Automation and Control Engineering

MRCET

AUTOMATION AND CONTROL ENGINEERING (R17A0327)

4th Year B. Tech I- sem, Mechanical Engineering

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COURSE OBJECTIVES

UNIT - 1	**CO1: To perform one or more processing operations & To understand the need of Mechatronics systems**
UNIT - 2	CO2: To make students familiar with the constructions and working principle of different types of sensors and transducers.
UNIT - 3	CO3: Understand the fundamental concepts of electro mechanics and fluid mechanics (hydraulics and pneumatics) of Actuators and drive systems.
UNIT - 4	CO4: To impart knowledge on the control elements
UNIT - 5	CO5: To understand the different control schemes generally used to get best output.

UNIT 1

INTRODUCTION TO AUTOMATION & MECHATRONICS

CO1: To perform one or more processing operations & To understand the need of Mechatronics systems

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UNIT – I (SYLLABUS)

INTRODUCTION TO AUTOMATION

- Types and strategies of automation
- Pneumatic and Hydraulic components circuits
- Mechanical Feeding and machine tool control to transfer the automation

Introduction to Mechatronics

- Role of various engineering disciplines in Mechatronics
- Mechatronics design elements
- Scope of Mechatronics
- Applications of Mechatronics.

COURSE OUTLINE

UNIT -1

LECTURE	LECTURE TOPIC	KEY ELEMENTS	LEARNING OBJECTIVES
1.	INTRODUCTION TO AUTOMATION	Definition of force.	Understanding of basics of Automation (B2)
2	Types and strategies of automation	Define types of automation	Understanding of types of automation (B2)
3	Pneumatic and Hydraulic components circuits	Working principle of pneumatic and hydraulic components circuits	Understanding and Analyze the Working principle of pneumatic and hydraulic components circuits Parallelogram law. (B2, B4)
4	Mechanical Feeding and machine tool control to transfer the automation	Transformation of materials	Remember the how material are transferred in between machines (B1)
5	Introduction to Mechatronics	Definition of Mechatronics	Understanding of basics of Mechatronics (B2)
6	Role of various engineering disciplines in Mechatronics	Importance of mechatronics	Understanding of role of mechatronics in various applications (B2)
7	Mechatronics design elements	Mechatronics elements	Understand the what are the major elements in mechatronics
8	Scope of Mechatronics, Applications of Mechatronics	Applications of Mechatronics	Analyse the working of the washing machine , water level controller (B4)

LECTURE 1

Introduction to Automation

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TOPICS TO BE COVERED

- Definition of Automation
- Types of Automation
- Reasons for Automation
- Automation Strategies
- Pneumatic and Hydraulic components circuits

LECTURE 1

Introduction - Automation

AUTOMATION

- **Definition:** It is technology concerned with the application of Mechanical, electronic & computer-based systems to operate and control production in order to improves productions.

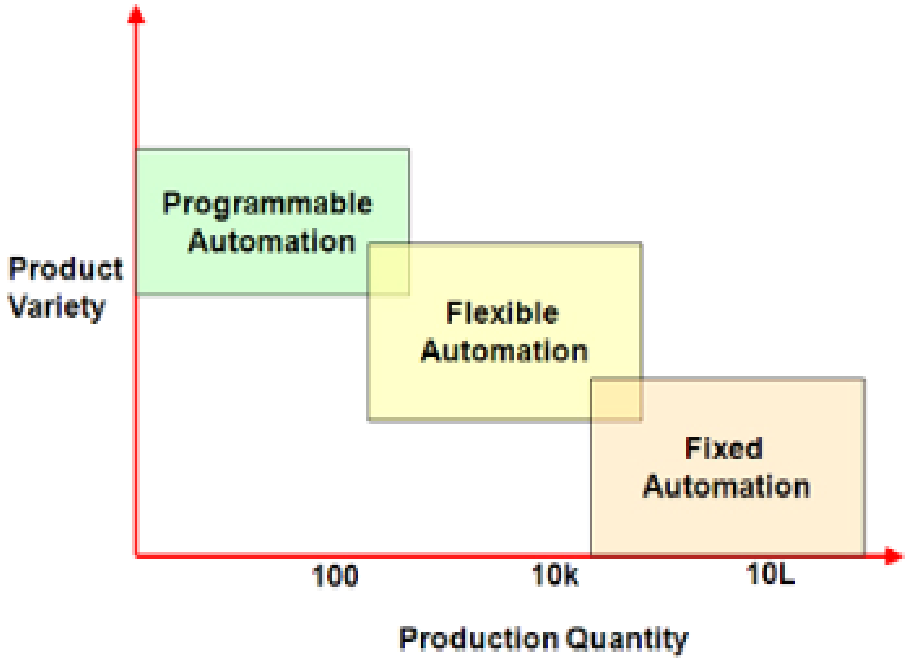
- **If Includes:**

1) Automated machine tools.
2) Automated assembly machines
3) Industrial robots.
4) Automated material handling & storages system
5) Automated inspection system for quality control
6) Feedback control & computer process control
7) Computer integrated system for planning, data collection decision making.

TYPE OF AUTOMATION

- Automated production systems are classified into three basic types:

  1) Fixed Automation
  2) Programmable Automation
  3) Flexible Automation



FIXED AUTOMATION

- ✓ Fixed automation is a system in which the sequence of processing (or assembly) operations is fixed by the equipment configuration.
- ✓ The operations in the sequence are usually simple.
- ✓ It is the integration and coordination of many such operations into one piece of equipment that makes the system complex.
- ✓ The typical features of fixed automation are:
  - High initial investment for custom-engineered equipment
  - High production rates
  - Relatively inflexible in accommodating product changes

PROGRAMMABLE AUTOMATION

- ✓ In programmable automation, the production equipment is designed with the capability to change the sequence of operations to accommodate different product configurations.
- ✓ The operation sequence is controlled by a program, which is a set of instructions coded so that the system can read and interpret them.
- ✓ New programs can be prepared and entered into the equipment to produce new products.
- ✓ The typical features of programmable automation are:
  - High investment in general-purpose equipment
  - Low production rates relative to fixed automation
  - Flexibility to deal with changes in product configuration
  - Most suitable for batch production

FLEXIBLE AUTOMATION

- ✓ The concept of flexible automation has developed only over the last 15 to 20 years, and the principles are still evolving.
- ✓ A flexible automated system is one that is capable of producing a variety of products (or parts) with virtually no time lost for changeovers from one product to the next.
- ✓ There is no production time lost while reprogramming the system and altering the physical setup (tooling, fixtures and machine settings).
- ✓ Consequently, the system can produce various combinations and schedules of products, instead of requiring that they be made in separate batches.
- ✓ The features of flexible automation can be summarized as follows:
  - High investment for a custom-engineered system
  - Continuous production of variable mixtures of products
  - Medium production rates
  - Flexibility to deal with product design variations

REASONS FOR AUTOMATION

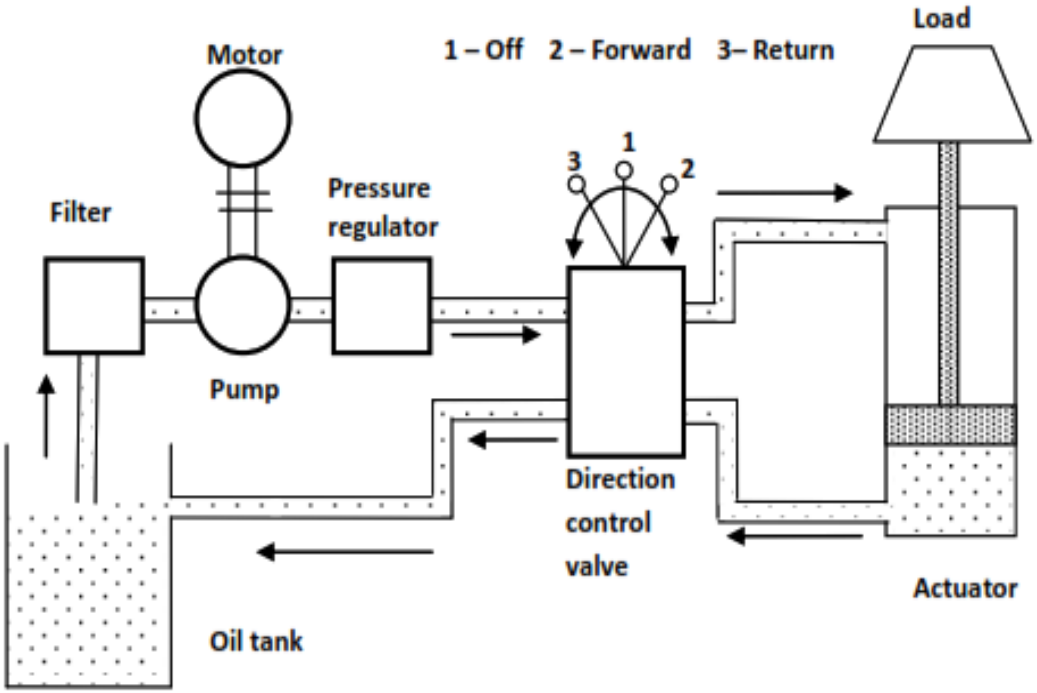
- ✓ Increased productivity due competition
- ✓ High cost of Labour
- ✓ Labour shortage
- ✓ Trend of Labour toward the sector
- ✓ Safety
- ✓ High cost of raw materials
- ✓ Improved Product Quality
- ✓ Reduced manufacturing Lead time
- ✓ Reduction of in process inventory
- ✓ High cost of not automation

AUTOMATION STRATEGIES

- ✓ Specialization of operations
- ✓ Combined operations
- ✓ Simultaneous operations
- ✓ Integration of operations
- ✓ Increased flexibility
- ✓ Improved material handling and storage
- ✓ On- line inspection
- ✓ Process control & optimization
- ✓ Plan operations control
- ✓ Computer-integrated manufacturing (CIM)

HYDRAULIC SYSTEM

- ✓ Hydraulic systems are power-transmitting assemblies employing pressurized liquid as a fluid for transmitting energy from an energy-generating source to an energy-using point to accomplish useful work

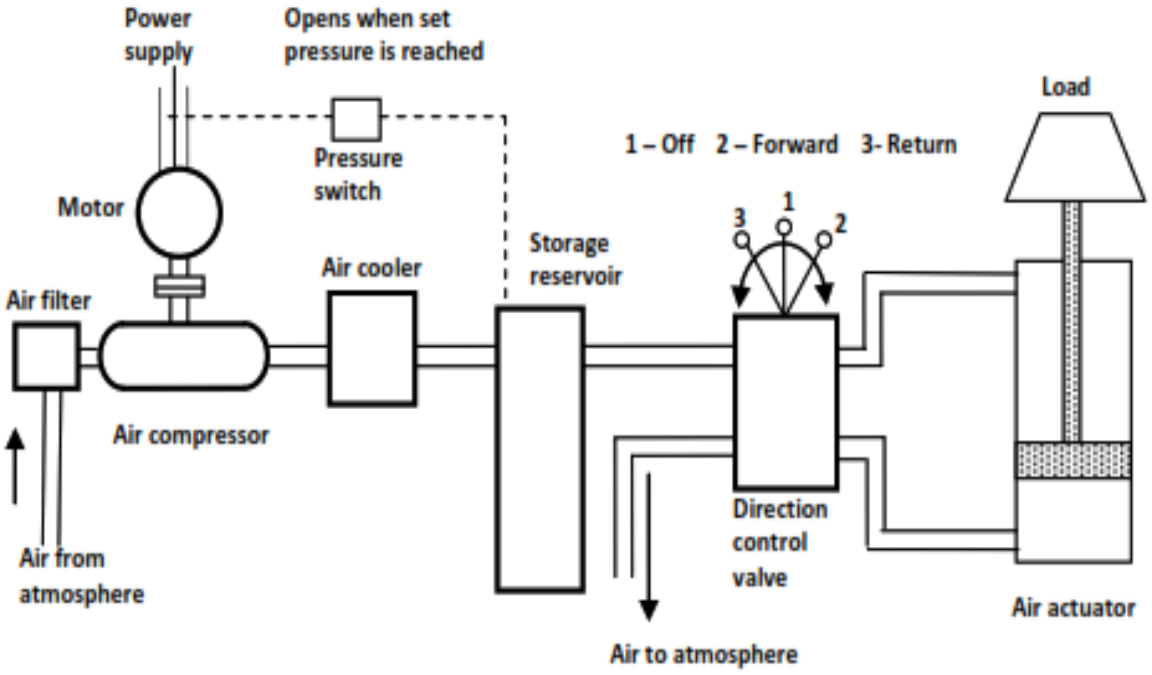


BASIC COMPONENTS OF A HYDRAULIC SYSTEM

- ✓ Hydraulic actuator
- ✓ Hydraulic pump
- ✓ Valves
- ✓ External power supply (Motor)
- ✓ Reservoir
- ✓ Piping system
- ✓ Filters
- ✓ Pressure regulator regulates

PNEUMATIC SYSTEM

- ✓ A pneumatic system carries power by employing compressed gas, generally air, as a fluid for transmitting energy from an energy-generating source to an energy-using point to accomplish useful work



BASIC COMPONENTS OF A PNEUMATIC SYSTEM

- ✓ Pneumatic actuator
- ✓ Compressor
- ✓ Storage reservoir
- ✓ Valves
- ✓ External power supply (motor)
- ✓ Piping system

COMPARISON BETWEEN HYDRAULIC AND PNEUMATIC SYSTEMS

S. No.	Hydraulic System	Pneumatic System
1	It employs a pressurized liquid as a fluid	It employs a compressed gas, usually air, as a fluid
2	An oil hydraulic system operates at pressures up to 700 bar	A pneumatic system usually operates at 5–10 bar
3	Generally designed as closed system	Usually designed as open system
4	The system slows down when leakage occurs	Leakage does not affect the system much
5	Valve operations are difficult	Valve operations are easy
6	Heavier in weight	Lighter in weight
7	Pumps are used to provide pressurized liquids	Compressors are used to provide compressed gases
8	The system is unsafe to fire hazards	The system is free from fire hazards
9	Automatic lubrication is provided	Special arrangements for lubrication are needed

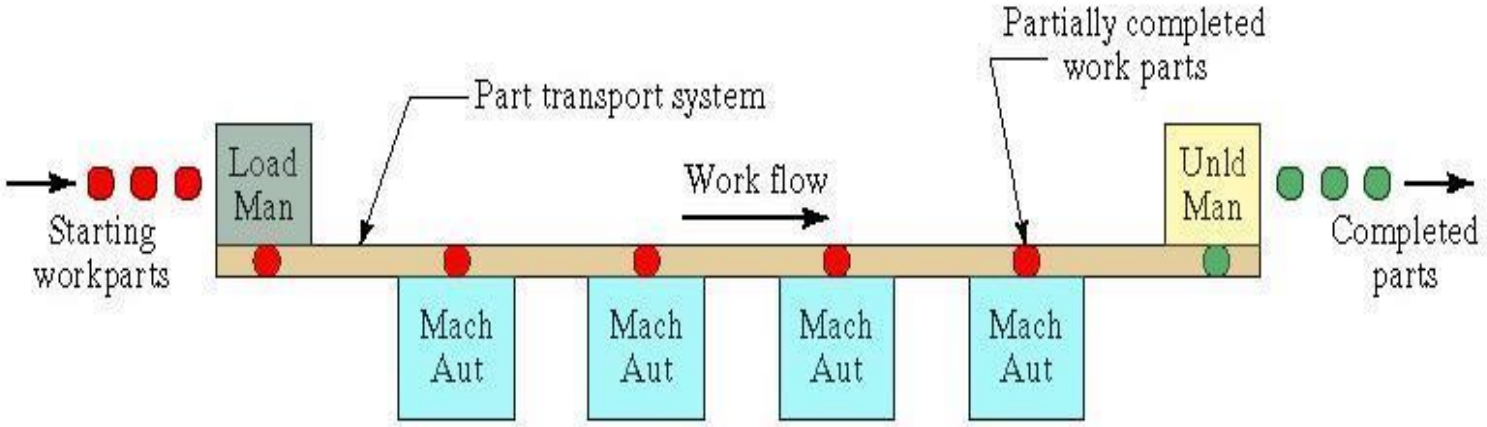
AUTOMATED FLOW LINES

It consists of several machines or workstations which are linked together by work handling devices that transfer parts between the stations. The transfer of work parts occurs automatically and the workstations carry out their specialized functions automatically.

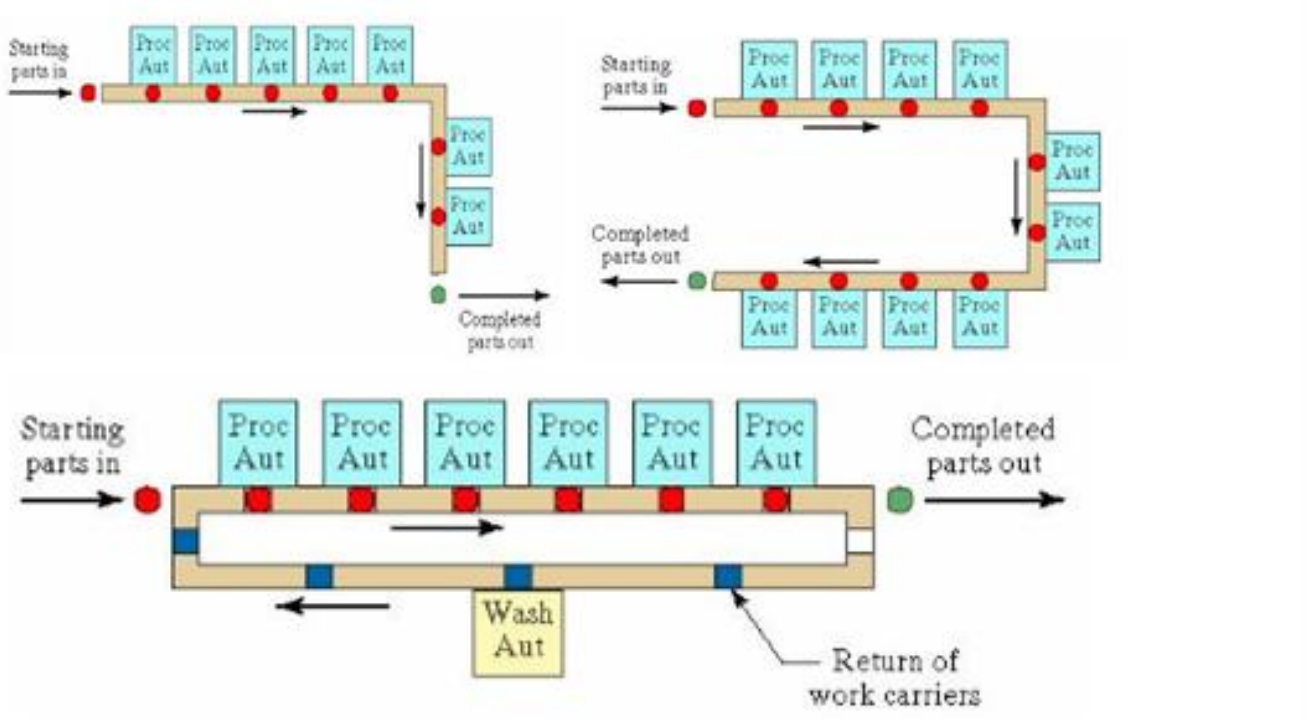
- The objectives of the use of flow line automation are, therefore:
  - ✓ To reduce labor costs
  - ✓ To increase production rates
  - ✓ To reduce work-in-process
  - ✓ To minimize distances moved between operations
  - ✓ To achieve specialization of operations
  - ✓ To achieve integration of operations

TYPES OF FLOW LINES

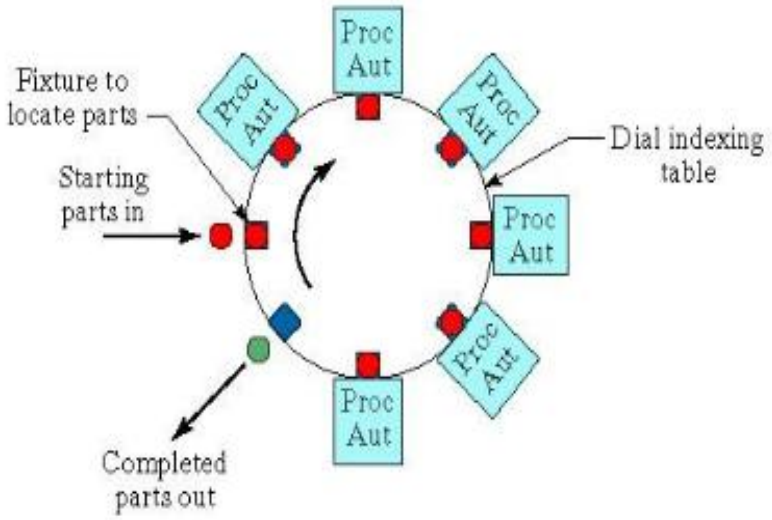
- **In-line type:** The in-line configuration consists of a sequence of workstations in a more or less straight-line arrangement as shown in below Figure. An example of an in-line transfer machine used for metal cutting operations.



- **Segmented in-line Type :** The segmented in-line configuration consists of two or more straight line arrangement which are usually perpendicular to each other with L shaped or U shaped or rectangular shaped as shown in below Figure. The flow of work can take a few 90°turns, either for workpiece reorientation, factory layout limitations, or other reasons, and still qualify as a straight-line configuration.



- **Rotary type:** In the rotary configuration, the work parts are indexed around a circular table or dial. The workstations are stationary and usually located around the outside periphery of the dial. The parts ride on the rotating table and arc registered or positioned, in turn, at each station for its processing or assembly operation. This type of equipment is often referred to as an indexing machine or dial index machine and the configuration is shown in below



METHODS OF WORK PART TRANSPORT

The transfer mechanism of the automated flow line must not only move the partially completed work parts or assemblies between adjacent stations, it must also orient and locate the parts in the correct position for processing at each station. The general methods of transporting workpieces on flow lines can be classified into the following three categories:

- Continuous transfer
- Intermittent or synchronous transfer
- Asynchronous or power-and-free transfer

TRANSFER MECHANISMS

There are various types of transfer mechanisms used to move parts between stations. These mechanisms can be grouped into two types:

1) Linear transfer mechanisms
2) Rotary transfer mechanisms

1. Linear transfer mechanisms

The commonly used linear transfer mechanisms are

a) Walking beam transfer bar system,

b) Powered roller conveyor system, and

c) Chain-drive conveyor system.

2. Rotary transfer mechanisms

There are several methods used to index a circular table or dial at various equal angular positions corresponding to workstation locations.

a) Rack and pinion

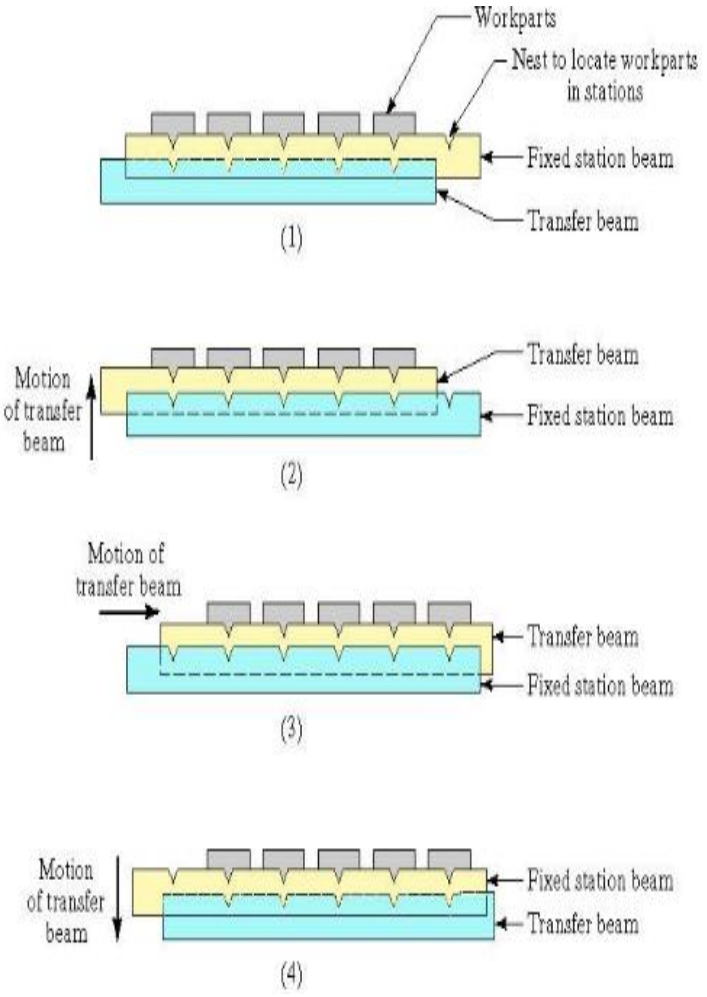
b) Ratchet and pawl

c) Geneva mechanism

d) CAM Mechanisms

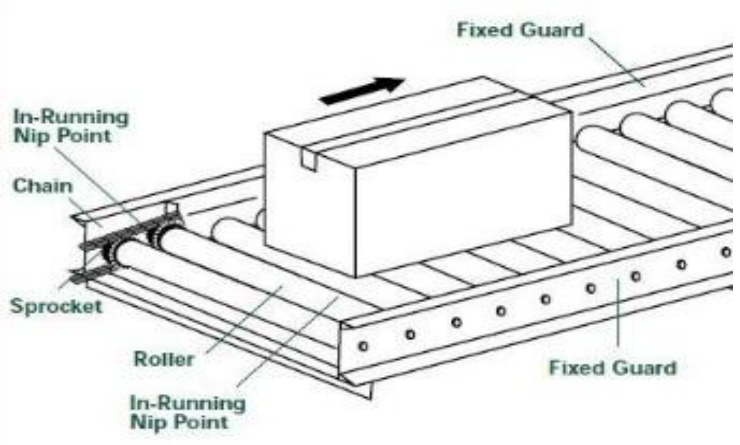
WALKING BEAM SYSTEMS

Walking beam transfer mechanism, the work-parts are lifted up from their workstation locations by a transfer bar and moved one position ahead, to the next station. The transfer bar then lowers the pans into nests which position them more accurately for processing. For speed and accuracy, the motion of the beam is most often generated by a rotating camshaft powered by an electric motor or a roller movement in a profile powered by hydraulic cylinder.



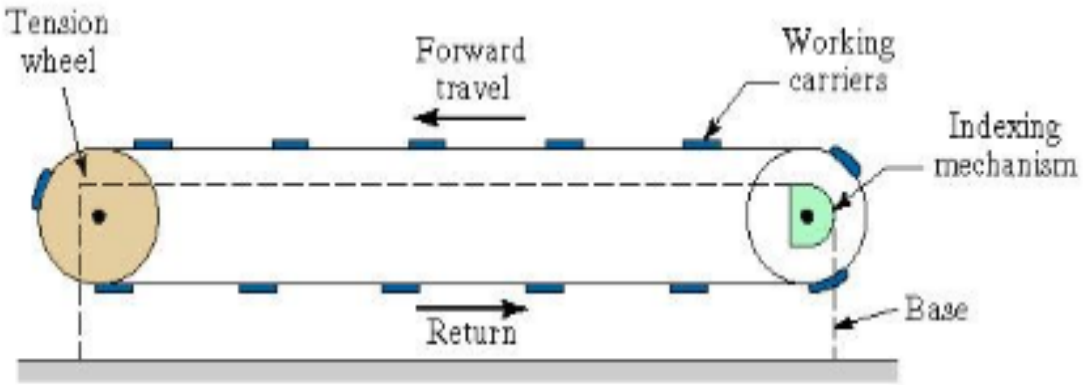
POWERED ROLLER CONVEYOR SYSTEM

The conveyor can be used to move pans or pallets possessing flat riding surfaces. The rollers can be powered by either of two mechanisms. The first is a belt drive, in which a flat moving belt beneath the rollers provides the rotation of the rollers by friction. A chain drive is the second common mechanism used to power the rollers. Powered roller conveyors are versatile transfer systems because they can be used to divert work pallets into workstations or alternate tracks.



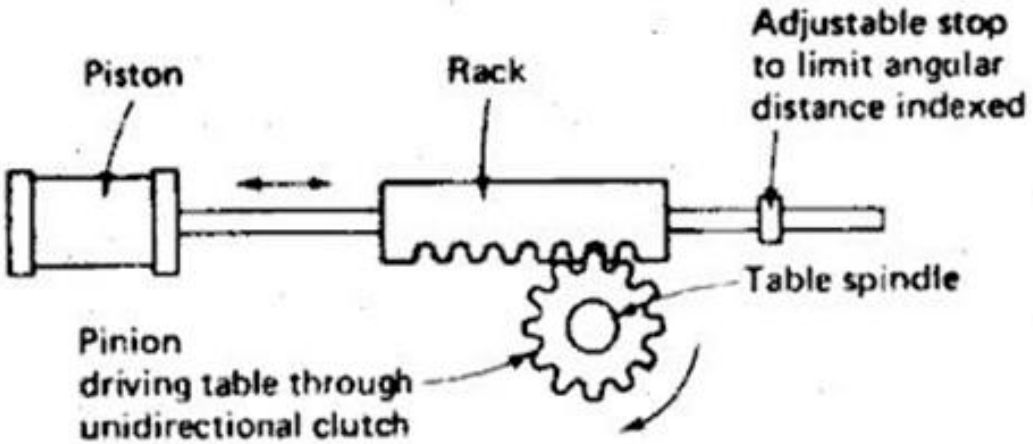
CHAIN-DRIVE CONVEYOR SYSTEM

In chain-drive conveyor system either a chain or a flexible steel belt is used to transport the work carriers. The chain is driven by pulleys in either an "over-and under" configuration, in which the pulleys turn about a horizontal axis, or an "around-the-corner" configuration, in which the pulleys rotate about a vertical axis.



RACK AND PINION

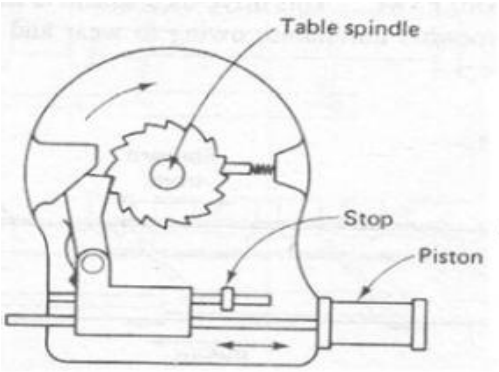
This mechanism is simple but is not considered especially suited to the high-speed operation often associated with indexing machines. The device is pictured in the below Figure and uses a piston to drive the rack, which causes the pinion gear and attached indexing table to rotate, A clutch or other device is used to provide rotation in the desired direction.

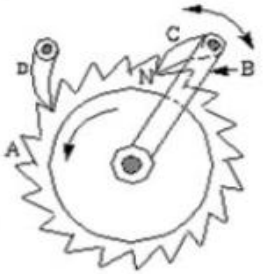


Rack-and-pinion mechanism for rotary indexing table.

RATCHET AND PAWL

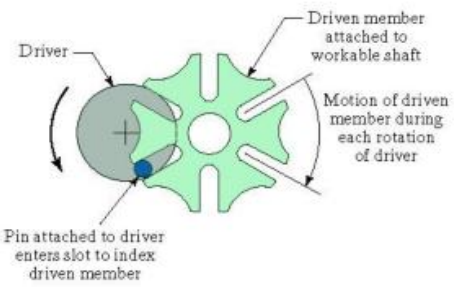
- A ratchet is a device that allows linear or rotary motion in only one direction, while preventing motion in the opposite direction. Ratchets consist of a gearwheel and a pivoting spring-loaded finger called a pawl that engages the teeth. Either the teeth, or the pawl, are slanted at an angle, so that when the teeth are moving in one direction, the pawl slides up and over each tooth in turn, with the spring forcing it back with a 'click' into the depression before the next tooth. When the teeth are moving in the other direction, the angle of the pawl causes it to catch against a tooth and stop further motion in that direction.

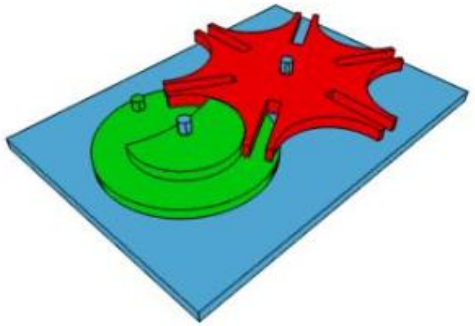




GENEVA MECHANISM

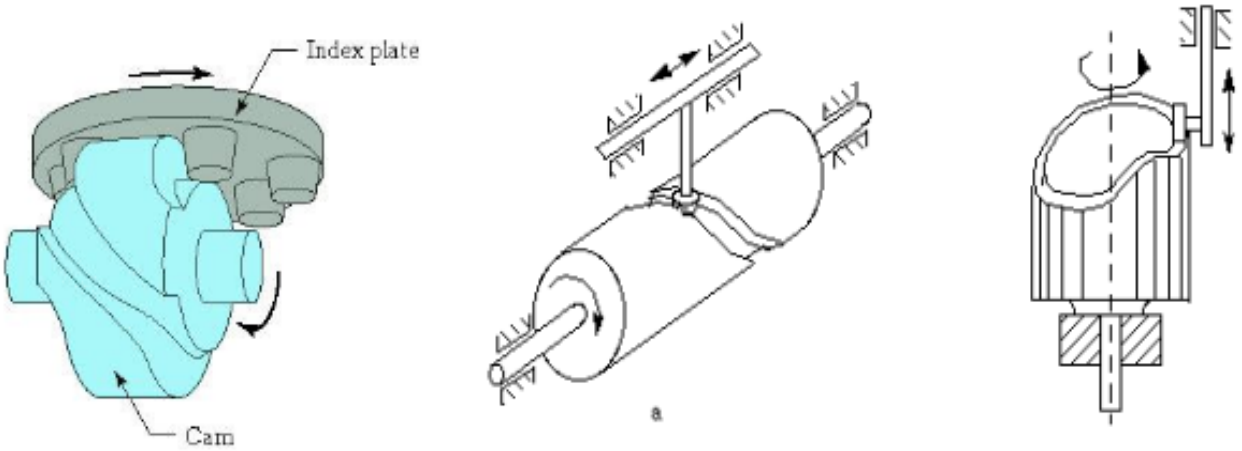
The Geneva mechanism uses a continuously rotating driver to index the table, as pictured below. If the driven member has six slots for a six-station dial indexing machine, each turn of the driver will cause the table to advance one-sixth of a turn. The driver only causes movement of the table through a portion of its rotation. For a six-slotted driven member, 120° of a complete rotation of the driver is used to index the table. The other 240° is dwell. For a four slotted driven member, the ratio would be 90° for index and 270° for dwell. The usual number of indexing per revolution of the table is four, five, six, and eight.





CAM MECHANISMS

Various forms of cam mechanism, an example of which is illustrated in the below Figure, provide probably the most accurate and reliable method of indexing the dial. They are in widespread use in industry despite the fact that the cost is relatively high compared to alternative mechanisms. The cam can be designed to give a variety of velocity and dwell characteristics.



CONTROL FUNCTIONS

Controlling an automated flow line is a complex problem, owing to the sheer number of sequential steps that must be carried out. There are three main functions that are utilized to control the operation of an automatic transfer system.

- The first of these is an operational requirement
- The second is a safety requirement, and
- The third is dedicated to improving quality.

TOPICS TO BE COVERED

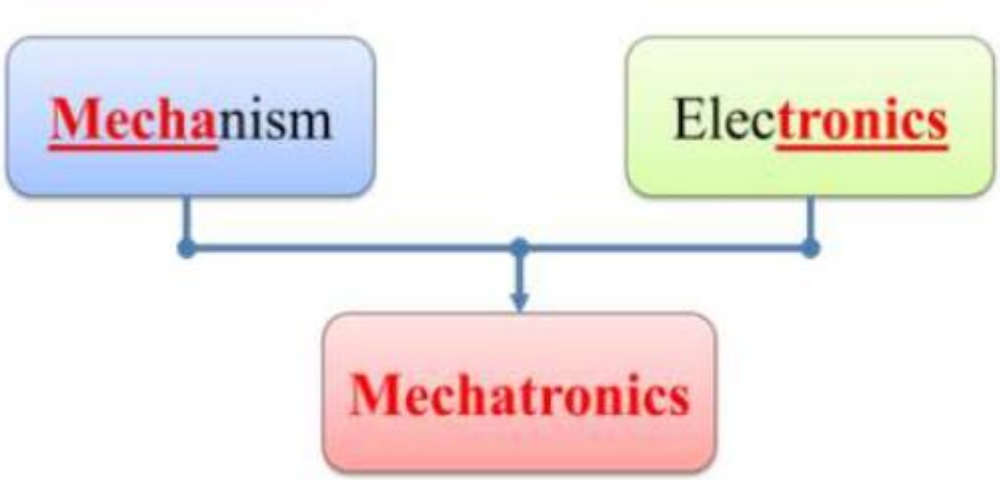
- Definition of Mechatronics
- Role of various engineering disciplines in Mechatronics
- Mechatronics design elements
- Scope of Mechatronics
- Applications of Mechatronics

LECTURE 2

Introduction - Mechatronics

INTRODUCTION

- Mechatronics is a concept of Japanese origin (1970's).
- The term Mechatronics coined by "Tetsuro Mori".
- Defined as the application of electronics and computer technology to control the motions of mechanical systems.



INTRODUCTION

- It is a multidisciplinary approach to product and manufacturing system design.
- It involves application of electrical, mechanical, control and computer engineering to develop products, processes and systems with greater flexibility, ease in redesign and ability of reprogramming.

EVALUATION OF MECHATRONICS:

The technology has evolved through several stages that are termed as levels.

