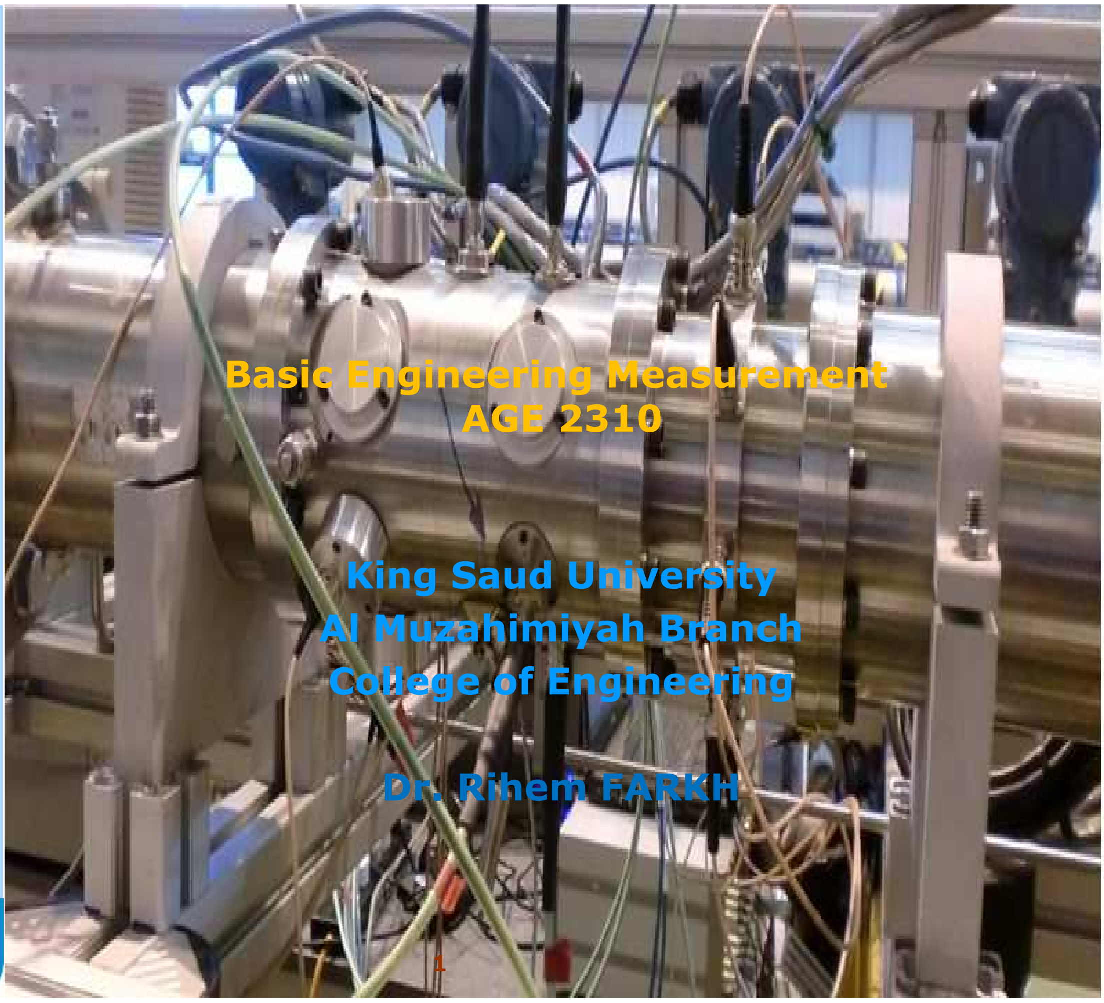
Lecture 1



Basic Engineering Measurement
AGE 2310

King Saud University
Al Muzahimiyah Branch
College of Engineering

Dr. Rihem FARKH

Syllabus

- Catalog Description: Measuring concepts; Engineering Problems and Fundamental Dimensions; System of Units and Unit Conversion. Types of instruments and measurand. Some basics about statistics and probability; Errors in measurement; Data collection and analysis; Uncertainty analysis of data; Evaluation of bias and precision uncertainty; Analog and digital signals analysis; Mean and RMS value of signals; Sampling of analog signals and associated errors; Digital signals; D/A and A/D converters. Instrumentation specifications; Basic components of electrical and mechanical measurement system; Response of measurement system: Concept of order of measurement system; Time response of measurement system Measurement of length; time; mass; force, electric current; resistances; pressure; temperature; energy and power
- Prerequisites: AGE 1150
- Course Text: Figiola, R. S. and Beasley, D. E., *Theory and Design for Mechanical Measurements* 4th Ed., John Wiley & Sons, 2005.

