UTM UNIVERSITI TEKNOLOGI MALAYSIA

SKEE 3133

SYSTEM MODELING AND ANALYSIS

CHAPTER 1
Introduction to control system

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Content

1.1
HISTORY OF CONTROL SYSTEMS

History of Control System

300 BC

Early
- Simple, primitive

- Water clock (300 BC)
- Steam pressure & temperature control systems (1680s)
- Speed control (1745)
- Stability Theories
  - Routh-Hurwitz (1877)
  - Lyapunov (1892)

1900's

20th Century
- Extensive use of sensors

- Automatic Ship Steering (1922)
- PID Controller (1920s)
- Feedback Control System Technique (1930s)
- Root locus, Bode, Nyquist (1948)
- Fuzzy control
- AI technique

2000's

Contemporary
- Widespread applications

- Navigation
- Entertainment
- Smart Homes
- Military
- Space Application
- Chemical Process
- Medical instrument

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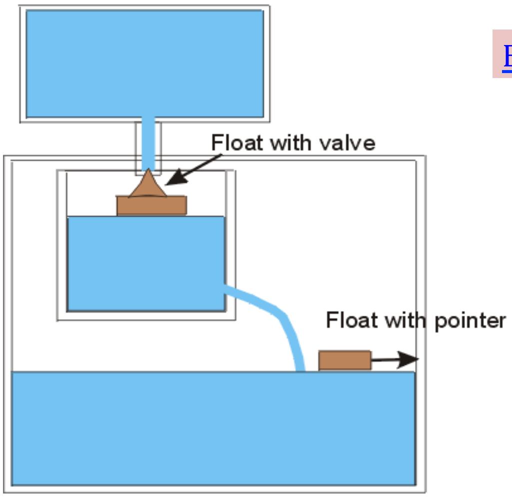
History – Water Clock

One of the earliest control systems known is the water clock invented by Ktesibios (300 BC).

Speed of water flow ∝ level of water in an upper tank

$P=\rho gh$

Elephant Clock



Time scale ∝ Level of water of lower tank

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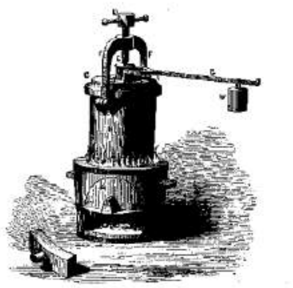
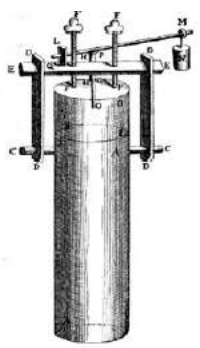
History – Steam Pressure Control

In 1681, Denis Papin introduced the steam pressure control systems, where he invented the safety valve (very similar to the present pressure cooker)





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History – 20th Century Applications

Household Appliances

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Contemporary Applications

Transportation

Industries

Robotic

Medical instrumentation

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1.2 CONTROL SYSTEMS BASICS

- General Block Diagram
- Purpose & Methods
- Manual vs. Automatic Control
- Control System Components
- Types of Control Problems

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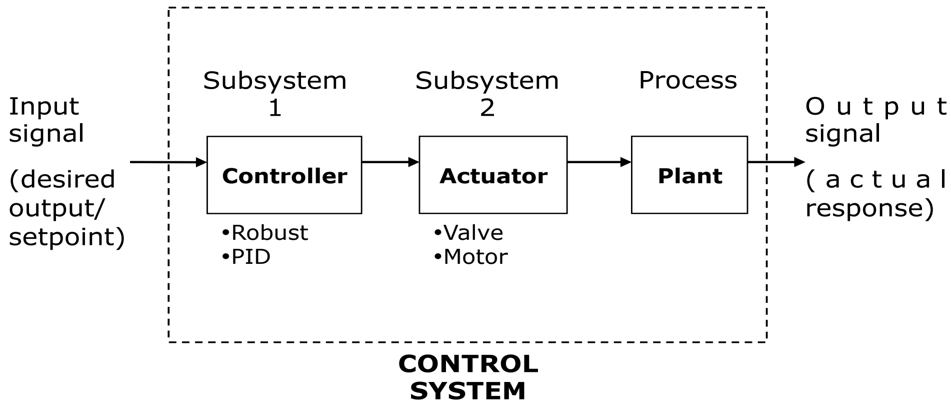
Control system definition:

A control system consists of *subsystems* and *processes* (or *plant*) assembled for the purpose of obtaining a desired *output* with desired *performance*, for a given specific *input*.



