RM 1511 – AUTOMATIC CONTROL

Introduction to Control System

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Several Questions?

- Why do we need to learn automatic control ?
- What are the objectives of learning automatic control ?
- Give examples of the applications of automatic control in real-life !

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Expectations
After you finish this course you should….

- Be able to model dynamic systems,

- Have a general understanding of the basic concepts of control systems,

- Be able to apply mathematical tools as they relate to the design of control systems,

- Be able to apply the control design techniques to real world problems.


Terminology

- **Control** is a series of actions directed for making a variable system adheres to a reference value (that might be either constant or variable).

- The desired reference value when performing control is the **desired output variable** (that might deviate from actual output)

- **Process,** as it is used and understood by control engineers, means the component to be controlled

- **Controlled variables -** these are the variables which quantify the performance or quality of the final product, which are also called output variables.

- **Manipulated variables -** these input variables are adjusted dynamically to keep the controlled variables at their set-points.

- **Disturbance variables -** these are also called "load" variables and represent input variables that can cause the controlled variables to deviate from their respective set points.
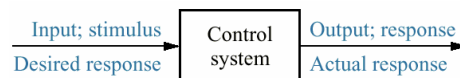
System → *is any collection of interaction elements for which there are cause and effect relationships among the variables.*
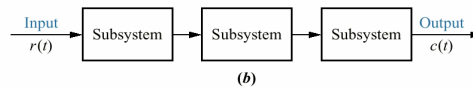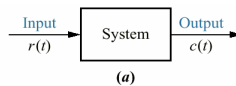
Note: The input, $r(t)$, stands for *reference input*.
The output, $c(t)$, stands for *controlled variable*.

Control systems consists of subsystems and processes (plants) assembled for the purposes of controlling the output of the processes

Controls are classified with respect to:

- technique involved to perform control (*i.e.* human/machines):
  manual/automatic control

- Time dependence of output variable (*i.e.* constant/changing):
  regulator/servo,
  (also known as regulating/tracking control)

- fundamental structure of the control (*i.e.* the information used for computing the control):
  Open-loop/feedback control,
  (also known as open-loop/closed-loop control)

Manual/Automatic Controls - Examples

A system that involves:

- a person controlling a machine is called *manual control.*
  Ex: Driving a car

- machines only is called a *automatic control.*
  Ex: Central AC

Servo/Regulator Controls - Examples

An *automatic* control system designed to:

- follow a changing reference is called *tracking control* or a *servo*.

  Ex: Remote control car

- maintain an output fixed (regardless of the disturbances present) is called a *regulating control* or a *regulator*.

  Ex: Cruise control

Open-Loop Control /Feedback control

The structures are fundamentally different:

In an **open-loop control**, the system does NOT measure the actual output and there is no correction to make that output conform to the desired output.

In a **closed loop control** the system includes a sensor to measure the output and uses feedback of the sensed value to influence the control input variable.

Examples of
Open-Loop & Feedback Controls

An electric toaster
is an *open-loop* control.

Since

- The controller is based on the knowledge.
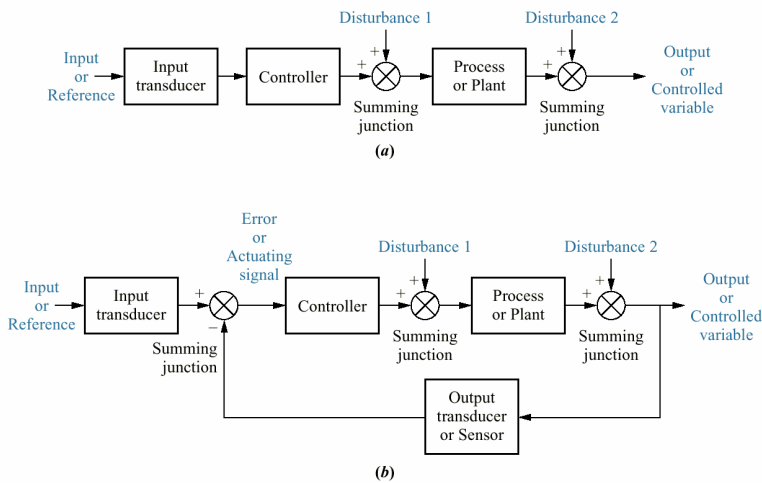- The output is not used in control computation

