AUTOMATICS and AUTOMATIC CONTROL

LECTURE 1

dr inż. Adam Kurnicki
Automation and Metrology Department
Room no E210

LECTURE CONTENT

1. **Introduction to automatics** – short history, control system and related nations, classification of control systems
2. **System models** – differential equations, state equations, Linearization of models, Laplace transform, transfer function
3. **Time responses –** impulse and step response
4. **Frequency responses –** Nyquist plot, Bode plots
5. **Basic dynamics elements –** first order system, integrator, differentiator, second order systems, systems with delay
6. **Structure of control system** – examples of control systems, description of closed-loop systems
7. **Closed loop system stability** – Hurwitz criterion, Nyquist criterion
8. **Quality of control** – analyses of steady state, method based on roots placement, method based on integral indices
9. **Compensators and regulators** - PID controller
10. **PID controller parameters tuning** – Ziegler-Nichols methods, Chien, Hrones and Reswick methods

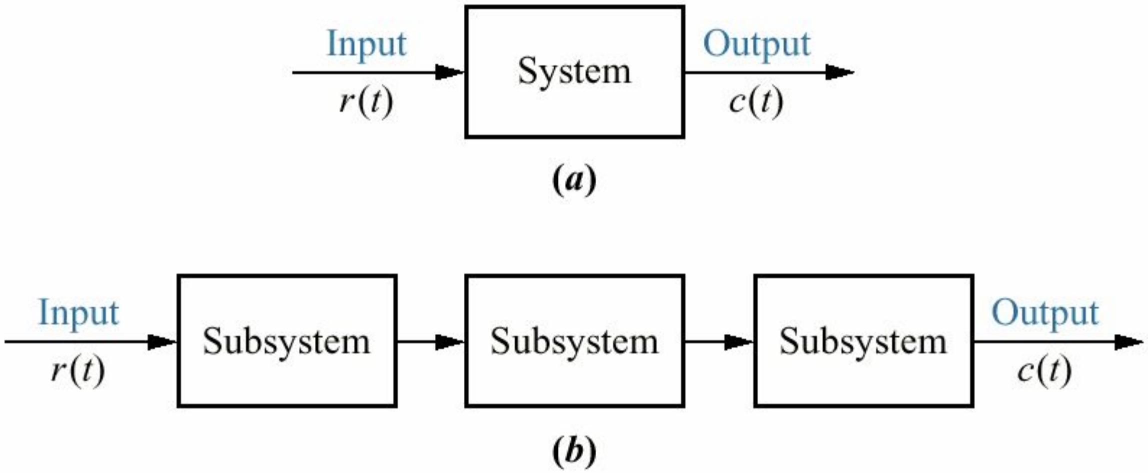
INTRODUCTION TO AUTOMATICS AND AUTOMATIC CONTROL

Automatics derives from Greek word *automatos,* "acting of one's own will, self-acting, of itself," made up of two parts, *auto-,* "self," and *-matos,* "willing,"

Automatics (offen called control or automatic control engineering) field of technology and science, which deals with issues of control of various processes, mainly technological and industrial (usually without the participation or with a limited participation of human being).

INTRODUCTION TO AUTOMATICS AND AUTOMATIC CONTROL
TERMINOLOGY

Control - is any intentional impact (action or series of actions) on the object (the technological process) in such a way as to achieve the intended objectives



Note: The input, $r(t)$, stands for *reference input*.
The output, $c(t)$, stands for *controlled variable*.

System *is any collection of interaction elements for which there are cause and effect relationships among the variables*

INTRODUCTION TO AUTOMATICS AND AUTOMATIC CONTROL
TERMINOLOGY

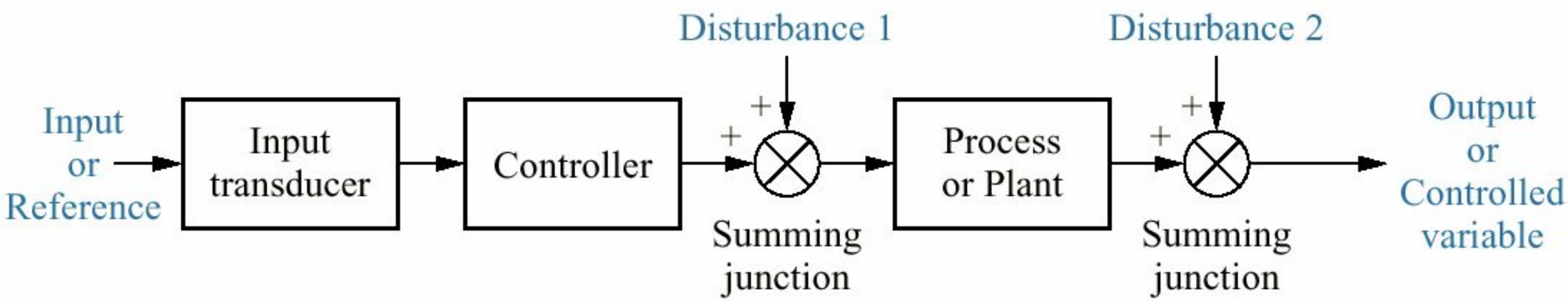
Controlled variables - these are the variables which quantify the performance or quality of the final product, which are also called output variables.

