NUST
SCHOOL OF ELECTRICAL ENGINEERING
& COMPUTER SCIENCE

- Course Name: Instrumentation and Measurements
- Course Code: EE383_Session: Fall 2022
- Class: BEE2K19 (C)
- **Lectures: Week 1**
- Course Instructor: Dr. Shahzad Younis

INSTRUMENTATION & MEASUREMENT

Ruler

Roll Meter

Calipers

Micrometer

Voltmeter

Barometer

Ammeter

KWH Meter

Sound Level

Thermo Meter

PH Meter

Beaker Glass

Stopwatch

Theodolite

Dial Indicator

Anemometer

Elbow Ruler

INSTRUMENTATION
& MEASUREMENT

Course Details

- Course Outline
- Material/Resources
- Assessment

Week 1

- Introduction to Instrumentation and Measurements
  - Understanding Basic Concepts

Course Description

- The course introduces Instrumentation and Measurement, providing undergraduate students with both a basic and practical understanding of the subject.
- The main objective of this course is to *study the fundamental principles of metrology along with the design techniques of electrical precision measurement equipment.*
- **Metrology** is the scientific study of measurement. It establishes a common understanding of units, crucial in linking human activities. The course explores how instrumentation is achieved?
- This course covers different sensors (transducers) and how simple physics concepts can be applied in their design. Also, students will be introduced to bio-sensors and real-life/ industrial devices.

Course Objective?

- The goal is to facilitate students a degree of comfort and familiarity with electronics instruments, so there is a great emphasis on practical aspect of the course.
- Students are required to design different electrical instruments in the lab experiments.
- They are also given a semester project where they apply their knowledge of the course to develop a product (an instrument) by themselves; this exercise would give them a great confidence.
- i 

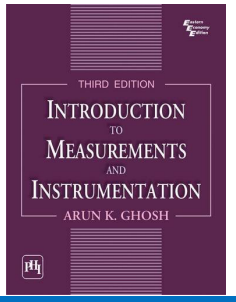
s engineering software for applications that require test, measurement, and control with rapid access to hardware and data insights.

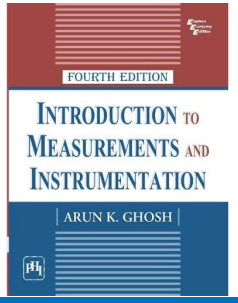
Main Topics to be Covered:

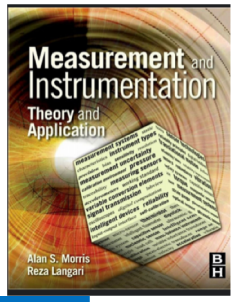
The course spans over a number of different topics as under:

Metrology	**Frequency Measuring Instruments**
Parameters of measurement and related definitions	Oscilloscopes
Types and Probability of error	**Transducers**
Uncertainty of measurement	Classification
Sensitivity factor, Degree of freedom	Bio-medical transducers
System of units	Temperature Measurements
Calibration of the equipment.	Photosensitive Devices
Standards and its classification	**Instrumentation & Data Acquisitioning**
Electromechanical Instruments	Instrumentation Systems
Suspension Galvanometer	Interfacing Transducers to Electronic Control and Measuring Systems
Torque and deflection of Galvanometer	Multiplexing
Multirange DC Ammeter and Voltmeter	**Computer Controlled Test Systems**
Bridge Measurements	Instruments used in Computer Controlled Instrumentation
Types of Bridges and Applications	

Course Material/Resources







Books:	
Text Book:	Introduction to Measurements and Instrumentation, by Arun K. Ghosh
Reference Books:	• Measurement and Instrumentation, Theory and Application, Alan S Morris, Reza Lengari • Modern Electronic Instrumentation and Measurement Techniques, Albert D. Helfrick, William D. Cooper • Electronic Instruments and Instrumentation Technology, M.M.S. Anand • "Instrumentation for engineering measurements" by James W. Dally, William E. Riley, Kenneth G. McConnell

Tools / Software Requirement:
National instruments LabView is required for lab exercises. The labs will also require use of sensing instruments.

