United Arab Emirates University

Faculty of Engineering
Industrial Training and Graduation Projects Unit
Graduation Project I

Water Tank Level Control System

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Overview

- Tasks done through this semester.
- Budget Estimate.
- The project Environmental Impact.
- Conclusion.

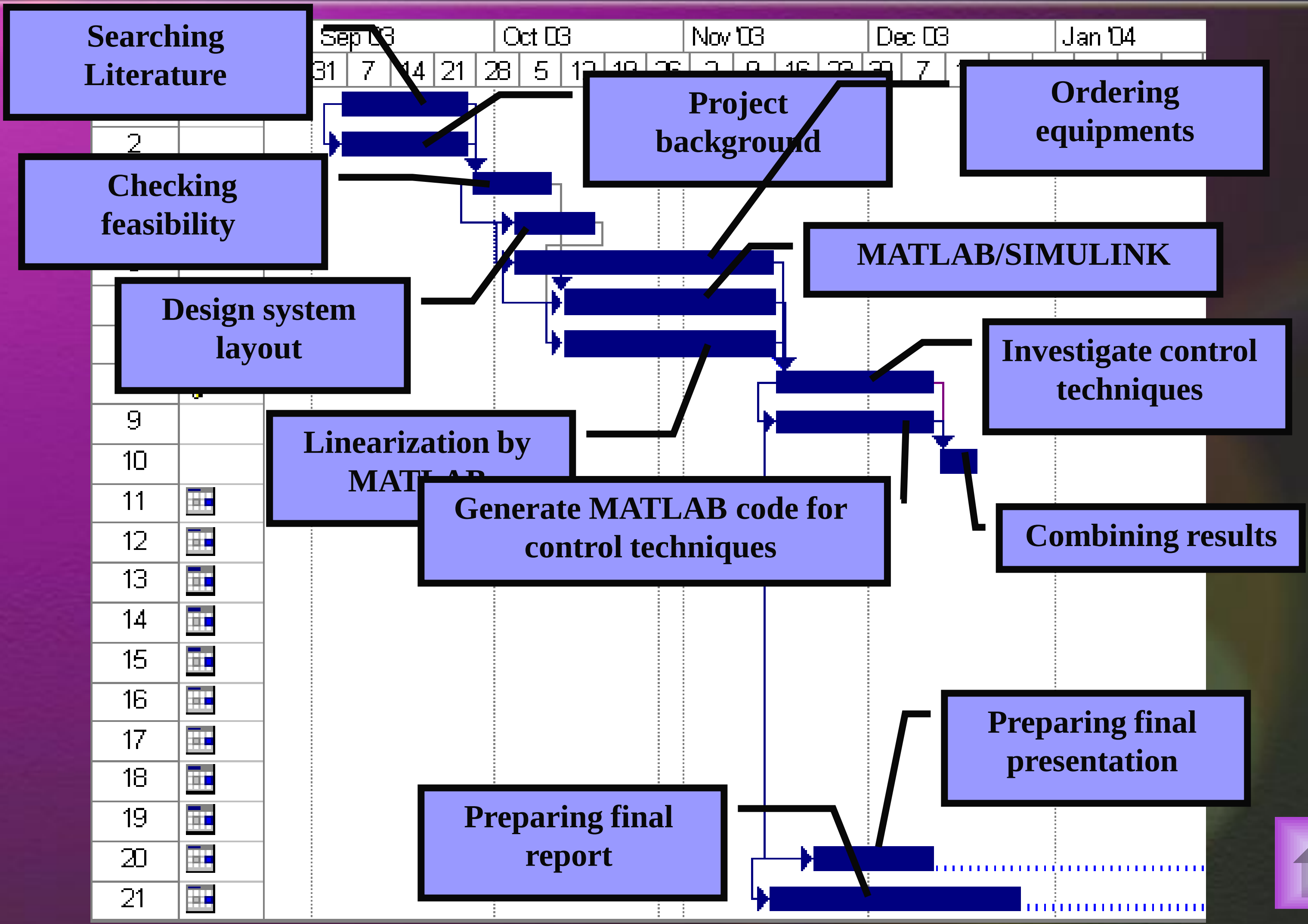
Tasks done

- Gantt Chart of the above mentioned tasks.

- Idea of the project:
  - Scope of the project.
  - Project description.

- Design of the project:
  - Design methodology.
  - Hardware designing:
    - *Project specifications*
  - Control designing:
    - *Simple case study.*
    - *Type of controllers.*
    - *Control techniques.*
  - Software techniques implementation

