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Laboratory Experiment No.5

Exercise 1:

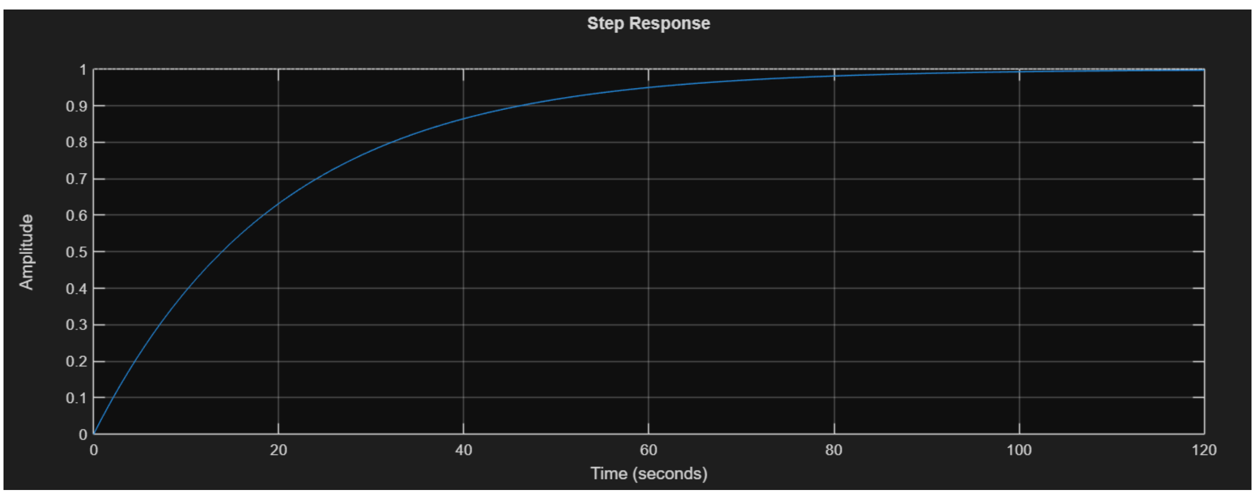
a) Given the values of *R* and *C*, obtain the unit step response of the first order system.

i. *R* = 2kΩ and *C* = 0.01 F

```
>> R = 2000;
C = 0.01;
tau = R*C;

num = 1;
den = [tau 1];
sys = tf(num, den);

figure;
step(sys);
grid on;
```



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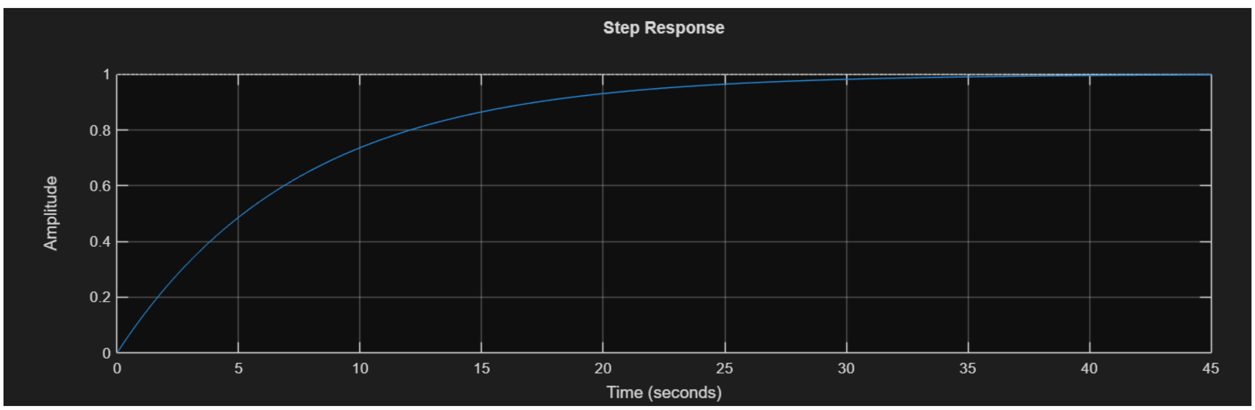
ii. *R* = 2.5kΩ and *C* = 0.003 F

```
>> R = 2500;
C = 0.003;
tau = R*C;

num = 1;
den = [tau 1];
sys = tf(num, den);

figure;
step(sys);
grid on;
```



b) Verify in each case that the calculated time constant ($\tau = RC$) and the one measured from the figure as 63% of the final value are same.