Tentative Lecture Schedule

Topics	week
Introduction and Basic Concepts.	1
Introduction to probability and Statistical distributions	1
Uncertainty Analysis	1
Static and Dynamic Characteristics of Signals	1.5
Measurement System Behavior	1.5
Analog Electrical Devices and Measurements	1.5
Sampling, Digital Devices,	1.5
Sensors, DAQ using Lab View and Data Acquisition	1
Measurement of basic electrical parameters	1
Temperature and Pressure Measurements	1
Flow Velocity Sensors and Measurements	1
Strain and Force Measurements	1

Reference

- Figliola, R. S. and Beasley, D. E., *Theory and Design for Mechanical Measurements*, 3th Ed., John Wiley & Sons, 2000.
- Wheeler A.J. and Ganji Ahmed, *Introduction to Engineering Experimentation* 2nd Ed., Pearson Prentice Hall, 2008.
- Holman, J. P., *Experimental Methods for Engineers*, 7th. Ed., McGraw-Hill, 2001.
- Beckwith, Marangoni, and Lienhard, *Mechanical Measurements*, 5th Ed., Addison-Wesley, 1993.
- Smith, C. A. and Corripio, A. B., *Principles and Practice of Automatic Process Control*, 2nd Ed., John Wiley & Sons, 2006.
- Spitzer, D. W., *Flow Measurement: Practice Guides for Measurement and Control*, ISA, 2001,
- Electronic references of Instrumentation, from http://www.engnetbase.com/

One thing you learn in science is that there is no perfect answer, no perfect measure.

A. O. Beckman

Topic 1: Measurements

Introduction and Basic Concepts

Course Objectives

- ☐ To review the basic concepts of measurement.

Significance of Measurement

- The primary objective in any measurement system is to establish the value or the tendency of some variable.
- Measurement provides quantitative information on the actual state of the physical variables and processes.
- The goal of a measurement system is to convert the sensed information into a form that can be easily quantified
- Significant Results of Measurements are
  - Fundamental data for research, design and development,
  - Basic input data for control of processes and operations,
  - Data for safe and economic performance of systems.

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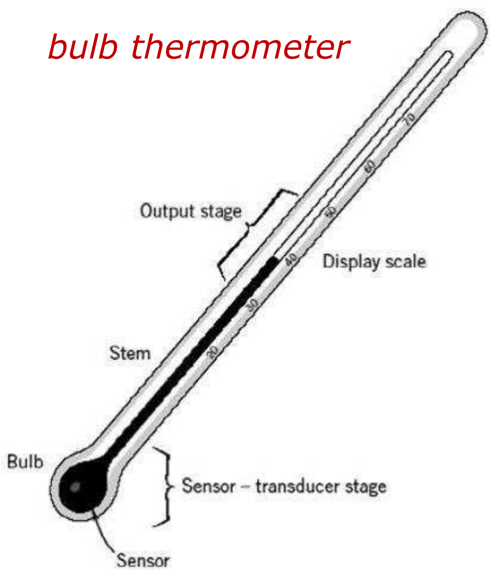
General Measurement System