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Primary Aim of Control system:

- To regulate certain variables about constant values even when there are disturbances.
- To force some parameter to vary in a specific manner.

Control Methods:

- 'Manual' control
- 'Automatic' control

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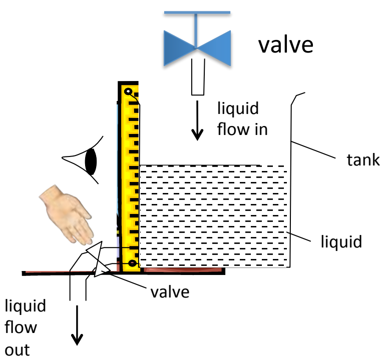
Manual Control

- Human-aided control
- Operator constantly observe the deviation and make corrections when necessary
- Not consistent
- Hundreds of variables to be controlled



Automatic Control

To replace humans with machines (nowadays, computers) to implement the control of the plant.

Measurement → sensors/transducers

Decision → computers

Control action → actuators

3 Main Control System Components

1. Sensor	2. Controller	3. Final control element
• sense the physical signals • convert into electrical signals • e.g. thermocouple measures a temperature and converts it into voltage	• the 'brain' of the control system • does all the calculations and decision-making processes – computer • compares the desired and actual plant output → calculate the amount of control to be applied	• accepts an input from the controller, which is then transformed into some proportional operation performed on the process • must be operated by an actuator

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4 main control purposes

1
- **For power amplification**
- e.g. in moving the radar antenna position to certain angle, small input power is amplified to produce high output torque

2
- **For remote control**
- e.g. in controlling the movements of robots working in contaminated areas where human presence should be avoided

3
- **For convenience of input form**
- e.g. in a temperature control system, the turn of a knob corresponds to certain desired room temperature.

4
- **For compensation for disturbance**
- e.g. to maintain antenna position in the presence of strong wind.

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1.3 CONTROL SYSTEM CONFIGURATION

◆ Open-Loop & Closed-Loop Systems

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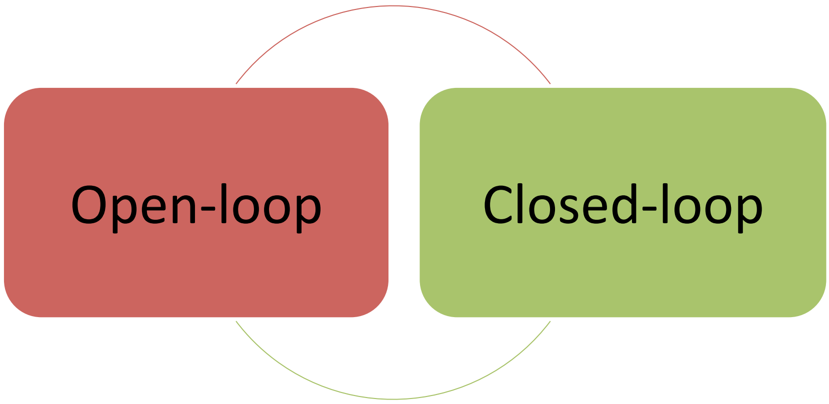
Control System Configuration



