# Lab 2

```
clear; clc;
global A B C D Q R S_f
t_f = 30;
```

## Task 1

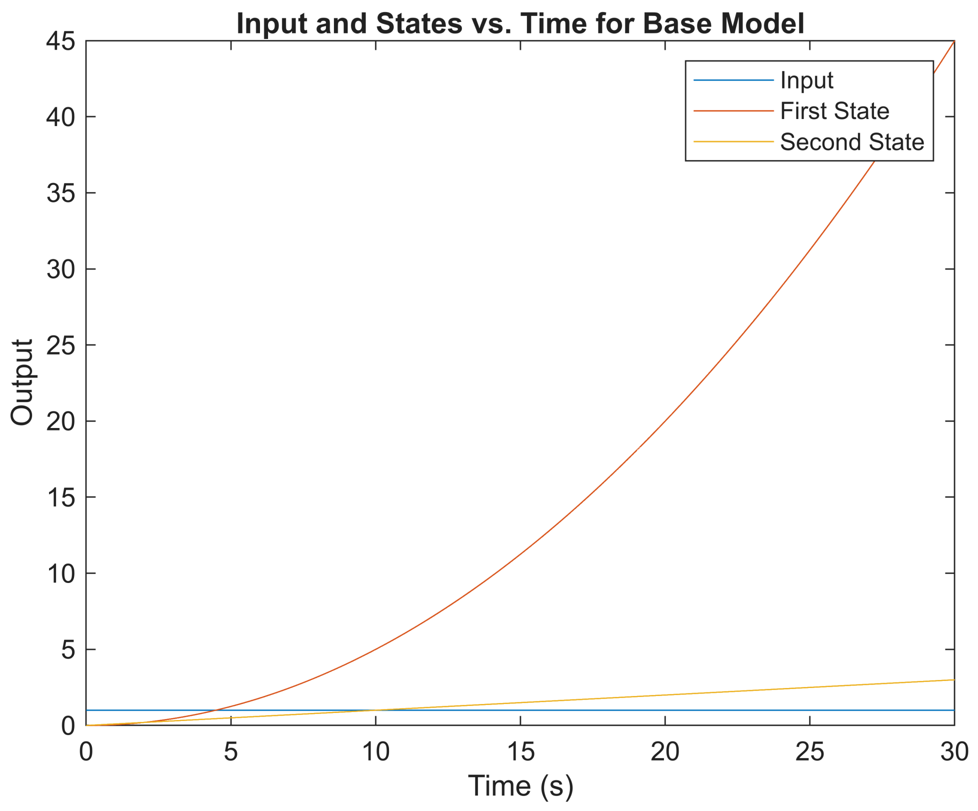
### Implement the Spacecraft Model in Simulink

```
A = [0 1; 0 0];
B = [0; 0.1];
% For full state measurements, C is identity
C = eye(2);
D = 0;
x_0 = [0; 0];

sys = ss(A, B, C, D);

out_base = runModel("base", string(t_f));
```

## Task 1

### Figures

```
figure
plot(out_base.tout, out_base.input, ...
    out_base.tout, out_base.ybar)
xlabel("Time (s)")
ylabel("Output")
title("Input and States vs. Time for Base Model")
legend("Input", "First State", "Second State")
```



## Task 2

### Design a LQR

```
Q = eye(2);
R = 1;

syms P1 P2 P3
P = [P1 P2; P2 P3];
assume(P1, "positive")
assume(P2, "positive")
assume(P3, "positive")

% Matrix Ricatti Equation
P_dot = -P*A - A'*P + P*B*inv(R)*B'*P - Q;

% For LQR, solve for P when P_dot = 0
[P1_sol, P2_sol, P3_sol] = solve(P_dot == 0, [P1, P2, P3]);
P_sol = [P1_sol P2_sol; P2_sol P3_sol];

% Gain Equation
K_lqr = double(inv(R)*B'*P_sol);

% Check Against lqr() and step()
K_check = lqr(sys, Q, R);
```

```
[y_check, t_check] = step(feedback(sys, K_check));
```

