```
[z,p,k]=tf2zp(b,a);
[c,d] = zp2tf(z,p,k)
subplot(3,1,1)
impulse(trans)
subplot(3,1,2)
step(trans)
subplot(3,1,3)
sgrid
pzmap(tf(c,d))
grid on
```

Fig 2: Impulse response of the system

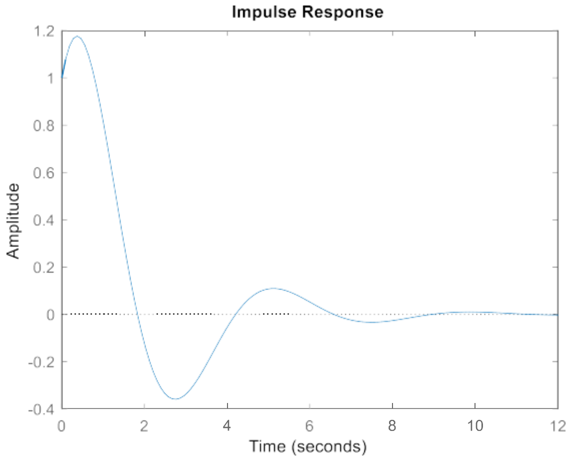


Fig 3: Step response of the system

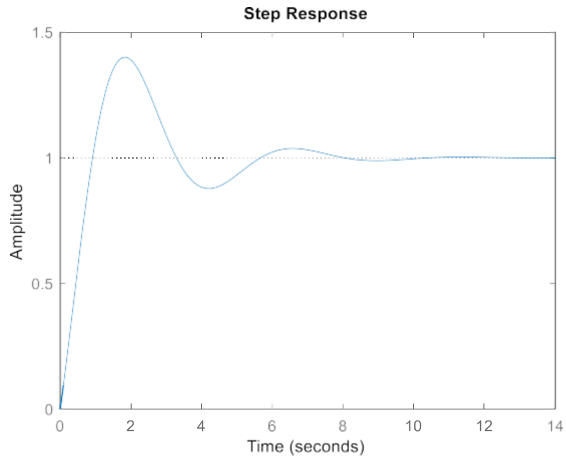
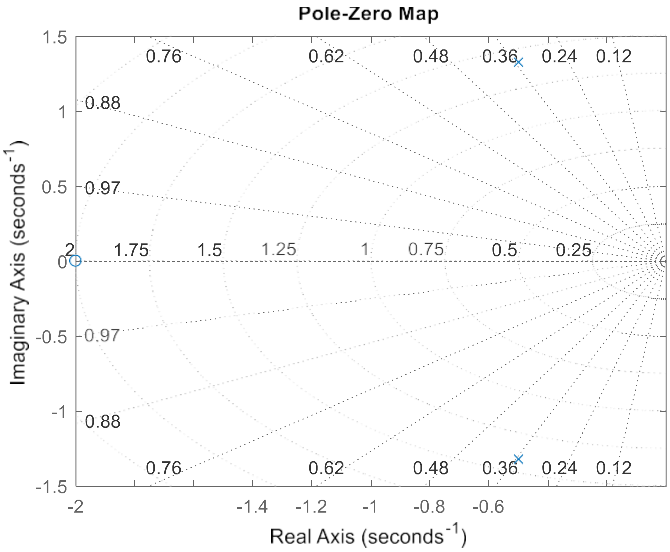


Fig 4: Pole Zero map



Simulink Diagram:

