INTRODUCTION TO
INDUSTRIAL ELECTRONIC

Nurul Syazrah Mat Yatim | Rasidah Rasid | Farih Deraman

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PREFACE

Thanks to Allah the Lord of the world because of his grace we can complete a book entitled "Introduction to Industrial Electronic".

We wish to express our deep and sincere gratitude for those who have guided and given full cooperation and commitment in completing this book.

This book is structured to meet the need of industrial electronic lecture for mechatronic engineering programme. This book can be used as a guidance for all the students and lecturers who are involved in mechatronic programme in Sultan Mizan Zainal Abidin Polytechnic (PSMZA).

We realize that this book is far from perfect, therefore constructive criticism and suggestions are welcomed to improve this book.

CONTENT

SUMMARY

Chapter 1: Introduction to Mechatronic Devices

Introduction to mechatronics devices.

Chapter 2: Switch

Basic function, configurations, types, movement methods, usage and specification according to NEMA (National Electrical Manufacturers Association).

Chapter 3: Relay

Function, application, specification referring to NEMA, logic circuit and function of relay ladder diagrams.

Chapter 4: Solenoid

Functions, applications, symbol and control circuit.

Chapter 5: Sensor

Position and shift sensors, acceleration and speed sensors, level and pressure sensors, temperature sensors, vision sensors (CCD, CID), contact and non-contact proximity sensors, photoelectric and microwave sensors, and laser sensors.

Chapter 6: Telemetry and Data Acquisition

Structure of the data collection and telemetry systems. Telemetry amplitude and wave. There are two different types of multiplexing: frequency division multiplexing and time division multiplexing.

CHAPTER 1

INTRODUCTION OF MECHATRONIC DEVICES

General objective: To understand the basics of mechatronic devices.
Specific objectives: At the end of the unit, you should be able to:
- List the types of mechatronic devices.
- Describe the basics of mechatronic.
- Explain the mechatronic devices.

1.1 Introduction of Mechatronic.

The Japanese came up with the term "mechatronic" to characterise the fusion of mechanical and electronic engineering. It refers more precisely to a multidisciplinary method of designing products and production systems. As seen in Figure 1.1, it represents the newest generation of tools, robots, and intelligent devices for doing work in a range of settings, primarily in factory, office, and home automation.

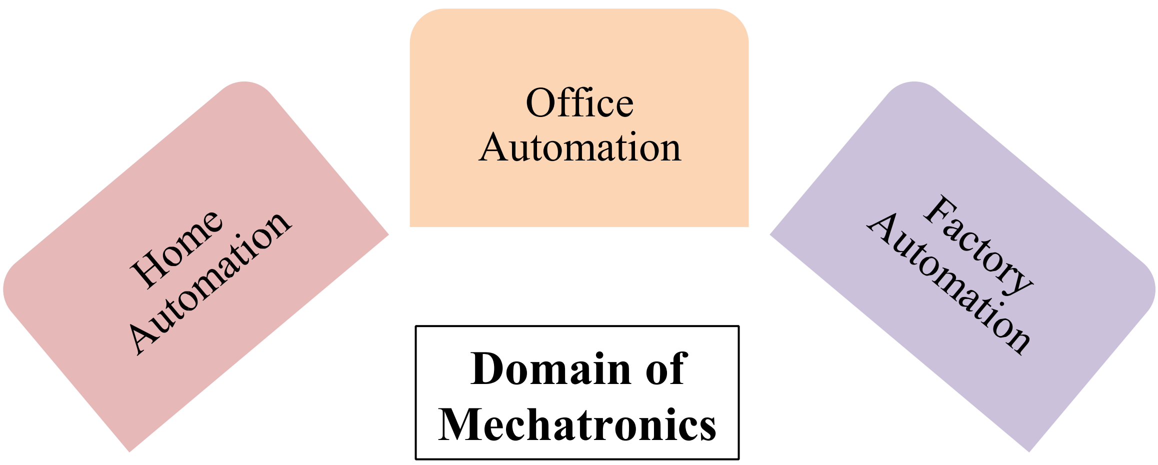


Figure 1.1: Domain of mechatronic

Mechatronics is a field that includes both electronics replacing mechanics and electronics augmenting mechanics (to give high levels of precision and reliability) (to provide new functions and capabilities). Automated bank tellers, industrial robots, and numerically controlled metal-cutting tools are a few instances of how mechanics has been improved by electronics. Digital watches, calculators, and other devices are examples of products in which electronics have replaced mechanical.

However, machines and robots powered by numerical control are the items that truly conflate electronics and mechanics. The Japanese machine tool industry has prospered because Japan was the first nation in the world to develop the technology of NC machines. This is since the Japanese have perfected mechatronics, the merger of fine mechanics and electronics in design, engineering, and manufacturing, as is illustrated in Figure 1.2, a popular representation of mechatronics in Japan.

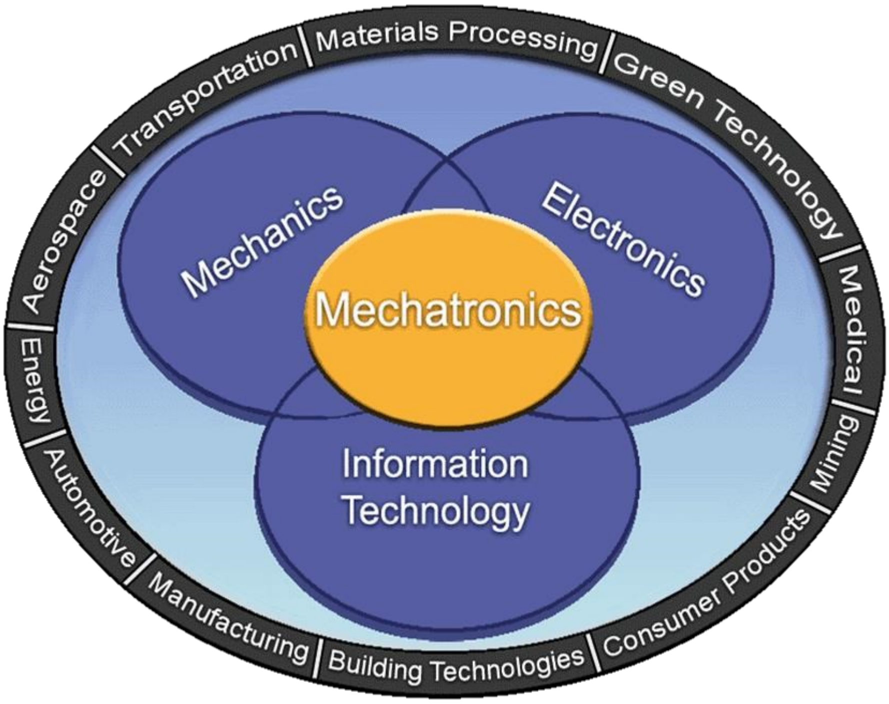


Figure 1.2: Concept of Mechatronics

1.2 Scope of Mechatronics

The technology of these items has undergone a significant transformation since the 1970s, mostly due to an increase in the proportion of echatronic—electric and electronic systems integrated with mechanical components—in the devices. Products that have already made the transition from simple mechanical to mechatronic technologies include.

Machine tools incorporating computer numerical control (CNC), electric servo drives, electronic measuring systems, precision mechanical parts, such as ball screws, anti-friction guide ways and each other's

- Electronic watches incorporating fine mechanical parts and sophisticate electronic circuits.
- Electronic consumer products – washing machines, electronic cooking appliances, fax, plain paper copiers and others
- Electronic consumer products – washing machines, electronic cooking appliances, fax, plain paper copiers and others.

In the last 20 years, production technology has seen the introduction of high precision measuring tools like electronic gauges and measuring instruments, in process gauge and quality control tools, laser measuring systems, and others to ensure high dimensional accuracy and increased shop floor productivity.

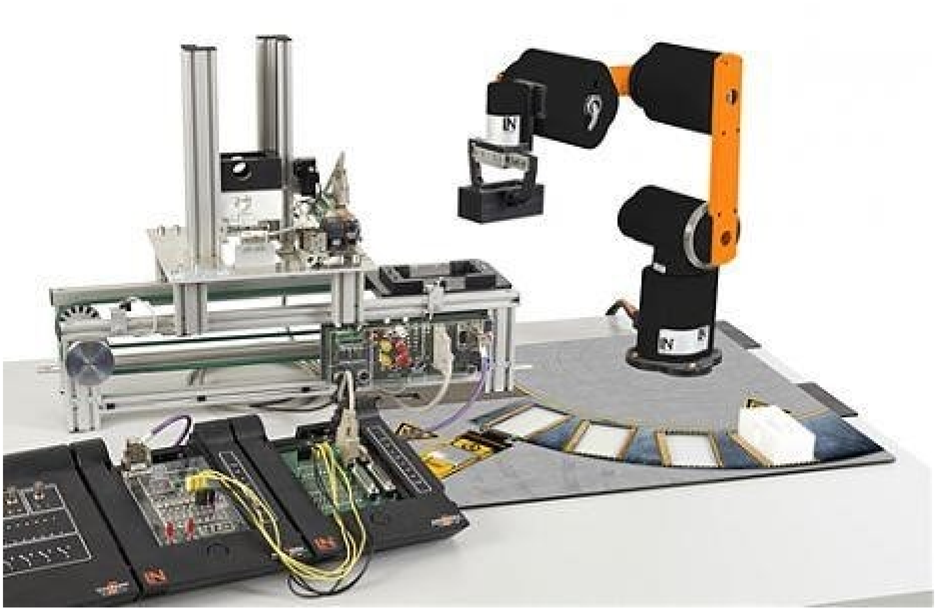


Figure 1.3: Application Mechtronic in Industry

Mechatronics has had a significant impact on manufacturing in the area of industrial automation and will continue to grow in importance. CNC machines, robotics, automation systems, and computer integration of all industrial processes are key components of factory automation. A key factor that boosts productivity and the quality of the goods produced by the clients is the proper application, utilisation, and maintenance of these high-tech items and systems. The advancements in high technology machinery and equipment are closely examined in order to ensure proper equipment selection and a precise assessment of the techno-economics of various manufacturing systems. Additionally, correct diagnostics and maintenance of different mechatronic components can lengthen the lifespan of those components, extending the lifespan of the final product or system.

The best people to provide these mechatronics inputs are the companies that make advanced manufacturing equipment and machinery. In fact, clients are now asking machine tool makers to provide a complete manufacturing solution in place of merely providing the individual machines. Many of the advanced nations have already seen this tendency. Evidently, mechatronics will be at the centre of all activities in product and production technology, and the design and manufacture of future products will entail a combination of precise mechanical and electronic systems.

1.3 Types of Mechatronic Devices.

In this module, we will discuss a several types of mechatronic devices which is in used by working design. Switches, relays, solenoids, sensors, and other mechatronic device types are used. These types of devices will be discussed in this module

Tutorial 1

1. Distinguish the mechatronic devices. (3 marks)

2. Explain mechatronic jobs description. (4 marks)

3. Describe the applications of Mechatronic? (3 marks)

4. There are structure and construction for designing a switch **EXCEPT**

A. Assumed to be ideal
B. Protection of power device
C. Design logic and gating circuits
D. Design of control circuits

5. Example of product which has already moved to mechatronic technology from simple mechanical product is

A. Fax
B. Analog watch
C. Switch
D. Relay

6. Mechatronic is the combination of engineering field **EXCEPT**

A. Civil
B. Mechanical
C. Electronic
D. Computer

CHAPTER 2

SWITCH

General objective: To understand the concept and basic application of a switch.
Specific objectives: At the end of the unit, you should be able to:

- ❖ Identify the basic function of switch.
- ❖ Identify the type of switches.
- ❖ Describe the application of switch in industrial. Draw the symbol of a switch.

2.1 Introduction of Switch.

A mechanical, electrical, or electronic switch is a tool that opens or closes a circuit. Making or breaking the circuit is another name for switching.

2.2 Basic Function of Switch and Switch Diagram.

The switches act as a device that opens or closes a circuit. Making the circuit is the act of shutting a switch. The act of opening a switch is known as breaking the circuit. The output of the system is determined by the switching pattern of the converter switches and the input voltage (or current). Converter's output quantities, like the linear system's, can be expressed in terms of input quantities using spectrum multiplication. The arrangement of a single-phase diagram of a converter and a basic hold circuit are shown in Figure 2.1 and 2.2 below.

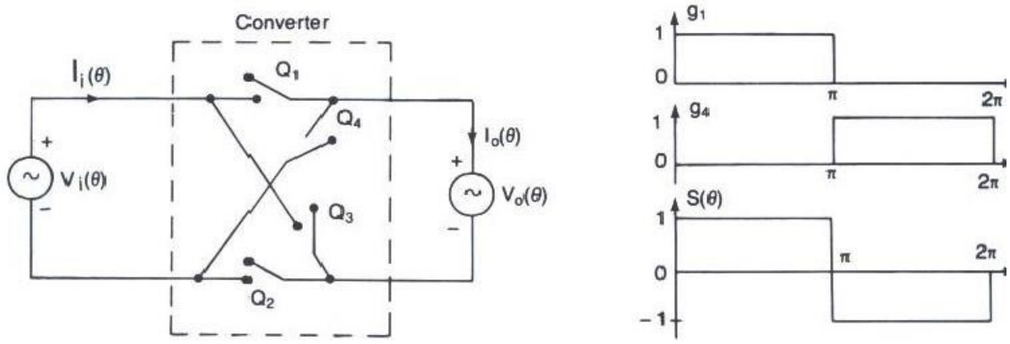


Figure 2.1: Single – phase diagram of converter structure

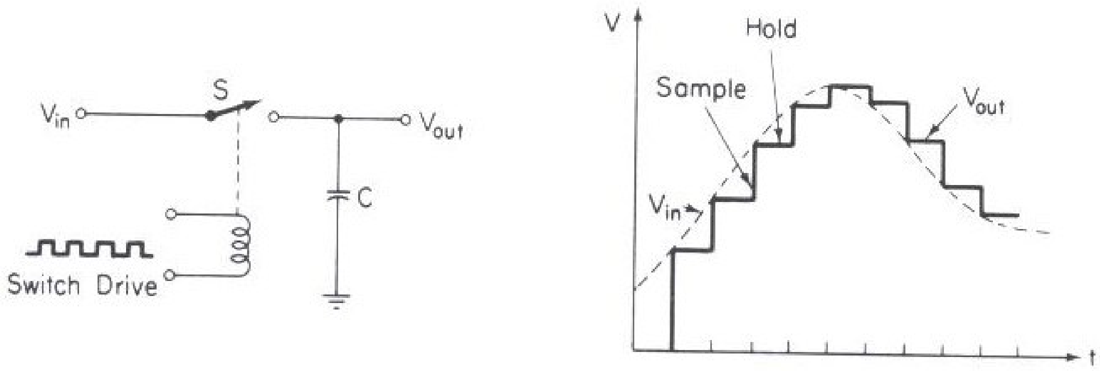


Figure 2.2: Simple sample and Hold circuit

2.3 Construction of Switch and Type of Structure

The construction and structure of power electronics switch can divide into four parts:

i. Design of power circuits.
ii. Protection of power devices.
iii. Determination of the control strategy.
iv. Design of logic and gating circuits

Unless otherwise stated, the power devices are assumed to be perfect switches in the study, and the effects of circuit stray inductance, circuit resistances, and source inductance are ignored. Power devices and circuits in use are also affected. However, in the early stages of design, simplified circuit analysis is particularly important for understanding circuit behaviour and establishing characteristics and control strategy.

Before building a prototype, the designer should evaluate the impact of circuit parameters (including device flaws) and, if required, revise the design. Only after the prototype has been created and tested can the designer be confident in the design's validity and more precisely estimate some of the circuit characteristics (e.g., stray inductance).

2.4 Types of Switches

Switches come in a wide variety of varieties. Pushbuttons, limit switches, slide switches, rocker switches, precision switches, and toggle switches are a few different switch kinds.

2.4.1 Push Buttons Switch.

A pushbutton is a switch activated by finger pressure. Two or more contacts open or close when the button is depressed. Pushbuttons are usually spring loaded so as to return to their normal position when pressure is removed. Figure 2.4, show that the mechanical-interlocked pushbutton with NO (normally open) and NC (normally close) contacts, rated to interrupt an ac current of 6A one million times.

Figure 2.3: Push Button switch

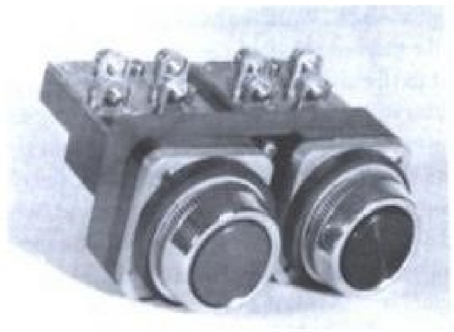


Figure 2.4: Mechanicalswitch – Interlock Pushbotton

2.4.2 Limit Switch

A limit switch is a low-power snap-action device that opens or closes a contact, depending upon the position of mechanical part. Other limit switches are sensitive to pressure, temperature, liquid level, direction of rotation and so on. Figure 2.5 show that the limit switch with one NC contact, rated for ten million operations, position accuracy is 0.5 mm.

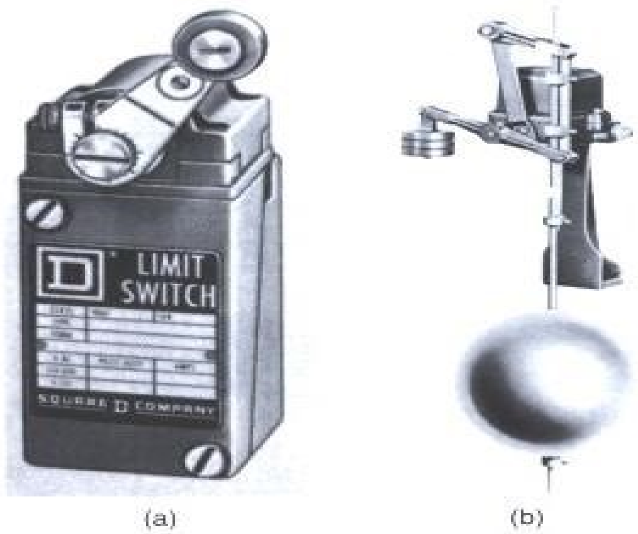


Figure 2.5: A Limit Switch

2.4.3 Slide Switch.

A slide switch is a switch activated by sliding of two or more contacts open or close when the button is depressed. Pushbuttons are usually spring loaded to return to their normal position when pressure is removed. Figure 2.6, show that the mechanical-interlocked sliding plate/rod with NO (normally open) and NC (Normally close) contacts.

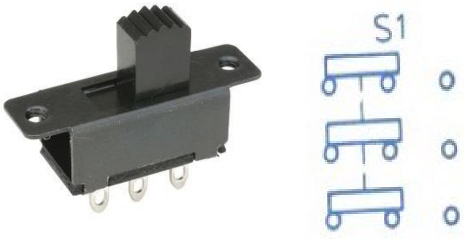


Figure 2.6: A Slide switch schematic

2.4.4 Rocker Switch.

A rocker switch is a switch activated by 3 finger which includes 2 finger push button for opening and closing of 2 circuits. Two contacts open or close for 2 circuits when the button are pressed and depressed. Pushbutton are usually spring loaded in the bottom to return to their normal position when pressure is removed. Figure 2.7, show that the mechanical-interlocked pushbutton with ON (normally open) and NC (Normally close) contacts through 2 circuit involved.

Figure 2.7: A Rocker switch

2.4.5 Precision Switch.

A precision switch is a switch activated by roller loaded on the top of pushbutton to open or close a circuit. Only one contact open or close when the button is depressed by load moving on top of the roller. Pushbutton are usually spring loaded so as to return to their normal position when load on top of roller is removed. Figure 2.8, show that the mechanical-interlocked pushbutton with ON (normally open) and NC (Normally close) contacts, rated to interrupt an ac current of mechanical effect to the top of roller device.

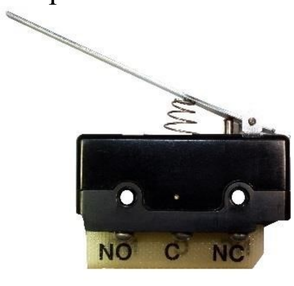


Figure 2.8: A Precision switch

2.4.6 Toggle Switch.

A toggle switch is a switch activated by ball bearing moving for open or close a circuit. The movement of roller makes a contact to open or close a circuit when the toggle is depressed. A toggle usually parallel with the force loaded so as to open or close. Figure 2.9, show that the mechanical-interlocked toggle pushbutton with NO (normally open) and NC (Normally close) contacts.

Figure 2.9: A Toggle Switch

2.5 Principle Operation Of Switch

Switches should follow the international system of units (SI) which defines the ampere (the fundamental unit of electric current) as the constant current which, if maintained in two straight parallel contactors of infinite length and negligible circular cross section place in a mechanism part that will produce a force between two parallel contactors.

By international agreement, the value of the international ampere for switches was based on the electrolytic deposition of silver form a silver nitrate solution. The resistance standard of switches is absolute measurement of the ohm and is carried out by the international standards laboratories, which preserve a group of primary resistant standard. For the voltage standard the saturated cell has a temperature dependence, and the out put voltage change about -40 m V/0C from the nominal 1.0185V.

The output of a converter depends on the switching pattern of the converter switches and the input voltage (on current). Similar to linear system, the output quantities of a converter can be expressed in terms of the output quantities, by spectrum multiplication.