Course Moodle (Website)
Learning Management System (LMS): http://lms.nust.edu.pk

Lecture slides and other contents will be shared on LMS

Assessment

- Score Distribution
- Theory : 75 %, Lab. 25%
- Tentative Distribution of theory component
  - Assignments 5%
  - Quizzes 10%
  - Mid Term 35%
  - Final Exam (ESE) 50%

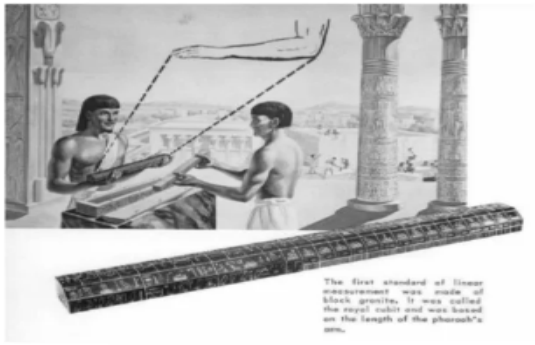
Assessment

Grading Policy:	
Quiz Policy:	The quizzes will be a combination of announced and unannounced and normally last for ten minutes. The question framed is to test the concepts involved in last few lectures. Number of quizzes that will be used for evaluation is minimum 5. Grading for quizzes will be on a fixed scale of 0 to 10. A score of 10 indicates an exceptional attempt towards the answer and a score of 1 indicates your answer is entirely wrong but you made a reasonable effort towards the solution. Scores in between indicate very good (8-9), good (6-7), satisfactory (4-5), and poor (2-3) attempt. Failure to make a reasonable effort to answer a question scores a 0. There will be no retest of a quiz for whatsoever reason and no 'best-of' policy.
Assignment Policy:	In order to develop comprehensive understanding of the subject, assignments will be given. Late assignments will not be accepted / graded. All assignments will count towards the total (No 'best-of' policy). The students are advised to do the assignment themselves. Copying of assignments is highly discouraged and violations will be dealt with severely by referring any occurrences to the disciplinary committee. The questions in the assignment are meant to be challenging to give students confidence and extensive knowledge about the subject matter and enable them to prepare for the exams.

Measurement

History

- **The earliest known uniform systems of weights and measures seem all to have been created at some time in the 4th and 3rd millennia BC**
- **Egypt, Mesopotamia and the Indus Valley, and perhaps also Elam (in Iran) as well**
- **The current international standard for the metric system is the International System of Units (Système international d'unités or SI). E.g. metre, kilogram, second, ampere, kelvin, mole, and candela**
- **In last part of 20th century "era of computers" new methods and instruments were developed**



Cubit was used by Egyptians for building pyramids (2750 B.C.)