A water tank of an
ordinary flush toilet
is a (basic)
feedback control

Since

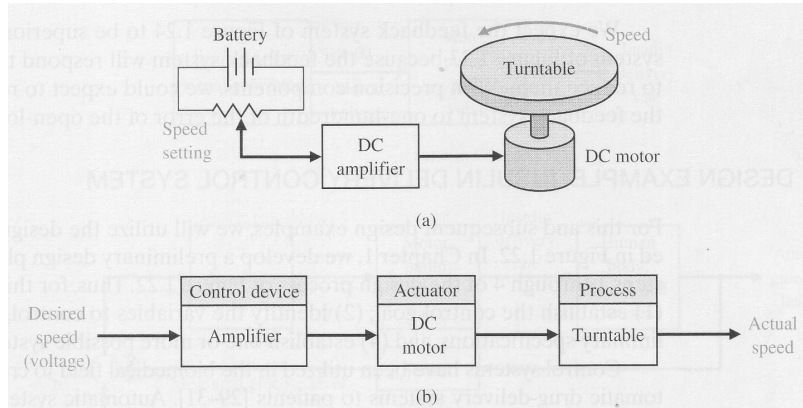- The output is fed back for control computation

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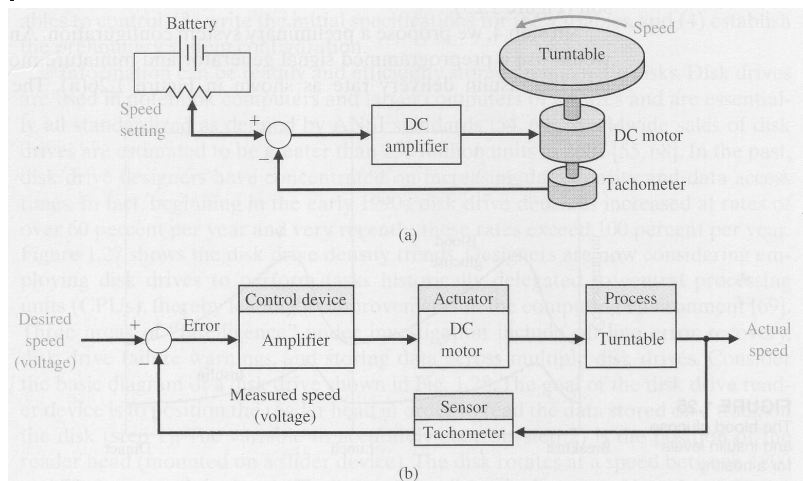
System configurations ➔ *open and closed loop systems*

(*a*)

(*b*)

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(a)

(b)

a. Open loop control of speed of turntable, **b.** block diagram model

(a)

(b)

a. Closed-loop control of speed of turntable, **b.** block diagram model

Pros & Cons of Open-Loop Control

- Generally simpler than closed-loop control,
- Does not require a sensor to measure the output,
- Does not, of itself, introduce stability problems;

BUT

- Has lower performance than closed-loop to match the desired output well.

Problems with Feedback Control

- More complex than open-loop control

- May have steady state error

- Depends on accuracy with which you can measure the output

- May cause stability problems

Advantages of Feedback Control

- System with well designed feedback control can respond to unforeseen events.

- Eliminates need for human adjustment of control variable

- Reduces human workload

- *Gives much better performance than it is possible with open-loop*

We build control systems for four primary reasons:

- **Power amplification (gain)**
  Positioning a large radar antenna by low-power rotation of a knob.
- **Remote control**
  Robot arm used to pick up radioactive material.
- **Convenience of input form**
  Changing room temperature by thermostat position.
- **Compensation for disturbances**
  Controlling antenna position in the presence of large wind disturbance torque.

Basic element of a closed-loop system

• Comparison unit → computes the difference between the desired and actual output variables to give the controller a measure of the system error

• Control element → computes the desired control input variable

• Correction element →device that can influence the control input variable of the process (ak: actuator)

• Process element → component whose the output is to be controlled

• Measurement element → measures the actual output variable
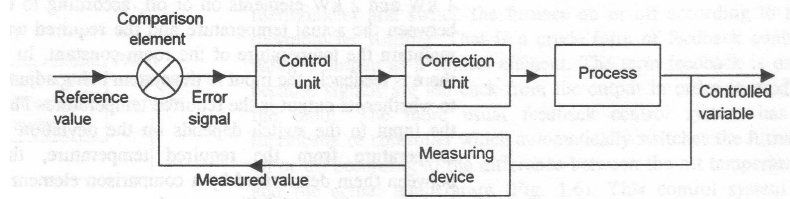
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**Generic Component of an Elementary FEEDBACK Control**
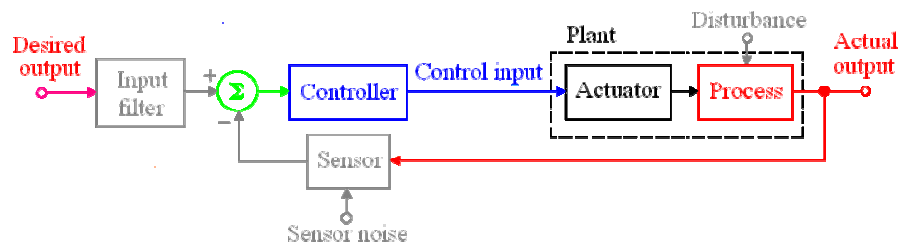
Our general system also includes: *Disturbance & Sensor noise*

