# COURSE OUTLINE

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>INTRODUCTION &amp; BASIC CONCEPTS</td>
</tr>
<tr>
<td>II</td>
<td>MODELING DYNAMIC SYSTEMS</td>
</tr>
<tr>
<td>III</td>
<td>CONTROL SYSTEM COMPONENTS</td>
</tr>
<tr>
<td>IV</td>
<td>STABILITY</td>
</tr>
<tr>
<td>V</td>
<td>TRANSIENT RESPONSE</td>
</tr>
<tr>
<td>VI</td>
<td>STEADY STATE RESPONSE</td>
</tr>
<tr>
<td>VII</td>
<td>DISTURBANCE REJECTION</td>
</tr>
<tr>
<td>VIII</td>
<td>BASIC CONTROL ACTIONS &amp; CONTROLLERS</td>
</tr>
<tr>
<td>IX</td>
<td>FREQUENCY RESPONSE ANALYSIS</td>
</tr>
<tr>
<td>X</td>
<td>SENSITIVITY ANALYSIS</td>
</tr>
<tr>
<td>XI</td>
<td>ROOT LOCUS ANALYSIS</td>
</tr>
</tbody>
</table>

ME 304 CONTROL SYSTEMS

Prof. Dr. Y. Samim Ünlüsoy
To get familiar with

- various control systems and to introduce
- fundamental concepts and terminology of Control Systems,
- classification of Control Systems.
A **control system** is a collection of components assembled to produce a desired response for a given input.
Automotive:
- Directional Control (Steering),
- Speed & Acceleration Control,
- ABS – ESP,
- Cruise Control,
- Climate Control,
- Engine Control,
- etc.
EXAMPLES of CONTROL SYSTEMS

Home Appliances:

- Home heating
- Automatic washing machine,
- Refrigerator,
- Microwave oven,
- Toaster,
- etc.
EXAMPLES of CONTROL SYSTEMS

Aviation / Aerospace:
- Autopilot Applications,
- Space Vehicles,
- Missile Guidance Systems,
- Target Tracking (radar),
- etc.
EXAMPLES of CONTROL SYSTEMS

Manufacturing Industry:

- Automation,
- Robotics,
- CNC Machining Centers,
- etc.
**Plant**: a physical object, system or process that is to be controlled.
**Process**: is an operation to be controlled.

**Examples:**
- chemical process,
- economic process,
- biological process.
**Input** : an effect (generated outside the plant) that causes the plant to behave in a certain way.

Steering wheel rotation  \[\rightarrow\]  Direction of travel

**Input**

**BASIC DEFINITIONS**
Output (controlled variable): the quantity or condition that is of interest and thus is controlled.
**Reference (command) input**:

A signal supplied to the control system which represents the desired value (or variation) of the controlled output.
**Disturbance input**: is an unwanted input that tends to adversely affect the value of the output of a system.

![Diagram of a car with disturbance input](image)

- **Steering wheel rotation**
- **Disturbance (Side wind)**
- **Direction of travel**
**BASIC DEFINITIONS**

**Disturbance input**: is an unwanted input that tends to adversely affect the value of the output of a system.
**Controller**: a device (or human being) which adjusts the control signals according to a set of predetermined rules.

**Control signal** is the output of the controller that will be used to bring the output of the system as close to the desired value as possible.
Control Law (strategy) : set of predetermined rules used (by the controller) to adjust the control signals.
Thus control is the process of:

- adjusting the control signals such that,
- regardless of the disturbances,
- the controlled output of the plant is forced to behave as close to the desired way as possible.
Control Systems can be classified into two basic types:

1) **Open loop (OL) control systems,**

2) **Closed Loop (CL) or Feedback (FB) control systems.**
Control systems in which the output has no effect on the control action are called Open Loop control systems.

In an open loop control system the output is neither measured nor fed back for comparison with the reference input.
OPEN LOOP CONTROL

Reference (command) input

Controller

Controlled output

Disturbance input

Plant or Process

Control signal

ME 304 CONTROL SYSTEMS
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Hot water is used to keep a room at a specified temperature.