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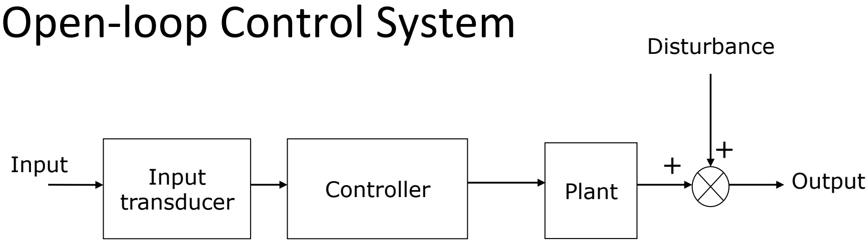
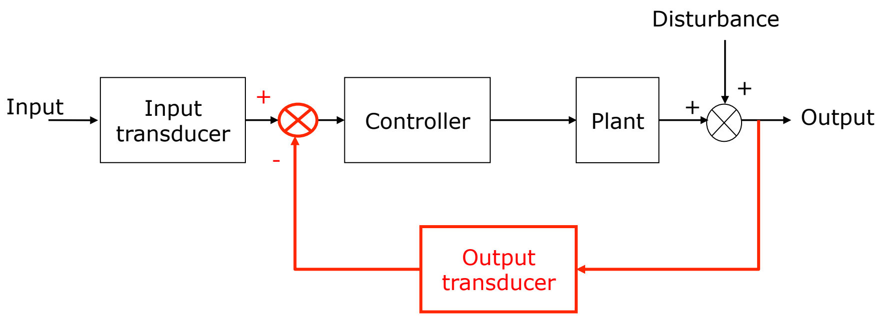
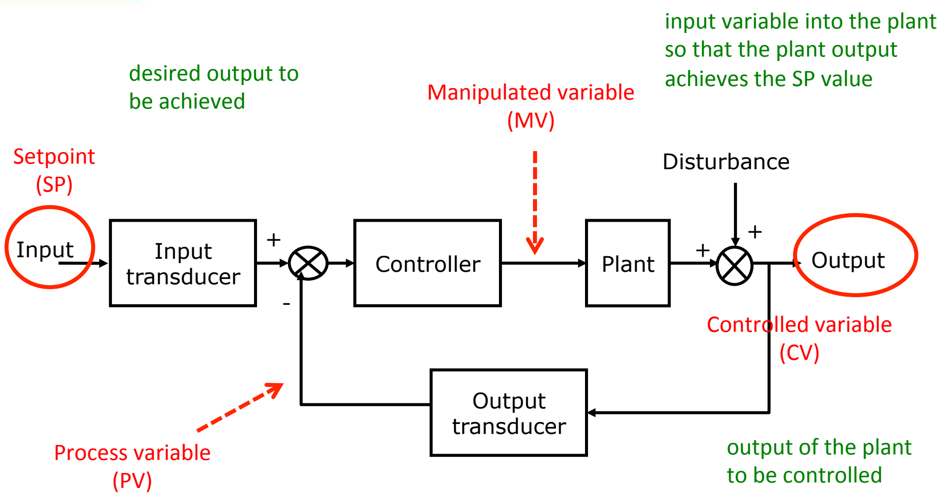
Open-loop Control System



- The output of OLS has no effect on the control action
- OLS do not correct for disturbances and are simply commanded by the input
- In any OLS the output is not compared with the reference input.
- Any control system that operates on a time basis is open loop

Closed-loop Control System





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Closed-loop Control System

- *Feedback control systems* are often referred to as **CLCS**
- *Input transducer* converts the form of the input to the form used by the controller
- *An output transducer* measures the output response and converts it into the form used by the controller (from physical parameters to electrical signals
- The first *summing junction* algebraically adds the signal from the I/P to the signal from the O/P, which arrives via the *feedback path*.

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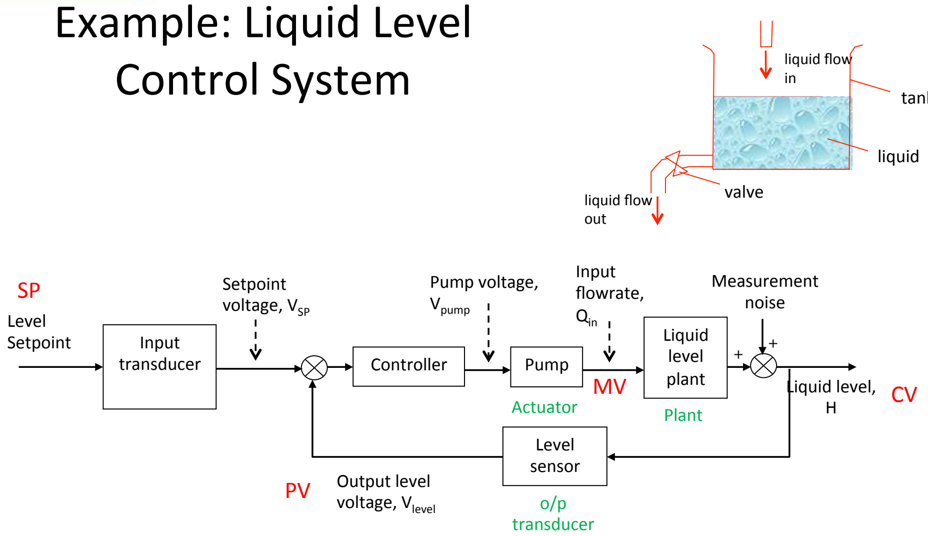
- The o/p signal is substracted from the i/p signal. The result is generally call the *actuating signal* (the actuating signal' s value is equal to the actual difference between the I/P and the O/P), the actuating signal is called the *error*.
- The CLCS compensates for disturbances by measuring the o/p response, feeding that measurement back through a feedback path, and comparing that response to the I/P:
  - If there is a difference between the two responses, the systems drives the plant, via the actuating signal, to make a correction.
  - If there is no difference, the system does not drive the plant, since the plant' s response is already the *desired response*