Tutorial 2

1. Draw the relay diagram when it's condition is normally open and explain the operation. (5M)

2. Explain the operation of relay if the relay is normally closed with aid of diagram.(5M)

3. Number of pole is

A. Number of conducting position

B. Number of switch contact

C. Number of way

D. Number of location.

4. Double Pole Single Throw (DPST) is equivalent to:

A. One SPST

B. Two SPST

C. Three SPST

D. DPDT

5. Toggle switch usually connected in ______________ with the force load.

A. series

B. parallel

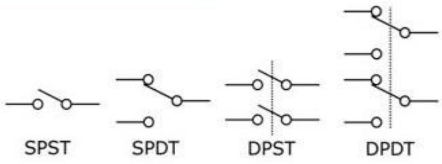
C. short circuit

D. no wire

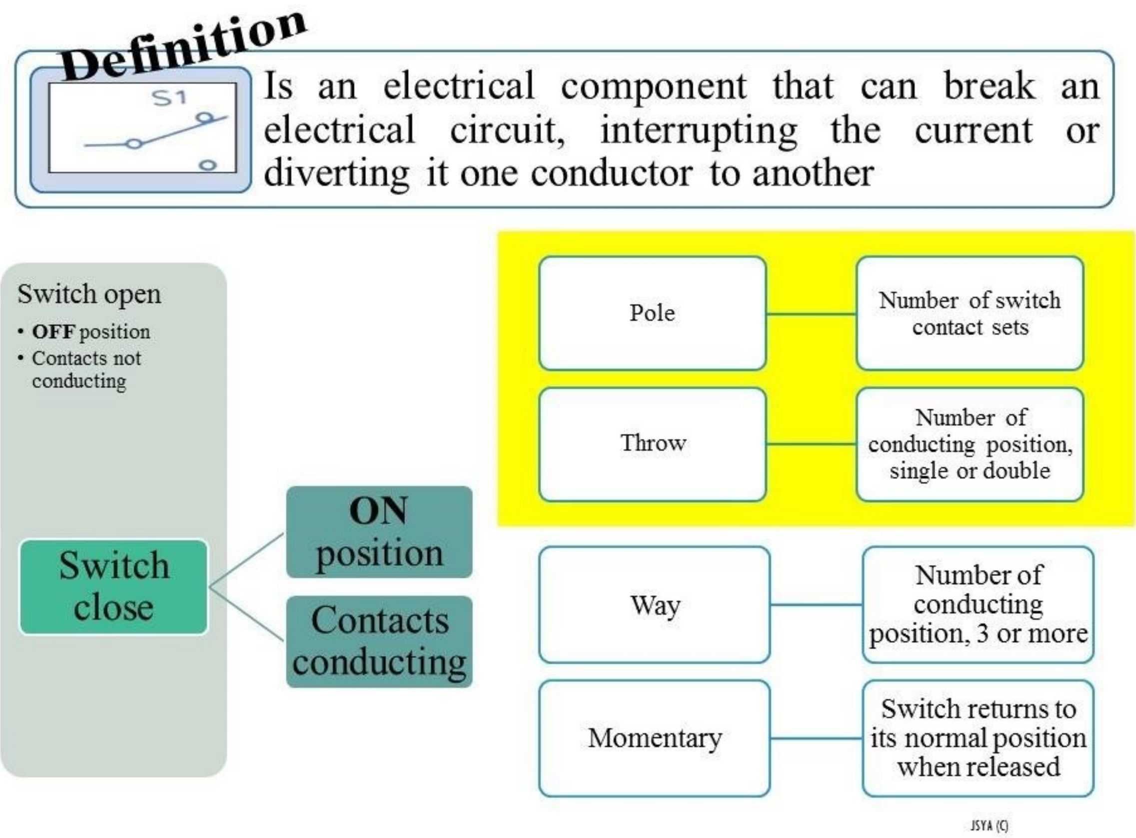
Mind Map

SELECTING A SWITCH

Contact	Single Pole Single Throw (SPST)	
	Single Pole Double Throw (SPDT)	
	Double Pole Single Throw (DPST)	
	Double Pole Double Throw (DPDT)	
Ratings	Max. voltage	
	Current	
Method of operation	Manual	
	Mechanical	



JSYA (C)



Structure and construction of switch

Design of power circuits

Protection of power devices

Determination of the control strategy

Design logic and gating circuits

Assumed to be ideal switches

Analysis circuit to establish the characteristic and control strategy

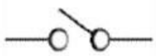
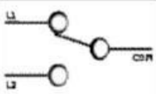
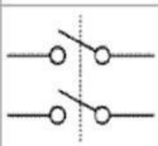
Investigate the effects of the circuit parameters

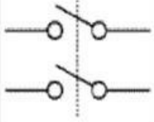
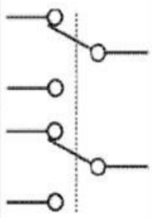
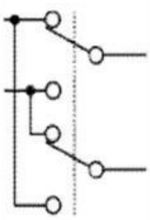
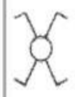
Types of switch

- Push button
- Limit switch
- Slide switch
- Rocker switch
- Precision switch
- Toggle switch

Types of switch	Description
Push buttons 	◈ This looks like a momentary action push switch but it is a standard on-off. ◈ Push once to switch on, push again to switch off (latching action) e.g. SPST = ON-OFF
Limit switch 	◈ a low power snap action device that opens or closes a contact, depending upon the position of mechanical part. ◈ sensitive to pressure, temperature, liquid level, direction of rotation and so on.. ◈ rated for 10 million operation, position accuracy is 0.5mm ◈ the activation method: mechanical
Slide switch 	● activated by sliding of 2@more contacts open@close when the button is depressed ● The mechanical-interlocked sliding plate/rod with NO (normally open) and NC (normally closed) contacts ● Usually spring loaded so as to return to their normal position when pressure is removed ▣ the activation method: manual JSYA (C)

Types of switch	Description
Rocker switch 	• Pressed and depressed • Usually spring loaded in the bottom • The mechanical-interlock with NO and NC through 2 circuit involved
Precision switch 	• activated by roller loaded on the top of puch botton to open@close a circuit • usually spring loaded so as to return their normal position when load on top of roller is removed • ratted to interrupt an ac current of mechanical effect to the top of roller device
Toggle switch 	• activated by ball bearing moving for open @ close • the movement of roller makes a contact to open @ close a circuit a circuit when the toggle is depressed • Usually parallel with the force loaded • the activation method: manual

Electronics specification and abbreviation	Expansion of abbreviation	British mains wiring name	American electrical wiring name	Description	Symbol	IEC 60617
SPST	Single pole, single throw	One way	Two way	A simple on-off switch: The two terminals are either connected together or not connected to anything. An example is a light switch.		
SPDT	Single pole, double throw	Two way	Three way	A simple changeover switch: C (COM, Common) is connected to L1 or to L2.		
SPCO **SPTT, c.o.**	Single pole changeover *or* Single pole, centre off *or* Single Pole, Triple Throw			Similar to *SPDT*. Some suppliers use *SPCO/SPTT* for switches with a stable off position in the centre and *SPDT* for those without.		
DPST	Double pole, single throw	Double pole	Double pole	Equivalent to two *SPST* switches controlled by a single mechanism		

DPST	Double pole, single throw	Double pole	Double pole	Equivalent to two *SPST* switches controlled by a single mechanism		
DPDT	Double pole, double throw			Equivalent to two *SPDT* switches controlled by a single mechanism: A is connected to B and D to E, or A is connected to C and D to F.		
DPCO	Double pole changeover *or* Double pole, centre off			Equivalent to *DPDT*. Some suppliers use *DPCO* for switches with a stable off position in the centre and *DPDT* for those without.		
		Intermediate switch	4-way switch	*DPDT* switch internally wired for polarity-reversal applications: only four rather than six wires are brought outside the switch housing; with the above, B is connected to F and C to E; hence A is connected to B and D to C, or A is connected to C and D to B.		

CHAPTER 3

RELAY

General Objective : To apply the concept of relay.
Specific Objectives : At the end of the unit you should be able to:

- Identify the main uses for a relay
- Identify the application of relay
- Show how the control relay is constructed mechanically
- Identify the specification of relay according to NEMA standard
- Draw the relay and switch logic circuit
- Identify the function of ladder-type diagram of relay
- Draw the schematic diagram and the ladder-type diagram of relay

3.1 Introduction Of Relays

The relay is an electromechanical device. The relay offers a simple ON/OFF switching action and response to a control signal.

3.2 Relay Principle

The electrical relay offers a simple ON/OFF switching action in response to a control signal. Figure 3.1 illustrates the principle. When a current flows through the coil of wire a magnetic field is produced. This pulls a movable arm that forces the contact to open or close. This might then be used to supply a current to a motor or perhaps an electric heater in a temperature control system.

Time-delay relays are control relays that have a delayed switching action. The time delay is usually adjustable and can be initiated when a current flows through the relay coil or when it ceases to flow through the coil.

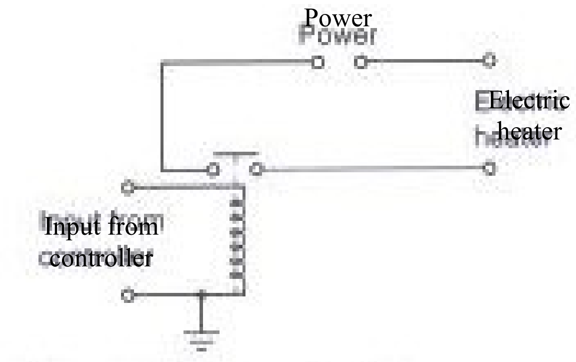


Figure 3.1: Relay Principle

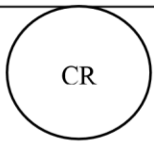
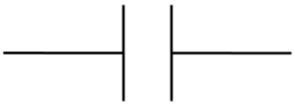
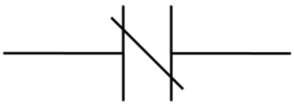
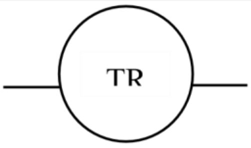
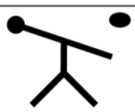
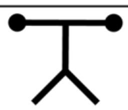
3.3 Application Of Relays In Industries

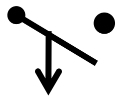
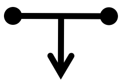
Relays are used in the control of fluid power valves and in many machine sequence controls such as boring, drilling, milling and grinding operations.

3.4 Symbol Of Relay

Below is the common electrical symbols of relay based on the function of relay.

Table 3.1: List of relay

Number of item	Symbol	Description
1		Relay coil
2		Normally opened Relay Contact
3		Normally closed Relay Contact
4		Time-Delay Relay Coil
5		Normally opened (time delayed after energizing)
6		Normally closed (time delayed after energizing)

7		Normally opened (time delayed after de-energizing)
8		Normally closed (time delayed after deenergizing)

3.5 Specification Of Relay

The standard voltage for relay used in machine control is 120 volt. The coils on electromechanical devices such as relays, contactors and motor starters are designed so as not to drop out (de-energize) until the voltage drops to minimum of 85% of the rated voltage. The relay coils also will not pick up (energize) until the voltage rises to 85% of the rated voltage. This voltage level is set by the National Electrical Manufacturer Association (NEMA). (htt3)

3.6 Relay And Switch Logic Circuit

Relays are widely applied in electromagnetic devices. Figure 3.2 and 3.3 shows a typical relay appearance. When the relay is not energized, the spring keeps the armature away from the coil. This produces an air gap and the main contact presses against the normally closed contact. When the relay is energized, the armature is attracted and moves toward the coil. This eliminates the air gap and the main contact touches the normally open contact and completes that circuit. The circuit with normally closed contact is opened. The relay acts as a single-pole double-throw switch. Many different contact arrangements are possible.

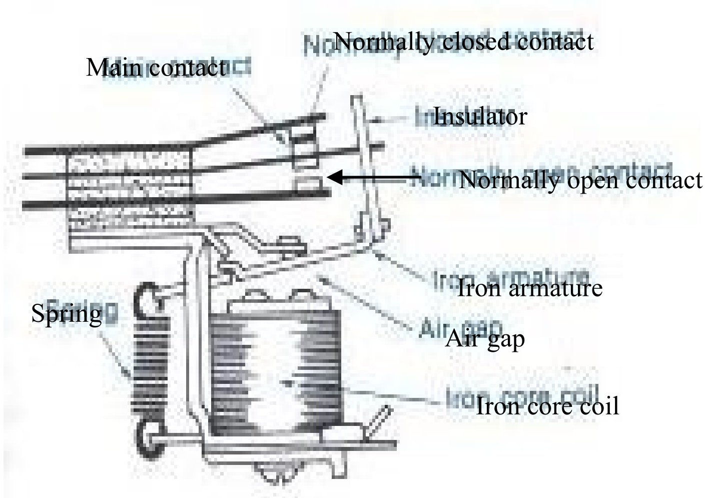


Figure 3.2: Typical physical appearance of a relay

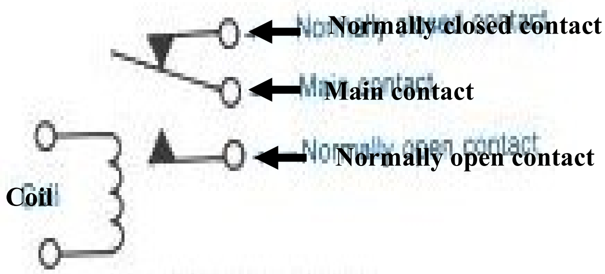


Figure 3.3: Single-pole double-throw relay schematic symbol

Relays require a given current for pull-in. Once they pull in, less current is required to hold them in the closed position. This is because the air gap is eliminated when the armature pulls in. The air has quite a bit more reluctance than the iron circuit and eliminating it means that less *mmf* is required to overcome the spring tension.

The switch logic circuit application in relay (Figure 3.4 shows a relay with two NO contacts). One contact is used as an interlock around the START push button. Thus, an interlock circuit is a path provided for electrical energy to the load after the initial path has been opened. The second relay contact is used to energize a light. Remember that when a relay coil is energized, the NO contacts close. The circuit can be de-energized by operating the STOP push-button switch.

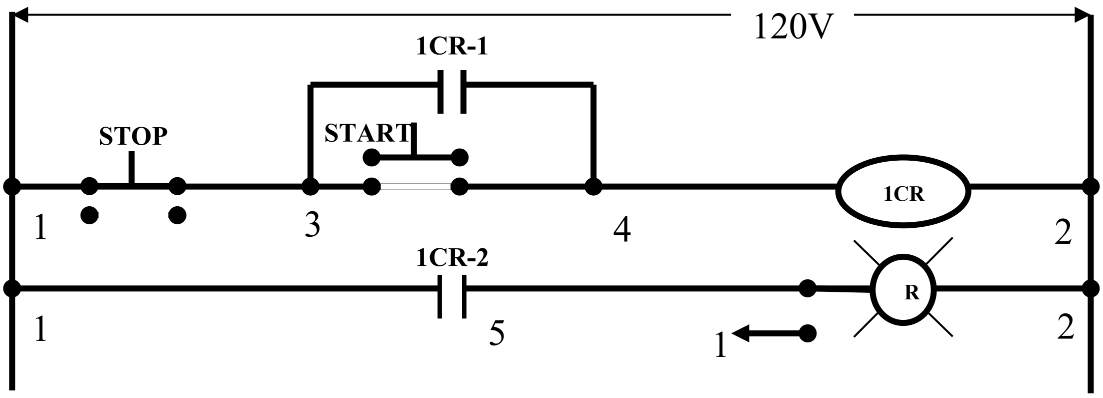


Figure 3.4: A relay with two NO contacts

Figure 3.5 shows the addition of a selector switch, fuse, pilot light and a second relay. When the selector switch is operated to the ON position, electrical energy is available at the two vertical sides of the circuit. The green light is energized, showing that the operation has been completed. One additional relay contact is added in the circuit from relay 1 CR. This contact closes when the relay1 CR is energized and it, in turn, energizes a second relay coil 2 CR. The operating circuit can be de-energized by operating the STOP push-button switch.

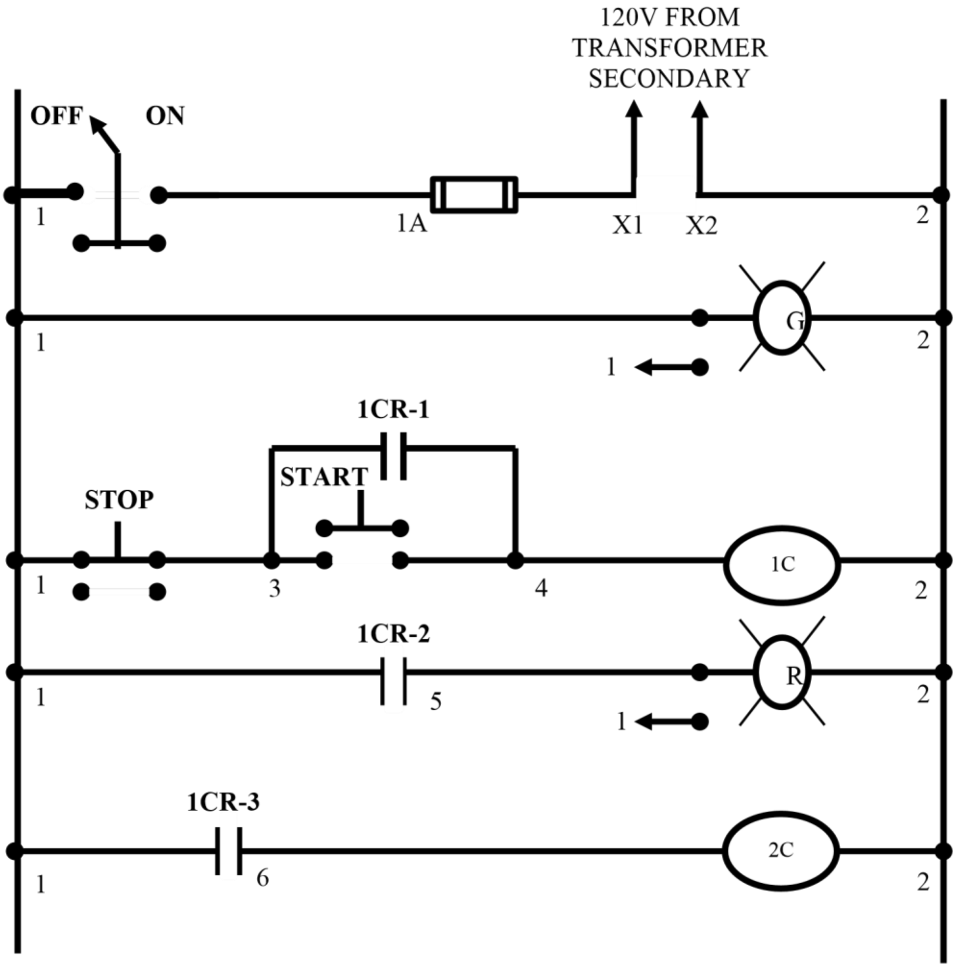


Figure 3.5: Addition of a selector switch, fuse, pilot light and a second relay.

Tutorial 3

1. Arrange right step for the operation of relay.

i. When the electromagnet is energized, the armature completes the second circuit.
ii. The armature is acting as a switch in the second circuit.
iii. When the electromagnet is not energized, the spring pulls the armature away and the circuit is not complete.
iv. When the switch is on, the electromagnet is on, and attracts the armature.

A. iii, iv, i, and ii.

B. iv, i, ii and iii.

C. iv, ii, i and iii.

D. ii, i, iii and iv.

2. Which type of device can switch AC and DC supply?

A. Transistor

B. Diode

C. Relay

D. Thyristor

3. Identify **TWO (2)** specifications to choose a relay. (4 marks)

4. Draw the symbol of the relay. (3 marks)

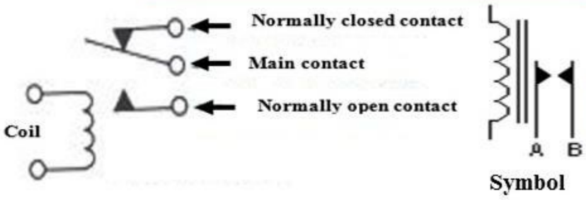
5. State the disadvantages of relay compare with transistor. (2 marks)

Mind Map

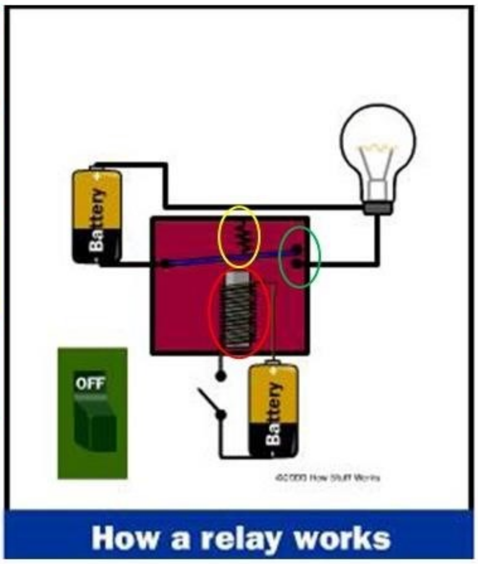
The relay offers a simple ON/OFF switching action and response to a control signal

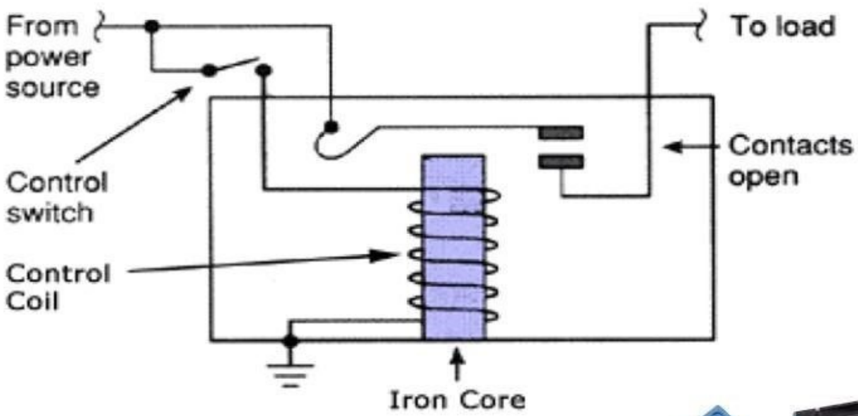
The relay acts as a single-pole double-throw switch

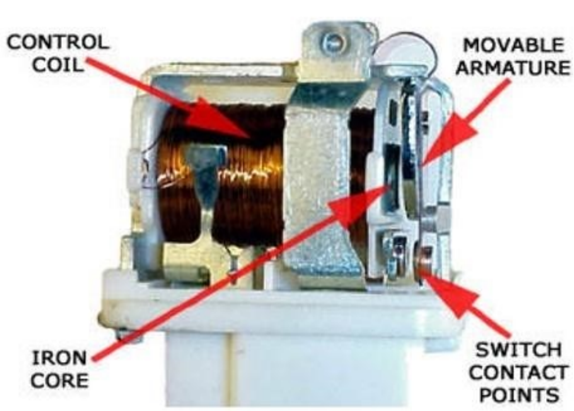
Parts in relay	Electromagnet
	Armature that can be attracted by the electromagnet
	Spring
	Set of electrical contacts