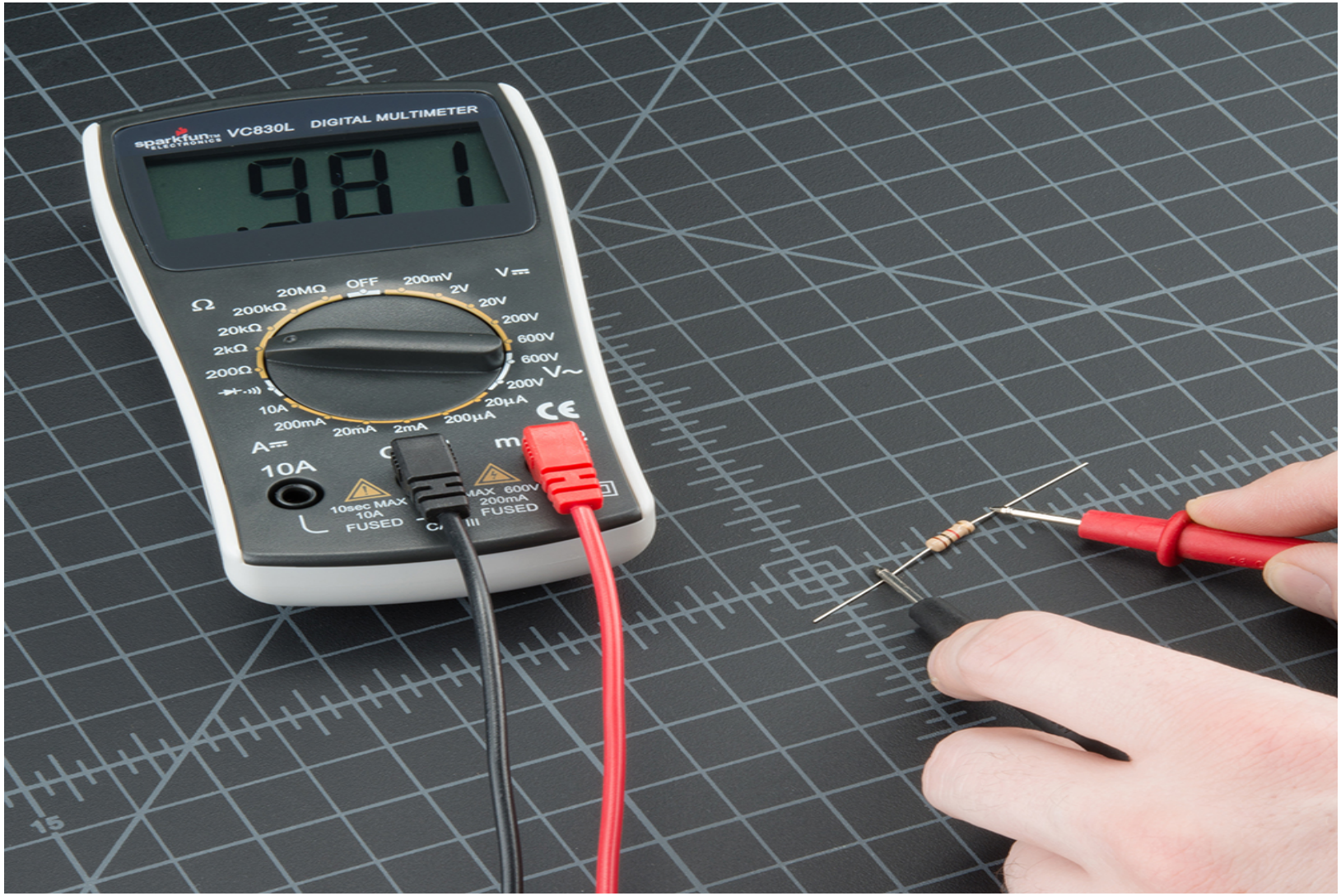
Concept Checks

- **What is measurement?**

Measurement

- **What is measurement?**
  - **Determining the value or magnitude of a quantity or a variable**
    - **Measurand: the quantity or the variable**

Measurement-Example



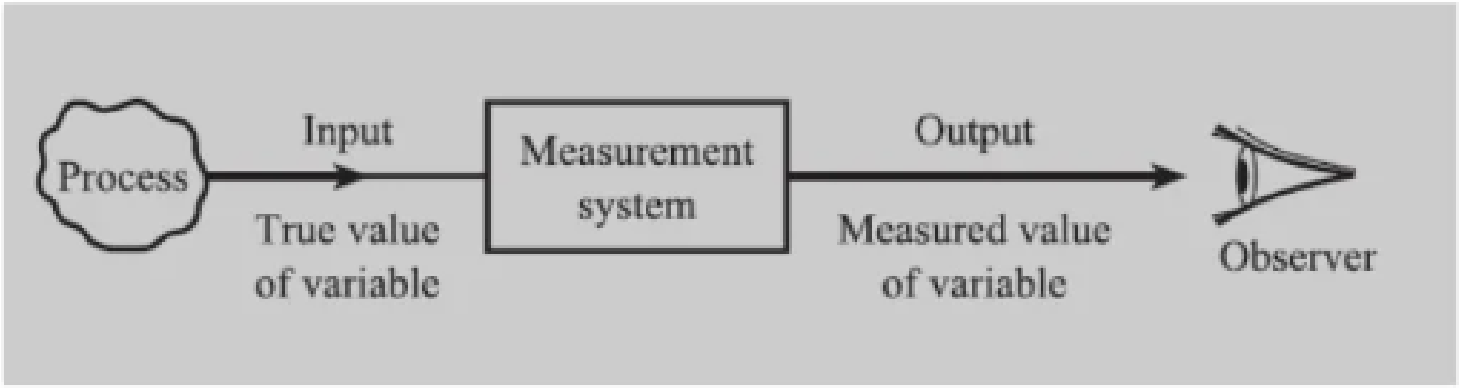
Why measurement?

- In the case of process industries and industrial manufacturing…
  - To improve the quality of the product
  - To improve the efficiency of production
  - To maintain the proper operation.