- It is circulated through a radiator and heat flows into the room.

- Heat will flow out through the walls.

- Room temperature is set by adjusting the flow rate of hot water through the radiator.
Ex -1 / Room Temperature Control

Outside Temperature $T_o$

Can you identify control system elements?

Valve

Hot water

Room Temperature $T_r$

Radiator

$q_i$

Water Temperature $T_w$

$20^\circ C$

$22^\circ C$

$24^\circ C$

$q_o$
In this example, the flow rate of the hot water is usually calibrated on the dial of the valve on a typical day.

Obviously, on a particularly cold day, the dial setting and the actual room temperature will not agree.
When switched on, a photocopy machine will not start until the drum is heated to a predetermined temperature.

One way of heating the drum may be passing a current through a coil inside the drum for a fixed period of time, say 2 minutes.
Depending upon
- how long ago it was switched off,
- environmental temperature, or
- the mains voltage
the drum temperature may have different values after 2 minutes of heating.
As a general rule of thumb:

“Any control system working on a time basis is open loop.”

Consider a simple toaster. Is it an open loop system?
In a *Closed Loop or Feedback* control system, the *controlled output* is measured and compared with the *reference input*.

The difference between the two, called *error*, is fed into the *controller* which produces a *control signal* to reduce this error.
Thus a closed loop (feedback) control system contains additional elements.

- Sensors or transducers,
- Comparator (error detector),
- Actuator.
Sensors

The controlled output is measured by sensors

“devices that measure a variable and convert it into a signal – usually electrical – which can be read by an observer or by an instrument”

so that it can be fed back and compared with the desired input.
CLOSED LOOP CONTROL

Comparator (error detector)

The difference between the
- desired (reference) input, and
- the controlled output

is measured by a comparator (error detector) and is fed into the controller which produces a control signal to reduce this error.
**Actuator**

The output of the controller is usually amplified to a sufficiently high power level to drive an actuator, which is usually a power device such as electric motor, hydraulic motor etc., to change the controlled output.

The actuator is usually combined with the plant in block diagrams.
Open Loop Systems

- Simple,
- Low cost,
- Stability is not a major problem,
- Cannot function properly in the presence of disturbances and parameter variations.
Closed Loop (Feedback) Systems

- More elements,
- Higher cost,
- Stability is a major problem,
- Relatively insensitive to disturbances and variations of parameter values.
Another classification of control systems - according to the objective of control

1) **Regulator**

2) **Servomechanism**
**Regulator**: Objective is to keep the controlled output at a constant value at all times in the presence of disturbances.

The command input for a regulator is either zero or constant.
Servomechanism: Objective is to keep the controlled output following a time varying command input.

In its original use, a servomechanism is a control system with mechanical position, velocity or acceleration as the controlled output.
FURTHER CLASSIFICATIONS

Analog – Digital

Manual – Automatic

Active - Passive

Continuous time – Discrete time

Single input/Single Output (SISO) – Multi input/Multi Output (MIMO)
In this course, the subject is classical control, which deals with Single Input/Single Output (SISO) systems only.

Multi input/Multi Output (MIMO) systems will be the subject of the graduate course ME 511 Modern Control.
EXAMPLE – Water Level Control

Adjustable length for setting the reference liquid height $h_r$
EXAMPLE – Driver/Car System

Desired Direction
Desired Speed

Controller

Actuator
Actuator

VEHICLE

Eyes and Brain

Hands

Feet

Steering Wheel Position
Gas (Brake) Pedal Position

Eyes

Speedometer

Eyes

Speed

Heading

Pedal Position

ME 304 CONTROL SYSTEMS

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- The autopilot system of an aircraft or ship.
- Guidance system of a (heat seeking) missile.
- Guidance system of a ballistic missile (inertial guidance system).
- A driver-car system.
READING

Nise, CH-1

(Dorf & Bishop, CH-1)
(Ogata, CH-1)