Gantt chart

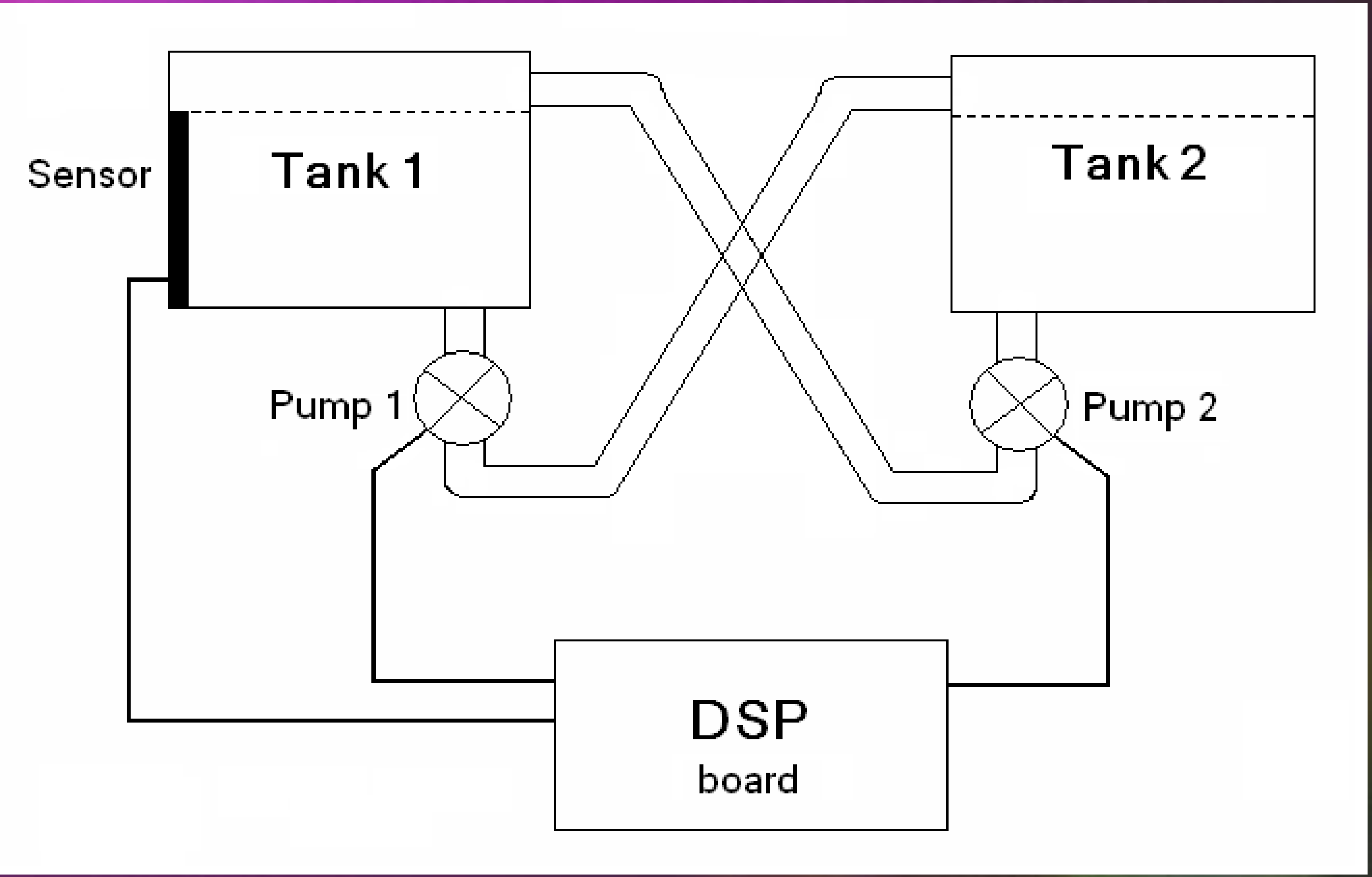


Sep '03
Oct '03
Nov '03
Dec '03
Jan '04
Searching Literature
Project background
Ordering equipments
Checking feasibility
MATLAB/SIMULINK
Design system layout
Investigate control techniques
Linearization by MATLAB
Generate MATLAB code for control techniques
Combining results
Preparing final presentation
Preparing final report

Scope of Project

- The project focuses on enhancing the student's experiences in the following fields:
  - *Product development.*
  - *Design and construction.*
  - *Computer modeling and analysis.*
  - *Testing and experimental investigations.*

The System Layout and Description



Design Methodologies

- A controller will be designed and simulated using *MATLAB/Simulink* software.
- A prototype of the Water Tank System will be built.
- The prototype will be interfaced to the computer via dSPACE (digital-Signal-Processor-Based) control board.

Project specifications

- It is supposed to build a middle sized prototype.
- Searching for Equipment:
  - Devices: pumps, tanks, hoses and sensors.
  - Software package: Simulink/MATLAB.
  - Interfacing board: dSPACE.

Pumps

- The quantity of water to be handled is approximately three liters. This yields to get small pumps.
- Pressure and frictional losses are negligible due to the size of layout and the nature of the used liquid (water).
- High-speed centrifugal (rotary pumps) are preferred due to direct coupling to the internal motor.
- Corrosion factor is negligible due to the layout nature.

Pumps

Hoses

- Volume of tanks and power of used pumps are essential factors for choosing hoses.
- Hoses should be as smooth as possible to avoid friction which leads to slow down the flow rate of water.
- Flexibility and ability of connecting chosen hoses to other components should be taken into consideration.
- Hoses’ length must be compatible with the system layout.

Hoses

Tanks

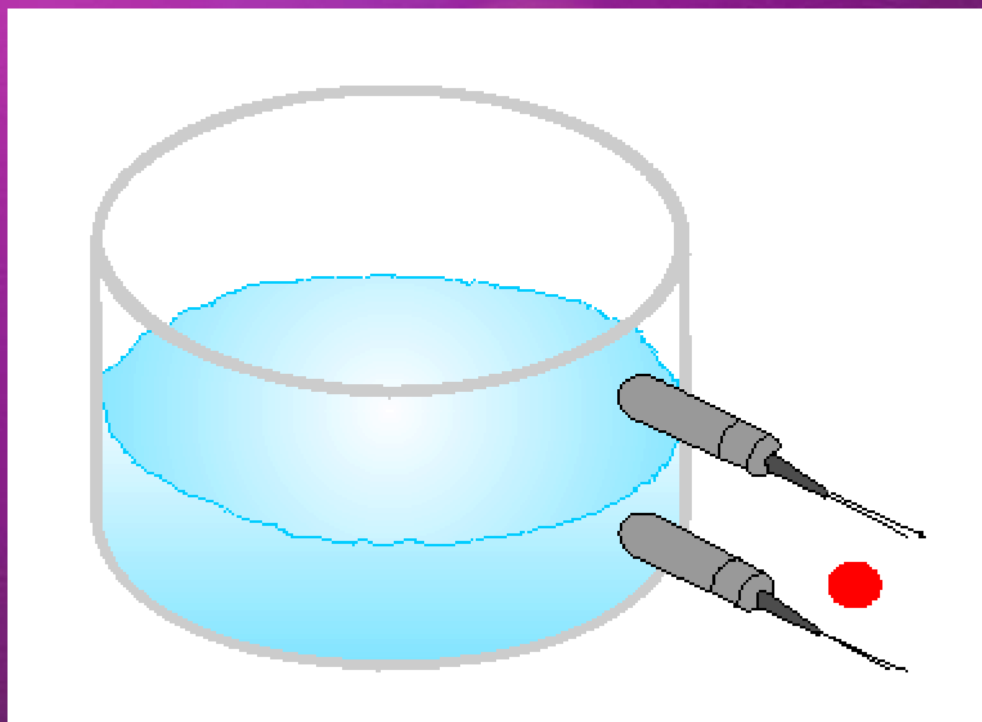
- Capacity of tanks should be chosen so that three liters of water are accommodated.
- Tanks should be of light materials (i.e: plastic) in order to be portable and easy to move.
- Tanks should be transparence in order to notice the water level.
- Also, they should be covered to avoid any disturbances that come from outside.