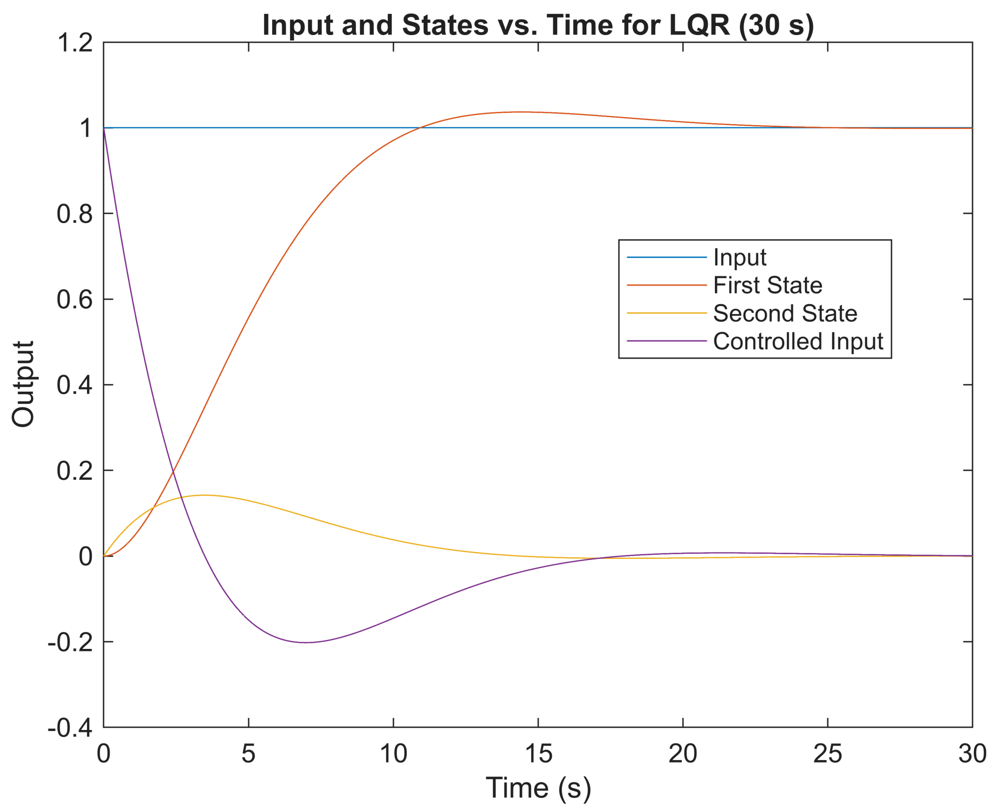
### Implement LQR in Simulink for a Unit Step Input

```
out_lqr = runModel("LQR", string(t_f));
```