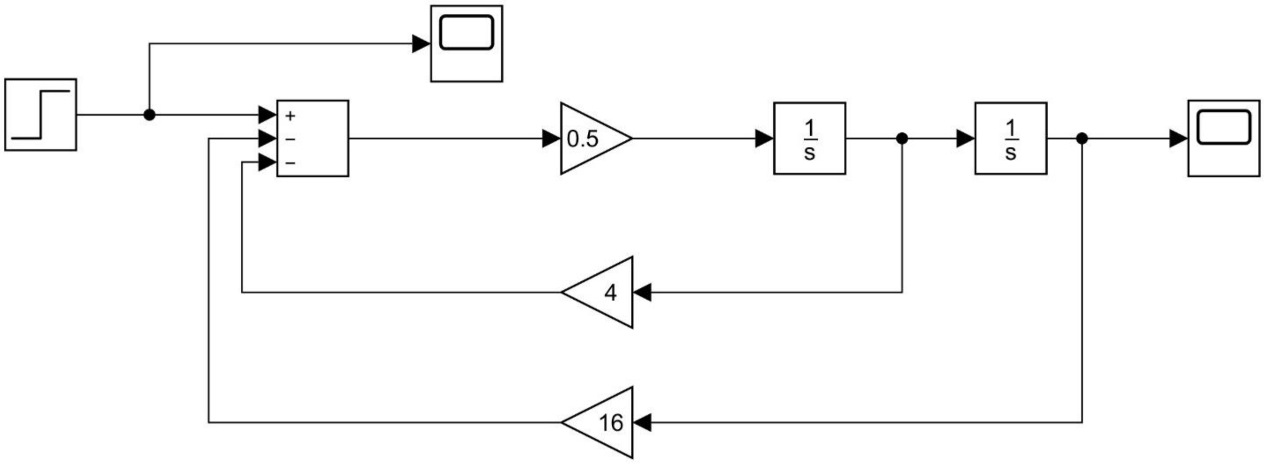


Fig 5: Simulink Diagram representing the spring mass

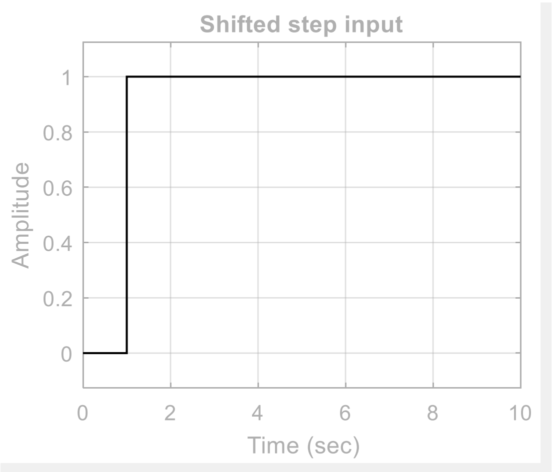


Fig 6: Shifted step input

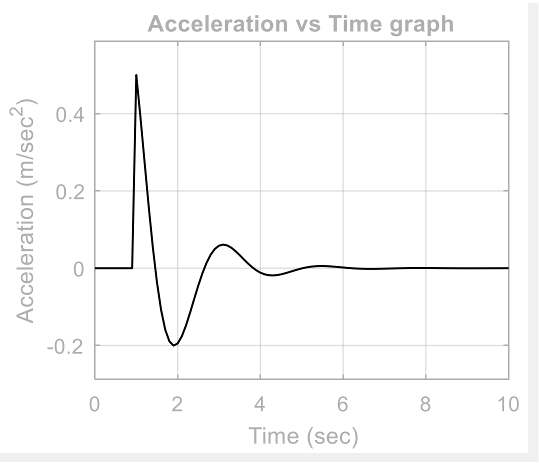


Fig 7: Acceleration vs Time graph

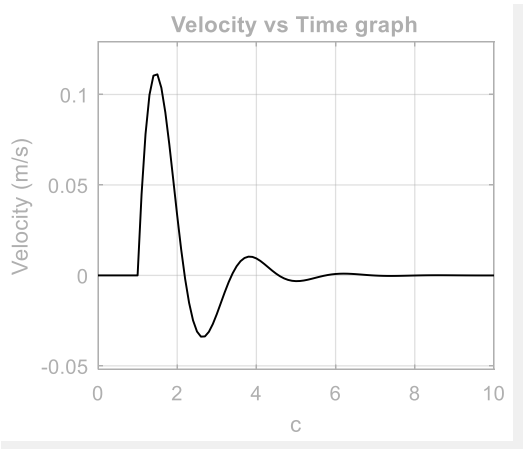


Fig 8: Velocity vs Time graph

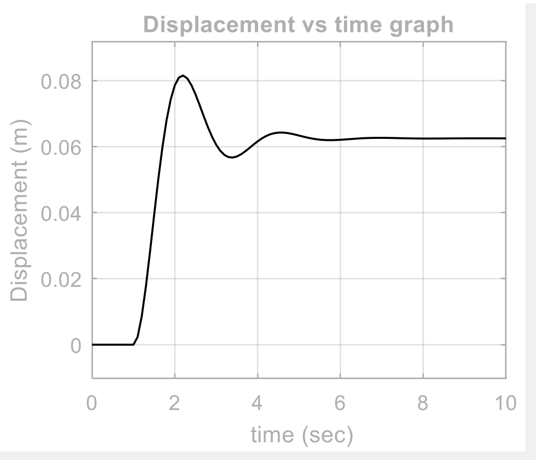


Fig 9: Displacement vs Time graph

Conclusion:

- Various MATLAB functions were used to formulate the transfer function. Impulse and step response were plotted for the given transfer function.
- It can be observed that in the initial time frame of 1 to 2 second, the effect of the spring force is very less compared to the applied step input, hence the mass accelerates to increase velocity and displacement, eventually due to high displacement and hence high spring force the mass is pulled back and forth by the counter acting spring and applied force, resulting in oscillations. These oscillations of the system are damped out and hence the mass attains a constant displacement after a few time constants.

Result:

- Transfer function was successfully generated using the Control System Toolbox and poles, zeros and gain was analysed.
- The damped spring mass system was modelled and analysed using Simulink.

Date: 19-08-2019

Experiment 3.a

Title of the experiment:

- To simplify the given system

$$G_1(s) = \frac{s^2+1}{s^2+s+4} \qquad G_2(s) = \frac{s^2+s+2}{s^3+s^2+s+4} \qquad H(s) = \frac{1}{500s^2}$$

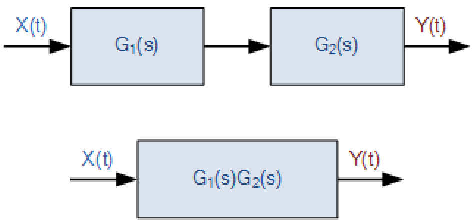


Fig-1: Series connection

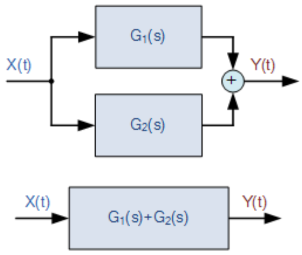


Fig-2: Parallel connection

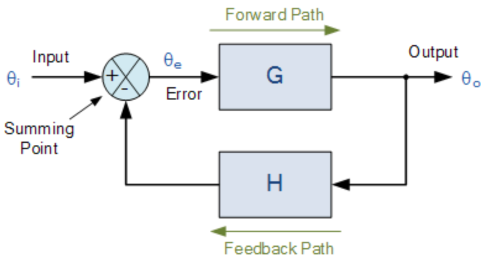


Fig-3: Feedback connection

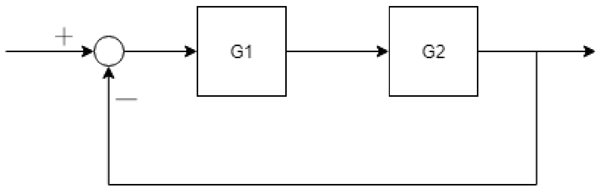


Fig-4: Unity feedback connection

- Use block diagram reduction techniques to replace the system with one block diagram

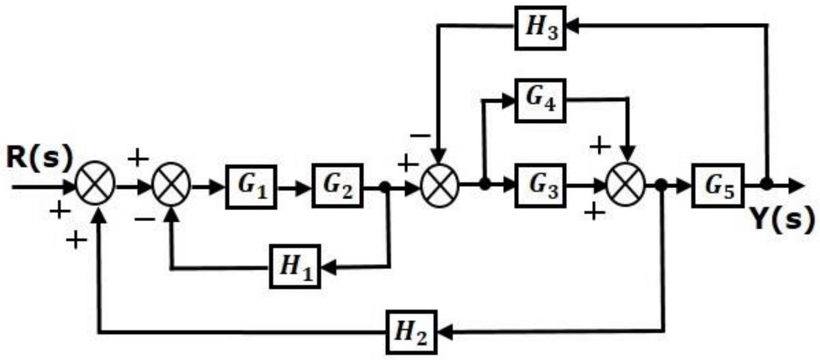


Fig-5

Objective of the Experiment:

To solve the ordinary differential equations in Mupad and obtain the desired time dependent equations along with necessary plots of the results.