Typically, **the sensor** converts the measured output into an electric signal for use by the controller. An input filter is then required.
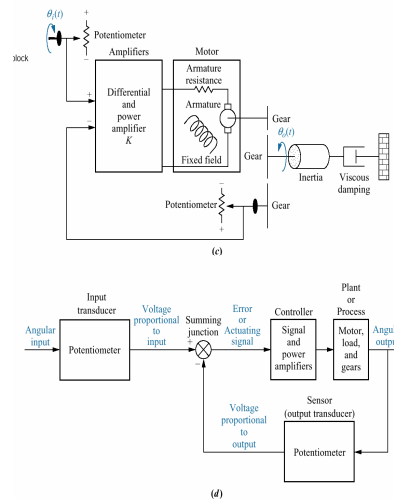
Input filter converts the desired output variable to electric form for later manipulation by the controller

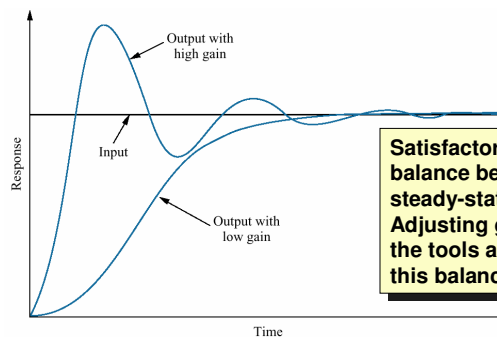**Intro - 20**

Antenna azimuth position control system:
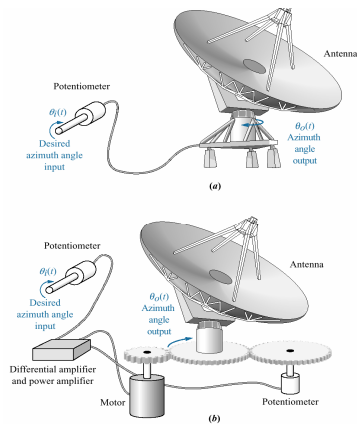
a. system concept, **b.** detailed layout;
c. schematic, **d.** functional block diagram

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Antenna Azimuth Position Control System Response

- System normally operates to drive pointing error to zero.
- Motor is driven only when there is a pointing error.
- The larger the error the faster the motor turns.
- Too large a signal amplifier gain could cause overshoot/instability.

Satisfactory design revolves around a balance between transient performance, steady-state performance, and stability. Adjusting gain & adding compensators are the tools a control engineer has to achieve this balance.

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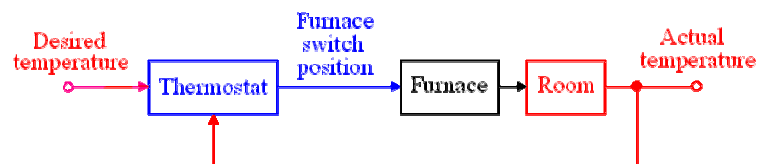Interrelation of many controlled variables → multivariable control sys

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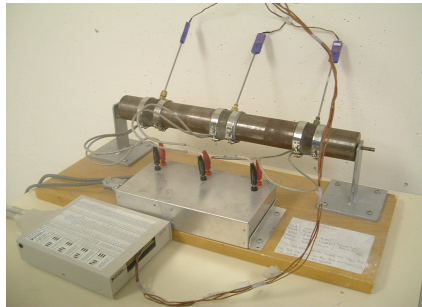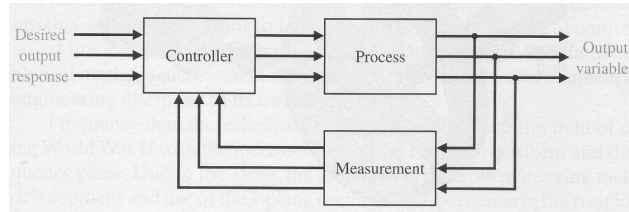
Example 1: Heater

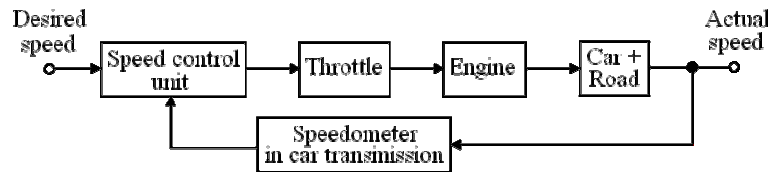**Question:** Identify:

      a) the process,

      b) the control input variable,

      c) the output variable,

      d) the controller.

