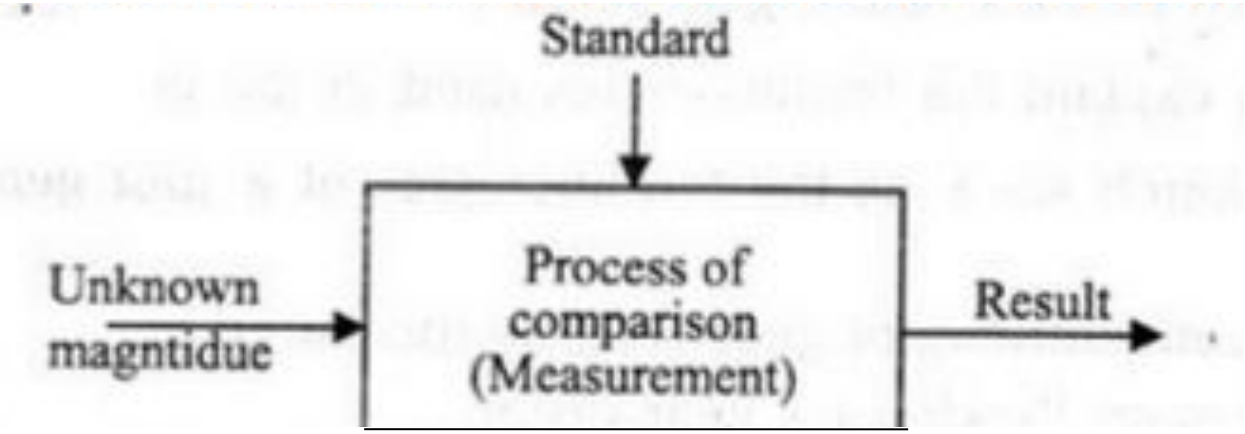
UNIT-I

Introduction to Measurement Systems

MEASUREMENT SYSTEM:

- Determination of anything that exists in some amount
- If related to mechanical engineering, then the determination of such amounts are referred to as mechanical measurements.
- Measurement of physical variables , concerned with their control
- Accuracy of control is essentially dependent on the accuracy of measurement.
- Design of Good control systems.

Measurement is defined as the process or the act of obtaining a quantitative comparison between a predefined standard and an unknown magnitude.