Software: MATLAB along with Control system toolbox

Equations/formula:

Various block diagram reduction rules are as follows:

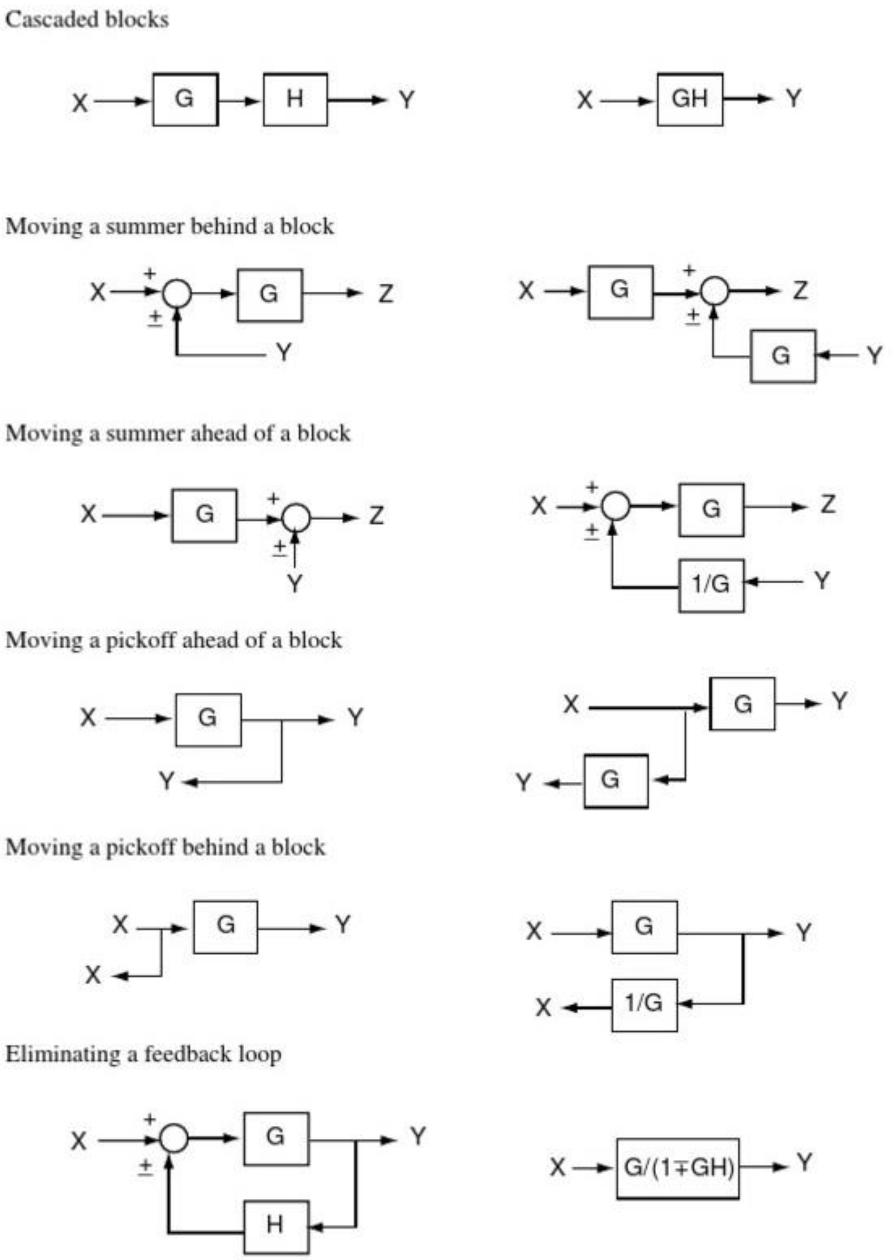


Fig-6

<u>Theory:</u>

Block diagrams of control system

A Block diagram is basically modelling of any simple or complex system. It Consists of multiple Blocks connected to represent a system to explain how it is functioning.

Basic Elements of Block Diagram

The basic elements of a block diagram are a block, the summing point and the take-off point.

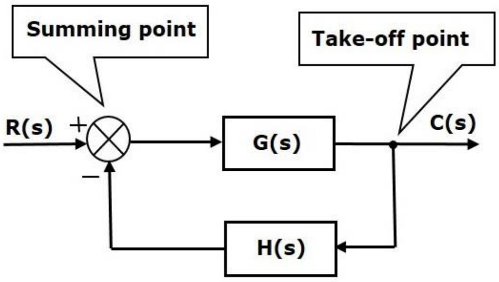


Fig-7

Summing Point

The summing point is represented with a circle having cross (X) inside it. It has two or more inputs and single output. It produces the algebraic sum of the inputs. It also performs the summation or subtraction, or combination of summation and subtraction of the inputs based on the polarity of the inputs.

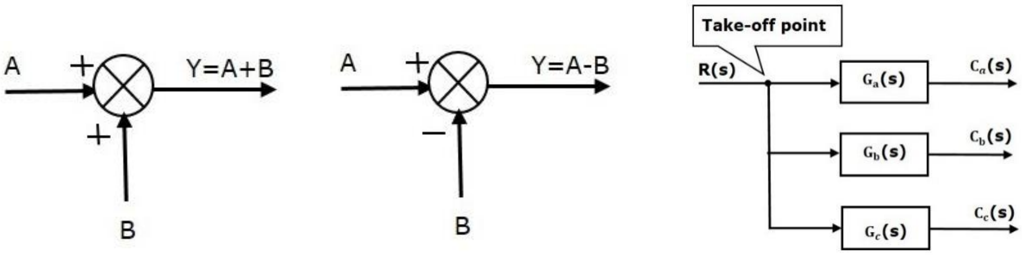


Fig-8

Take-off Point

The take-off point is a point from which the same input signal can be passed through more than one branch. That means with the help of take-off point, we can apply the same input to one or more blocks, summing points.

Consider the block diagram shown in the following figure. Simplifying using the rules of block diagram reduction

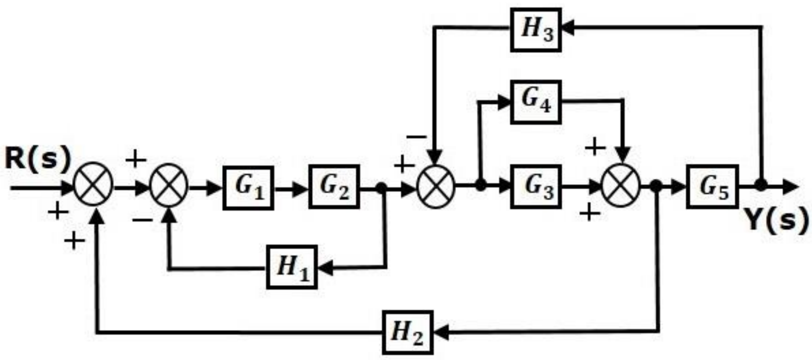


Fig-9

Step 1 − Use Rule 1 for blocks G_1 and G_2. Use Rule 6 for blocks G_3 and G_4.

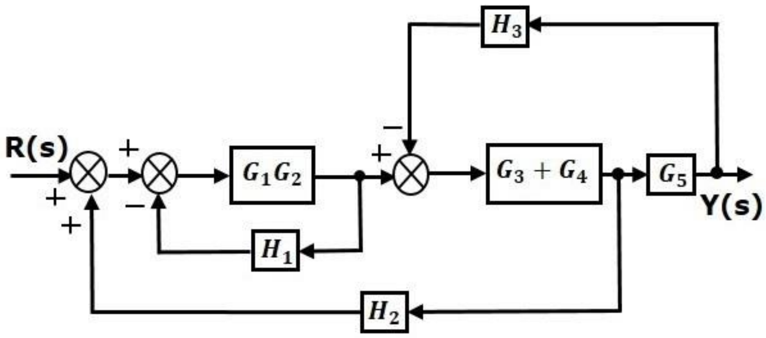


Fig-10

Step 2 − Use Rule 6 for blocks G_1G_2 and H_1. Use shifting take-off point after the block G_5.

