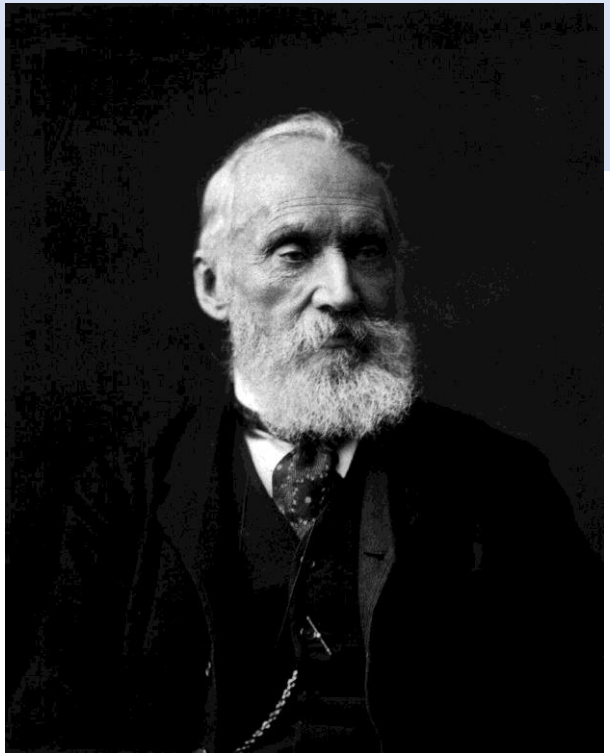
BASIC CONCEPTS OF MEASUREMENT METHODS

LEARNING OBJECTIVES

- The importance of studying mechanical measurements
- Understand purpose and performance of measurement system
- Typical structure of measurement system
  - Temperature measurement system
  - Flow measurement system
  - Mass measurement system
- Types of measurement systems (instruments)
  - Active and Passive instruments
  - Analog and digital instruments
- Static Calibration
  - Traceability
- Static Characteristics
  - Resolution
  - Range

WHY STUDY MEASUREMENT METHODS

I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot express it in numbers, your knowledge is of meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be.



Sir William Thomson (Lord Kelvin)

Common devices that involve measurement

Petrol pumping station

Measurement Cup

Speedometer

PURPOSE AND PERFORMANCE OF MEASUREMENT SYSTEMS

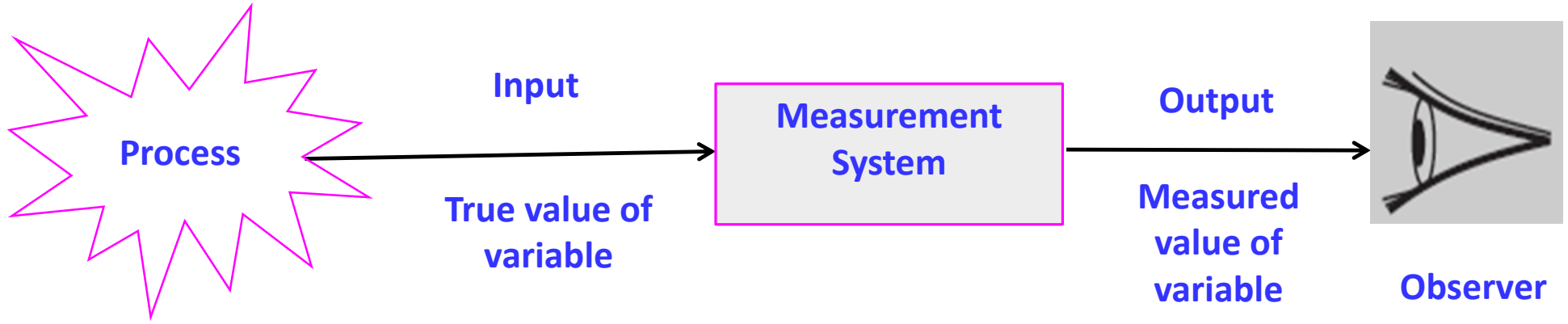
PROCESS - system which generates information

Ex: Nuclear reactor, a jet fighter, a submarine, a car, a human heart, and a weather system.

COMMON INFORMATION/MEASURED VARIABLES

Acceleration, Velocity, Displacement , Force–Weight, Pressure, Torque, Volume, Mass, Flow rate, Level, Density, Viscosity, Composition, pH, Humidity, Temperature, Heat Flux, Current, Voltage, Power

PURPOSE OF MEASUREMENT SYSTEM

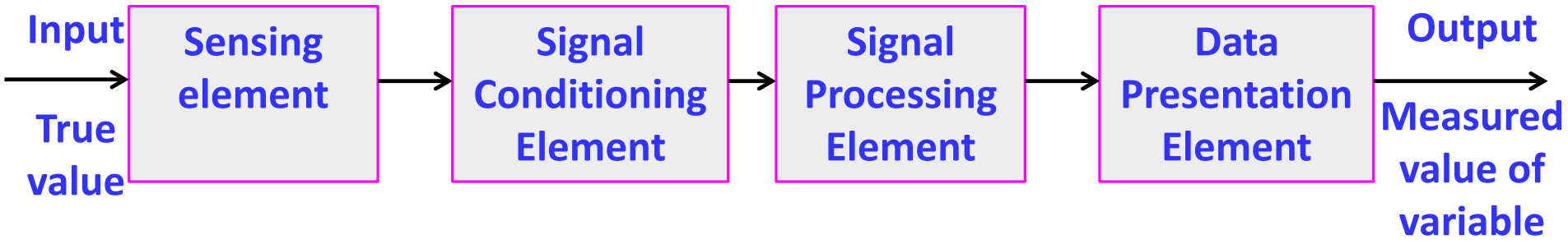


E = measured value – true value

E = system output – system input

Accuracy of the system is high as the measurement system error decreases

Structure of measurement systems



Sensing element - is in contact with the process and gives an output which depends in some way on the variable to be measured.

Ex: Thermocouple where millivolt e.m.f. depends on temperature
Strain gauge where resistance depends on mechanical strain
Orifice plate where pressure drop depends on flow rate.

If there is more than one sensing element in a system, the element in contact with the process is termed the primary sensing element, the others secondary sensing elements

Signal conditioning element - takes the output of the sensing element and converts it into a form more suitable for further processing, usually a d.c. voltage, d.c. current or frequency signal.

Examples :

- Deflection bridge which converts an impedance change into a voltage change
- Amplifier which amplifies millivolts to volts

Signal processing element - takes the output of the conditioning element and converts it into a form more suitable for presentation.

Examples :

- Analogue-to-digital converter (ADC) which converts a voltage into a digital form for input to a computer
- Computer which calculates the measured value of the variable from the incoming digital data.