The evolution levels of Mechatronics are:

A. Primary level Mechatronics (first)

B. Secondary level Mechatronics (second)

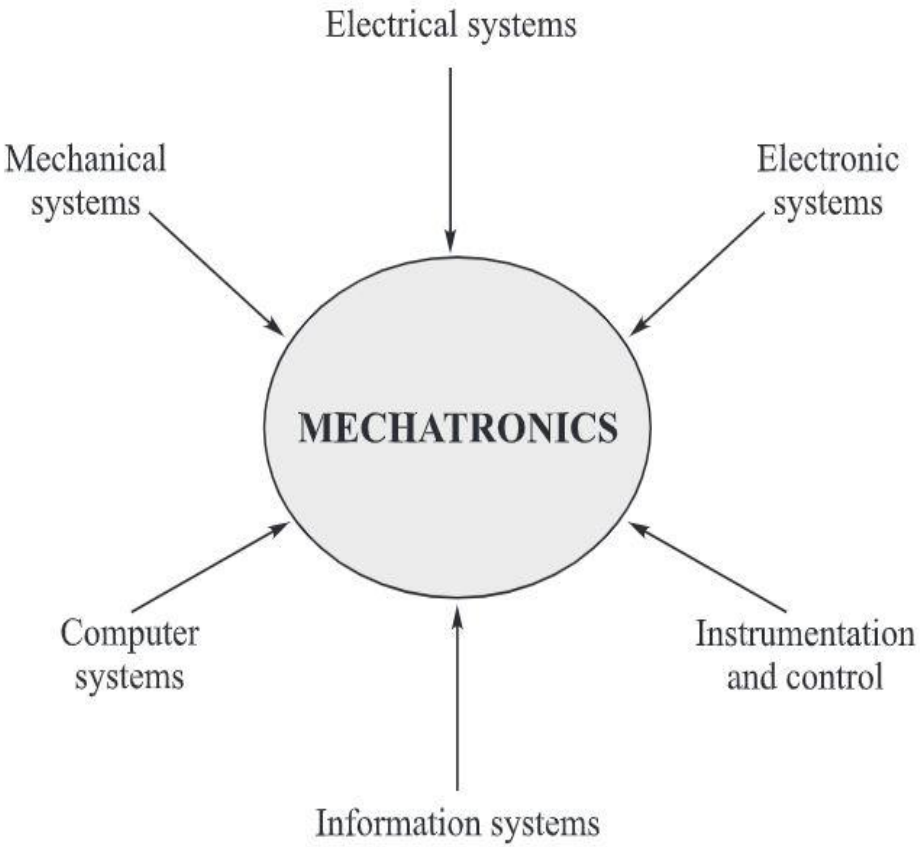
C. Tertiary level Mechatronics (third)

D. Quaternary level Mechatronics (fourth)

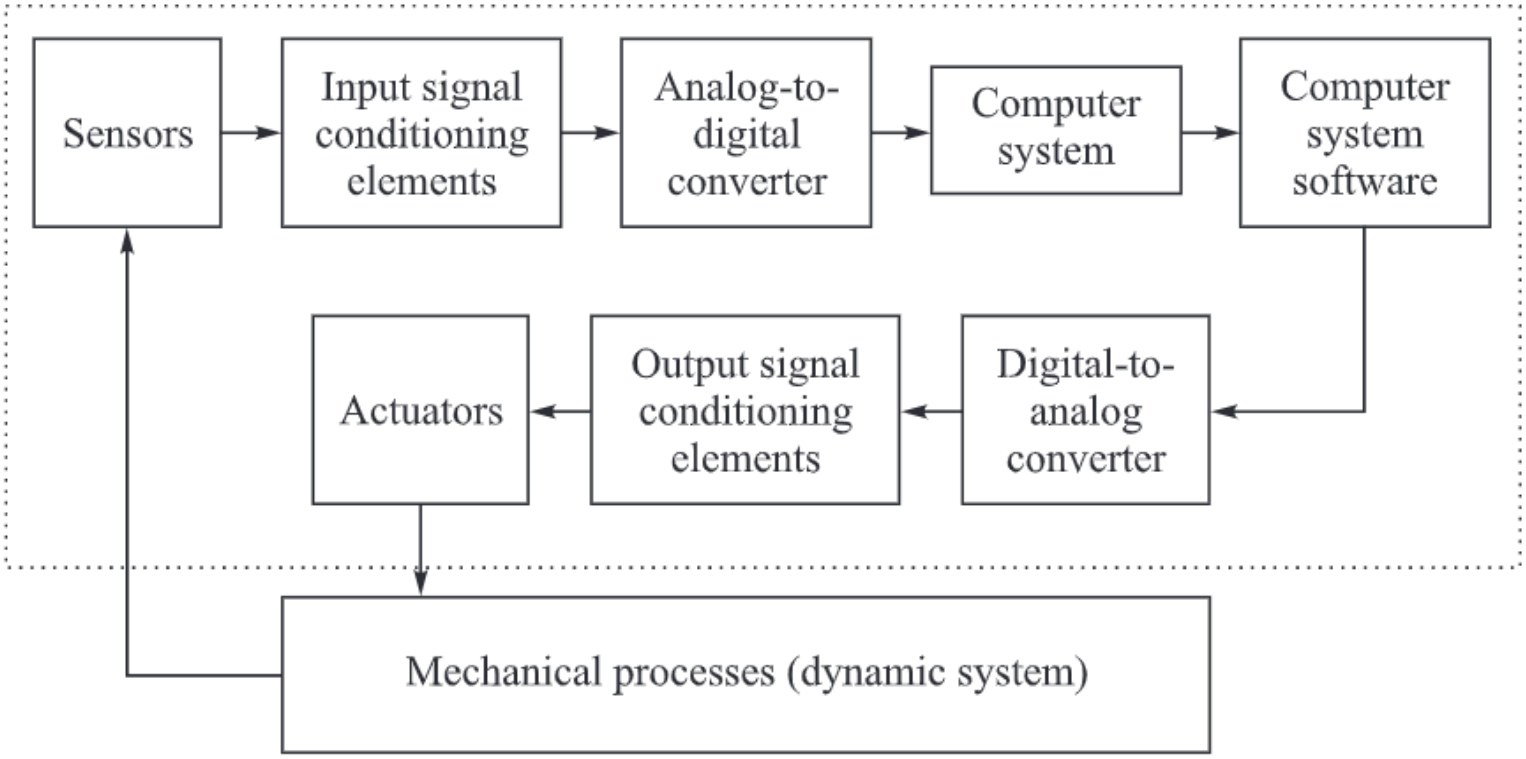
Evolution

First Level	Incorporates I/O devices like sensors and actuators, integrates electrical signals with mechanical action. E.g. Fluid valves and relays
Second Level	Integrates microelectronics into electrically controlled devices. E.g.: Cassette player
Third Level	Incorporates advanced feed back functions. "Smart Systems" E.g. Hard disk, CD drives, automatic washing machines
Fourth Level	Intelligent control in mechatronic system E.g. Fault Detection and Isolation (FDI) capability systems.

ROLE OF VARIOUS ENGINEERING DISCIPLINES IN MECHATRONICS



MECHATRONIC DESIGN ELEMENTS



SCOPE OF MECHATRONICS

Mechatronics plays a vital role in industrial sector. The scope of mechatronic in industrial sector is discussed as follows:

- ***Better design of products***
- ***Better process planning***
- ***Reliable and quality-oriented manufacturing***..
- ***Intelligent process control.***.
  - *Passive applications*
  - *Active applications*

GENERAL PARAMETERS FOR DESIGNING AN INTELLIGENT MECHATRONIC SYSTEM ARE AS FOLLOWS:

- ✓ Analyze product design and development specifications
- ✓ Select process variables, set points, processes, etc.
- ✓ Design proper analog and digital circuits
- ✓ Select mechanical components and devices
- ✓ Design proper mechanical system like hydraulic, pneumatic, etc.
- ✓ Select sensors, actuators and control components
- ✓ Design accurate and precise control system for various process variables
- ✓ Develop computer-based system (real time interfacing)
- ✓ Develop necessary computer software and database
- ✓ Integrate the above-stated parameters effectively
- ✓ Monitor the performance of designed system

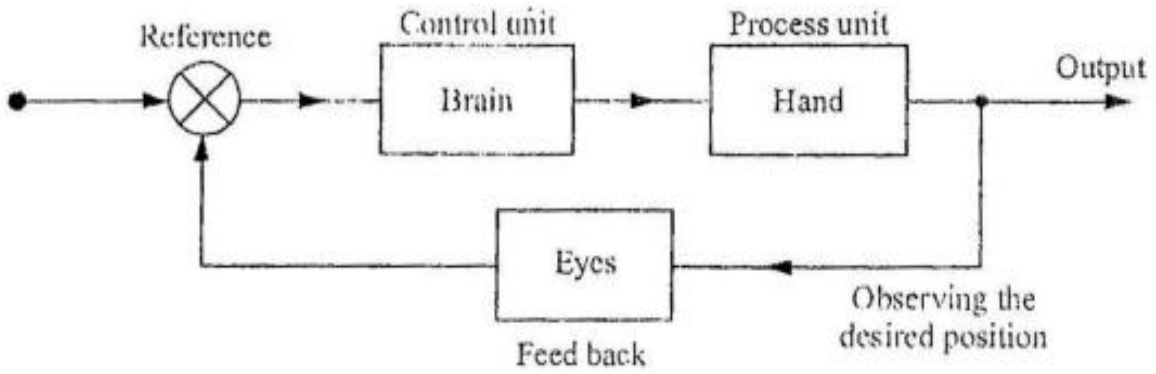
ADVANTAGES & DISADVANTAGES

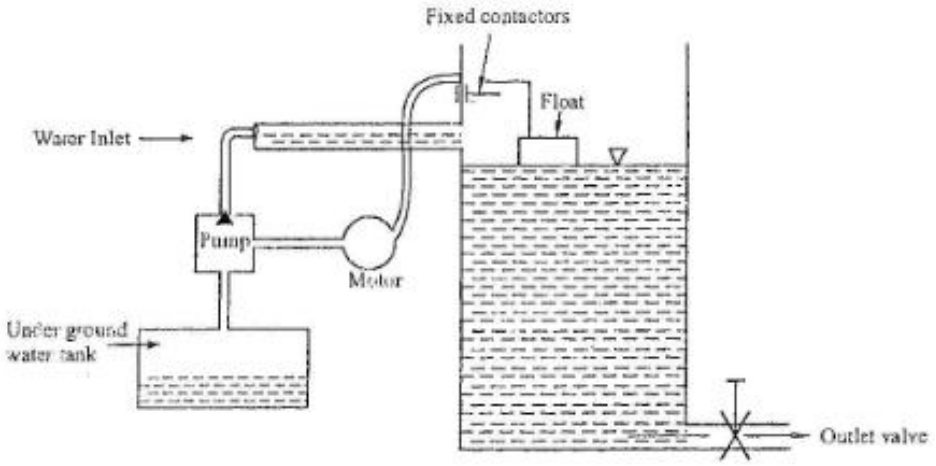
Advantages	Disadvantages
Cost effective and reliable product	High initial cost of the system.
High degree of flexibility and productivity	Imperative to have knowledge of different engineering fields for design and implementation.
Greater extent of machine utilisation.	Specific problems for various systems will have to be addressed separately and properly.
Reduction in the capital expense due to integration of complex systems.	Expensive to incorporate mechatronics approach to an existing/old system

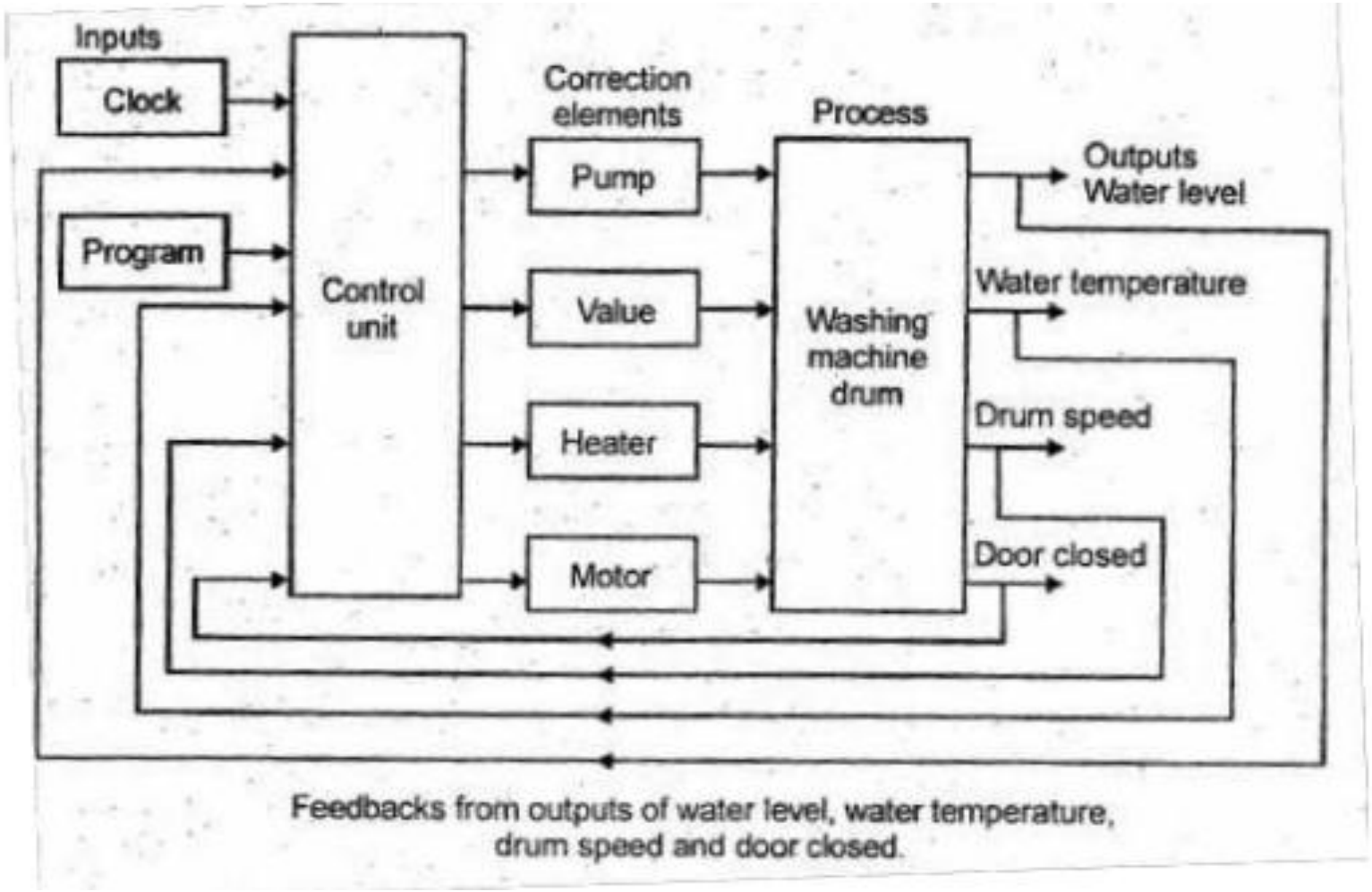
CHARACTERISTICS OF MECHATRONIC SYSTEM:

1. High quality product.
2. Safe.
3. Low cost.
4. Portable produced quickly
5. Serviceability, maintainability and upgradeability.

REAL TIME APPLICATIONS






Inputs
Clock
Program
Control unit
Correction elements
Pump
Value
Heater
Motor
Process
Washing machine drum
Outputs
Water level
Water temperature
Drum speed
Door closed
Feedbacks from outputs of water level, water temperature, drum speed and door closed.

THANK YOU

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UNIT - 2	**CO2: To make students familiar with the constructions and working principle of different types of sensors and transducers.**
UNIT - 3	CO3: Understand the fundamental concepts of electro mechanics and fluid mechanics (hydraulics and pneumatics) of Actuators and drive systems.
UNIT - 4	CO4: To impart knowledge on the control elements
UNIT - 5	CO5: To understand the different control schemes generally used to get best output.

UNIT 2

SENSORS AND TRANSDUCERS

CO2: To make students familiar with the constructions and working principle of different types of sensors and transducers.

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UNIT – II (SYLLABUS)

INTRODUCTION TO SENSORS AND TRANSDUCERS

- Performance terminology,
- Displacement Sensors,
- Position and Proximity Sensors
- Velocity and Motion Sensors
- Force and Fluid pressure Sensors
- Liquid flow and Liquid level Sensors
- Temperature and light sensors
- Selection of sensors.

COURSE OUTLINE

UNIT -2

LECTURE	LECTURE TOPIC	KEY ELEMENTS	LEARNING OBJECTIVES
1	Introduction to Sensors and transducers, performance terminology	Definition of Sensors and transducers	Understanding of basics of Sensors and transducers (B2)
2	Displacement sensors	Working principle of Displacement sensors	Understand the applications of sensors in various systems and to know the functions of each element(B2)
3	Position and proximity sensors	Working principle of Position and proximity sensors	
4	Velocity and motion sensors	Working principle of Velocity and motion sensors	
5	Force, fluid pressure sensors	Working principle of Force, fluid pressure sensors	
6	Liquid flow, liquid level sensors	Working principle of Liquid flow, liquid level sensors	
7	Temperature, light sensors, selection of sensors.	Working principle of Temperature, light sensors, selection of sensors.	

LECTURE 1

INTRODUCTION TO SENSORS AND TRANSDUCERS

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TOPICS TO BE COVERED

- Introduction - Sensors And Transducers
- Performance terminology,
- Displacement Sensors,
- Position and Proximity Sensors
- Velocity and Motion Sensors
- Force and Fluid pressure Sensors
- Liquid flow and Liquid level Sensors
- Temperature and light sensors
- Selection of sensors.

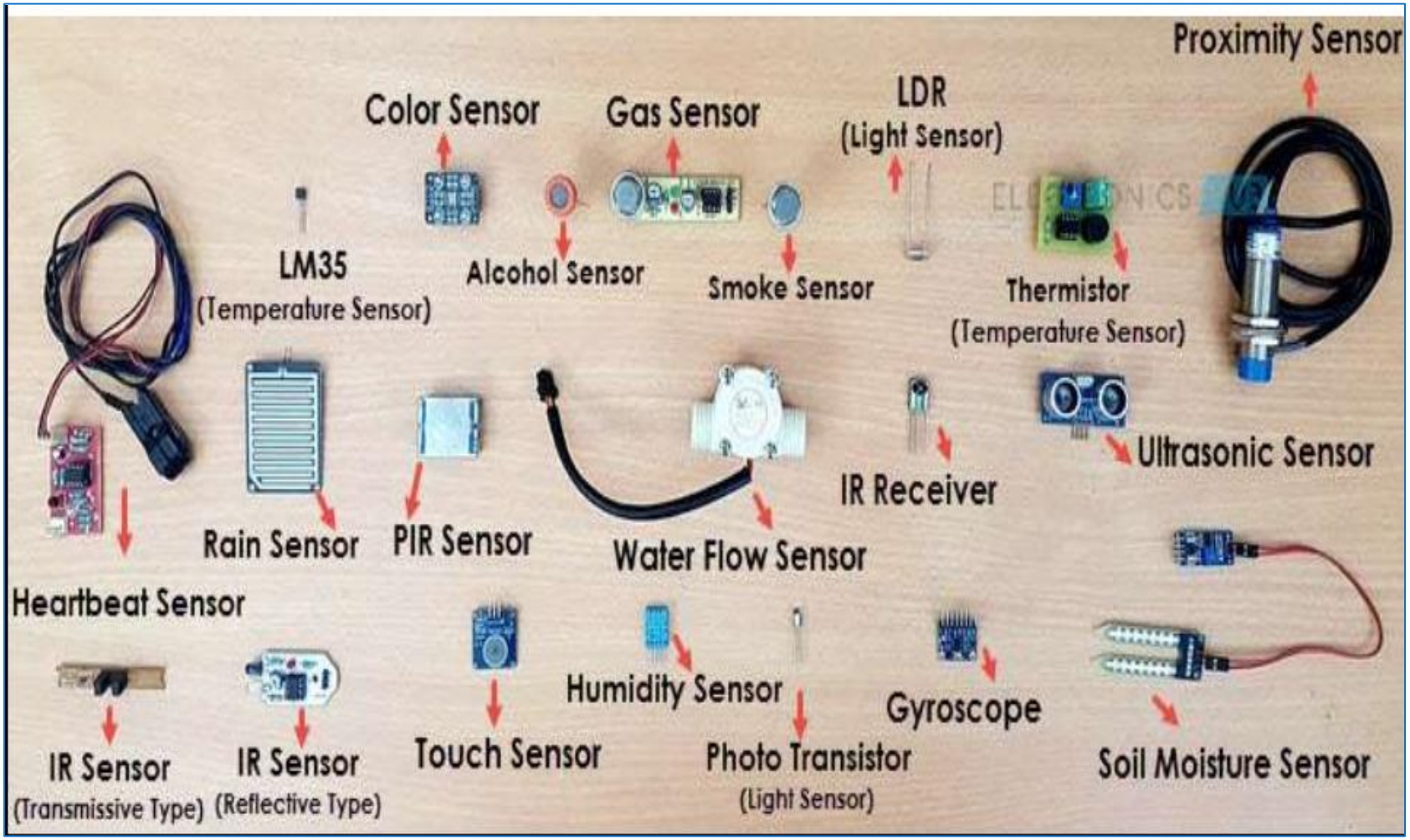
LECTURE 1

Introduction - Sensors And Transducers

SENSORS

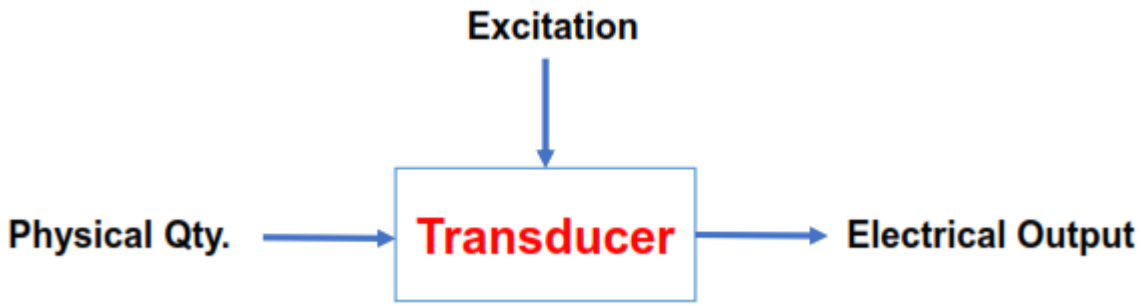
- Sensor is an element which produces a signal relating to the quantity being measured.
- An input device which provides an output (signal) with respect to a specific physical quantity.
- A device that converts signals from one energy domain to electrical domain.

SENSORS


Proximity Sensor
Color Sensor
Gas Sensor
LDR
(Light Sensor)
LM35
(Temperature Sensor)
Alcohol Sensor
Smoke Sensor
Thermistor
(Temperature Sensor)
Ultrasonic Sensor
IR Receiver
Rain Sensor
PIR Sensor
Water Flow Sensor
Heartbeat Sensor
Humidity Sensor
Gyroscope
Touch Sensor
Photo Transistor
(Light Sensor)
Soil Moisture Sensor
IR Sensor
(Transmissive Type)
IR Sensor
(Reflective Type)

TRANSDUCER

- A device that converts variations in a physical quantity, such as pressure or brightness, into an electrical signal, or vice versa.
- A transducer is an electronic device that converts energy from one form to another.
- E.g. microphones, loudspeakers, thermometers, position and pressure sensors, and antenna



SENSORS OR TRANSDUCERS ARE USED IN MECHATRONICS FOR THE FOLLOWING PURPOSES:

- To provide position, velocity, and acceleration information of the measuring element in a system which provides feedback information
- To act as protective mechanism for a system
- To help eliminate mechanically complex and expensive feeding and sorting devices
- To provide identification and indication of the presence of different components
- To provide real time information concerning the nature of the task being performed

PERFORMANCE TERMINOLOGY

- Transducers or measurement systems are not perfect systems. Mechatronics design engineer must know the capability and shortcoming of a transducer or measurement system to properly assess its performance. There are a number of performance related parameters of a transducer or measurement system. These parameters are called as sensor specifications.
- Sensor specifications inform the user to the about deviations from the ideal behaviour of the sensors.

PERFORMANCE TERMINOLOGY

- Static Characteristics
  - Range and Span
  - Error
  - Accuracy
  - Sensitivity
  - Hysteresis error
  - Repeatability
  - Reliability
  - Stability
  - Drift
  - Dead band
  - Dead time
  - Resolution
  - Backlash
- Dynamic Characteristics
  - Response Time
  - Time Constant
  - Rise Time
  - Settling Time

CLASSIFICATION OF SENSOR /TRANSDUCER

Sensors are classified in the following ways.

- **According to the power supply**
  - Active type
  - Passive type
- **According to the mode of operation**
  - Null type
  - Deflection type
- **According to the signal characteristics (or) output**
  - Analog
  - Coded type
  - Digital type
  - Frequency type

CLASSIFICATION OF SENSOR /TRANSDUCER

According to the measurement (or) Function

- Displacement
- Velocity
- Acceleration
- Dimensional
- Mass
- Force
- Proximity
- Pressure
- Fluid Flow
- Liquid level
- Temperature

According to the performance characteristics

- Accuracy
- Repeatability
- Linearity
- Sensitivity
- Range

LECTURE 2

DISPLACEMENT SENSORS

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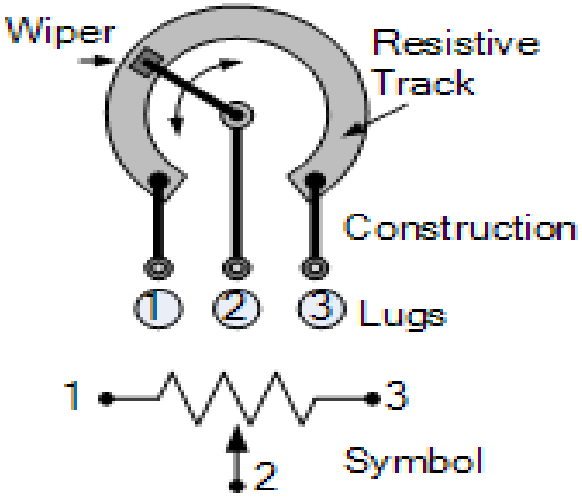
DISPLACEMENT SENSORS

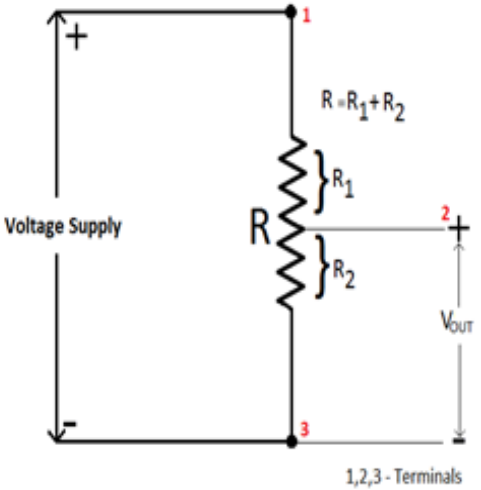
The following are examples of commonly used displacement sensors.

1. Potentiometer
2. Strain gauge
3. Capacitive sensors
4. Linear variable differential transformer

POTENTIOMETER

Linear or Rotary potentiometer is a variable resistance displacement transducer which uses the variable resistance transduction principle in which the displacement or rotation is converted into a potential difference due to the movement of sliding contact over a resistive element.





$$V_{out} = \{R2/ (R1+R2)\} \times V;$$

ADVANTAGES AND DISADVANTAGES

Advantages

- Less expensive
- Different sizes and shapes of potentiometers in different ranges are easily available
- High output
- A.C Excitation
- Rugged Construction
- Less sensitive towards vibration and temperature
- High electrical efficiency
- Operation is simple

Disadvantages

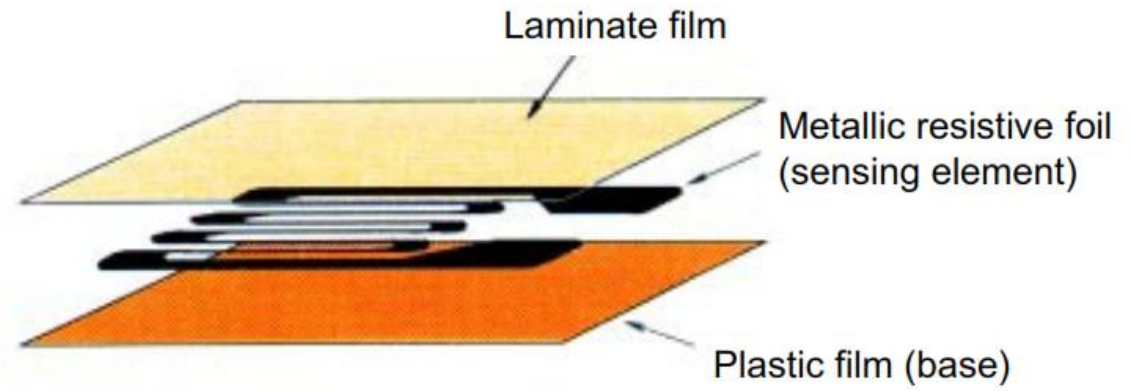
- Slow Dynamic Response
- Low Resolution
- Early wear of the wiper is possible
- Noisy output under high speed operation or high vibrating conditions
- Noise becomes too high when the slide velocity exceeds 3 m/sec

STRAIN GAUGE

Strain gauge: it is an electrical conductor whose resistance changes as it is strained.

Structure of Strain Gauges

- There are many types of strain gauges. Among them, a universal strain gauge has a structure such that a grid-shaped sensing element of thin metallic resistive foil (3 to 6μm thick) is put on a base of thin plastic film (15 to 16μm thick) and is laminated with a thin film.



PRINCIPLE OF STRAIN GAUGES

- The strain gauge is tightly bonded to a measuring object so that the sensing element (metallic resistive foil) may elongate or contract according to the strain borne by the measuring object.
- When bearing mechanical elongation or contraction, most metals undergo a change in electric resistance.
- The strain gage applies this principle to strain measurement through the resistance change. Generally, the sensing element of the strain gage is made of a copper-nickel alloy foil.
- The alloy foil has a rate of resistance change proportional to strain with a certain constant.

Let's express the principle as follows:

$$\frac{\Delta R}{R} = K.\varepsilon$$

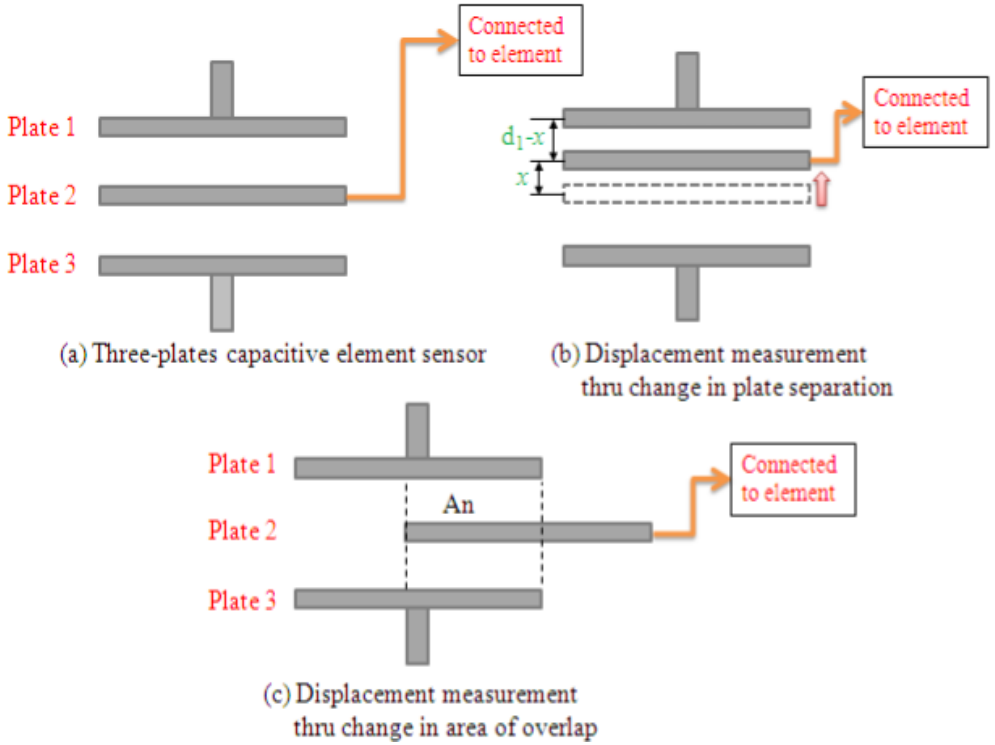
where, R: Original resistance of strain gage, Ω (ohm)
ΔR: Elongation- or contraction-initiated resistance change, Ω (ohm)
K: Proportional constant (called gage factor)
ε: Strain

CAPACITIVE SENSORS

Capacitive sensor is of non-contact type sensor and is primarily used to measure the linear displacements from few millimeters to hundreds of millimeters. It comprises of three plates, with the upper pair forming one capacitor and the lower pair another.

The linear displacement might take in two forms:

- ✓ one of the plates is moved by the displacement so that the plate separation changes
- ✓ area of overlap changes due to the displacement.



The capacitance C of a parallel plate capacitor is given by,

$$C = (\varepsilon_r \varepsilon_o A) / d$$

Where

ε_r is the relative permittivity of the dielectric between the plates,

ε_o permittivity of free space,

A area of overlap between two plates and

d the plate separation.

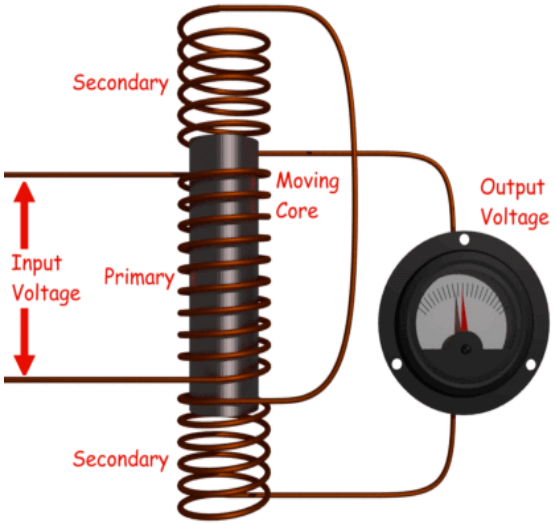
APPLICATIONS

- ✓ Feed hopper level monitoring
- ✓ Small vessel pump control
- ✓ Grease level monitoring
- ✓ Level control of liquids
- ✓ Metrology applications
- ✓ to measure shape errors in the part being produced
- ✓ to analyze and optimize the rotation of spindles in various machine tools such as surface grinders, lathes, milling machines, and air bearing spindles by measuring errors in the machine tools themselves
- ✓ Assembly line testing o to test assembled parts for uniformity, thickness or other design features
- ✓ to detect the presence or absence of a certain component, such as glue etc.

LINEAR VARIABLE DIFFERENTIAL TRANSFORMER

Definition of LVDT

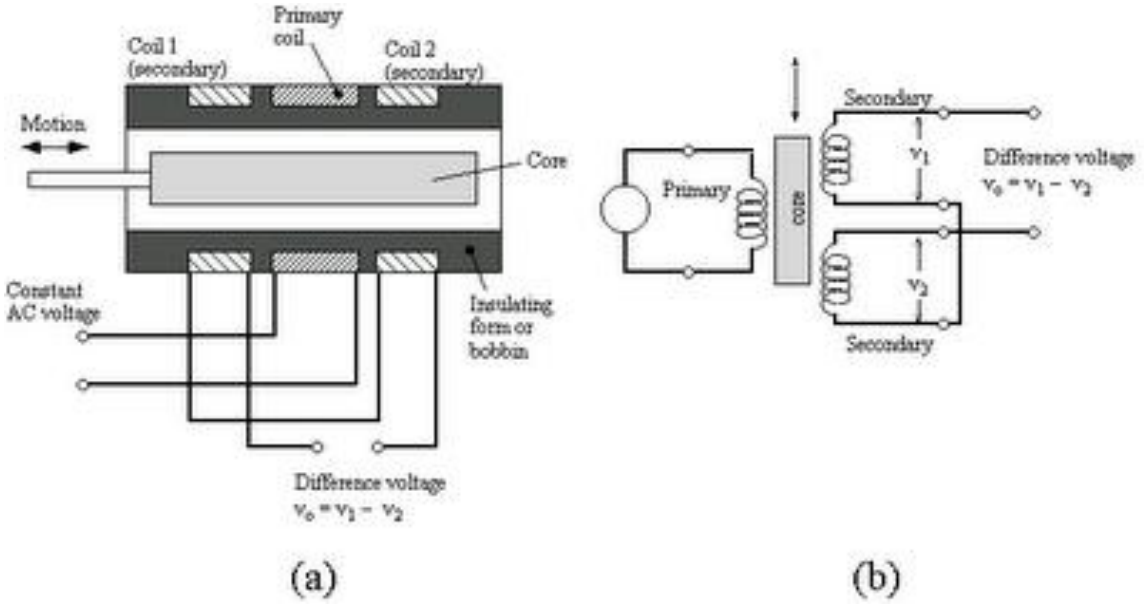
- The term **LVDT** stands for the **Linear Variable Differential Transformer**. It is the most widely used inductive transducer that converts the linear motion into the electrical signal.
- The output across secondary of this transformer is the differential thus it is called so. It is very accurate inductive transducer as compared to other inductive transducers.



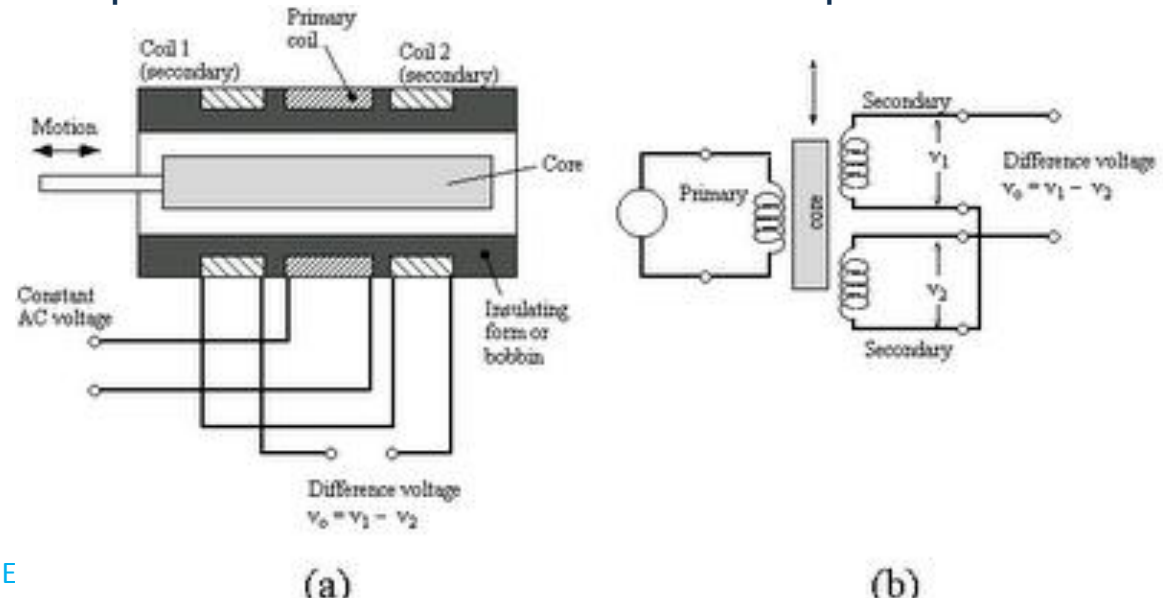
WORKING PRINCIPLE OF LVDT

Now three cases arise according to the locations of core which explains the working of LVDT are discussed below as,

- ✓ **CASE-I**: When the core is at null position (for no displacement) When the core is at null position then the flux linking with both the secondary windings is equal so the induced emf is equal in both the windings. So, for no displacement the value of output e_{out} is zero as e_1 and e_2 both are equal. So, it shows that no displacement took place.