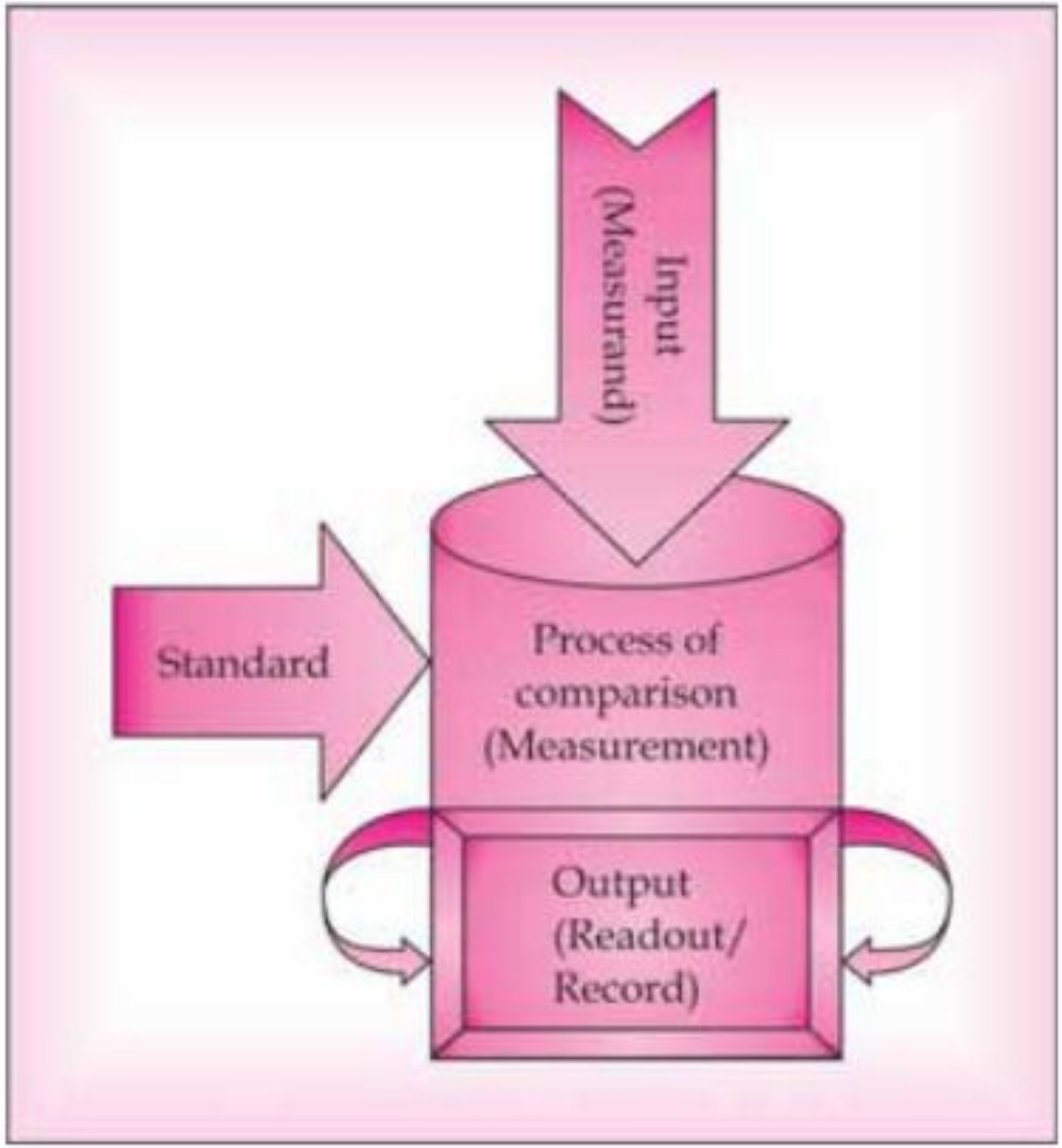


Fig. 1.1 The Process of Measurement

Requirements of Measurements

If the result has to be meaningful, two conditions must be satisfied.

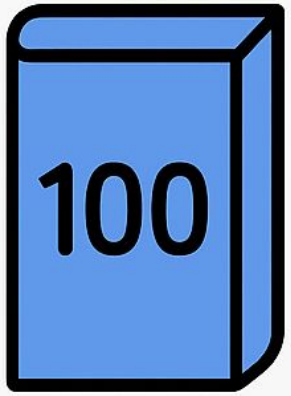
- Standard: Known and accepted.
- Procedure and Apparatus: Commonly accepted and provable.

SIGNIFICANCE OF MEASUREMENT SYSTEM

No.	Significance	Description
1	**Ensures Product Quality**	Maintains dimensional accuracy and performance of products.
2	**Enables Process Control**	Helps monitor and control manufacturing processes for consistent output.
3	**Facilitates Standardization**	Ensures interchangeability of parts produced at different times or places.
4	**Supports Design & Development**	Provides data for design validation and material selection.
5	**Ensures Safety & Reliability**	Confirms that components meet safety and reliability standards.

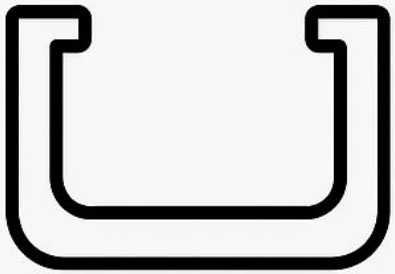
No.	Significance	Description
6	**Reduces Waste & Cost**	Detects errors early, minimizing rework and material wastage.
7	**Enables Calibration & Traceability**	Maintains accuracy through reference to standard measurements.
8	**Assists Research & Innovation**	Provides accurate data for experiments and new developments.
9	**Enhances Customer Confidence**	Ensures product quality and builds trust with users.
10	**Improves Productivity & Efficiency**	Optimizes machine and process performance.

Measuring Means



Standards

Used to reproduce one/several definite values



Fixed Gauges

Check the dimension/form of product

Measuring Instruments

Check the dimension/form of product

Quantity:

The attribute or property being measured is known as the quantity - Length, Mass, Time, Temperature, Electric current, and various other physical properties.

Unit:

A unit is a standardized quantity used for measurement. It provides a reference against which the measured quantity can be compared. Units can be basic (e.g., meters, kilograms, seconds) or derived (e.g., speed, volume).

Instrument or Measurement Device:

An instrument or measurement device is a tool used to make measurements. Instruments can range from simple rulers and thermometers to complex devices such as spectrometers and oscilloscopes. The choice of instrument depends on the nature of the quantity being measured.

Procedure:

The procedure outlines the steps and conditions under which the measurement is conducted. It includes details about the use of the measurement instrument, environmental conditions, and any necessary precautions to ensure accurate and consistent results.

Observer or Operator:

The person performing the measurement, known as the observer or operator, plays a crucial role. The observer needs to follow the measurement procedure carefully, interpret readings accurately, and account for any potential sources of error.