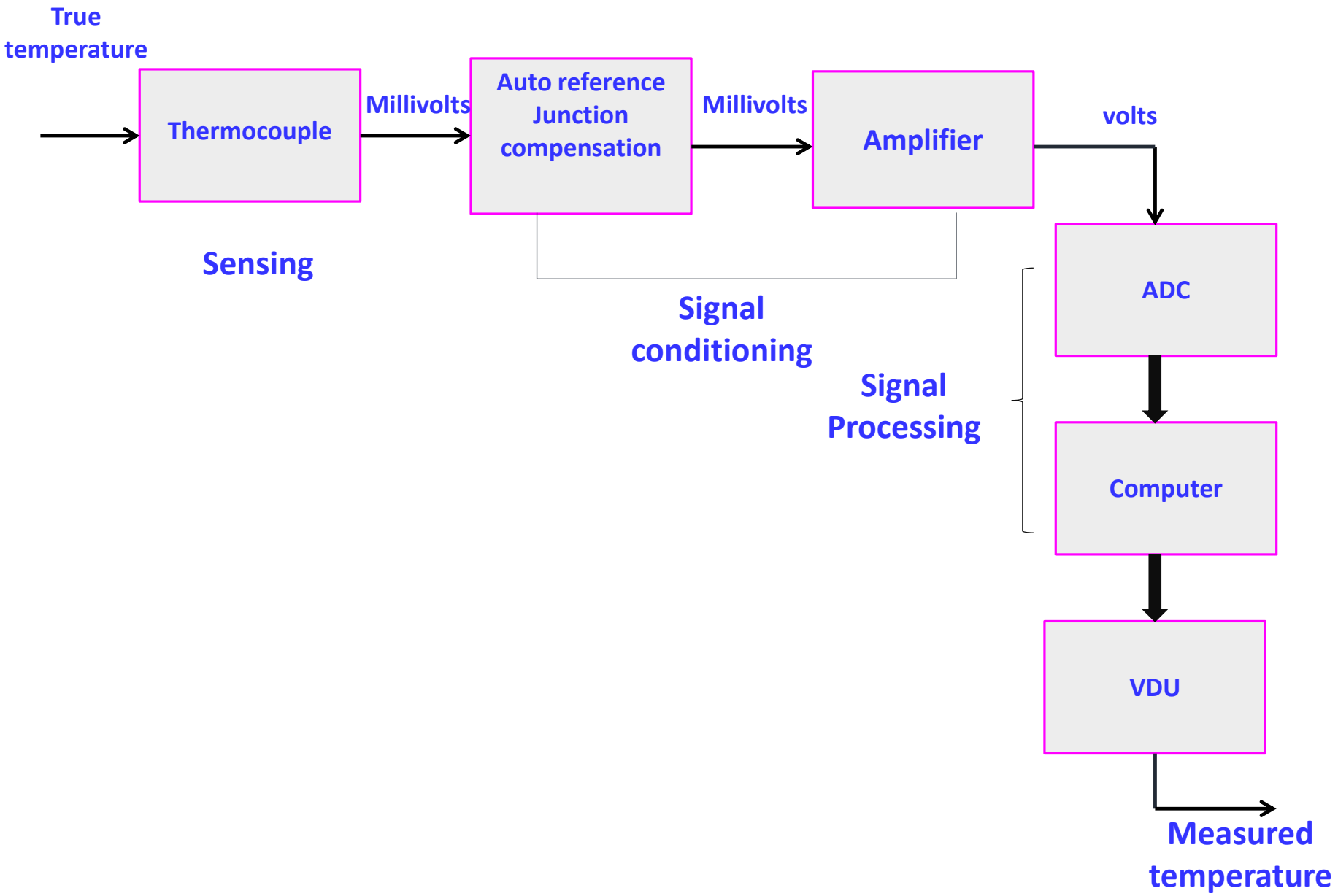
Data presentation element

This presents the measured value in a form which can be easily recognised by the observer.

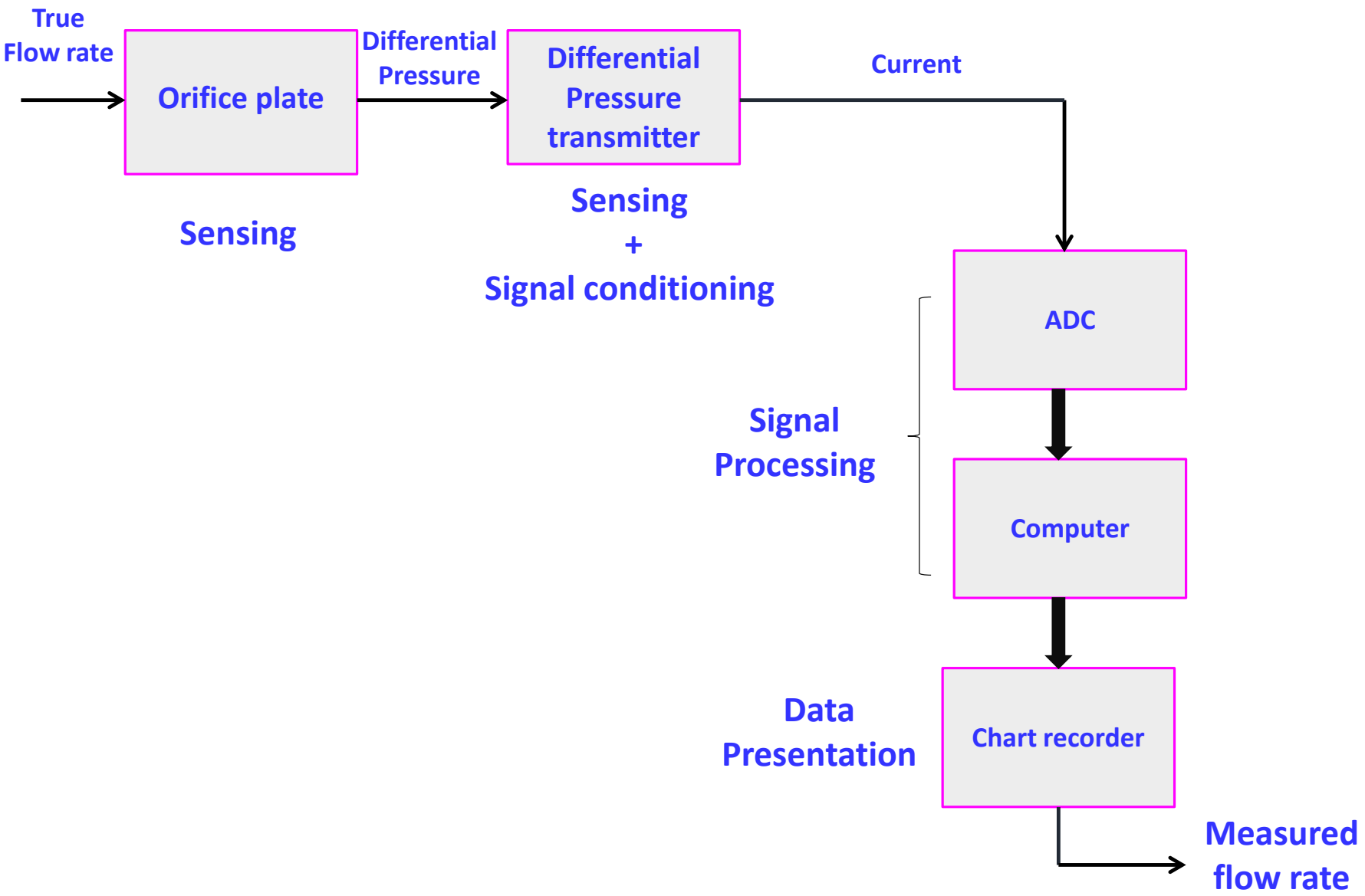
Examples are:

- Simple pointer–scale indicator
- Alphanumeric display
- Video Display Unit

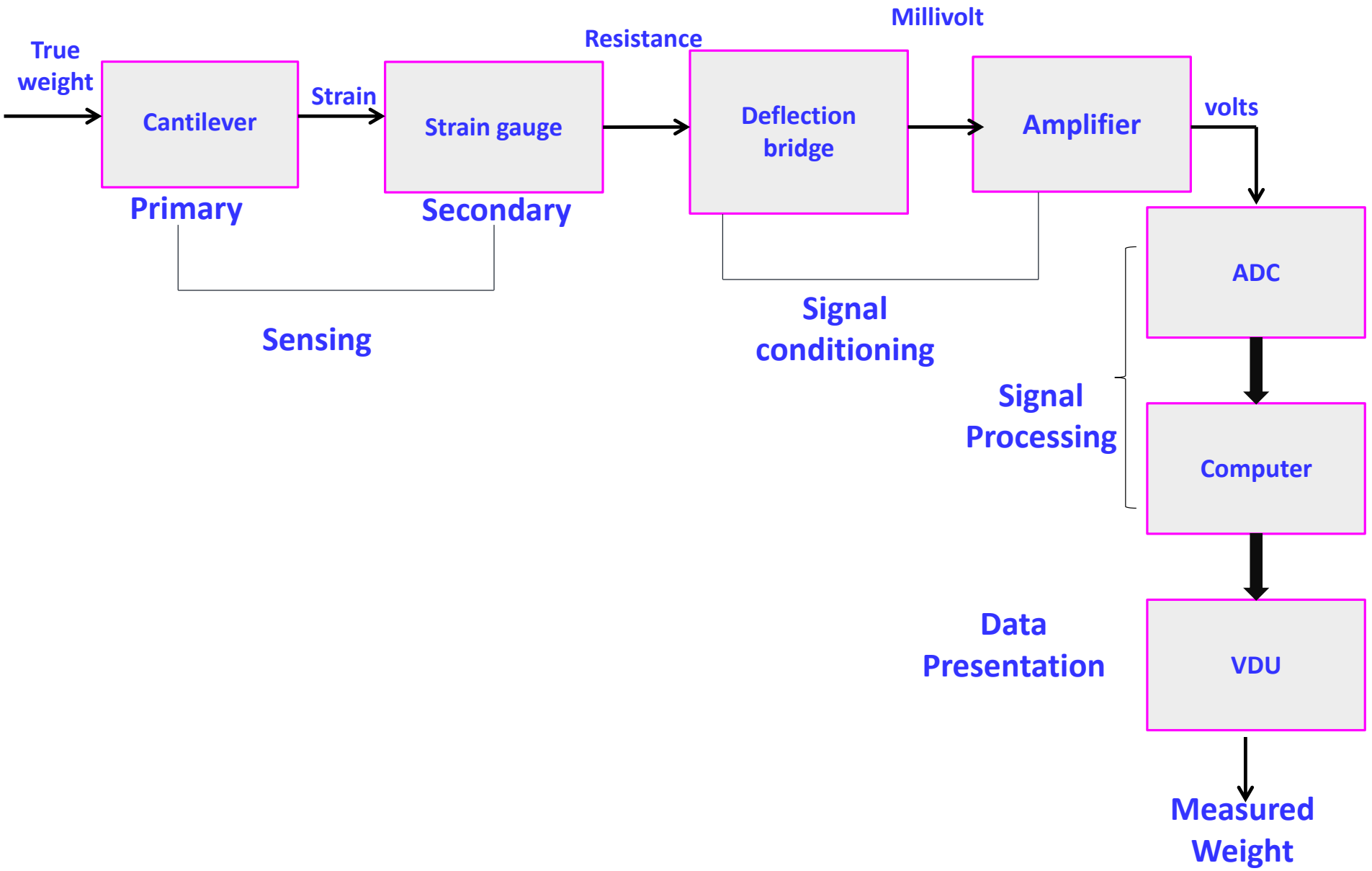
Temperature system with a thermocouple sensing element



The flow system has an orifice plate sensing element



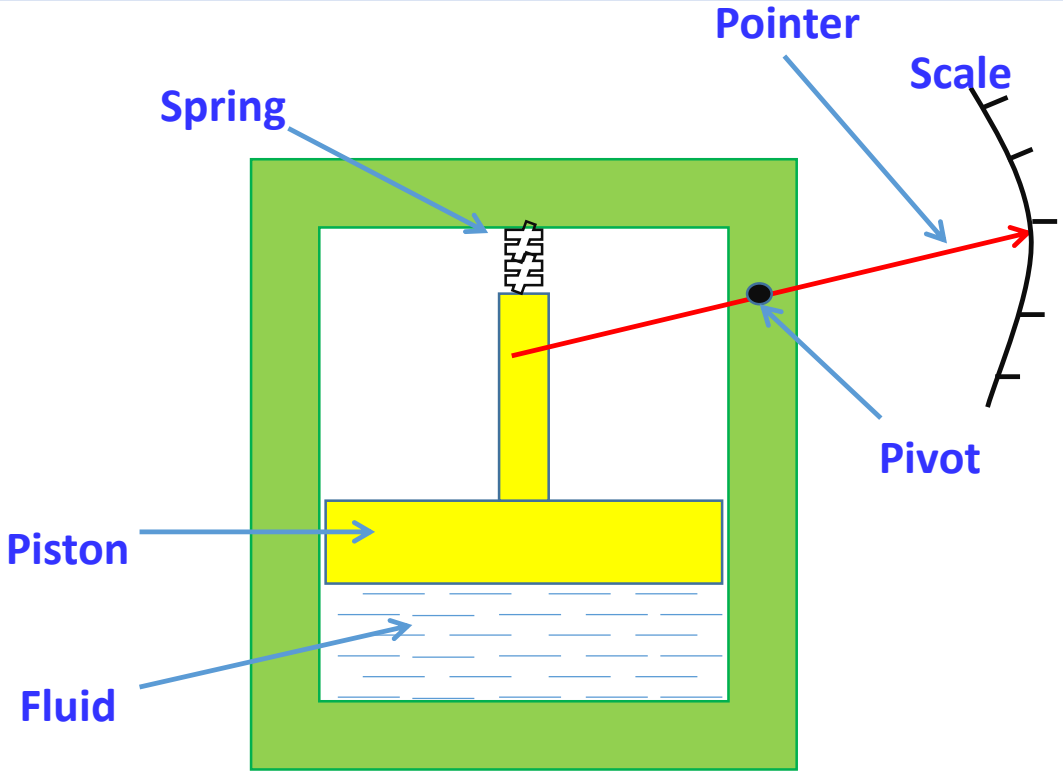
Weighing system has two sensing elements: the primary element is a cantilever which converts weight into strain