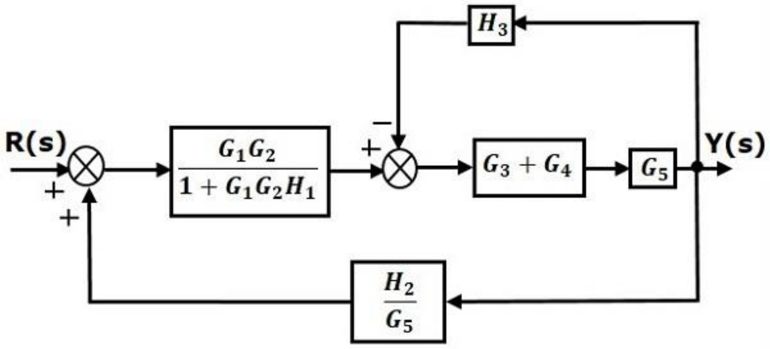


Fig-11

Step 3 − Use Rule 1 for blocks (G_3+G_4) and G_5.

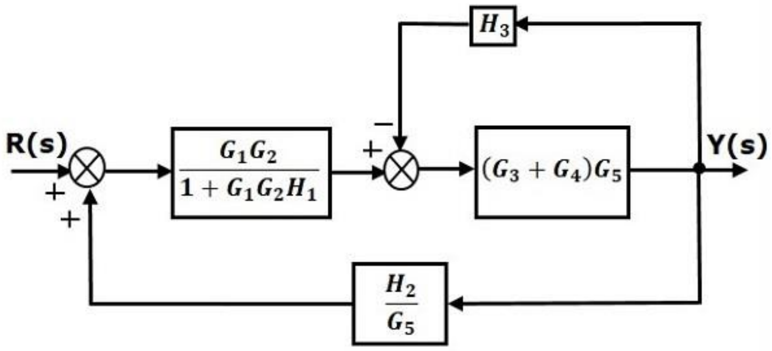


Fig-12

Step 4 − Use Rule 6 for blocks $(G_3+G4)G_5$ and H_3.

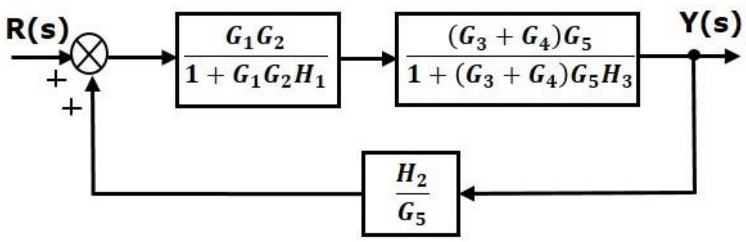


Fig-13

Step 5 − Use Rule 1 for blocks connected in series.

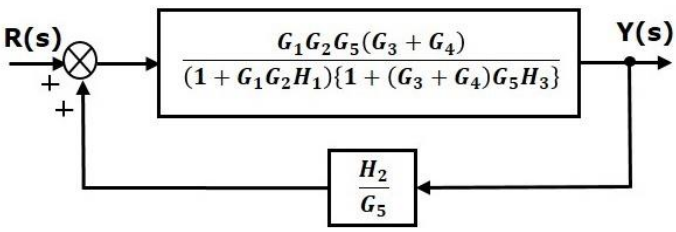


Fig-14

Step 6 − Use Rule 6 for blocks connected in feedback loop.

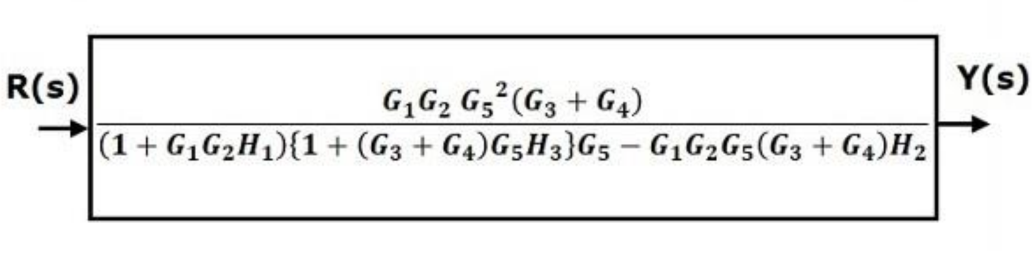


Fig-15

MATLAB Code 1:

```
g1 = tf([1 0 1],[1 1 4]);
g2 = tf([1 1 2], [1 1 1 4]);
h = tf([1], [500 0 0]);

sys1 = series(g1, g2)
sys2 = parallel(g1, g2)
sys3 = feedback(sys1, 1)
sys4 = feedback(sys1, h)
```

Output

```
sys1 =

        s^4 + s^3 + 3 s^2 + s + 2
  --------------------------------------
  s^5 + 2 s^4 + 6 s^3 + 9 s^2 + 8 s + 16

Continuous-time transfer function.


sys2 =

  s^5 + 2 s^4 + 4 s^3 + 12 s^2 + 7 s + 12
  ---------------------------------------
  s^5 + 2 s^4 + 6 s^3 + 9 s^2 + 8 s + 16

Continuous-time transfer function.


sys3 =

         s^4 + s^3 + 3 s^2 + s + 2
  ---------------------------------------
  s^5 + 3 s^4 + 7 s^3 + 12 s^2 + 9 s + 18

Continuous-time transfer function.


sys4 =

            500 s^6 + 500 s^5 + 1500 s^4 + 500 s^3 + 1000 s^2
  ----------------------------------------------------------------------
  500 s^7 + 1000 s^6 + 3000 s^5 + 4501 s^4 + 4001 s^3 + 8003 s^2 + s + 2

Continuous-time transfer function.
```

MATLAB Code 2:

```
g1 = tf(1,[1 14 40]);
g2 = tf([1 0 1], [1 6 5]);
g3 = tf([1 1], [1 4 4]);
g4 = tf([1 0 4], [1 2 2]);
g5 = tf([1 1], [1 2 1]);
h1 = tf(1);
h2 = tf([1],[100,0,0]);
h3 = tf([2 4],[1 1 4]);

l1 = feedback(series(g1,g2), h);
l2 = parallel(g3, g4);
h4 = h2 / g5;
l3 = feedback(series(l2,g5),h3);
X = feedback(series(l1,l3),h4) s=tf('s');

Y = (100 *s^12 + 800 *s^11 + 3400 *s^10 + 10500 *s^9 + 23700 *s^8 + 41000
*s^7 + 55400 *s^6 + 55500 *s^5 + 42200 *s^4 + 24200 *s^3 + 7200 *s^2)/(100
*s^15 + 3000 *s^14 + 38000 *s^13 + 277600 *s^12 + 1.351e06 *s^11 + 4.763e06
*s^10 + 1.271e07 *s^9 + 2.617e07 *s^8 + 4.187e07 *s^7 + 5.158e07 *s^6 +
4.74e07 *s^5 + 3.03e07 *s^4 + 1.183e07 *s^3 + 2.091e06 *s^2 + 314*s + 72);

isequal(Y,X)
```