Tanks

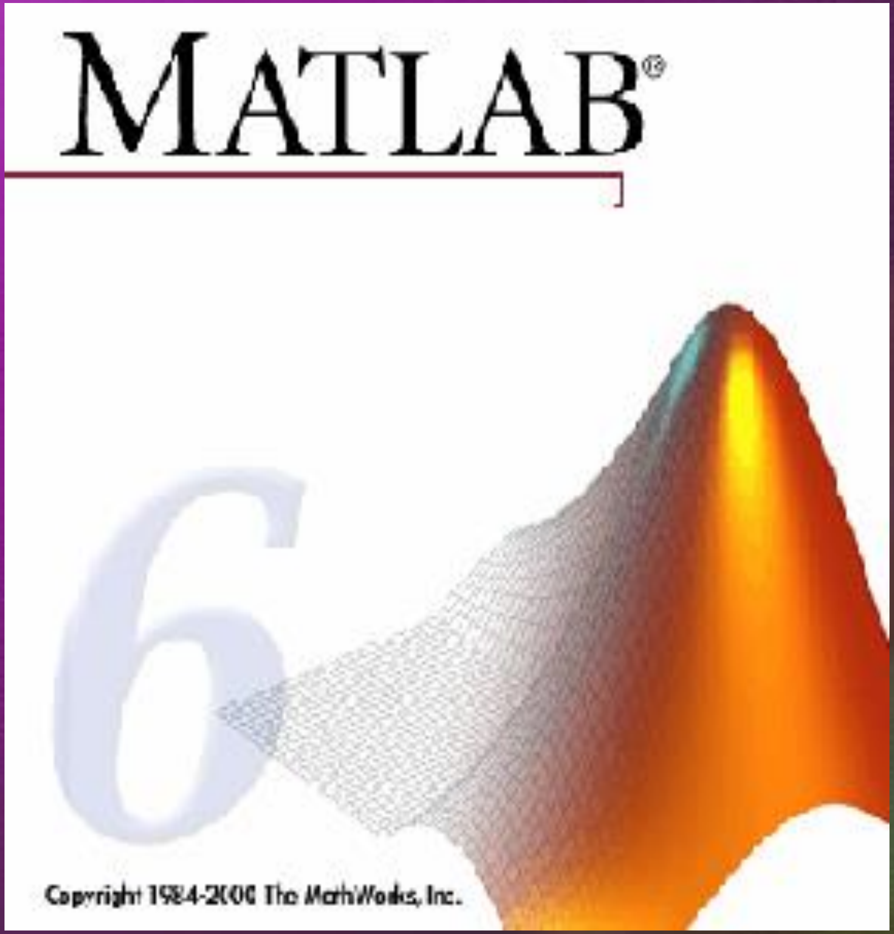
Sensors

- Pressure of water and tanks’ specifications, such as volume and height, should be considered while choosing sensors.
- Volume of sensors must be compatible with the system layout.
- Sensitivity of sensors has to be as high as possible.

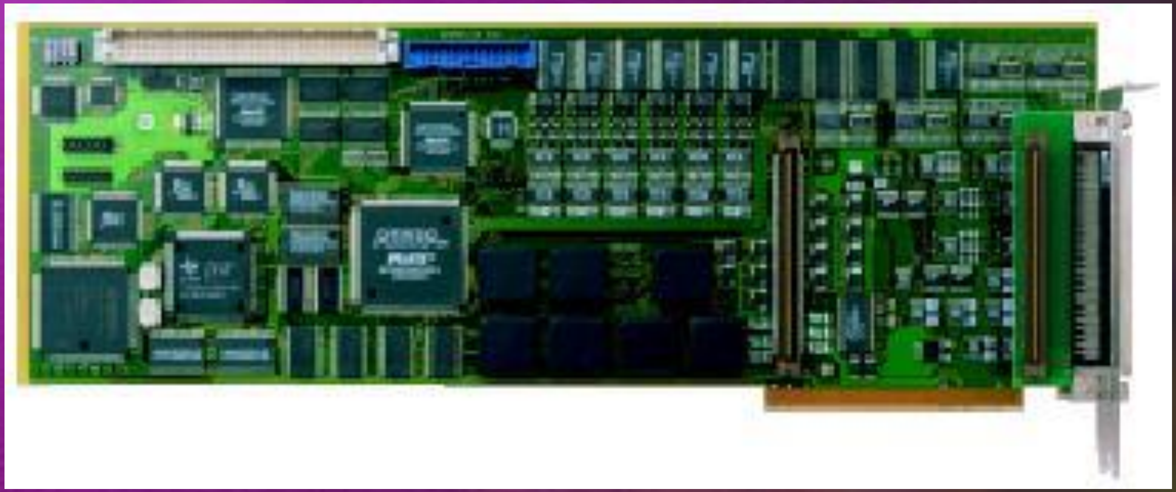
Sensors



MATLAB / Simulink



The dSpace Board



Case Study (Process Control)

- The case study introduced the simple control concepts to be generalized to our project. They are:
  - Linearization.
  - Types of controllers.

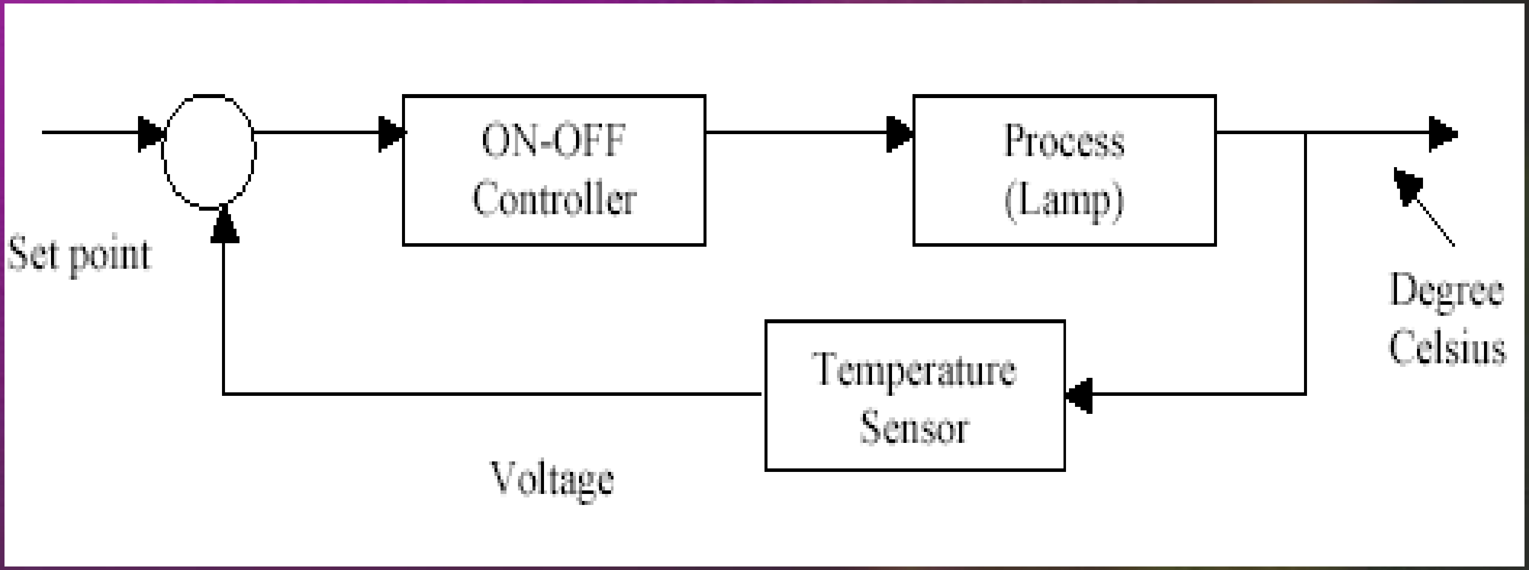
- Process control experiment.