## Task 2

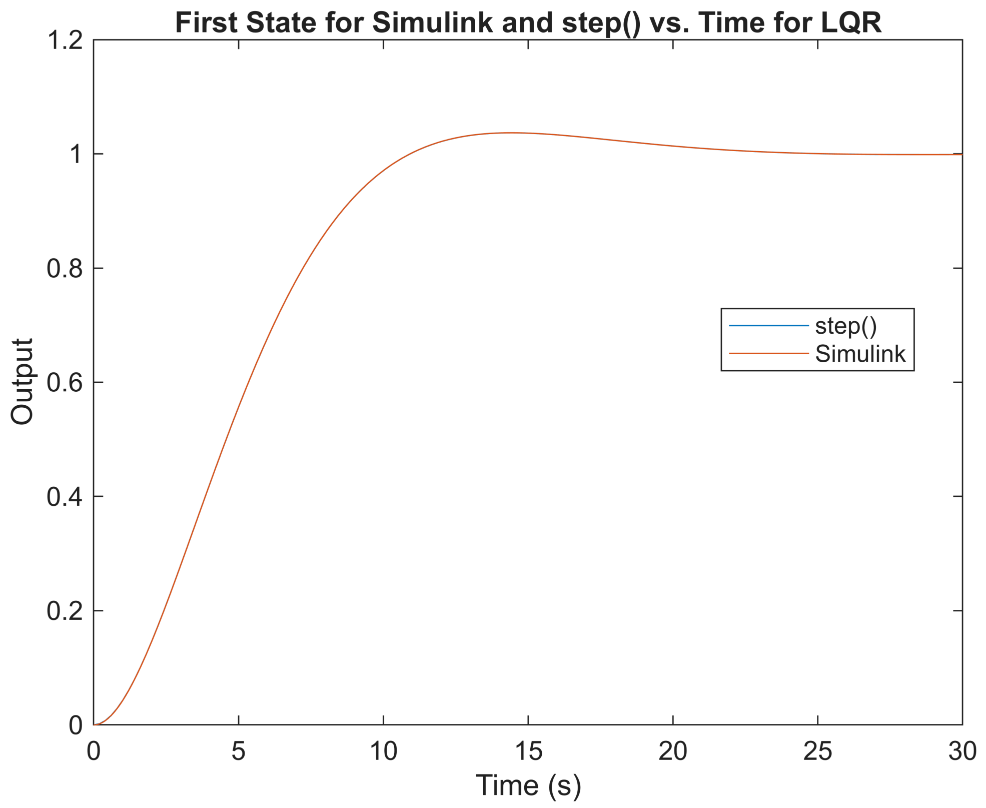
### Figures

```
figure
plot(out_lqr.tout, out_lqr.input, ...
    out_lqr.tout, out_lqr.ybar, ...
    out_lqr.tout, out_lqr.controlled_input)
xlabel("Time (s)")
ylabel("Output")
title("Input and States vs. Time for LQR (30 s)")
legend("Input", "First State", "Second State", "Controlled Input", "Location",
"best")
```

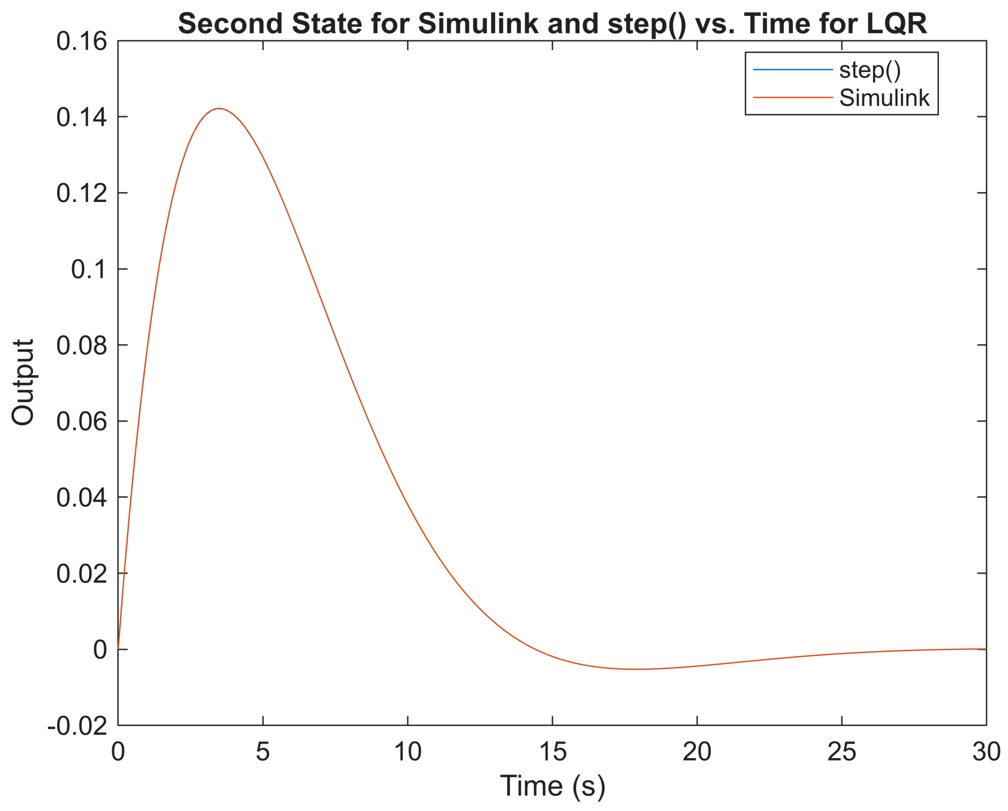


```
figure
plot(t_check, y_check(:, 1), ...
    out_lqr.tout, out_lqr.ybar(:, 1))
xlabel("Time (s)")
ylabel("Output")
title("First State for Simulink and step() vs. Time for LQR")
```

```
legend("step()", "Simulink", "Location", "best")
xlim([0, 30])
```



```
figure
plot(t_check, y_check(:, 2), ...
    out_lqr.tout, out_lqr.ybar(:, 2))
xlabel("Time (s)")
ylabel("Output")
title("Second State for Simulink and step() vs. Time for LQR")
legend("step()", "Simulink", "Location", "best")
xlim([0, 30])
```