Output

```
>> X =

100 s^12 + 800 s^11 + 3400 s^10 + 10500 s^9 + 23700 s^8 + 41000 s^7 + 55400
s^6 + 55500 s^5 + 42200 s^4
+ 24200 s^3 + 7200 s^2

  ---------------------------------------------------------------------

100 s^15 + 3000 s^14 + 38000 s^13 + 277600 s^12 + 1.351e06 s^11 + 4.763e06
s^10 + 1.271e07 s^9 + 2.617e07 s^8 + 4.187e07 s^7 + 5.158e07 s^6 + 4.74e07
s^5 + 3.03e07 s^4 + 1.183e07 s^3 + 2.091e06 s^2 + 314 s + 72


>> ans =

  logical

   1
```

Result and Conclusions:

1. From the above results we can deduce that a large system can be simplified to a single block using simple block reduction techniques. This makes the analysis of system like finding out responses much easier.

Date: 20-08-2019

Assignment 3

Title of the experiment:

- To study about potentiometer as measurement instruments of angular displacement, and analyse their application in error detection and in measurement of the relative angle of two entities and application in control systems

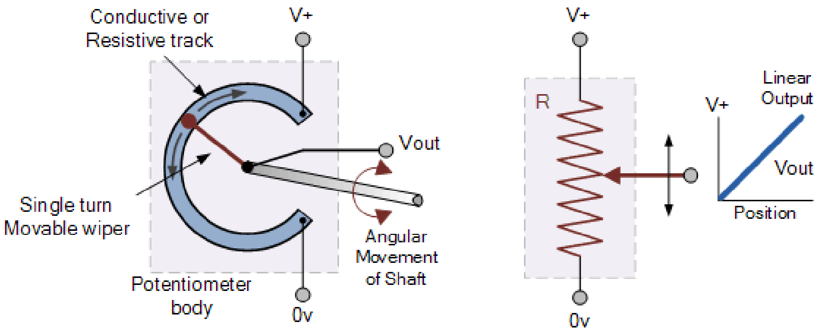
Objective of the Experiment:

To get familiar with using potentiometer for error detection and in measurement of the relative angle of two entities.

Software: Potentiometer based angular displacement measurement kit, Patch Chords and Power Supply

Theory:

Angular displacement of a body is the angle in radians (degrees, revolutions) through which a point revolves around a centre or line has been rotated in a specified sense about a specified axis. When a body rotates about its axis, the motion cannot simply be analysed as a particle, as in circular motion it undergoes a changing velocity and acceleration at any time (t). When dealing with the rotation of a body, it becomes simpler to consider the body itself rigid. A body is generally considered rigid when the separations between all the particles remains constant throughout the body's motion, so for example parts of its mass are not flying off. In a realistic sense, all things can be deformable, however this impact is minimal and negligible. Thus, the rotation of a rigid body over a fixed axis is referred to as rotational motion.



Potentiometric displacement transducers:

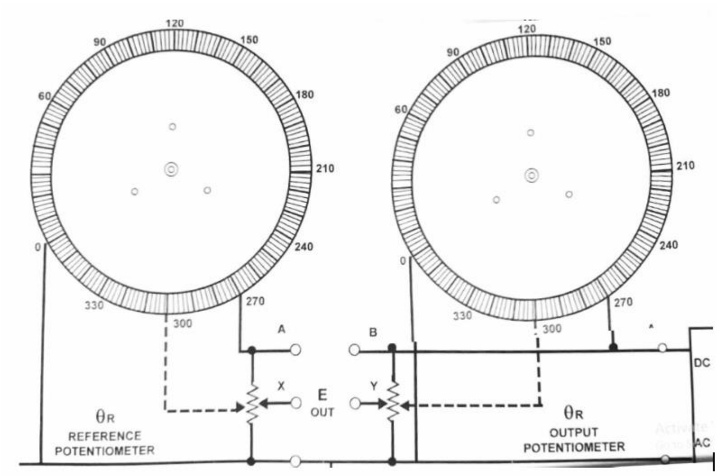
Displacement transducers using potentiometric variable resistance transduction elements are invariably shaft-coupled devices. The sensing element is basically a resistance-potentiometer with a movable wiper contact attached to an insulated plunger-type shaft mechanically linking the point under measurement. The contact motion can be translation, rotation or a combination of both.

The resistivity and temperature of the resistance element should be such value that the device operates with appreciable constant sensitivity over a wide temperature range. The three major elements critical in a potentiometric device are the winding wire, winding former and the wiper.

Error detector is a device which gives output proportional to the difference between the two inputs. If one is used as a reference and the other is used as output potentiometer then differential inputs of two shaft positions gives the error between the respective positions.

If θ_R is the reference and θ_0 is output position, then output

$$e_0 = k * (\theta_R - \theta_0)$$



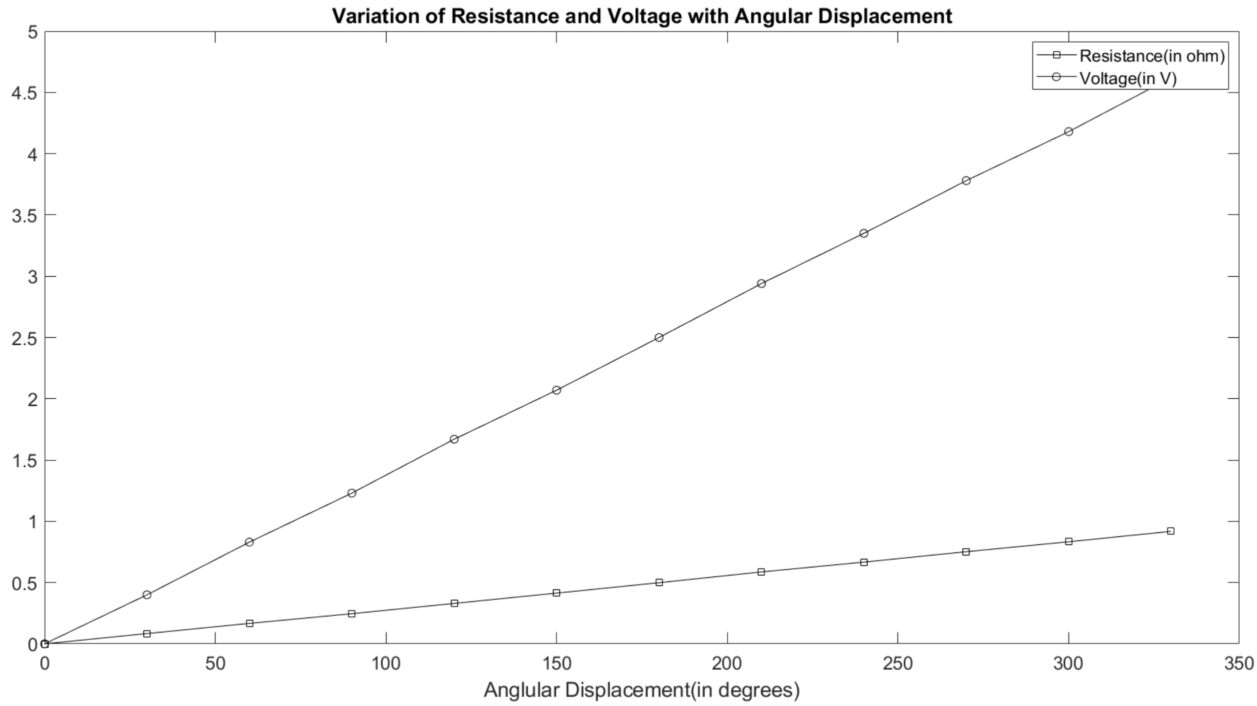
Observation Table:

Table 1: Measurement of Resistance and Output voltage for angular displacement

Angular Displacement θ_i(Degrees)	Measured Resistance R_i(ohm)	Output Voltage V_0(volts)
0	0	0
30	0.084	0.4
60	0.167	0.83
90	0.246	1.23
120	0.330	1.67

Table 2: Measurement of Error voltage and amplified voltage for error measurement $\theta_i = 120°$

Error	Error	Amplified output Voltage(volts)				
$(\theta_f - \theta_i)(°)$	Voltage(volts)	Gain = -0.5	Gain = -1	Gain = -1.4	Gain = -1.9	Gain = -2.5
0	0.48	-0.23	-0.48	-0.70	-0.91	-1.20
-30	0.421	-0.204	-0.41	-0.60	-0.78	-1.03
-60	0.33	-0.16	-0.32	-0.47	-0.62	-0.82
+30	0.54	-0.26	-0.54	-0.79	-1.02	-1.35
+60	0.606	-0.29	-0.59	-0.87	-1.13	-1.49



Calculations: Gain $= \frac{V_A}{V_e}$ where, V_A = Amplified Voltage and V_e = Error Voltage

Result: It was observed that the error voltage was proportional to the difference between the angles of the two potentiometers.

$$\Delta\theta \propto V_e$$

Conclusion: Potentiometers with error amplifiers were found to be a good basis for instrumentation of measurement of both in angular displacement and error in it.

Date: 20-08-2019

Assignment 1

Title of the experiment:

- Satellite single-axis altitude control system
  K, a, b are controller parameters where $K = 10.8 * 10^8$, a = 1, b = 8.
  J is spacecraft moment of inertia where $J = 10.8 * 10^8$
    - Obtain $T(s) = \frac{\theta(s)}{\theta_d(s)}$
    - Plot step response to a 10 degree step input.
    - Compare the step response of spacecraft when J is reduced by 20% and 50% and discuss the results.

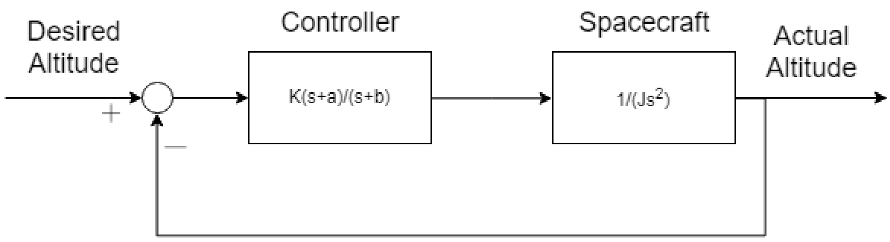


Fig-1: Block diagram of the system

Objective of the Experiment:

To obtain the transfer function of the given system and plot its step response.

Software: MATLAB along with Simulink

Theory:
The original diagram can be simplified

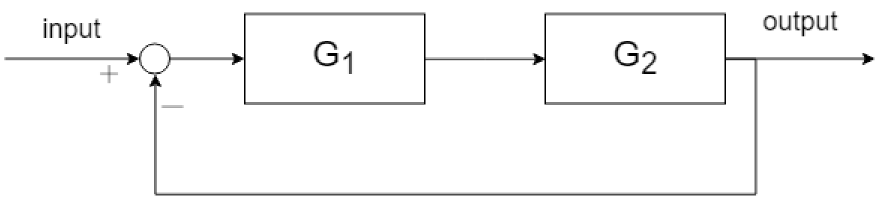


Fig2: The original diagram

G_1 and G_2 are in series therefore it can be reduced.

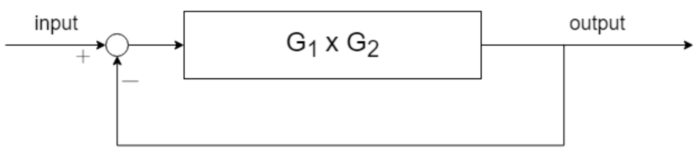


Fig3: Cascaded blocks

The above diagram can further be simplified since it is a feedback connection with unity gain.

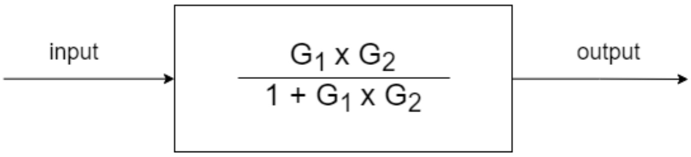


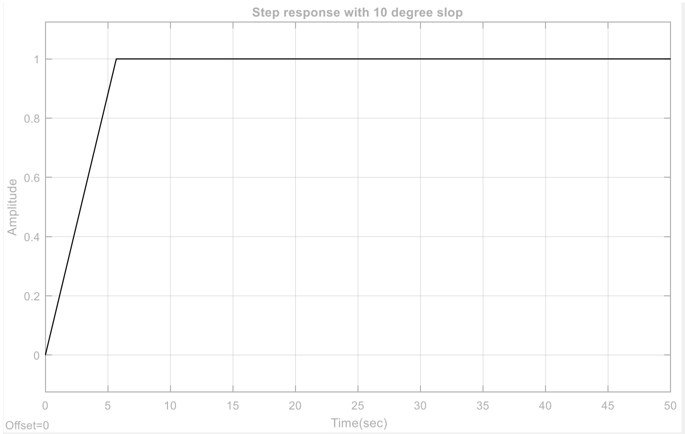
Fig4: The final block

There On solving the expression we get:

$$\mathrm{T(s)} = \frac{\theta(\mathrm{s})}{\theta_{\mathrm{d}}(\mathrm{s})} = \frac{\frac{\mathrm{K(s+a)}}{\mathrm{s+b}}}{1 + \frac{1}{\mathrm{Js^2}} * \frac{\mathrm{K(s+a)}}{\mathrm{s+b}}}$$

$$\mathbf{T(s)} = \frac{\mathbf{Js^2} \ * \mathbf{K(s+a)}}{\mathbf{Js^2(s+b)} + \mathbf{K(s+b)}}$$