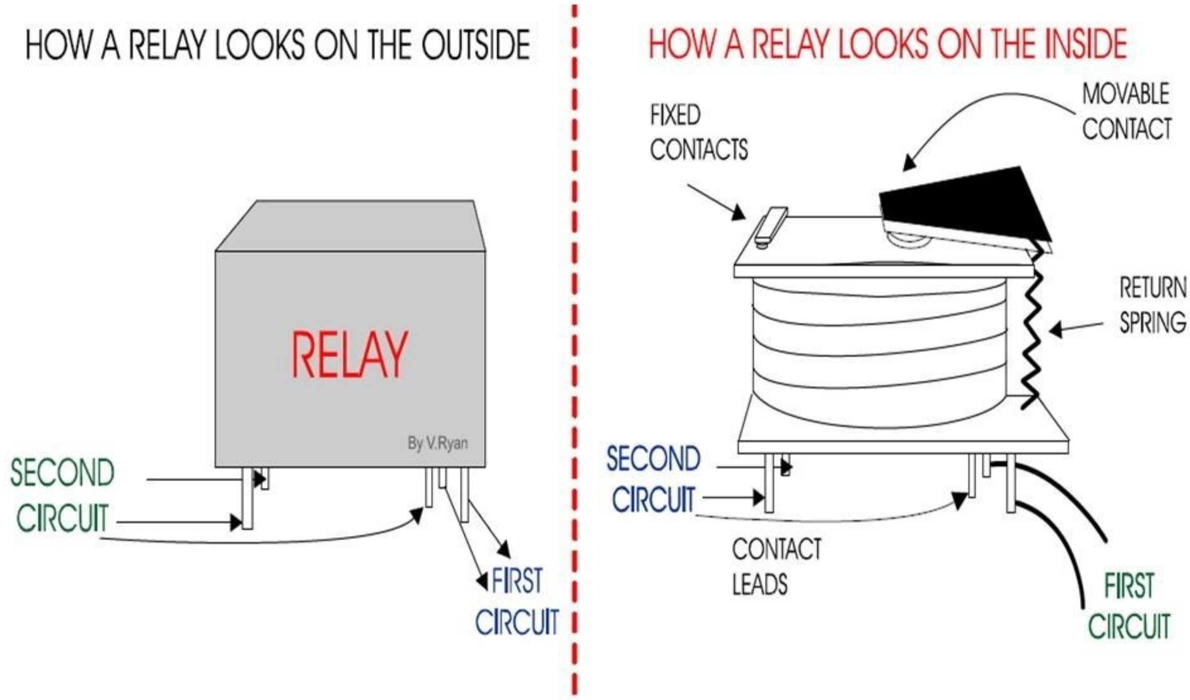


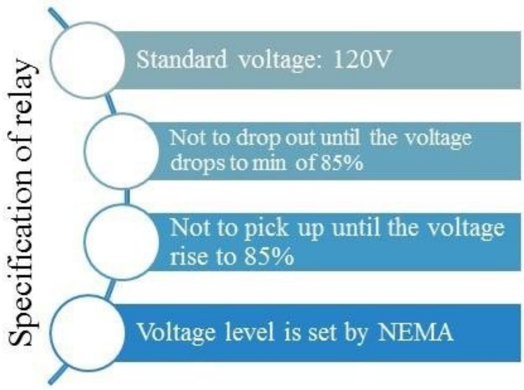
Symbol

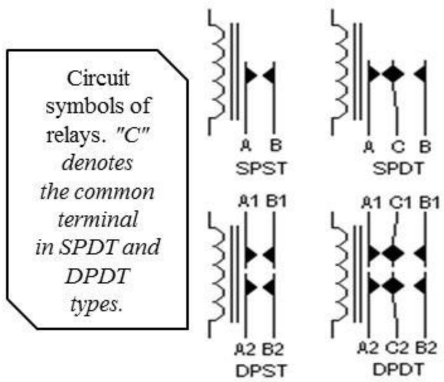


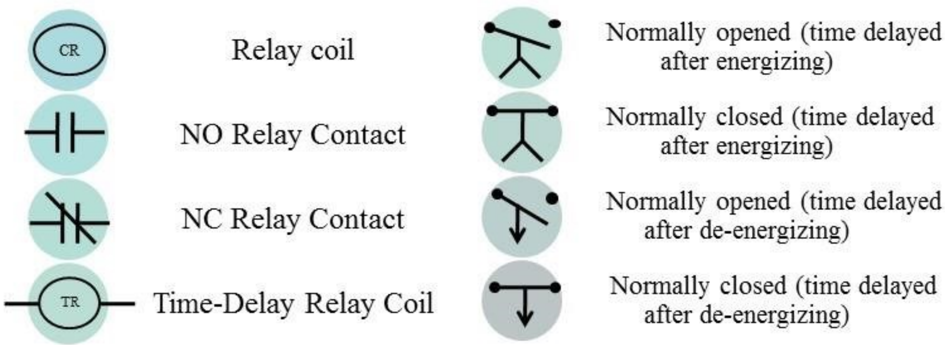





HOW A RELAY LOOKS ON THE OUTSIDE
RELAY
By V.Ryan
SECOND CIRCUIT
FIRST CIRCUIT
HOW A RELAY LOOKS ON THE INSIDE
FIXED CONTACTS
MOVABLE CONTACT
RETURN SPRING
SECOND CIRCUIT
CONTACT LEADS
FIRST CIRCUIT


Specification of relay
Standard voltage: 120V
Not to drop out until the voltage drops to min of 85%
Not to pick up until the voltage rise to 85%
Voltage level is set by NEMA


Circuit symbols of relays. "C" denotes the common terminal in SPDT and DPDT types.
A B
SPST
A C B
SPDT
A1 B1
A2 B2
DPST
A1 C1 B1
A2 C2 B2
DPDT

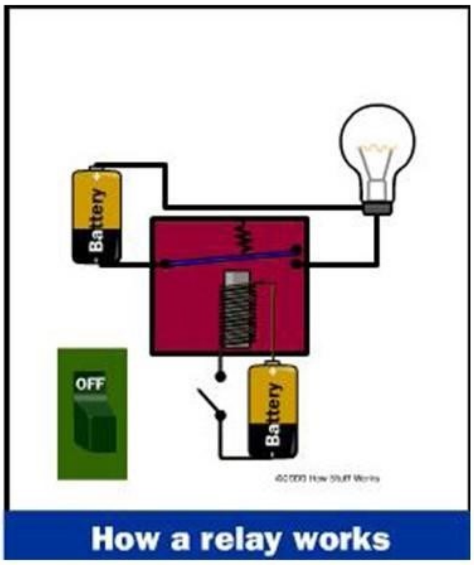

CR
Relay coil
NO Relay Contact
NC Relay Contact
TR
Time-Delay Relay Coil
Normally opened (time delayed after energizing)
Normally closed (time delayed after energizing)
Normally opened (time delayed after de-energizing)
Normally closed (time delayed after de-energizing)

When the switch is on, the electromagnet is on, and it attracts the armature (blue).

The armature is acting as a switch in the second circuit.

When the electromagnet is energized, the armature completes the second circuit and the light is on.

When the electromagnet is not energized, the spring pulls the armature away and the circuit is not complete. In that case, the light is dark.



Variables of relay

- The voltage and current that is needed to activate the armature
- The maximum voltage and current that can run through the armature and the armature contacts
- The number of armatures (generally one or two)
- The number of contacts for the armature (generally one or two - the relay shown here has two, one of which is unused)
- Whether the contact (if only one contact is provided) is **normally open (NO) or normally closed (NC)**

Application of relays in industries

Control of fluid power valve

Machine sequence controls

- ❖ Boring
- ❖ Drilling
- ❖ Milling
- ❖ Grinding

Applications of Relay

Control high voltage circuit with a low voltage signal

- Modems
- Audio amplifiers

Control a high current circuit with a low current signal

- Starter solenoid of an automobile

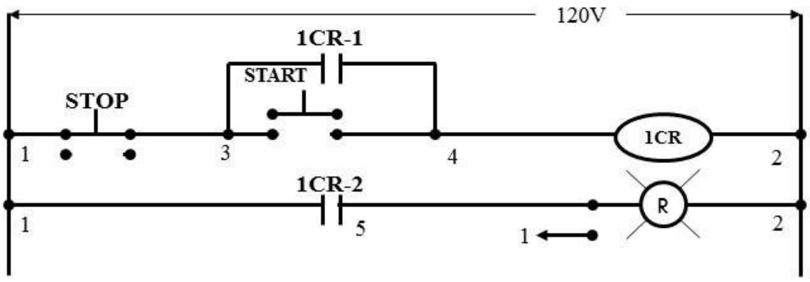
Detect and isolate faults on transmission and distribution lines

- Protection relays

Logic function

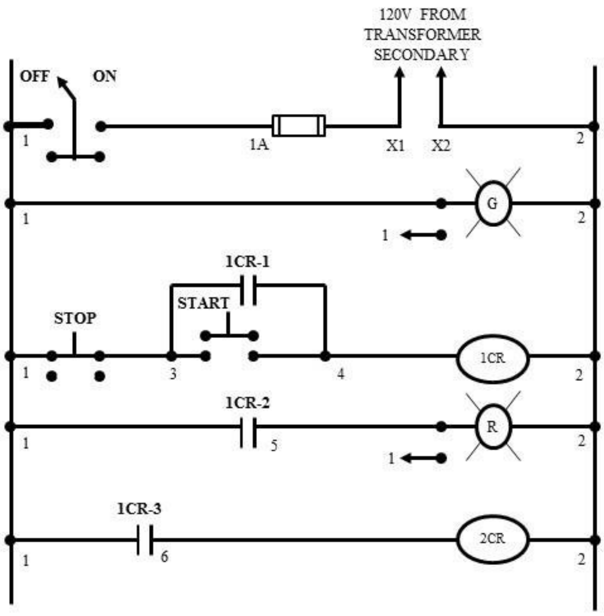
- AND function by connecting normally open relay contacts in series
- OR function by connecting normally open contacts in parallel

A RELAY WITH TWO NO CONTACTS



1. One contact is used as an interlock around the START push button
2. Thus, an interlock circuit is a path provided for electrical energy to the load after the initial path has been opened
3. The second relay contact is used to energize a light
4. Remember that when a relay coil is energized, the NO contacts close
5. The circuit can be de-energized by operating the STOP push-button switch

Addition of selector switch, fuse, pilot light and a second relay



When the selector switch is operated to the ON position, electrical energy is available at the two vertical sides of the circuit

The green light is energized, showing that the operation has been completed

Additional relay contact closes when the relay1 CR is energized and it, in turn, energizes a second relay coil 2 CR

The operating circuit can be de-energized by operating the STOP push-button switch

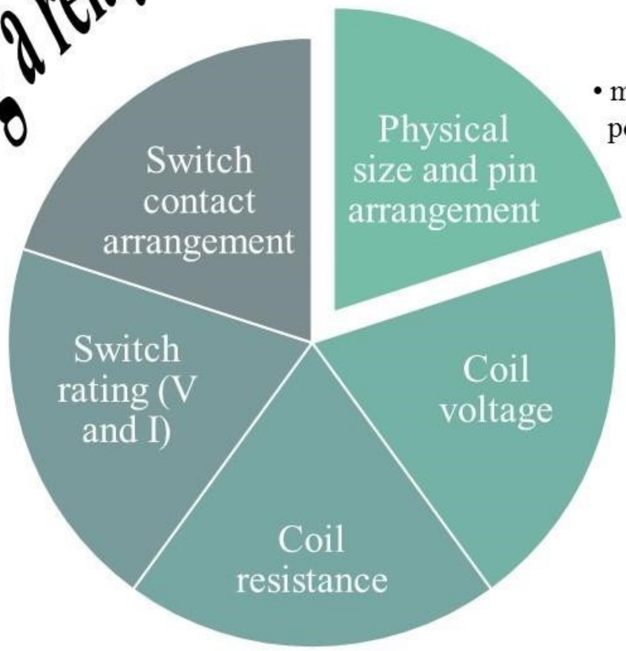
Advantages

- Can switch in AC and DC
- Can switch in high voltages
- Switching large currents (>5A)
- Switching many contacts at once

Disadvantages

- Bulkier
- Cannot switch rapidly
- Use more power due to the current flowing through their coil
- Require more current than many Ics can provide

Choosing a relay



• must suit the circuit powering the relay

$$\text{Relay coil current} = \frac{\text{suppply voltage}}{\text{coil resistance}}$$

CHAPTER 4

SOLENOID

General objective : To apply the concept of a solenoid.
Specific objectives : At the end of the unit you should be able to:

- Identify the main function of a solenoid
- Identify the application of a solenoid
- Describe the application of solenoids with operating valves
- Draw the symbol of a solenoid with a standard symbol
- Draw a control circuit showing the energizing of a solenoid through the closing of relay contact, using a control relay, two push- button switches and a solenoid

4.1 Introduction Of Solenoid

The general principle of the solenoid action is very important in machine control. Solenoid is an electromechanical device. Electrical energy is used to magnetically cause mechanical movement.

4.2 Principle Operation Of Solenoid

A solenoid is a coil with an iron core and moveable iron plunger. When the coil is energized, the plunger is attracted by the coil. It "pulls in", and this motion can be used to activate another mechanism.

The solenoid shown in Figure 4.2 (a), is used in many electrically activated devices such as valves, locks, punches and marking machines.

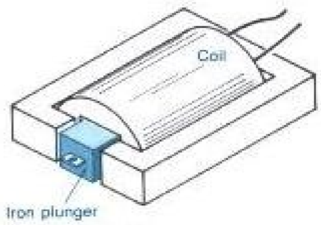


Figure 4.1: Schematic Diagram of Solenoid.

Solenoid is made up of three basic parts**: (a) Frame, (b) Plunger, (c) Coil.**

The frame and plunger are made up of laminations of high-grade silicon steel. The coil is wound of an insulated copper conductor. Solenoids for alternating current use are now available as oilimmersed types. Heat dissipation and wear conditions are improved with this design.

4.3 Symbol Of A Solenoid.

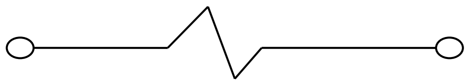


Figure 4.2 : Standard symbol of a solenoid**.**

4.4Types Of Solenoid.

There are many kinds of solenoids. Figure 4.3, shows one type of solenoid in industrial use.

Figure 4.3:Plug in, oil immersed of solenoid.

4.5 Basic Function Of Solenoid Control Circuit

Operating the START push-button switch close the circuit to the coil of relay ICR as shown in Figure 4.4. The coil is now energized. Relay contact 1CR-1 as shown below then closes, interlocking around the START push-button switch. Contact 1CR-2 closes, energizing solenoid A. The circuit can be de-energized by operating the REVERSE push-button switch.

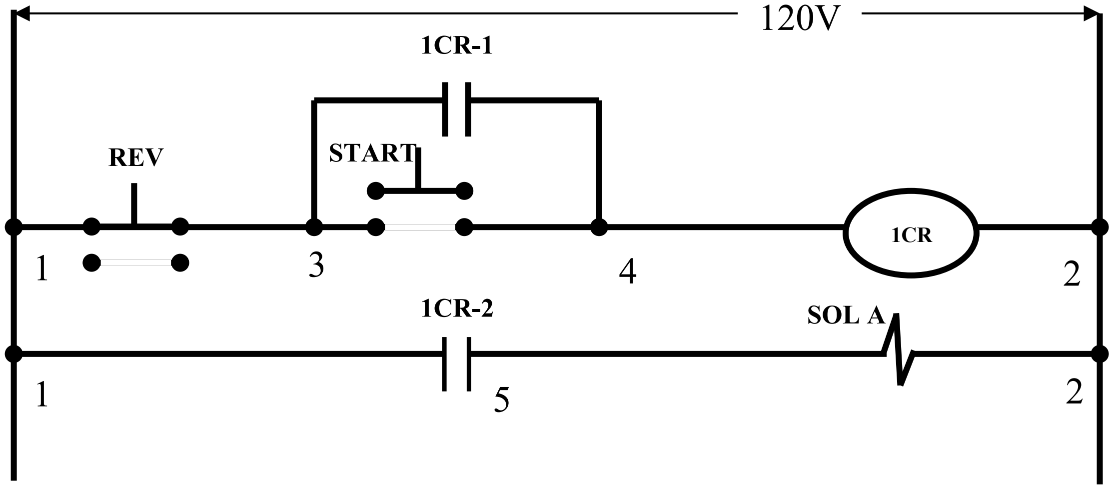


Figure 4.4: Single Solenoid Spring Return Valve.

In Figure 4.5, a time-delayed relay is added. Operating the START push button switch closes the circuit to the coil of relay 1CR. The coil is now energized. Contact 1CR-1 closes, interlocking around the START push button switch. Contact 1CR-2 closes, energizing solenoid 1A. Contact 1CR-3 closes, energizing the coil of timing relay 1TR. After a time delay, as set on the timing relay, the timing constant contact closes, energizing solenoid 1B. The circuit can be de-energized by operating the REVERSE push-button switch. Note that if for some reason the REVERSE push button switch is operated before the time set on the timing relay expires, solenoid 1B will not be energized, as the timing relay coil will be de energized . With the relay coil de-energized, the timing contact remains in the normal open condition.

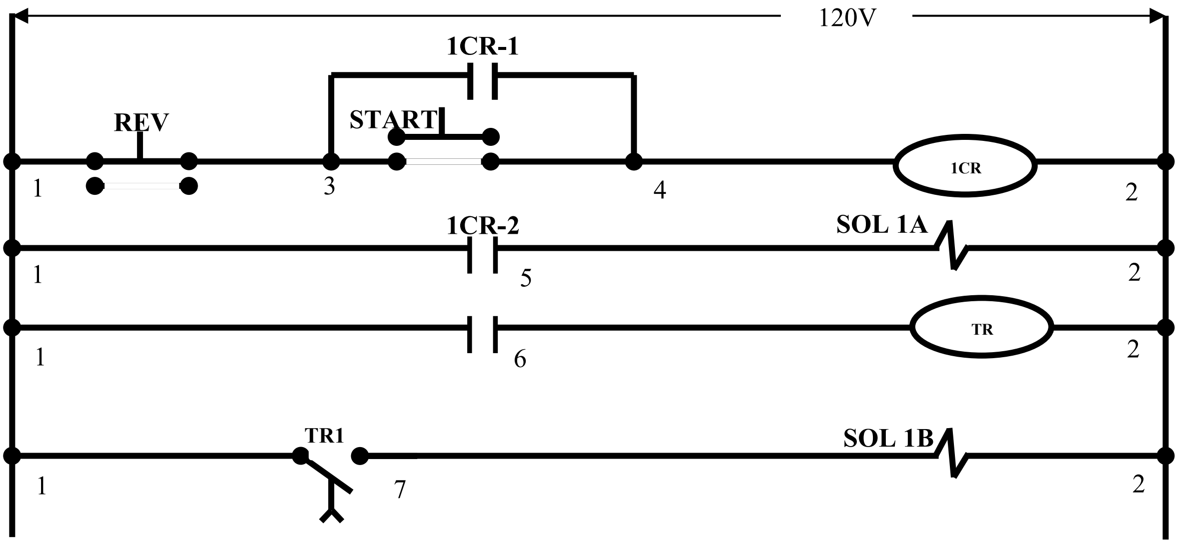


Figure 4.5: Single Solenoid Spring Return Valve.

4.6 Application Of Solenoids

Solenoids are used to control fluid flow in hydraulic or pneumatic system. Solenoids are also applied in many electrically activated devices such as valves, locks, punches and marking machines.