Linearization and control concepts

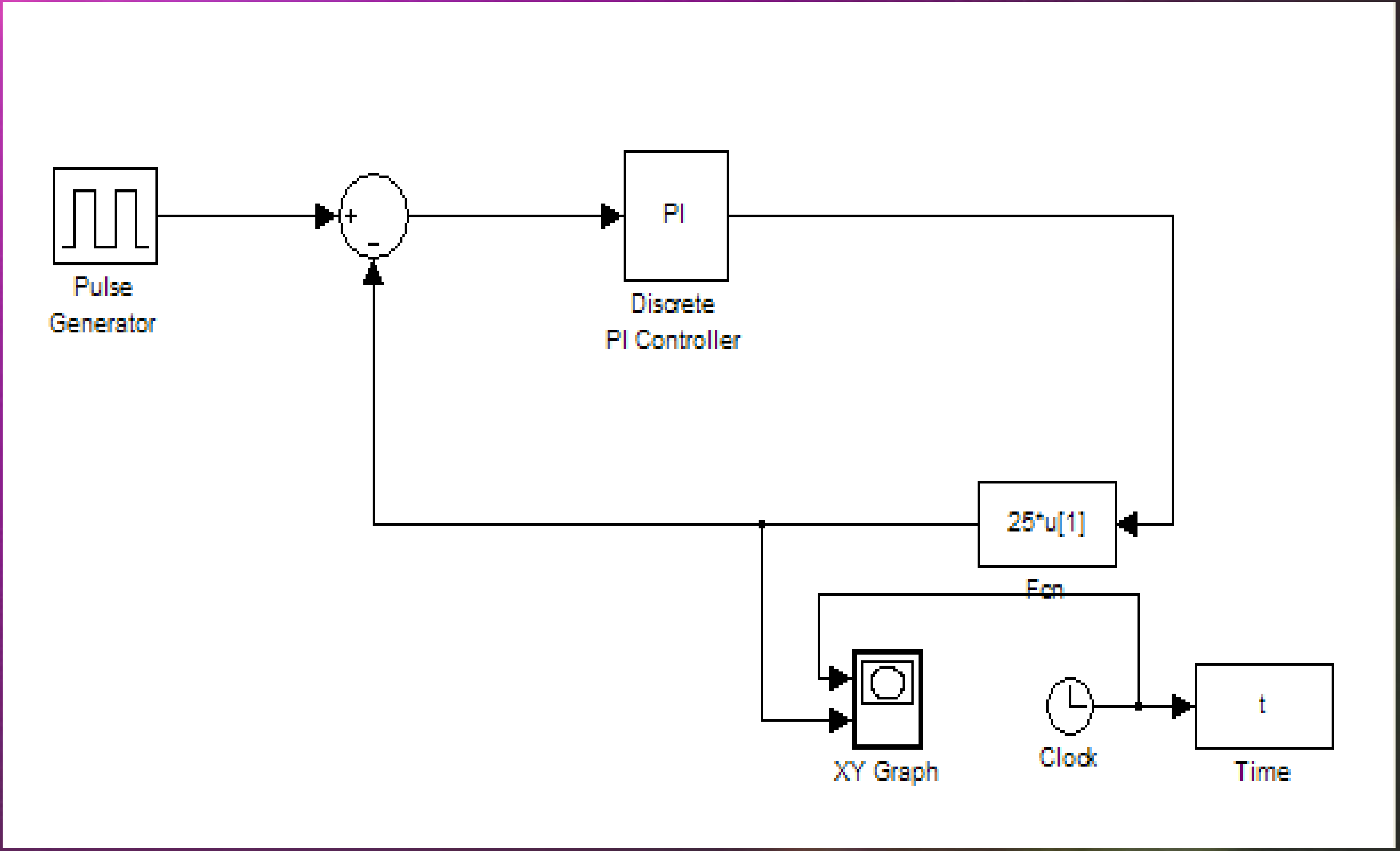
- All real systems are non-linear.
- Linearization is a method at which non-linear system is converted to linear systems to simplify dealing with systems.

Simple experiment of a temperature control system

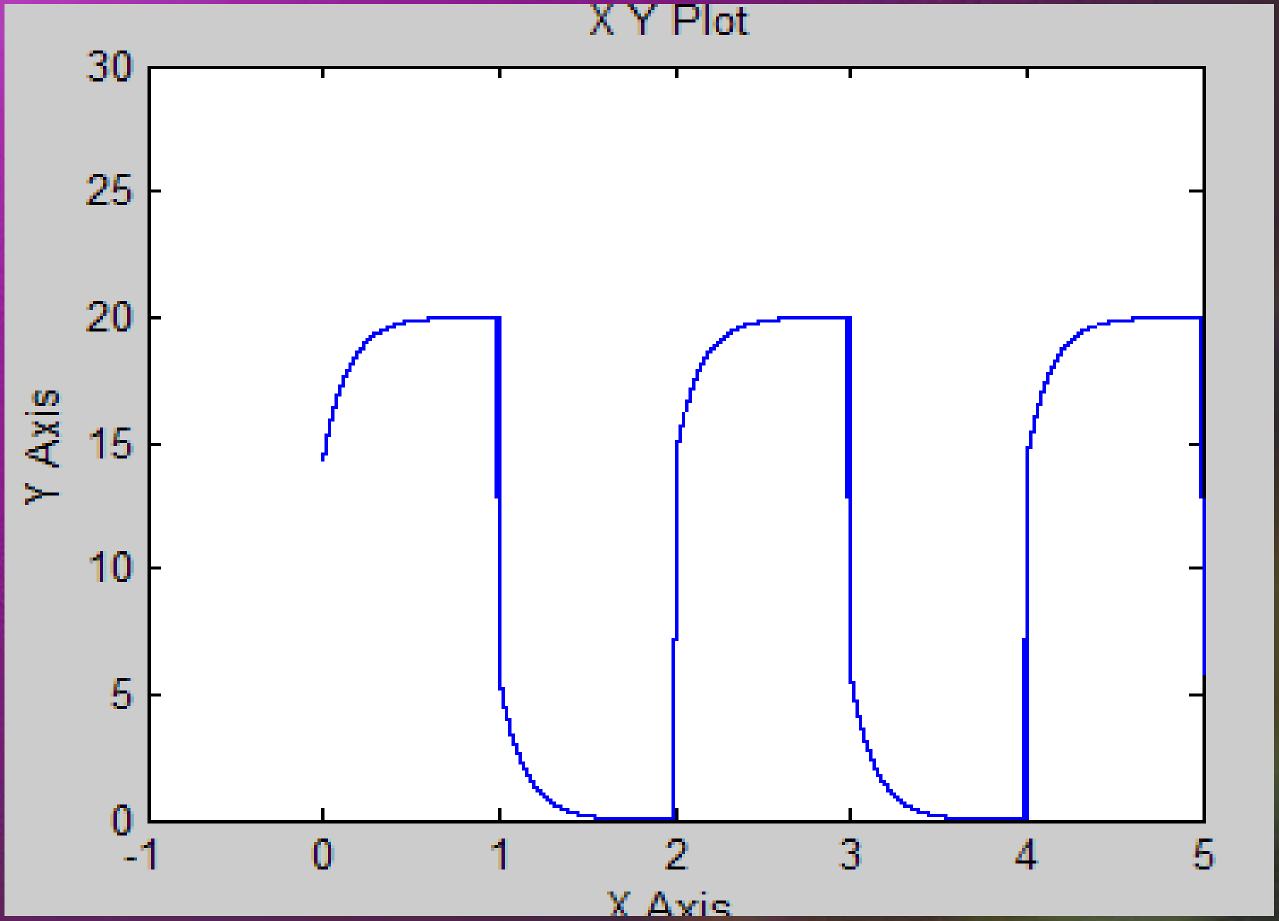
- Design of a simple experiment by MATLAB/Simulink.
- Controlling temperature by ON-OFF controller.