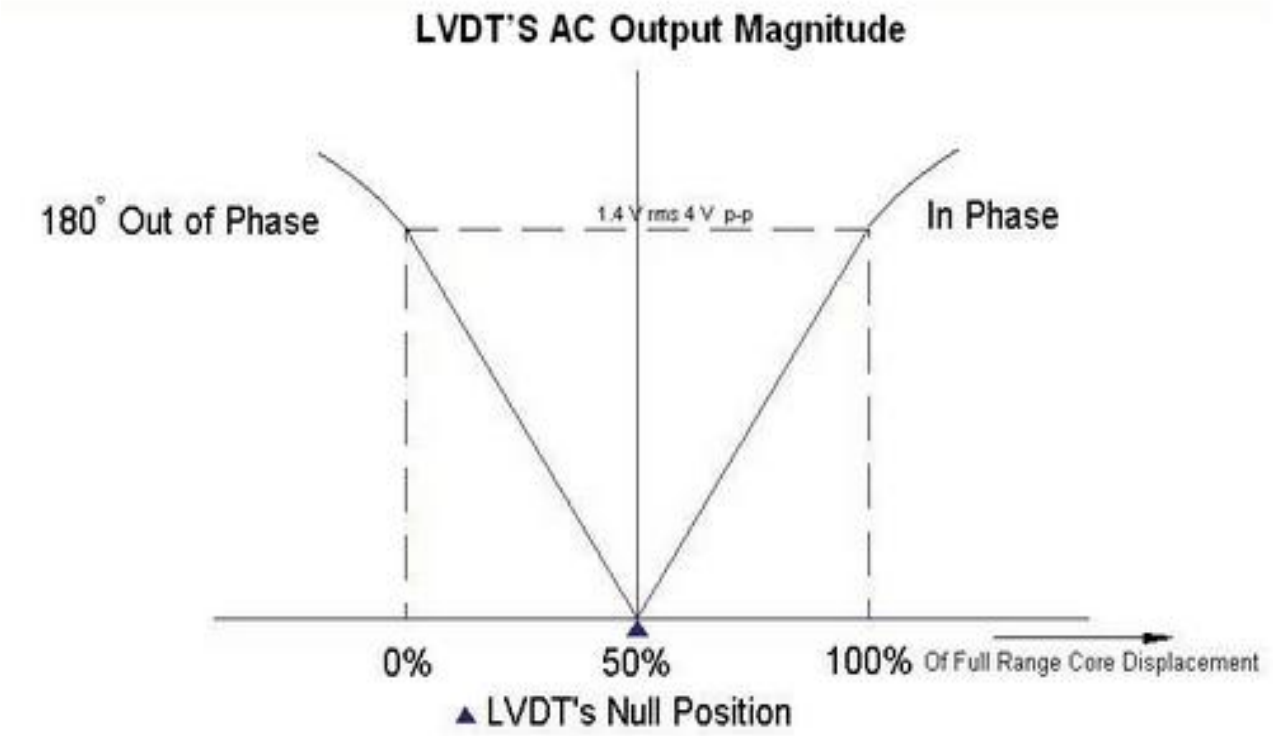


- ✓ **CASE-II**: When the core is moved to upward of null position (For displacement to the upward of reference point) In this case the flux linking with secondary winding S_1 is more as compared to flux linking with S_2. Due to this e_1 will be more as that of e_2. Due to this output voltage e_{out} is positive.
- ✓ **CASE-III:** When the core is moved to downward of Null position (for displacement to the downward of the reference point). In this case magnitude of e_2 will be more as that of e_1. Due to this output e_{out} will be negative and shows the output to downward of the reference point.



OUTPUT VS CORE DISPLACEMENT

- A linear curve shows that output voltage varies linearly with displacement of core.



AC Output of Conventional LVDT Versus Core Displacement

ADVANTAGES OF LVDT

- High Range
- No Frictional Losses
- High Input and High Sensitivity
- Low Hysteresis
- Low Power Consumption.
- Direct Conversion to Electrical Signals

DISADVANTAGES

- LVDT is sensitive to stray magnetic fields so it always requires a setup to protect them from stray magnetic fields.
- LVDT gets affected by vibrations and temperature.

Applications of LVDT

- We use LVDT in the applications where displacements to be measured are ranging from a fraction of mm to few cms. The LVDT acting as a primary transducer converts the displacement to electrical signal directly.
- The LVDT can also act as a secondary transducer. E.g. the Bourbon tube which acts as a primary transducer and it converts pressure into linear displacement and then LVDT coverts this displacement into an electrical signal which after calibration gives the readings of the pressure of fluid.

LECTURE 3

Position and Proximity Sensors

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POSITION SENSORS

- Position sensors are basically sensors for measuring the distance travelled by the body starting from its reference position. How far the body has moved from its reference or initial position is sensed by the position sensors and often the output is given as a fed back to the control system which takes the appropriate action. Motion of the body can be rectilinear or curvilinear; accordingly, position sensors are called linear position sensors or angular position sensors.

    1. Photoelectric Sensors
    2. Hall effect Sensors
    3. Digital Optical Encoder

PHOTOELECTRIC SENSORS

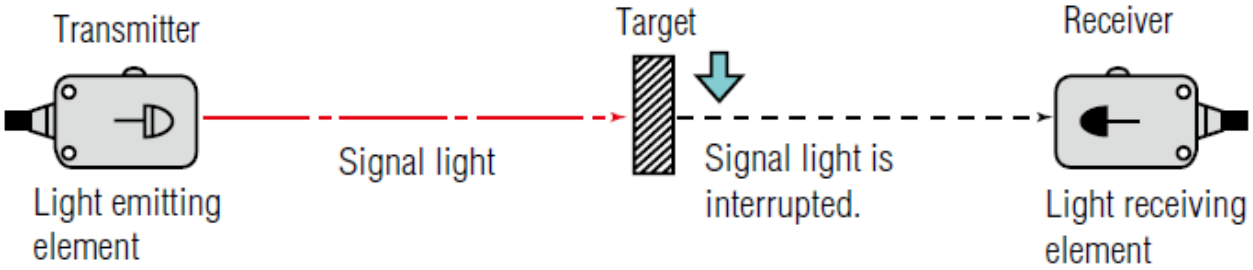
Photoelectric sensor is a generic name for sensors which detect an object by using light. The optical signal transmitted from the emitting part of the sensor is modified by being reflected, transmitted, absorbed, etc., by the sensing object and is then detected by the receiving part of the sensor to generate a corresponding output signal. Further, it can also be a sensor which detects light radiated from the sensing object to generate an output signal.

Sensing Methods or Working Principle of Photoelectric Proximity Sensor

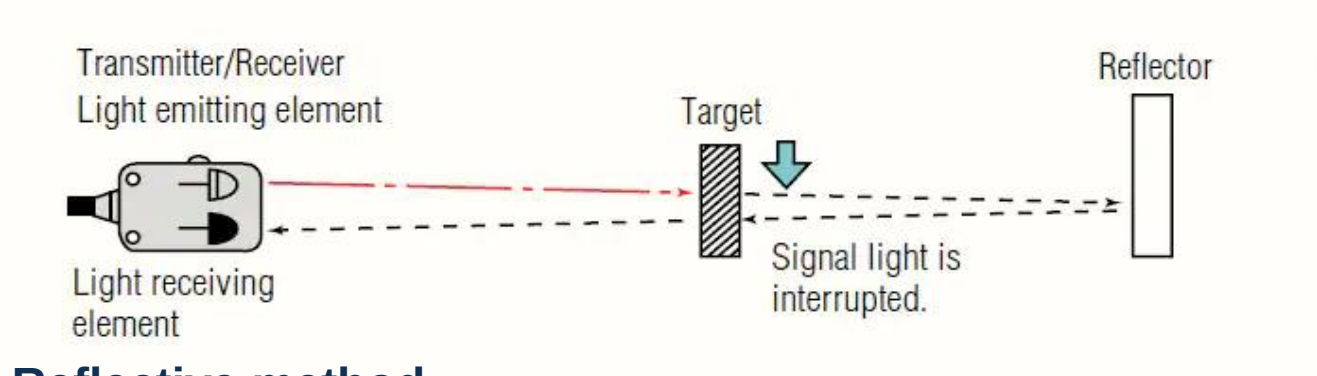
There are three main sensing methods of the photoelectric proximity sensor and they are,

1. Through beam method
2. Retro-reflective method
3. Diffuse or Reflective method

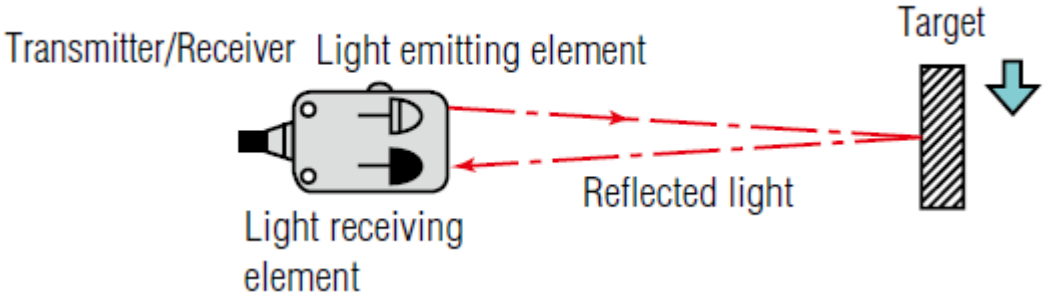
Through beam method



Retro-reflective method



Diffuse or Reflective method



ADVANTAGES OF PHOTOELECTRIC SENSOR

- ✓ The sensor senses all kinds of materials.
- ✓ It has longer life, long sensing range and very reliability.
- ✓ Very fast response time and less costly.
- ✓ Diffuse photoelectric sensor detects small objects including color mark and label detection.
- ✓ mostly retro-reflective type sensor can detect transparent objects.
- ✓ Through beam type can detect long range and it is tolerant of dirty environment.

DISADVANTAGES OF PHOTOELECTRIC SENSOR

- ✓ Over coarse of time lens get contaminated.
- ✓ Generally, the sensing range is affected due to color and reflectivity of the target.
- ✓ Through beam type requires transmitter (Tx) and receiver (Rx) at two separate locations
- ✓ Retro reflective type requires reflector in addition to Tx/Rx. This makes system installation complex

HALL EFFECT SENSORS

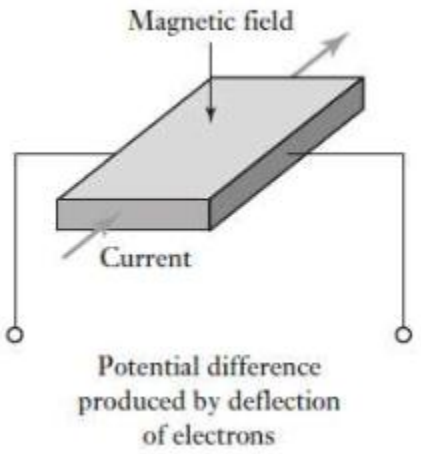
- A Hall effect sensor is a device that is used to measure the magnitude of a magnetic field.
- Its output voltage is directly proportional to the magnetic field strength through it.
- Hall effect sensors are used for proximity sensing, positioning, speed detection, and current sensing applications

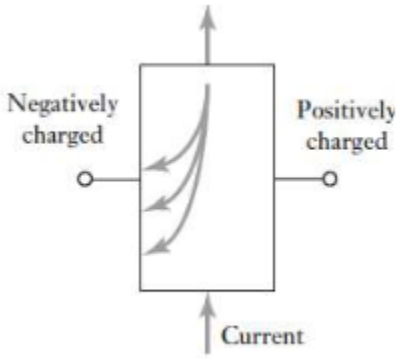
Principle

- When a beam of charged particles passes through a magnetic field, forces act on the particles and the beam is deflected from its straight line path.
- This effect was discovered by E.R. Hall in 1879 and is called the Hall effect.

WORKING

- Consider electrons moving in a conductive plate with a magnetic field applied at right angles to the plane of the plate.
- As a result of the magnetic field, the moving electrons are deflected to one side of the plate, and that side becomes negatively charged, while the opposite side becomes positively charged since the electrons are directed away from it.
- This charge separation produces an electric field in the material.
- The charge separation continues until the forces on the charged particles from the electric field just balance the forces produced by the magnetic field.

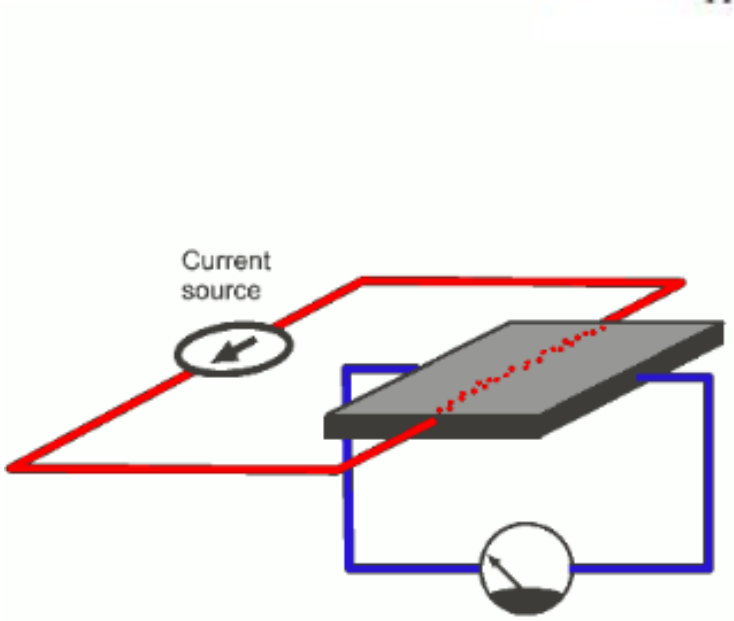




HALL EFFECT SENSORS

- The result is a transverse potential difference V given by

$$V = K_H \frac{BI}{t}$$



B= magnetic flux density

I = current

K_H = constant, Hall coefficient

t= plate thickness

ADVANTAGES OF HALL EFFECT SENSORS

- ✓ They can be used for multiple sensor functions like position sensing, speed sensing as well as for sensing the direction of movement too.
- ✓ As they are solid state devices, there is absolutely no wear and tear due to absence of moving parts.
- ✓ They are almost maintenance free.
- ✓ They are robust.
- ✓ They are immune to vibration, dust and water.

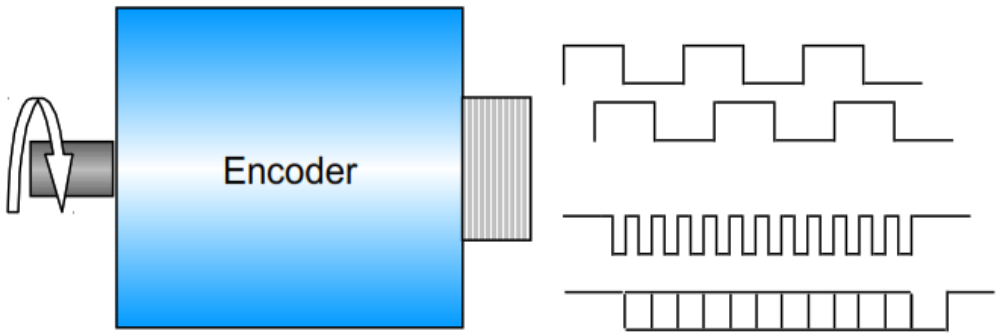
DISADVANTAGES OF HALL EFFECT SENSORS

- ✓ They are not capable to measure current flow at a distance more than 10 cm. The only solution to overcome this issue is to use a very strong magnet that can generate a wide magnetic field.
- ✓ Accuracy of the measured value is always a concern as external magnetic fields may affect the values.
- ✓ High Temperature affects the conductor resistance. This will in turn affect the charge carrier's mobility and sensitivity of Hall Effect Sensors.

DIGITAL OPTICAL ENCODER:

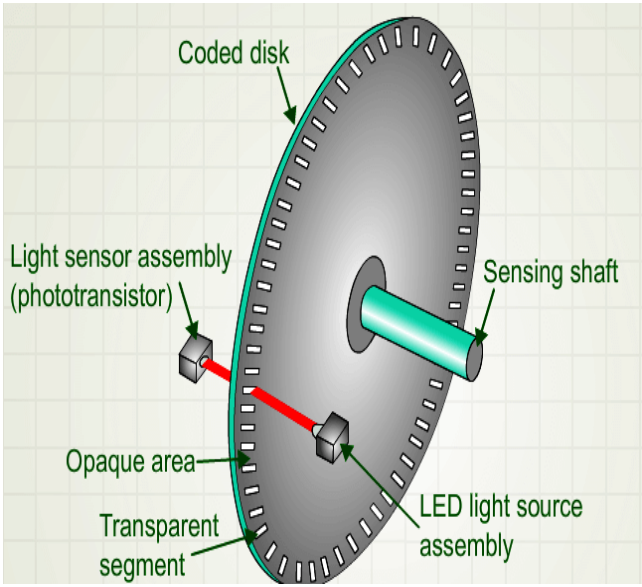
- A digital optical encoder is a device that converts motion into a sequence of digital pulses.
- By counting or decoding these bits and the pulses can be converted into relative or absolute position measurements.
- Encoders are in Rotary, linear configurations.
- The Rotary encoders are in two forms.

1. Absolute encoder
2. Incremental encoder.



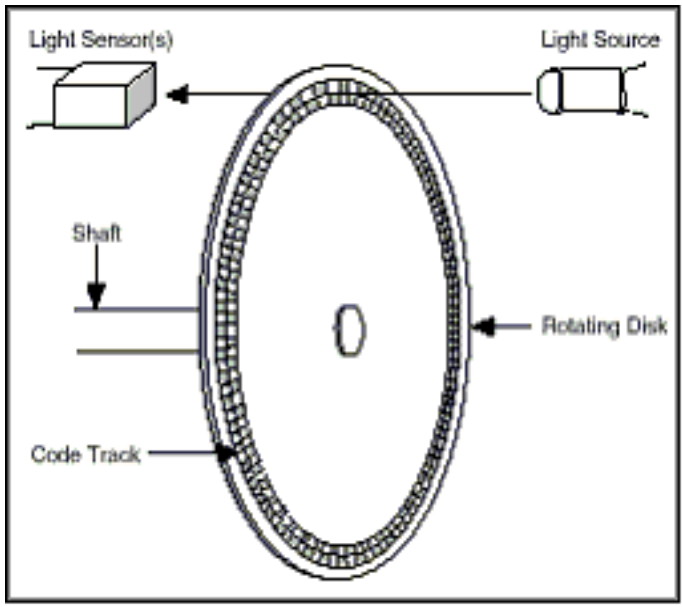
ABSOLUTE ENCODER

- The absolute encoder is designed to produce a digital word that distinguishes ‘ N’ distinct positions of the shaft.
- The rotating disc has four concentric circles of slots and four sensors to detect the light pulses.
- The slots are arranged in such a way that the output is made in the binary code.
- The number of bits in the binary number will be equal to the number of tracks.
- The most common types of numerical encoding used in the absolute encoder are gray and natural binary codes.



INCREMENTAL ENCODER:

- A beam of light passes through the slots in a disc and it is detected by a suitable light sensor.
- When the disc is rotated, the output is shown in terms of pulses and these pulses being proportional to the angle of disc rotation.
- So the angular position of the disc is determined by the number of pulses produced. The inner track has just one hole and other two tracks have a series of equally spaced holes.
- The angle is determined by the number slots on the disc.



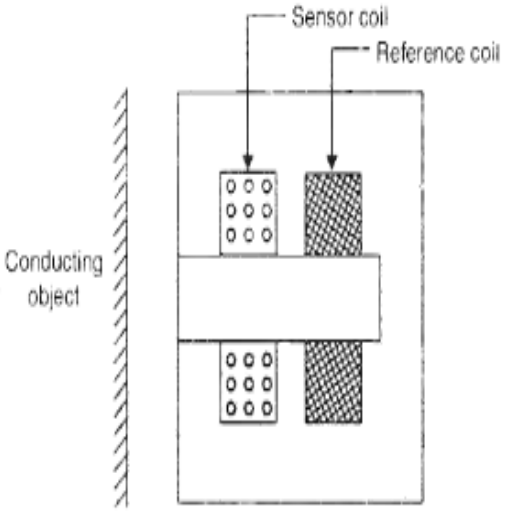
PROXIMITY SENSOR

- A proximity sensor is a sensor able to detect the presence of nearby objects without any physical contact.
- Common applications for proximity sensors and limit switches include:

    1. Counting moving objects;
    2. Limiting the traverse of a mechanism.

EDDY CURRENT PROXIMITY SENSORS

- When a coil is supplied with an alternating current an alternating magnetic field is produced. If there is a metal object in close proximity to this attending magnetic field, then eddy currents are induced in it. The eddy currents themselves produce a magnetic field which distorts the magnetic field responsible for their production. Consequently, the impedance of the coil changes and so the amplitude of the alternating current. This change, at some preset level, can be used to trigger a switch.



CAPACITIVE PROXIMITY SENSORS

- A capacitor consists of two conductors (plates) that are electrically isolated from one another by a nonconductor (dielectric).
- When the two conductors are at different potentials (voltages), the system is capable of storing an electric charge. The storage capability of a capacitor is measured in Farads.
- The principle of operation of capacitive transducers is based upon the equation for capacitance of a parallel plate capacitor as shown below:

$$\textbf{\textit{Capacitance}}\ C = \frac{\in A}{d}$$

- The capacitive transducers are commonly used for measurement of linear displacement, by employing the following effects.

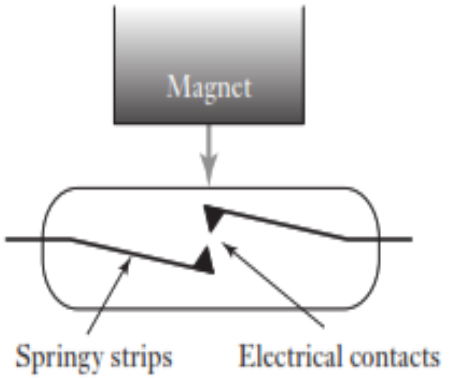
  1. Change in capacitance due to change in overlapping area of plates.
  2. Change in capacitance due to change in distance between the two plates.
  3. Change in capacitance due to change in dielectric between the two plates.

PROXIMITY SWITCH'S

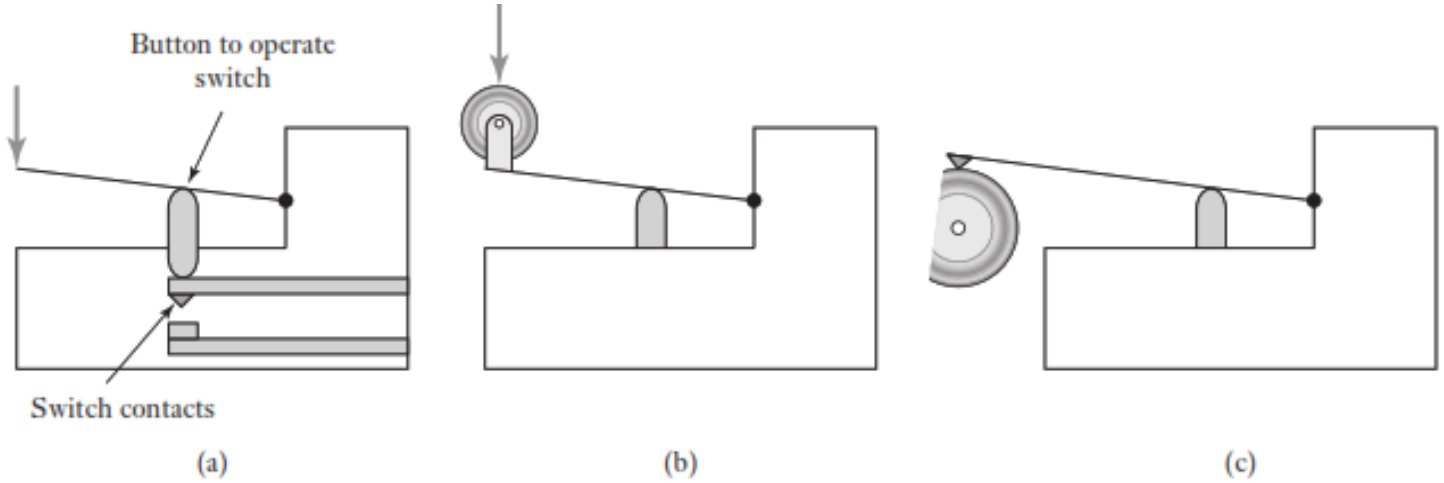
- A proximity sensor is a sensor able to detect the presence of nearby objects without any physical contact.
- The microswitch is a small electrical switch which requires physical contact and a small operating force to close the contacts.
- For example: A conveyor belt.

PRINCIPLE OF WORKING OF PROXIMITY SWITCHES

- It consists of two magnetic switch contacts sealed in a glass tube.
- When a magnet is brought close to the switch, the magnetic reeds are attracted to each other and close the switch contacts.

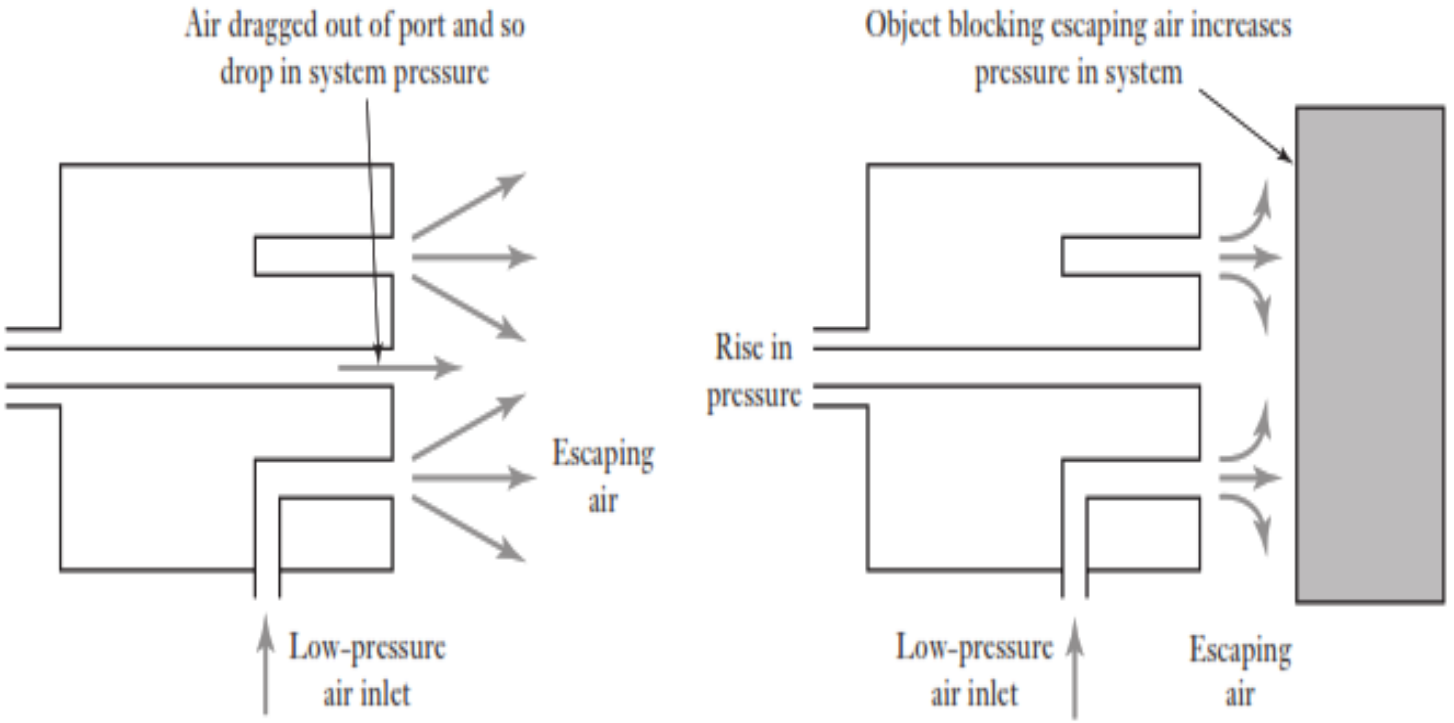


Reed switch.



(a) Lever-operated, (b) roller-operated, (c) cam-operated switches.

PNEUMATIC PROXIMITY SENSOR



LECTURE 4

VELOCITY AND MOTION SENSORS

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VELOCITY SENSORS

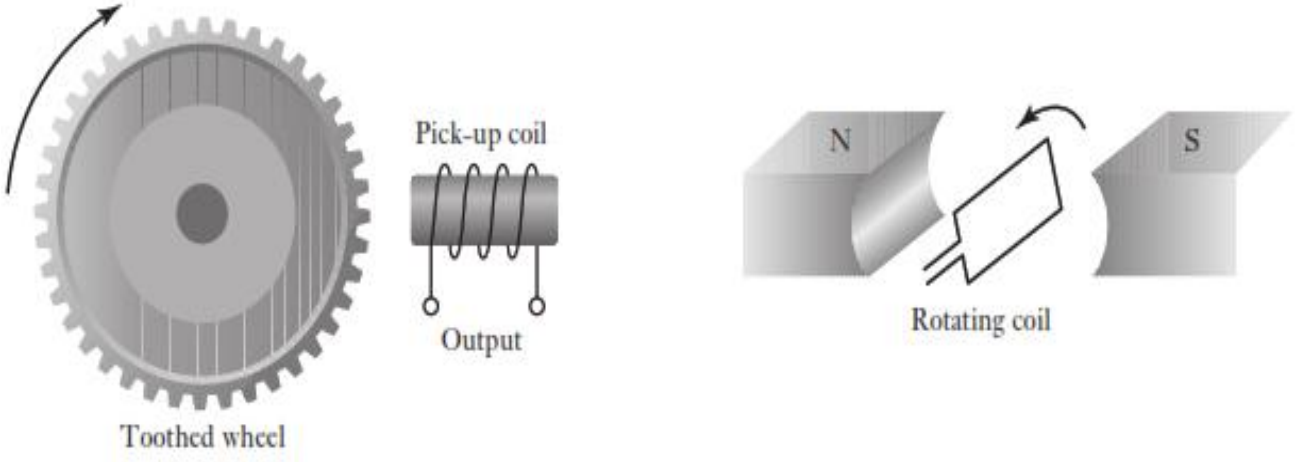
- Velocity sensors or tachogenerators are devices that give an output proportional to angular velocity.
- These sensors find wide application in motor speed control systems.

  ✓ Tachogenerator

  ✓ Pyroelectric sensors

  ✓ Strain Gauge as force Sensor

TACHOGENERATOR



- If the wheel contains n teeth and rotates with an angular velocity ω, then the flux change with time for the coil can be considered to be of the form

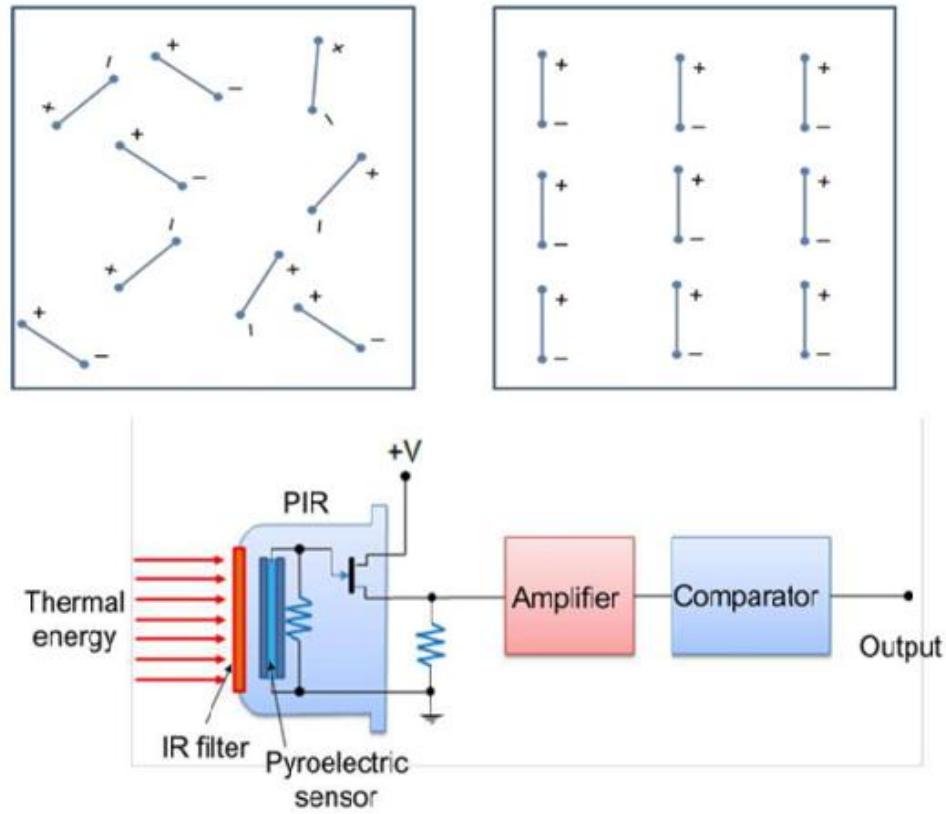
$$\Phi = \Phi_0 + \Phi_a \cos n\omega t$$

- The induced e.m.f. e in the N turns of the pick-up coil is -N dΦ / dt and thus

$$e = N\Phi_a n\omega \sin \omega t$$

PYROELECTRIC SENSORS

- These sensors work on the principle of pyroelectricity, which states that a crystal material such as Lithium tantalite generates charge in response to heat flow.



APPLICATIONS OF PYROELECTRIC SENSORS

- ✓ Intrusion detector
- ✓ Optothermal detector
- ✓ Pollution detector
- ✓ Position sensor
- ✓ Solar cell studies
- ✓ Engine analysis

LECTURE 5

FORCE AND FLUID PRESSURE SENSORS

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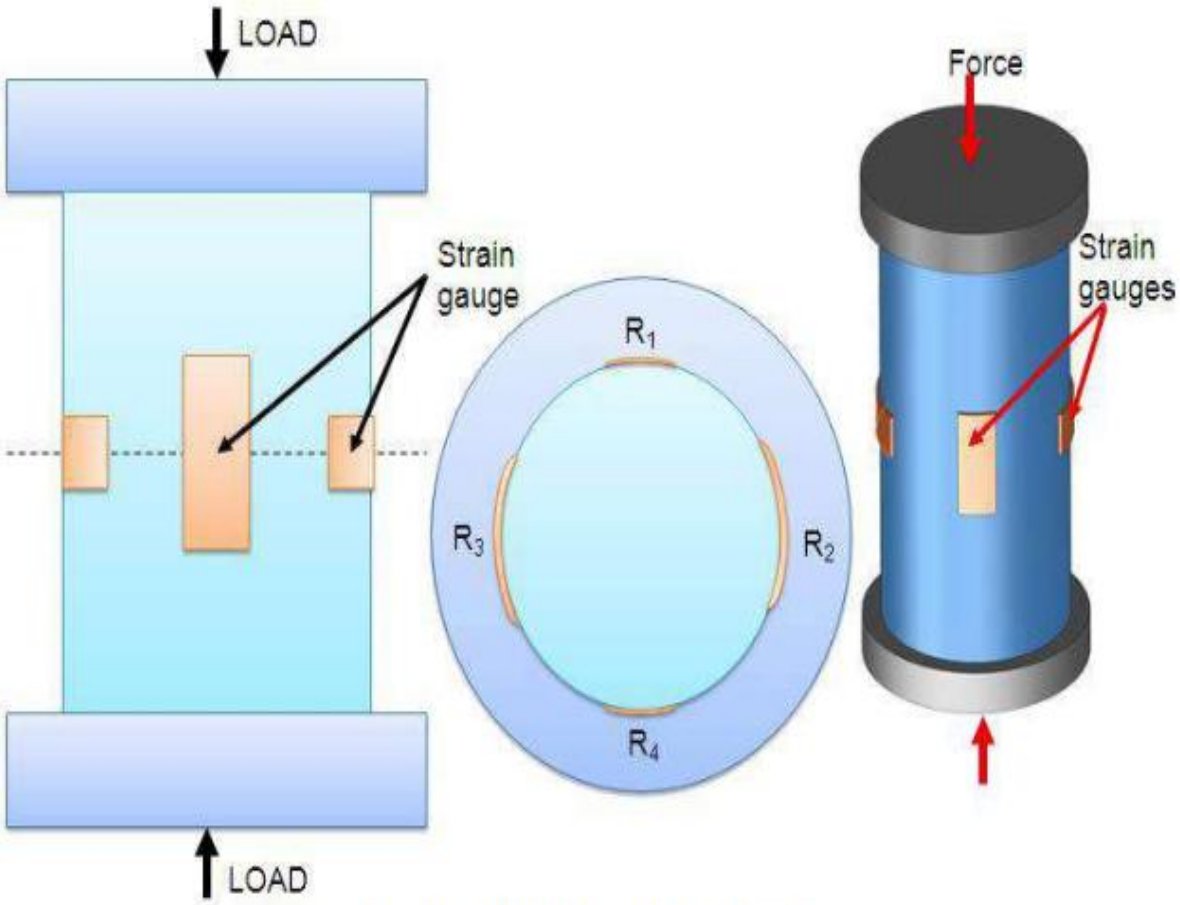
STRAIN GAUGE AS FORCE SENSOR



Strain gauge based Load cell

PRESSURE SENSORS

- The devices which are used to monitor fluid pressure in industrial processes is diaphragms, bellows, capsules and tubes.
- The types of pressure measurements required are

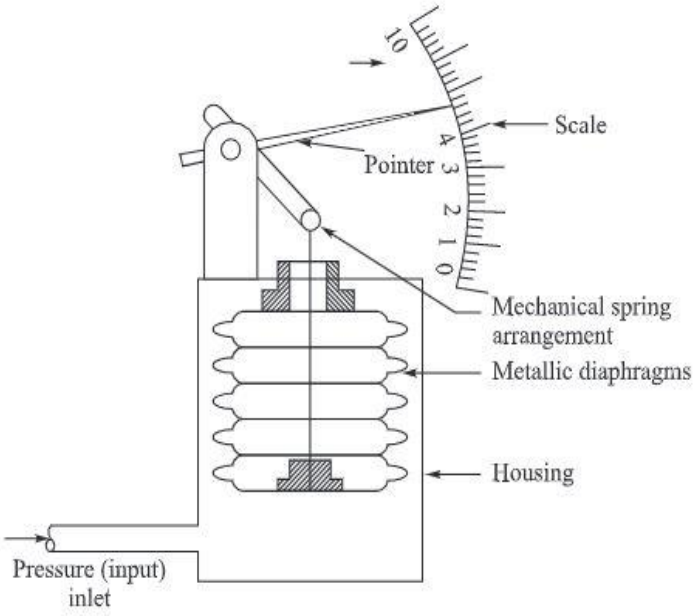
  (1) Absolute pressure measurement,

  (2) Differential pressure measurements.

- In absolute pressure measurements the measurement is related to vacuum pressure (zero pressure) and in differential pressure measurement the difference in pressure is measured.

DIAPHRAGM

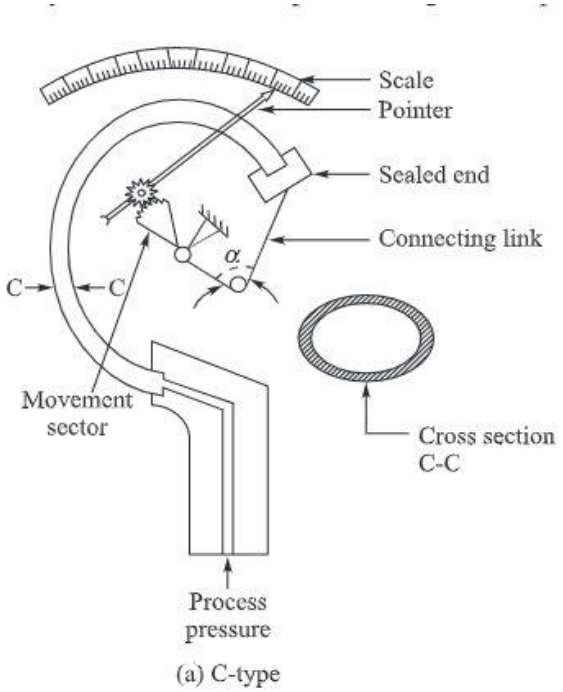
- When the pressure, which is to be measured, is applied through the pressure inlet, the deflection of metallic diaphragm takes place. This deflection is applied to a pointer through spring or proper mechanism arrangement, due to which the pointer slides over the calibrated scale. The reading is indicated by indicating or recording instrument, which is proportional to the applied pressure.