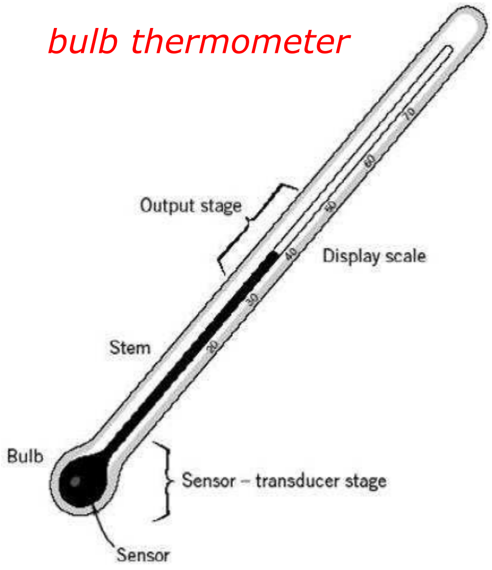
bulb thermometer



- The liquid contained within the bulb exchanges energy with its surroundings until the two are in thermal equilibrium
- At that point they are at the same temperature
- This energy exchange is the input signal to this measurement system
- The thermal expansion of the liquid results in its movement up and down the stem
- It forms an output signal from which we determine temperature

General Measurement System

bulb thermometer



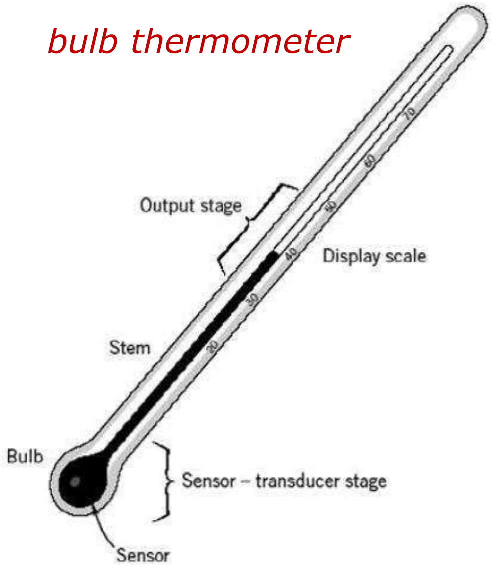
- The liquid in the bulb acts as the sensor.
- the bulb's internal capillary design acts as a transducer.
- the term "transducer" is also often used in reference to a packaged device, which may contain a sensor, transducer, and even some signal conditioning elements

General Measurement System

- Sensor - As the term suggests, it is a body which reacts to a physical, chemical or biological condition. It senses.
- It can be considered as a detector
- Transducer - The conversion of energy from one form to another is known as Transduction. A transducer serves for this purpose : **energy converter**