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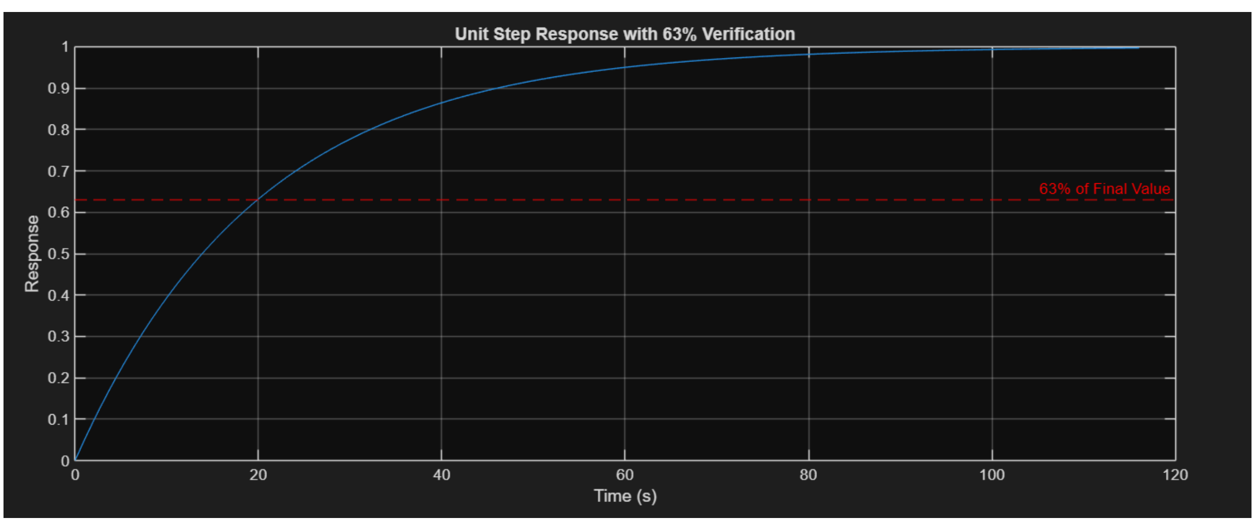
For *R* = 2kΩ and *C* = 0.01 F

```
>> R = 2000;
C = 0.01;
tau = R*C;

sys = tf(1, [tau 1]);

[y,t] = step(sys);

final_val = dcgain(sys);
target_val = 0.63 * final_val;

[~,idx] = min(abs(y - target_val));
t_measured = t(idx);

fprintf('Theoretical tau = %.2f s\n', tau);
fprintf('Measured tau (from 63%% rule) = %.2f s\n', t_measured);

figure;
plot(t,y); hold on;
plot(t(idx),y(idx));
yline(target_val,'r--','63% of Final Value');
grid on;
title('Unit Step Response with 63% Verification');
xlabel('Time (s)');
ylabel('Response');
```

```
Theoretical tau = 20.00 s
Measured tau (from 63% rule) = 20.26 s
```