MATLAB/Simulink model of the Temperature Experiment



Resultant temperature



ON-OFF Controller

- Simplest control method.
- Easy to be developed.
- Effective for most disturbances.
- Drawback: uses a lot of energy.

PI Controller

- PI stands for Proportional-Integral Control.

- It depends on two parameters:
  - Proportional gain (Kp).
  - Integral gain (KI).
  - Easy to be developed.

- Consumes less energy than ON-OFF controller.

State variable feedback

- When the control signal for the process is a direct function of all the state variables.

Fuzzy Controller

- An intelligent and complicated controller.
- Will be studied later according to the availability of time.

Control Techniques

- A system was used from a reference book to apply the following techniques.

- The technique implemented are:
  - *Regulation:*
    - *With observer.*
    - *Without observer.*
  - *Tracking:*
    - *With observer.*
    - *Without observer.*

Regulation with observer

X' = AX + BU,

noting that X is the state to be estimated

Y = CX,

Y is the output desired from the system described in these equations

Here we are assuming having a new equation for the error. This error gives a value that describes how far we are from the desired state variable value.

Depending on the following set of equations:

E = X – X^, *E represents the error*

E' = (A-LC) E *L is a matrix form factor that appears in the X^ equation*

as:

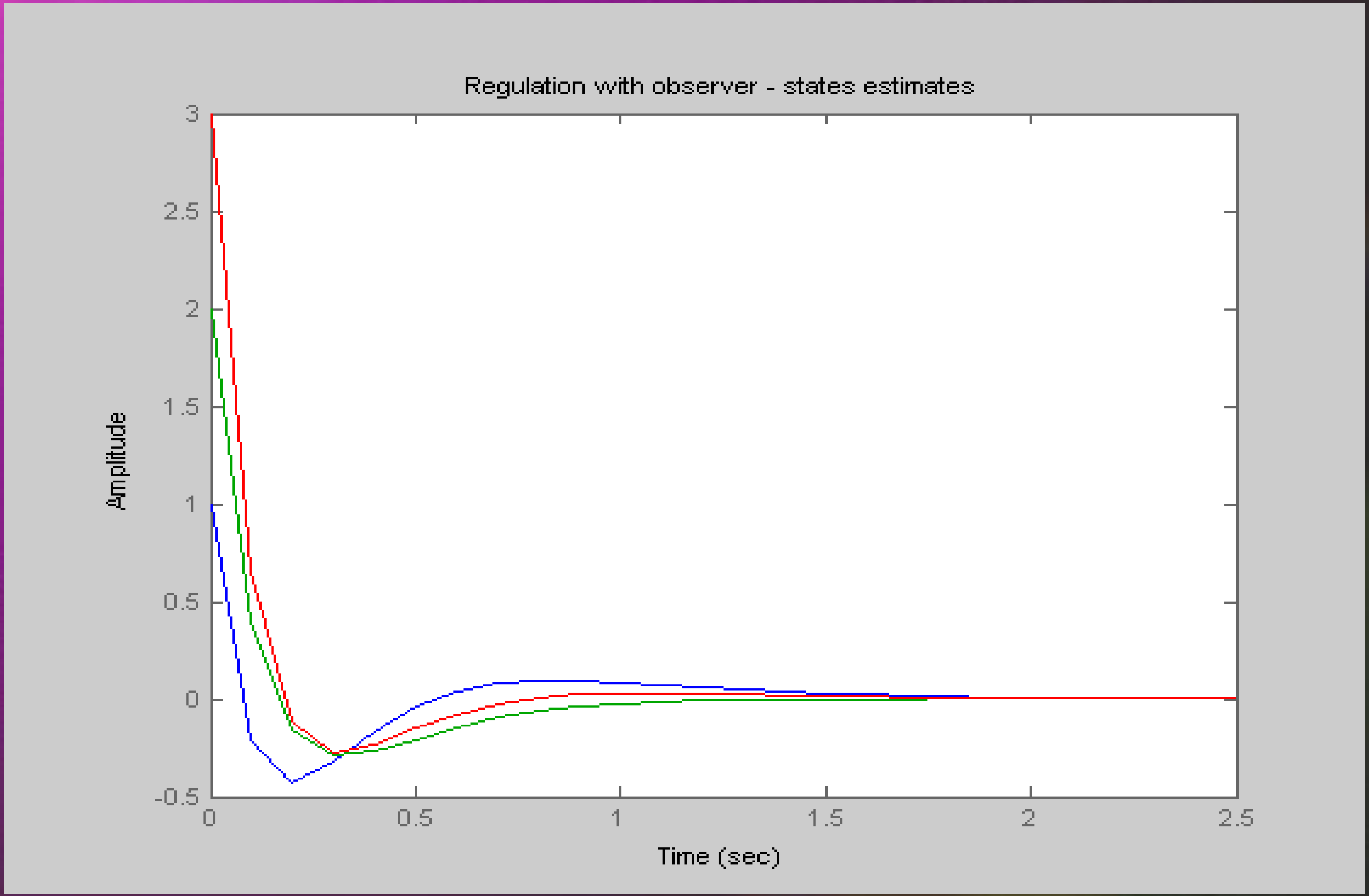
X^ = AX + BU + L(Y-Y^)

The goal here is to choose the following parameters with accordance to the following constrains:

Select K such that (A-BK < 0)

Select L such that (A-LC < 0)

Regulation with observer system



Regulation without observer

$X' = AX + BU$,

noting that X is the state.

$Y = CX$,

Y is the output desired from the system described in these equations.