Pressure measurement using diaphragm.

BOURDON TUBE

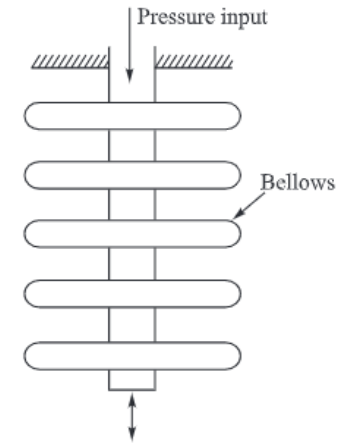
When the pressure is applied at the open end, the tube tends to straighten out because the internal and outer radii of the bourdon tube are different. So the tube takes different areas for the pressure. The non-linear motion is converted into linear motion or displacement by means of a pointer and calibrated scale (deflection) arrangement. Necessary link, lever gear and pinion attachment is provided to the deflection system. Thus the applied pressure is measured by means of deflection over linear scale.



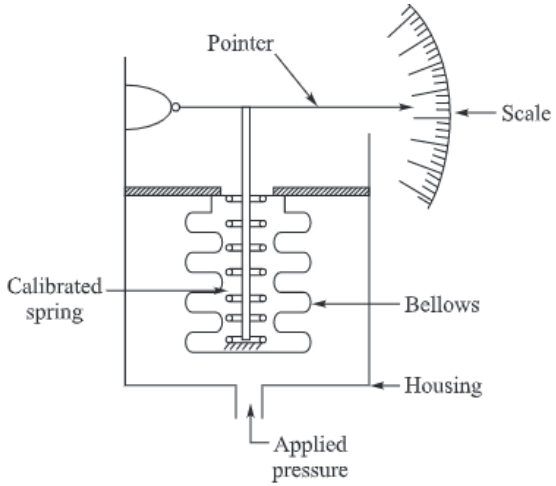
(a) C-type

BELLOWS

As the pressure is applied to the spring-loaded metal bellows, it gets compressed and hence forces the lower end of the bellow in upward direction. This results in opposing the spring force. The pointer is connected to the spring through suitable linkage and calibration. When pressure is applied in vertical movement, the pointer moves over the calibrated scale.



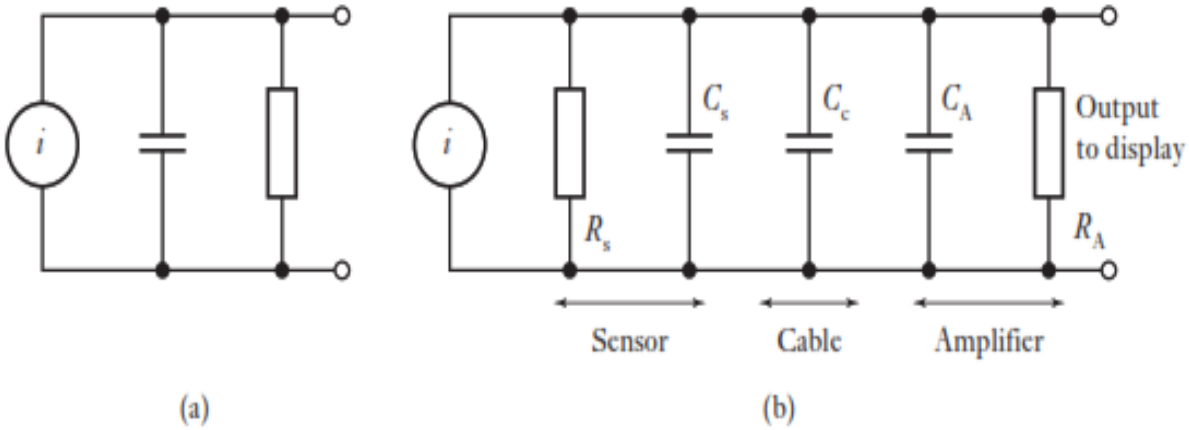
(a) A basic bellows element



(b) Pressure measurement using single bellows element

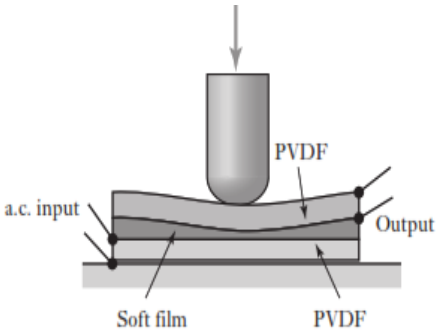
PIEZOELECTRIC SENSORS

- The electrical circuit for a piezo electric sensor is a charge generator in parallel with capacitance Cs and in parallel with Resistance Rs.
- The effective circuit is as shown by the Fig. when the sensor is connected via a cable of capacitance C and resistance RA.
- The sensor is charged subject to pressure change and the capacitor will discharge with time. The discharge time depends on the time constant of the circuit.



TACTILE SENSOR

- There are two layers of such film is used and it is separated by a soft film which transmits vibrations.
- The alternating voltage is supplied in the lower PVDF film and this results in mechanical oscillations of the film.
- The intermediate film transmits these vibrations to the upper PVDF film.
- Due to the piezoelectric effect the vibrations formed are cause an alternating voltage to be produced across the upper film.
- So the pressure is applied to the upper PVDF film and its vibrations are affected the output voltage.



LECTURE 6

LIQUID FLOW AND LIQUID LEVEL SENSORS

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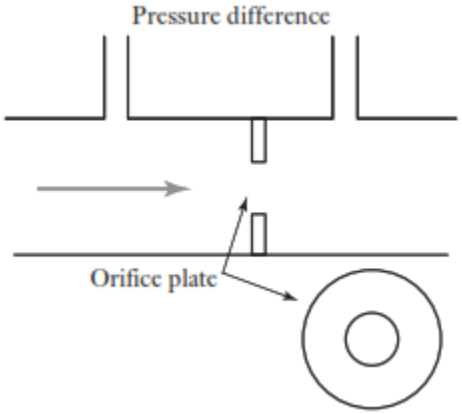
LIQUID FLOW SENSORS

- There are many devices used to measure the liquid flow.
- The basic principle in measuring flow is the fluid flowing through the pipe per second is proportional to square root of pressure difference.
- The following flow measuring devices are used to measure the liquid flow.

1. **Orifice plate**
2. **Turbine meter**

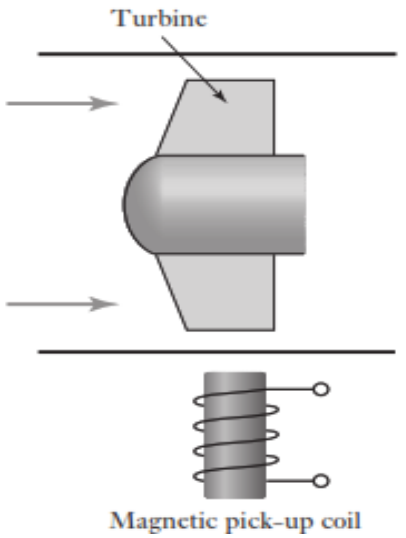
ORIFICE PLATE

- The orifice plate is simply a disc, with a central hole, which is placed in the tube through which the fluid is flowing. The pressure differences is measured between a point equal to the diameter of the tube upstream and a point equal to half the diameter downstream. The orifice plate is simple, cheap, with no moving parts, and is widely used. It does not, however, work well with slurries. The accuracy is typically about ±1.5% of full range, it is non-linear, and it does produce quite an appreciable pressure loss in the system to which it is connected.



TURBINE METER

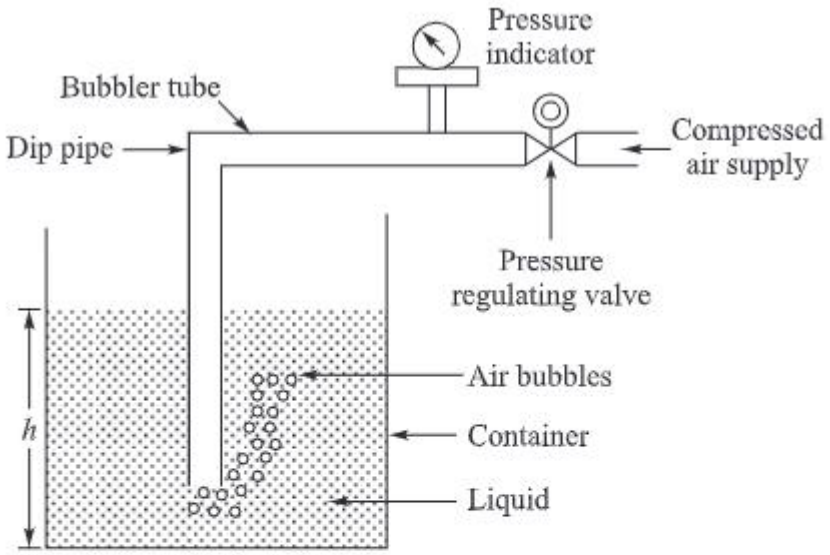
- The turbine flowmeter consists of a multi-bladed rotor that is supported centrally in the pipe along which the flow occurs. The fluid flow results in rotation of the rotor, the angular velocity being approximately proportional to the flow rate. The rate of revolution of the rotor can be determined using a magnetic pick-up. The pulses are counted and so the number of revolutions of the rotor can be determined. The meter is expensive with an accuracy of typically about ±0.3%.



LEVEL MEASUREMENT

Liquid level measurement is an important and the oldest function in measurements. It is widely useful in power plants, petrochemical, paper and sugar industries. It is also useful for level measurement of exotic and hazardous process matters, fuel handling and so on. The liquid level affects pressure and rate of flow in and out of a container or vessel, due to which it is necessary to measure and control liquid levels. The service of level measurements is applicable for both solid and liquid materials or any process material. But the most important factor is to consider the nature and type of material.

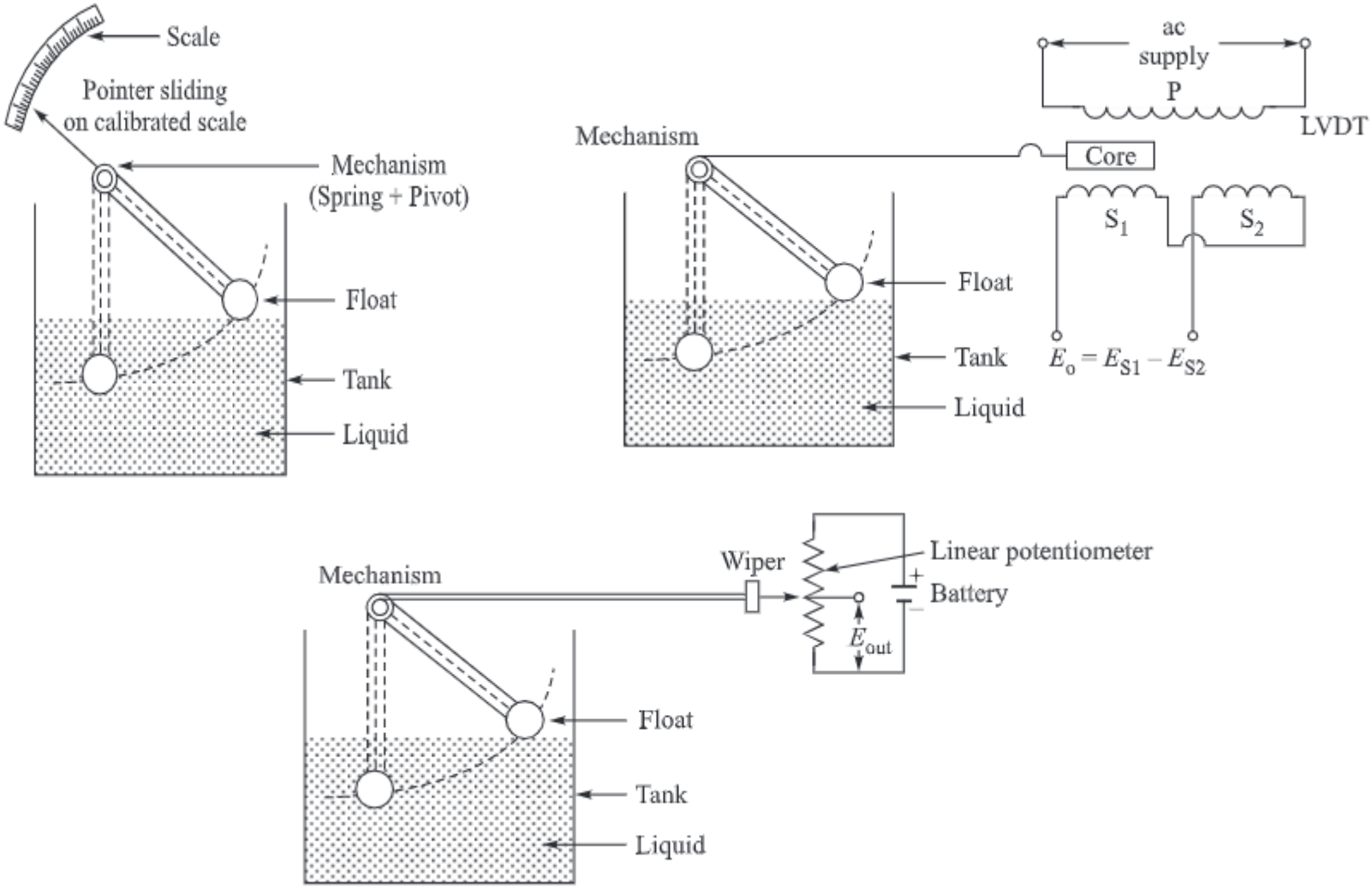
BUBBLER METHOD



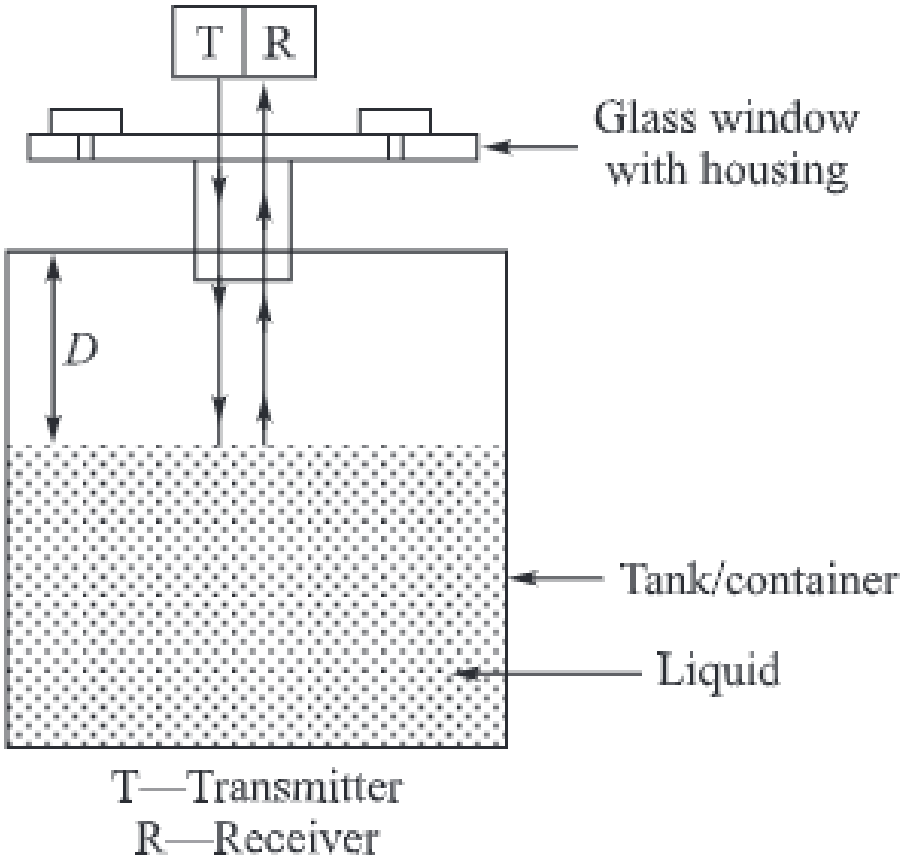
(a) Liquid level measurement using the bubbler method

(b) Different shapes of the dip pipe (or bubbler tube)

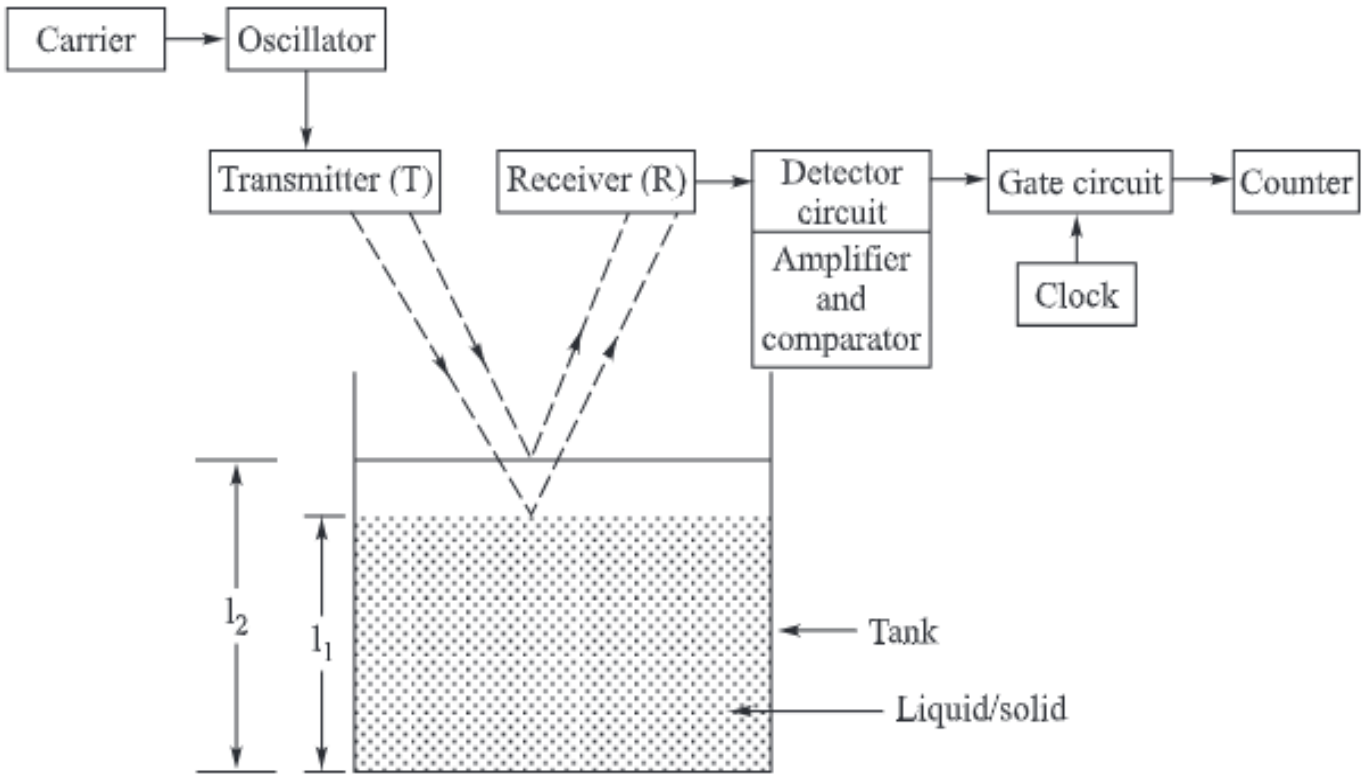
LIQUID LEVEL MEASUREMENT USING FLOAT



LASER LEVEL SENSOR OR LEVEL MEASUREMENT USING LASER



ULTRASONIC LIQUID LEVEL DETECTOR



LECTURE 7

Temperature, light sensors, selection of sensors.

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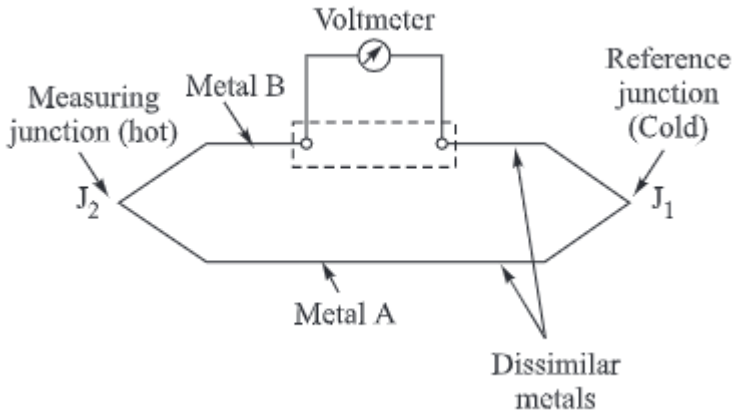
TEMPERATURE SENSORS

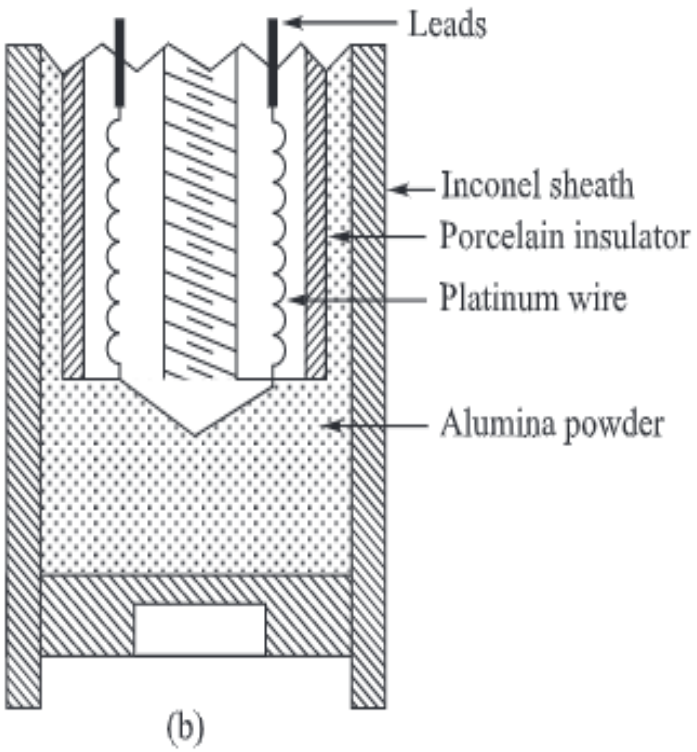
- The term temperature is defined as the degree of hotness or coldness of a substance or medium. Temperature may be defined as degree of heat.
- Due to heating or cooling, the following effects are used for measurement:
    i. Change in physical or chemical state of the substance or medium
    ii. Change in physical dimensions
    iii. Change in electrical properties such as resistance
    iv. If two dissimilar metals get joined or welded, an emf gets developed at the junction.
    v. Change in the intensity of total radiation emitted.

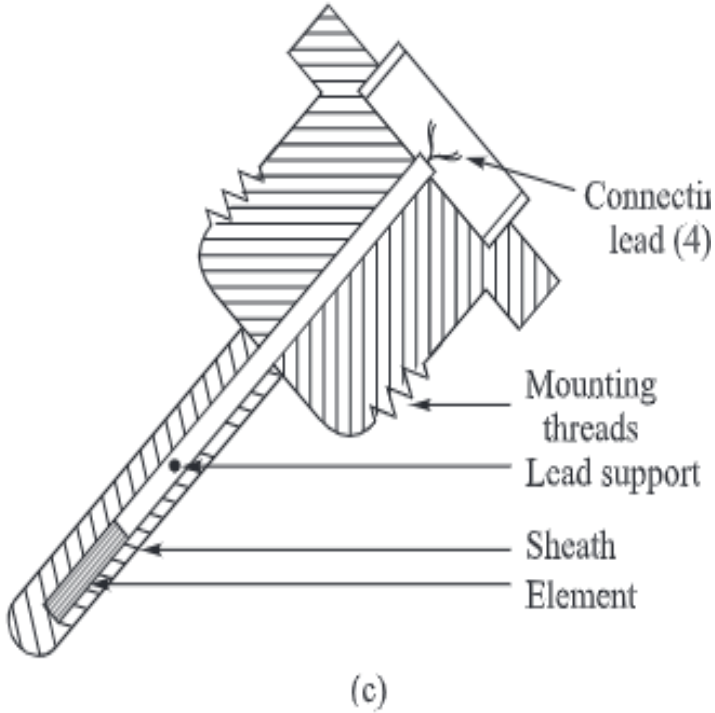
THERMOCOUPLE

- A thermocouple works on the following principle: When two dissimilar metals A and B are welded or joined together to form a closed circuit and the junctions (J1 and J2) are kept at two different temperatures (T1 and T2), then an emf is generated resulting flow of current in the circuit or loop." One of the two junctions in the loop is reference or cold junction which is generally kept at 0°C and the other is the measuring or hot junction at which the temperature is to be measured as shown in Figure.

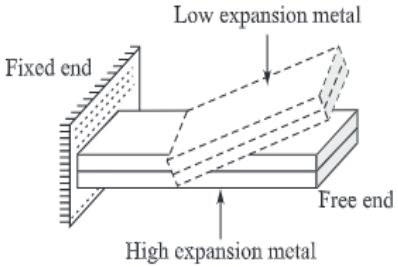


RESISTANCE TEMPERATURE DETECTOR (RTD)

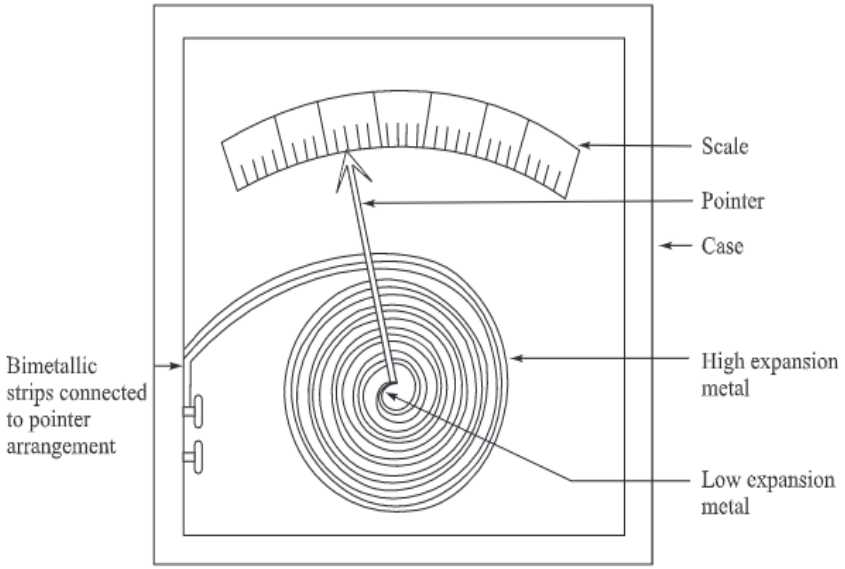




BIMETALLIC THERMOMETERS



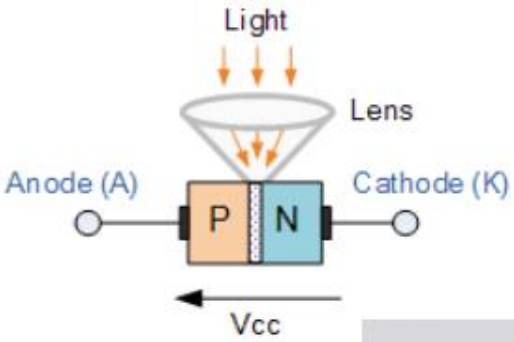
(a) Working principle

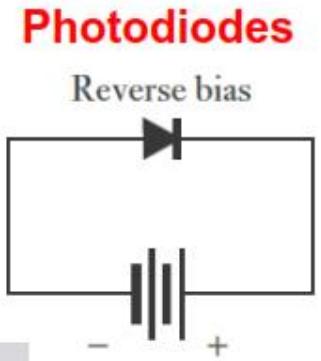


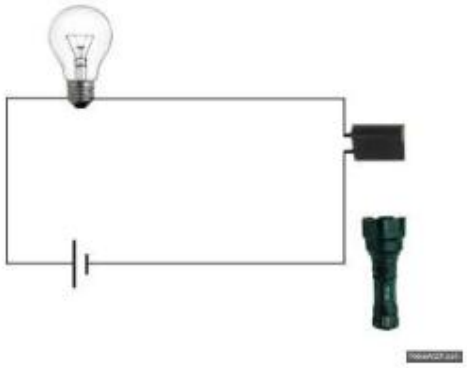
(b) Construction

LIGHT SENSORS

- Light Sensors are photoelectric devices / Photo sensors that convert light energy (photons) whether visible or infra-red light into an electrical signal.





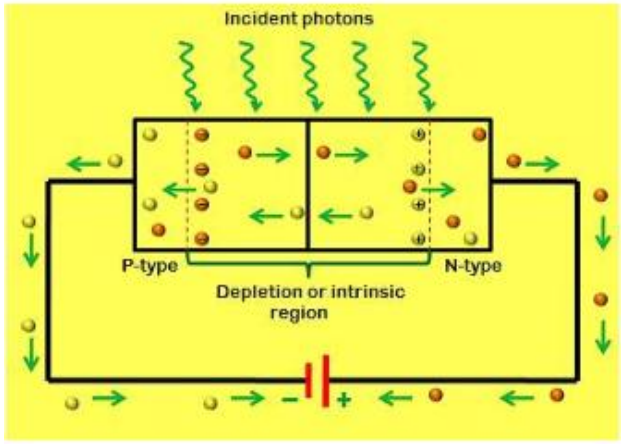


Applications

Smoke detectors, compact disc players, and televisions, remote controls in VCRs, clock radios, street light

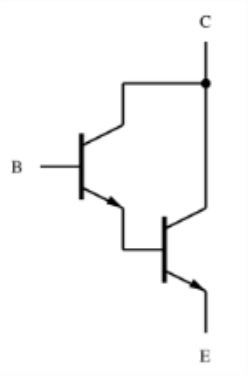
PHOTODIODES

- Are semiconductor junction, connected into a circuit in reverse bias giving a very high resistance.
- With no incident light, the reverse current is almost negligible and is termed the dark current.
- When light falls on the junction, extra hole–electron pairs are produced and there is an increase in the reverse current and the diode resistance drops.
- The reverse current is very nearly proportional to the intensity of the light.

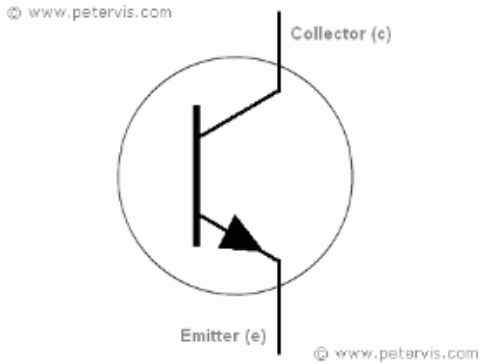


PHOTOTRANSISTORS

- The phototransistors have a light-sensitive collector–base p–n junction.
- When there is no incident light there is a very small collector-to-emitter current.
- When light is incident, a base current is produced that is directly proportional to the light intensity. This leads to the production of a collector current which is a measure of the light intensity.
- Phototransistor are connected in a Darlington arrangement with a conventional transistor, for higher current gain.

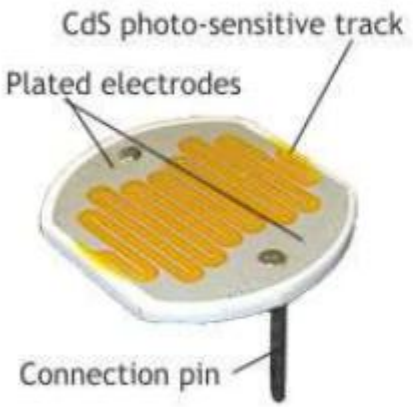


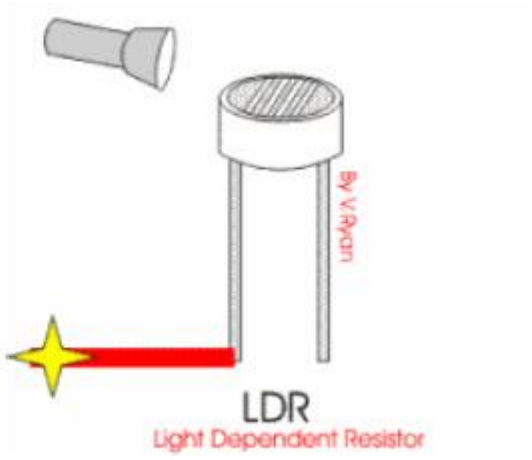
In electronics, a multi-**transistor** configuration called **Darlington pair**



PHOTORESISTOR

- A photoresistor (or light-dependent resistor, LDR, or photo-conductive cell) is a light-controlled variable resistor. The resistance of a photoresistor decreases with increasing incident light intensity (photoconductivity).





SELECTION OF SENSORS

- ✓ The nature of output required from the sensor.
- ✓ The nature of measurement required.
- ✓ The accuracy of the sensor.
- ✓ The cost of the sensor.
- ✓ The power requirement of the sensor.
- ✓ The speed response of the sensor.
- ✓ The linearity of the sensor.
- ✓ The Reliability and Maintainability of the sensor.
- ✓ Environmental conditions under which the measurement is to be made.
- ✓ Signal conditioning requirements.
- ✓ The nominal and range of values of the sensor.
- ✓ Suitable output signals from the measurement.

THANK YOU

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AUTOMATION AND CONTROL ENGINEERING (R17A0327)

4th Year B. Tech I- sem, Mechanical Engineering

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COURSE OBJECTIVES

UNIT - 1	CO1: To perform one or more processing operations & To understand the need of Mechatronics systems
UNIT - 2	CO2: To make students familiar with the constructions and working principle of different types of sensors and transducers.
UNIT - 3	**CO3: Understand the fundamental concepts of electro mechanics and fluid mechanics (hydraulics and pneumatics) of Actuators and drive systems.**
UNIT - 4	CO4: To impart knowledge on the control elements
UNIT - 5	CO5: To understand the different control schemes generally used to get best output.

UNIT 3

ACTUATORS AND DRIVE SYSTEMS

CO3: Understand the fundamental concepts of electro mechanics and fluid mechanics (hydraulics and pneumatics) of Actuators and drive systems.

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UNIT – III (SYLLABUS)

ACTUATORS AND DRIVE SYSTEMS

- Mechanical, Electrical, Hydraulic drive systems Characteristics mechanical, electrical, hydraulic and pneumatic actuators and their limitations.