<u>Tutorial 4</u>

1. List **THREE (3)** structures of the solenoid. (3 marks)

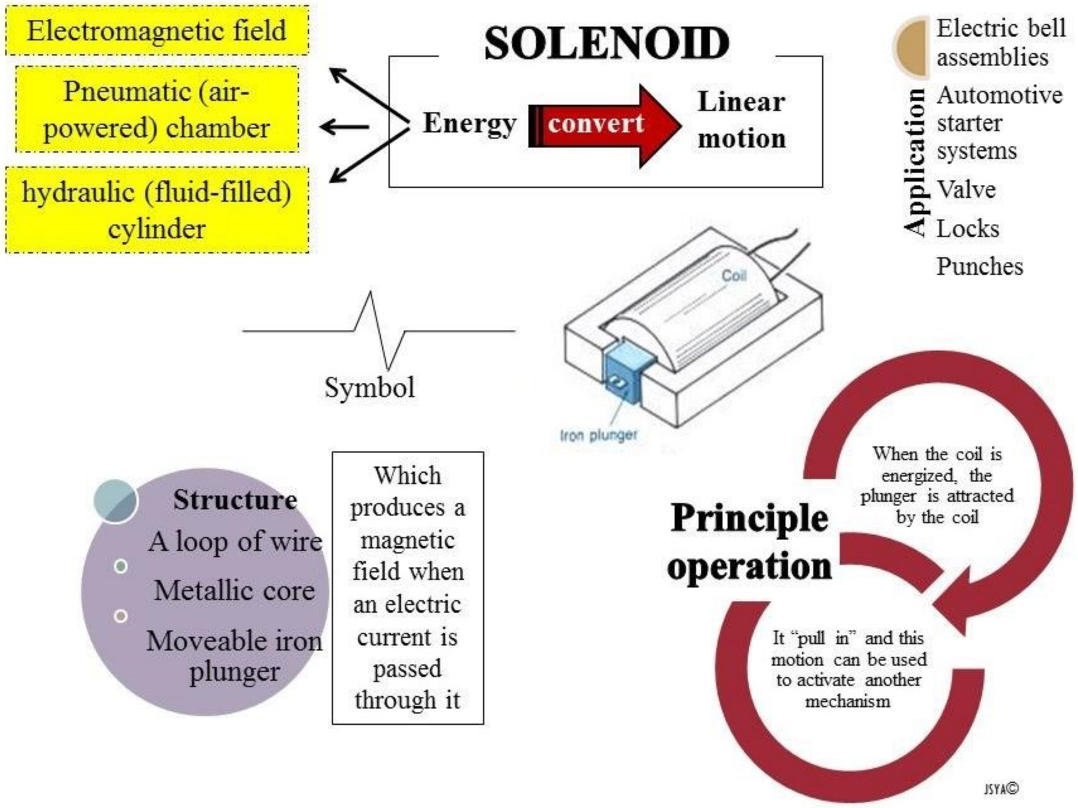
2. List **THREE (3)** application of the solenoid. (3 marks)

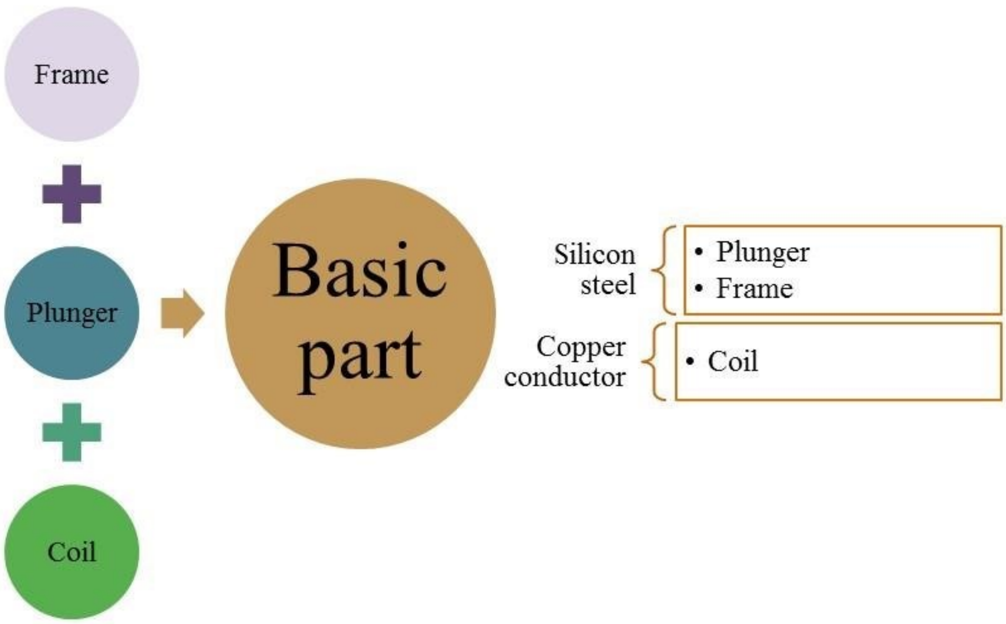
3. The figure 1 below refer to:

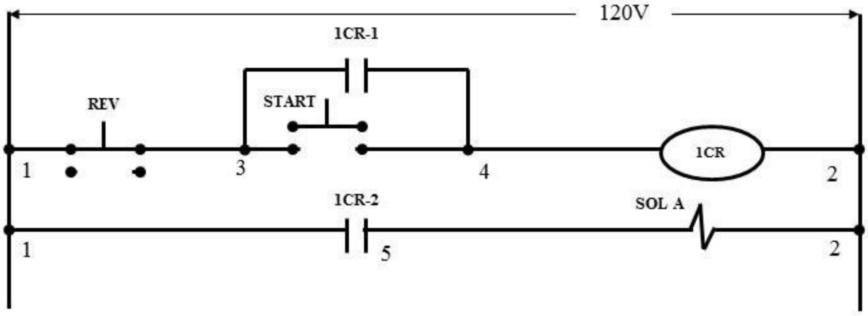
Figure 1

A. Solenoid
B. Relay
C. Switch
D. Resistor

Mind Map


SOLENOID
Energy
convert
Linear motion
Electromagnetic field
Pneumatic (air-powered) chamber
hydraulic (fluid-filled) cylinder
Application
Electric bell assemblies
Automotive starter systems
Valve
Locks
Punches
Symbol
Coil
Iron plunger
Structure
A loop of wire
Metallic core
Moveable iron plunger
Which produces a magnetic field when an electric current is passed through it
Principle operation
When the coil is energized, the plunger is attracted by the coil
It "pull in" and this motion can be used to activate another mechanism
JSYA©

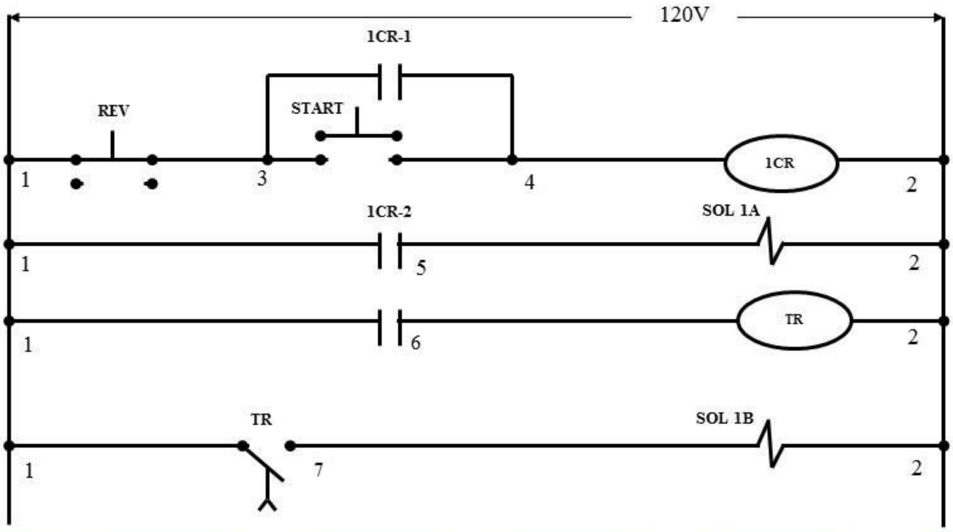

Frame
Plunger
Coil
Basic part
Silicon steel
• Plunger
• Frame
Copper conductor
• Coil
JSYA©



Single solenoid spring return valve

1. START push-button switch close the circuit to the coil of relay 1CR [Coil energized]
2. Relay contact 1CR-1 then closes, interlocking around the START push-button switch
3. Contact 1CR-2 closes, energizing solenoid A
4. The circuit can be de-energized by operating the REVERSE push-button switch

JSYA©



The START push button switch closes the circuit to the coil of relay 1CR [Coil energized] → Contact 1CR-1 closes, interlocking around the START push button switch → Contact 1CR-2 closes, energizing solenoid 1A → Contact 1CR-3 closes, energizing the coil of timing relay 1TR → After a time delay, as set on the timing constant contact closes, energizing solenoid B → The circuit can be de-energized by operating the REVERSE push button switch

Note that if for some reason the **REVERSE push button** switch is **operated before** the time set on the **timing relay expires**, solenoid **1B will not be energized** , as the **timing relay coil will be de energized** . With the relay coil de-energized , the timing contact **remains in the normal open condition.** JSYA©

CHAPTER 5

SENSOR

General objective: To understand the function of transducer and sensor.
Specific objectives: At the end of the unit, you should be able to:

- List the advantages and disadvantages of transducer and sensor.
- Describe the application of transducer and sensor.
- Identify the types of transducers and sensor.
- Describe the specification of sensor and transducer.

5.1 Introduction of Transducer.

The function of transducer is to converts one quantity into another. It has the elements that can convert one signal quantity to another. For example, it can convert pressure to displacement, displacement to electrical movement force, and so on. In other terms, a transducer is a device that connects the electrical to the non-electrical. Physical characteristics are converted into electrical signals that the acquisition system can understand. Temperature, pressure, acceleration, weight displacement, and velocity are examples of typical parameters. Electrical quantities such as voltage, resistance, and frequency can also be measured directly. Transducer includes a sensor.

5.2 Classification of Transducer.

A measurement is produced, and the results are recorded by a group of electronic components that make up an instrumentation system. An input device, signal conditioning or processing devices, and output devices are the three fundamental parts of an instrumentation system. The amount to be measured is received by the input device, which then transmits a proportionate electrical signal to the signal-conditioning apparatus. To make the signal suitable with the output device, it may be amplified, filtered, or modified in some other way. The output device might be a basic indicating metre, an oscilloscope, or a chart recorder for visual display. It may be a magnetic tape recorder for temporary or permanent storage of the input data, or it could be a digital computer for data processing or process control. The type of system used is determined by what is to be measured and how the measurement results are to be presented.

Most instrumentation systems have non-electrical input quantities. For the purpose of using electrical methods and procedures for measurement, manipulation, or control, a transducer transforms a non-electrical quantity into an electrical signal. According to one meaning, a transducer is "a device that, when triggered in one transmission system, delivers energy in the same or a different form to a second transmission system." This conveyance of energy might be electrical, mechanical, chemical, optical, or thermal.

Devices that convert displacement or force from mechanical to electrical, for example, are included in this wide definition of transducer. The instrumentation engineer's focus is on this kind of energy conversion, and these devices are a component of a large and important class of transducers used in industrial instrumentation. Transducers may also transform many additional physical factors (such as heat, light intensity, and humidity) into electrical energy. When stimulated by a nonmechanical input, these transducers produce an output signal; for example, an electron beam reacts to magnetic influences, a thermistor to temperature changes, a photocell to variations in light intensity, and so on. In every situation, the electrical output is measured according to standard procedures, giving the size of the input quantity as an analogue electrical measure.

Transducers are categorised based on their use, energy conversion mechanism, output signal type, and so on. All these classifications frequently result in regions that overlap. It is challenging to distinguish and classify different types of transducers.

5.3 Specification of Transducer.

The transducer is the input device in a measuring system that performs the important function of converting some physical quantity to a proportionate electrical signal. The first and possibly most critical step in achieving accurate findings is hence the selection of the proper transducer. Before selecting a transducer, a few basic questions should be answered, such as: what the physical amount is to be measured, which transducer principle may best be utilised to measure this quantity, and what precision is necessary for this measurement.

By determining the sort and range of the measurand, the first question can be answered. The transducer's input and output properties must be compatible with the recording or measuring system in order to provide a satisfactory answer to the second question. In most circumstances, these two issues are easily addressed, meaning that the right transducer is picked simply by adding an accuracy tolerance. In fact, because to the complexities of the different transducer characteristics that impact accuracy, this is rarely attainable. The degree to which individual aspects contributing to accuracy must be addressed is determined by the entire system's accuracy requirements. Some of these elements are as follows:

a. Fundamental transducer parameters – type and range of measurand, sensitivity, excitation.
b. Physical conditions – mechanical and electrical connection, mounting provisions, corrosion resistance.
c. Ambient conditions – nonlinearity effects, hysteresis effects, frequency response, resolution.
d. Environment conditions – temperature effects, acceleration, shock and vibration.

e. Compatibility of the associated equipment – zero balance provisions, sensitivity tolerance, impedance matching, insulating resistance.

Categories (a) and (b) are the transducer's fundamental electrical and mechanical properties. Transducer accuracy, as an independent component, is included in categories (c) and (d) (d). Category (e) analyses the transducer's compatibility with the system equipment.

The total measurement error in a transducer-activated system may be reduced to fall within the required accuracy range by the following techniques,

a. Using in-place system calibration with corrections performed in the data reduction.
b. Simultaneously monitoring the environment and correction the data accordingly.
c. Artificially controlling the environment to minimize possible errors.

Some individual faults are known and can be calibrated out of the system. When the complete system has been calibrated, the calibration data may be utilised to adjust the recorded data. Environmental mistakes can be rectified by data reduction if the environmental impacts are captured concurrently with the real data. The data is then adjusted by utilising the transducers' known environmental properties. These two strategies have the potential to significantly improve system accuracy.

Another way to increase overall system accuracy is to intentionally regulate the transducer's surroundings. These mistakes are reduced to zero if the transducer's environment is kept constant. This form of control may include either physically shifting the transducer to a more advantageous position or providing the necessary isolation from the environment through the use of a heating enclosure, vibration isolation, or other similar measures.

5.4 Principles Of Sensor/Transducers Operation.

5.4.1 Displacement Sensor.

Many types of transducers use the principle of translating an applied force into a displacement. Force-summing devices are mechanical elements that are used to transform an applied force into a displacement. The following are the most often used force-summing members:

a. Diaphragm,
b. Bellows
c. Bourdon tube, circular or two suspensions twisted.
d. Straight tube
e. Mass cantilever, single or
f. Pivot torque.

Example of these force-summing devices as shown in Figure 5.1.

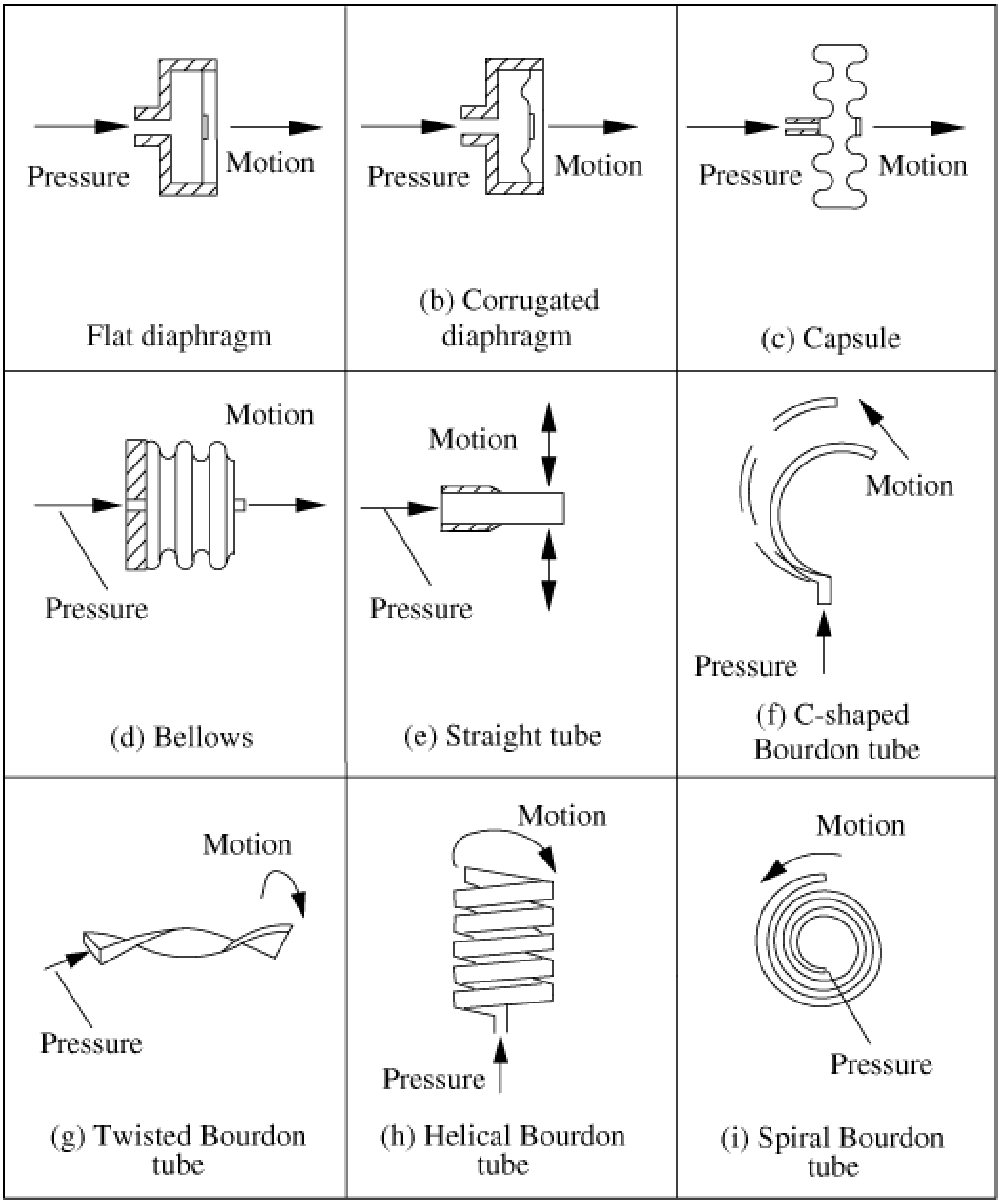


Figure 5.1: Force-summing devices. (htt1)

The The displacement caused by the force-summing device's operation is transformed into a change in an electrical parameter. The electrical concepts most typically utilised in displacement measuring are as follows:

a. Capacitive.
b. Inductive
c. Differential transformer
d. Ionization
e. Oscillation.

5.4.1.1 Capacitive Sensor.

Because capacitance is inversely proportional to parallel plate spacing, any difference results in a corresponding fluctuation in capacitance. This technique is used in the capacitive transducer shown in Figure 5.2. A force applied to a diaphragm that serves as one plate of a simple capacitor alters the distance between the diaphragm and the static plate. The resultant capacitance change might be detected using an ac bridge, but it is commonly tested with an oscillator circuit. The transducer, as part of the oscillatory circuit, changes the frequency of the oscillator. This variation in frequency represents the magnitude of the applied force.

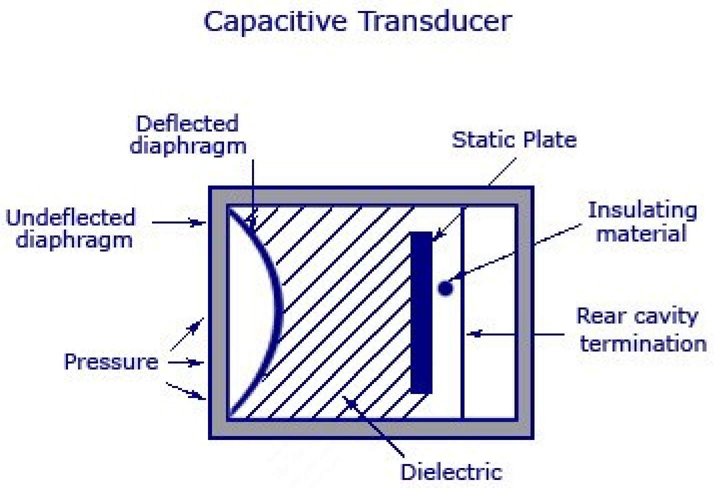
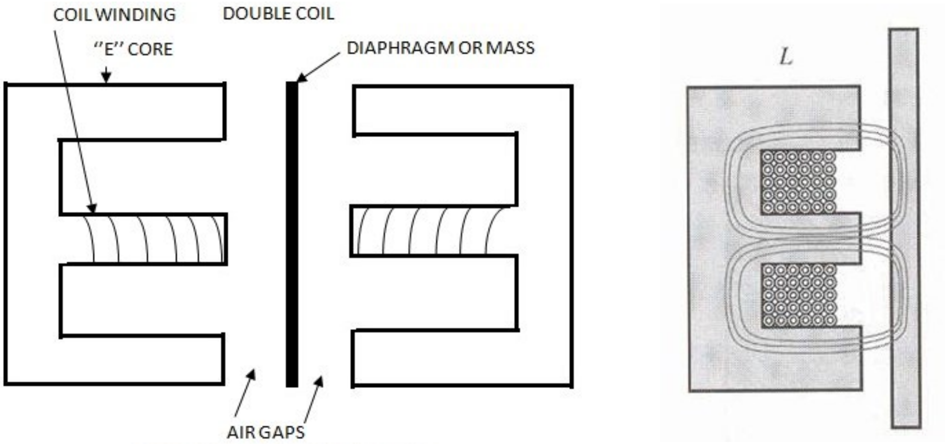


Figure 5.2: Capacitive Transducer. (htt2)

The capacitive transducer has a high frequency response and can detect both static and dynamic events. Its drawbacks include susceptibility to temperature changes and the likelihood of irregular or distorted signals due to the large lead length. Furthermore, the receiving apparatus can be vast and sophisticated, and it frequently incorporates a second fixed-frequency oscillator for heterodyning. The resulting differential frequency can be read by a suitable output device, such as an electronic counter.

5.4.1.2 Inductive Sensor.

The change in the inductance ratio of a pair of coils or the change in inductance in a single coil is used to measure force in an inductive transducer. The ferromagnetic armature is shifted by the force being measured in each example, altering the reluctance of the magnetic circuit. Figure 5.3 depicts how changing the location of the armature affects the air gap. The change in inductance that results is a measure of the magnitude of the applied force.



(a) Double Coil (b) Single Coil

Figure 5.3: Inductive Transducer (htt4)

The coil can be used as a component of an LC oscillator, whose frequency fluctuates when force is applied. With a single coil that regulates the frequency of a local oscillator, this form of transducer is widely employed in telemetry systems.

The mechanical components of the transducer are nearly completely responsible for hysteresis errors. When a diaphragm is utilised as the force-summing member, as illustrated in figure 5.3, it may become a component of the magnetic circuit. Because the desirable mechanical qualities of the diaphragm must be compromised to increase magnetic performance, the overall performance of the transducer is considerably decreased in this configuration.

The inductive transducer reacts to static and dynamic measurements, and it has a high output and continuous resolution. Its downside is that the frequency response (variation of the applied force) is restricted by the forcesumming member's structure.

5.4.2 Velocity Sensor.

As illustrated in Figure 5.4, the velocity transducer is essentially made up of a moving coil hung in the magnetic field of a permanent magnet. The motion of the coil in the field produces a voltage. Because the output is proportional to the velocity of the coil, this sort of pickup is commonly employed for measuring linear, sinusoidal, or random velocities. Damping is provided electronically, ensuring good stability under temperature variations.