The desired **reference signal (input signal or set-point)** when performing control is the desired output variable (that might deviate from actual output)

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.

INTRODUCTION TO AUTOMATICS AND AUTOMATIC CONTROL
OPEN LOOP / CLOSED LOOP SYSTEMS

The **open-loop system** is also called the non-feedback system - the system does NOT measure the actual output and there is no correction to make that output conform to the desired output

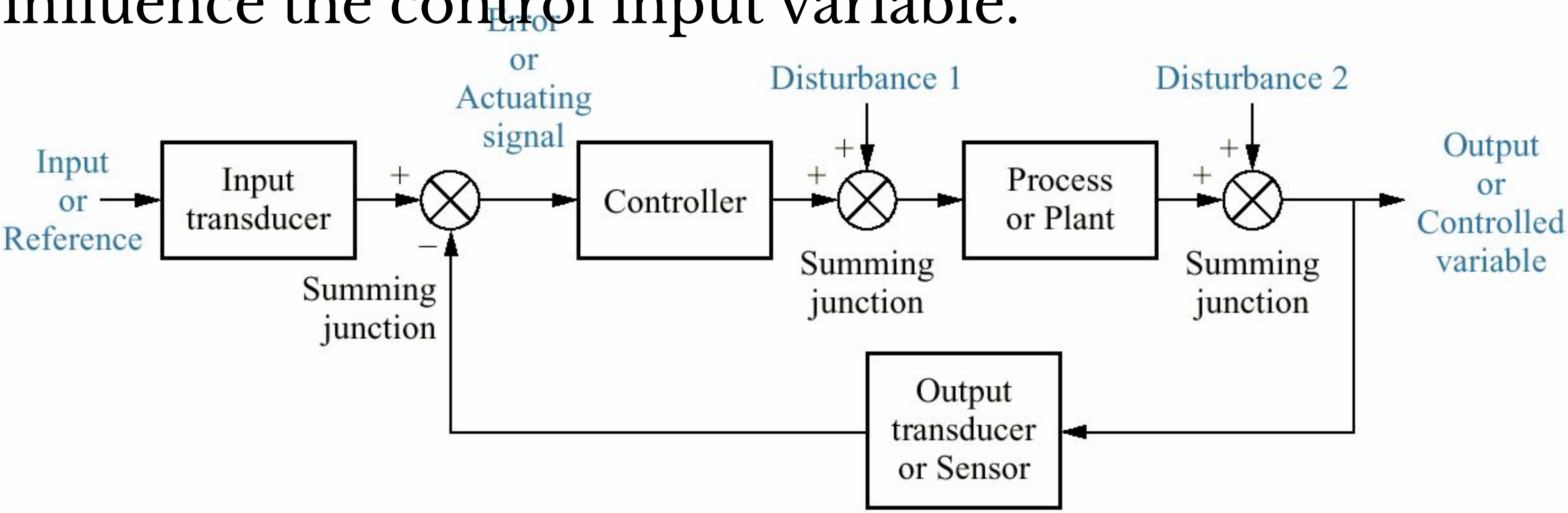


(*a*)

An open-loop system cannot compensate for any disturbances that add to the controller's driving signal or to the process output

Introduction to Automatics and Automatic Control
Open Loop / Closed Loop Systems

The **closed-loop system** is also called the feedback system - the system includes a sensor to measure the output and uses feedback of the sensed value to influence the control input variable.



The closed-loop system can compensate for disturbances by measuring the output, comparing it to the desired output, and driving the difference

Introduction to Automatics and Automatic Control
Open Loop / Closed Loop Systems
Example:

1. A blind person driving a car: open loop control
2. Driving a car by using vision: feedback control

In the first case driver does not have much information about the current position of the car with respect to the road.