COURSE OUTLINE

UNIT - 3

LECTURE	LECTURE TOPIC	KEY ELEMENTS	LEARNING OBJECTIVES
1	Introduction to Actuators	Define Actuator	Understanding of basics of control system (B2)
2	Classification of Actuators Electric Motors like: Servomotors, Stepper motors or Direct-drive electric Hydraulic actuators Pneumatic actuators	Types of Actuators	Understanding of types of Actuators (B2)
3	Drive Systems	Working principle of Types of Drive systems	• Understand the applications of Drive systems and to know the working principles of system(B2) • Advantages and disadvantages of Drive systems(B4)
4	Types of Drive systems		

TOPICS TO BE COVERED

- Definition
- Types of Actuators
- Advantages and Disadvantages
- Drive Systems
- Applications
- Problems
- Assignments

LECTURE 1

Introduction - Actuators

LECTURE TEMPLATE

- **Introduction**
  - **Definition**
  - **Units**
  - **Classification etc…**
- **Demonstration**
  - Text
  - Graphic/ Pictorial
  - Video etc…
- **Industrial Applications**
- Solved Problems (1-2)
  - Procedure
- Self Learning Questions
- Assignment Exercises
- Summary

Actuators

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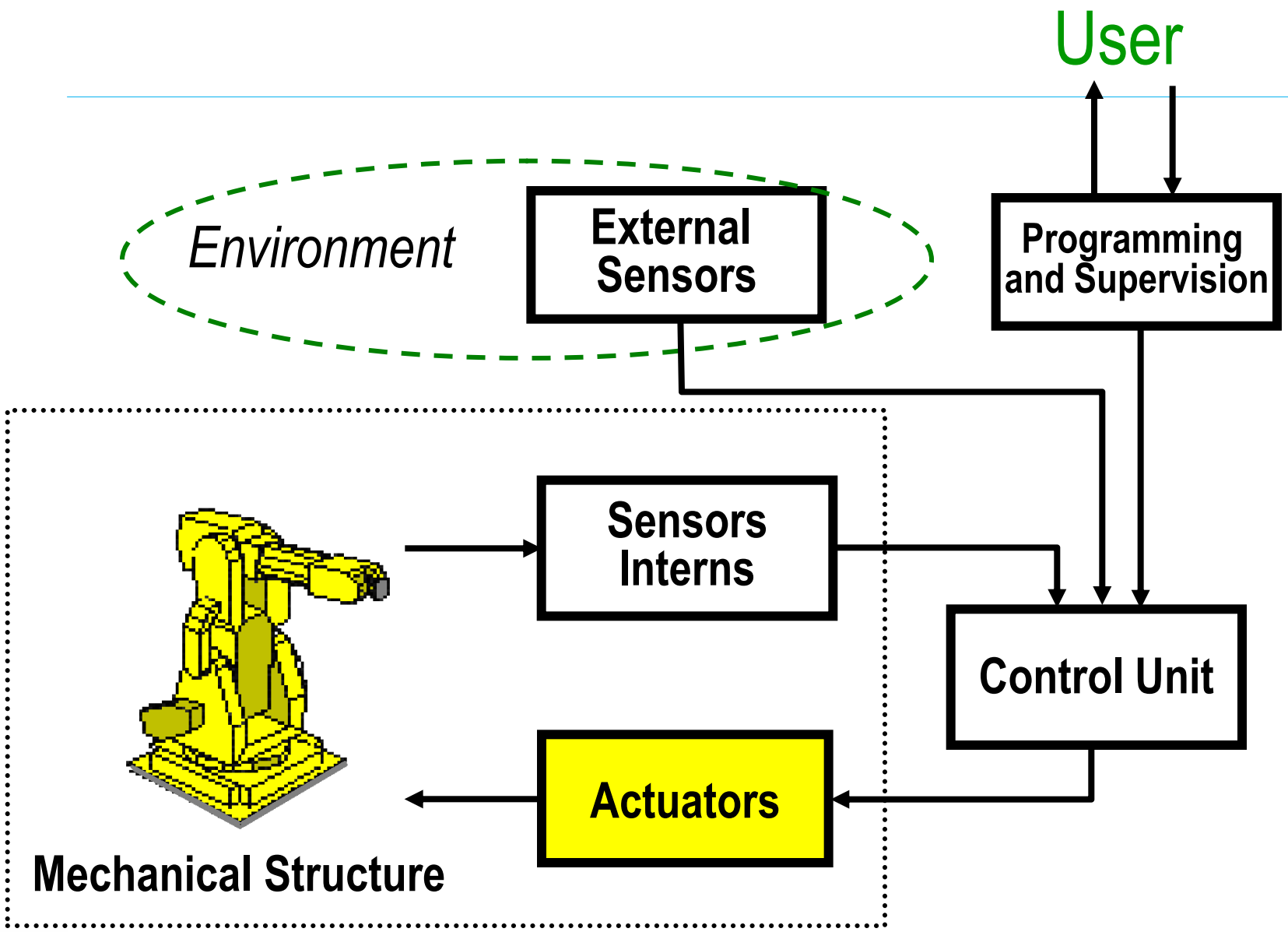

User
Environment
External Sensors
Programming and Supervision
Sensors Interns
Control Unit
Actuators
Mechanical Structure

ACTUATORS

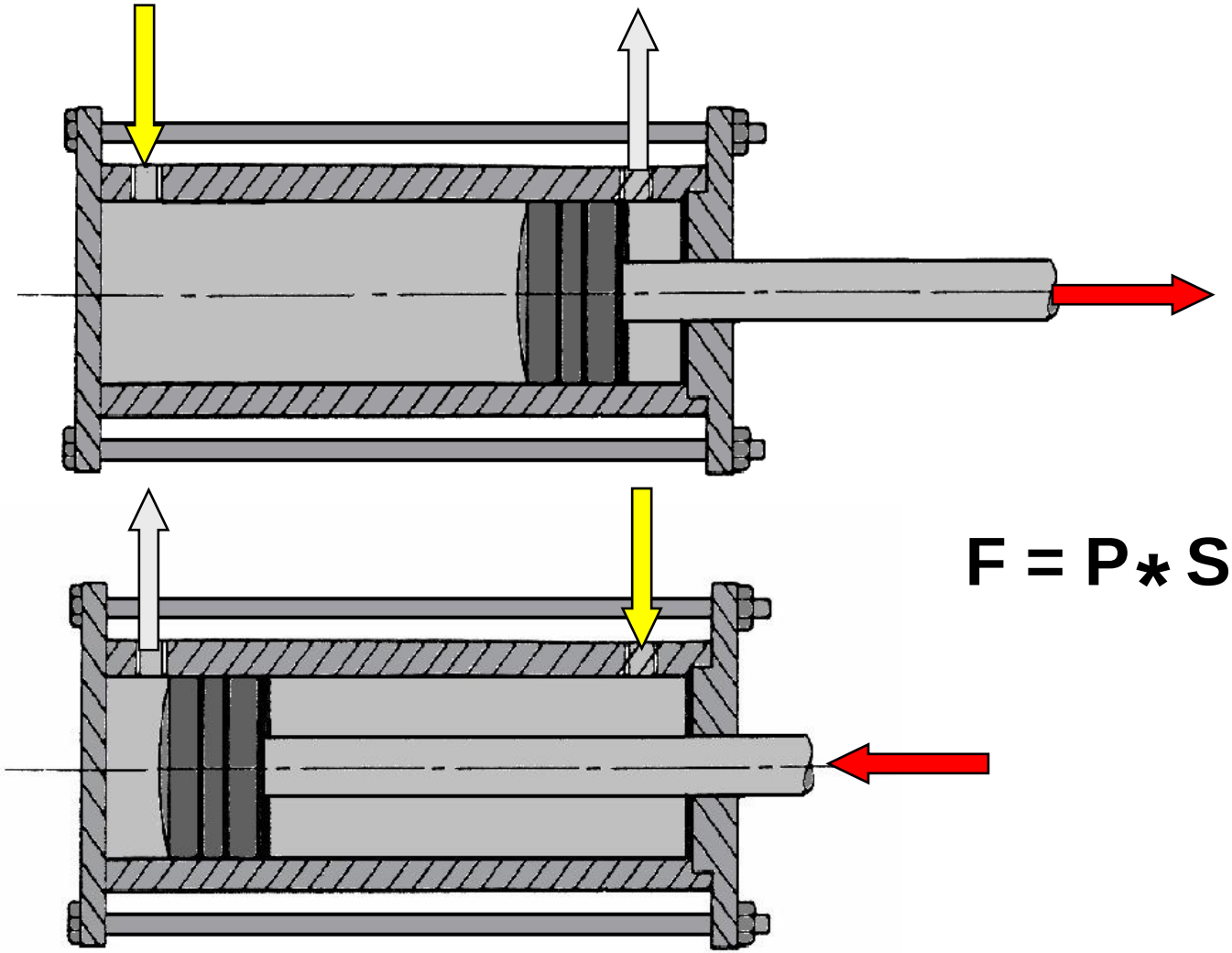
1 – Pneumatic actuators
Cylinders

2 – Hydraulic actuadors
Cylinders
Motors

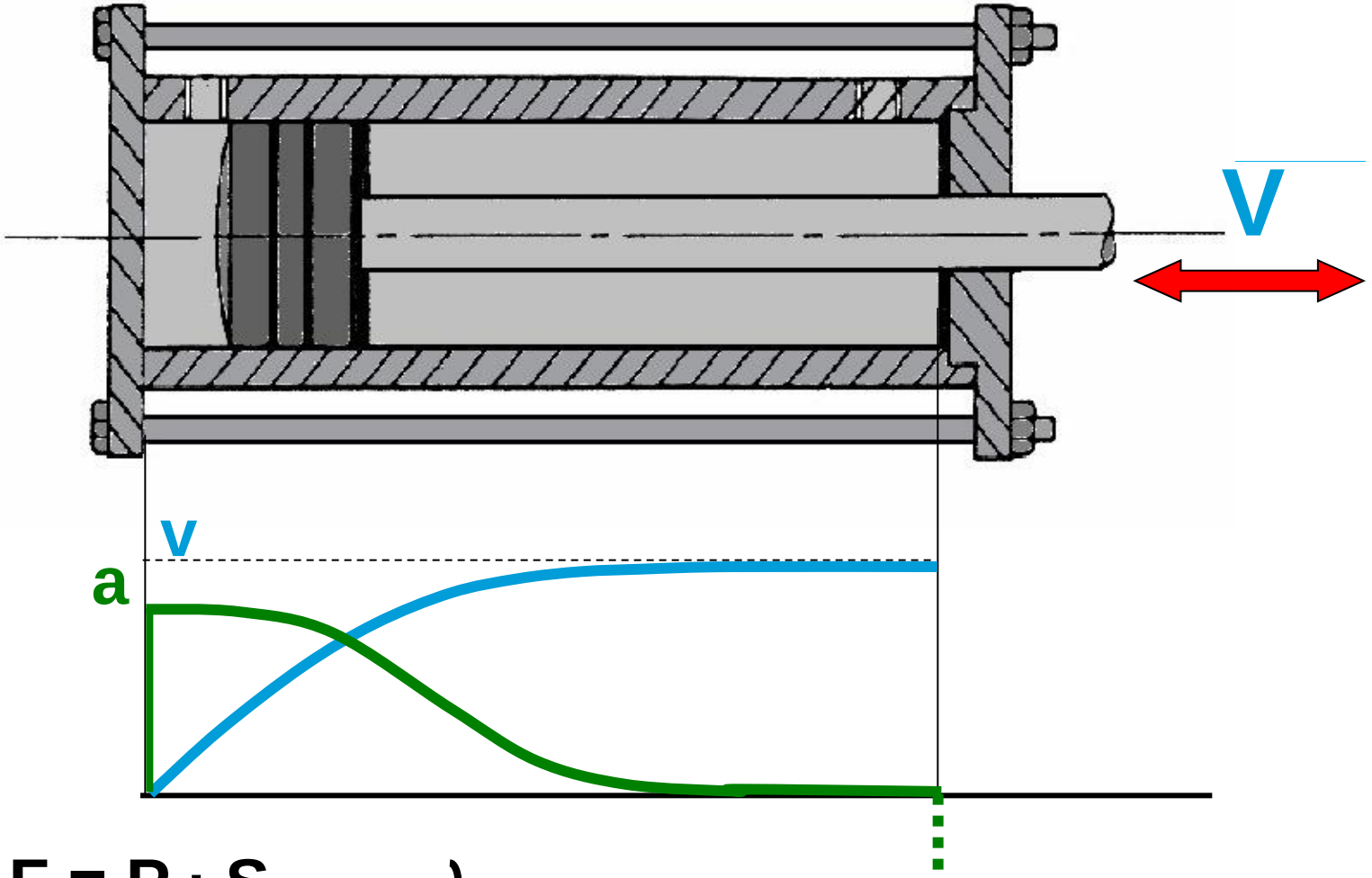
3 – Electrical actuators
Dc motors.
Ac motors
Steeper motors.

1 – Pneumatic actuators (cylinders)

Double effect pneumatic cylinders

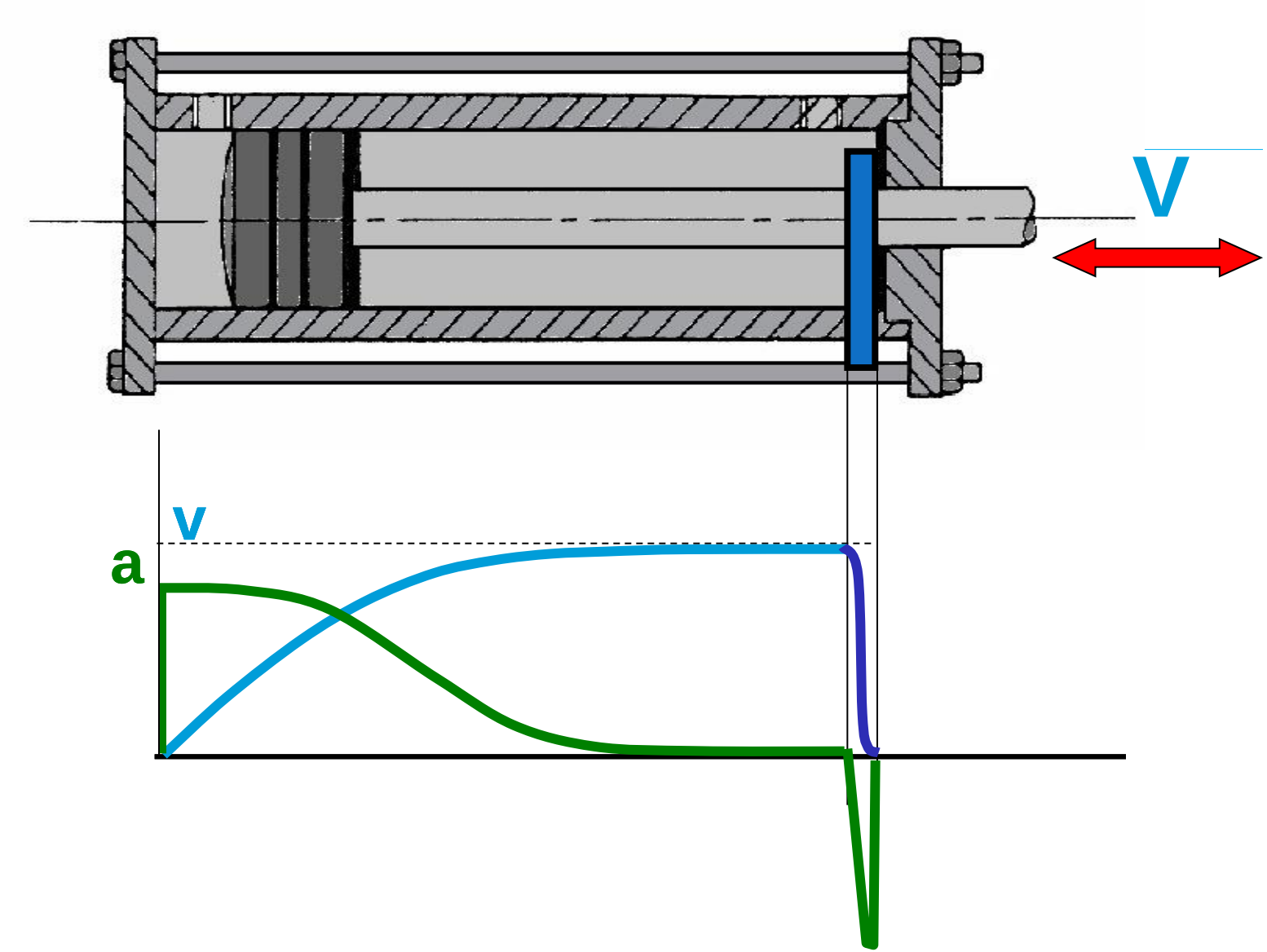


$$F = P * S$$

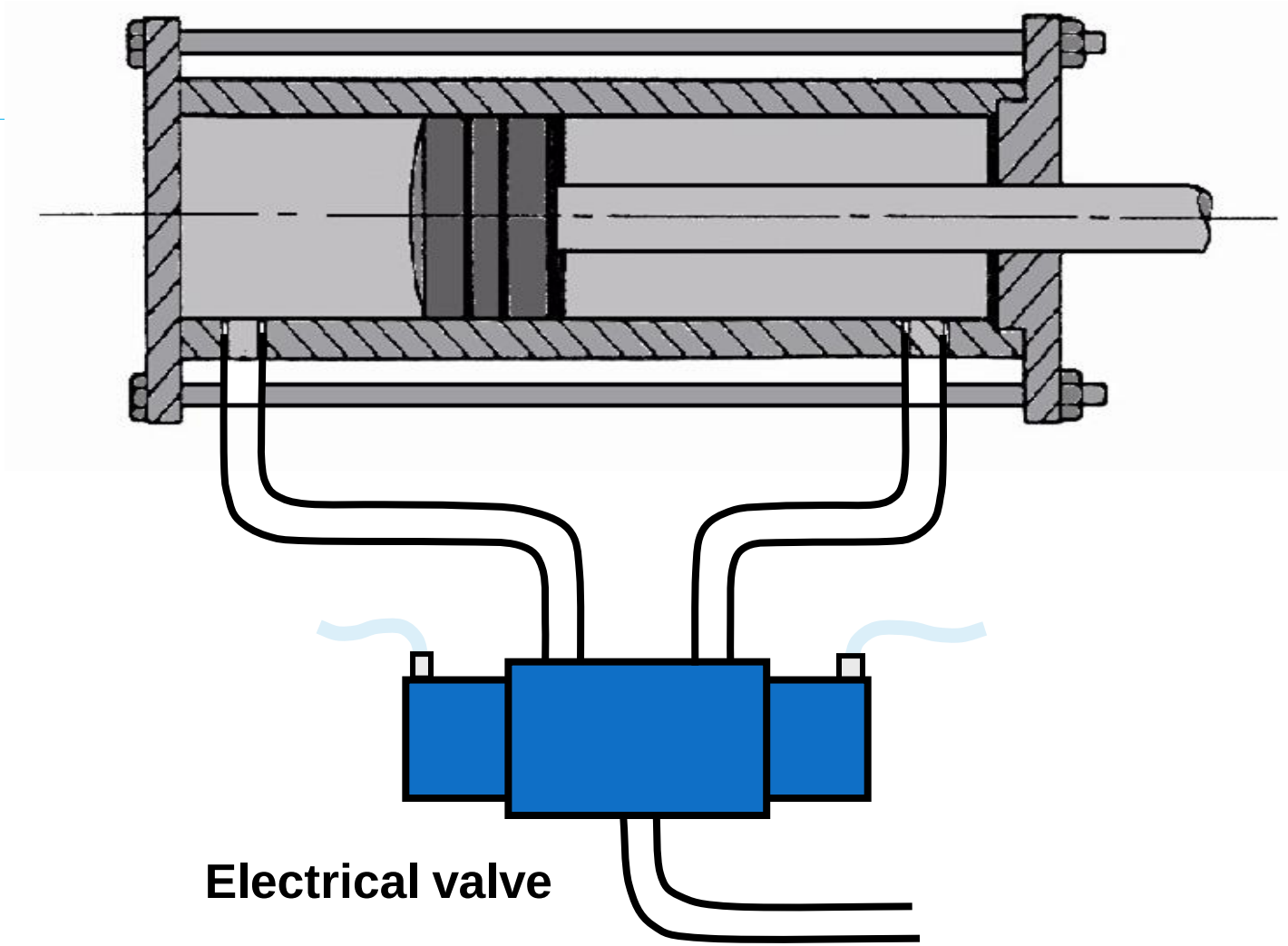


$$\left.\begin{aligned} F &= P * S \\ F - F_f &= M * a \\ F_f &= k * v^2 \end{aligned}\right\} \Rightarrow a = \frac{P * S - k * v^2}{M}$$

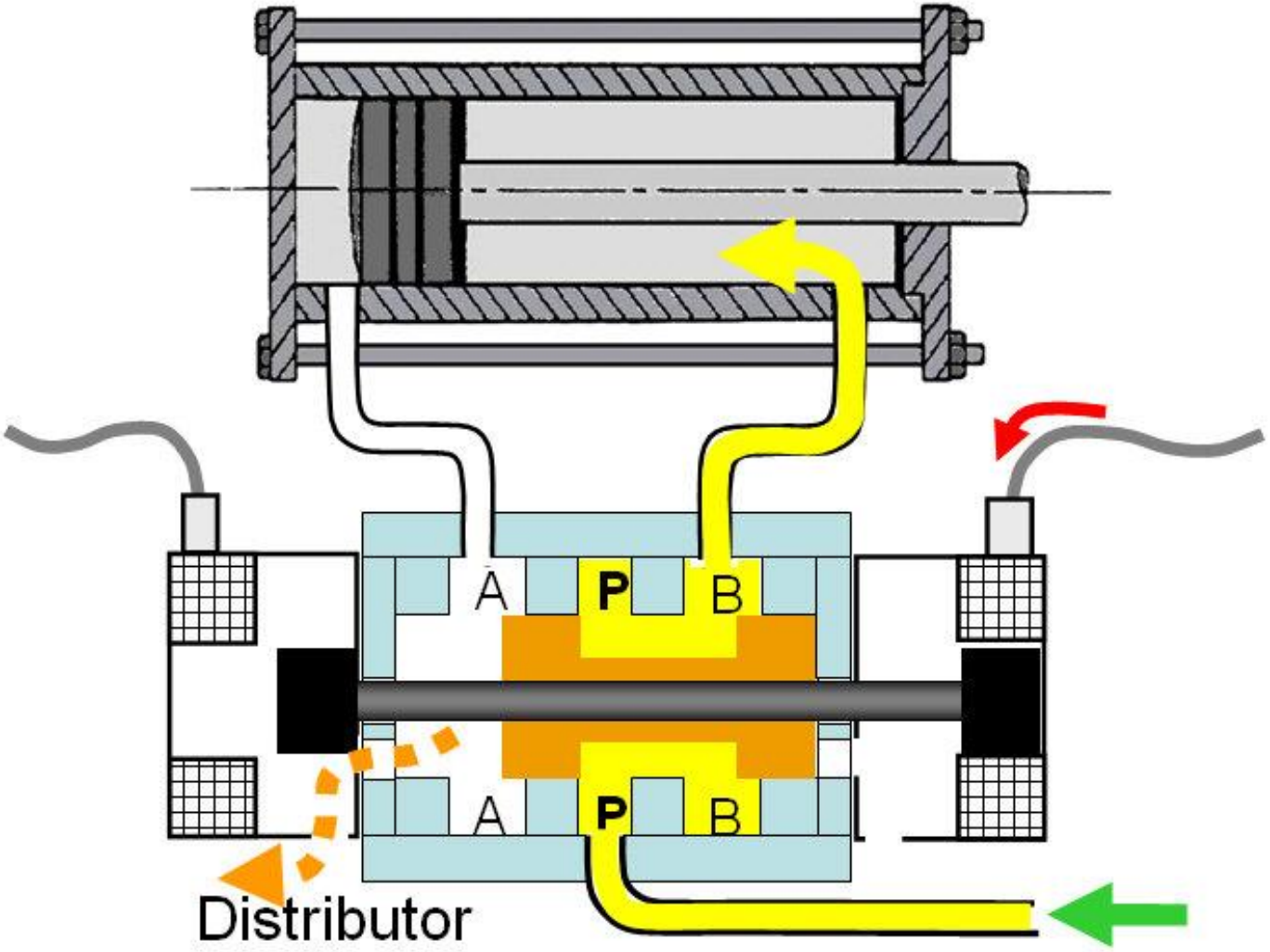
Speed is not controllable. The cylinder maximum speed is achieved when friction forces (kv^2) equal those that produce the advancing movement (F = P.S), and a = 0.



- The impact produced when reaching the end of the run is reduced using a shock absorber.



- Electrical valve: the hydraulic-electrical interface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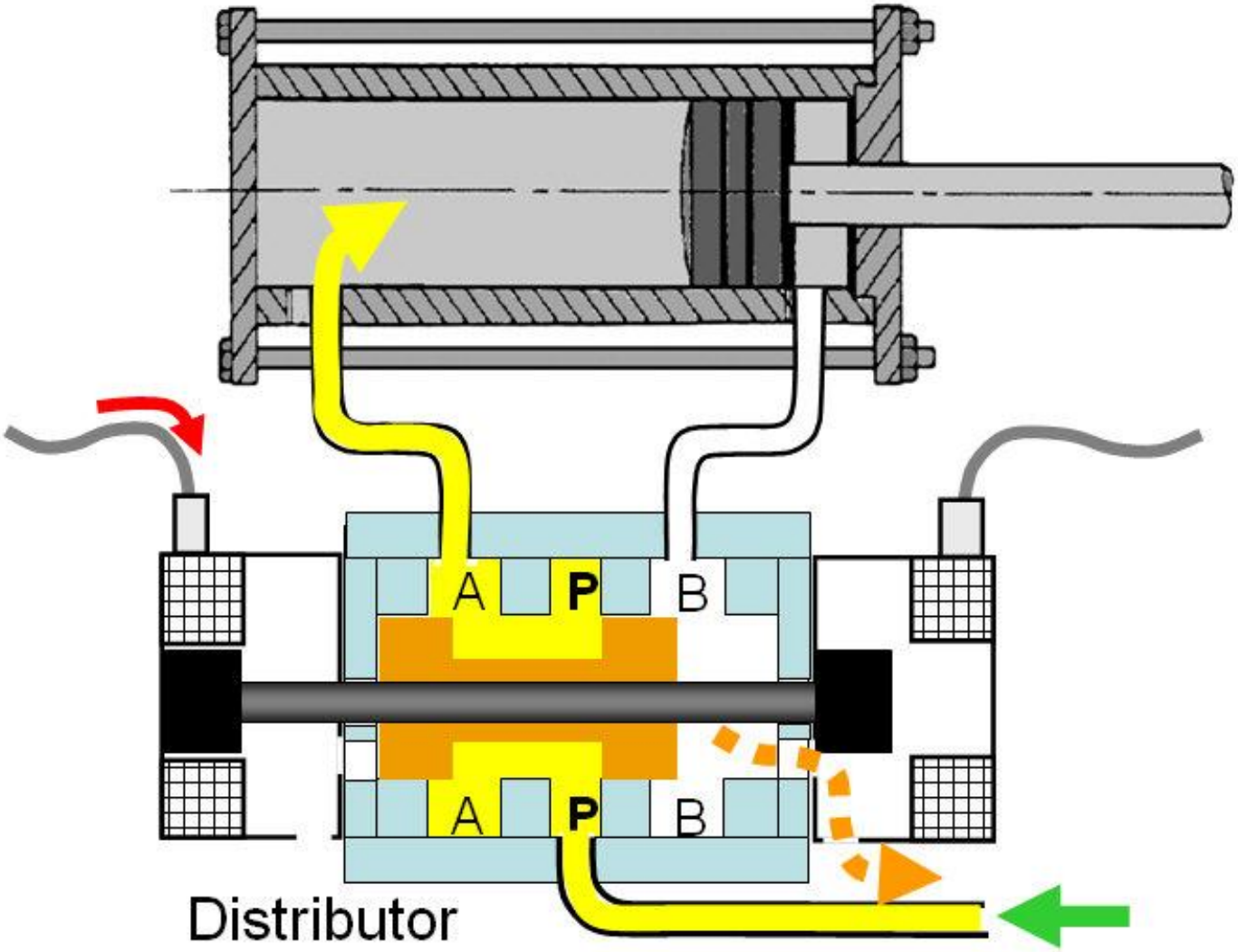
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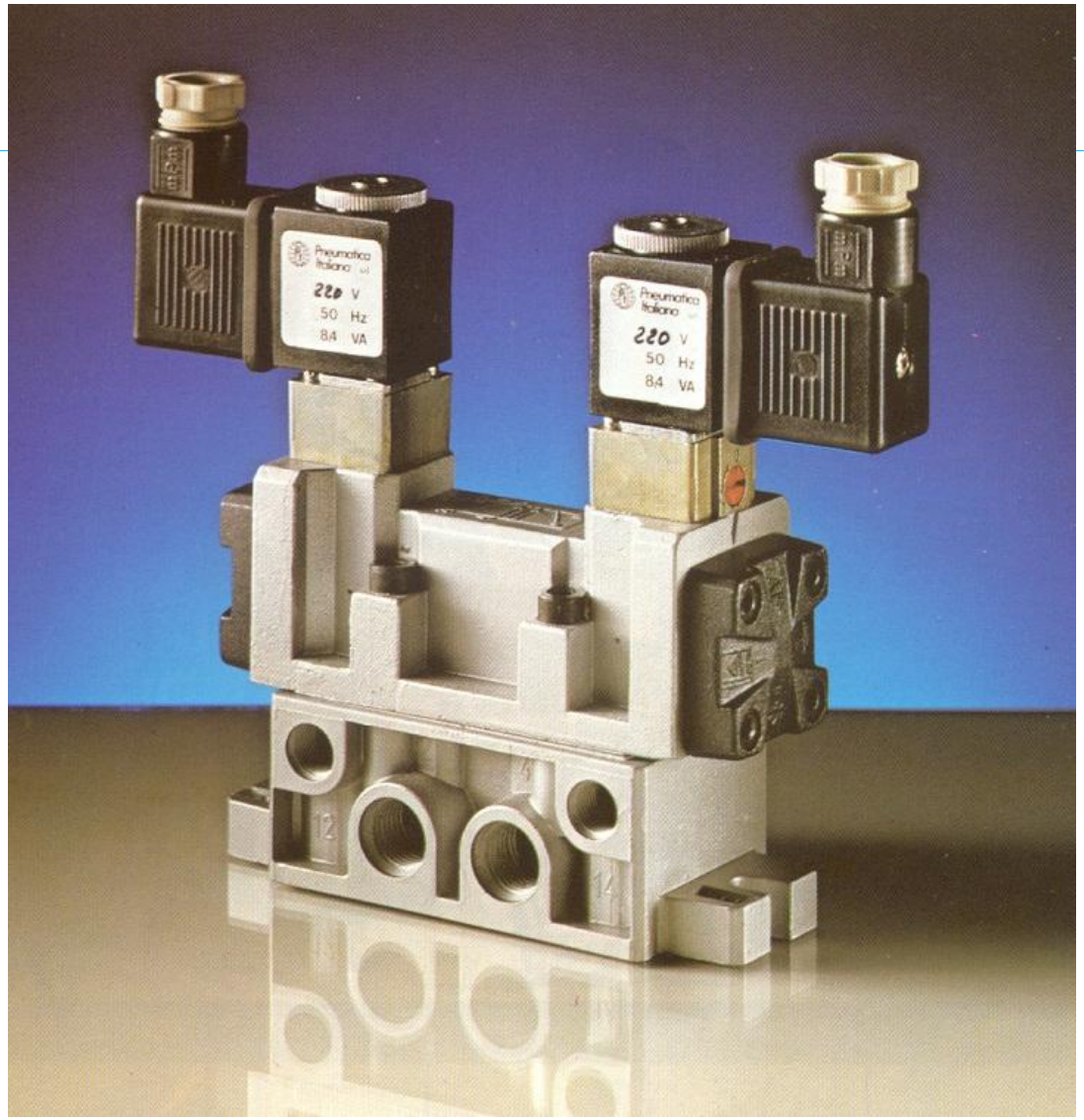

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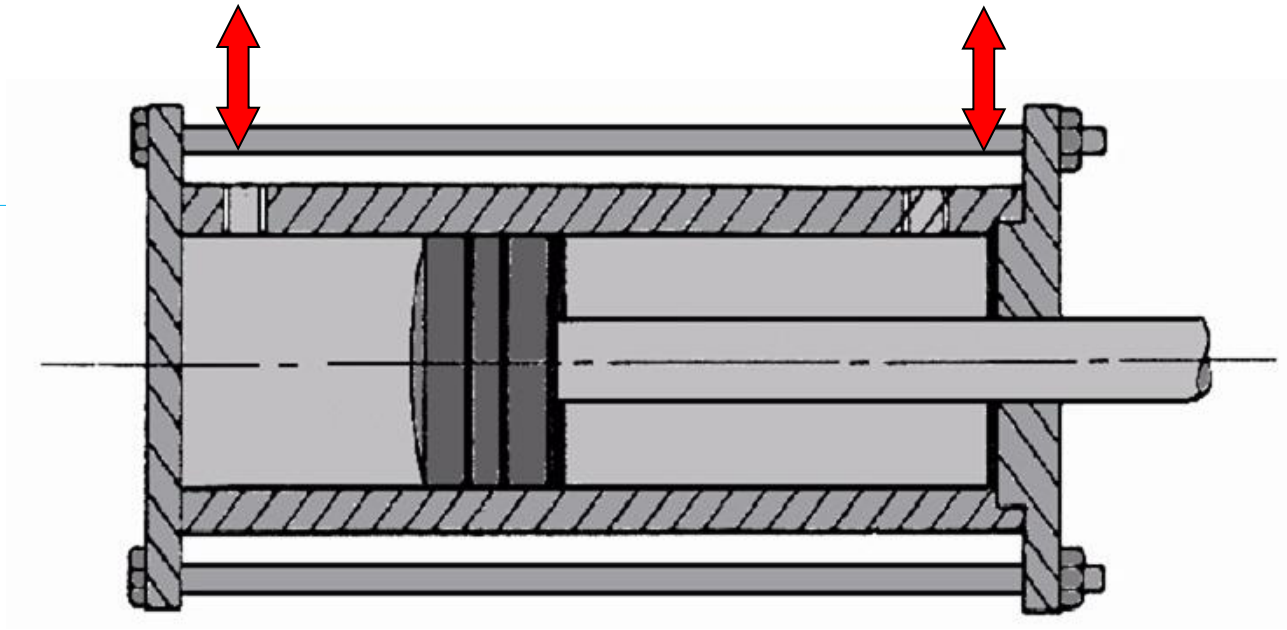
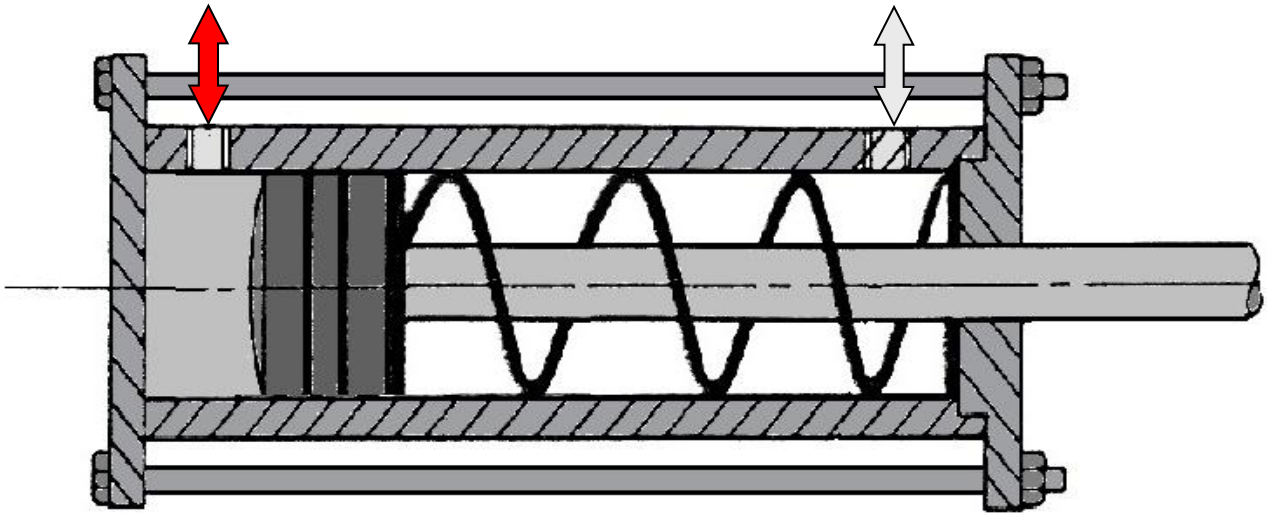


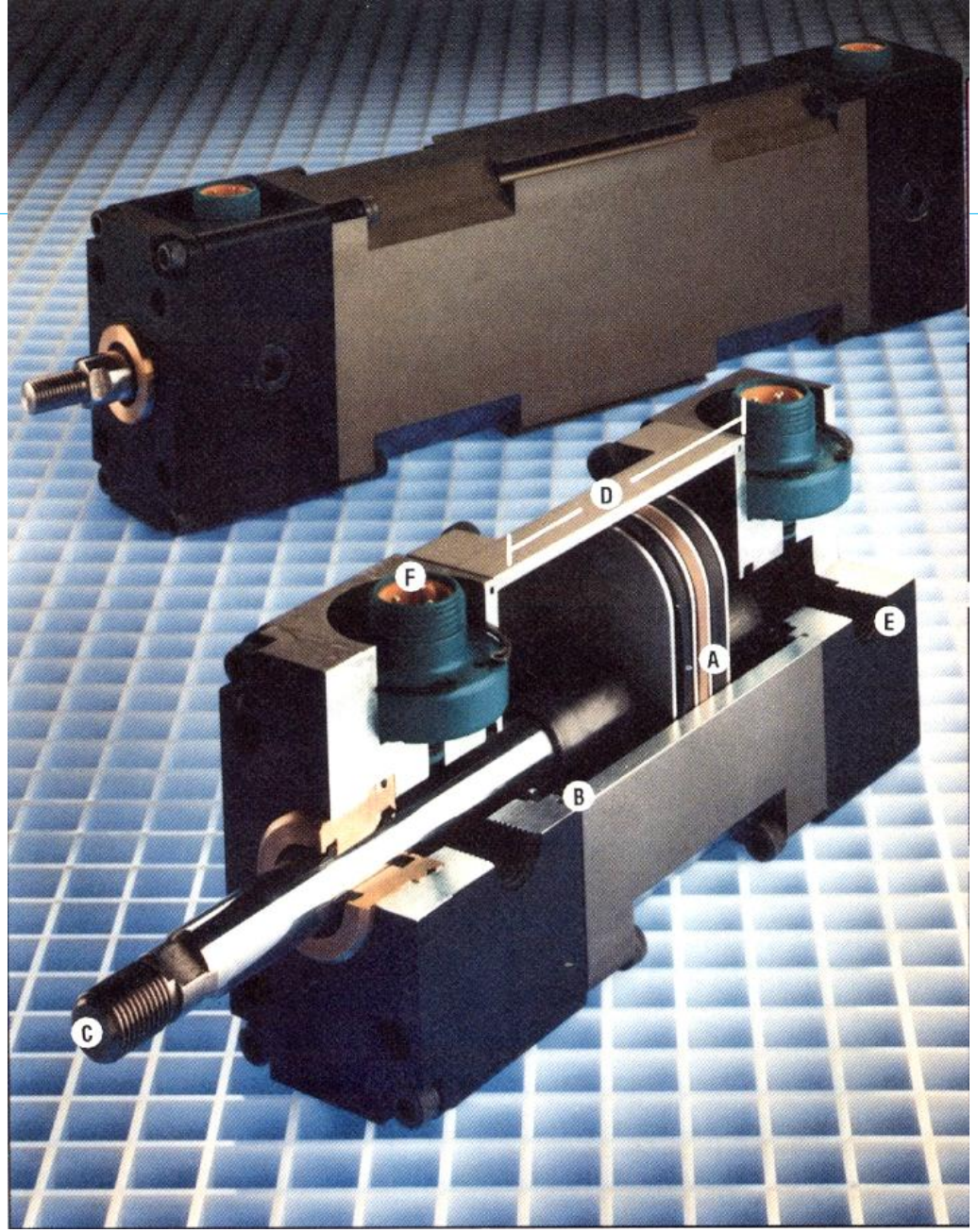
Double effect cylinders



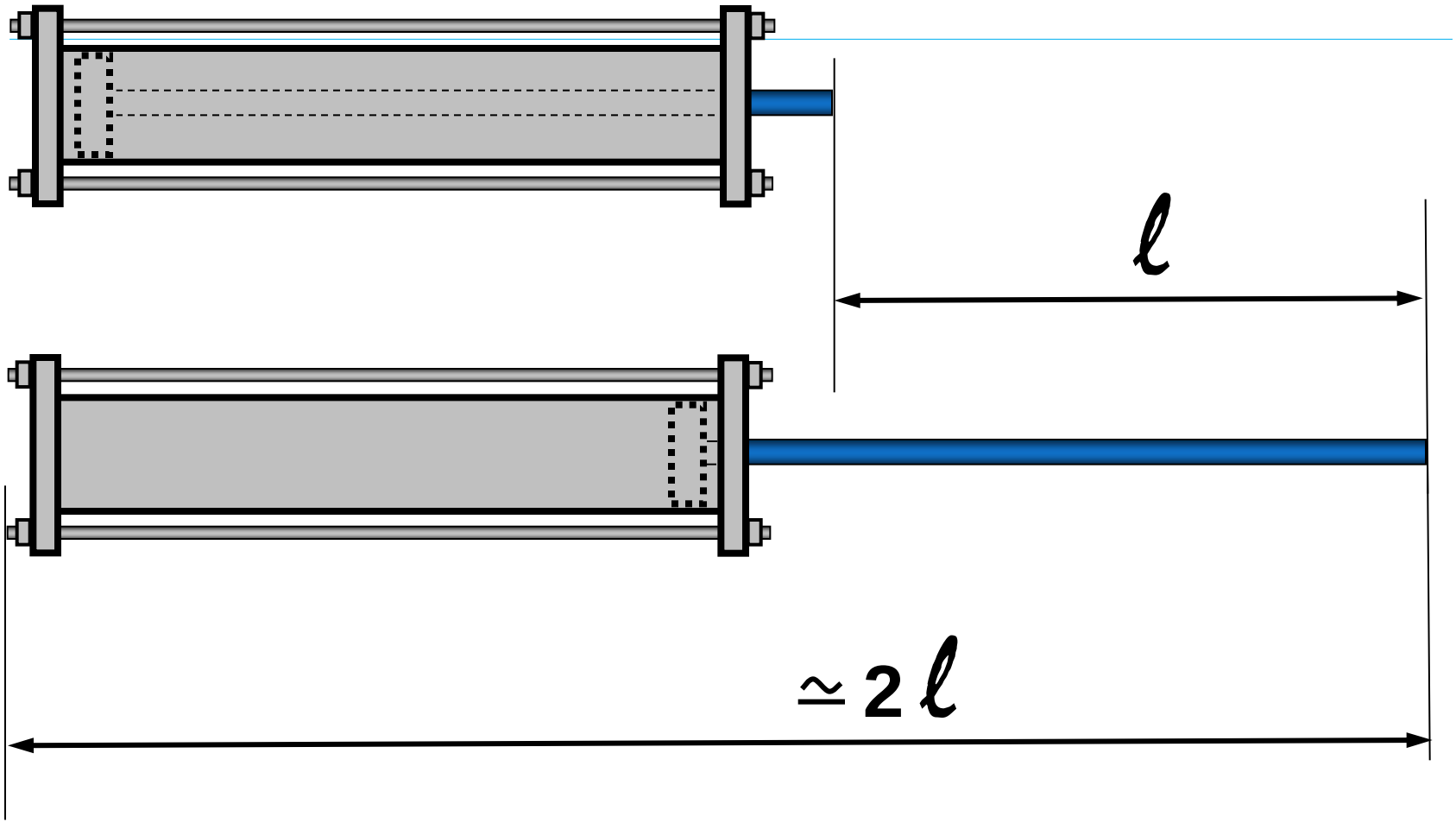
Single effect cylinders

Example of commercial pneumatic cylinders

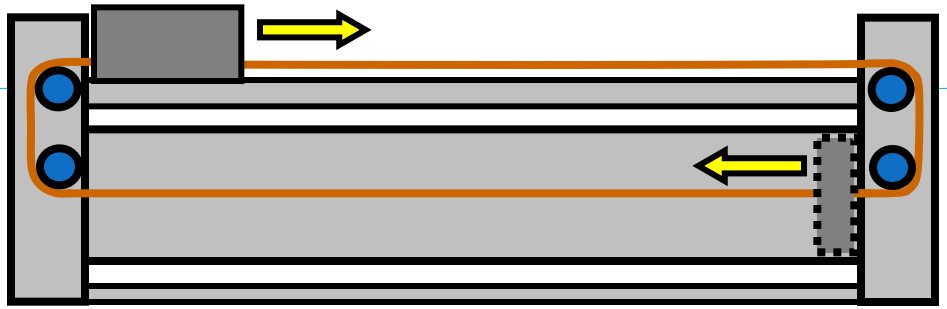
(Lateral guides to prevent axial rotation)