Calibration:

Calibration involves comparing the measurement device to a standard to ensure its accuracy. Regular calibration helps maintain the reliability of measurement instruments over time, compensating for wear and tear or drift.

Basic Methods of measurement

(i) Direct method of measurement.

- In this method the value of a quantity is obtained directly by comparing the unknown with the standard.
- involves, no mathematical calculations to arrive at the results,
  - » for example, measurement of length by a graduated scale.
- The method is not very accurate because it depends on human insensitiveness in making judgement.

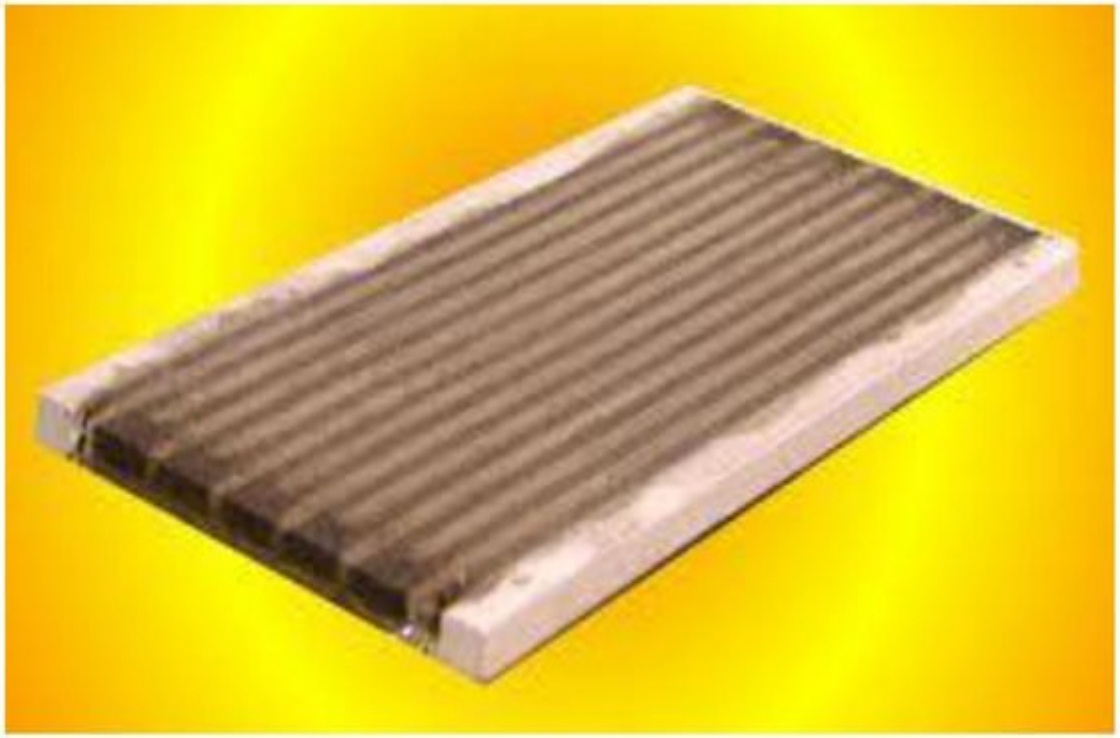
- Measurements are directly obtained
  - Ex: Vernier Caliper, Scales

(ii) **Indirect method of measurement.**

In this method several parameters (to which the quantity to be measured is linked with) are measured directly and then the value is determined by mathematical relationship.

- For example, measurement of density by measuring mass and geometrical dimensions.

- Obtained by measuring other quantities
  - Ex : Weight = Length x Breadth x Height x Density



The Generalized Measuring System

A **measurement system** is a combination of instruments, devices, and procedures used to determine the value of a quantity or condition..

A **generalized measurement system** represents the basic functional elements that exist in *all* measurement processes — from simple mechanical gauges to advanced electronic sensors.

The main objective of any measurement system is to produce a meaningful output (display, record, or control signal) that corresponds accurately to the physical quantity being measured.

Basic Elements of a Generalized Measurement System

1. Primary Sensing Element - detects the physical quantity (measurand).
2. Variable Conversion Element - Converts the output of the primary sensing element into another form that is more convenient for measurement or further processing.
3. Variable Manipulation Element - Modifies or amplifies the signal for better transmission, indication, or control.
4. Data Transmission Element - Transfers the signal from one part of the system to another
5. Data Processing Element - Performs operations such as signal conditioning, computation, comparison, or correction.
6. Data Presentation Element - Final stage that provides the output in readable or usable form.