TYPES OF INSTRUMENTS

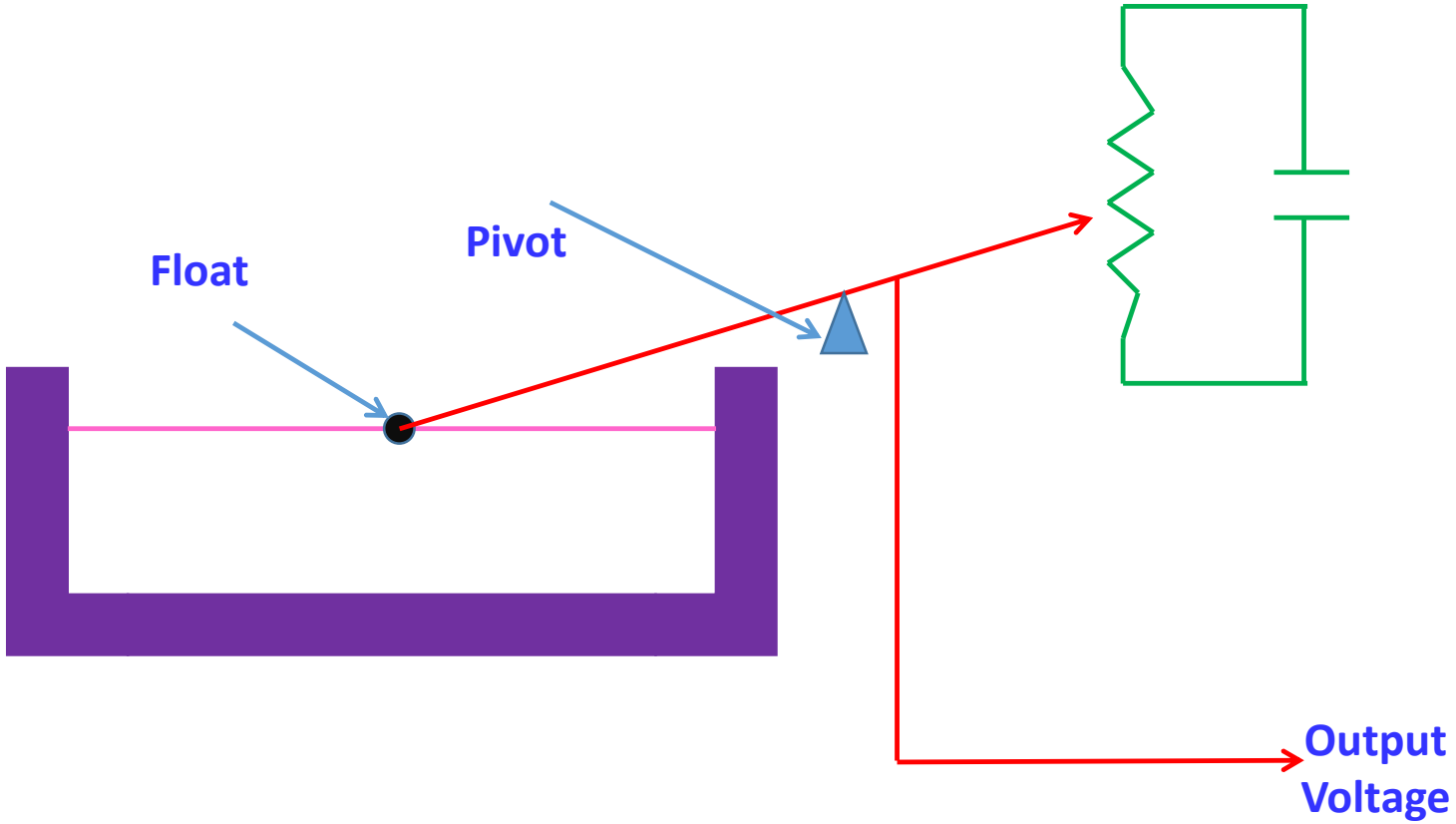
Active and passive instruments

Passive Instrument – Pressure Measuring Device



The pressure of the fluid is translated into a movement of a pointer against a scale. The energy expended in moving the pointer is derived entirely from the change in pressure measured: there are no other energy inputs to the system

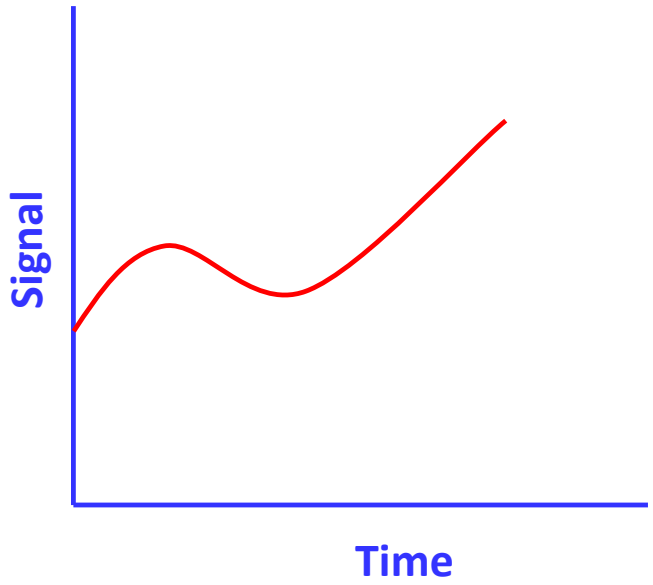
Active Instrument – Petrol tank level indicator

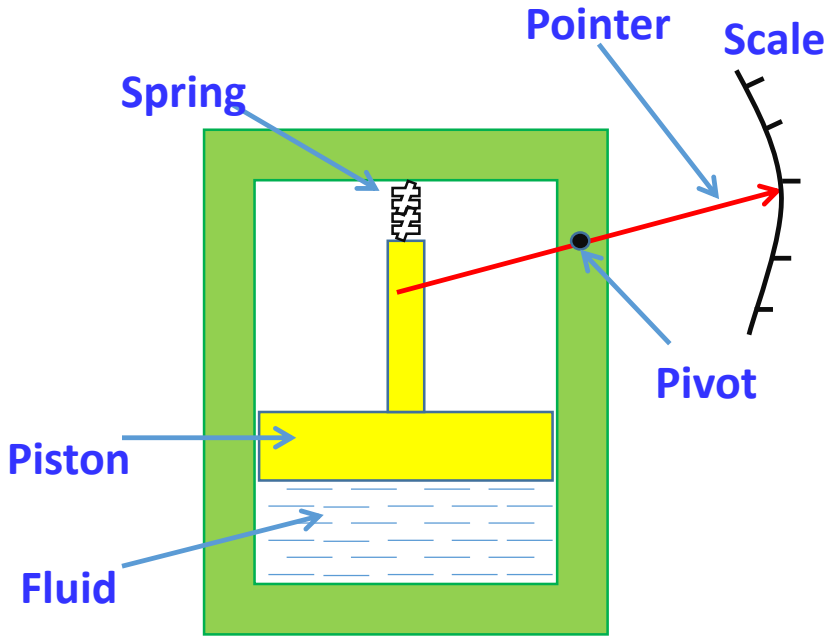


the change in petrol level moves a potentiometer arm, and the output signal consists of a proportion of the external voltage source applied across the two ends of the potentiometer. The energy in the output signal comes from the external power source: the primary transducer float system is merely modulating the value of the voltage from this external power source.