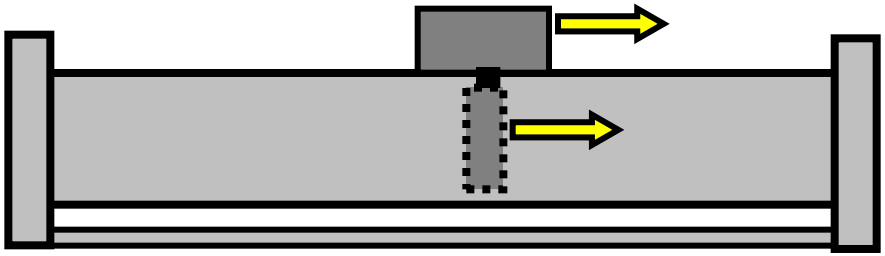


Oval pistons to prevent the rotation of the axis avoiding the need of auxiliary guides



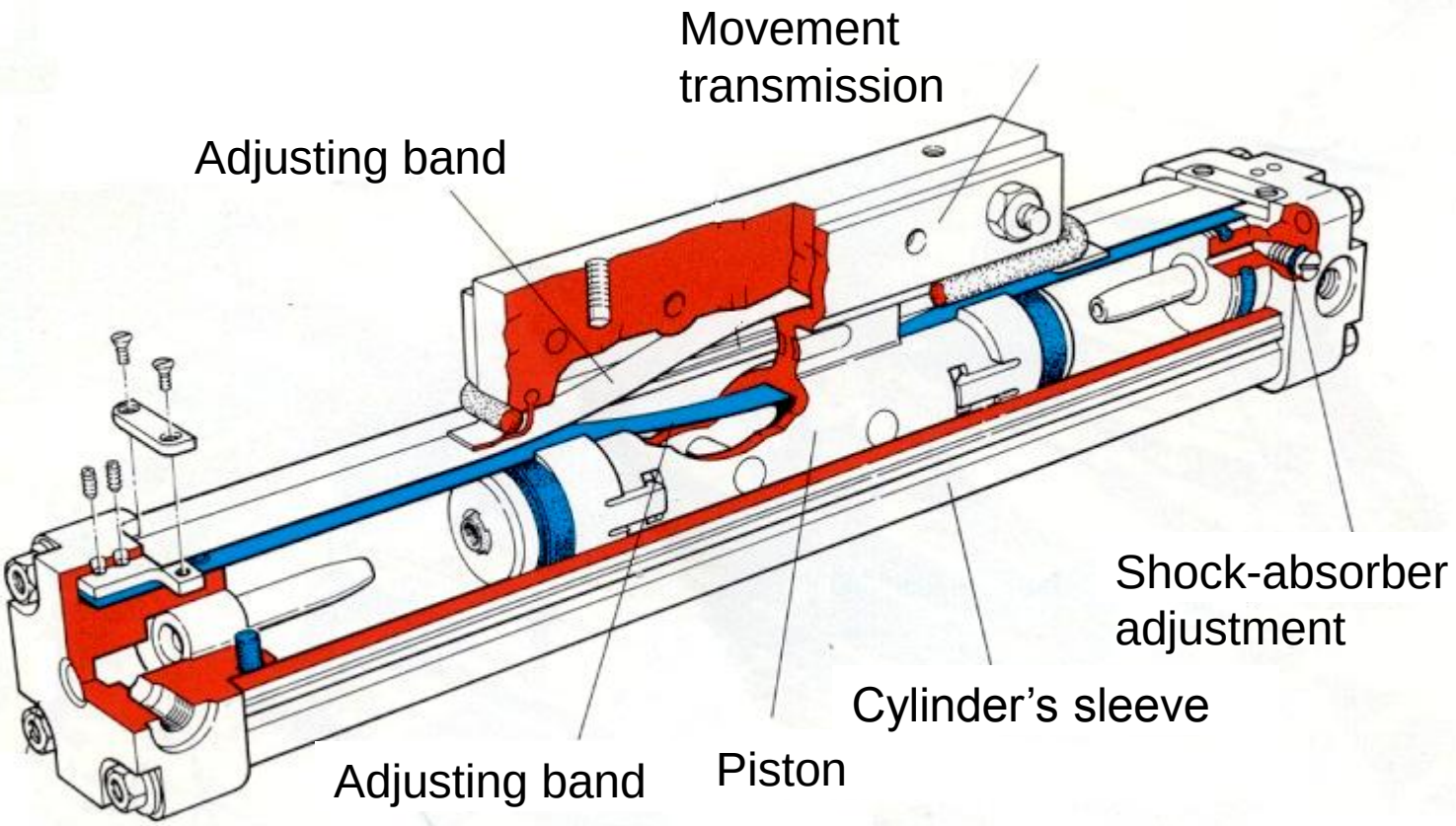
Classical cylinders drawbacks: a displacement of length ℓ requires an additional length ℓ.





$$\Delta \ell \simeq \ell$$

Solutions to reduce the occupied space

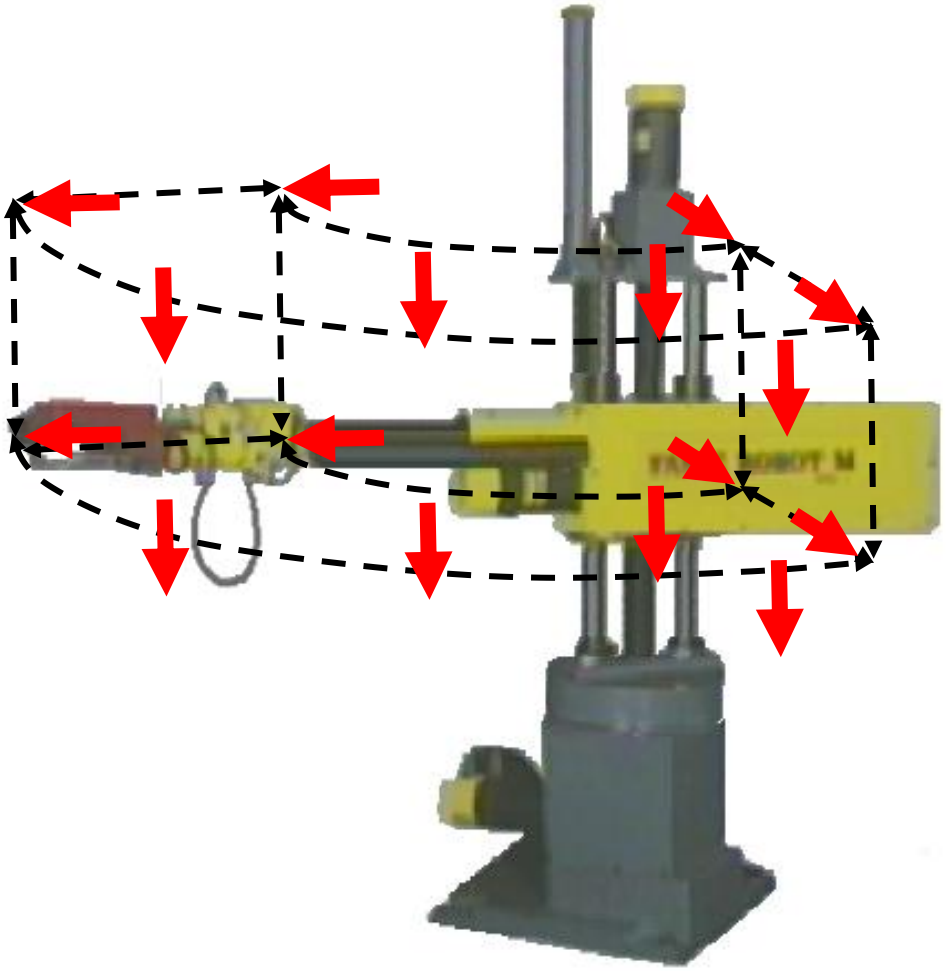

Movement
transmission
Adjusting band
Shock-absorber
adjustment
Cylinder’s sleeve
Adjusting band
Piston


③
④
⑤
⑧
②
* ⑨
⑦
⑥
①
⑪

Pneumatic actuators (cylinders)

- Economic
- Reliable
- High operation speed
- Operation at constant force
- Resistant to overloads

- No speed control
- Poor position speed
- Noisy operation



Example of pneumatic manipulator, and its mechanical states (End positions of all its cylinders)

ACTUATORS

1 – Pneumatic actuators

Cylinders

Motors

2 – Hydraulic actuadors

Cylinders

Motors

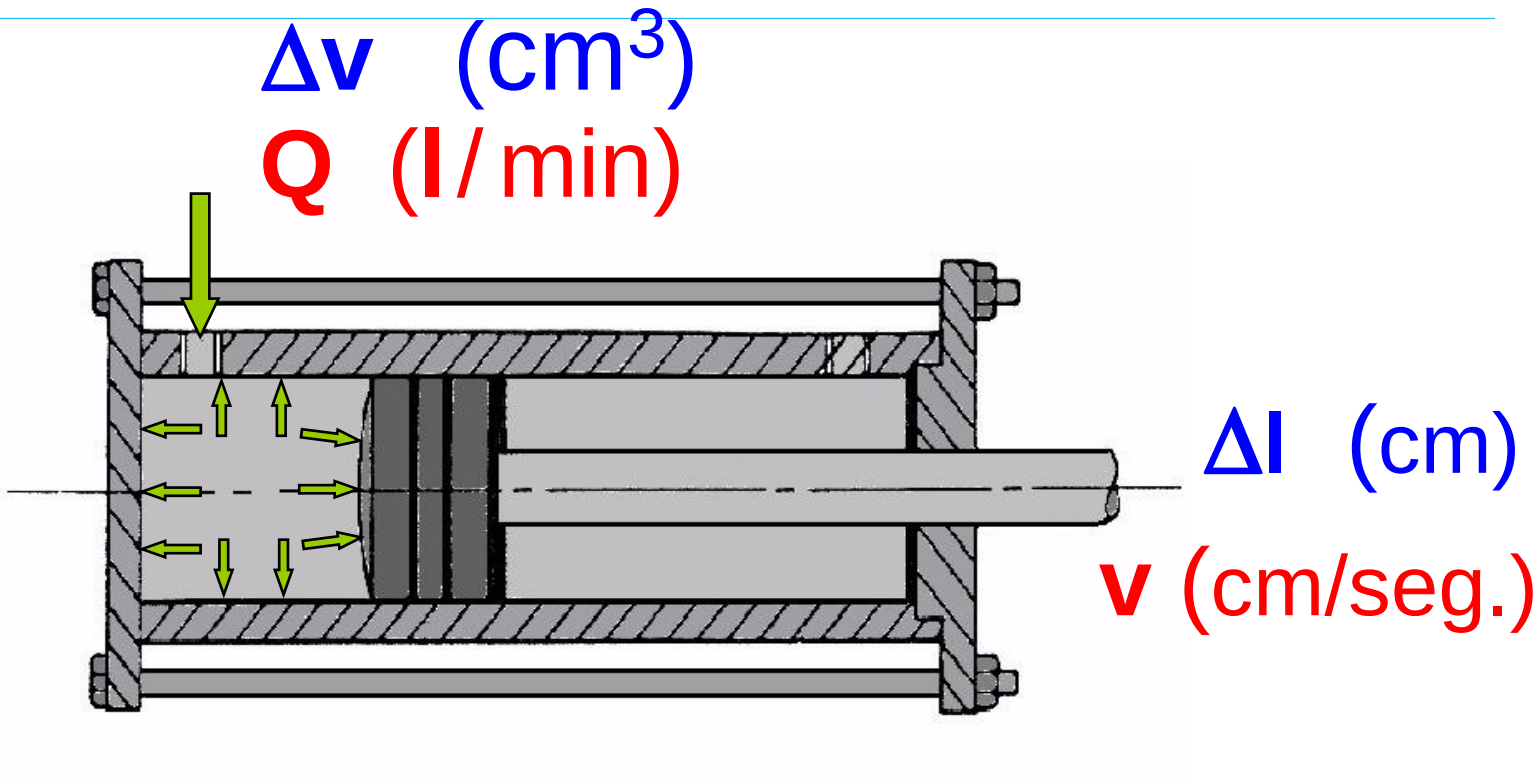
3 – Electrical actuators

Dc motors.

Ac motors

Steeper motors.

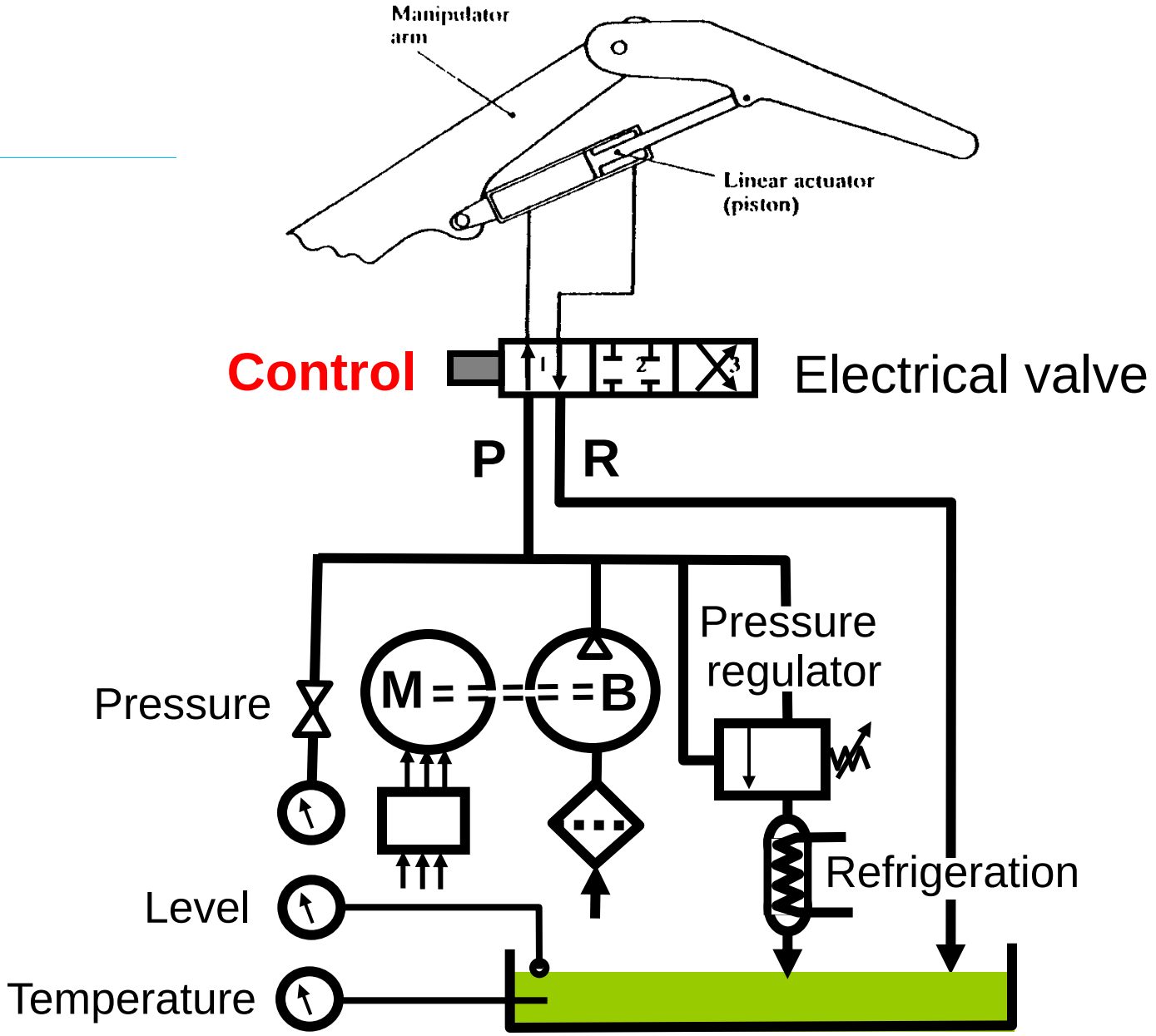
2 – Hydraulic actuators (cylinders)



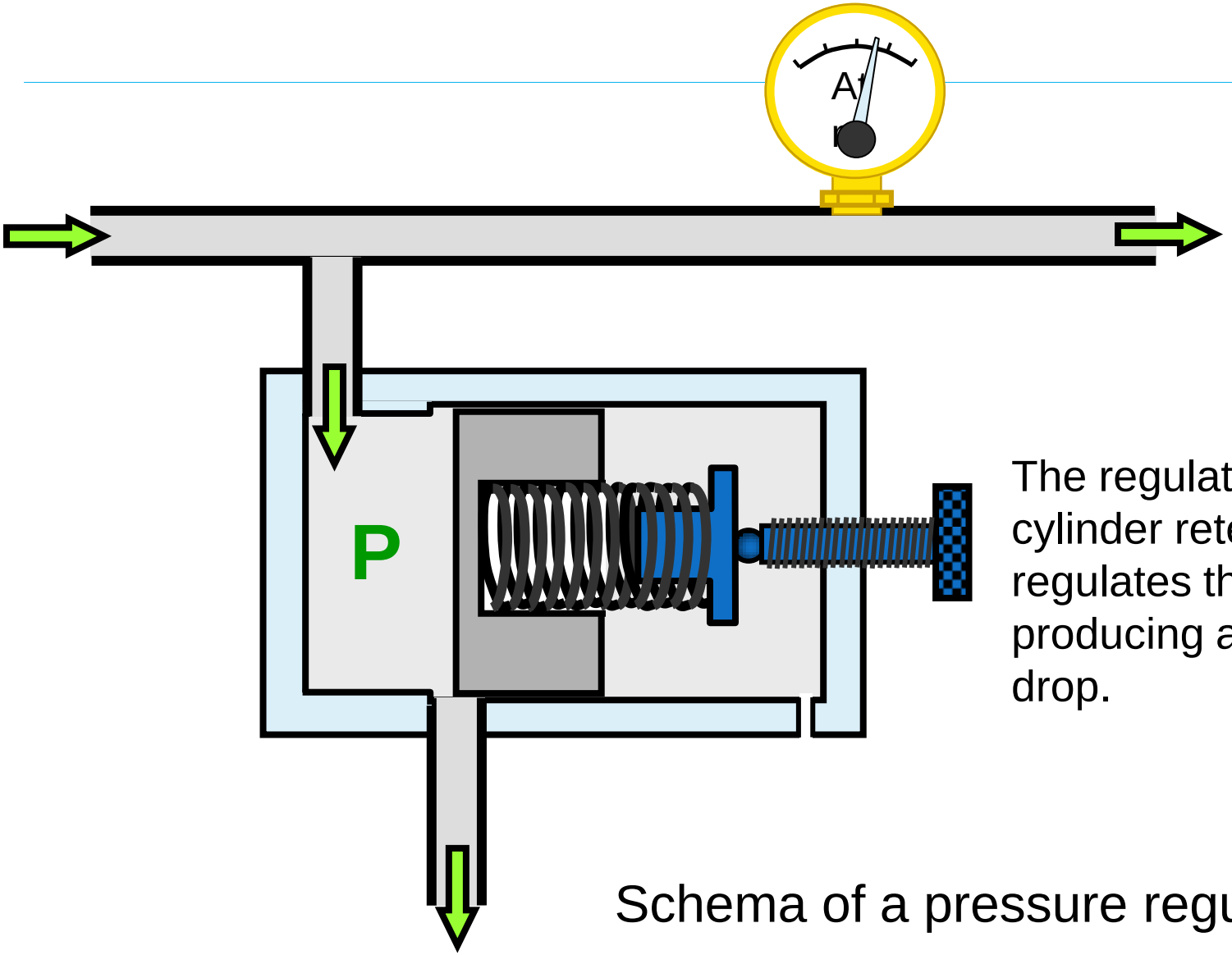
Energy source: oil pressurized between 20 and 300 bars.

$F = P * S$ If $P \uparrow\uparrow \rightarrow F \rightarrow \infty$

- Controllable position
- Controllable speed

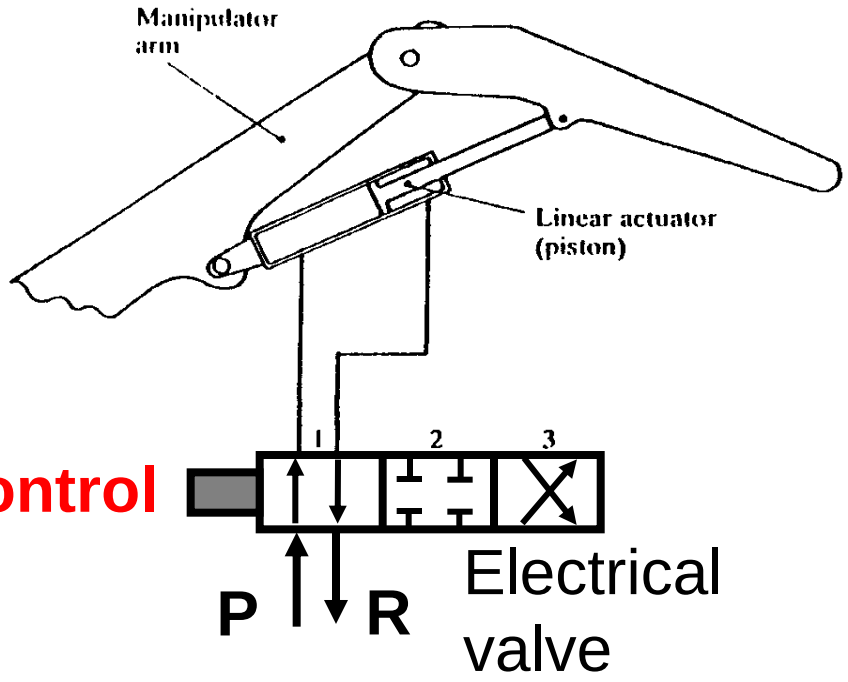


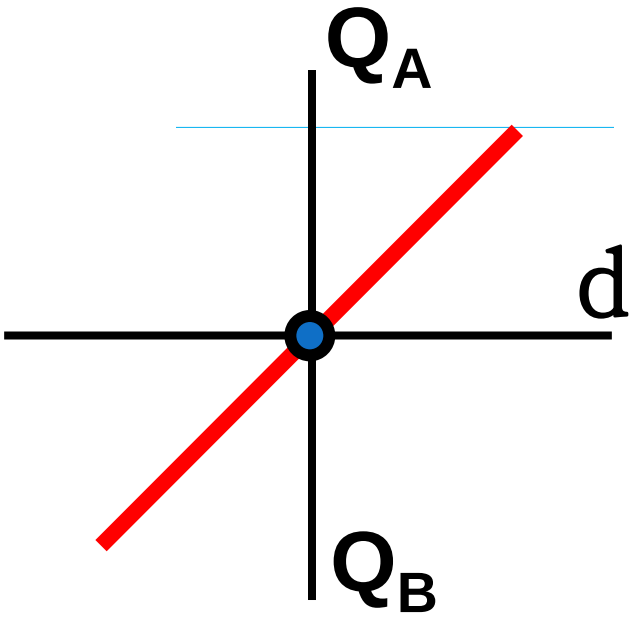
Hydraulic circuit showing its essential elements



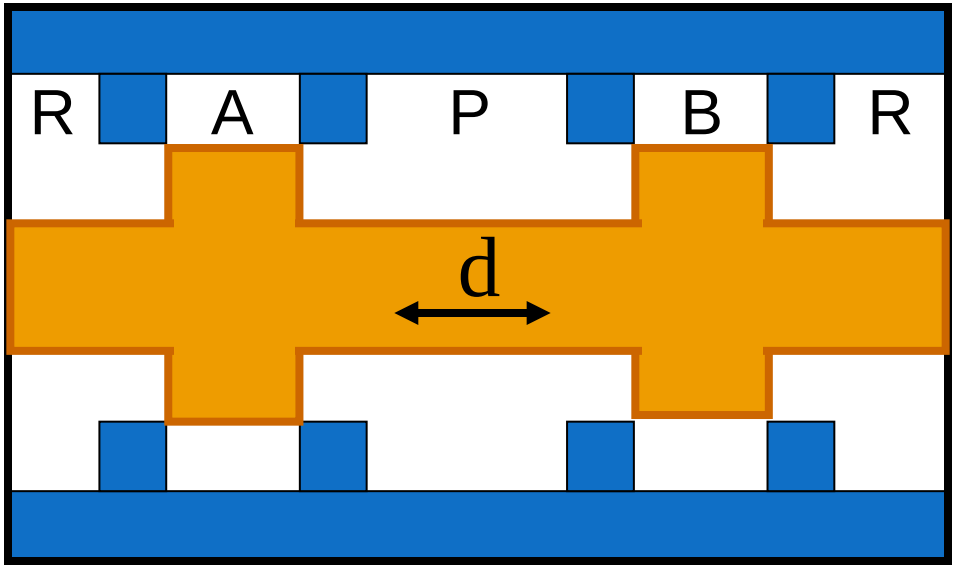
The regulation of the cylinder retention force regulates the oil output producing a pressure drop.

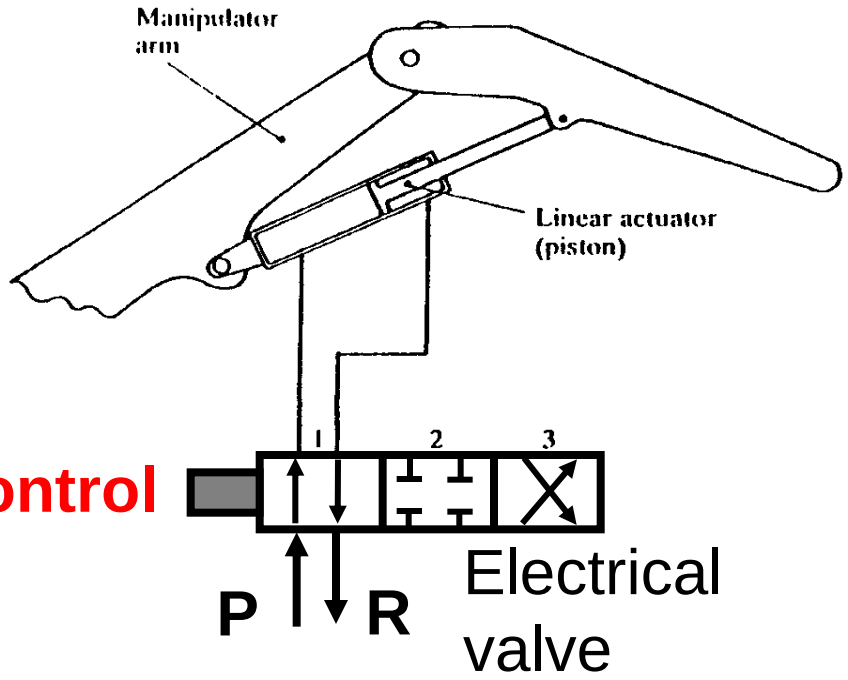
Schema of a pressure regulator

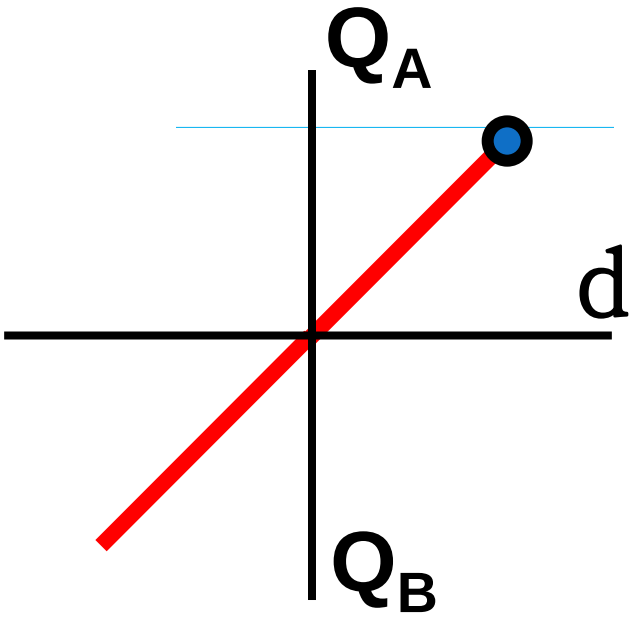


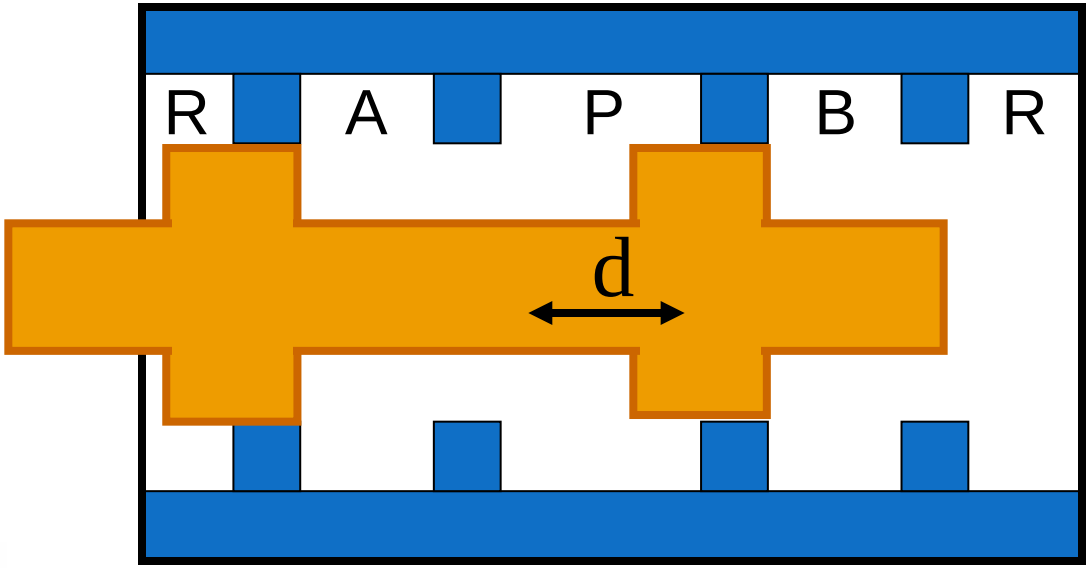


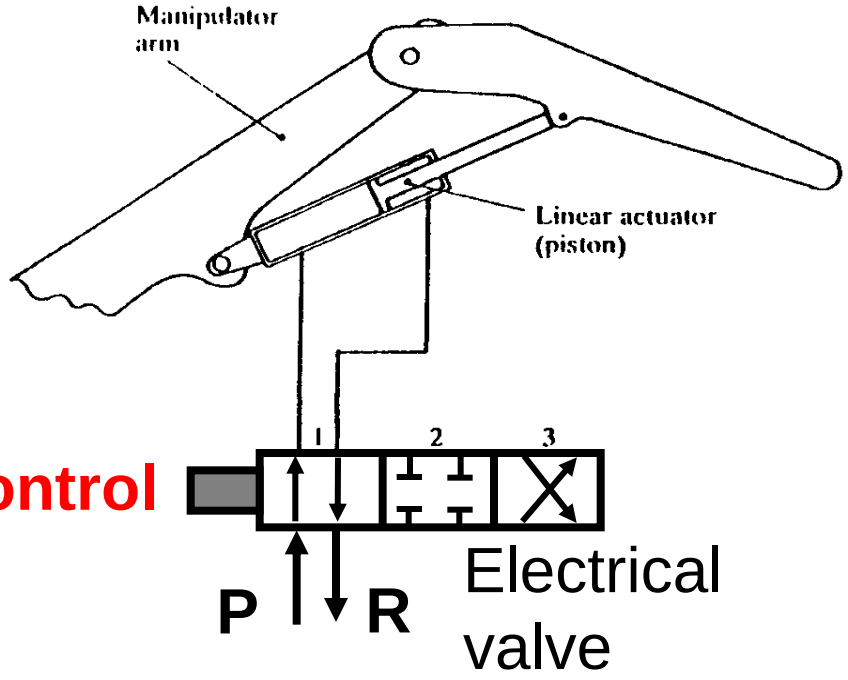
Ideal characteristic




Manipulator arm
Linear actuator (piston)
Control
1
2
3
P
R
Electrical valve


Q_A
d
Q_B


R
A
P
B
R
d


Manipulator arm
Linear actuator (piston)
Control
1
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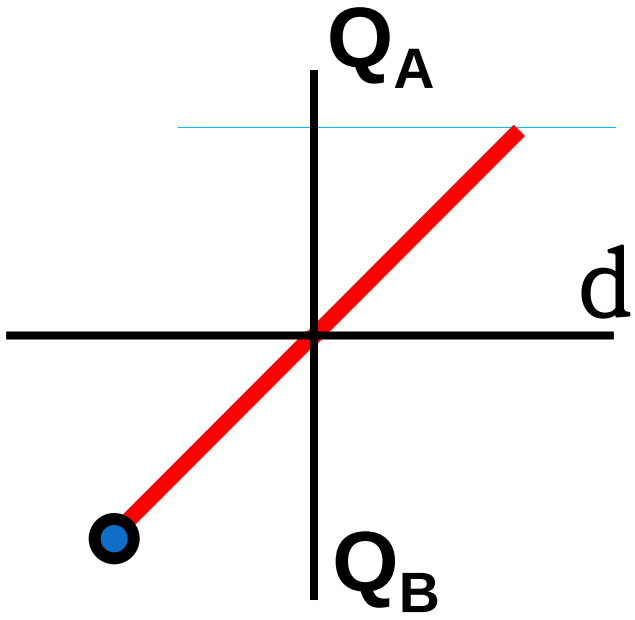
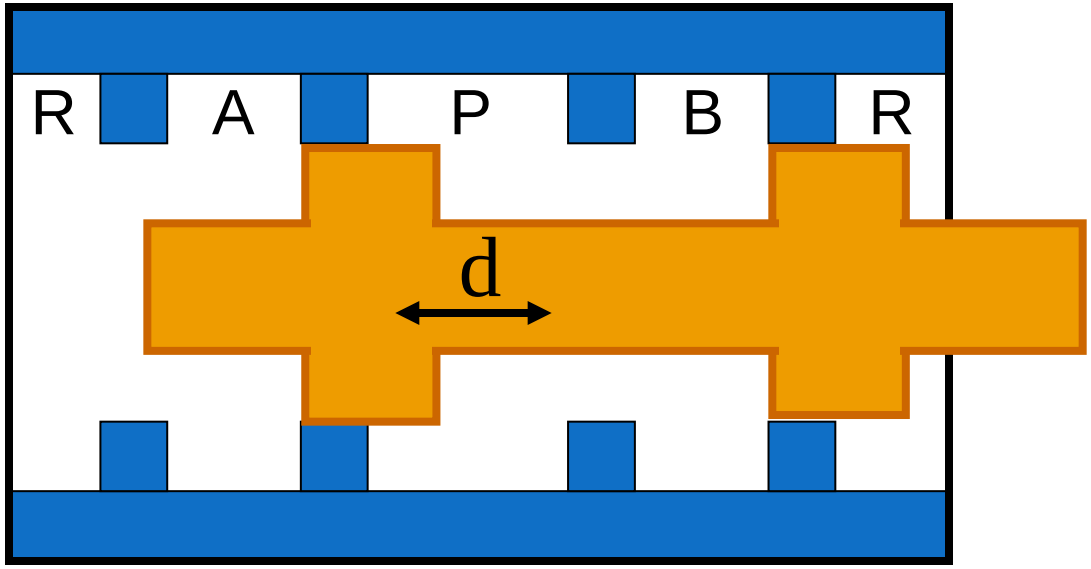
P
R
Electrical valve