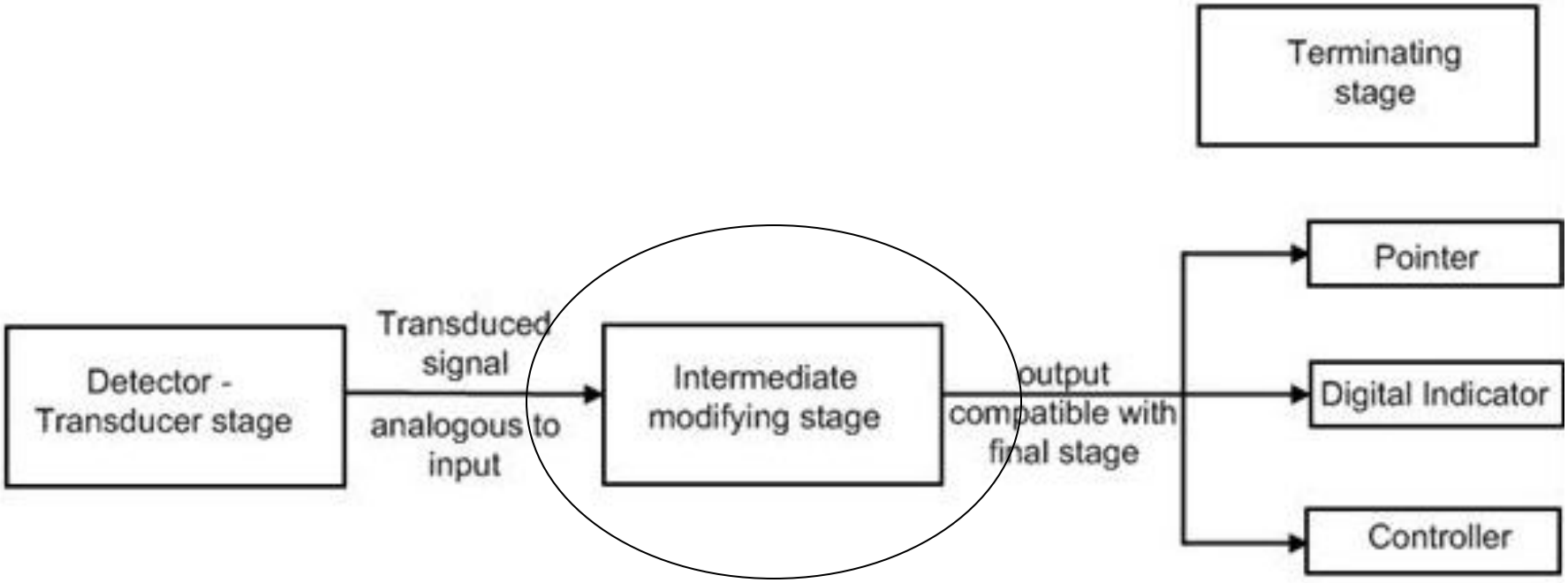
General Measurement system, consists of three phases or stages:

Stage 1. A detection-transduction, or sensor-transducer, stage

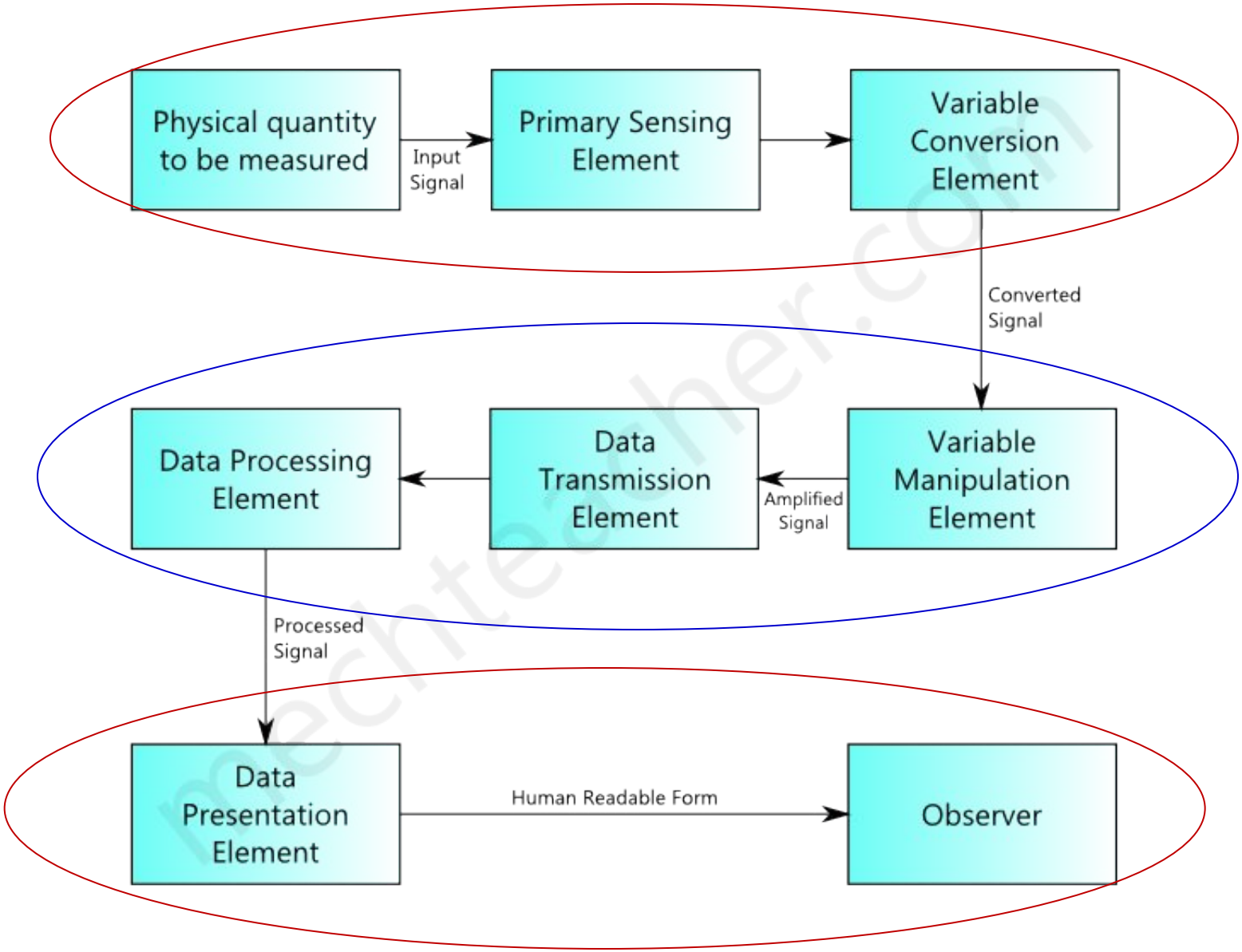
Stage 2. An intermediate stage, or signal-conditioning stage

Stage 3. A terminating, or readout-recording, stage

Each stage consists of a distinct component or group of components that performs required and definite steps in the measurement. These are called basic elements



General Measurement System


Physical quantity to be measured
Input Signal
Primary Sensing Element
Variable Conversion Element
Converted Signal
Data Processing Element
Data Transmission Element
Amplified Signal
Variable Manipulation Element
Processed Signal
Data Presentation Element
Human Readable Form
Observer

Stage - 1

- The primary function - detect or to sense the measurand.
- At the same time, ideally, this stage should be insensitive to every other possible input.

Eg:

- if it is a pressure pickup-insensitive -acceleration;
- if it is a strain gage - insensitive - temperature; •
- if a linear accelerometer, - insensitive -angular acceleration; and so on. •

- Unfortunately, it is rare indeed to find a detecting device that is completely selective.
- Unwanted sensitivity is a measuring error, called noise.