Example: Liquid Level Control System



CLCS versus OLCS

Matters	CLCS	OLCS
Design	With feedback control action in order to reduce system error	Simple design and construction , and ease of maintenance
Cost	The accuracy and the number of components used is more than open-loop components, thus the system is generally higher in cost, more expensive	Less expensive, simple design and less components
Sensitivity	Less sensitive to noise, disturbances and changes in the environment. System performances can be controlled conveniently and greater flexibility with simple adjustment of the gain or controller	Sensitive to disturbances or noise, the system do not correct for these disturbances because there is no feedback path

Matters	CLCS	OLCS
Accuracy	Greater accuracy, by measuring the output response, and comparing that response to the input at the summing junction. If there is a difference between the two responses, the systems drives the plant, via the actuating signal, to make a correction	Relatively Inaccurate. Disturbances and changes in calibration cause errors, and the output may be different from what desired. To maintain the required quality in output, recalibration is necessary from time to time. More convenient when output is hard to measure or measuring the output is economically not feasible
Stability	Stability is a major problem, which may tend to overcorrect errors and thereby can cause oscillations of constant or changing amplitude	There is no stability problem

A proper combination of open-loop and closed-loop controls is usually less expensive and will give satisfactory overall system performance

1.4 EXAMPLES OF CONTROL SYSTEMS

- Based on System Paradigms
- Based on Types of Signals Used
- Based on System Models
- Based on Control Objectives

Examples

Power amplification in a dish-type antennas

- Varying in diameter from 8 to 30 metres
- Serving an Earth station in a satellite communications network.

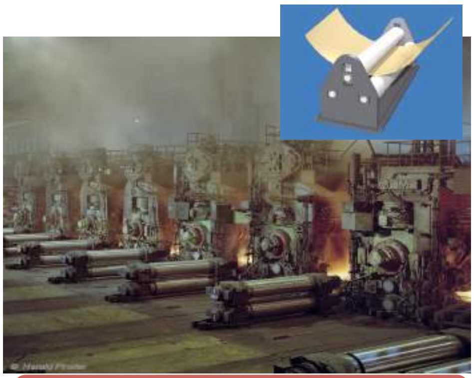
Remote control robots in contaminated area: Sojourner

- Roving on Mars in 1997.
- Solar-powered, 11.5 kg.
- Speed: 0.4 meters/minute
- Its wheel system enabled it to climb over obstacles one-and-a-half wheel diameters tall.

Examples

Convenient input for a thermostat

- Position to heat



Disturbance compensation in a Rolling Mill

- Maintain steel thickness despite variations/disturbance

1.5
CONTROL SYSTEM DESIGN PROCESS

Classifications of control systems

Based on the purpose of the system and the relevant classes it belongs to

Type of Signal	Mathematical model	Control Objectives
• Continuous control system • Discrete control system	• Linear control system • Non-linear control system	• Kinatic (tracking) control system • Process (regulating) control system

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Control System Design Process - General

STEP 1
- Transform requirements into physical systems

STEP 2
- Draw a functional block diagram

STEP 3
- Create a schematic

STEP 4
- Develop mathematical model (block diagram)

STEP 5
- Reduce block diagram

STEP 6
- Analyze & Design

Chapter 1 (Steps 1–3) | Chapter 2 (Step 4) | Chapter 3 (Step 5) | Chapter 4 & 5 (Step 6)