Q_A
d
Q_B


R
A
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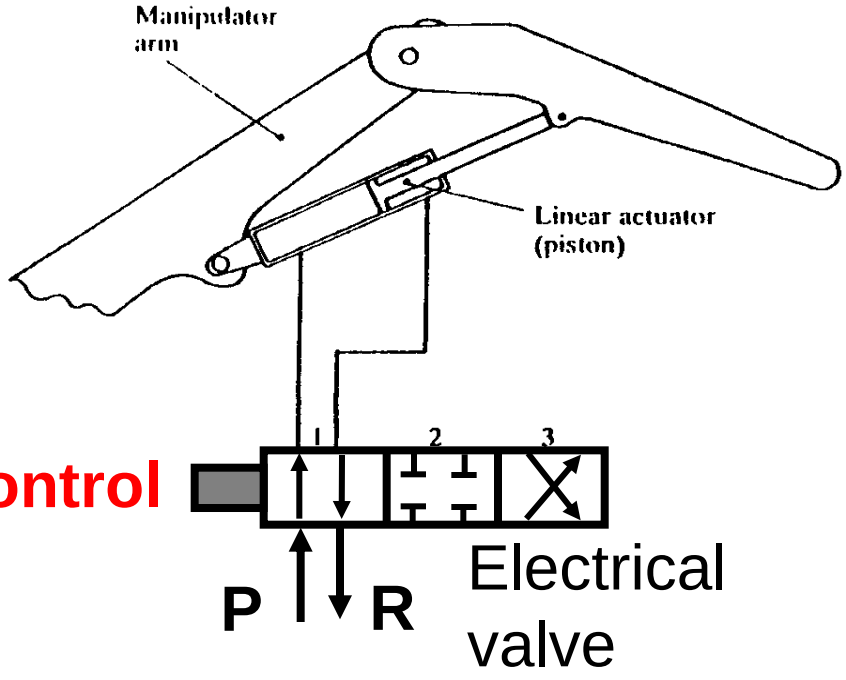
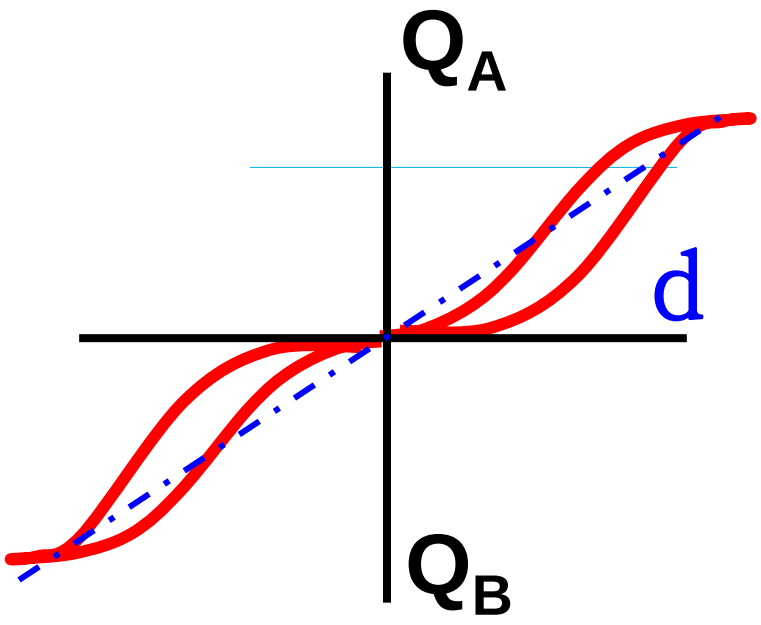
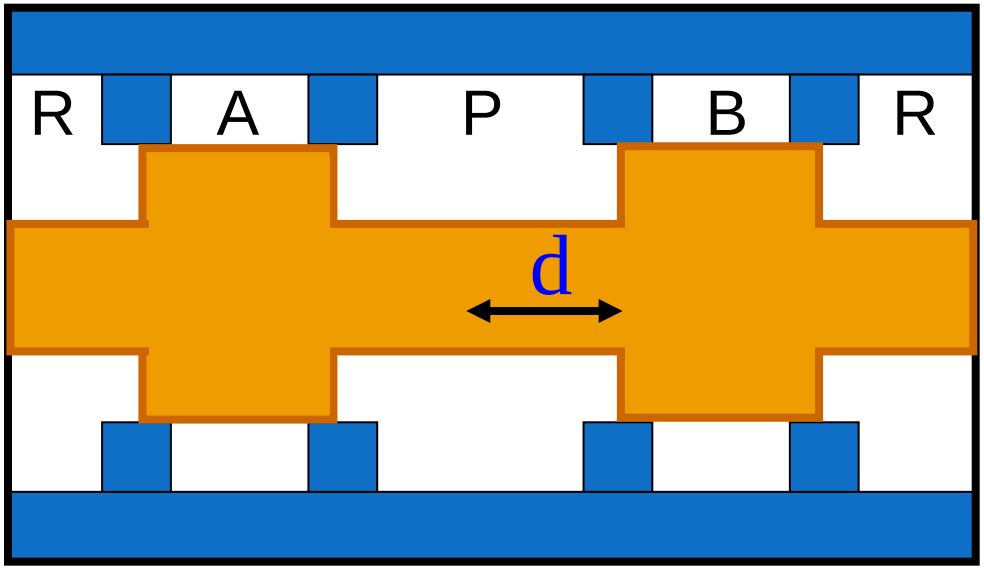
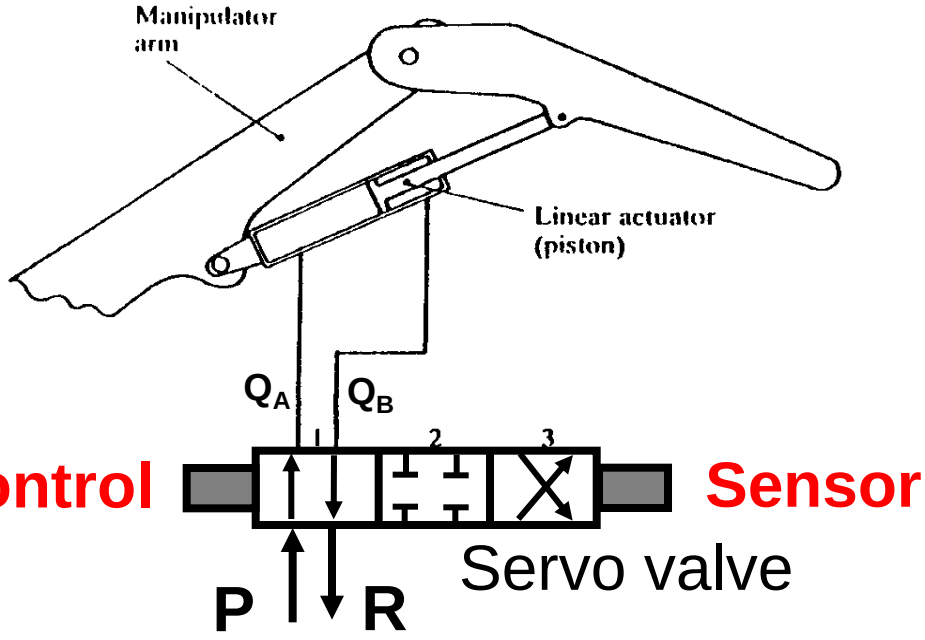
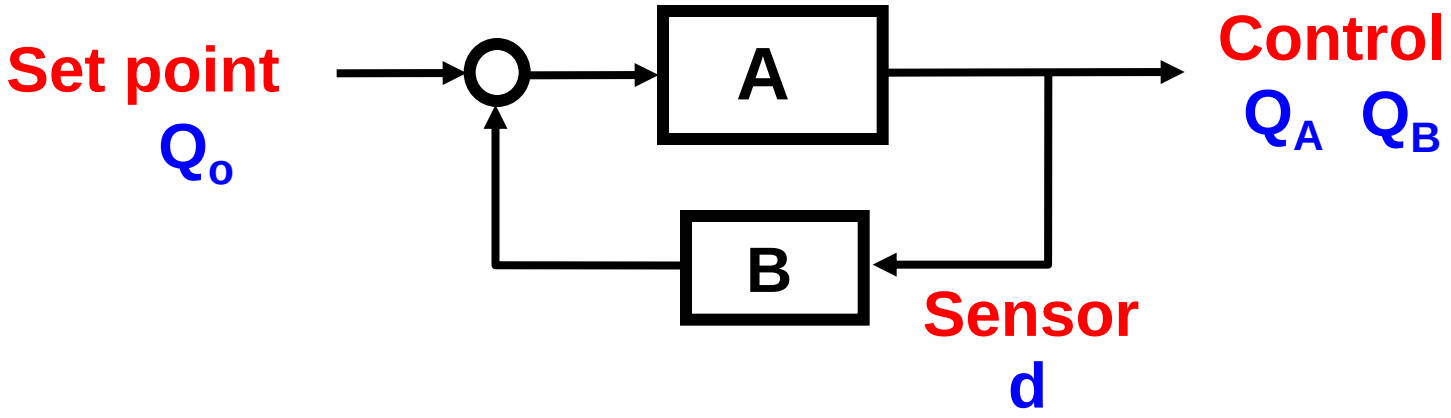




Real characteristic







The use of a position sensor d makes the position servo control possible and thus hysteresis is minimized. The dead zone is minimized as well.

ACTUATORS

1 – Pneumatic actuators

Cylinders

Motors

2 – Hydraulic actuadors

Cylinders

Motors

3 – Electrical actuators

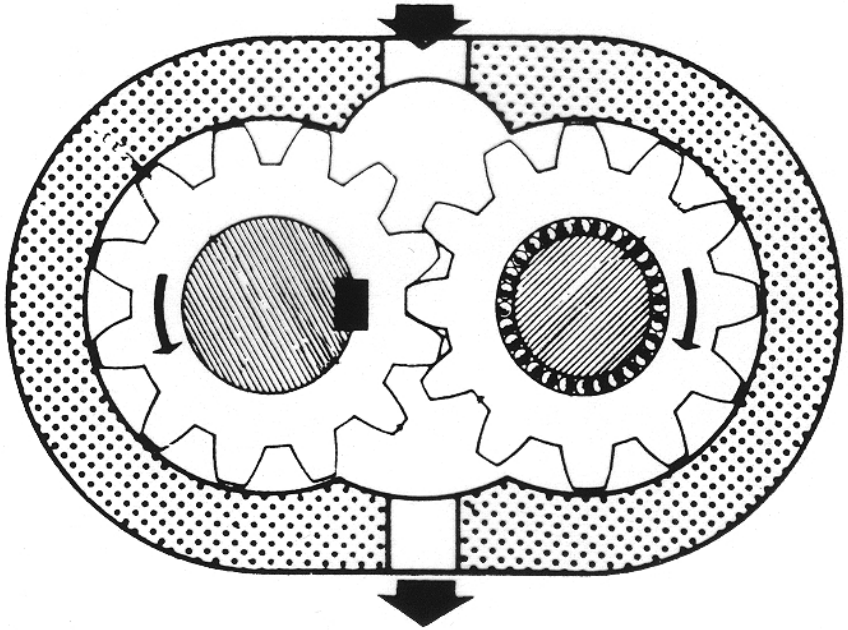
Dc motors.

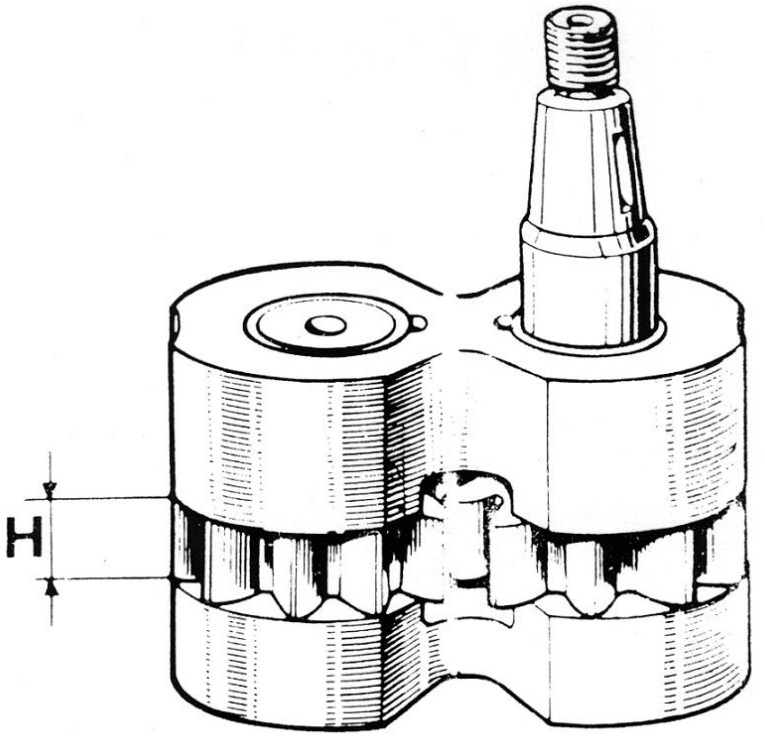
Ac motors

Steeper motors.

Hydraulic pumps and motors

(Kind of gears)

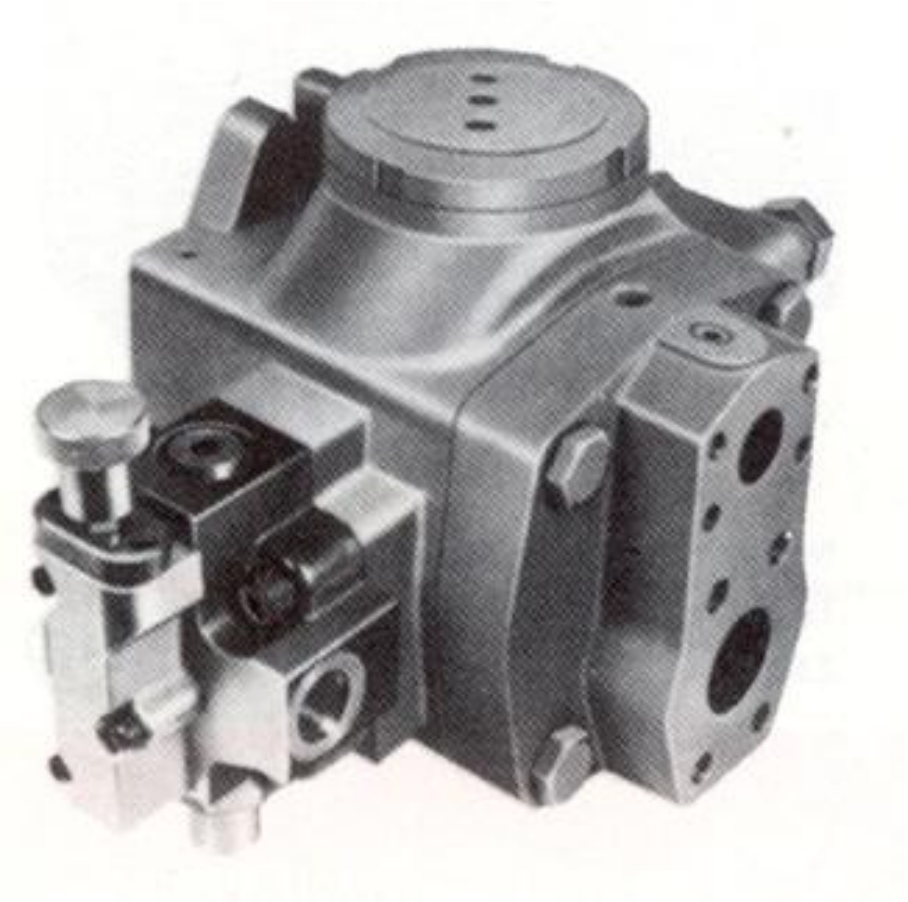




Fix caudal

Hydraulic pumps and motors

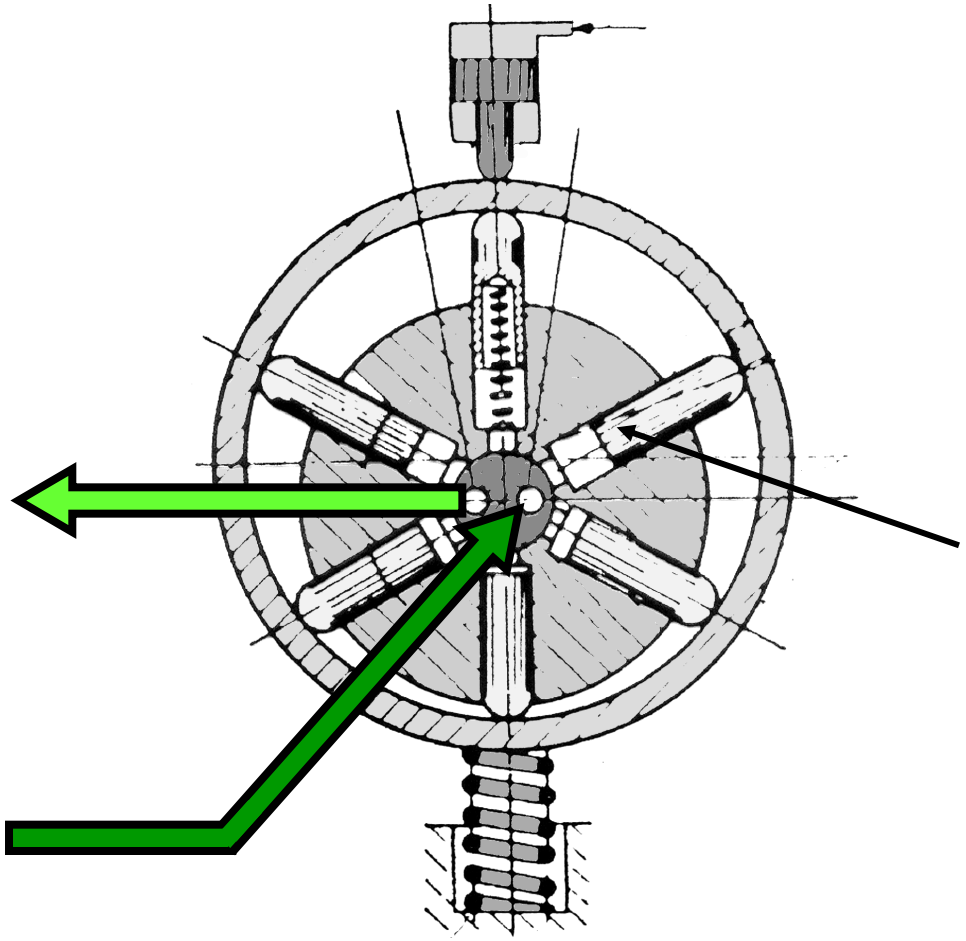
(Kind of gears)



Fix caudal

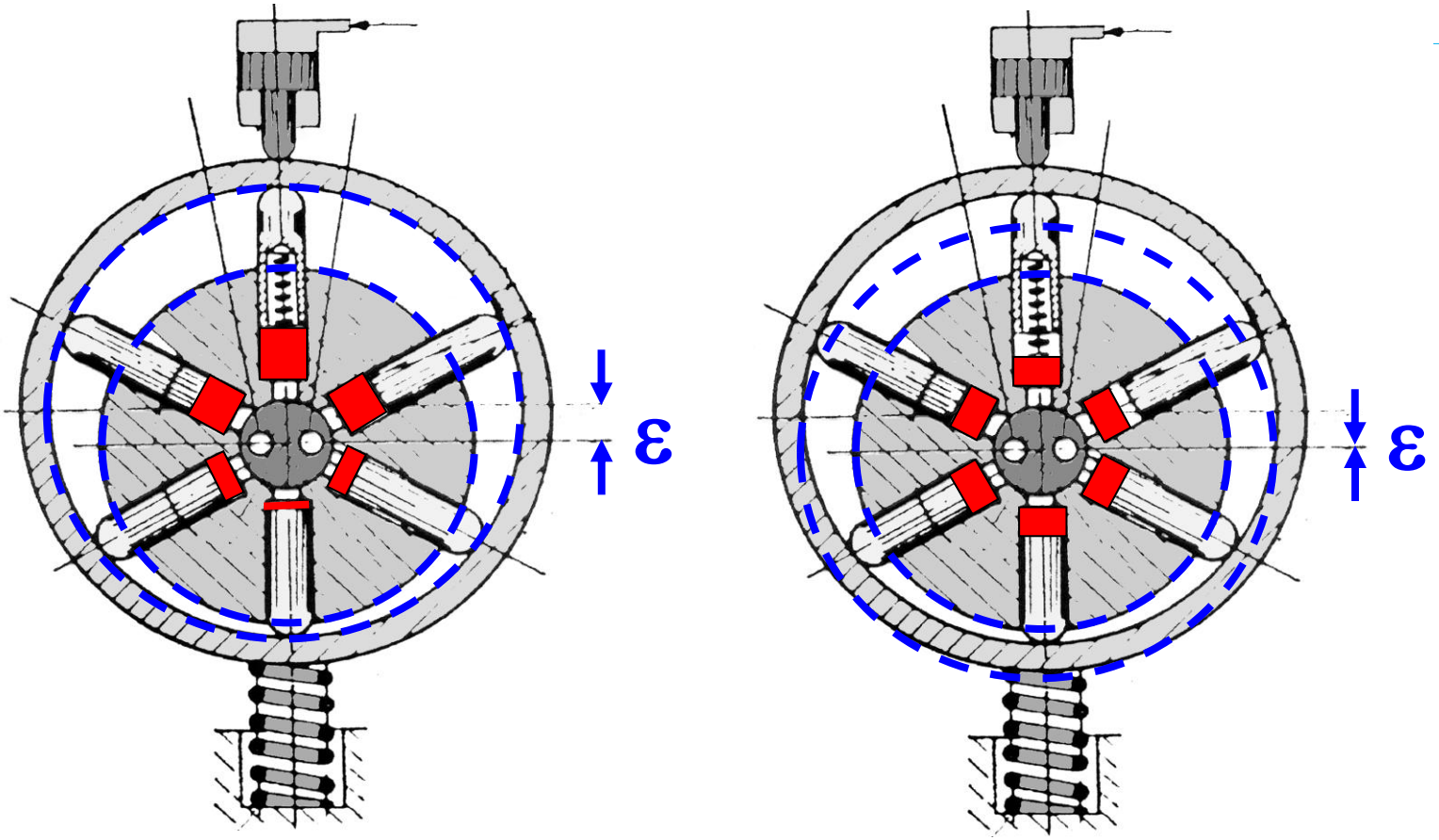
Hydraulic pumps

(Kind of radial pistons)



Cylindrical pumps

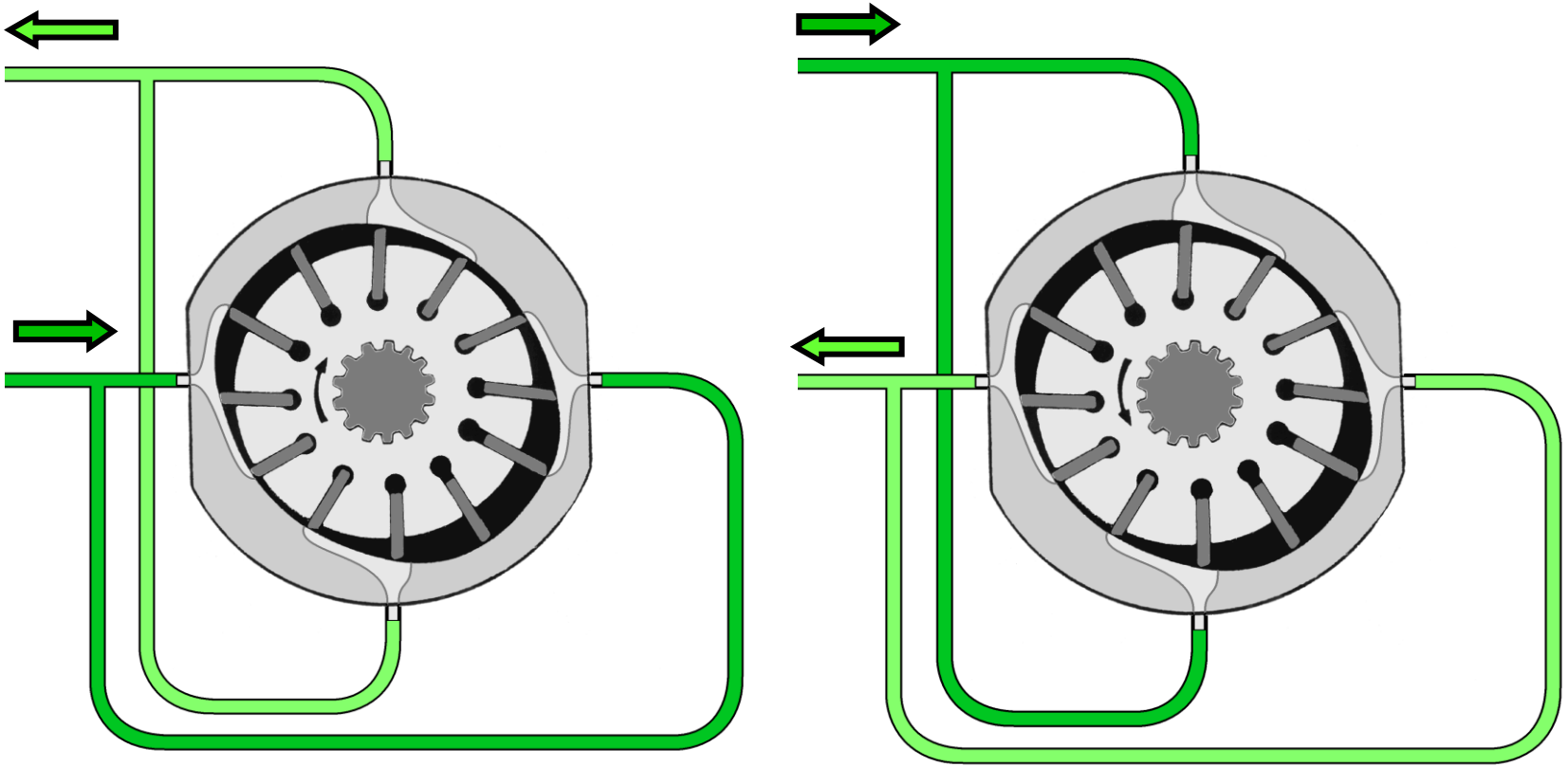
Variable caudal



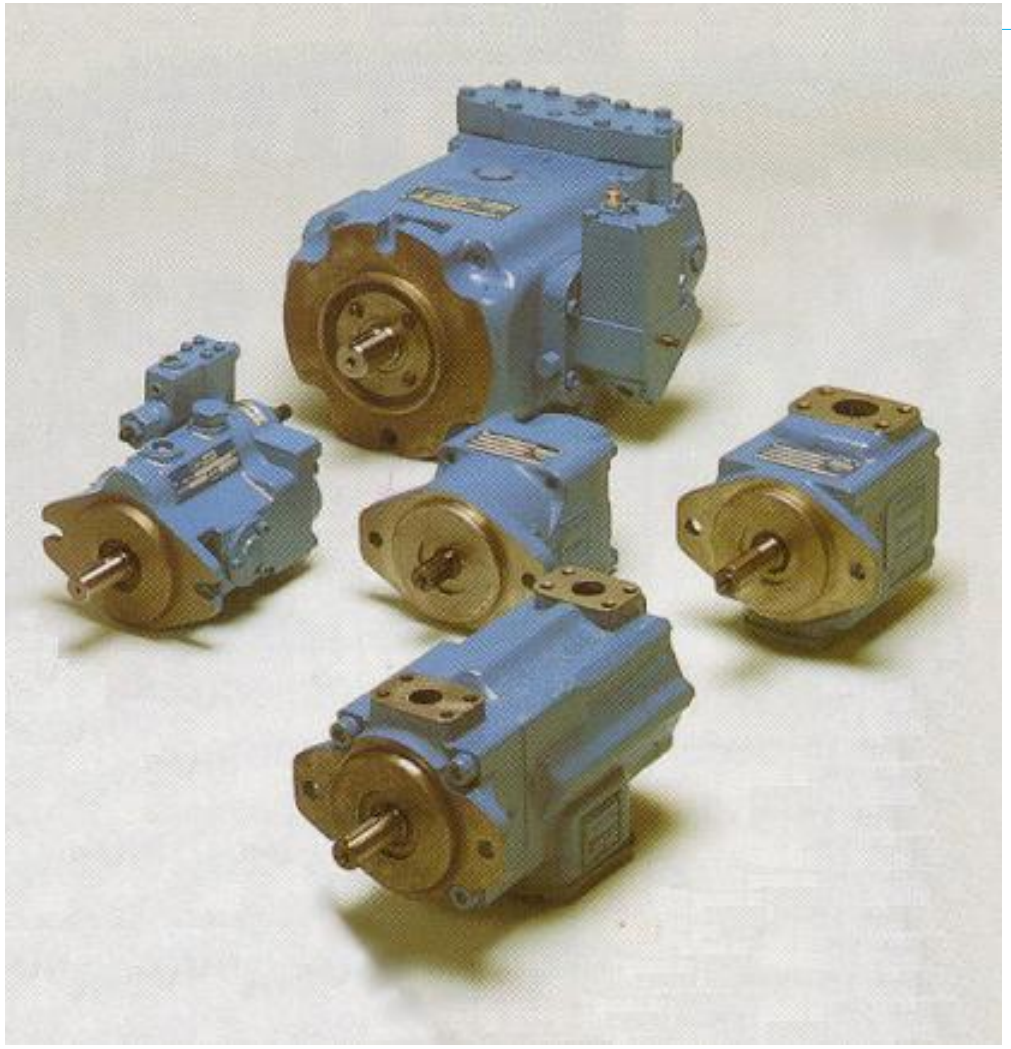
Caudal variation as a function of eccentricity **ε**

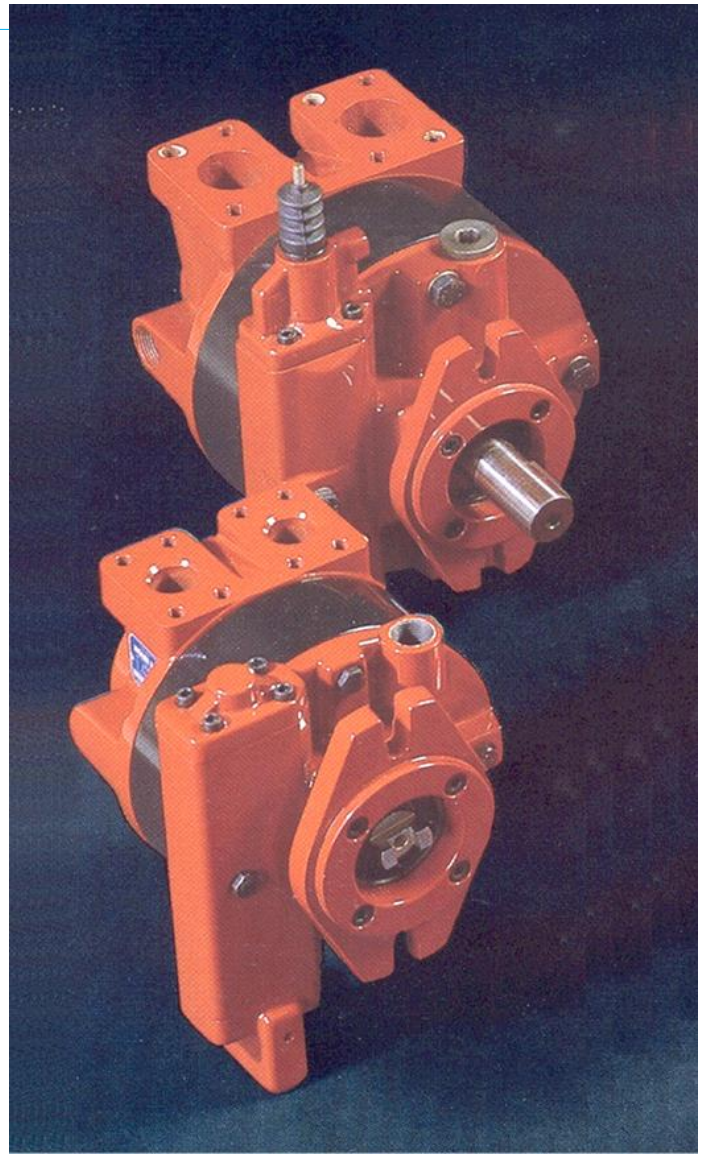
Hydraulic pumps and motors

(Kind of blades)



Hydraulic pumps or motors





Hydraulic actuators

- Economic
- Reliable
- Able to support heavy loads
- Resistant to overloads

- Low working speed
- Hydraulic group noisy in operation
- Possible oil leakage

INDUSTRIAL APPLICATIONS

- They are used in a wide range of **industries** where linear positioning is needed. The **actuators** are driven by several means including ball or lead screws, belts, or voice coils, among others. Typical **applications** include opening and closing dampers, locking doors, braking machine motions, etc.

- Link:https://www.kerryactuator.com/seven-types-of-actuators-for-industrial-applications

SELF LEARNING QUESTIONS

1. Explain about types of Actuators
2. Explain about types of Drive systems
3. Explain the advantages and disadvantages of Drive systems

ASSIGNMENT EXERCISES

1. Define Actuator? Explain types of Actuators?

2. Explain about Hydraulic and Pneumatic Actuators?

3. Explain about different Drive systems?

4. Explain the characteristics of different drive systems?

5. What are the Limitations of different drive systems?

THANK YOU

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AUTOMATION AND CONTROL ENGINEERING (R17A0327)

4th Year B. Tech I- sem, Mechanical Engineering

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COURSE OBJECTIVES

UNIT - 1	CO1: To perform one or more processing operations & To understand the need of Mechatronics systems
UNIT - 2	CO2: To make students familiar with the constructions and working principle of different types of sensors and transducers.
UNIT - 3	CO3: Understand the fundamental concepts of electro mechanics and fluid mechanics (hydraulics and pneumatics) of Actuators and drive systems.
UNIT - 4	**CO4: To impart knowledge on the control elements**
UNIT - 5	CO5: To understand the different control schemes generally used to get best output.

UNIT 4

CONTROL SYSTEM COMPONENTS

CO4: To impart knowledge on the control elements

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UNIT – IV (SYLLABUS)

Control system components

- Introduction, classification of control system- classification of control systems on the basis of control signal used, Adaptive control system, Process control systems

COURSE OUTLINE

UNIT - 4

LECTURE	LECTURE TOPIC	KEY ELEMENTS	LEARNING OBJECTIVES
1	Introduction to control system	Define control system	Understanding of basics of control system (B2)
2	Classification of control system - Open and closed loop control system - Linear and Non-linear control system - Continuous time and discrete time control system - Lumped and distributed parameter control system	Types of control system	Understanding of types of control systems (B2)
3	Adaptive control system	Working principle of Types of control systems	• Understand the applications of control systems in various systems and to know the functions of each element(B2) • Analyze the control system in machines (B4)
4	Process control systems		

LECTURE 1

Introduction to control system

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TOPICS TO BE COVERED

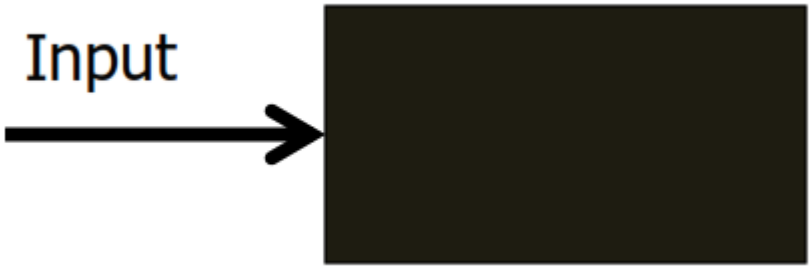
- Introduction to control system
- Classification of control system
- Adaptive control system
- Process control systems

LECTURE 1

Introduction to control system

INPUT

- The stimulus or excitation applied to a control system from an external source in order to produce the output is called input

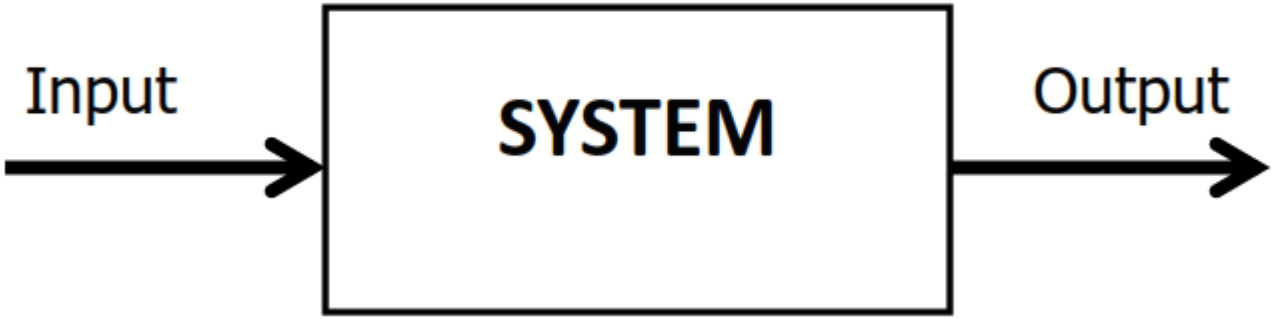


OUTPUT

- The actual response obtained from a system is called output.

SYSTEM

- A system is an arrangement of or a combination of different physical components connected or related in such a manner so as to form an entire unit to attain a certain objective.



CONTROL

- It means to regulate , direct or command a system so that the desired objective is attained

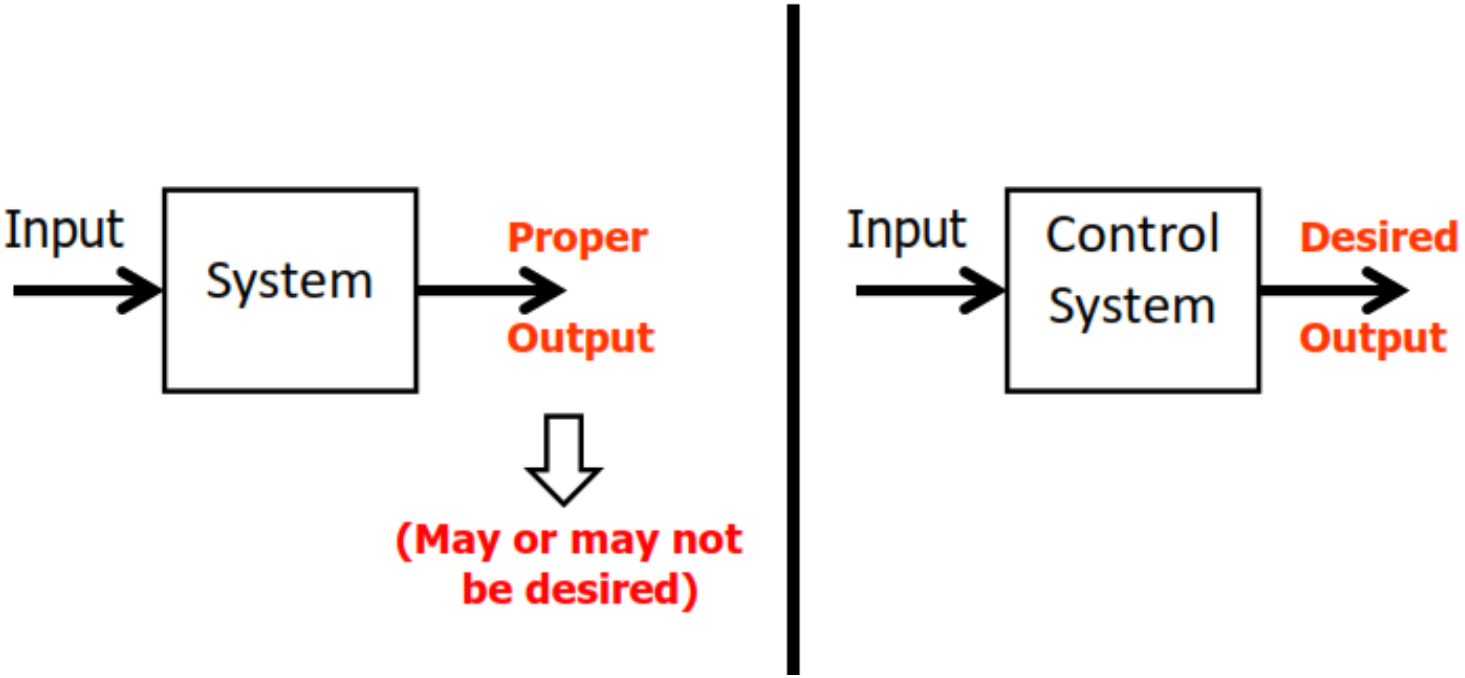
Combining above definitions

System + Control = Control System

CONTROL SYSTEM

- It is an arrangement of different physical elements connected in such a manner so as to regulate, direct or command itself to achieve a certain objective.

DIFFERENCE BETWEEN SYSTEM AND CONTROL SYSTEM



DIFFERENCE BETWEEN SYSTEM AND CONTROL SYSTEM

An example : Fan

A FAN: CAN'T SAY SYSTEM

- A Fan without blades cannot be a “SYSTEM” , Because it cannot provide a desired/proper output i.e. airflow

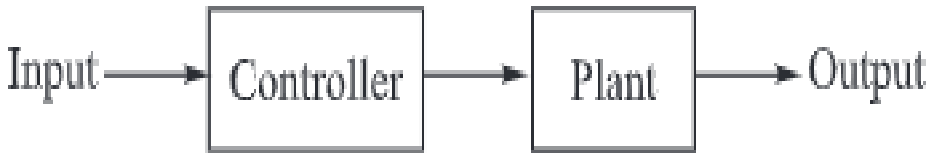
A FAN: CAN BE A SYSTEM

- A Fan with blades but without regulator can be a “SYSTEM” Because it can provide a proper output i.e. airflow
- But it cannot be a “Control System” Because it cannot provide desired output i.e. controlled airflow

CLASSIFICATION OF CONTROL SYSTEM

- In general control systems are classified into two categories—open loop and closed loop.