Stage - II

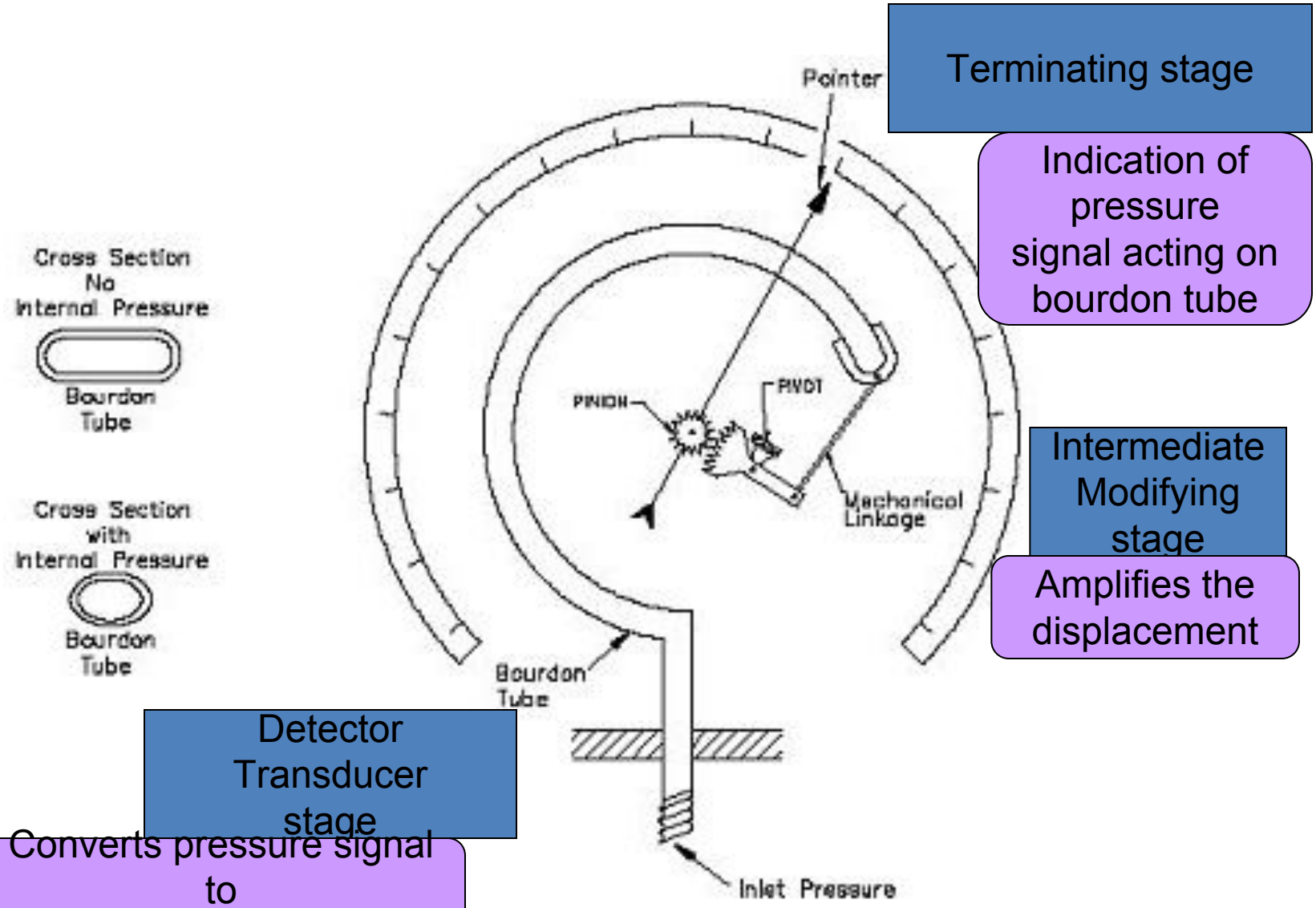
- Modify the transduced information so that it is acceptable to the third, or terminating stage.

- perform one or more basic operations, such as selective filtering to remove noise, integration, differentiation, as may be required.

- increase either amplitude or power of the signal, or both, to the level required to drive the final terminating device.