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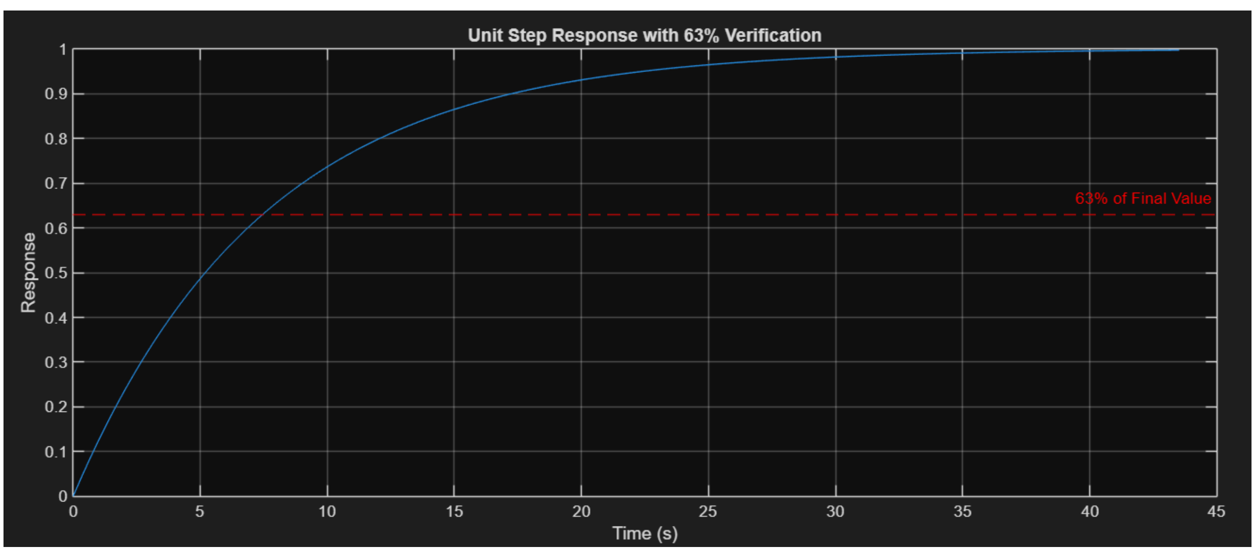
For $R = 2.5\text{k}\Omega$ and $C = 0.003$ F

```
>> R = 2500;
C = 0.003;
tau = R*C;

sys = tf(1, [tau 1]);

[y,t] = step(sys);

final_val = dcgain(sys);
target_val = 0.63 * final_val;

[~,idx] = min(abs(y - target_val));
t_measured = t(idx);

fprintf('Theoretical tau = %.2f s\n', tau);
fprintf('Measured tau (from 63%% rule) = %.2f s\n', t_measured);

figure;
plot(t,y); hold on;
plot(t(idx),y(idx));
yline(target_val,'r--','63% of Final Value');
grid on;
title('Unit Step Response with 63% Verification');
xlabel('Time (s)');
ylabel('Response');
```

```
Theoretical tau = 7.50 s
Measured tau (from 63% rule) = 7.60 s
```



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c) Obtain the steady state value of the system.

For *R* = 2kΩ and *C* = 0.01 F

```
>> R = 2000;
C = 0.01;
tau = R*C;

sys = tf(1, [tau 1]);
steady_val = dcgain(sys)

steady_val =

     1
```

For *R* = 2.5kΩ and *C* = 0.003 F

```
>> R = 2500;
C = 0.003;
tau = R*C;

sys = tf(1, [tau 1]);
steady_val = dcgain(sys)

steady_val =

     1
```

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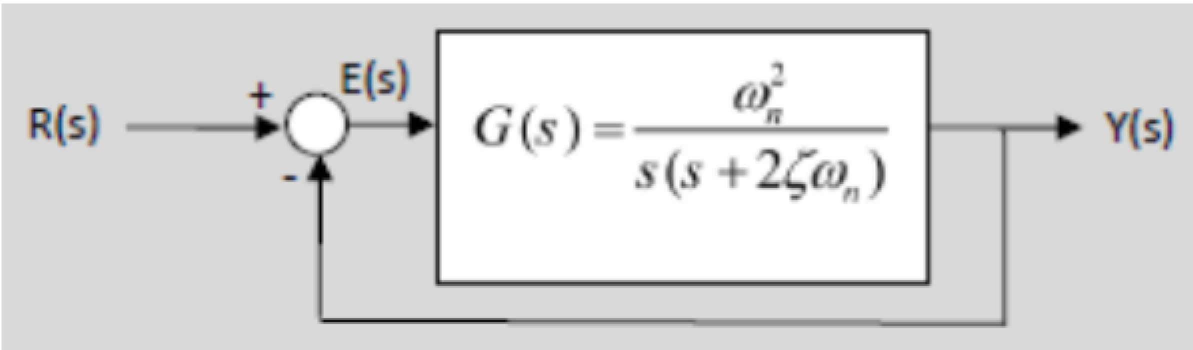
Exercise 2: Effect of damping ratio ζ on performance measures. For a single-loop second order feedback system given below.