Here $\mathrm{K} = 10.8 * 10^8$, a = 1, b = 8, $J = 10.8 * 10^8$



Plot1: Step input to the system

The above function can be generated using two ramp function.

$$\mathrm{slope} \ = \ \mathrm{m} = \tan(10°) = 0.1763$$

$$\mathrm{y(t)} = \mathrm{mt} * \mathrm{r(t)} - \mathrm{mt} * \mathrm{r}\left(\mathrm{t} - \frac{1}{\mathrm{m}}\right)$$

$$\mathrm{y(t)} = 0.1763\mathrm{t} * \mathrm{r(t)} - \mathrm{mt} * \mathrm{r(t} - 5.6721)$$

Simulink simulation:

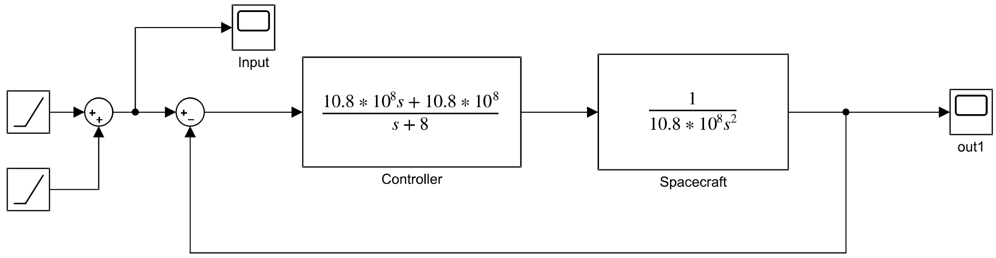
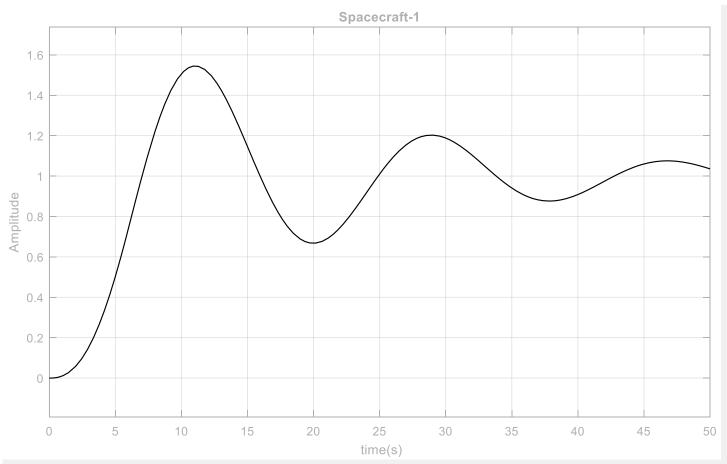


Fig5: Satellite single-axis altitude control system



Plot5: Step response of Fig5

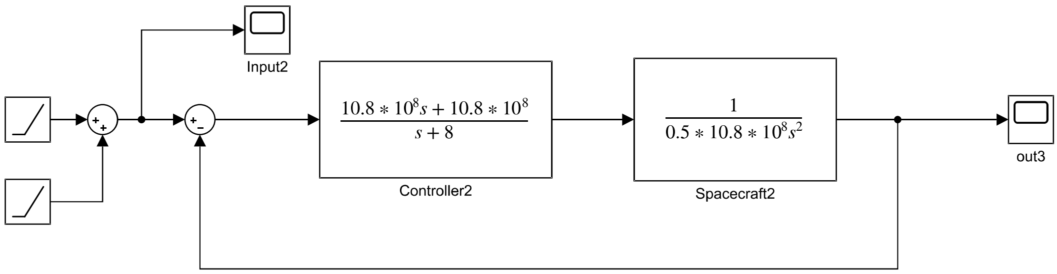
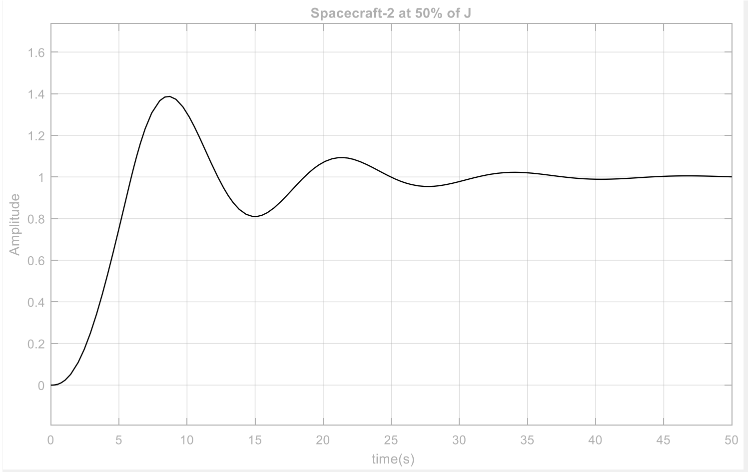


Fig6: Satellite single-axis altitude control system with 50% of J



Plot6: Step response of Fig6

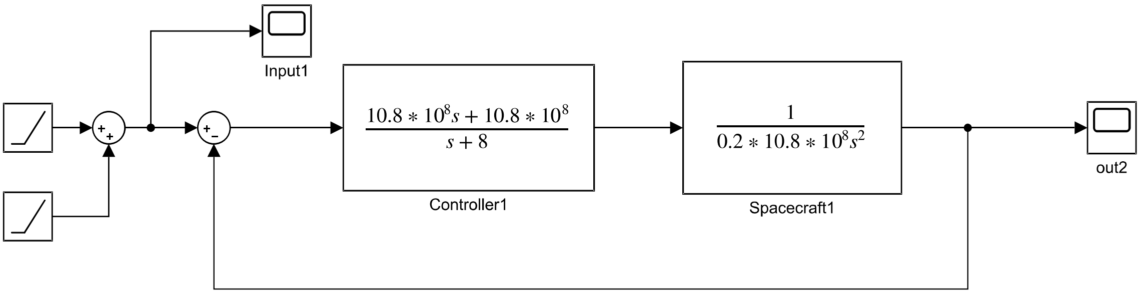
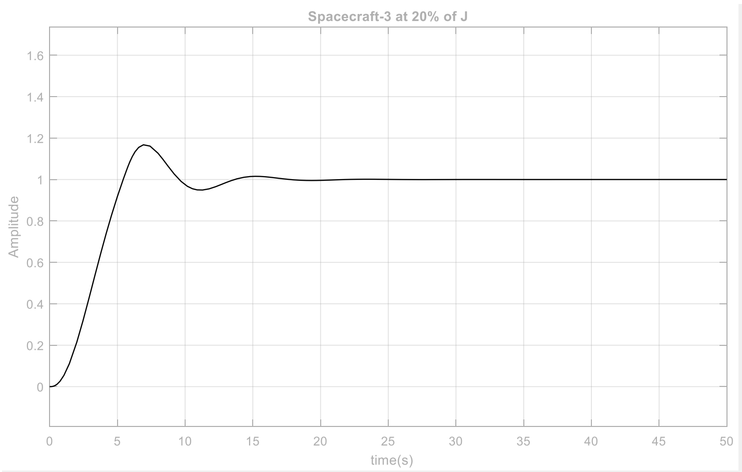