General Measurement System

bulb thermometer

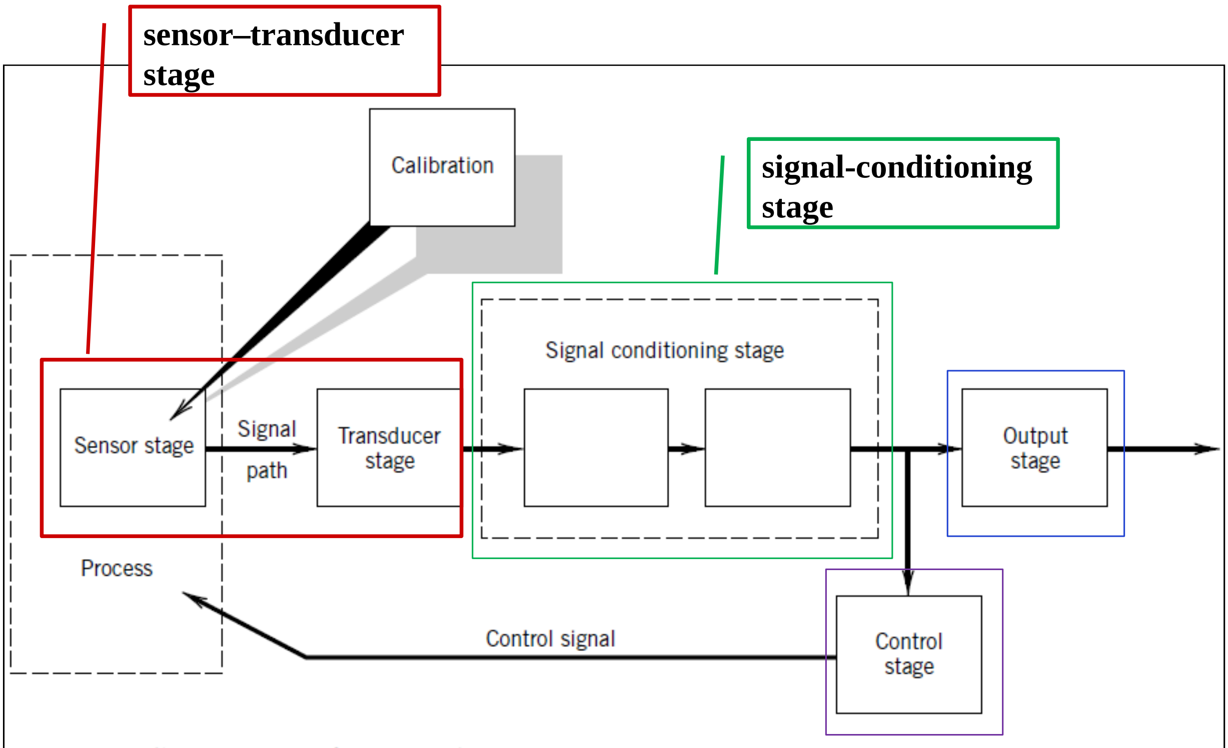


- Detector-transducer or sensor stage
- Intermediate or signal conditioning stage
- Terminating or readout stage
- Feedback control stage (optional)

❑These stages form the bridge between the input to the measurement system and the system output.

❑The relationship between the input information and the system output is established by a calibration.

Components of a General Measurement System



Components of a general measurement system.

Components of a General Measurement System

- Detector-transducer or sensor stage:
  - The physical variable to be measured is detected.
  - Signal is transformed into more usable form.
  - Insensitive to every other possible input.
  - Minimize *loading error.*
- Intermediate or signal processing stage:
  - The transduced signal is modified by one or more basic operations, such as amplification, filtering, differentiation, integrating or averaging, etc.
- Terminating or readout stage:
  - Acts to indicate, record or control the variable being measured. Output may be *analog or digital.*
- Feedback control stage:
  - In those measurement systems involved in process control, feedback control stage contains a controller that interprets the measured signal and makes a decision regarding the control of the process.

Calibration

- Calibration affords the opportunity to check the instrument against a known standard and subsequently to reduce errors in accuracy.
  - Example: Calibration of a flow-meter
  - Comparison with a standard flow-measurement facility.
  - Comparison with a flow-meter of known accuracy, which is higher than the instrument to be calibrated.

Units in the SI System

- A common denomination of units is essential for the development of trade and economics around the world

Quantity	SI Base Unit	Abbreviation
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	Kelvin	K
Amount of substance	mole	mol
Light intensity	candela	cd

Derived Units in the SI System

Quantity	SI Derived Unit	Abbreviation	Definition
Length	micrometer or micron	μm	$1\ \mu\text{m} = 10^{-6}\ \text{m}$
Volume	liter	L	$1\ \text{L} = 0.001\ \text{m}^3$
Force	newton	N	$1\ \text{N} = 1\ (\text{kg} \cdot \text{m})/\text{s}^2$
Torque, or moment of a force	newton-meter	$\text{N} \cdot \text{m}$	—
Pressure or stress	pascal	Pa	$1\ \text{Pa} = 1\ \text{N/m}^2$
Energy, work, or heat	joule	J	$1\ \text{J} = 1\ \text{N} \cdot \text{m}$
Power	watt	W	$1\ \text{W} = 1\ \text{J/s}$
Temperature	degree Celsius	°C	$°\text{C} = \text{K} - 273.15$

Derived Units in USCS

Quantity	Derived Unit	Abbreviation	Definition
Length	mil	mil	1 mil = 0.001 in.
	inch	in.	1 in. = 0.0833 ft
	mile	mi	1 mi = 5280 ft
Volume	gallon	gal	1 gal = 0.1337 ft^3
Mass	slug	slug	1 slug = 1 $(lb \cdot s^2)/ft$
	pound-mass	lbm	1 lbm = 3.1081×10^{-2} $(lb \cdot s^2)/ft$
Force	ounce	oz	1 oz = 0.0625 lb
	ton	ton	1 ton = 2000 lb
Torque, or moment of a force	foot-pound	ft · lb	—
Pressure or stress	pound/$inch^2$	psi	1 psi = 1 lb/in^2
Energy, work, or heat	foot-pound	ft · lb	—
	British thermal unit	Btu	1 Btu = 778.2 ft · lb
Power	horsepower	hp	1 hp = 550 (ft · lb)/s
Temperature	degree Fahrenheit	°F	°F = °R – 459.67