ANALOG AND DIGITAL INSTRUMENTS

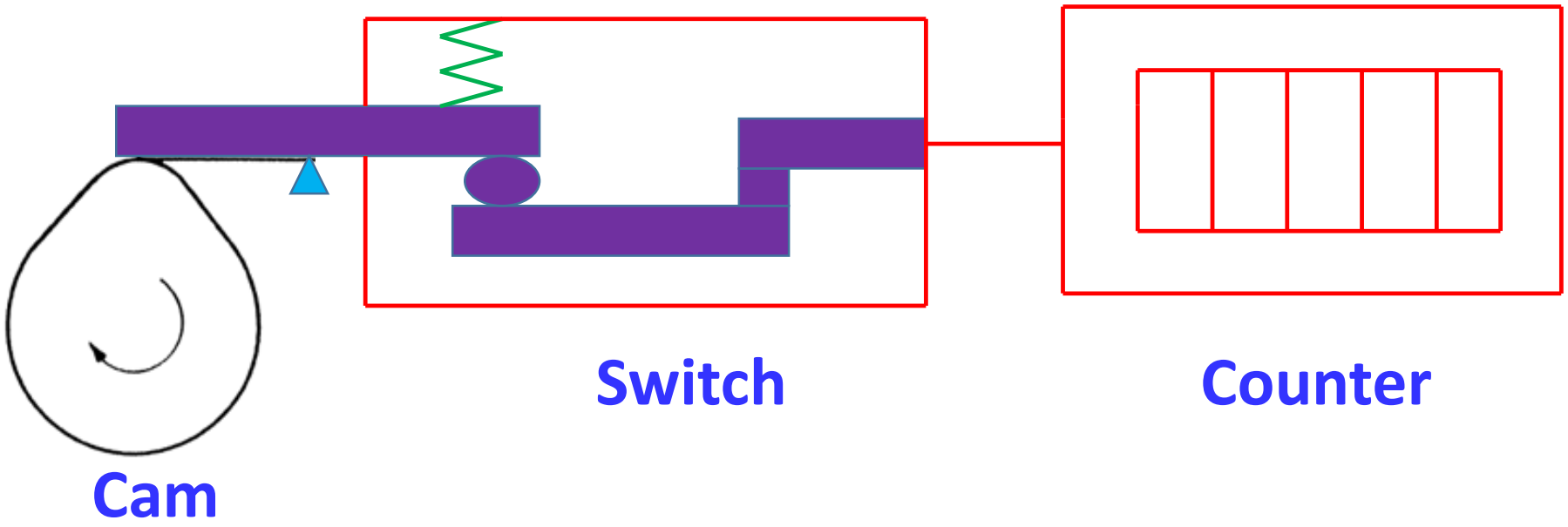
An analogue instrument gives an output that varies continuously as the quantity being measured changes. The output can have an infinite number of values within the range that the instrument is designed to measure





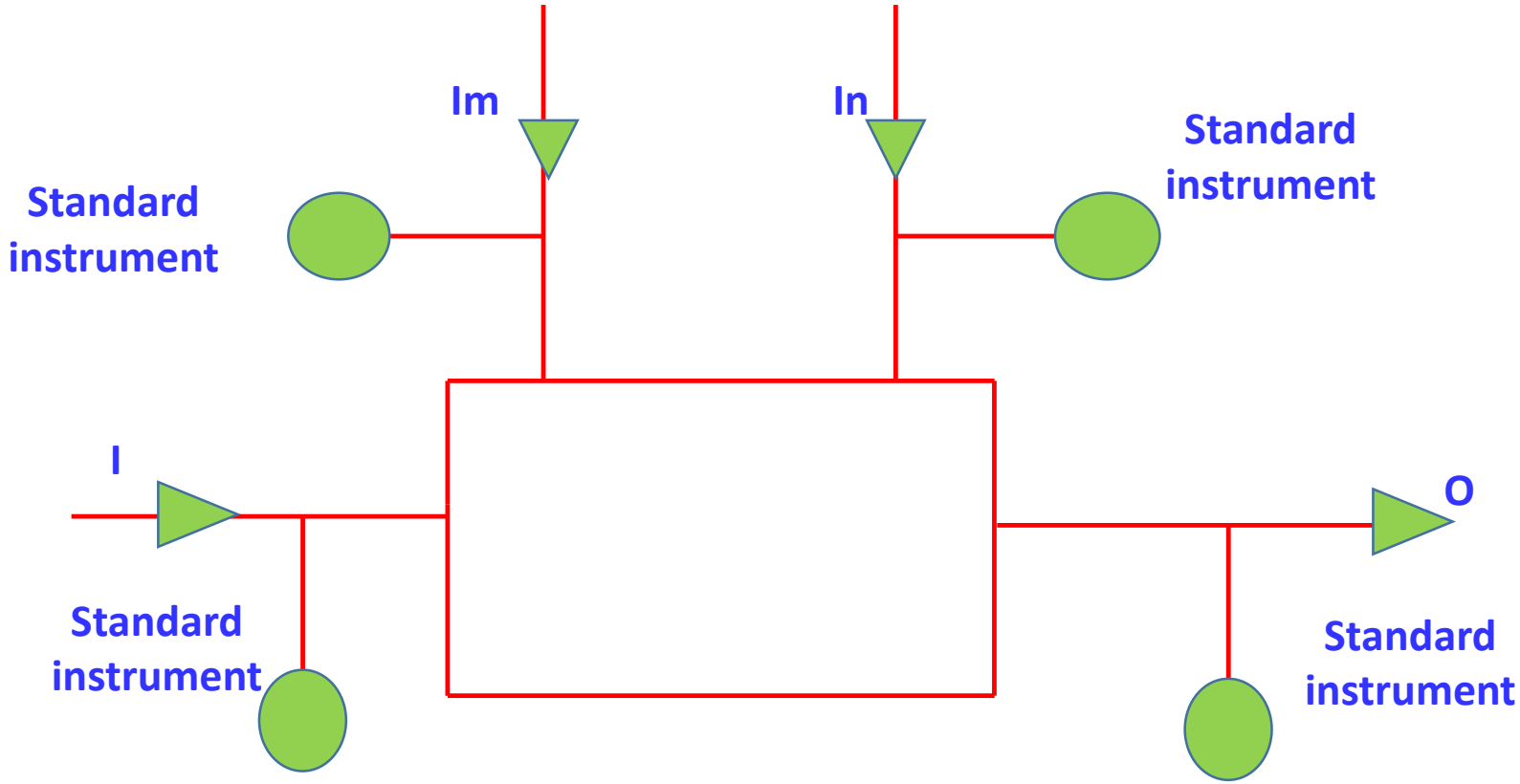
A digital instrument has an output that varies in discrete steps and so can only have a finite number of values

REVOLUTION COUNTER



CALIBRATION

A calibration applies a known input value to a measurement system for the purpose of observing the system output value. It establishes the relationship between the input and output values. The known value used for the calibration is called the standard.