## Task 3

### Design a LQC with an End Time of 30 Seconds

```
Q = eye(2);
R = 1;
S_f = [100 0; 0 100];

[~, ~, P_struct, ~, ~, ~] = matint(t_f, 0, S_f);

mult_lqc = inv(R)*B';
```

### Implement LQC in Simulink for a Unit Step Input

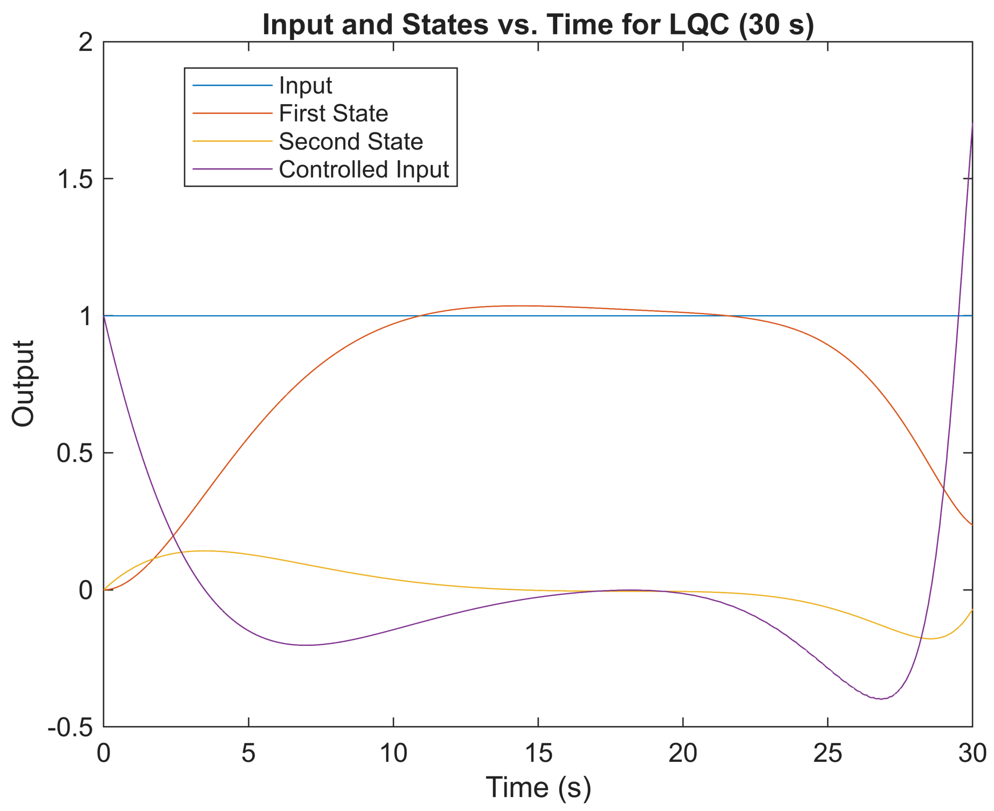
```
out_lqc = runModel("LQC", string(t_f));
```