Prefixes for SI Units

Examples:

- 1 kW = 1000 W
  = 10^3 W
- 1 kpsi = 1000 psi
- 2 GHz = 10^9 Hz
  =1,000,000,000 Hz

Name	Symbol	Multiplicative Factor
tera	T	$1{,}000{,}000{,}000{,}000 = 10^{12}$
giga	G	$1{,}000{,}000{,}000 = 10^9$
mega	M	$1{,}000{,}000 = 10^6$
kilo	k	$1000 = 10^3$
hecto	h	$100 = 10^2$
deca	da	$10 = 10^1$
deci	d	$0.1 = 10^{-1}$
centi	c	$0.01 = 10^{-2}$
milli	m	$0.001 = 10^{-3}$
micro	μ	$0.000{,}001 = 10^{-6}$
nano	n	$0.000{,}000{,}001 = 10^{-9}$

Conversion

Quantity	USCS		SI
Length	1 in.	=	25.4 mm
	1 in.	=	0.0254 m
	1 ft	=	0.3048 m
	1 mi	=	1.609 km
	1 mm	=	3.9370×10^{-2} in.
	1 m	=	39.37 in.
	1 m	=	3.2808 ft
	1 km	=	0.6214 mi
Area	1 in^2	=	645.16 mm^2
	1 ft^2	=	9.2903×10^{-2} m^2
	1 mm^2	=	1.5500×10^{-3} in^2
	1 m^2	=	10.7639 ft^2
Volume	1 ft^3	=	2.832×10^{-2} m^3
	1 ft^3	=	28.32 L
	1 gal	=	3.7854×10^{-3} m^3
	1 gal	=	3.7854 L
	1 m^3	=	35.32 ft^3
	1 L	=	3.532×10^{-2} ft^3
	1 m^3	=	264.2 gal
	1 L	=	0.2642 gal

Classification of sensors

- Many authors have tried to build up a consistent classification scheme of sensors:
  - according to the measurand
  - according to application fields

- sensors follow a classification according to the measurand

- measurand = quantity to be measured

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Classification of sensors

- list of physical quantities (measurands)

Mechanical, solids
Acceleration
Angle
Angular velocity
Area
Diameter
Distance
Elasticity
Expansion
Filling level
Force
Gradient
Hardness
Height
Length
Mass
Moment
Movement
Orientation
Pitch
Position
Pressure
Proximity
Rotation
Roughness
Shape
Tension
Torque
Torsion
Velocity
Vibration
Weight

Mechanical, fluids
Density
Flow direction
Flow velocity
Level
Pressure
Rate of flow
Viscosity
Volume

Thermal
Enthalpy
Entropy
Temperature
Thermal capacity
Thermal conduction
Thermal expansion
Thermal radiation

Optical
Colour
Light polarization
Light wavelength
Luminance
Luminous intensity
Reflection
Refractive index

Nuclear radiation
Ionization degree
Mass absorption
Radiation dose
Radiation energy
Radiation flux
Radiation type

Chemical
Cloudiness
Composition
Concentration
Electrical conductivity
Humidity
Impurity
Ionization degree
Moisture
Molar weight
Particle form
Particle size
pH
Polymerization degree
Reaction rate
Redox potential
Thermal conductivity
Water content

Acoustic
Sound frequency
Sound intensity
Sound polarization
Sound pressure
Sound velocity
Time of flight

Magnetic, electrical
Capacity
Charge
Current
Dielectric constant
Electric field strength
Electric power
Electric resistance
Frequency
Inductivity
Magnetic field strength
Phase
Pulse duration
Signal distortion

Time
Time
Frequency
Duty cycle

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Technical word

value	القيمة
tendency	اتجاه
variable	متغير
quantitative information	معلومات كمية
actual state	الحالة الفعلية
physical variables	للمتغيرات المادية
Processes	العمليات
Basic input	بيانات الادخال الاساسية
Input signal output signal provide Surroundings	اشارة الادخال اشارة الاخراج يوفر محيط