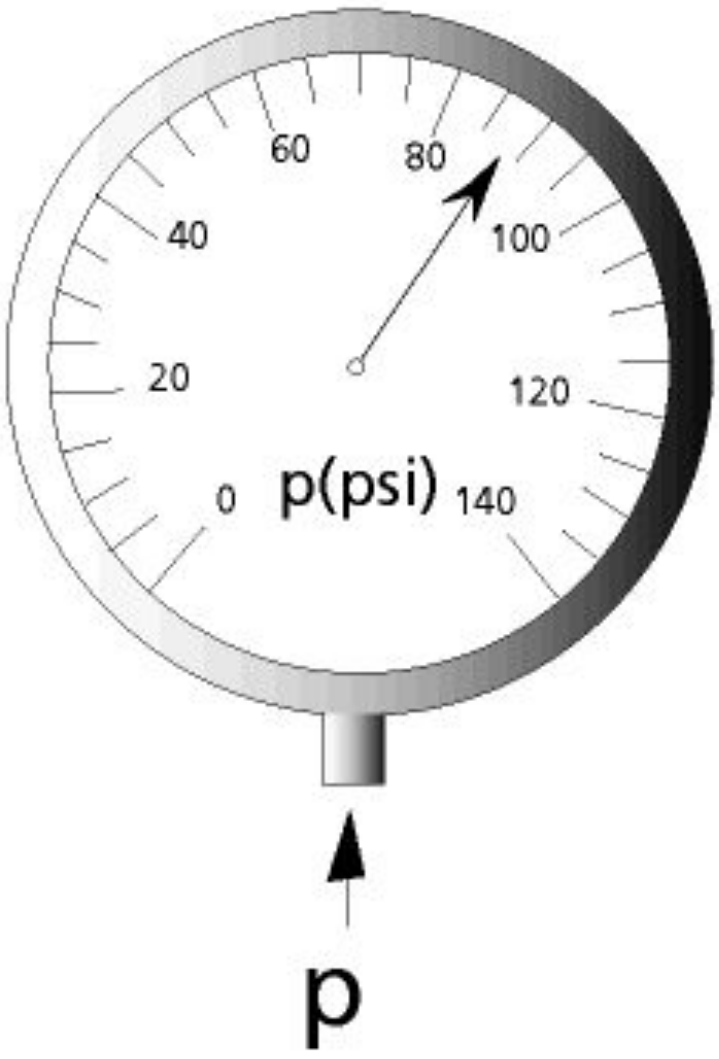
Stage - III

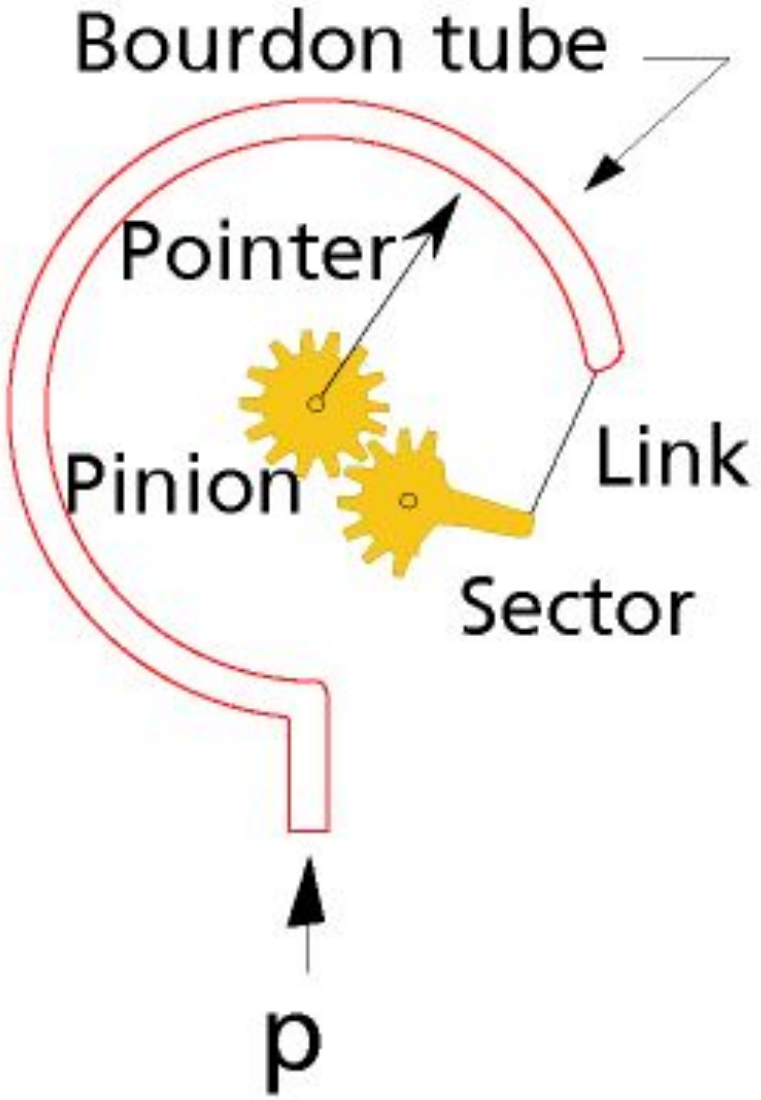
- Provides the information sought in a form comprehensible to one of the human senses or to a controller.
- output is intended for immediate human recognition,
- It is presented in one of the following forms: –
  - As a relative displacement, such as movement of an indicating hand or digital form, as presented by a counter such as an automobile odometer.
  - Liquid crystal display (LCD) or light-emitting diode (LED) display as on a digital voltmeter



Bourdon Tube

Stage	Component	Function
Primary Sensing Element	Bourdon tube	Converts pressure into tip displacement
Variable Conversion	Mechanical linkage	Converts motion into rotation
Variable Manipulation	Gearing mechanism	Amplifies motion
Data Transmission	Shaft connection	Transmits motion to pointer
Data Presentation	Dial gauge	Displays pressure reading