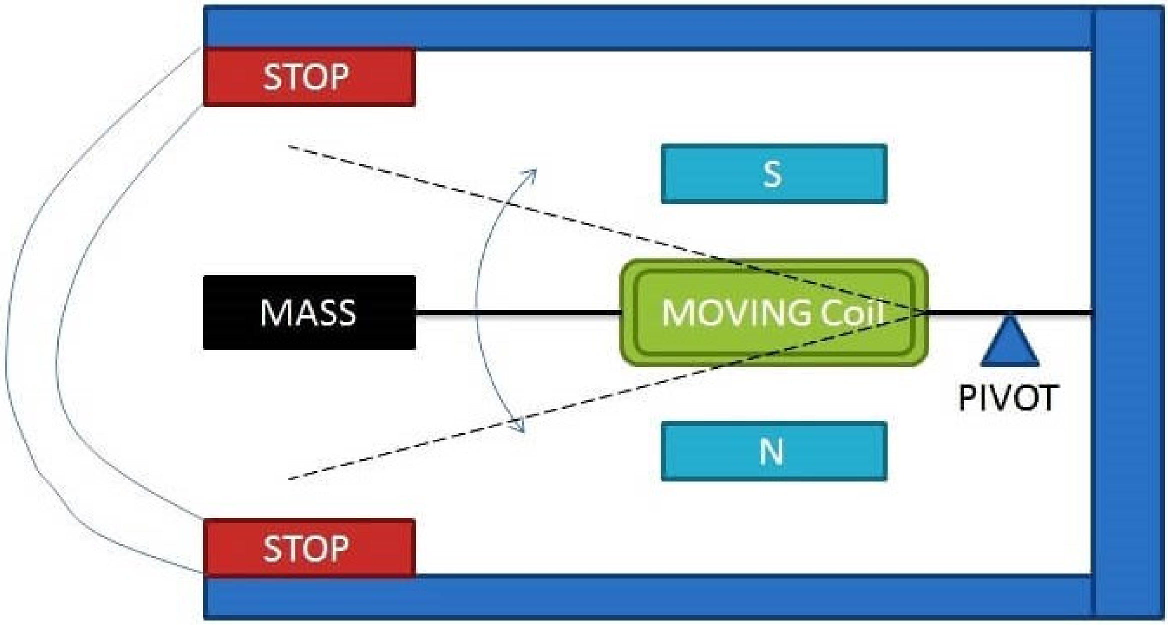


Figure 5.4: Element Of A Velocity Transducer.

5.4.3 Pressure And Level Sensor.

5.4.3.1 Bourdon-Tube Pressure Gauge.

A Bourdon tube is a long thin-walled cylinder with a noncircular cross section that is sealed at one end and built of materials such as phosphor bronze, steel, and beryllium-copper. A pressure applied to the inside of the tube induces a proportionate deflection of the free end. The C-type is the most often used form, as seen in Figure 5.5. Using spiral and helical-shaped tubes can improve sensitivity. A gear-and-lever mechanism converts the displacement into a pointer spin along a scale. Using any of the displacement transducers, you may simply obtain remote pressure indication.

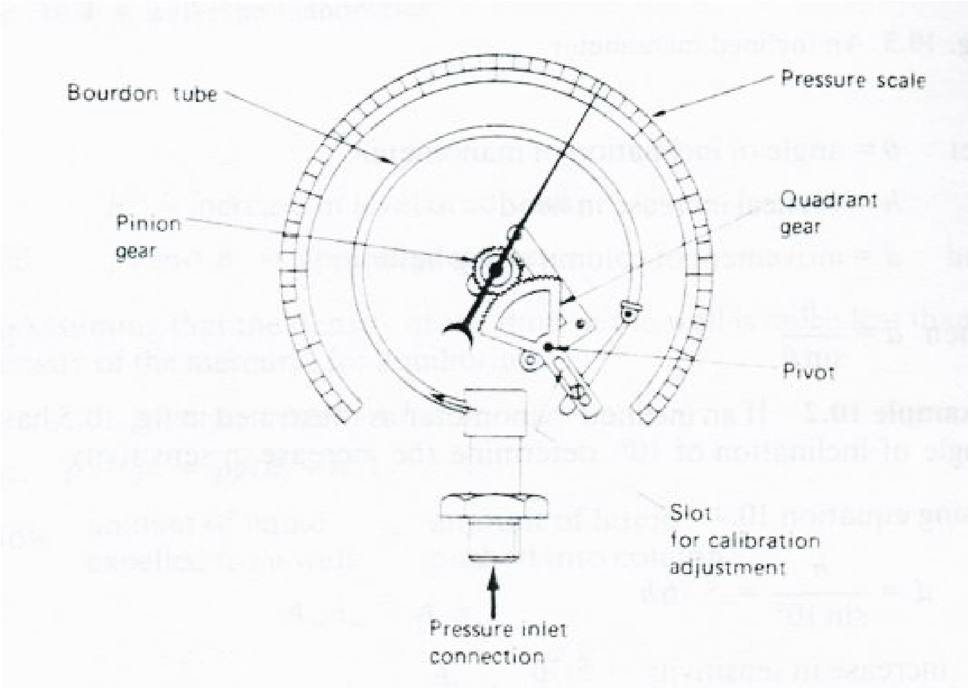


Figure 5.5: A Bourdon-Tube Pressure Gauge.

Up to 500MN/m2 of static and low-frequency pressure. If electrical displacement transducers are utilised, the frequency range is restricted by the inertia of the Bourdon tube.

5.4.3.2 Diapraghm Pressure Transducer.

Flat diaphragms are frequently used as primary sensing components in pressure transducers, employing either the diaphragm's centre deflection or the strain caused in the diaphragm. They are easily constructed as flush-mounted sensing elements with a clean smooth face, making them excellent for usage in unclean settings for surface pressure monitoring.

For high-pressure transducers, a very rigid diaphragm must be employed to keep the centre deflection to less than one-third of the diaphragm thickness, else the result will be non-linear. Lower pressure ranges, up to a few bars, need a beryllium-copper corrugated diaphragm and bellow to provide the requisite sensitivity.

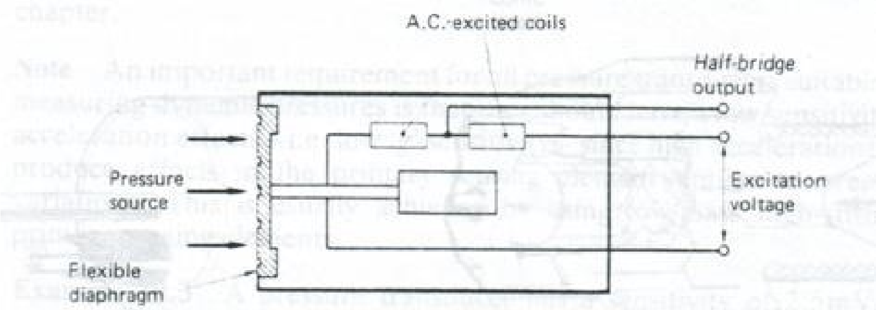


Figure 5.6: An Inductive Pressure Transducer.

5.4.3.3 Piezo-Electric Pressure Transducer.

The design of piezoelectric pressure transducers is similar to that of quartz load cells. A diaphragm in in touch with the pressure being measured compresses the quartz discs. Because of the excellent sensitivity of the quartz-crystal modules, transducers may be made in incredibly small sizes. The great sensitivity of quartz transducers is a distinguishing feature.

Piezo-electric pressure transducers can be used at temperatures as high as 240°C, however care must be given to adjust for temperature-induced zero-drift. Special water-cooled transducers, as illustrated in figure 5.7, are available and are especially suitable for high-temperature applications.

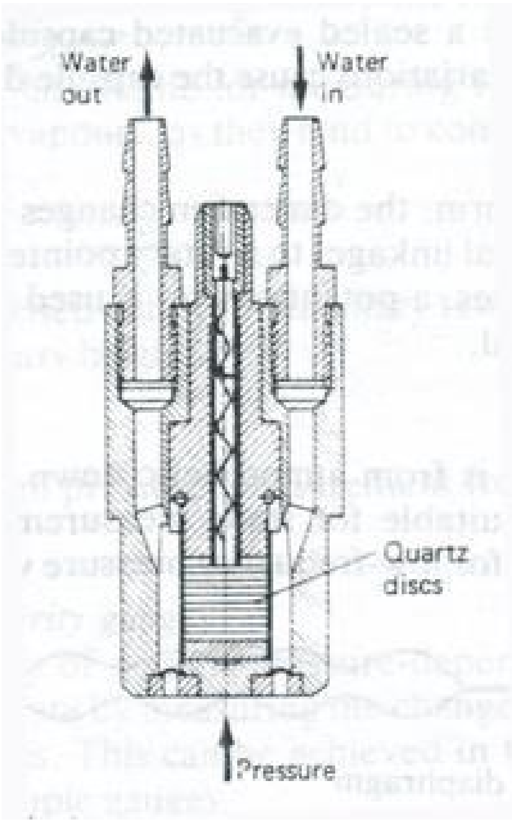


Figure 5.7: A Water –Cooled Piezo-Electric Pressure Transducer.

5.4.4 Temperature Sensor.

5.4.4.1 Resistance Thermometers.

Resistance thermocouples or resistance-temperature detectors use a sensitive element made of exceptionally pure platinum, copper, or nickel wire that produces a defined resistance value at each temperature within its range. The equation may be used to calculate the connection between temperature and resistance of conductors in the temperature range approaching 0º C.

$$Rf = Rref\,(1 + \alpha \Delta t)$$

Where ,

Rf = resistance of the conductor at temperature t (ºC) $Rref$ = resistance at the reference temperature, usually 0 ºC.

α= temperature coefficient of resistance.

Δt = difference between operating and reference temperature.

Almost all metallic conductors have a positive temperature coefficient of resistance, which means that their resistance increases as the temperature rises. Some materials, such as carbon and germanium, have a negative temperature coefficient of resistance, which means that resistance decreases as temperature rises. In a temperature-sensing element, a high value of is preferred such that a significant change in resistance occurs for a relatively little change in temperature. This resistance change (R) may be measured using a Wheatstone bridge, which can be calibrated to show the temperature that produced the resistance change rather than the resistance change itself.

The sensing element of a resistance thermometer is chosen based on its intended application. Platinum wire is utilised for most laboratory work and high-accuracy industrial tests. Nickel wire and copper wire are less expensive and easier to produce than platinum wire elements, and they are frequently used in low-level industrial applications.

Resistance thermometers are typically probe thermometers that are immersed in the medium whose temperature is being measured or regulated. A common probe-type thermometer sensing element is made by covering a tiny platinum or silver tube with ceramic material, wrapping the resistance wire over the coated tube, and coating the final winding with ceramic again. This little assembly is then burned at high temperatures to ensure annealing of the winding before being inserted at the probe's tip. To create the full sensing element, the probe is shielded by a sheath.

When used to measure the resistance fluctuations of a resistance thermometer, the Wheatstone bridge has certain drawbacks. These are the effects of contact resistances of connections to bridge terminals, imbalance current heating of the elements, and heating of the wires connecting the thermometer to the bridge. Most of these issues are solved by minor modifications to the Wheatstone bridge, such as the twin slide-wire bridge. Despite these measurement challenges, the resistance thermometer method is sufficiently precise that it is one of the standard methods of measuring temperature between -183oC and 630oC. The properties of the three most often utilised resistance materials are summarised in Table 5.1.

Table 5.1: Resistance Thermocouple Elements.

TYPE	PLATINUM	COPPER	NICKEL
Temperature Range	-300^{O}F to 1,500^{O}F	-325^{O}F to 250^{O}F	-32^{O}F to 150^{O}F
Accuracy	± 1^{O}F	± 0.5^{O}F	± 0.5^{O}F
Advantages	• Low Cost. • High Stability. • Wide Operating range.	• High linearity. • High accuracy in ambient temperature range. • High stability.	• Long life. • High sensitivity. • High temperature coefficient.
Disadvantages	• Relatively slow response time (15s). • Not as linear as copper thermometers.	• Limited temperature range (to 250^{O}F).	• More nonlinear than copper • Limited temperature range (to 150 ^{O}F)

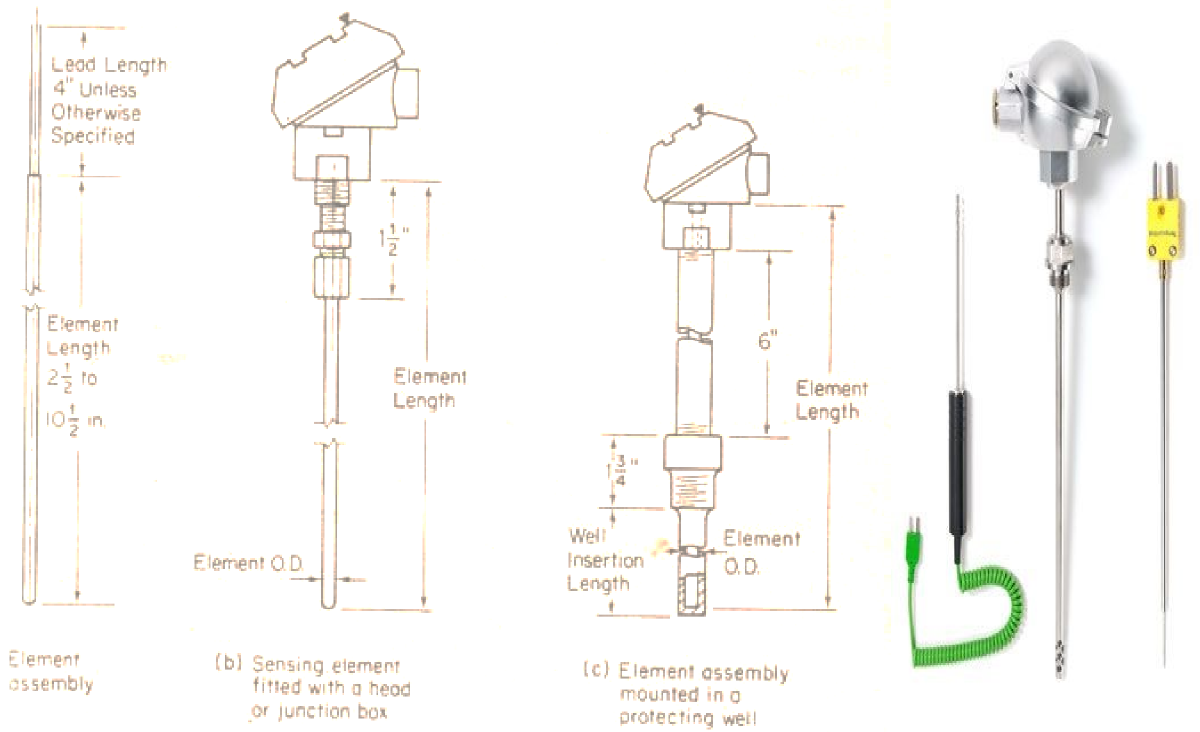


Figure 5.8: Resistance Thermometers.

5.4.4.2 Thermocouples.

A thermocouple is made up of two different metal wires that are linked together at one end (the sensing, or hot, junction) and terminated at the other end (the reference, or cold, junction) at a known constant temperature (reference temperature). When there is a temperature differential between the sensing and reference junctions, an emf is formed, which causes a current to flow through the circuit. When a metre or recording device is used to terminate the reference junction, as shown in figure 5.9, the metre indication is proportionate to the temperature differential between the hot junction and the reference junction. The Seeback Effect refers to the thermoelectric effect generated by contact potentials at junctions.

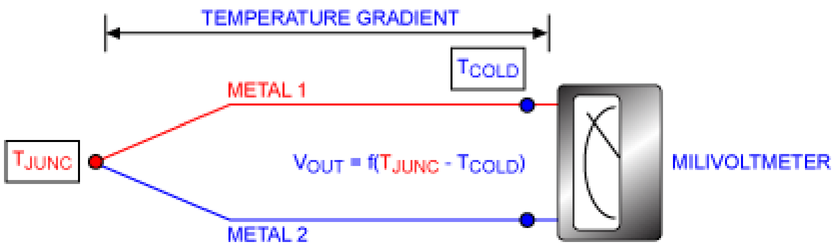


Figure 5.9: Basic Thermocouple Circuit.

A thermocouple is covered in an open or closed end metal protective tube or well to guarantee extended life in its operating environment. The protective tube is both chemically inert and vacuum tight to avoid contamination of the pair when valuable metals (platinum and its alloys) are utilised. Because the thermocouple is frequently located far away from the measurement device, connections are established using special extension cables known as compensation wires. When the compensating wires are made of the same material as the thermocouple wires, measurement accuracy is maximised.

The most basic thermocouple temperature measurement is to attach a sensitive millivoltmeter directly across the cold junction. The temperature difference between the hot and reference junctions is thus almost directly proportional to the meter's deflection. The thermocouple's ability to provide only a very small amount of electricity to operate the metre movement is one of the basic instrument's most significant disadvantages.

The major frequent way for measuring thermocouple temperature is to use a potentiometer.

5.4.4.3 Thermistor.

Thermistors, also known as thermal resistors, are semiconductor devices that act like resistors but have a high, generally negative, temperature coefficient of resistance. In certain situations, a thermistor's resistance at room temperature might drop by as much as 6% for every 1°C increase in temperature. Because of its great detection to temperature change, the thermistor is ideal for precise temperature monitoring, control, and correction. As a result, thermocouples are commonly utilised especially in the lower temperature range of -100°C to 300°C, in such applications.

A sintered mixture of metallic oxides, including those of manganese, nickel, cobalt, copper, iron, and uranium, is what makes up a thermocouple. The tiniest beads have dimensions between 0.15mm and 1.25mm. To generate probes that are simpler to attach than beads, beads might be sealed inside the tips of solid glass rods. Disks and washers are created by applying high pressure to thermistor material and pressing it into flat cylindrical forms ranging in diameter from 2.5 mm to 25 mm. For enhanced power dissipation, washers can be stacked and connected in series or parallel.

The resistance-temperature characteristic, the voltage-current characteristic, and the current-time characteristic are three fundamental characteristics of thermistors that make them particularly useful in measurement and control applications.

5.4.5 Photoelectric Sensor.

The photo emissive cell or phototube properties are utilised by the photoelectric transducer. When exposed to incoming light, the phototube regulates its electron emission. A phototube's architecture is seen in figure 5.10, and its symbol is depicted in figure 5.11.

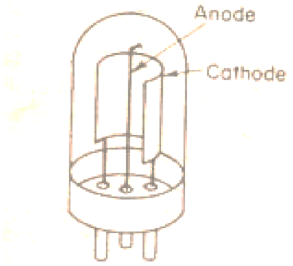


Figure 5.10 : Construction

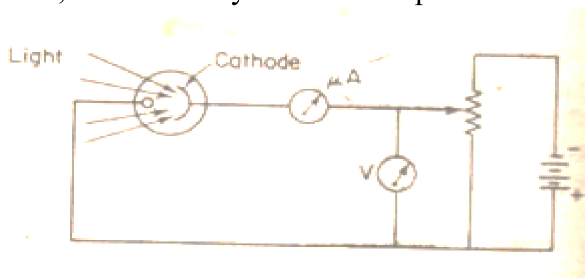


Figure 5.11: Test Circuit.

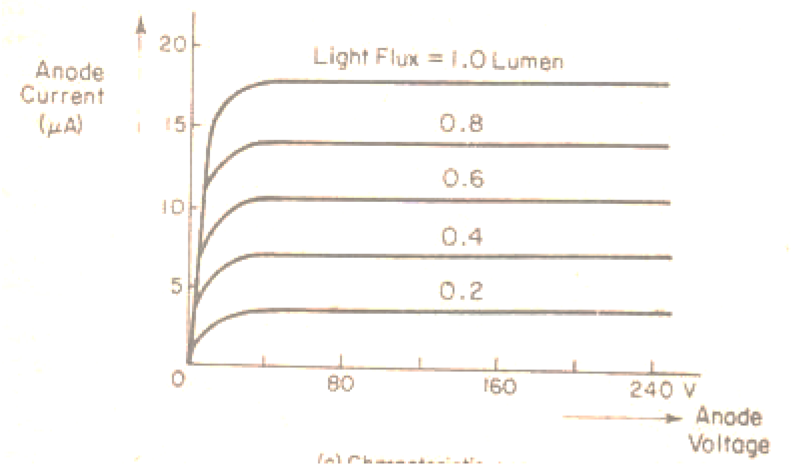


Figure 5.12: Characteristic Curves.

The photosensitive cathode is the huge semicircular element, while the anode is the thin wire running along the centre of the tube. Both components are enclosed in a glass enclosure with a high vacuum. The current in the circuit is exactly proportional to the amount of light falling on the cathode when a constant voltage is supplied between the cathode and the anode. The anode characteristics of a typical high-vacuum phototube are shown in Figure 5.12.

It is important to keep in mind that at about 20V, the output current is completely dependent on the amount of incoming light while being essentially independent of the applied anode voltage. Extremely little current—often in the range of a few microamperes—flows through the tube at any given time. To produce a useful output, the phototube is often linked to an amplifier.

Figure 5.13 depicts a photoelectric transducer whose aperture is controlled by the force-summing component of the pressure transducer and uses a phototube and a light source independently. The movement of the force-summing member modulates the amount of incoming light that reaches the photosensitive element. Figure 5.12 demonstrates how the photo emissive properties change with a change in light intensity at a rate that is essentially linear with displacement. This transducer may use an alternating current modulated light source or a continuous light source.

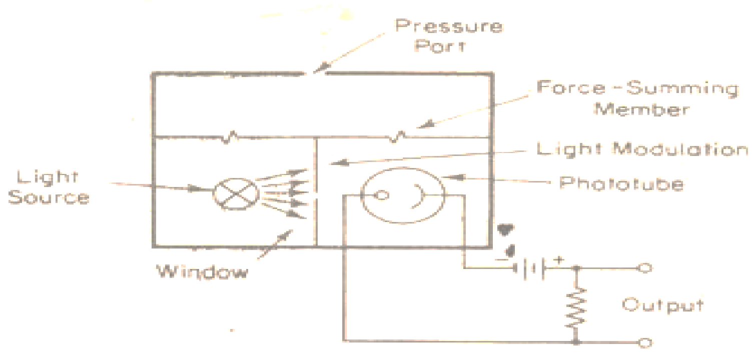


Figure 5.13: Element Of A Photoelectric Transducer.

The excellent efficiency and adaptability of this type of transducer make it ideal for monitoring both static and dynamic conditions. The devices might not respond to high frequency light variations, have poor long-term stability, and need a significant displacement of the force-summing component.

5.4.5 Laser Velocimeters.

Laser sources may be used to measure velocity with high precision and a wide dynamic range. Now that the technology has been improved, it can be purchased. The laser beam is split (see figure 5.14), creating two coherent sources that interact optically at the location of the velocity measurement. An optical comparison is necessary since electrical interference is not possible and we do not yet have detectors for such high frequencies.