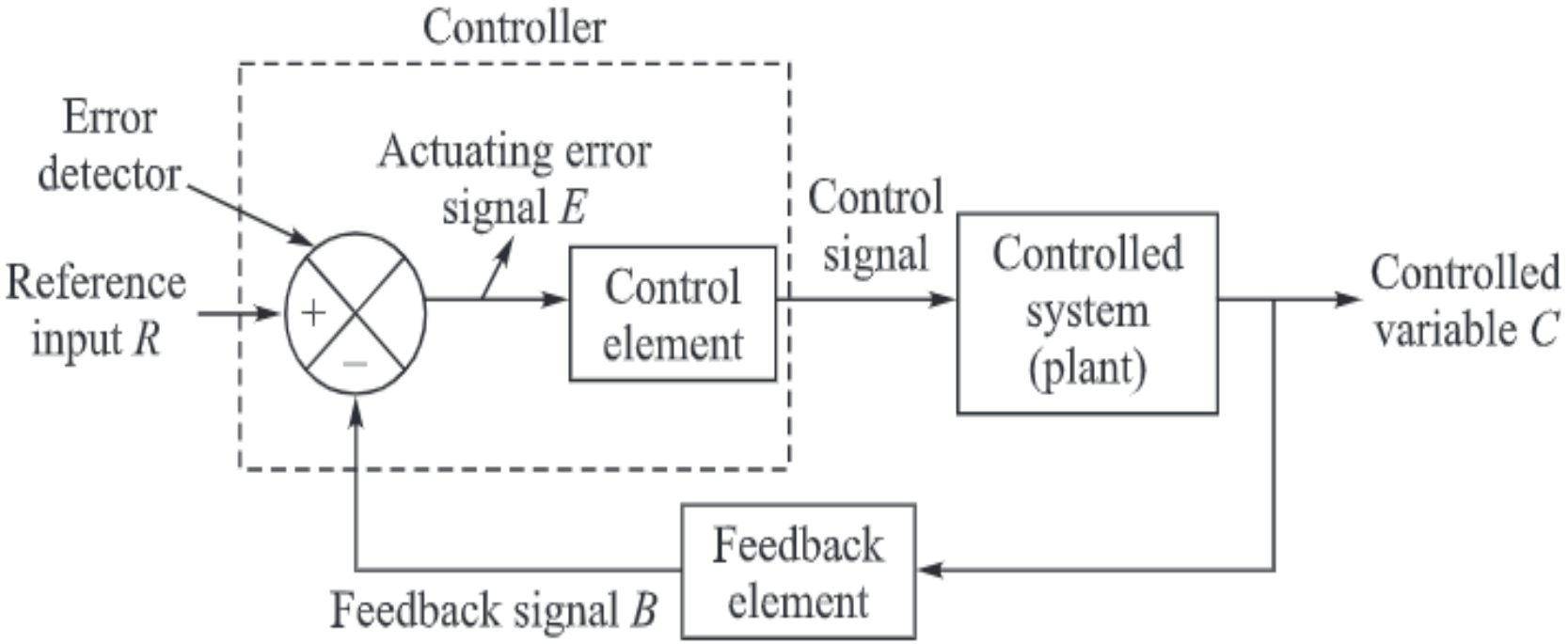
Open loop control system



EXAMPLES OF OPEN LOOP CONTROL SYSTEM

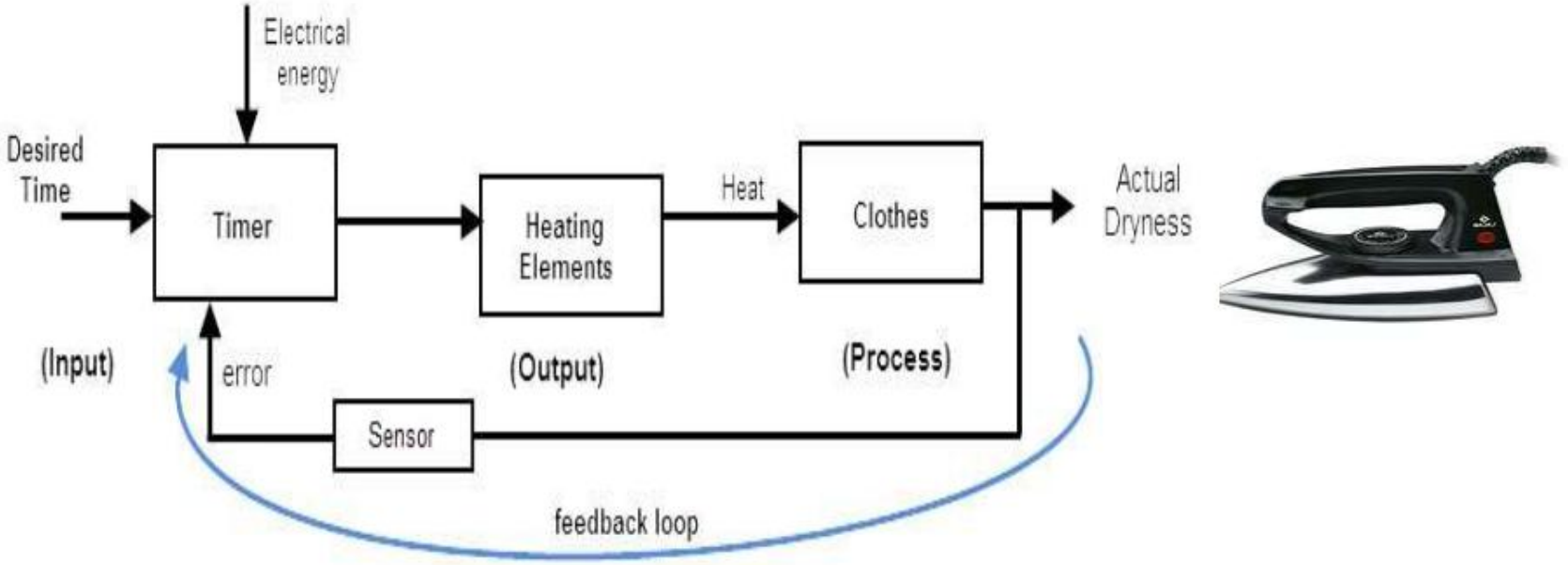
- Bread Toaster
- Traffic control system using lights

CLOSED LOOP CONTROL SYSTEM



EXAMPLES OF CLOSED LOOP CONTROL SYSTEM

- Automatic Electric Iron



DIFFERENCE BETWEEN OPEN LOOP & CLOSED LOOP SYSTEM

Comparison	Open Loop System	Closed Loop System
Definition	The system whose control action is free from the output	In closed loop, the output depends on the control action of the system.
Other Name	Non-feedback System	Feedback System
Components	Controller and Controlled Process.	Amplifier, Controller, Controlled Process, Feedback.
Construction	Simple	Complex
Reliability	Non-reliable	Reliable
Accuracy	Depends on calibration	Accurate because of feedback.
Stability	Stable	Less Stable
Optimization	Not-Possible	Possible
Response	Fast	Slow
Calibration	Difficult	Easy
System Disturbance	Affected	Not-affected
Linearity	Non-linear	Linear
Examples	Traffic light, automatic washing machine, immersion rod, TV remote etc.	Air conditioner, temperature control system, speed and pressure control system, refrigerator, toaster.

LINEAR AND NON-LINEAR CONTROL SYSTEMS

- A linear control system consists of the components having a linear relationship between the input and output signals under steady state conditions. Any system is called linear when the principle of superposition is applied.
- A non-linear control system consists of one or more elements, which exhibits a non-linear relationship between the input and output signals. In such system, principle of superposition is not applicable.

LINEAR-TIME VARYING AND TIME-INVARIANT SYSTEMS

- In a control system, most physical systems are characterized by differential equations. A differential equation is linear if the coefficients are constants or functions only of an independent variable. If the coefficients of describing differential equations are functions of time, then the mathematical model is time varying. The systems which consist of linear time-variant components or elements described by linear time-variant differential equations, whose coefficients are functions of time, are called linear time-varying systems. On the other hand, dynamic systems that are composed of linear time-invariant components by linear time-invariant differential equations are called linear time-invariant systems (parameters do not vary with time).

CONTINUOUS-TIME AND DISCRETE-TIME CONTROL SYSTEMS

- A control system in which all the system parameters are continuous functions of time t is called continuous-time control system. A control system in which all the system parameters are discrete functions of time t is called discrete-time control system.

LUMPED PARAMETER AND DISTRIBUTED PARAMETER CONTROL SYSTEM

- The control system which can be described by ordinary differential equations is called lumped parameter control system. On the other hand, the control system which can be represented by partial differential equations, is called distributed parameter control system.

DETERMINISTIC AND STOCHASTIC CONTROL SYSTEM

- In any control system if the response to input is predictable and repeatable, then the system is called deterministic control system. If the response to input is unpredictable and non-repeatable, then the system is called stochastic control system.

CLASSIFICATION OF CONTROL SYSTEMS ON THE BASIS OF CONTROL SIGNAL USED

- Depending upon the nature of signals involved like electrical, mechanical, hydraulic, pneumatic or combination of these signals, the control systems may be classified as single input-single output (SISO) and multiple input-multiple output (MIMO) systems.

SISO system. As the name indicates, it is a system having a single input and a single controlled variable. The output is produced by the single input solely. Only one input signal flows or passes through the system. The examples of SISO systems are voltage regulators, temperature controllers and so on.

MIMO system. There are certain systems having multiple inputs and multiple outputs. The systems in which any change in one of the outputs causes a subsequent change in the other output during transient and steady state conditions are called MIMO systems. The examples are boiler in which the controlled variables are steam pressure, temperature, water level and so on. Figure shows block diagram of an MIMO system.

Adaptive Control System

The control systems in which the system parameters are automatically adjusted to keep the system at an optimum level are called adaptive control systems. Such type of control systems itself detects changes in the plant parameters and make essential adjustments in the controller parameters to maintain optimum level or performance.

Process Control System

It is an automatic regulating system (feedback control system) in which the output is a variable (physical parameters) such as temperature, pressure, pH value, flow, liquid level and so on. It is widely used in different industries like paper, sugar, petrochemical, rubber and so on.

TRANSFER FUNCTION

- The *transfer function* of a linear time-invariant system is defined as the ratio of Laplace transform of the output variable to Laplace transform of the input variable under the assumption that all the initial conditions are zero. The concept of the transfer function is limited to linear, time-invariant, differential equations systems. It is widely used in designing and analysis of such systems.

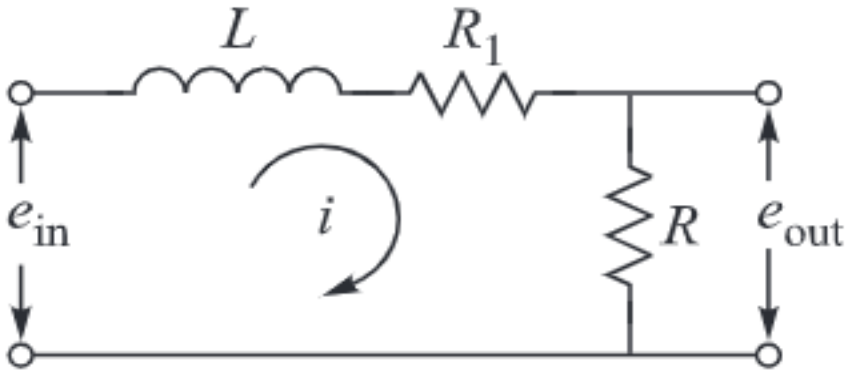
I. Let G(s) is the transfer function of single-input single-output system with input r(t) and controlled output c(t).

II. Consider an nth order differential equation for input-output relation of linear time-invariant system.

- To obtain transfer function of any equation, take Laplace transforms on both sides and assume all initial conditions as zero.

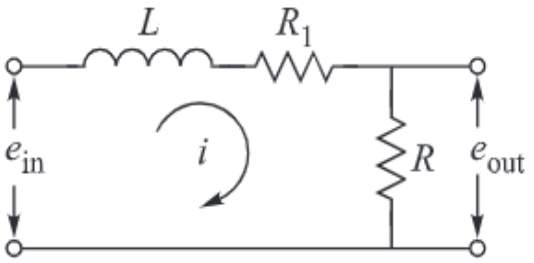
TRANSFER FUNCTION FOR ELECTRICAL SYSTEMS

Determine the Transfer function for below circuit



Solution

Suppose a current i is flowing through the circuit (loop).



Step 1. Write Kirchhoff's voltage equation for the system (apply KVL to the system).

$$L\frac{di}{dt} + R_1 i + Ri = e_{\text{in}}$$

$$Ri = e_{\text{out}}$$

Step 2. Take Laplace transform of the above equations.

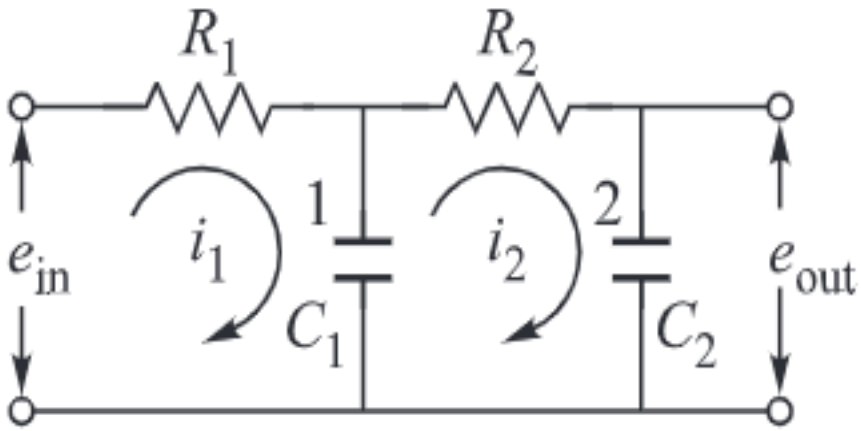
$$\begin{aligned} LsI(s) + R_1 I(s) + RI(s) &= E_{\text{in}}(s) \\ RI(s) &= E_{\text{out}}(s) \\ (R + R_1 + Ls)I(s) &= E_{\text{in}}(s) \\ RI(s) &= E_{\text{out}}(s) \end{aligned}$$

Step 3. Determine the transfer function from the above equations.

$$\text{TF} = \frac{E_{\text{out}}(s)}{E_{\text{in}}(s)} = \frac{R}{R + R_1 + Ls}$$

TRANSFER FUNCTION FOR CASCADE SYSTEMS

- **Determine the Transfer function for below circuit**



Step 1. Write Kirchhoff's voltage equation for the system (apply KVL to the system).

$$\frac{1}{C_1}\int (i_1 - i_2)\,dt + R_1 i_1 = e_{\text{in}}$$

$$\frac{1}{C_1}\int (i_2 - i_1)\,dt + R_2 i_2 = \frac{-1}{C_2}\int i_2\,dt = e_{\text{out}}$$

Take Laplace transform of the above equations.

$$\frac{1}{C_1 s}[I_1(s) - I_2(s)] + R_1 I_1(s) = E_{\text{in}}(s)$$

$$\frac{1}{C_1 s}[I_2(s) - I_1(s)] + R_2 I_2(s) = -\frac{1}{C_2 s} I_2(s) = E_{\text{out}}(s)$$

By eliminating $I_1(s)$ and $I_2(s)$ from the above equations, the transfer function is

$$\frac{E_{\text{out}}(s)}{E_{\text{in}}(s)} = \frac{1}{R_1 C_1 R_2 C_2 s^2 + (R_1 C_1 + R_2 C_2 + R_1 C_2)\, s + 1}$$

As stated above, the circuit (system) contains two *RC* circuits cascaded. But their overall transfer function is not a product of $1/R_1C_1s + 1$ and $1/R_2C_2s + 1$. If we derive transfer function for single circuit, the output is unloaded. Also when input of the second circuit is taken from the first circuit, the original transfer function is no longer valid. The degree of loading effect of the circuit decides modified transfer function.

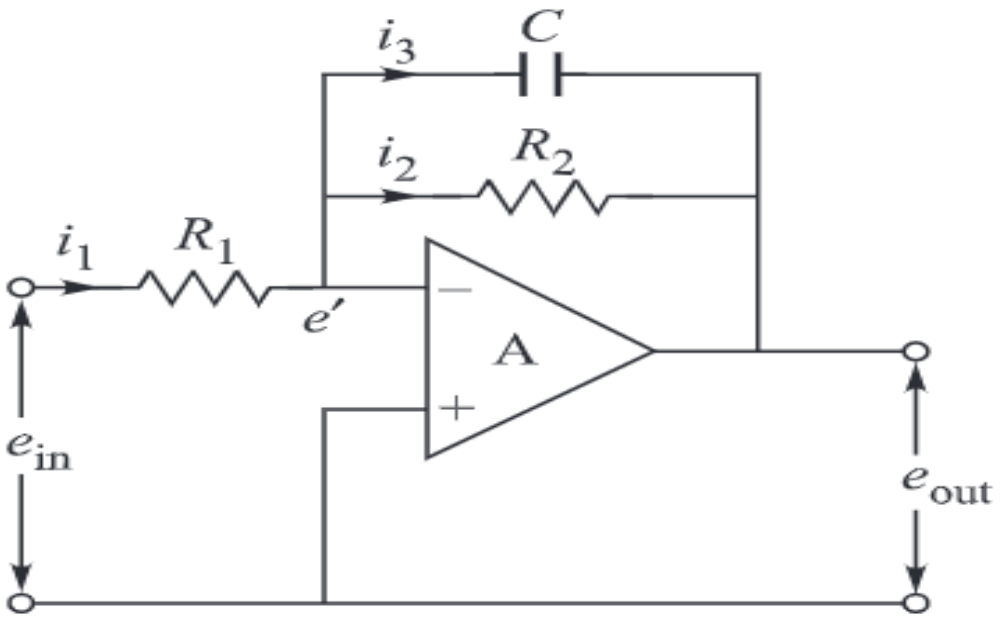
TRANSFER FUNCTION OF PASSIVE AND ACTIVE ELEMENTS

- **Passive elements**. These elements do not take part in any energy transformation, e.g. resistors, capacitors and inductors. Such elements in the system store the energy but can also be used later in the system. This energy cannot exceed when delivered to the system. System elements which contain passive elements are called passive systems.

- **Active elements.** These elements take part in energy transformation. They can deliver external energy into the system. The examples of such elements are transistor, diode, op-amp.

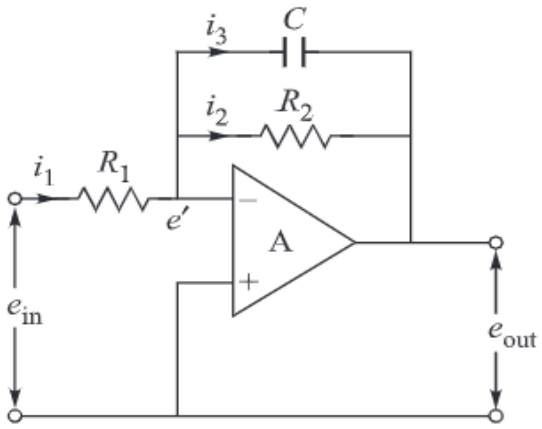
TRANSFER FUNCTION OF PASSIVE AND ACTIVE ELEMENTS

- **Determine the Transfer function for below circuit**



Solution

The circuit contains both active and passive elements. Here A is the operational amplifier.



Step 1. Determine e_{out}

Step 2. Calculate i_1, i_2 and i_3.

$$i_1 = \frac{e_{in} - e'}{R_1}; \quad i_2 = \frac{e' - e_{out}}{R_2};$$

$$i_3 = \frac{C dv_c}{dt} = C \frac{d(e' - e_{out})}{dt}$$

$\therefore$ $$i_1 = i_2 + i_3$$

$$\frac{e_{in} - e'}{R_1} = \frac{e' - e_{out}}{R_2} + \frac{Cd(e' - e_{out})}{dt}$$

Step 3. According to virtual ground concept of op-amp, $e' = 0$.

$\therefore$ $$\frac{e_{in}}{R_1} = \frac{-e_{out}}{R_2} - C\frac{de_{out}}{dt}$$

Step 4. Take Laplace transform of the above equation.

$$\frac{E_{in}(s)}{R_1} = \frac{-E_{out}(s)}{R_2} - CsE_{out}(s)$$

$$\frac{E_{in}(s)}{R_1} = -E_{out}(s)\left[\frac{1}{R_2} + Cs\right]$$

$$\frac{E_{in}(s)}{R_1} = -E_{out}(s)\left[\frac{1 + R_2Cs}{R_2}\right]$$

COMMONLY USED CONTROL SYSTEM COMPONENTS

- DC motors which are used in servosystems are called tic servomotors. This motor provides high starting torque due to low inertia. This low inertia can be achieved by reducing armature diameter with increasing armature length so that the desired output power can be achieved.

- Low power rating dc servomotors are used in computer disk drives, printer, tape drives and so on. Medium and large power dc servomotors are used in machine tool industries, robots and numerically-controlled machines.

- In dc servomotors, field winding may be connected either in series with the armature or separate from the armature.

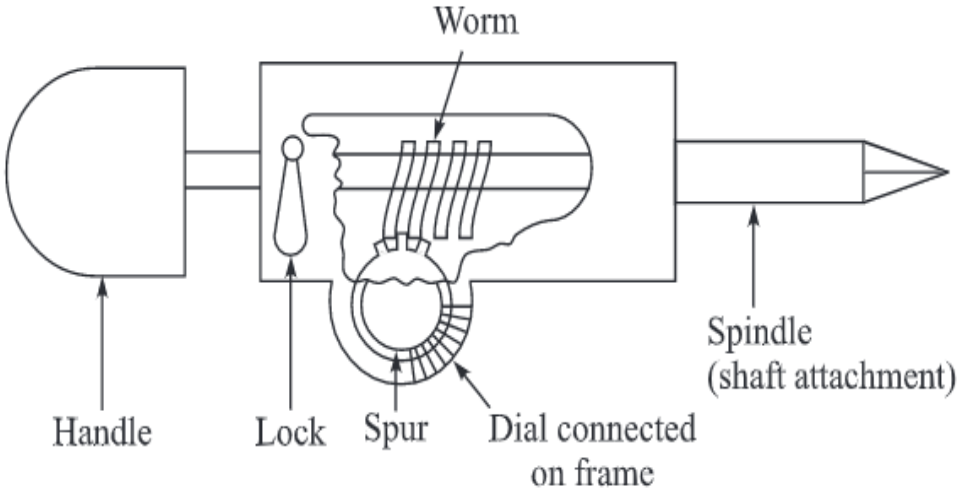
- DC servomotors may be used in two different control modes as follows:
  - Armature control mode, in which the speed of the dc servomotor is controlled by armature current with field current constant.
  - Field control mode, in which the armature current is maintained constant and speed of the dc servomotor is controlled by field voltage.

TACHOMETERS

- Tachometer is used for angular speed measurement. Basically, tachometers are classified as mechanical and electrical tachometers. Electrical tachometers are further divided into ac and dc tachometers. In control system, tachometer is used as a feedback element.

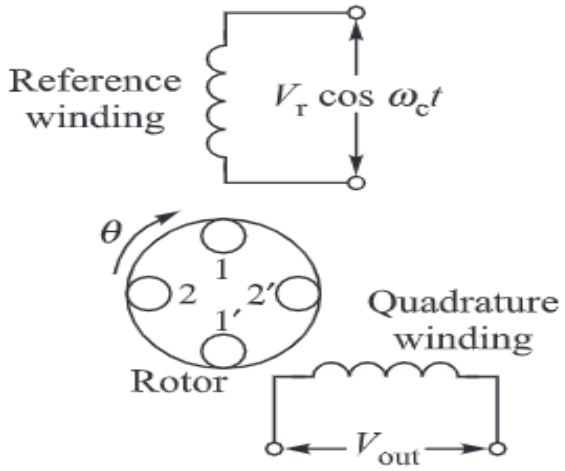
MECHANICAL TACHOMETERS

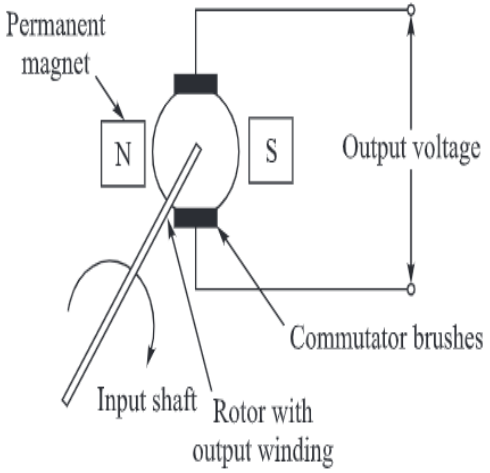
- This type of tachometer consists of mechanical assembly and movements for the measurement of speed. Revolution counter is a type of mechanical tachometer. Figure shows the construction of a revolution counter (mechanical counter).



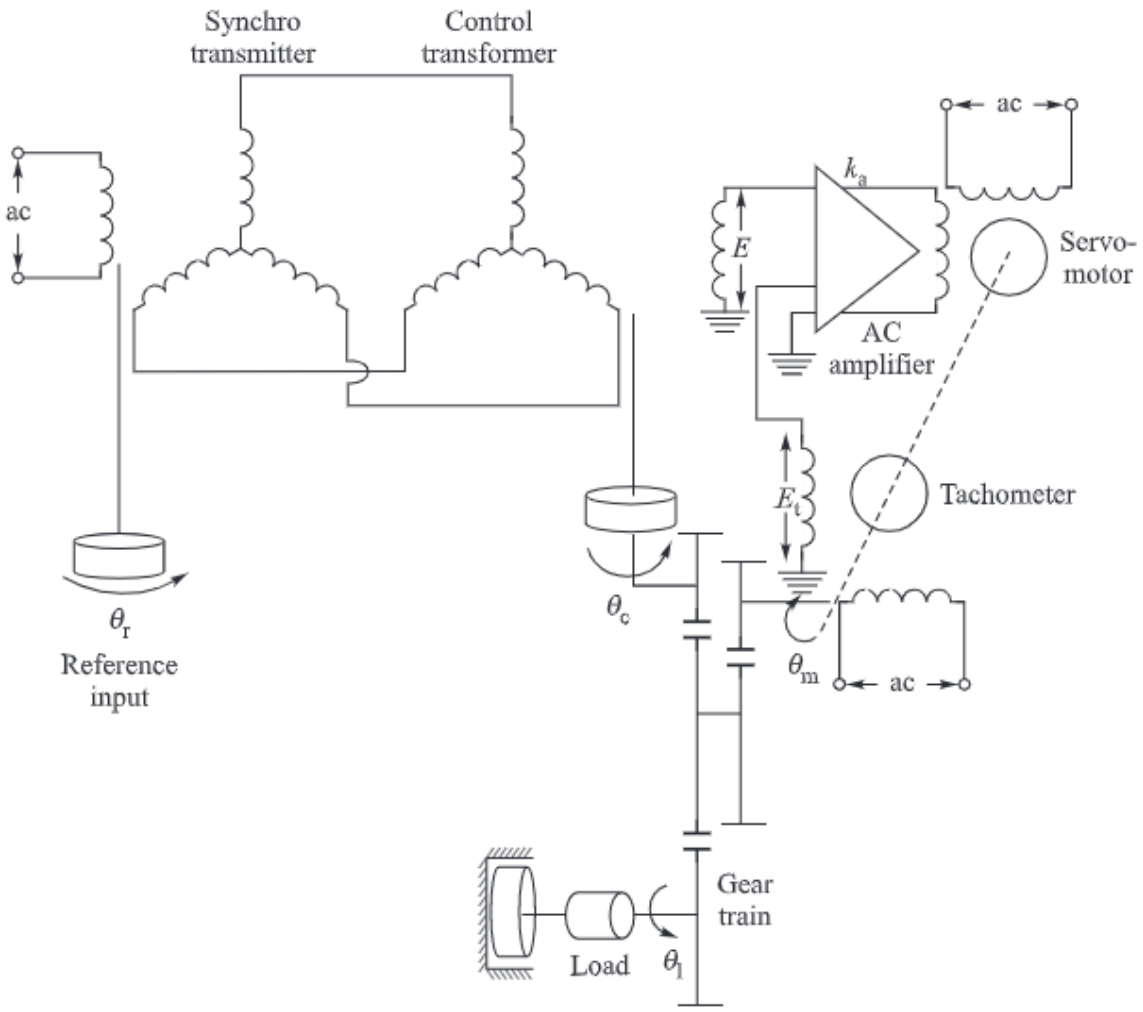
ELECTRICAL TACHOMETERS

- This type of tachometer converts the angular or rotational speed into electrical signal and indicates on the indicator provided.





AC POSITION CONTROL SYSTEM



ADVANTAGES OF AC POSITION CONTROL SYSTEMS

- AC amplifiers are more stable so there is no drift in operation.
- Because of small size of ac components, the system is compact.
- It has low cost.

THANK YOU

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AUTOMATION AND CONTROL ENGINEERING (R17A0327)

4th Year B. Tech I- sem, Mechanical Engineering

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COURSE OBJECTIVES

UNIT - 1	CO1: To perform one or more processing operations & To understand the need of Mechatronics systems
UNIT - 2	CO2: To make students familiar with the constructions and working principle of different types of sensors and transducers.
UNIT - 3	CO3: Understand the fundamental concepts of electro mechanics and fluid mechanics (hydraulics and pneumatics) of Actuators and drive systems.
UNIT - 4	CO4: To impart knowledge on the control elements
UNIT - 5	**CO5: To understand the different control schemes generally used to get best output.**

UNIT 5

ACTUATORS AND DRIVE SYSTEMS

CO5: To understand the different control schemes generally used to get best output.

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UNIT – V (SYLLABUS)

ACTUATORS AND DRIVE SYSTEMS

- Introduction, concept of process control, Automatic controllers, Digital Controller, Electronic Controllers, Pneumatic Controllers, P-I Controller, PD Controller, P-I-D Controller, Hydraulic Controllers.

COURSE OUTLINE

UNIT - 5

LECTURE	LECTURE TOPIC	KEY ELEMENTS	LEARNING OBJECTIVES
1	Introduction to Process control	Define controller	Understanding of basics of control system (B2)
2	Automatic controllers -Digital controller -Analog controller	Types of Automatic controllers	Understanding of types of Automatic controllers (B2)
3	Electronic controllers -Control models -Composites mode electronic controllers	Working principle of Types of Pneumatic controllers	• Understand the applications of controllers • Controllers systems and to know the working principles of system(B2) • Advantages and disadvantages of controllers systems(B4)
4	Pneumatic controllers -P-I controller -PD controller -P-I-D controller		
5	Hydraulic controllers -Hydraulic integral controller Hydraulic proportional controller	Working principle of types of process control systems	• Understand the applications of process control systems in various systems and to know the functions of each element(B2) • Able to analyze the which Advantages and disadvantages of Drive systems(B4)

TOPICS TO BE COVERED

- Definition
- Types of Automatic controllers
- Working principle of Types of controllers
- Applications
- Problems
- Assignments

LECTURE 1

Introduction - Actuators

LECTURE TEMPLATE

- **Introduction**
  - **Definition**
  - **Units**
  - **Classification etc…**
- **Demonstration**
  - Text
  - Graphic/ Pictorial
  - Video etc…
- **Industrial Applications**
- Solved Problems (1-2)
  - Procedure
- Self Learning Questions
- Assignment Exercises
- Summary

Process Control

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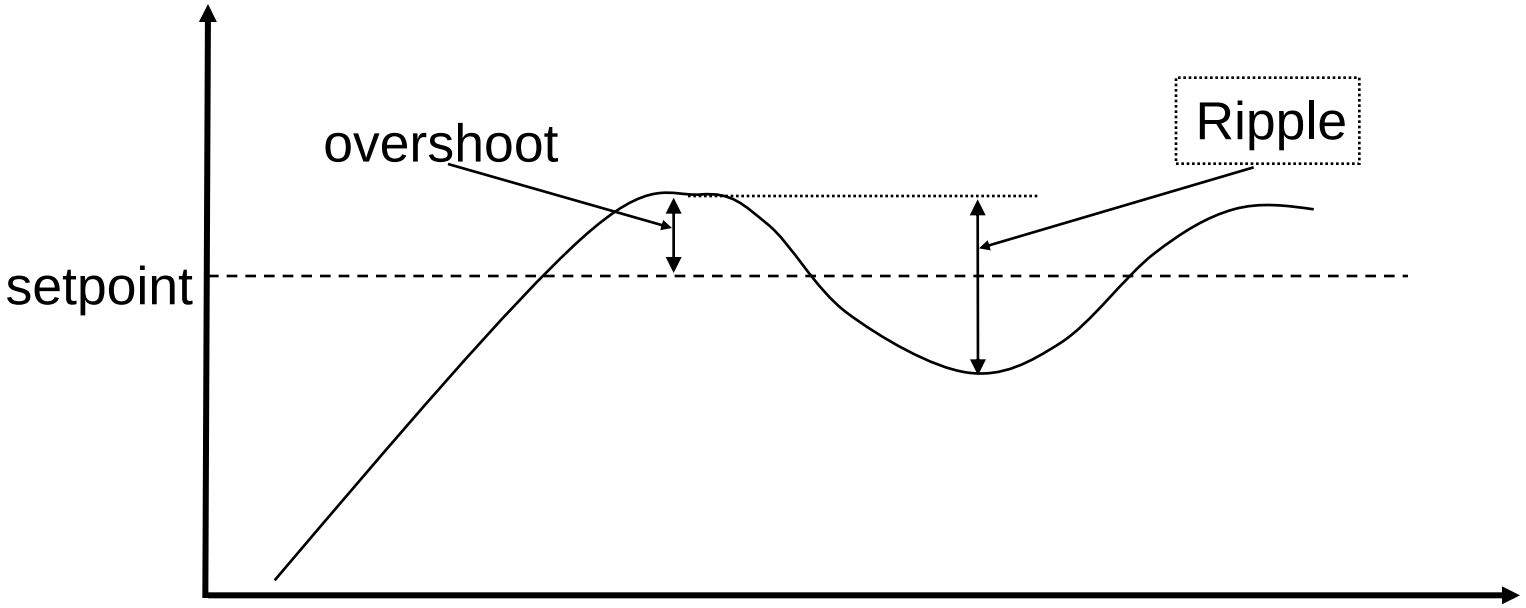
INTRODUCTION

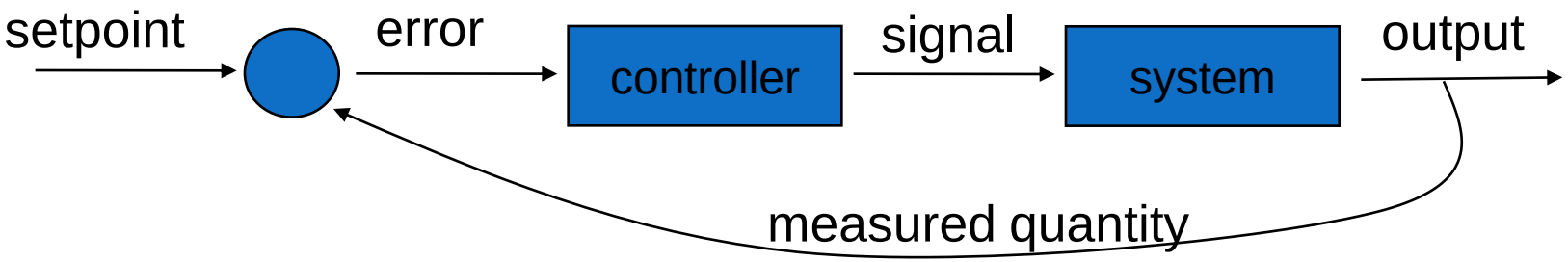
- Suppose you have a system that needs to be controlled
- Your software gives commands, the system responds to it
  - Turn x degrees to the right
  - Move forward 15 wheel rotations
- Can you always trust your commands will be executed accurately?

PROBLEM EXAMPLE



- Increase the quantity until you get to the setpoint
  - Temperature, angle, speed, etc
- If too much, reduce the quantity, until the setpoint

CLOSED LOOP CONTROLLER



- closed loop because it has feedback
- output is measured at a certain frequency
- signal is generated at a certain frequency
- which frequency is not smaller?

ON-OFF CONTROL

- For some systems, on-off signaling is sufficient
- For example, a thermostat, when the heater is either on or off, and early cruise-control systems
  - Could do airflow or speed control also
  - More modern systems do it
- Depending on the frequency of control, overhead of on-off, etc, this could cause overshoots and undershoots (ripples)
  - Oscillation is a common behavior in control systems
  - Need to avoid it at all costs… well, almost all costs

PROPORTIONAL CONTROL

- Good alternative to on-off control: more “control” ☺
- Signal becomes proportional to the error
  - *P (setpoint – output)*
  - Example, car speed for cruise control
- Need to find out value of constant P
  - Tuning the controller is a **hard** job
  - If P is too high, what happens?
  - If P is too low, what happens?
- Typically a prop cntrl decreases response time (quickly gets to the setpoint) but increases overshoot

ADDING DERIVATIVE CONTROL

- To avoid (or reduce) overshoot/ripple, take into account how fast are you approaching the setpoint
  - If very fast, overshoot may be forthcoming: reduce the signal recommended by the proportional controller
  - If very slow, may never get to setpoint: increase the signal
  - In general: *D (current measure – previous measure)*
- PD controllers are slower than P, but less oscillation, **smaller** overshoot/ripple

INTEGRAL CONTROL

- There may still be error in the PD controller
  - For example, the output is close to setpoint
    - P is very small and so is the error, discretization of signal will provide no change in the P controller
    - D controller will not change signal, unless there is change in output
- Take the sum of the errors over time, even if they're small, they'll eventually add up
  - I * sum_over_time (setpoint — output)
- Again the main problem is the value of I
- Can we let sum grow to infinity?

SUMMARY

- Different types of controllers
- PID hardest task is tuning

Controller	Response time	Overshoot	Error
On-off	Smallest	Highest	Large
Proportional	Small	Large	Small
Integral	Decreases	Increases	Zero
Derivative	Increases	Decreases	Small change

WHERE TO GET MORE INFORMATION

- newton.ex.ac.uk/teaching/CDHW/Feedback/
- ~don/cs1567/reference/pidworksheet.xls

INDUSTRIAL APPLICATIONS

- The Modern **Industrial** Workhorse: PID **Controllers**. Proportional-Integral-Derivative (PID) **controllers** are used in most automatic process **control applications** in **industry** today to regulate flow, temperature, pressure, level, and many other **industrial** process variables.

- Link: https://controlstation.com/pid-control/

ASSIGNMENT EXERCISES

1. What is meant by controller? Briefly explain about Process control?

2. Explain about Automatic controllers?

3. Explain about Electronic and Pneumatic controllers?

4. What is meant by P-I, PD and P-I-D controllers explain briefly?

5. Explain about Hydraulic controllers?

THANK YOU

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