Example 2: Cruise Control

Desired speed → Speed control unit → Throttle → Engine → Car + Road → Actual speed

Speedometer in car transmission

Question: Identify:

  a) the process,

  b) the control input variable,

  c) the output variable,

  d) the controller.

Design Objectives

- Produce desired transient response.
- Reduce steady-state error.
- Achieve closed-loop stability.

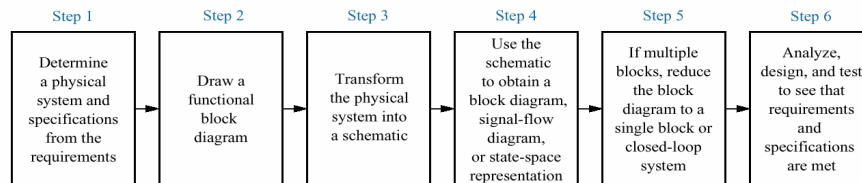 Total Response = Natural Response +

           Forced Response

The closed-loop control system's natural response must not dominate! The output must follow the input.
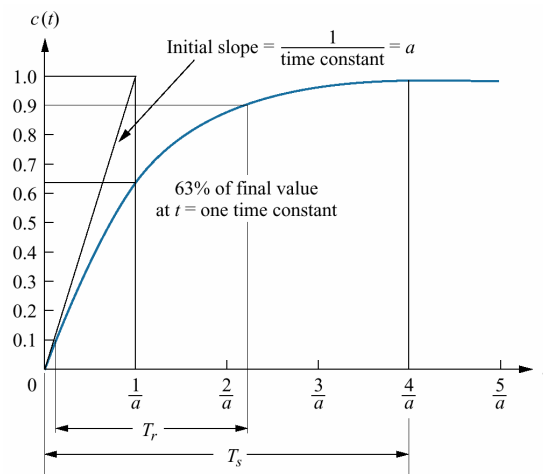
- Other considerations (cost, hardware selection etc)

The Design Process

| Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Determine a physical system and specifications from the requirements	Draw a functional block diagram	Transform the physical system into a schematic	Use the schematic to obtain a block diagram, signal-flow diagram, or state-space representation	If multiple blocks, reduce the block diagram to a single block or closed-loop system	Analyze, design, and test to see that requirements and specifications are met

Control system design process

Response of systems – first order system
exp: a kettle system

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Response of systems – second order system

exp : a bathroom scales system
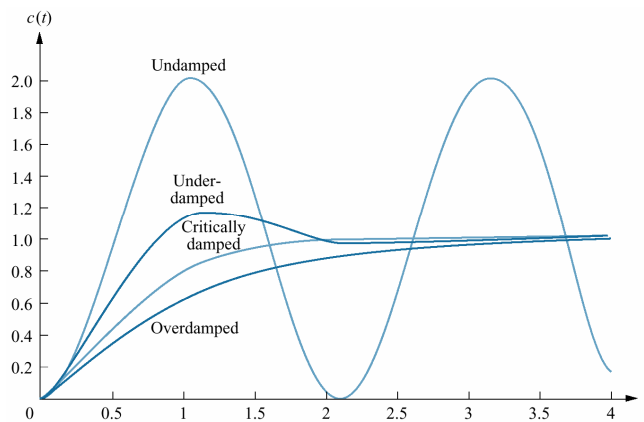
Standard Test Signals

Input	Function	Description	Sketch	Use
Impulse	$\delta(t)$	$\delta(t) = \infty$ for $0- < t < 0+$ $= 0$ elsewhere $\int_{0-}^{0+} \delta(t)\,dt = 1$	$f(t)$ $\delta(t)$	Transient response Modeling
Step	$u(t)$	$u(t) = 1$ for $t > 0$ $= 0$ for $t < 0$	$f(t)$	Transient response Steady-state error
Ramp	$tu(t)$	$tu(t) = t$ for $t \geq 0$ $= 0$ elsewhere	$f(t)$	Steady-state error
Parabola	$\frac{1}{2}t^2 u(t)$	$\frac{1}{2}t^2 u(t) = \frac{1}{2}t^2$ for $t \geq 0$ $= 0$ elsewhere	$f(t)$	Steady-state error
Sinusoid	$\sin \omega t$		$f(t)$	Transient response Modeling Steady-state error

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