## Task 3

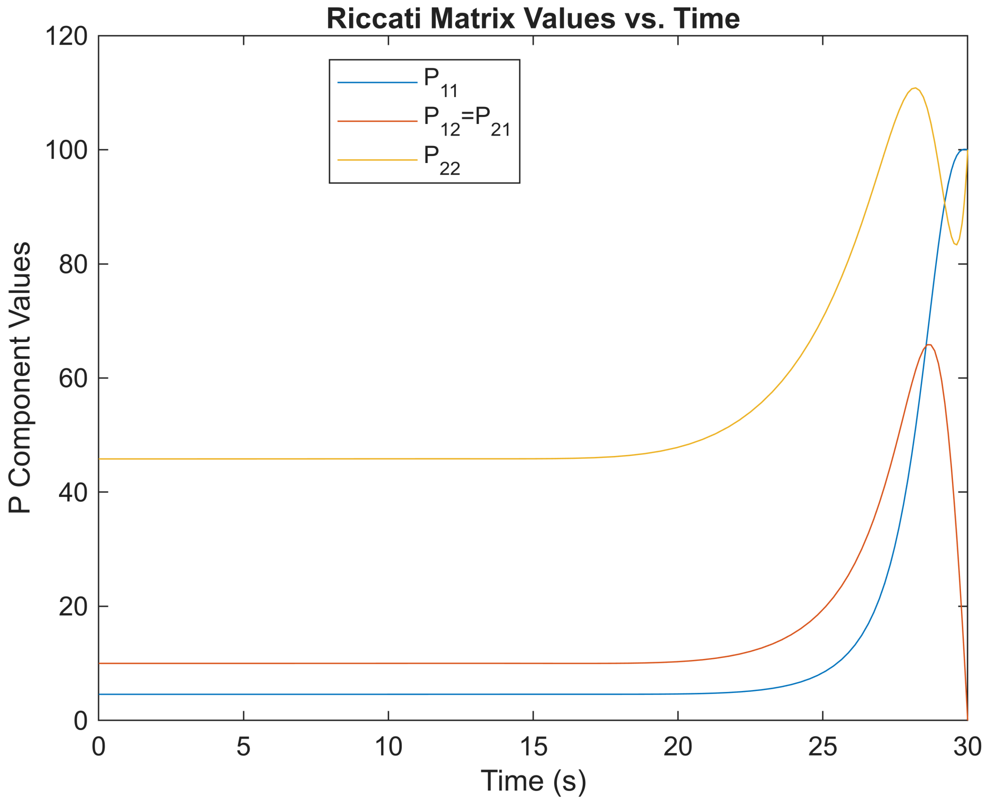
### Figures

```
figure
plot(out_lqc.tout, out_lqc.input, ...
    out_lqc.tout, out_lqc.ybar, ...
    out_lqc.tout, out_lqc.controlled_input)
xlabel("Time (s)")
ylabel("Output")
```

```
title("Input and States vs. Time for LQC (30 s)")
legend("Input", "First State", "Second State", "Controlled Input", "Location",
"best")
```



```
length = length(P_struct.signals.values);

figure
plot(P_struct.time, reshape(P_struct.signals.values(1, 1, :), [length 1]), ...
    P_struct.time, reshape(P_struct.signals.values(1, 2, :), [length 1]), ...
    P_struct.time, reshape(P_struct.signals.values(2, 2, :), [length 1]))
xlabel("Time (s)")
ylabel("P Component Values")
title("Riccati Matrix Values vs. Time")
legend("P_{11}", "P_{12}=P_{21}", "P_{22}", "Location", "best")
```


Riccati Matrix Values vs. Time
$P_{11}$
$P_{12}=P_{21}$
$P_{22}$
P Component Values
Time (s)
0
20
40
60
80
100
120
0
5
10
15
20
25
30