0
20
40
60
80
100
120
140
p(psi)
p

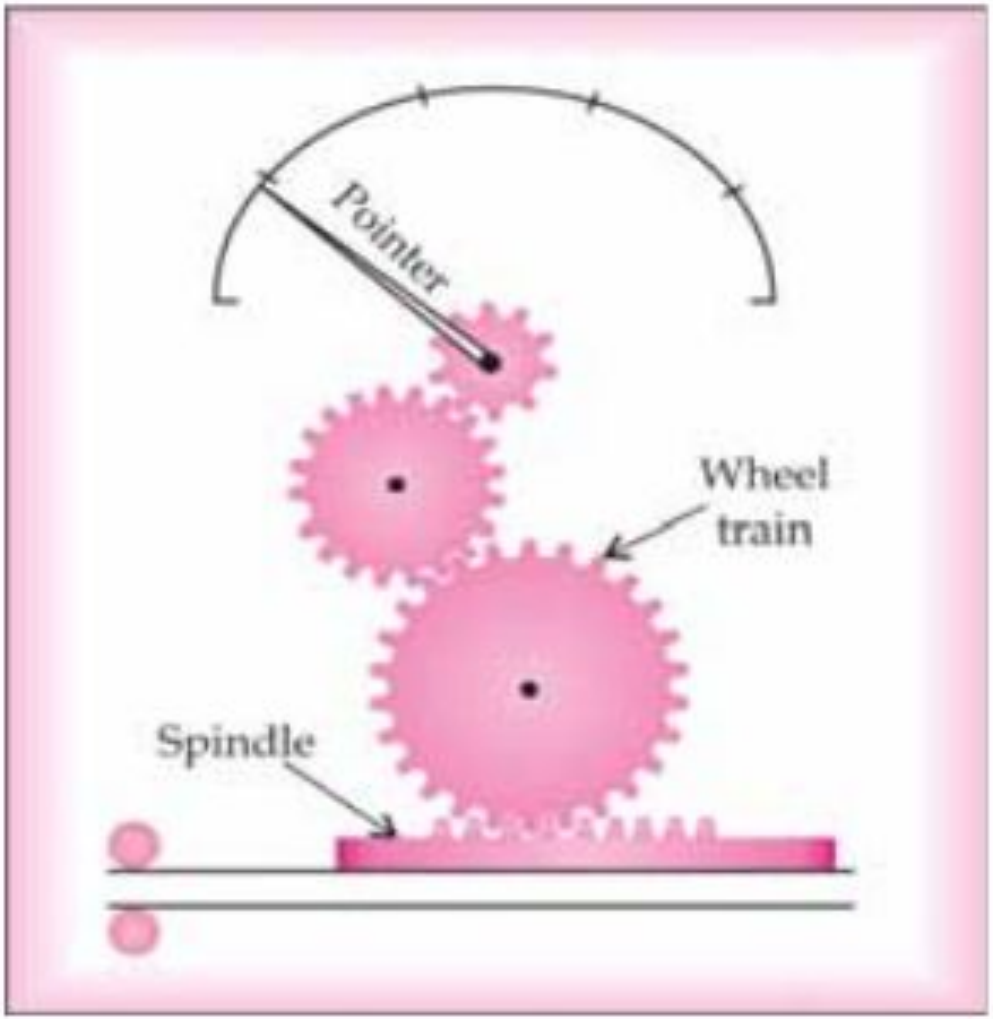

Bourdon tube
Pointer
Pinion
Link
Sector
p


0.8
0.4
1.2
1.6

Clinical thermometer, the temperature measuring instrument

- **Thermometer bulb** containing mercury acts as the primary sensing element.
- The **capillary** thus has the role of signal manipulation and data transportation elements.
- The **scale** on the thermometer stem acts as a presentation stage.

Example - 3



Dial Indicator

- The **Spindle** is sensitive to the linear displacement and acts as the primary sensing element.
- The **Gear train** train converts translator motion to rotator motion.
- The Data presented is the **Pointer** position on the dial - and that acts as a terminating stage.

Stage one:

Detector Transducer Stage

Senses desired input to the exclusion of all others and provides an analogous output

Mechanical	Contacting Spindle, Spring mass, Elastic devices such as Bourdon Tube, Proving
Hydraulic Pneumatic	Orifice, Venturi, Vane, Propeller
Optical	Photographic Film, Photoelectric cell
Electrical	Contactor, Resistance capacitance, thermocouple, Moving Electrode, Streaming Potential

Stage Two:

Intermediate Modifying Stage

Modifies transduced signal into form usable by final stage. Usually increases amplitude and/power depending on the type.

Mechanical	Gearing, Cranks, Slides, Connecting Links, cams etc.,
Hydraulic Pneumatic	Piping, valving, dash-pots
Optical	Mirrors, lens, light levers, optical fibers
Electrical	Amplifying or attenuating Systems, matching devices, filters, telemetering systems .

Stage Three:

Terminating or Read – out Stage

Provides an indication or recording in form which may be evaluated by an unaided human sense, or by a controller.

Indicators	**Displacement types:** Moving pointer and scale, moving scale and index, light beam scale, Electron Beam and scale(CRO), Liquid column **Digital types:** Direct reading (Alphanumeric read out)
Recorders	Digital printing, inked pen and chart, hot stylus and chart, light beam and photographic film, direct photography(Still or moving), magnetic recording.
Controlling devices	All types