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Controller Design Process

Mathematical modelling

Laws of Physics	System identification

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Analysis

Time domain	Frequency domain

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Design of controller

Controller structure	Controller type

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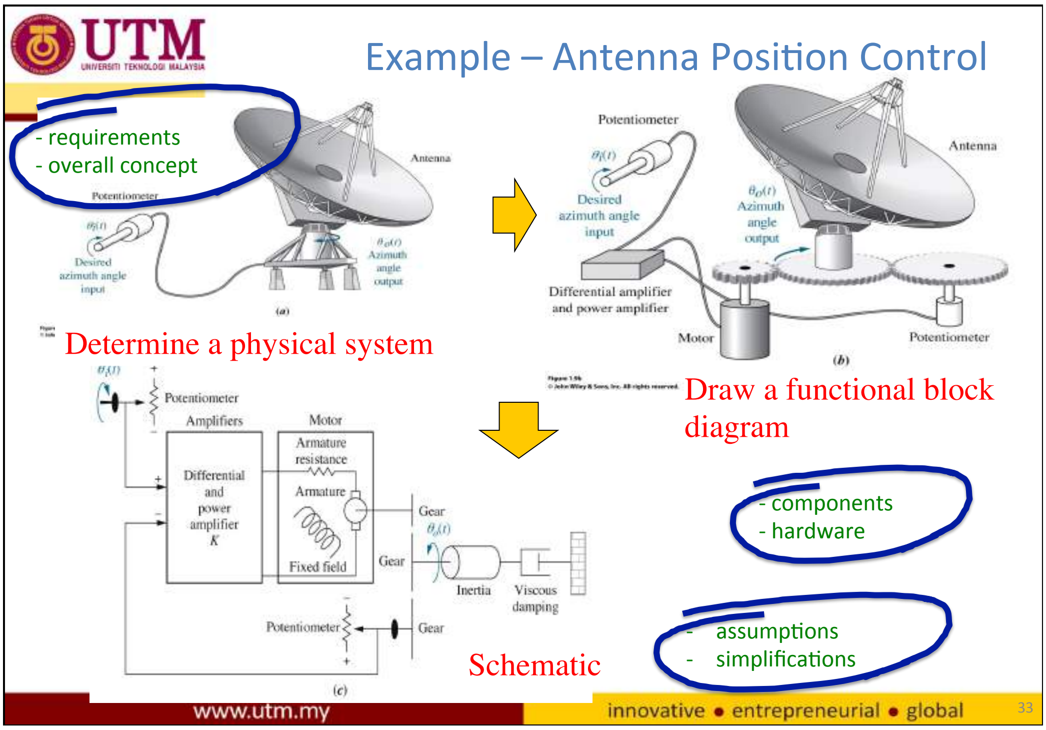
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Example – Antenna Position Control
- requirements
- overall concept
Antenna
Potentiometer
Desired azimuth angle input
Azimuth angle output
(a)
Determine a physical system
Potentiometer
Desired azimuth angle input
Azimuth angle output
Antenna
Differential amplifier and power amplifier
Motor
Potentiometer
(b)
Draw a functional block diagram
- components
- hardware
Potentiometer
Amplifiers
Differential and power amplifier K
Motor
Armature resistance
Armature
Fixed field
Gear
Gear
Inertia
Viscous damping
Potentiometer
Gear
(c)
Schematic
- assumptions
- simplifications
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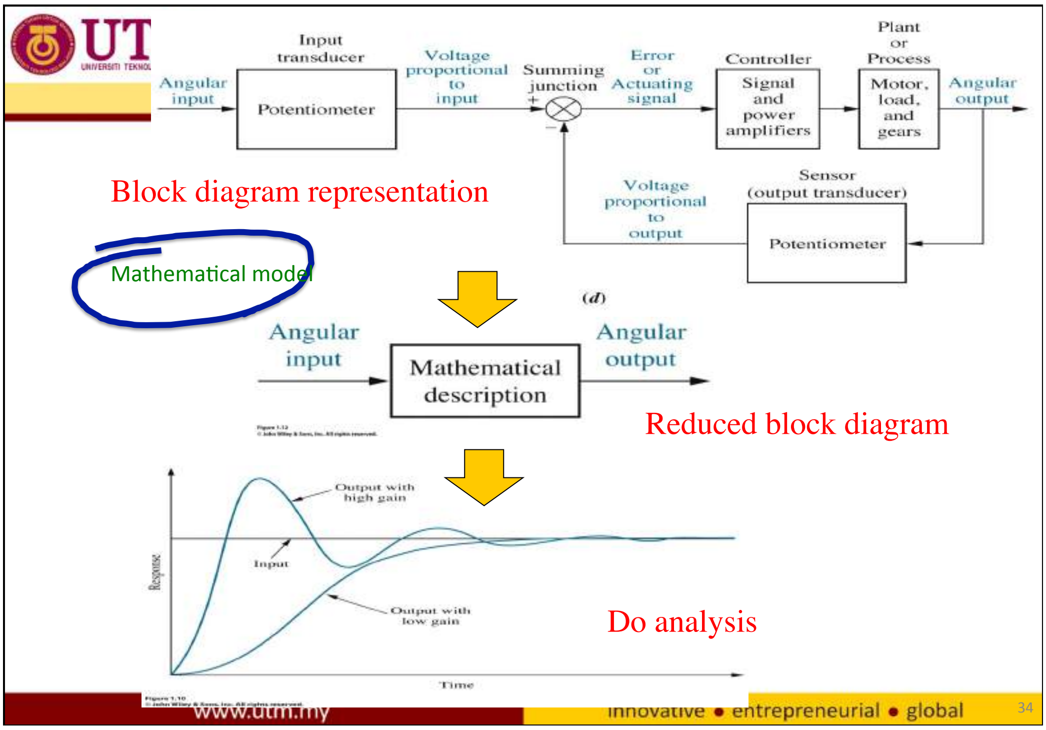
UT
Angular input
Input transducer
Potentiometer
Voltage proportional to input
Summing junction
Error or Actuating signal
Controller
Signal and power amplifiers
Plant or Process
Motor, load, and gears
Angular output
Sensor (output transducer)
Potentiometer
Voltage proportional to output
(d)
Block diagram representation
Mathematical model
Angular input
Mathematical description
Angular output
Reduced block diagram
Output with high gain
Input
Output with low gain
Response
Time
Do analysis
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1.6 MATLAB