$X' = AX – BKX$

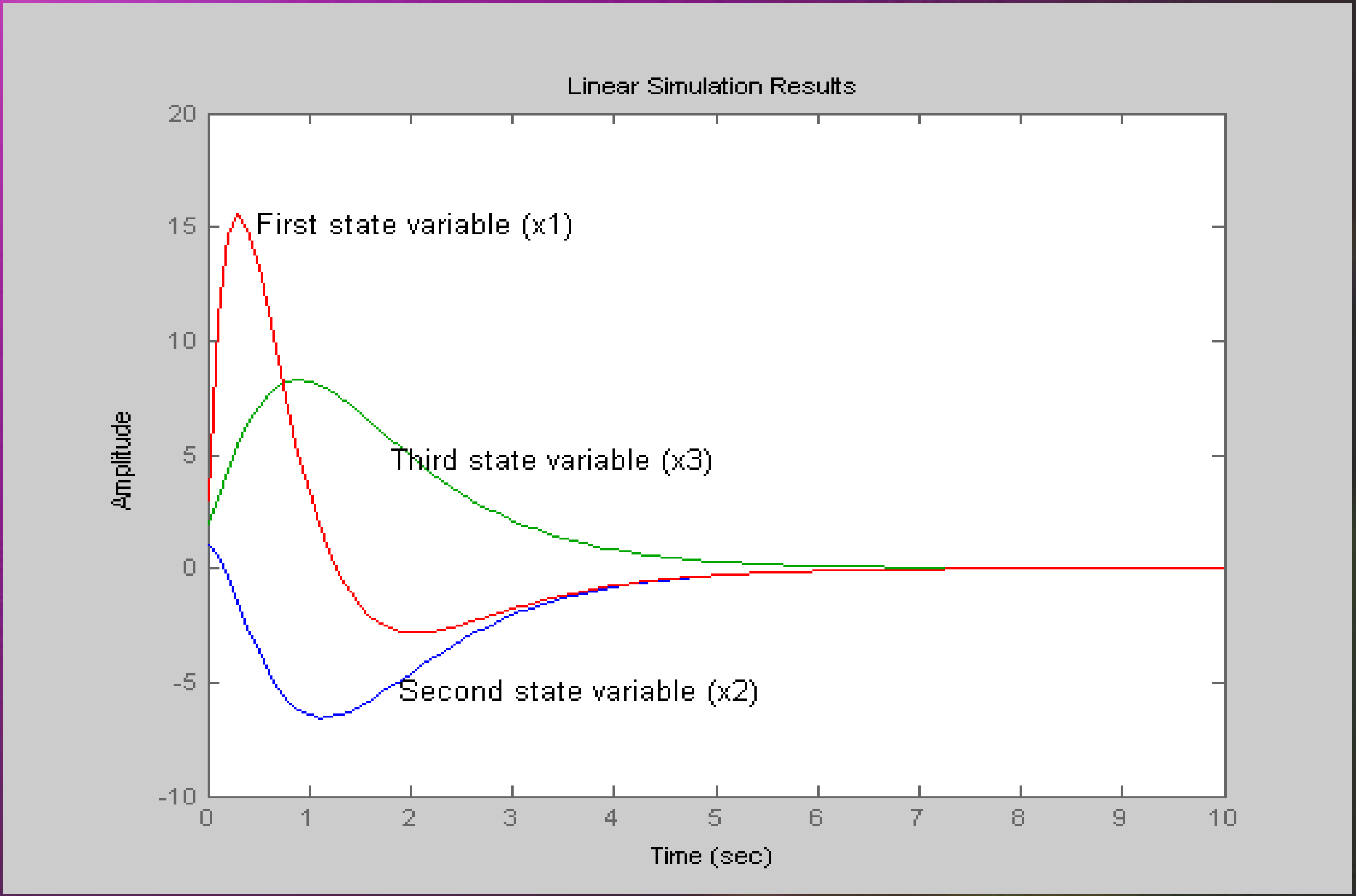
as: $U = -KX$

Then:

$X' = (A-BK)\ X$

select K such that $(A-BK < 0)$

Regulation without observer



Tracking without observer

$X' = AX + BU$,

noting that X is the state to be estimated.

$Y = CX$,

Y is the output desired from the system described in these equations.

$U = -KX + JR$ R is the desired trajectory.

After some algebraic steps, the closed loop system can be stated as:

$X' = Abar\ X + Bbar\ R$

$Y = Cbar\ X + Dbar\ U$

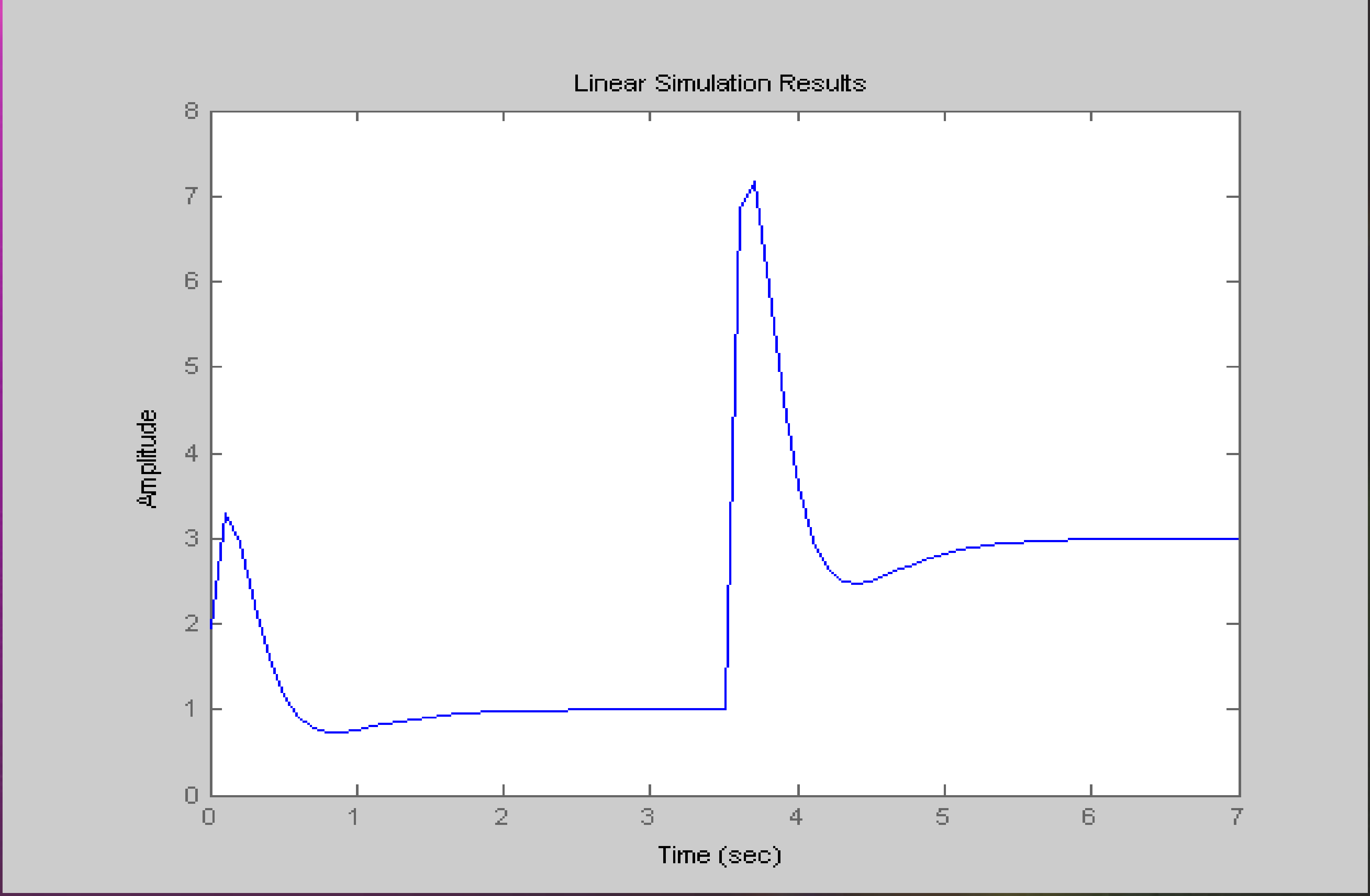
Where:

$Abar = A - BK$

$Bbar = BJ$

$Cbar = C$ and $Dbar = 0$.

Tracking without observer system



Tracking with observer system

$X' = AX + BU$ — X is the state

$Y = CX$ — Y is the output

$U = -KX + JR$ — R is the desired trajectory.