In the second case the driver can steer the car back to the desired position despite bumps, wind and other uncontrollable effects.

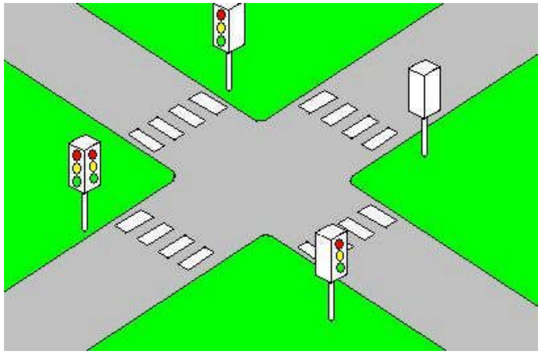
INTRODUCTION TO AUTOMATICS AND AUTOMATIC CONTROL
OPEN LOOP / CLOSED LOOP SYSTEMS
EXAMPLE:

Central heating system in house/room:

- without temperature sensor - open loop control
- with temperature sensor – closed loop control

Washing machine (open loop control) :
There is no sensor to measure how dirty is laundry

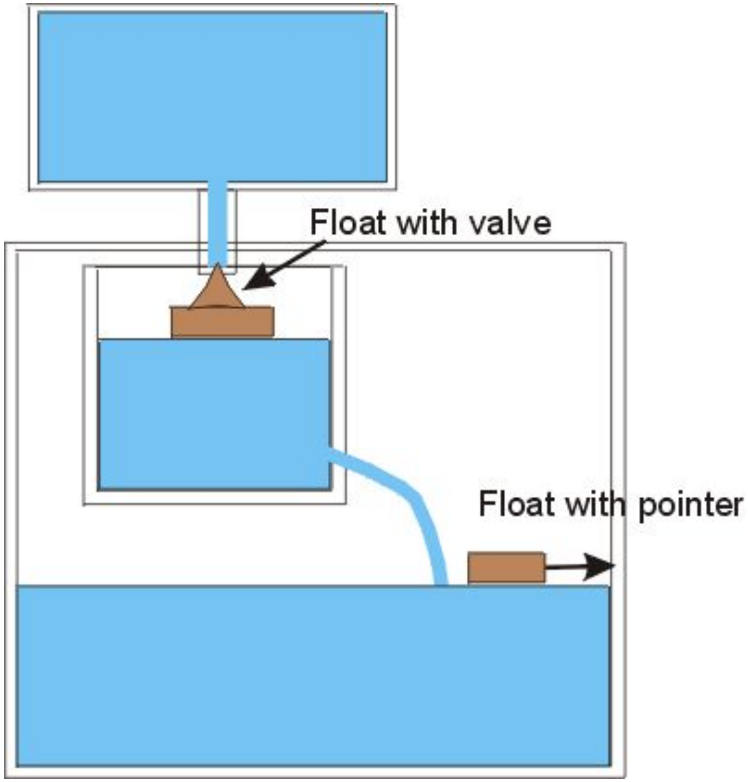
TRAFIC LIGHTS (open loop control) :
That system don’t control traffic according to crowd