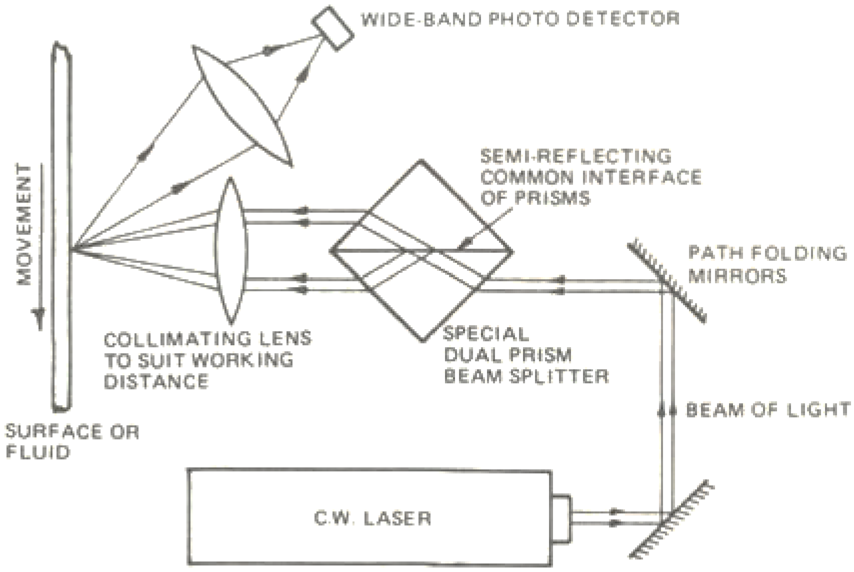


Figure 5.14: Laser Velocimeter.

A sensor looking at this place detects a little circular fringe pattern whose amplitude fluctuates as scattering changes. When the medium moves over the sensor's range of vision, the sensor sense passing fringes and generates small sets of signals. The velocity is measured by the period of the cycles in a burst. To get precise flow measurements from such erratic data, extensive electronic processing is required. The fundamental benefit of laser flow metres is that they can measure the velocity of a volume of fluid as small as 10-3 mm3. The approach works best for solutions and profile research. It is critical that some scattering particles exist, but not too much, in order to deliver a signal to the sensor. To boost signal strength, air bubbles or a colloidal substance are frequently injected.

Tutorial 5

1. Identify **THREE (3)** methods to reduce error in a transducer. (3 marks)

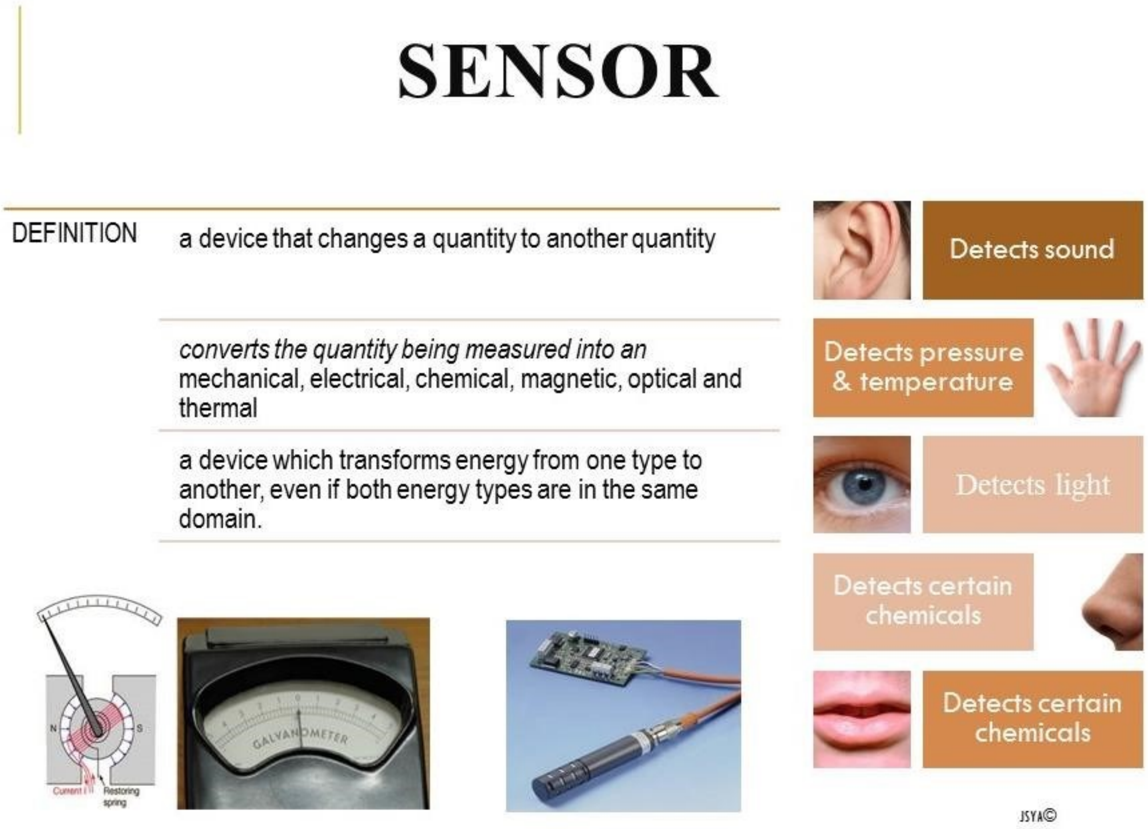
2. Identify the **FOUR (4)** types of transducer and sensor. (4 marks)

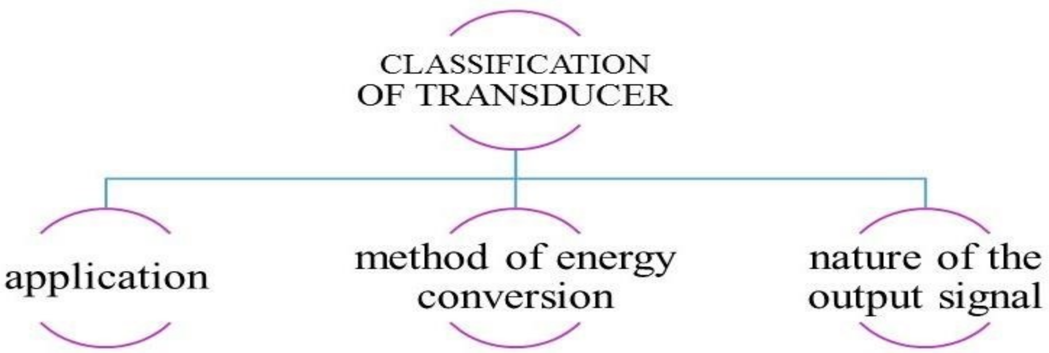
3. Define the meaning of sensor. (2 marks)

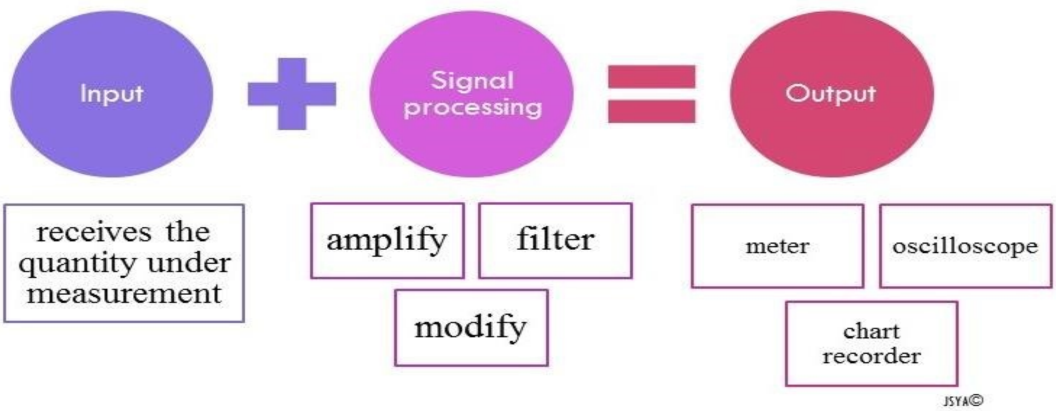
4. State **FOUR (4)** factors to select the sensor in the mechatronics systems. (4 marks)

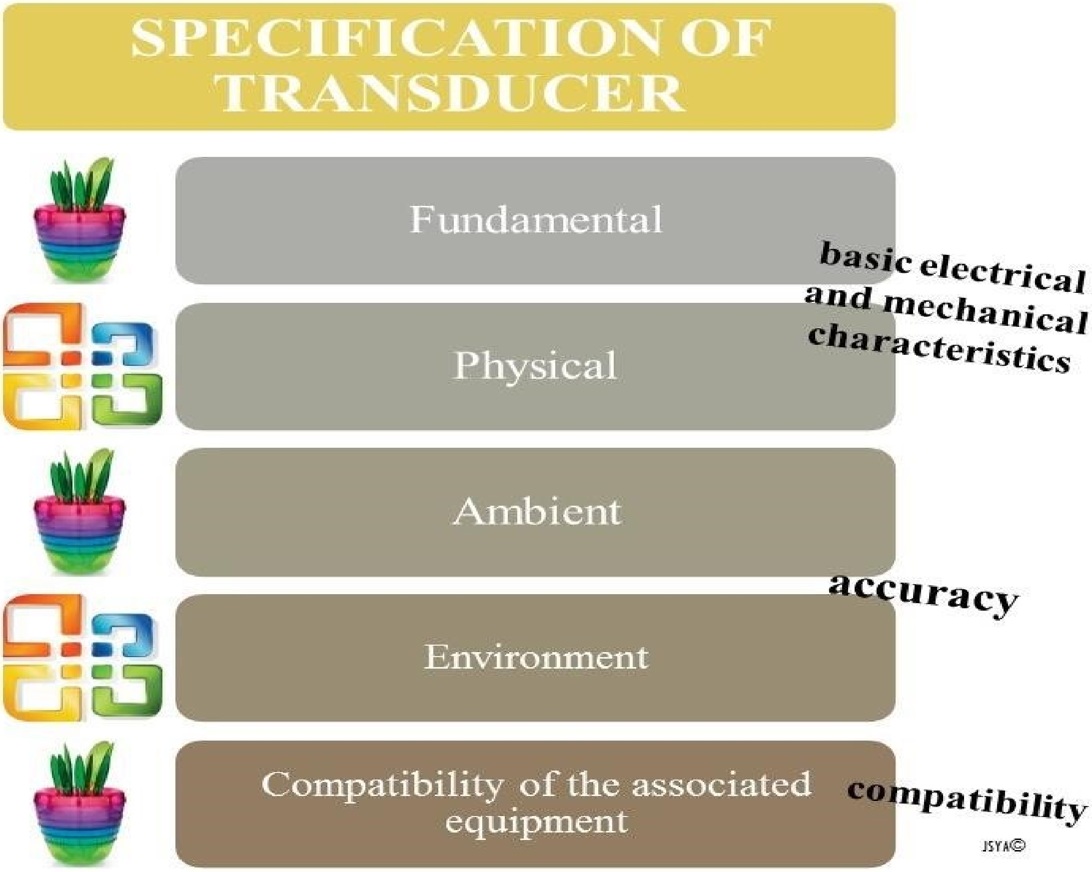
5. Resistance thermometers are often probe-type devices that are immersed in the medium whose temperature is being measured or regulated. Based on platinum, copper and nickel, which ONE the best resistance material? And state TWO (2) reasons why.

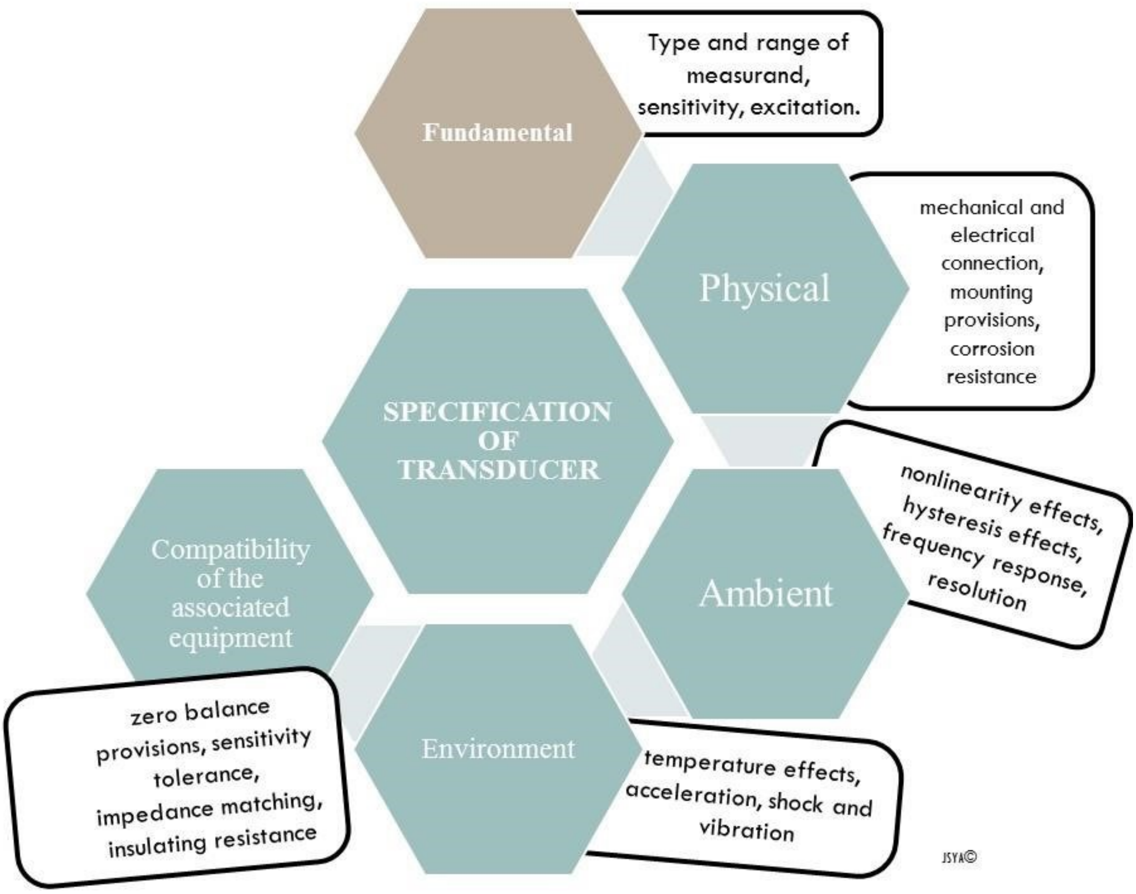
Mind Map


SENSOR
DEFINITION
a device that changes a quantity to another quantity
converts the quantity being measured into an mechanical, electrical, chemical, magnetic, optical and thermal
a device which transforms energy from one type to another, even if both energy types are in the same domain.
GALVANOMETER
Detects sound
Detects pressure & temperature
Detects light
Detects certain chemicals
Detects certain chemicals
JSYA©


CLASSIFICATION OF TRANSDUCER
application
method of energy conversion
nature of the output signal


Input
Signal processing
Output
receives the quantity under measurement
amplify
filter
modify
meter
oscilloscope
chart recorder
JSYA©


SPECIFICATION OF TRANSDUCER
Fundamental
basic electrical and mechanical characteristics
Physical
Ambient
accuracy
Environment
Compatibility of the associated equipment
compatibility
JSYA©


Fundamental
Type and range of measurand, sensitivity, excitation.
Physical
mechanical and electrical connection, mounting provisions, corrosion resistance
SPECIFICATION OF TRANSDUCER
Ambient
nonlinearity effects, hysteresis effects, frequency response, resolution
Environment
temperature effects, acceleration, shock and vibration
Compatibility of the associated equipment
zero balance provisions, sensitivity tolerance, impedance matching, insulating resistance
JSYA©

IDEAL TRANSDUCER

- High fidelity
- minimum interference
- Size must be capable
- Linear relationship between the measurand and the transducer signal
- minimum sensitivity to external effects
- natural frequency separated from the frequency and harmonic of the measurand

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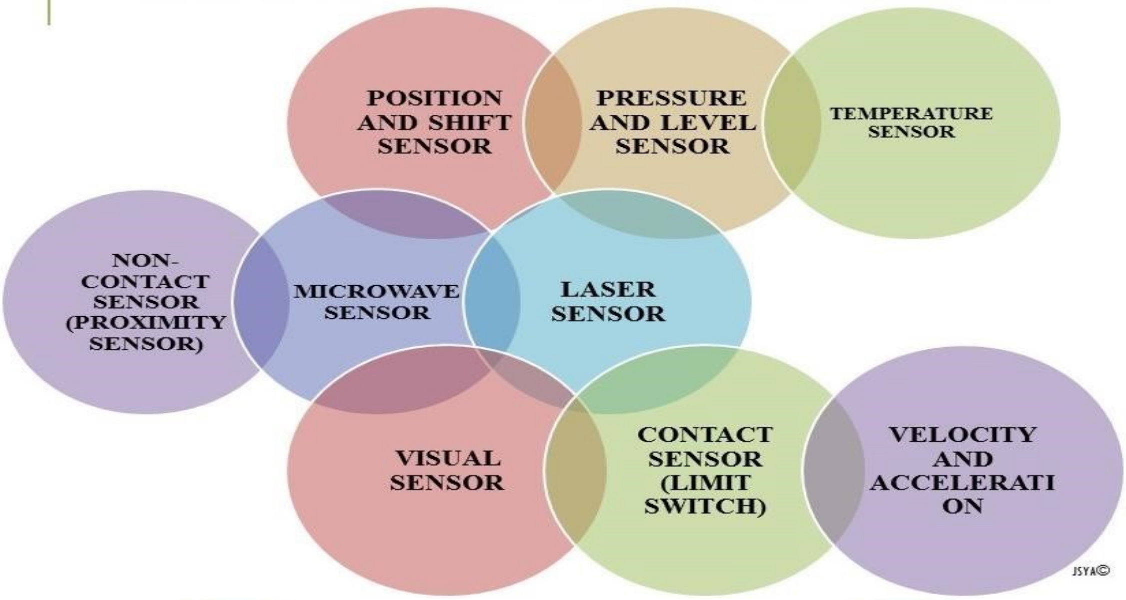
PRINCIPLES OF SENSOR/TRANSDUCERS OPERATION



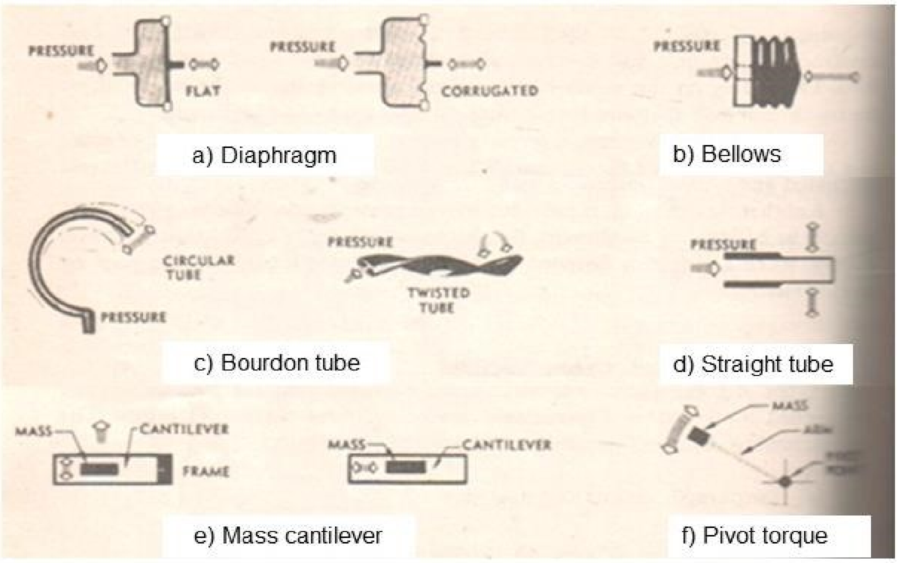
ADVANTAGES

- high operational safety
- interference reflections rarely trigger the receiver
- wide measuring range
- high rigidity

DISADVANTAGES

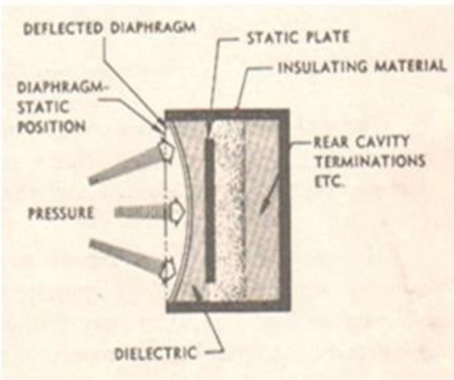
- poor long-term stability
- does not respond to high frequency light variations
- requires a large displacement of the force-summing member

DISPLACEMENT SENSOR



DISPLACEMENT SENSOR

Capacitive transducer



The capacitance **is inversely proportional to the spacing of the parallel plates**, any variation causes a corresponding variation in capacitance.

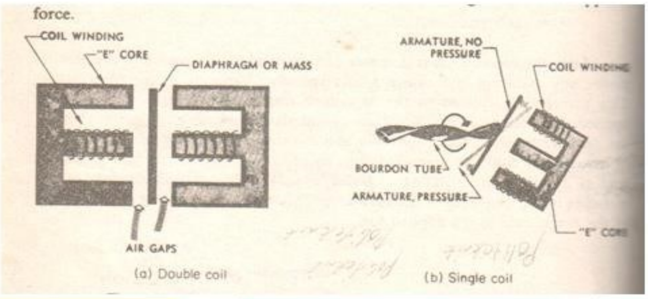
A force applied to a diaphragm that functions as one plate of a simple capacitor, changes the distance between the diaphragm and static plate

Advantages
- excellent frequency response
- an measure both static and dynamic phenomena

Dis-advantages
- sensitivity to temperature variations
- possibility of erratic or distorted signals due to long lead length
- receiving instrumentation may be large and complex
- includes a second fixed-frequency oscillator for heterodyning purposes

DISPLACEMENT SENSOR

Inductive transducer



The change in the inductance ratio of a pair of coils or by the change of inductance in a single coil.

In each case, the ferromagnetic armature is displaced by the force being measured, varying the reluctance of the magnetic circuit.