The closed-loop system is:

$$\dot{\bar{x}} = \bar{A}\bar{x} + \bar{B}r$$
$$y = \bar{C}\bar{x}$$

$$\bar{x} = \begin{bmatrix} x \\ \hat{x} \end{bmatrix}$$

$$\bar{A} = \begin{bmatrix} A & -BK \\ LC & A - BK - LC \end{bmatrix}$$

$$\bar{B} = \begin{bmatrix} BJ \\ BJ \end{bmatrix}$$

$$\bar{C} = \begin{bmatrix} C & 0 \end{bmatrix}$$

$$H(s) = C[sI - \bar{A}]^{-1}\bar{B}$$

$$ACgain = \lim_{s \to 0} sH(s) = 1$$

$As:$

$$\bar{B} = \bar{\bar{B}}J$$

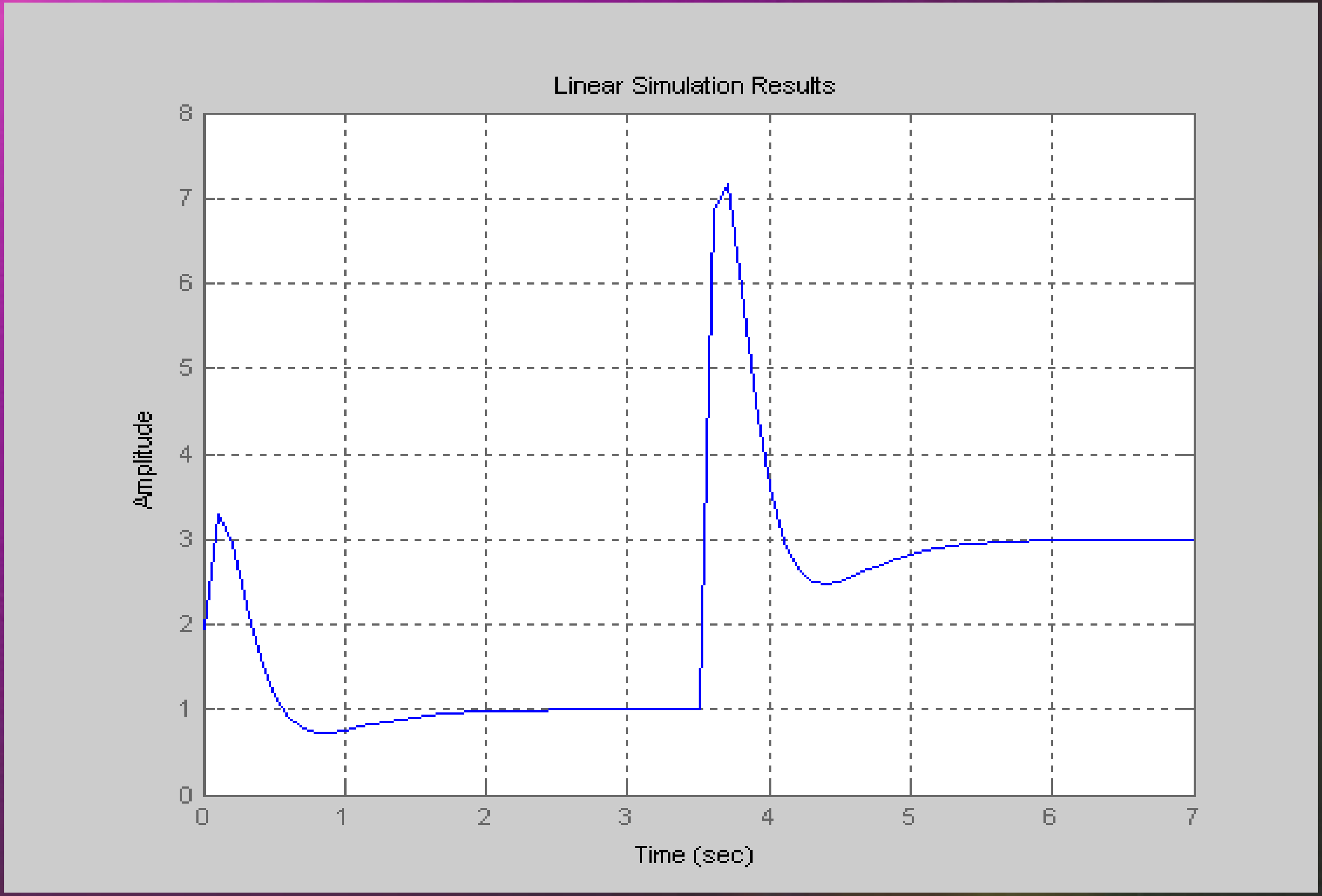
$$Then: J = \frac{1}{\lim_{s \to 0} sC[sI - \bar{A}]^{-1}\bar{\bar{B}}}$$

How to choose K ⟶ A-BK<0

How to choose L ⟶ A-LC<0

How to choose J ⟶ DC gain=1

Tracking with observer



The generated MATLAB code is available in the Appendix if needed.

Budget Estimation

Component	Quantity	Cost (Dhs)	Total Cost
Pump	2	2 X 280	440
P.V.C sheet	4	4 X 250	1000
Hose 1/2" X 6m	1	1 X 25	25
Nipple 1/2“ & Hose Fittings	10	10 X 4	40
Non-returned Valve 1/2"	2	2 X 15	30
Clamps 1/2"	12	12 X 1.25	15
Relays	10	10 X 12	120
Switch	2	2 X 35	70
Reducer Brush 1" & 2"	2	2 X 5	10
P.V.C glue	2	2 X 10	10
Silicon glue	2	5 X 2	10
Tapes	5	5 X 1	5
Socket 1/2"	4	4 X 2	8
Pipe Wrench	1	1 X 25	25
Drill 10m	1	1 X 180	180
Hole Saw 19mm	1	1 X 25	25
Hole Saw Bit	1	1 X 20	20
Sensor	1	1 X 100	100
PC	1	Available	
dSpace Board	1	Available	
Total	64		**2133**

Some descriptive pictures for the components used in the prototype are shown in this Appendix

Environmental Impact

- Control the level of any liquid in any container.
- Example: Chemical industrial environment used in factories that pack drinks or medicines.
- The designed control system has almost no bad effect on the environment, except if the subjects remaining of building the prototype are to be thrown in the environment.

Conclusion

- Software experience is to be gained throughout working on this project on different scales.

- Working in team, organizing project timings and dealing with products are essentials for good engineer. Hopefully, they will be well-covered.

- Learned Ethics and lessons.