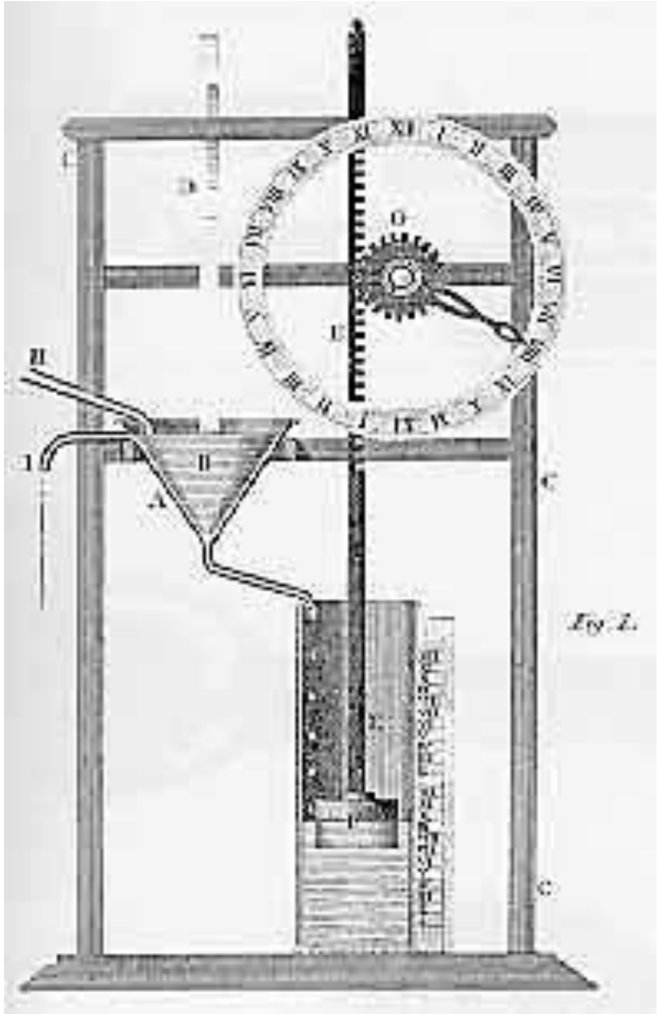


HISTORY

- Automatic control systems were first developed more than two thousand years ago.
- The first feedback control device on record is thought to be the ancient Ctesibios's water clock in Alexandria (3rd century BC).

Ctesibios's water clock





It kept time by regulating the water level in a vessel and, therefore, the water flow from that vessel.
This certainly was a successful device as water clocks .

HISTORY

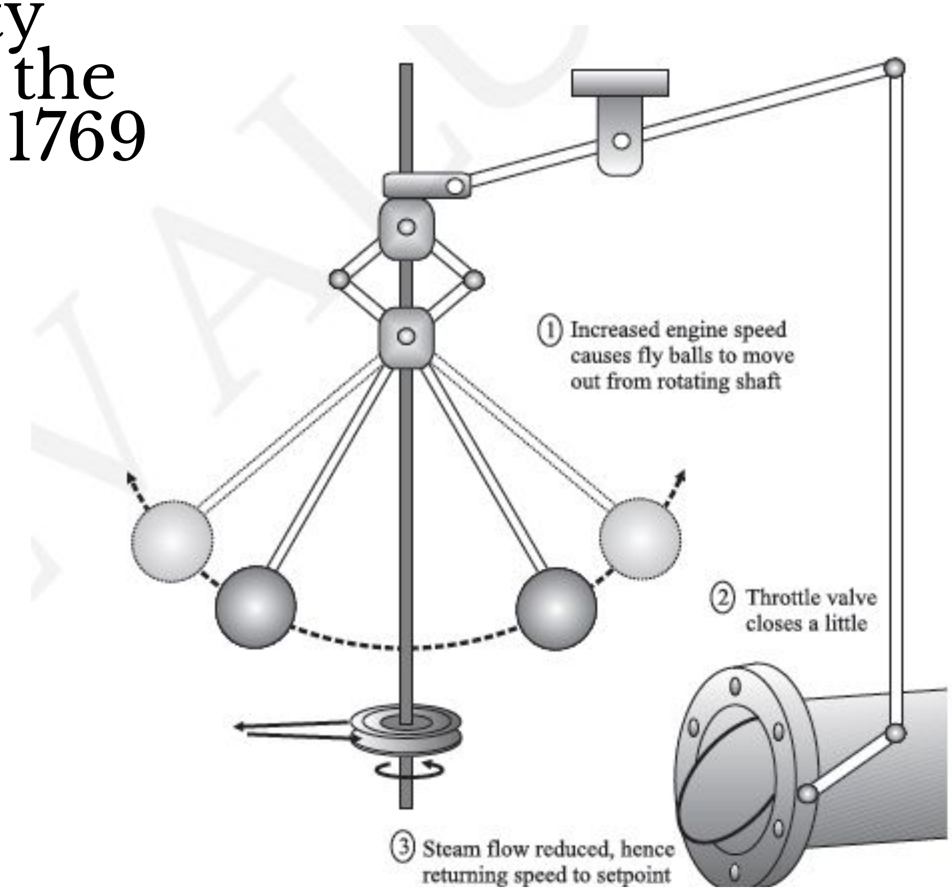
- In the 17th and 18th centuries were popular in Europe, automata equipped with dancing figures that repeat the same task over and over again

- Temperature regulator (invented in 1624)
- Pressure regulator (invented in 1681)

