

Contents

- [Control Systems Engineering](#)
- [Initial Conditions](#)

Control Systems Engineering

% Mass-Spring Damper System

Initial Conditions

```
m_1 = 1;      % units in Kg
m_2 = 1;      % units in Kg
k_1 = 10;     % units in N/m
k_2 = 10;     % units in N/m
c_1 = 0.1;    % units in Kg/s
c_2 = 0.1;    % units in Kg/s

X = [0.5; 1; -0.1; 0.5];

% State Space matrices

A = [ 0          0          1          0
      0          0          0          1
      -(k_1+k_2)/m_1  k_2/m_1  -(c_1+c_2)/m_1  c_2/m_1
      k_2/m_2      -k_2/m_2  c_2/m_2      -c_2/m_2]

B = [0; 0; 1; 0]

C = [1 0 0 0]

D = 0

% to track x_1 = 10m
r = 10

% Conditions for Riccati Equation
Qy = 50;
Qw = 1;
R = 2;

nu = size(B,2); % No of Inputs
nx = length(A); % No of States
ny = size(C,1); % No of outputs

% LQR gains
[K,S] = lqr(A,B,C'*Qy*C,R)

% Adding Integral Action
A_ = [A  zeros(nx,ny)
      -C  zeros(ny,ny)]
B_ = [B;zeros(ny,nu)]
C_ = [C zeros(ny,ny)]

F = -inv(R)*B'*inv((A-B*K)')*C'*Qy;

Q_ = [C'*Qy*C      zeros(nx,ny)
      zeros(ny,nx) Qw];

% LQR for the new state
[K_ S_] = lqr(A_,B_,Q_,R)

W = inv(R)*B_'*inv((A_-B_*K_)');
W1 = W(:,1:nx);
```

```
G = W*S_  
G2 = G(:,nx+1:nx+ny);  
  
Kr = G2-W1*C'*Qy  
Kw = K_(:,nx+1:nx+ny)  
Kx = Khat(:,1:nx)  
  
% [t,X] = sim('p3.slx');
```

A =

0	0	1.0000	0
0	0	0	1.0000
-20.0000	10.0000	-0.2000	0.1000
10.0000	-10.0000	0.1000	-0.1000

B =

0
0
1
0

C =

1	0	0	0
---	---	---	---

D =

0
---

r =

10
----

K =

0.7890	0.3913	1.1286	0.7352
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S =

32.4632	-6.9042	1.5780	0.7183
-6.9042	23.2562	0.7826	0.7673
1.5780	0.7826	2.2571	1.4704
0.7183	0.7673	1.4704	3.7386

A\_ =

0	0	1.0000	0	0
0	0	0	1.0000	0
-20.0000	10.0000	-0.2000	0.1000	0
10.0000	-10.0000	0.1000	-0.1000	0
-1.0000	0	0	0	0

B\_ =

0
0
1
0
0

C\_ =

1        0        0        0        0

K\_ =

0.8706        0.4412        1.1931        0.7976        -0.7071

S\_ =

32.6950    -6.7661        1.7412        0.8747        -1.8350  
-6.7661    23.3713        0.8824        0.8629        -1.1218  
1.7412        0.8824        2.3862        1.5953        -1.4142  
0.8747        0.8629        1.5953        3.8622        -1.3518  
-1.8350    -1.1218        -1.4142        -1.3518        15.9973

Kr =

11.3118

Kw =

-0.7071

Kx =

0.8706        0.4412        1.1931        0.7976