Advantages

- responds to static and dynamic measurements
- it has continuous resolution
- a fairly high output.

Disadvantages

- the frequency response (variation of the applied force) is limited by the construction of the force-summing member.

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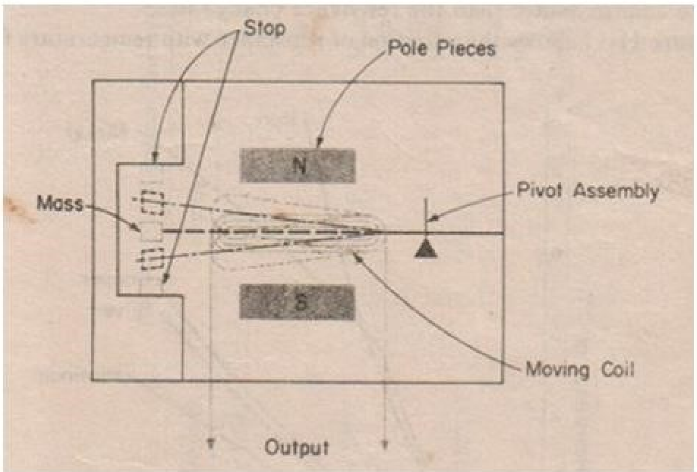
VELOCITY SENSOR.



Description

- **a moving coil suspended in the magnetic field of a permanent magnet**
- **A voltage is generated by the motion of the coil in the field**
- **The output is proportional to the velocity of the coil**

Advantage

- **high stability under varying temperature condition**

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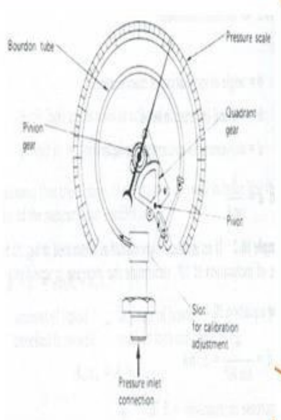
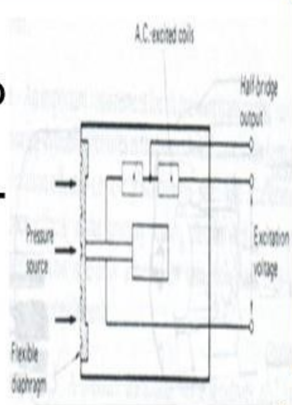
PRESSURE SENSOR.

Bourdon-Tube



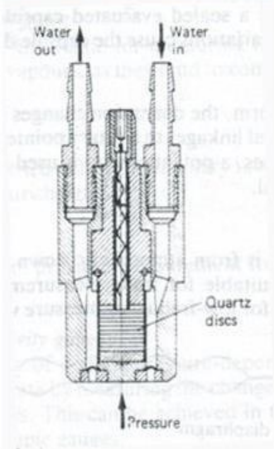
- A pressure applied to the inside of the tube causes a deflection of the free end, proportional to the applied pressure.
- Static and low-frequency pressure up to $500 MN/m^2$

Diapraghm



- **For high-pressure transducers, very stiff diaphragm must be used to limit the center deflection to less than one third of the diaphragm thickness, otherwise non-linear result.**
- **For lower pressure ranges, up to a few bars, beryllium-copper corrugated diaphragm and bellow are also used to give the higher sensitivity required.**

Piezo-Electric



The high sensitivity of the quartz-crystal modules permits the transducers to be manufactured in extremely small size

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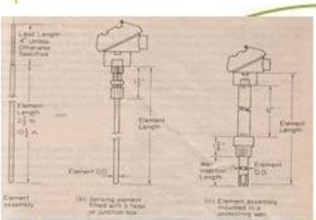
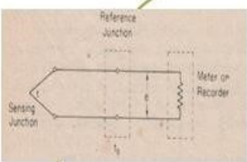
TEMPERATURE SENSOR.



Resistance Thermometers

- pure platinum, copper or nickel wire
- Disadvantages: variations of the resistance thermometer



Thermocouples

- pair of dissimilar metal wires joined together at one end (sensing, or hot, junction) and terminated at the other end (reference, or cold, junction) which constant temperature (reference temperature)
- Example: potentiometer

Thermistor

- devices that behave as resistors with a high, usually negative, temperature coefficient of resistance
- Characteristic measurement: *resistance-temperature* characteristic, the *voltage-current* characteristic and the *current-time* characteristic.

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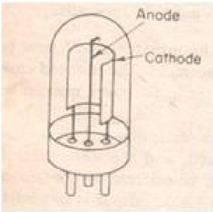
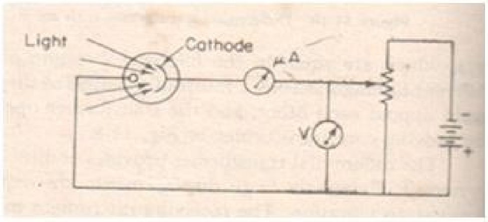
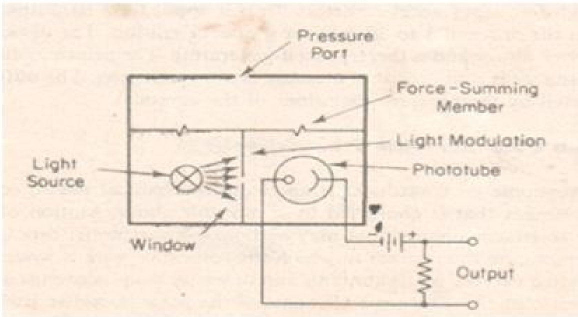
PHOTOELECTRIC SENSOR

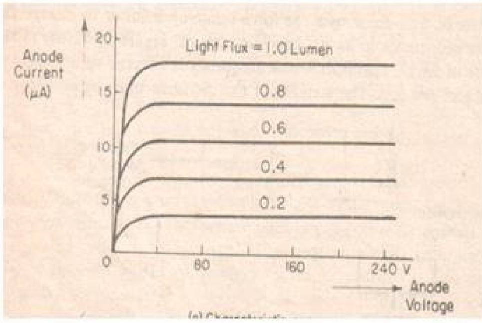
Advantages

- high efficiency
- its adaptability to measuring both static and dynamic conditions



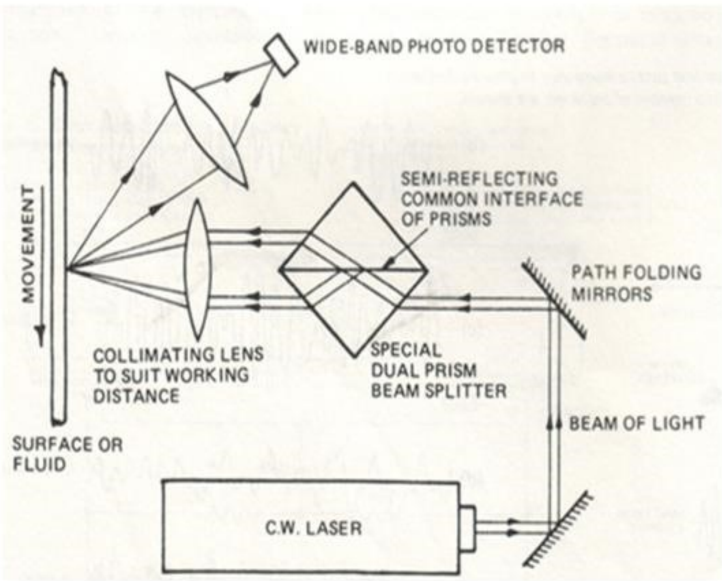






Disadvantages: poor long-term stability, does not respond to high frequency light variations, and requires a large displacement of the force-summing member.

LASER SENSOR



Advantage:
The velocity of a volume of fluid only 10^{-3} mm^3 is viewed.

Disadvantages:
Often air bubbles or a colloidal solid are injected to enhance the signal strength.

CHAPTER 6

TELEMETRY AND DATA ACQUISITION

General objective: To understand the concept of telemetry and data acquisition.
Specific objectives: At the end of the unit, you should be able to:

- Identify the main concept of telemetry system and data acquisition.
- Explain the structure of data collection system.
- Define the specification of data acquisition system.
- Identify the types of telemetry system.
- Explain the function of multiplexing system.

6.1 Introduction of Telemetry.

Telemetry is the transmission of data for monitoring and control across very long distances. Up to a few metres, data can be transmitted as a direct DC voltage or current. Over long distances, speed is severely constrained, and noise becomes a significant problem. Direct current (DC) was utilised in the early Morse trans-Atlantic cables of the nineteenth century to transmit at a speed of less than one word per minute.

We transform DC voltage or current into audio tones and send them across longer distances via wire. This thing is known as modulation, while the opposite process (turning the changing signal to data) is known as demodulation. A modem is a device that does it.

An analogue signal is a continuously changing wave. When we measure its height at different moments in time, we get a sequence of voltages with numerical values. These values can be expressed in binary form and sent as a sequence of bits. A bit is a binary digit, either 0 or 1, whose combination in the form of a code encodes information in digital communication.

An analogue signal is a wave that changes constantly. Its height can be measured at specified times to produce a sequence of voltages with numerical values. Binary representations of these values are possible, and a string of bits can be used to transport them. In digital communication, a bit is a binary digit, either 0 or 1, that when combined into a code carries information.

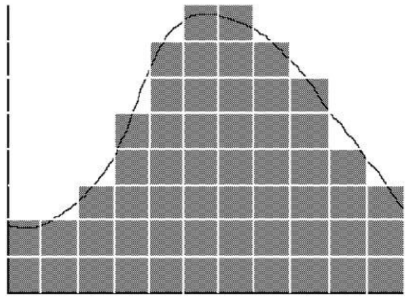


Figure 6.1: Converting the analog to digital signal.

In other words, sensors in telemetry systems generate electrical signals that change in some way in response to changes in physical characteristics, as previously stated. A thermistor, which measures temperature, is an example of a sensor. The resistance of a thermistor changes inversely with temperature: as the temperature rises, the resistance falls. The thermistor is typically linked to a resistive network, such as a voltage divider or bridge, as well as a DC voltage source. The result is a DC output voltage that fluctuates with temperature and is sent to a distant receiver for measurement, reading, and recording. The thermistor is converted into a channel in a frequency division multiplexing (FDM) system.

Different outputs are produced by other sensors. Many only have variable DC outputs, but some have AC outputs. Each of these signals is often amplified, filtered, and subject to various conditions before being used to modulate a carrier. After then, the carriers are merged to create a single multiplexed channel.

6.2 Data Acquisition Systems – The Structure

Data acquisition systems are used to measure and record signals acquired in two ways:

i. Signals resulting from direct measurement of electrical quantities, such as ac and dc voltages, resistance or frequency and are commonly discovered in areas such as electronic component testing, quality analysis work and environmental studies.
ii. Transducer strain signals gauge and thermocouple.

Data acquisition systems are utilised in a huge and growing number of applications in a wide range of industrial and scientific fields, including biomedical, aerospace, and telemetry. The type of data acquisition system, whether analogue or digital, is largely determined by the intended use of the input data. Analog data systems are typically used when a large bandwidth is required or when lower accuracy is acceptable. When the physical process being monitored is slowly varying (narrow bandwidth), and great precision and cheap per-channel cost are required, digital solutions are utilised. Digital systems range in complexity from basic single-channel dc voltage measuring and recording systems to sophisticated automated multi-channel systems that measure many input parameters, compare them to predefined limits or criteria, then compute and make choices on the input signal. In general, digital data acquisition systems are more complicated than analogue systems, both in terms of equipment and the volume and complexity of input data they can process.

Magnetic tape recorders are often used in data acquisition systems. Converts are used in digital systems to change discrete digital quantities or numbers from analogue voltages. To be used as a feedback quantity governing an industrial process, digital information may need to be converted back into analogue form, such as a voltage or current.

Analog systems and digital systems are the two basic types of instrumentation systems. Analog systems handle measurement data in analogue form. An analogue signal is a continuous function, such as a plot of pressure vs displacement or a voltage against time. Data in digital form is handled by digital systems. A digital amount may consist of several discrete and intermittent pulses, the temporal relationship between which reveals details about the size or nature of the quantity.

Analog data acquisition and digital data acquisition are the two forms of data acquisition.

6.2.1 Analog Data Acquisition.

Typically, an analogue data acquisition system will include any or all the following components:

i. Transducers – Physical properties are converted into electrical impulses.
ii. Signal conditioners – amplification, modification, or selection of certain sections of these signals.
iii. Visual display devices – monitoring the input signals continuously. A single-channel or multi-channel oscilloscope, a storage oscilloscope, panel metres, a numerical display, and other devices may be among these.
iv. Graphic recording instruments – collecting the data input's permanent records. To give continuous records on paper charts, these tools include stylus and ink recorders, optical recording systems as mirror galvanometer recorders, and UV recorders.
v. Magnetic tape instrumentation – collecting input data, keeping it in its electrical form, and duplicating it later for a more thorough examination.

6.2.2 Digital Data Acquisition.

Some items depicted in Figure 9.2 were used in a digital data capture. Managing analogue signals, measuring, Digital data conversion, management, internal control, and programming are all fundamental functions of a digital system. Each of the system elements in figure 9.2 has a specific function, which is stated below.

i. Transducer – Converting physical parameters into electrical signals that the acquisition system will accept. Temperature, pressure, acceleration, weight displacement, and velocity frequency are some typical parameters that can be directly measured.
ii. Signal conditioner – typically contains the transducer's supporting electronics. This circuitry could offer calibrating components, balance circuits, and excitation power. A strain-gauge bridge balance and power supply device are a prime illustration of a signal conditioner.
iii. Scanner or multiplexer – accept multiple analogue inputs and sequentially connects them to one measuring instrument.

iv. Signal converter – converts the analogue signal into a format that the analogue to digital converter can understand. An amplifier used to boost low-level voltages produced by thermocouples or strain gauges is an example of a signal converter.
v. Analog –to-digital (A/D) converter - transforms an analogue voltage into its corresponding digital form. The output of the A/D converter may be visually displayed in addition to being made available as discrete voltage outputs for additional processing or recording on a digital recorder.
vi. Auxiliary equipment – Tools for system programming and digital data processing are included in this category. Limit operation and linearization are two frequently used auxiliary functions. These tasks can be completed using specialised tools or a computer.
vii. Digital recorder – records digital data on typewritten pages, punched cards, perforated paper tape, magnetic tape, or a combination of methods. A coupling unit that converts the digital information into the right format for entrance into the digital recorder chosen may come before the digital recorder.

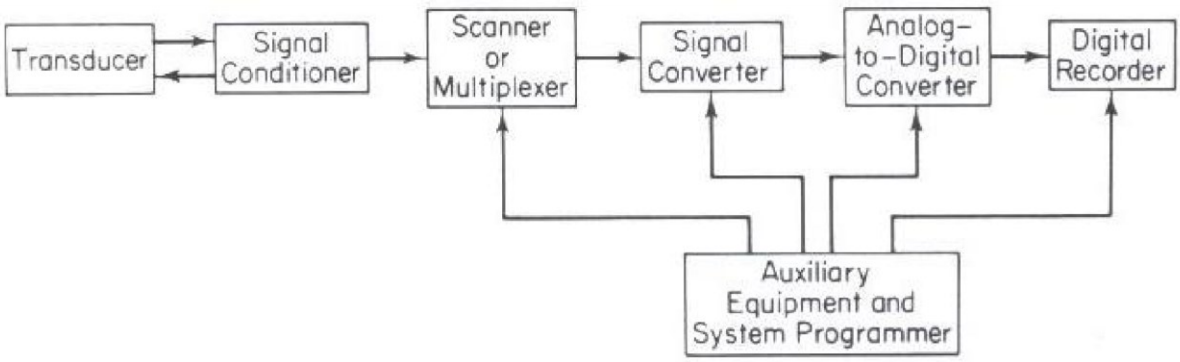


Figure 6.2: Elements of digital data-acquisition system.

6.3 Telemetry: The Frequency

Within the carrier frequency for the telemetry procedure is changed over and underneath its centre value (balanced) in understanding with the sufficiency of the information signal. the frequency carrier's rate of change veers off from its centre value could be a work of the recurrence signal. The adequacy and recurrence characteristics that define the information flag are in this manner contained within the recurrence varieties of the recurrence telemetry carrier around its centre esteem. When this balanced recurrence by counting the quantity and frequency of zero intersections in the demodulator.

Due to the apparent carrier modulation that occurs when the tape speed varies, frequency telemetry recording is excessively sensitive to tape speed fluctuations (flutter) (noise). As a result, the dynamic range of the system is decreased by the tape speed's instability.

Since the system is not subject to amplitude instability since the data signal is wholly contained in the frequency characteristics of the frequency carrier. Deviation ratio and percentage deviation are two important elements in telemetry tracking. The carrier deviation ratio from the central frequency to the signal frequency is the definition of the deviation ratio, or

$$\square = \frac{\square\square}{\square_m}$$

where $\square$ = deviation ratio

$\square\square$ = carrier deviation from centre frequency

$\square_m$ = data signal frequency

6.4 System of Multiplexing.

The act of simultaneously delivering more distinct signals across a single communications channel is known as multiplexing. To transfer more information, multiplexing multiplies the number of communication channels.

In many communication situations, it is required or preferable to broadcast several speech or data signals. Utilising a single channel for communication to convey several information signals can save money because the application itself can need multiple signals. Applications for telephones and telemetry are two good examples. Multiplexing is necessary for satellite communications to make the system workable and cost-effective.

Figure 9.3 demonstrates how a simple multiplexer works. The multiplexer combines many input signals the transmission of a single composite signal through the communications medium. Instead, a carrier could be altered before transmission by the multiplexed signals. At the other end of the communications link, a demultiplexer is used to separate the signal into its original form.

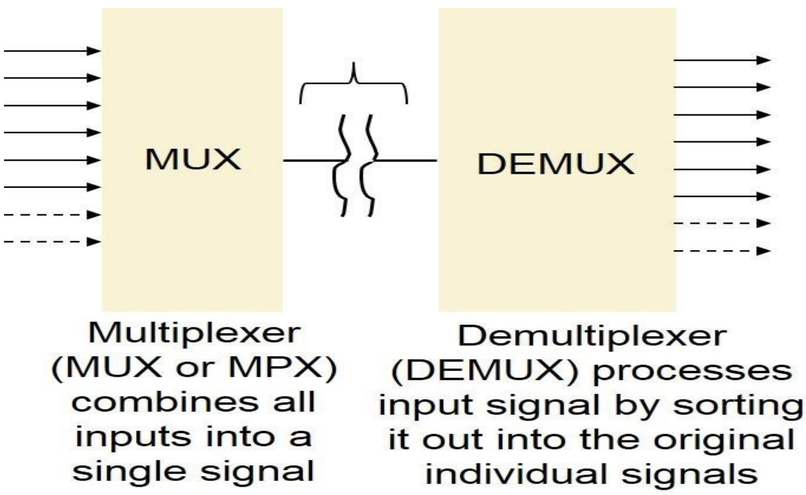


Figure 6.3: Concept of multiplexing.

Time division multiplexing (TDM) and frequency division multiplexing are the two fundamental types of multiplexing (FDM). FDM systems are used to handle analogue information, while TDM systems are used for digital information.

6.4.1 Frequency Division of Multiplexing.

The foundation of frequency division multiplexing is the notion that a few signals can use a single communications channel's capacity. Each of the many signals that will be sent over this channel will be utilised to modulate a different carrier. Different carriers operate on various frequencies. Following the addition of the modulated carriers, a complex signal is created and sent across a single channel.

A general block diagram of the FDM system is shown in Figure 6.4. A modulator circuit is fed by each signal that will be broadcast. Every modulation fc has a different frequency for the carriers. Over a particular frequency range, the carrier frequencies are typically evenly spaced from one another. A certain amount of bandwidth is allocated to each incoming signal. The outcome is shown in figure 6.5. You can use any conventional sort of modulation, such as AM, SSB, FM, or PM, as far as the type of modulation is concerned.

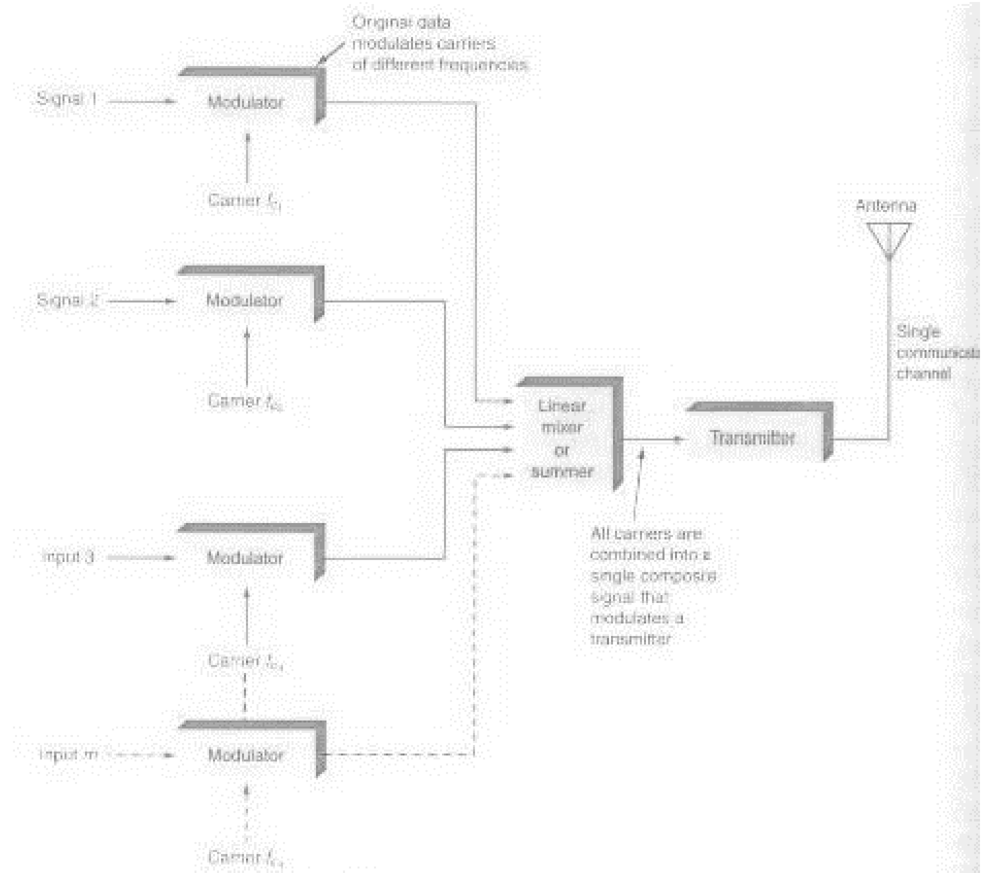


Figure 6.4: The transmitting end of an FDM system.