STATIC CALIBRATION

A known value is input to the system under calibration and the system output is recorded.

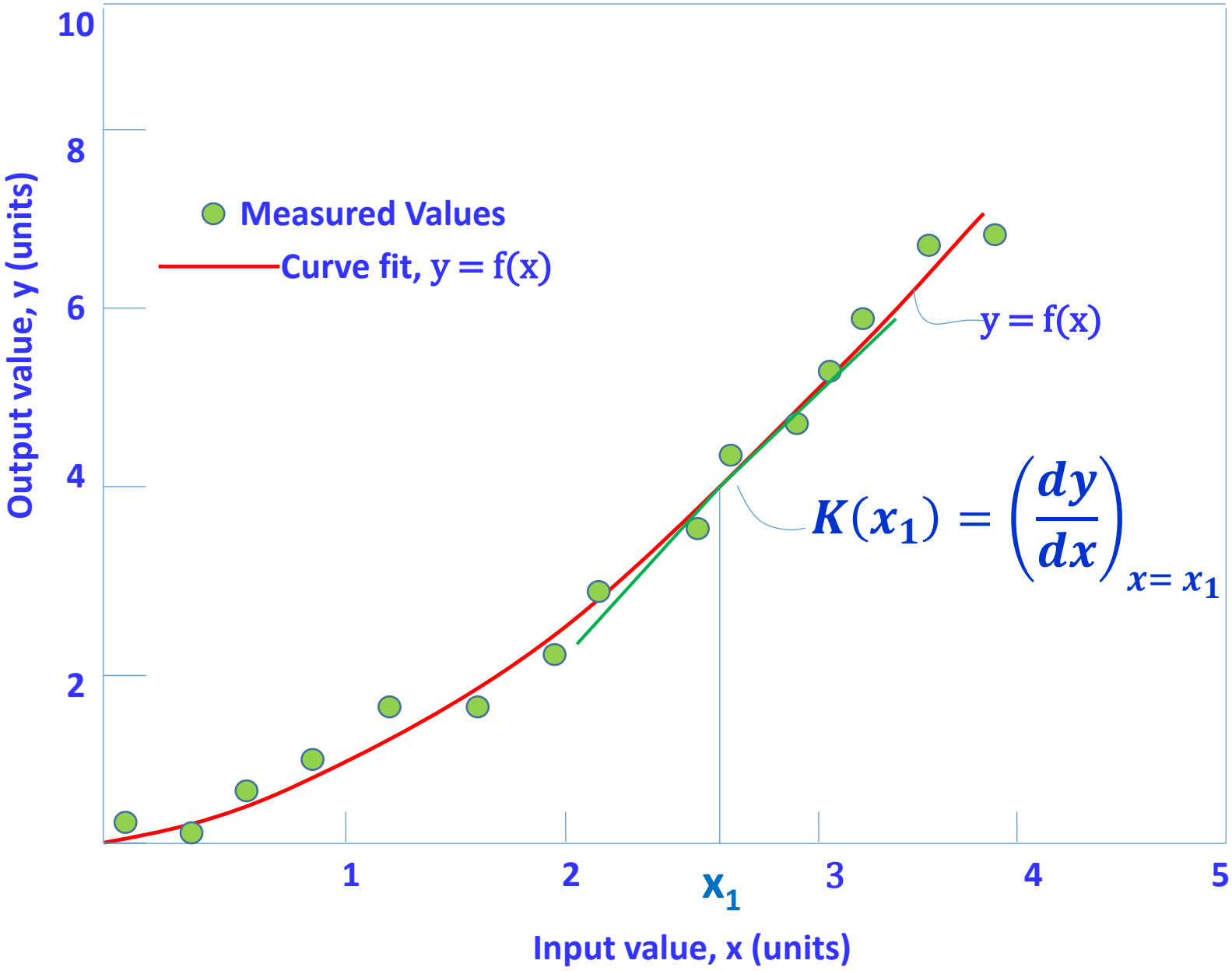
The term "static" implies that the values of the variables involved remain constant; that is, they do not vary with time or space.

In static calibrations, only the magnitudes of the known input and the measured output are important.

By applying a range of known input values and by observing the system output values, a direct calibration curve can be developed for the measurement system.

In a calibration the input value is usually a controlled independent variable, while the measured output value is the dependent variable of the calibration.