Any
Questions
Please

Regulation without observer

```
A=[1 1 -1;4 3 0;-2 1 10];
B=[0;0;1];
n=length(B);
p=[-2 -3 -1];
k=place(A,B,p);
Abar=A-B*k;
t=0:0.1:10;
D=[0];
u=0*ones(1,length(t));
C=[1 0 0];
sys=ss(Abar,zeros(n,1),C,D);
lsim(sys,u,t,[1,2,3])
hold on
C=[0 1 0];
sys=ss(Abar,zeros(n,1),C,D);
lsim(sys,u,t,[1,2,3])
C=[0 0 1];
sys=ss(Abar,zeros(n,1),C,D);
lsim(sys,u,t,[1,2,3])
```

Regulation with observer

```
A = [-2 -2.5 -0.5; 1 0 0; 0 1 0];
B = [1; 2; 3];
C = [1 4 3.5];
D = [0];
[n,n]=size(A);
p = [-3 -5 -7];
Lt= place(A',C',p);
L = Lt';
K=place(A,B,p);
Abar = [A  -B*K ; L*C  A-B*K-L*C];
t=0:0.1:2.5;
u=0*ones(1,length(t));
figure
sys3=ss(Abar,ones(2*n,1),[1 0 0 0 0 0],[0]);
lsim(sys3,u,t,[1,2,3,1,2,3])
hold on
sys3=ss(Abar,ones(2*n,1),[0 1 0 0 0 0],[0]);
lsim(sys3,u,t,[1,2,3,1,2,3])
hold on
sys3=ss(Abar,ones(2*n,1),[0 0 0 0 0 1],[0]);
lsim(sys3,u,t,[1,2,3,1,2,3])
title('Regulation with observer - states estimates')
sys3=ss(Abar,ones(2*n,1),[0 0 1 0 0 0],[0]);
lsim(sys3,u,t,[1,2,3,1,2,3])
title('Regulation with observer - actual states')
figure
sys3=ss(Abar,ones(2*n,1),[0 0 0 1 0 0],[0]);
lsim(sys3,u,t,[1,2,3,1,2,3])
hold on
sys3=ss(Abar,ones(2*n,1),[0 0 0 0 1 0],[0]);
lsim(sys3,u,t,[1,2,3,1,2,3])
```

Tracking without observer

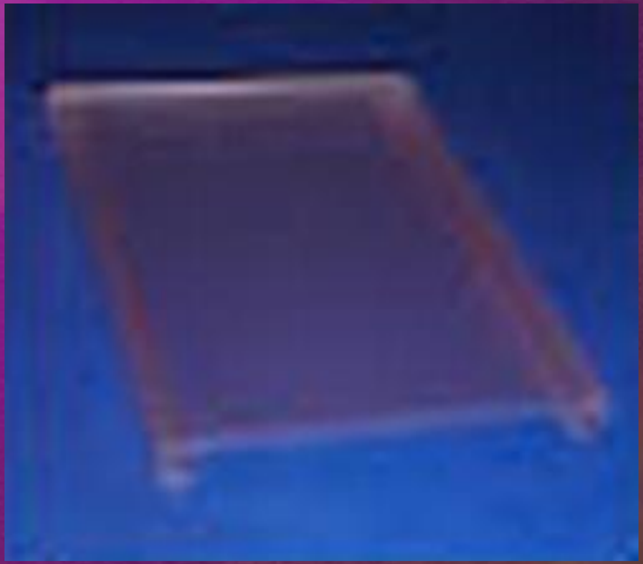
```
A = [-2 -2.5 -0.5; 1 0 0; 0 1 0];
B = [1; 2; 3];
C = [1 4 3.5];
D = [0];
[n,n]=size(A);
p = [-3 -5 -7];
K=place(A,B,p);
Abar =A-B*K ;
Cbar=C;
Dbar=[0];
sysx=tf(ss(Abar,B,Cbar,Dbar));
J=1/dcgain(sysx);
Bbar=B*J;
t=0:0.1:7;
lt=length(t);
r=[1*ones(1,(lt-1)/2) 3*ones(1,((lt-
    1)/2)+1)];
figure
sys4=ss(Abar,Bbar,Cbar,Dbar);
lsim(sys4,r,t,[0.1,0.2,0.3])
```

Tracking with observer

```
A = [-2 -2.5 -0.5; 1 0 0; 0 1 0];
B = [1; 2; 3];
C = [1 4 3.5];
D = [0];
[n,n]=size(A);
p = [-3 -5 -7];
K=place(A,B,p);
Lt= place(A',C',p);
L = Lt';
Abar = [A  -B*K ; L*C  A-B*K-L*C];
Bbar=[B;B];
Cbar=[C 0 0 0];
Dbar=[0];
sysx=tf(ss(Abar,Bbar,Cbar,Dbar));
J=1/dcgain(sysx);
B2bar=Bbar*J;
t=0:0.1:7;
lt=length(t);
r=[1*ones(1,(lt-1)/2) 3*ones(1,((lt-
        1)/2)+1)];
figure
sys4=ss(Abar,B2bar,Cbar,Dbar);
lsim(sys4,r,t,[0.1;0.2;0.3;0.1;0.2;0.3])h
```

P.V.C. sheet

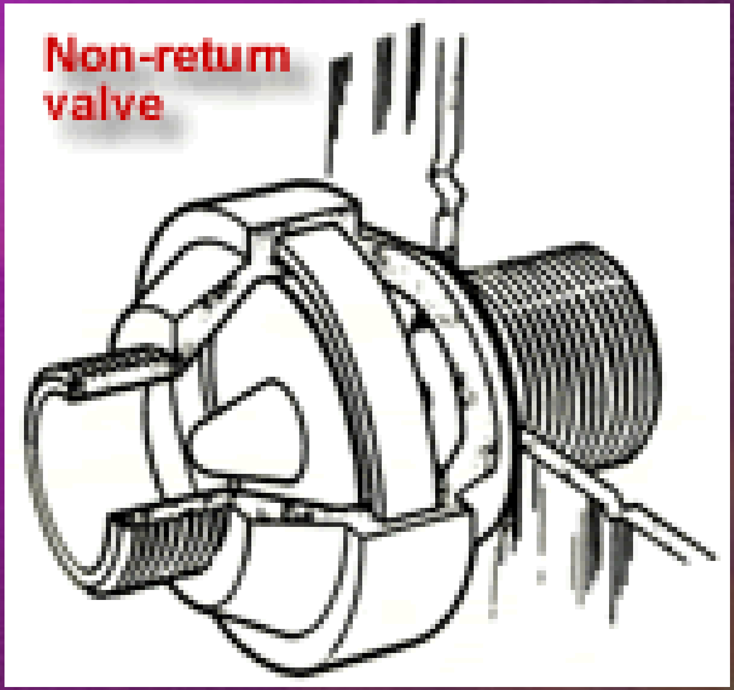
- $1.22 \times 2.44\ m^2$



Hose Fittings

Nipple ½”

Non-return Valve



Clamps ½”

Relays

Silicon Glue

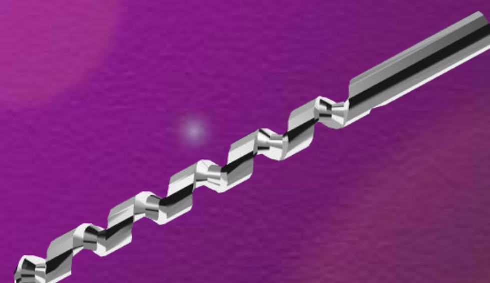
PVC Glue

Tapes

Pipe wrench (Resemble adjustable spanner)

Drill, Hale Saw & Hale Saw bit

Drill



Hale Saw

Hale Saw bit