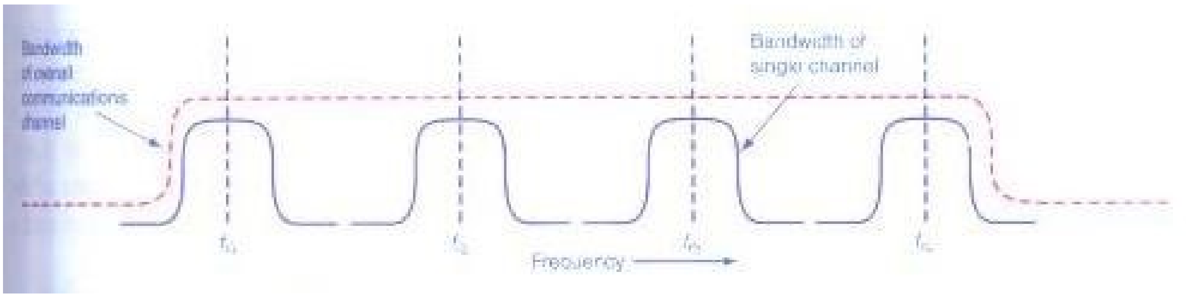


Figure 6.5: Spectrum of an FDM signal.

In a linear mixer, the modulator output containing the sideband data is combined. Modulation and the creation of sidebands don't happen in a linear mixer. Instead, an algebraic summation of all the signals is used. All the carriers' modulation is combined to create the output signal. A radio transmitter is then modulated using this signal. The composite signal itself could also be sent through the one communication channel as an alternative. The composite signal may also be fed into another multiplexer system as an additional option.

6.4.2 Time Division Multiplexing - TDM.

By sharing the channel bandwidth, many signals can be delivered across a single channel in FDM. This is accomplished by allotting a piece of the spectrum within that bandwidth to each transmission. Each signal in TDM could use the entire channel bandwidth. Each signal is only transmitted for a brief time, though. In other words, different signals alternately transmit over the same channel. In figure 6.6, this idea is depicted graphically.

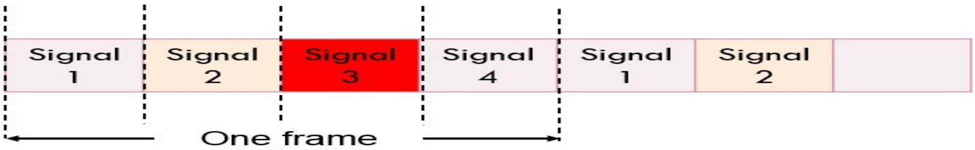


Figure 6.6: The basic TDM concept

In this case, a single channel is used to transmit four signals, each of which is given a set amount of time to use the channel, one after the other. The cycle continues until all the signals have been transmitted.

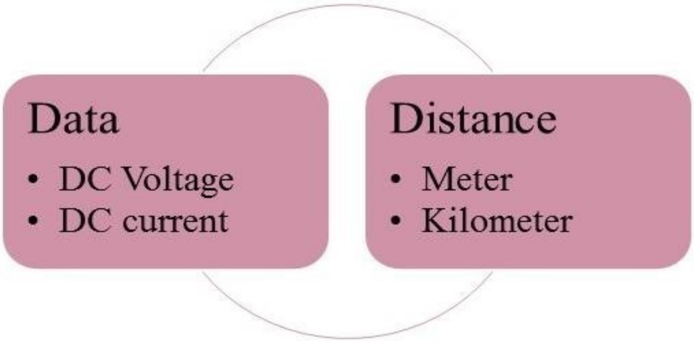
Both digital and analogue streams can be combined using time division multiplexing. The data that needs to be communicated is formatted into serial data words in order to transmit numerous digital signals. For instance, the data can be made up of consecutive bytes. During the time period allotted to a specific channel, one byte of data may be transferred. For instance, in figure 9.6, each time slot can include one byte from each channel. Each channel transmits 8 bits. The third channel transmits its data word after that, and so on. A frame is a cycle of operation that is finished by one transmission on each channel. A rapid repetition of the cycle occurs. The data bytes of each channel are merely interleaved in this manner. the single-channel signal that is produced is

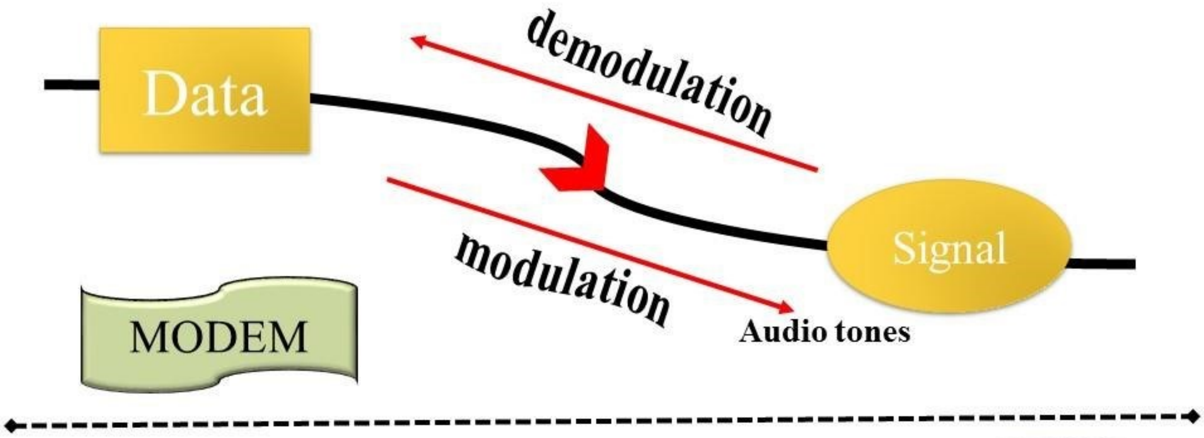
<u>Tutorial 6</u>

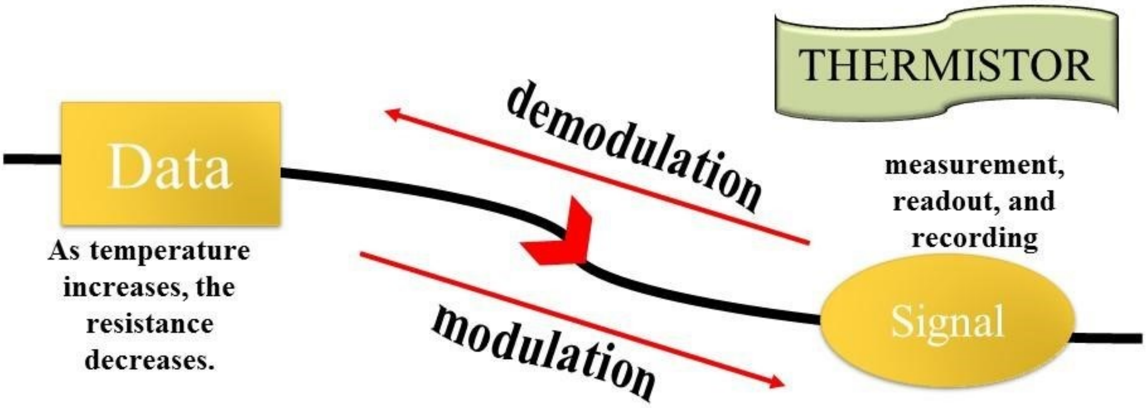
1. Identify **THREE (3)** differences between analog and digital data acquisition systems. (3 marks)

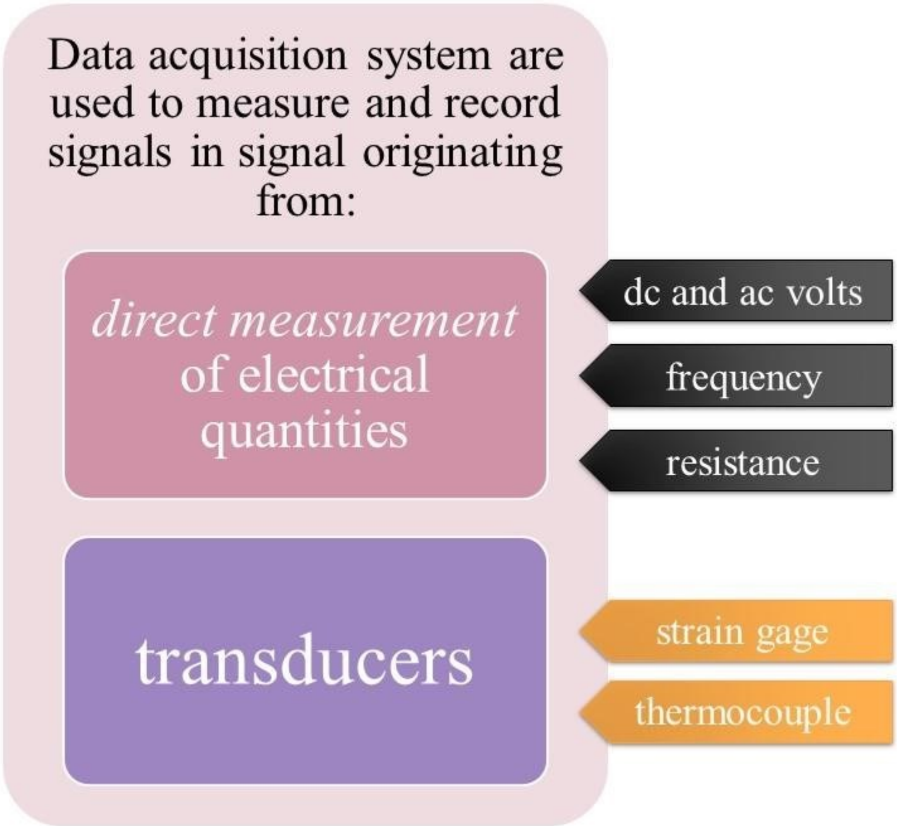
Mind Map

Telemetry means the transmission of data for monitoring and control over long distances.

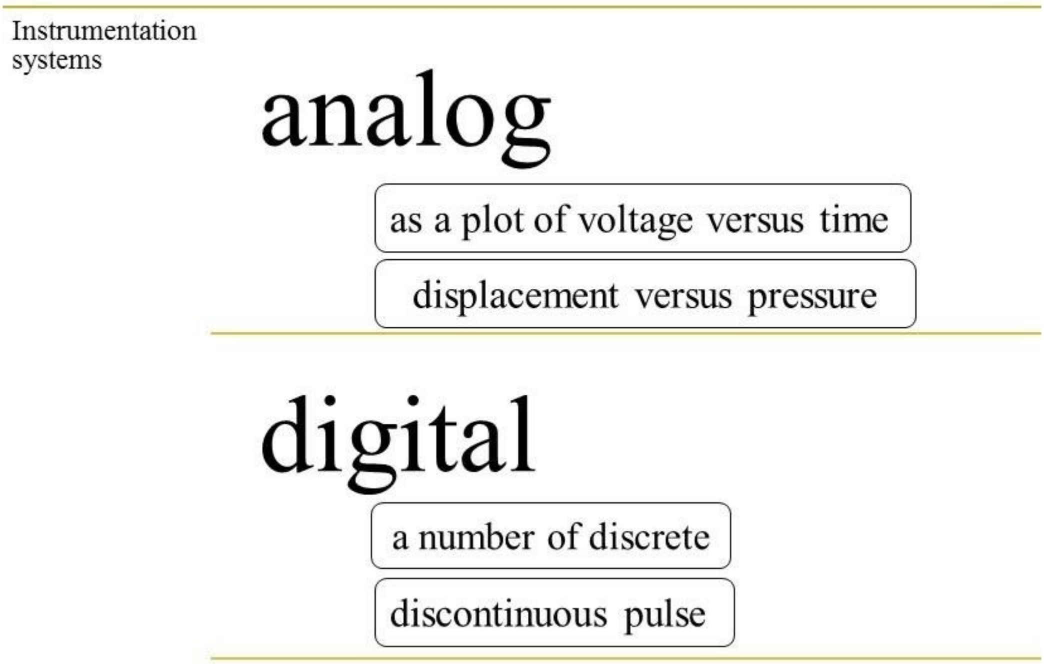


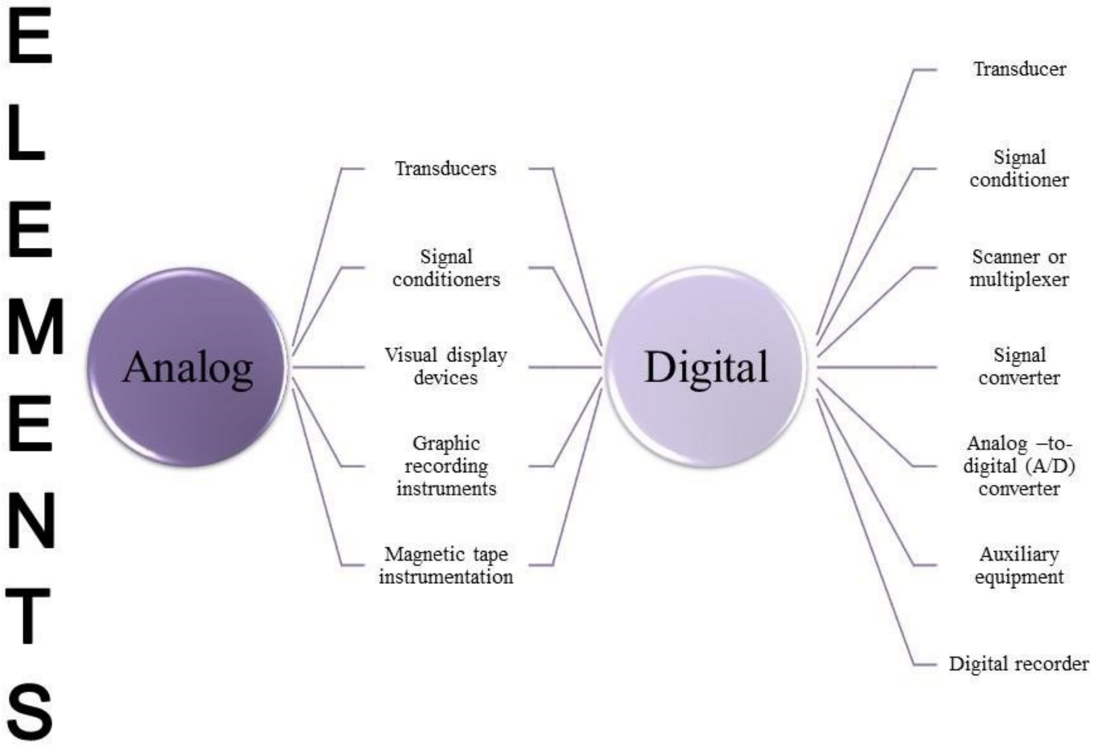






Instrumentation systems





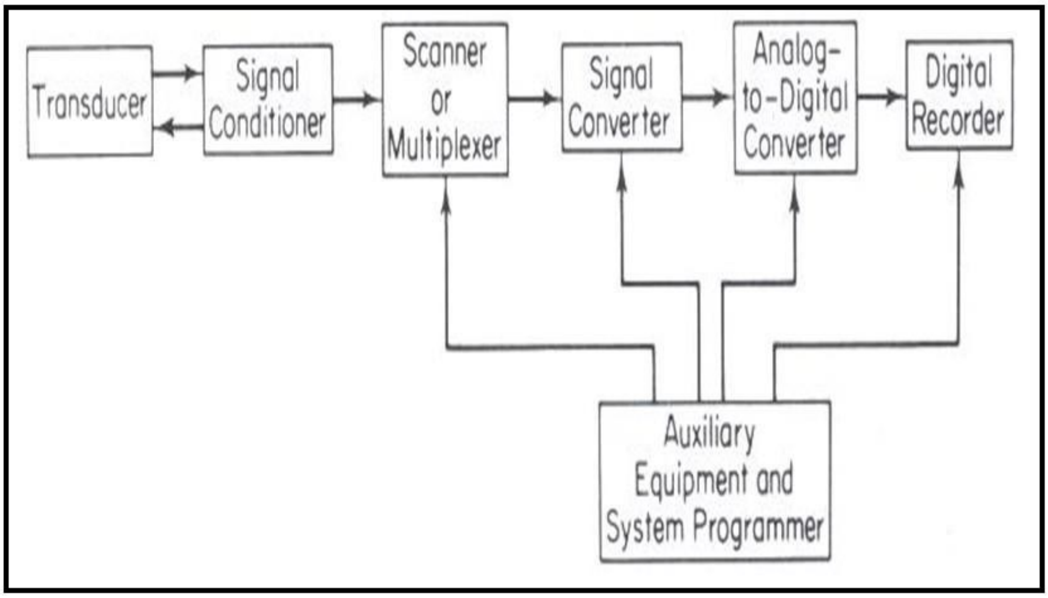


Fig. 1: Elements of digital data-acquisition system

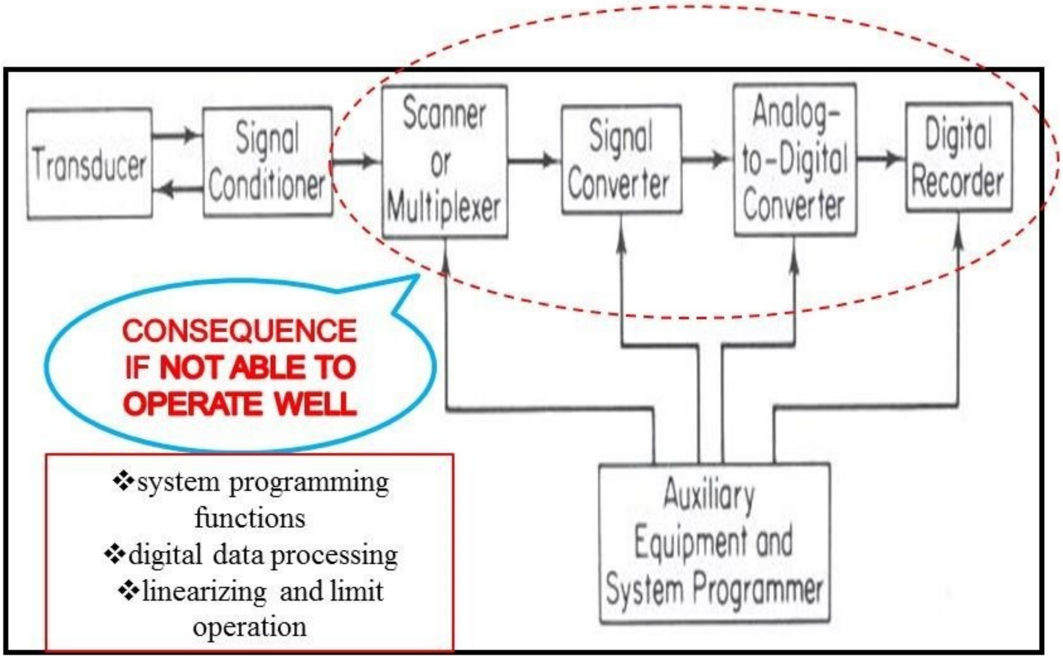


Fig. 1: Elements of digital data-acquisition system

DIFFERENTIAL BETWEEN

Analog	Digital
Wide Bandwidth	Narrow Bandwidth
Lower Accuracy	High Accuracy
Not Complex	More Complex

FREQUENCY OF TELEMETRY

$\delta = \Delta f / f_m$

where

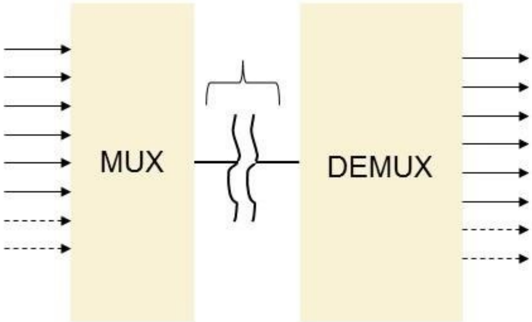
δ = deviation ratio

Δf = carrier deviation from center frequency

f_m = data signal frequency

MULTIPLEXING SYSTEM

Multiplexing is the process of simultaneously transmitting two or more individual signals over a single communications channel



Multiplexer (MUX or MPX) combines all inputs into a single signal

Demultiplexer (DEMUX) processes input signal by sorting it out into the original individual signals

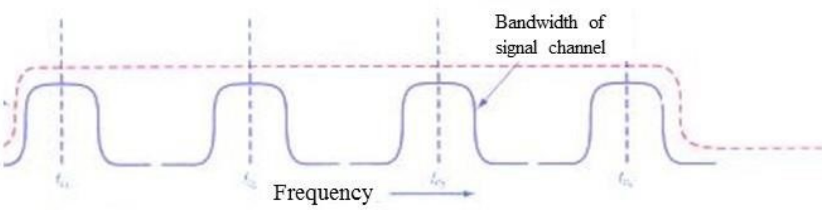
Frequency Division Multiplexing (*FDM*)

used to deal with analog information

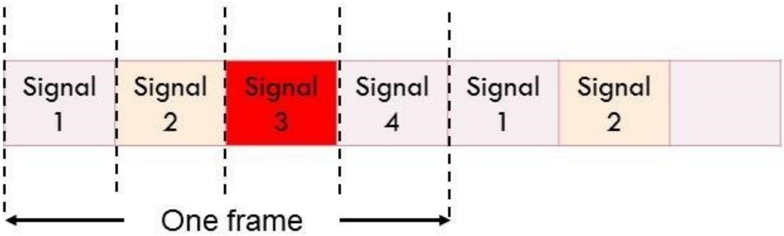
Time Division Multiplexing (*TDM*)

used for digital information

Spectrum of an FDM signal



The basic TDM concept



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