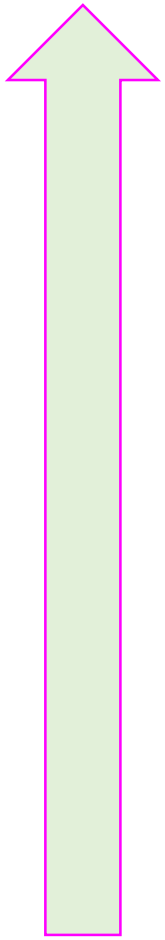
Representative static calibration curve



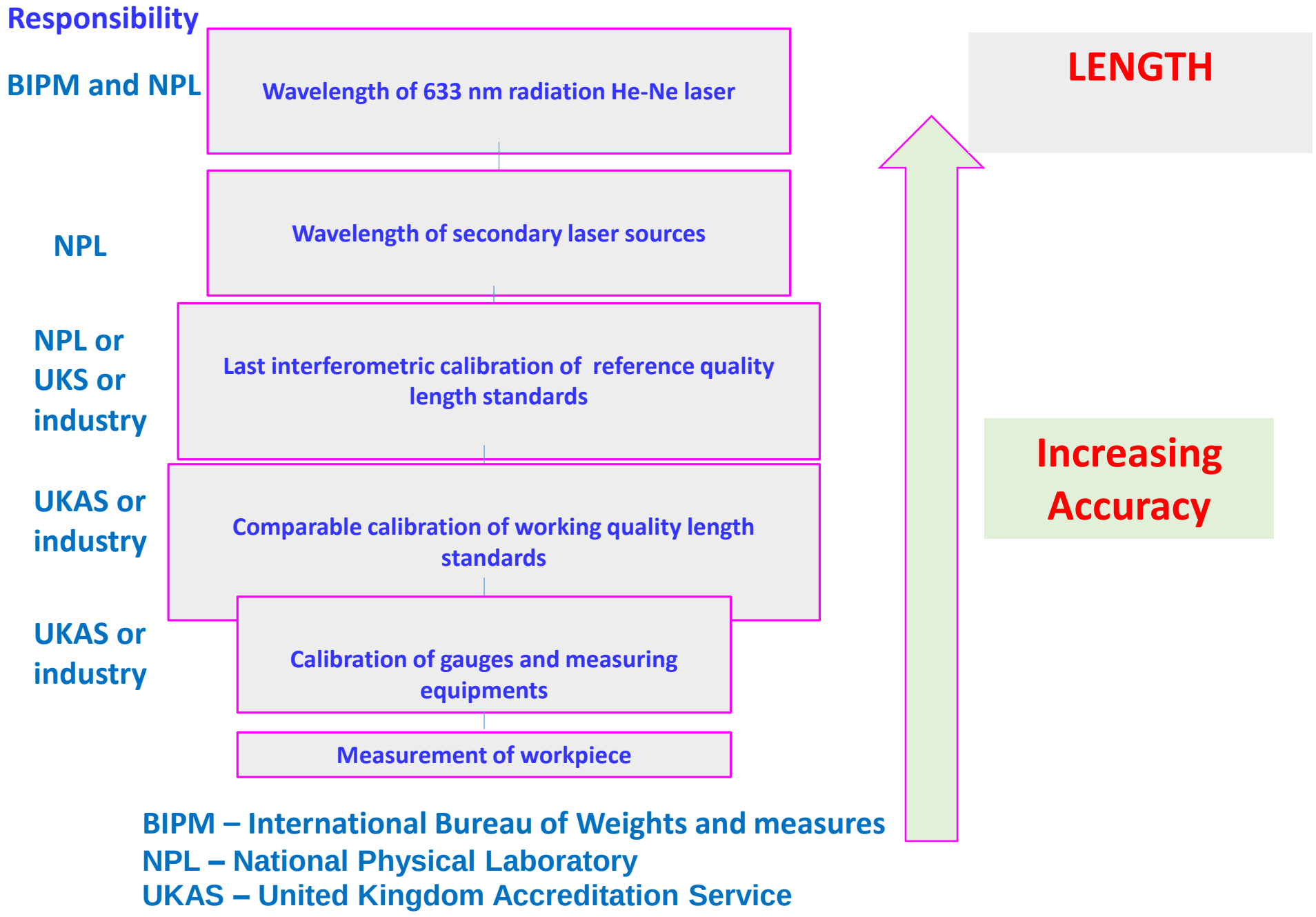
SIMPLIFIED TRACEABILITY LADDER

MASS

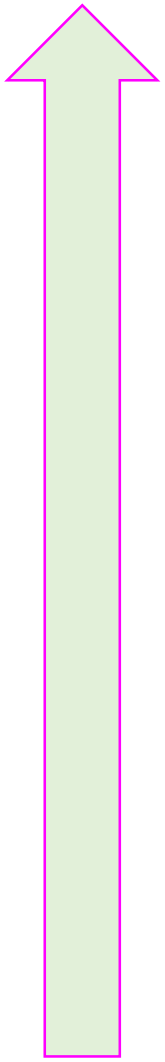
Increasing Accuracy



Accuracy	
3 in 10^{11}	The international kilogram (Paris)
1 in 10^{7}	National primary standard kg (London)
1 in 10^{6}	National secondary standard weight (London)
1 in 10^{5}	National transfer standard weight (portable)
1 in 10^{4}	Local standard weight (held by weights and measures dept)
	Your own laboratory standard weight
	Your weighing instrument


Responsibility
BIPM and NPL
Wavelength of 633 nm radiation He-Ne laser
NPL
Wavelength of secondary laser sources
NPL or UKS or industry
Last interferometric calibration of reference quality length standards
UKAS or industry
Comparable calibration of working quality length standards
UKAS or industry
Calibration of gauges and measuring equipments
Measurement of workpiece
LENGTH
Increasing Accuracy
BIPM – International Bureau of Weights and measures
NPL – National Physical Laboratory
UKAS – United Kingdom Accreditation Service