Find the step response of the system for values of $\omega_n = 1$ and $\zeta = 0.1, 0.4, 0.7, 1.0$ and 2.0. Plot all the results in the same figure window and fill the following table.

ζ	Rise time	Peak Time	% Overshoot	Settling time	Steady state value
0.1	**1.1272 sec**	**3.1416 sec**	**72.9160%**	**38.3730 sec**	**1**
0.4	**1.4652 sec**	**3.4539 sec**	**25.3470%**	**8.4094 sec**	**1**
0.7	**2.1268 sec**	**4.4078 sec**	**4.5986%**	**5.9789 sec**	**1**
1.0	**3.3583 sec**	**0**	**0**	**5.8341 sec**	**1**
2.0	**8.2308 sec**	**0**	**0**	**14.8790 sec**	**1**

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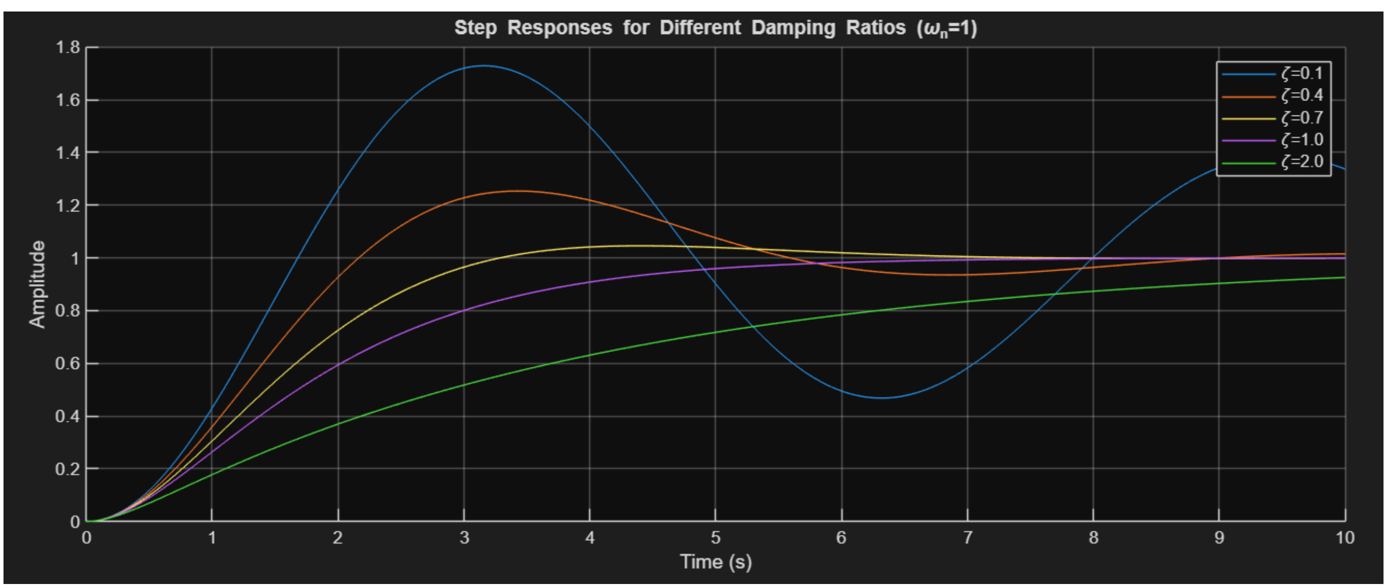
```
>> wn = 1;

zeta1 = 0.1; sys1 = tf([wn^2],[1 2*zeta1*wn wn^2]);
zeta2 = 0.4; sys2 = tf([wn^2],[1 2*zeta2*wn wn^2]);
zeta3 = 0.7; sys3 = tf([wn^2],[1 2*zeta3*wn wn^2]);
zeta4 = 1.0; sys4 = tf([wn^2],[1 2*zeta4*wn wn^2]);
zeta5 = 2.0; sys5 = tf([wn^2],[1 2*zeta5*wn wn^2]);

t = 0:0.01:10;

[y1,t1] = step(sys1,t);
[y2,t2] = step(sys2,t);
[y3,t3] = step(sys3,t);
[y4,t4] = step(sys4,t);
[y5,t5] = step(sys5,t);

figure; hold on; grid on;
plot(t1,y1);
plot(t2,y2);
plot(t3,y3);
plot(t4,y4);
plot(t5,y5);

legend('\zeta=0.1','\zeta=0.4','\zeta=0.7','\zeta=1.0','\zeta=2.0');
title('Step Responses for Different Damping Ratios (\omega_n=1)');
xlabel('Time (s)');
ylabel('Amplitude');
```