HISTORY

- James Watt fly-ball governor

Rotational velocity stablilization of the steam engine – 1769



Reduced steam flow – reduced pressure on the blades of the engine turbine

HISTORY

- **1868 Governor control analysis (Maxwell)**
- **1927 Telephone amplifier analysis (Bode -** frequency domain analysis**)**
- **1932 Stability analysis (Nyquist)**
- **1940 Autopilots, radar, etc.**
- **1952 Machine tool numerical control (MIT)**
- **1970 State variable models, optimal control**
- 1983 personal computers

CLASIFICATION OF CONTROL SYTEMS

The classification can be carried out in many different ways, by taking into consideration various properties of the system

1. With respect to the number of controlled variables:

- single-variable control system - SISO
- multi-variable control system - MISO, MIMO

CLASIFICATION OF CONTROL SYTEMS

2. With respect to the task performed by the system:

- Systems of stabilization

The purpose of these systems is to keep the controlled quantities at a given (desired) level.

In the stabilization systems the reference value is well known and constant

Typical applications: stabilization of: liquid level, temperature in the room, motor speed, etc.

CLASIFICATION OF CONTROL SYTEMS

2. With respect to the task performed by the system:

- Programmed control systems

The purpose of these systems is to change the controlled quantitiy according to the time function given.

In these systems the reference value is well known, but it is changing according to the time function given

Typical applications: CNC machine tools (milling machine, lasers, lathes) where the movement of the tools (cutters, turning tools) should be controlled by a programmed

CLASIFICATION OF CONTROL SYTEMS

2. With respect to the task performed by the system:

- Tracking systems (also called follow-up systems)

The purpose of these systems is to change the magnitude of the controlled quantity according to an unknown time function of reference value (stochastic values of reference).

In these systems, the reference value is not known and varies stochastically

Typical application: anti-aircraft radar system

CLASIFICATION OF CONTROL SYTEMS

2. With respect to the task performed by the system:

- Systems having more complicated tasks:
  - extremal systems,
  - optimal systems,
  - adaptive systems.

CLASIFICATION OF CONTROL SYTEMS

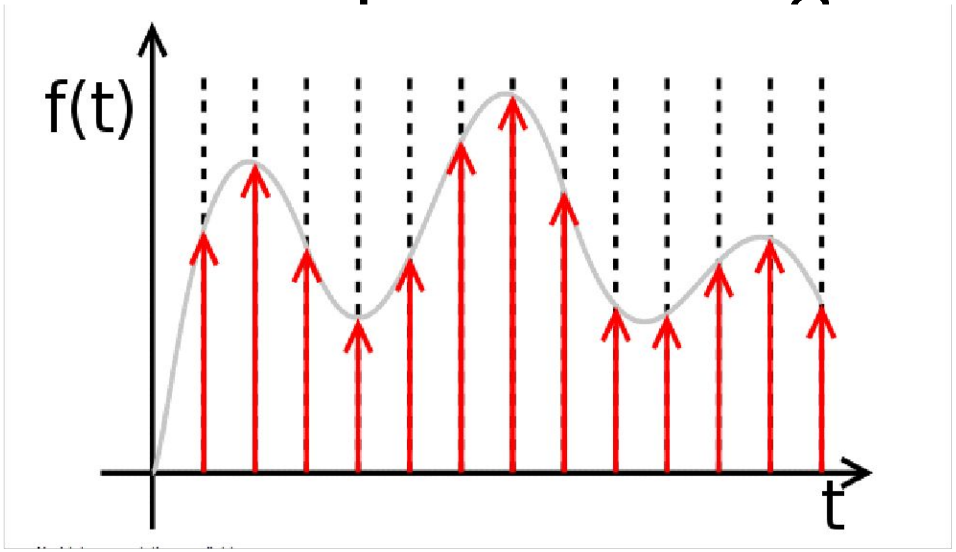
3. With respect to the instants of supervision:

- Continous-time control systems
- Discrete-time control systems

In a continuous-time control systems changes in control signals are generated in a continuous-time way. This signals will have some values at every instant of time (they are also called analog signals)

CLASIFICATION OF CONTROL SYTEMS

In a discrete-time control systems changes in control signals are generated only in some periodically repeating instants of time, which are called the sampling intants. This signals are also called impulses or digital signals).



CLASIFICATION OF CONTROL SYTEMS

4. With respect to the possibility of application of the superposition principle :

- Linear systems
- Nonlinear systems

For linear systems the so called superposition principle can be used, according to which the reaction of the system to a sum of two (or more) inputs equals to the sum of reactions to each of the inputs separately.

$$F(x_1 + x_2 + \cdots) = F(x_1) + F(x_2) + \cdots$$

These systems can be described by linear differential equations

THANK YOU