- MATLAB
- Control System Toolbox
- Simulink

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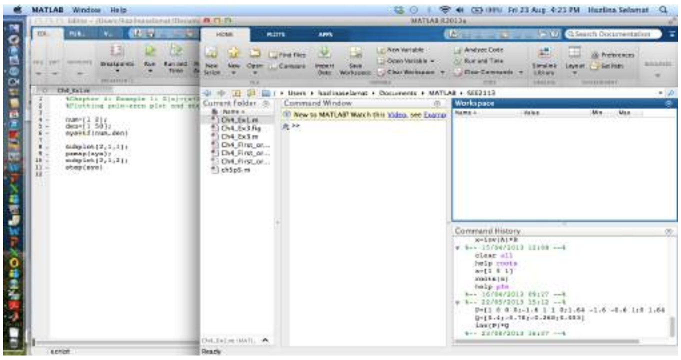
MATLAB

- Important tool in current control system design.
- Recall:
  - To achieve:
    - » **PO4:** Ability to work with modern instrumentation, software and hardware.
  - through:
    - » **CO4:** Apply **MATLAB** software in analyzing control system performance
- MATLAB contains:
  - Lots of Toolboxes – one of them is 'Control System Toolbox'
  - Simulink – click and drag

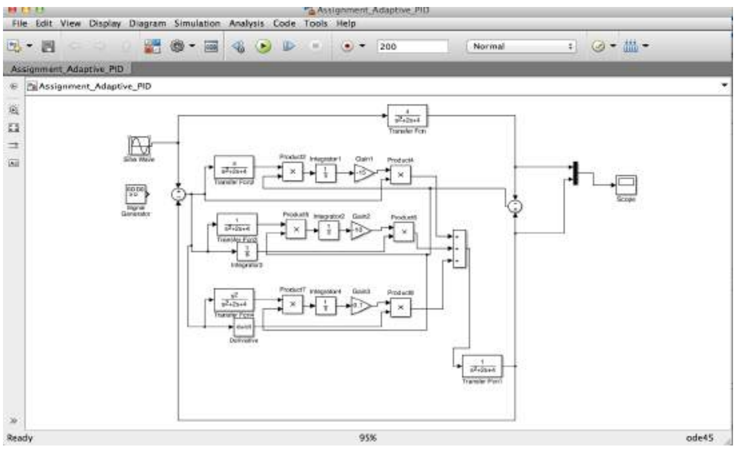
Control System Toolbox

- Contains a set of functions relation to control system design.
- Can be used together with other MATLAB functions or functions from other toolboxes.



Simulink

- More graphical.
- Code writing is minimal.



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Review questions

- Name 3 applications of feedback control system.
- Give 3 examples of open-loop systems.
- Give an example of what happen to a system that is unstable.
- Name 3 approaches to the mathematical modeling of control systems.
- How do we classify control systems?
- What are the steps involved in designing a control system?