PRESSURE



Increasing Accuracy

Primary Standard

e.g. NPL pressure balance

Transfer Standard

e.g. Dead weight tester

Laboratory Standard

e.g. Standard Pressure gauge

Element to be calibrated

e.g. Pressure transducer

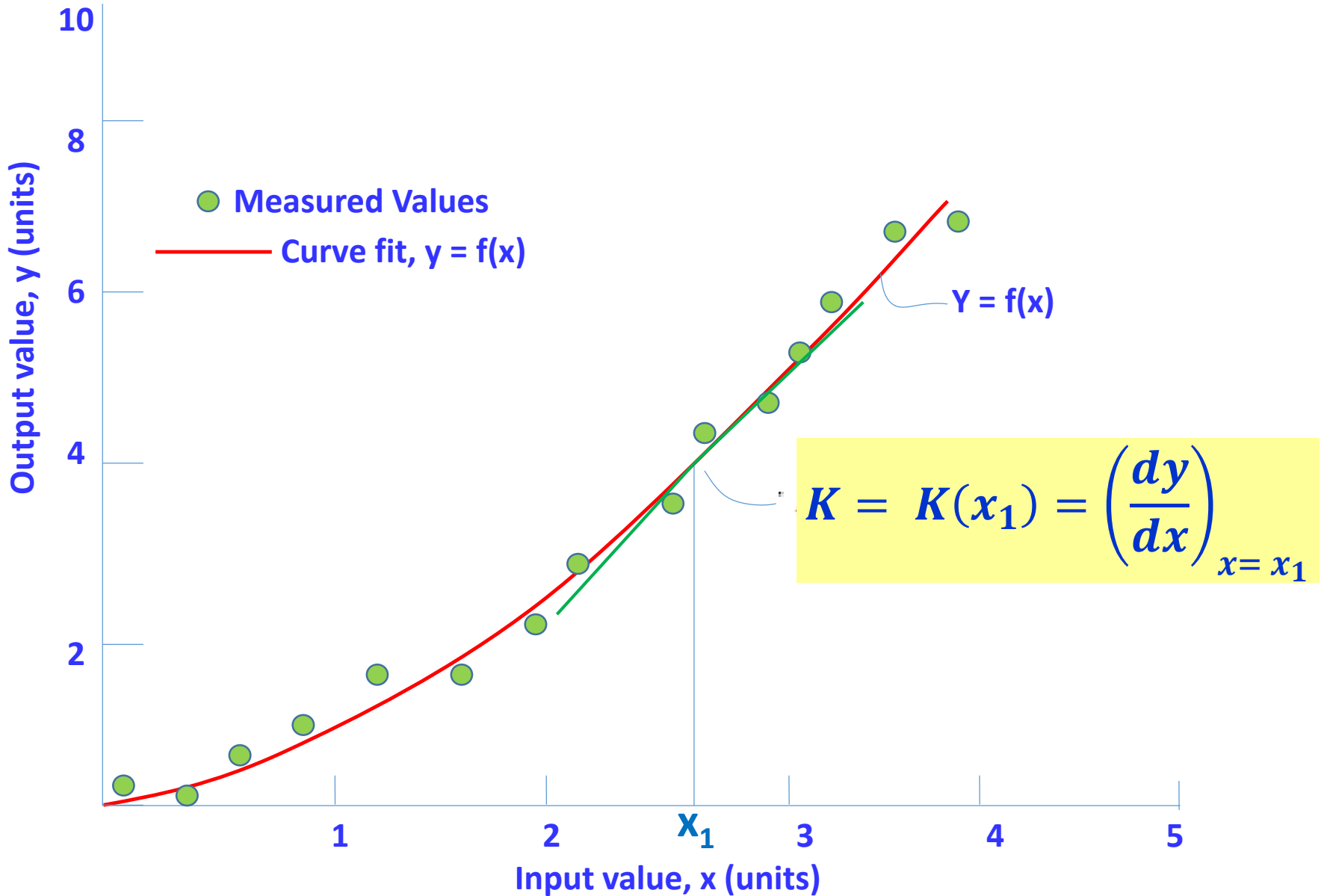
Hierarchy of Standards

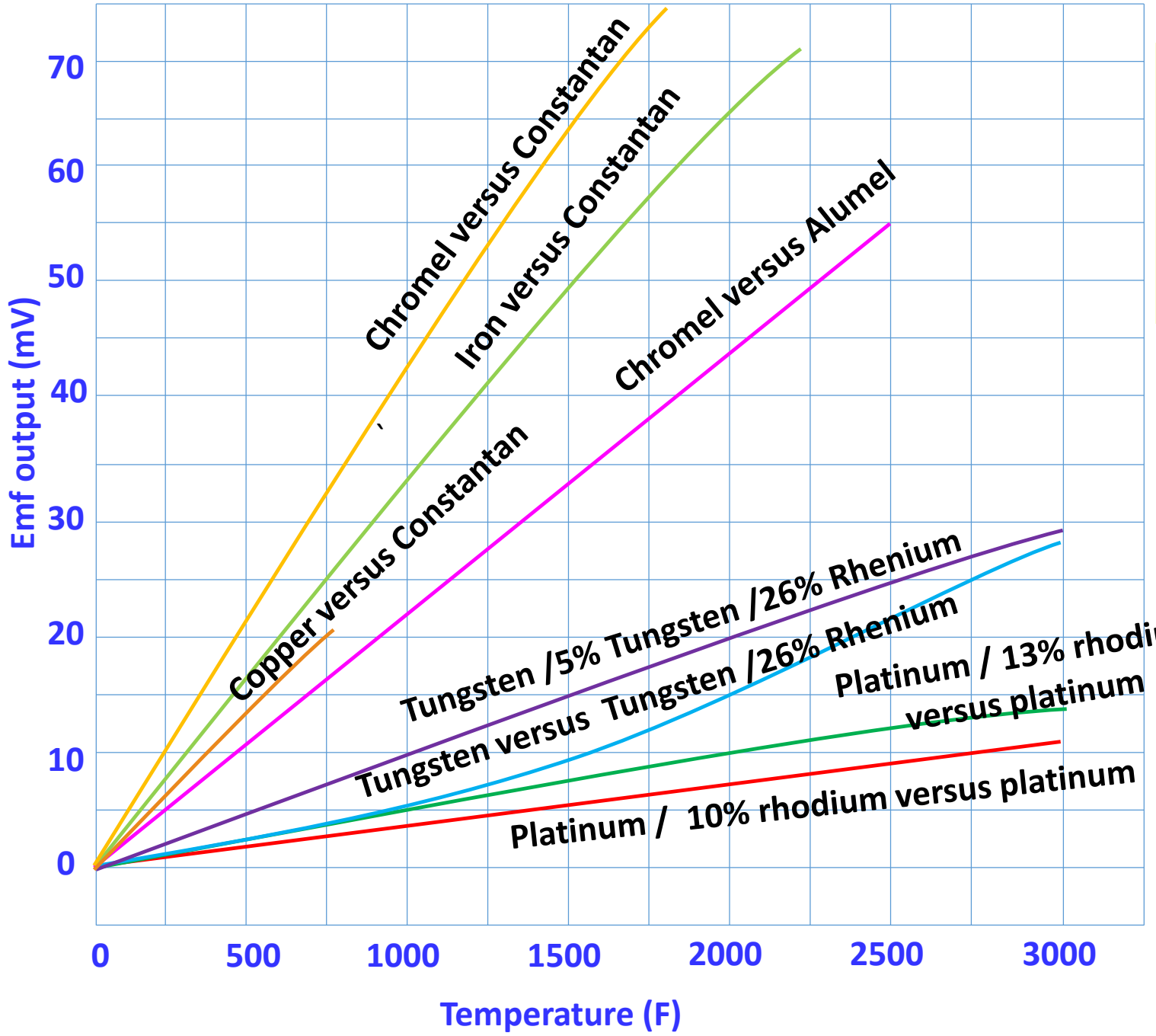
Primary Standard	Maintained as absolute unit standard
Transfer Standard	Used to calibrate local instruments
Local Standard	Used to calibrate local standards
Working Standard	Used to calibrate working standards

Standard		
Level	Method	Uncertainty [°C]
Primary	Fixed Thermodynamic points	0
Transfer	Platinum resistance thermometer	± 0.005
Local	Platinum resistance thermometer	± 0.05
Working	Thermocouple	± 0.5

STATIC CHARACTERISTICS

STATIC SENSITIVITY: CHANGE IN THE INDICATED OUTPUT ASSOCIATED WITH A GIVEN CHANGE IN INPUT





Emf variation with temperature

Reference junction at zero deg C

RANGE: A calibration applies known inputs ranging from the minimum to the maximum values for which the measurement system is to be used. These limits define the operating range of the system.

It is important to avoid extrapolation beyond the range of known calibration during measurement since the behaviour of the measurement system is uncharted in these regions.

RESOLUTION: represents the smallest increment in the measured value that can be discerned.

In terms of a measurement system, it is quantified by the smallest scale increment or least count (least significant digit) of the output readout indicator.

Typical questions to be answered after the completion of this module

1. What is the purpose of a measurement system?
2. Draw a schematic of a typical structure of a measurement system. Explain each element of the measurement system with suitable examples
3. Draw a schematic of the structure of a measurement system involving the measurement of volume flow rate using orifice plate
4. Draw a schematic of the structure of a measurement system involving the measurement of temperature using thermocouple
5. Draw a schematic of the structure of a measurement system involving the measurement of mass using cantilever beam and strain gages
6. Differentiate
   i. Active and passive measurement system
   ii. Analog and digital system
7. Explain the following
   i. Calibration
   ii. Static calibration
   iii. Traceability
   iv. Range
   v. Resolution