><td>Question in Experiment 2.</td></tr>
<tr><td>5</td><td colspan="2">Conclusions
Write down your conclusions, things learned, problems encountered during the lab and how they were solved, etc.</td></tr>
<tr><td>6</td><td colspan="2">Images
Paste images (e.g. scratches, drafts, screenshots, photos, etc.) in Postlab report document (only .docx, .doc or .pdf format is accepted). If the sizes of images are too large, convert them to jpg/jpeg format first, and then paste them in the document.

Attachments (If needed)
Zip your projects. Send it as attachments, or provide link to the zip file on Google Drive / Dropbox, etc.</td></tr>
</table>

5. REFERENCES & ACKNOWLEDGEMENT

1. Norman S. Nise, “Control Systems Engineering”, 7th Ed.
2. https://en.wikipedia.org/wiki/Transfer_function