Fig6: Satellite single-axis altitude control system with 20% of J



Plot6: Step response of Fig6

Result:

The step response plots for the single axis satellite altitude control system were plotted for different values of J and the graphs were analysed.

Conclusion:

From the above step responses, we can infer that as the moment of inertia decreases the time required to reach the steady state condition also decreases

Date: 20-08-2019

Assignment 2

Title of the experiment:

Block diagram reduction to find the transfer function of the two-tank system.

- Creating transfer functions.
- With the use of block reduction techniques find the resulting transfer function

Objective of the Experiment:

Finding the transfer function of the two-tank system.

Software: MATLAB along with Control system toolbox

Theory:

We know that a two-tank system can be modelled using the given equations:

Here C_1 C_2 denotes capacity, h_1 and h_2 denotes heights and q_1, q_2 denotes rate of flow for tank one and tank two respectively

$$C_1 \frac{dh_1}{dt} = q - q_1,$$

$$C_2 \frac{dh_2}{dt} = q_1 - q_2,$$

$$q_1 = \frac{h_1 - h_2}{R_1} \text{ and } q_2 = \frac{h_2}{R_2}$$

Applying Laplace Transformation both sides, we get

$$sC_1 H_1(S) = Q(S) - Q_1(S),$$

$$sC_2 H_2(S) = Q_1(S) - Q_2(S),$$

$$Q_1(S) = \frac{H_1(S) - H_2(S)}{R_1} \text{and} Q_2(S) = \frac{H_2}{R_2}$$

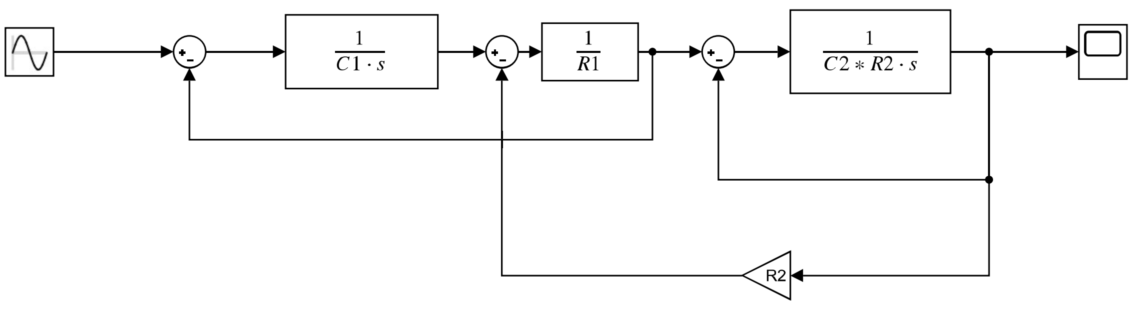


Fig.1: Non-simplified block diagram for a two-tank system

Simplifying by applying shifting of take take-off points we get:

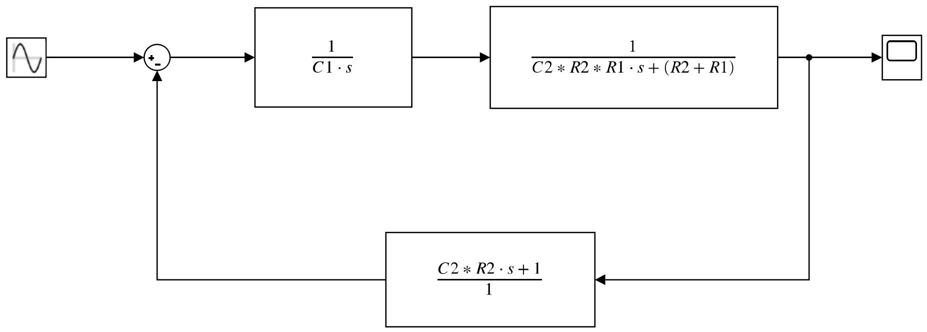


Fig.2: After applying simplification properties

Since it's a negative feedback we can substitute it using a single block as shown below:

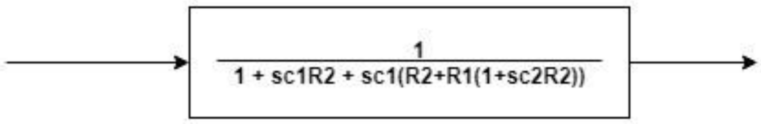


Fig.3: Simplified block diagram

Final transfer function of the system is given below:

$$G_f(s) = \frac{1}{1 + sC_1\left(R_2 + R_1(1 + sC_2R_2)\right)}$$

Matlab Code:

```
% value of C1, C2,C3,C4 is defined for calculations
c1 = 1; c2 = 2; r1 = 1; r2 = 2;

% various declarations for the transfer functions
H1 = tf([0 1],[c1 0]);
H2 = tf(1/r1);
H3 = tf([0 1],[c2 0]);
H4 = tf(1/r2);

% interconnections of transfer functions
G3_4 = series(H3,H4);
G3_4 = feedback(G3_4,1);
G2_t = series(G3_4,H2);
GH_2t = feedback(G2_t,r2);
GT = series(GH_2t,H1);
G_f = feedback(GT,1/G3_4)

%Manullay created Transfer functions
CAL = tf([0 0 1],[4 7 1])

%verifying LHS = RHS
intG_f-CAL
```

Matlab Result:

```
G_f =

         0.25

  -------------------

  s^2 + 1.75 s + 0.25

Continuous-time transfer function.


CAL =

         1

  ---------------

  4 s^2 + 7 s + 1


Continuous-time transfer function.

ans =

  0

Static gain.
```

Conclusion:

- The above result successfully verifies that the two-tank system can be mathematically modelled for and can be converted to block diagrams. We can also further reduce these block diagrams using various properties.