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```
>> zetas = [zeta1, zeta2, zeta3, zeta4, zeta5];
infos = {info1, info2, info3, info4, info5};
ss    = [ss1, ss2, ss3, ss4, ss5];

RiseTime     = [info1.RiseTime, info2.RiseTime, info3.RiseTime, info4.RiseTime, info5.RiseTime]';
PeakTime     = [info1.PeakTime, info2.PeakTime, info3.PeakTime, info4.PeakTime, info5.PeakTime]';
Overshoot    = [info1.Overshoot, info2.Overshoot, info3.Overshoot, info4.Overshoot, info5.Overshoot]';
SettlingTime = [info1.SettlingTime, info2.SettlingTime, info3.SettlingTime, info4.SettlingTime, info5.SettlingTime]';
SteadyState  = ss';

PeakTime(zetas >= 1)  = 0;
Overshoot(zetas >= 1) = 0;

RiseTime     = round(RiseTime,4);
PeakTime     = round(PeakTime,4);
Overshoot    = round(Overshoot,4);
SettlingTime = round(SettlingTime,4);
SteadyState  = round(SteadyState,4);

PerformanceTable = table(zetas', RiseTime, PeakTime, Overshoot, SettlingTime, SteadyState, ...
    'VariableNames', {'Zeta','RiseTime','PeakTime','Overshoot','SettlingTime','SteadyState'})
```

Zeta	RiseTime	PeakTime	Overshoot	SettlingTime	SteadyState
0.1	1.1272	3.1416	72.916	38.373	1
0.4	1.4652	3.4539	25.374	8.4094	1
0.7	2.1268	4.4078	4.5986	5.9789	1
1	3.3583	0	0	5.8341	1
2	8.2308	0	0	14.879	1

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Observation

From the experiments conducted, it was observed that MATLAB effectively simulated both first-order and second-order systems, confirming their theoretical performance characteristics. For the first-order RC circuit, the command step(tf(1,[tau 1])) was used with R=2kΩ, C=0.01, and with R=2.5kΩ, C=0.003F, producing unit step responses where the output reached 63% of its final value at one time constant τ=RC. This verified that the measured and calculated time constants matched as expected. For the second-order case, the effect of the damping ratio zeta (ζ) on system behavior was analyzed by plotting step responses for values of ζ = 0.1, 0.4, 0.7, 1.0, and 2.0. The results showed that lower damping produced high overshoot and long settling time, while higher damping removed oscillations but slowed the rise time. These findings validated that MATLAB not only confirmed theoretical predictions but also provided clear visualization of performance measures such as rise time, overshoot, settling time, and steady-state value.

Conclusion

This laboratory exercise emphasized the importance of studying the performance characteristics of first and second-order systems, since these models are foundational in engineering practice. Understanding time response indices such as rise time, overshoot, and settling time is essential for predicting system performance and ensuring stability in real-world applications. These principles extend to practical scenarios such as the smooth charging of capacitors in electronics, the design of suspension systems in vehicles, and the damping of vibrations in aerospace structures. By using MATLAB as a tool to analyze and visualize these dynamics, engineers are better equipped to optimize designs for safety, efficiency, and reliability, bridging theoretical knowledge with real-life applications.