Measurement

❑ Purpose/objective

Purpose of a measurement system



measurand | Sensor, signal conditioning, display | Man, tracking control etc

Measurement

- **Purpose/objective**
  1. **Monitoring**
  2. **Control**
  3. **Analysis**

Monitoring

- Thermometers
- Barometers
- Electricity Meters
- Gas Meters
- Water Meters

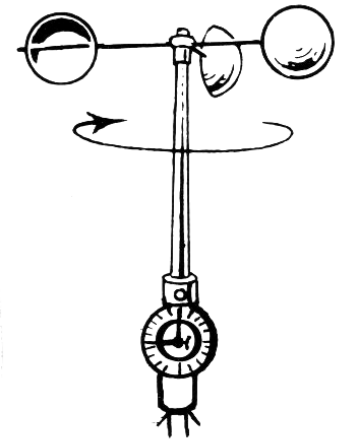
Measurement

1. **Monitoring**
   - **To monitor processes and operations**
     - **Thermometer, barometer, anemometer, water, gas, and electricity meters etc.**
   - **No (direct) control**

Measurement

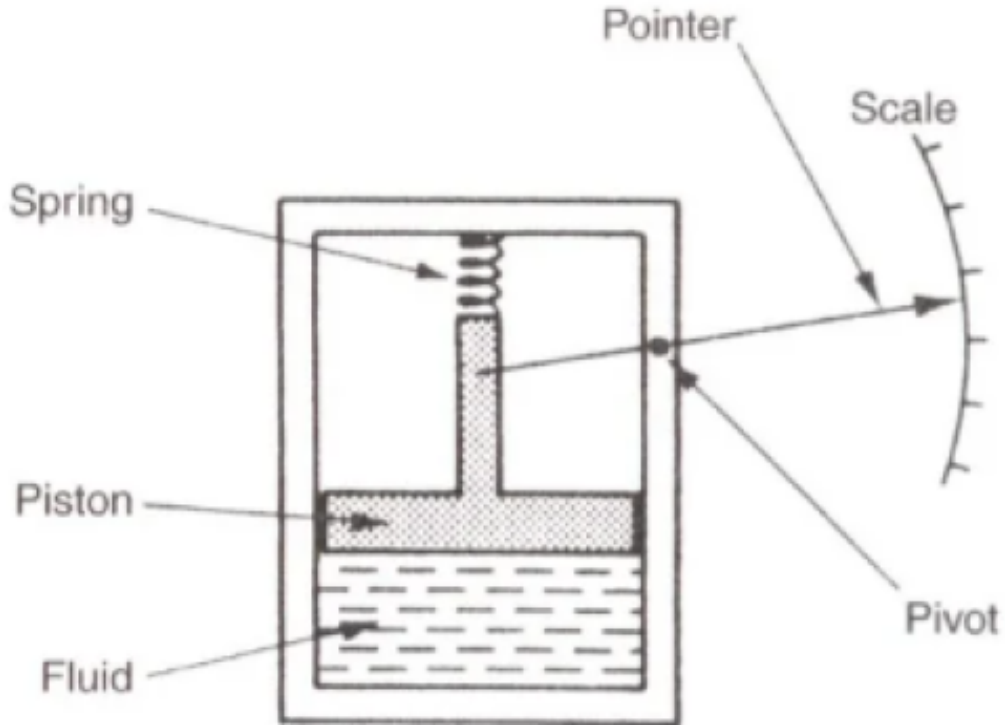
1. **Monitoring**
   - **To monitor processes and operations**
     - **Thermometer, barometer, anemometer, water, gas, and electricity meters etc.**
   - **No (direct) control**

Thermometer: temperature



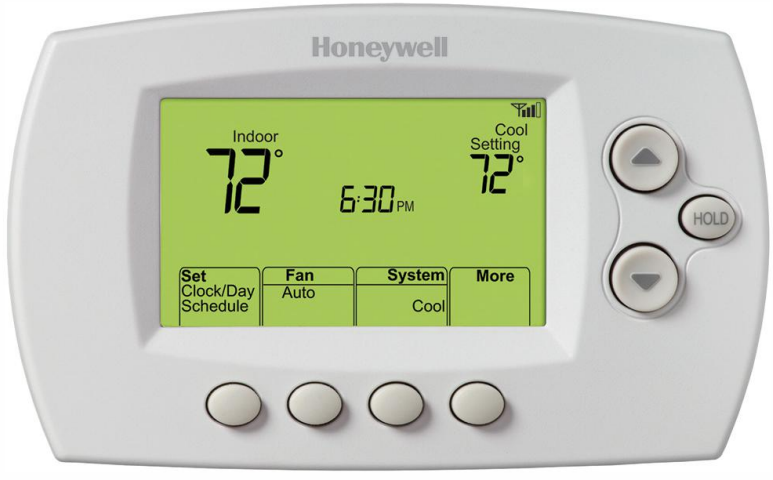
Anemometer: wind speed etc.

Pressure-measuring device



Control

- **Thermostat** in geyser or refrigerator
- Monitor the temperature of the relevant environment and accordingly switch on and off the heating or cooling mechanism



Measurements

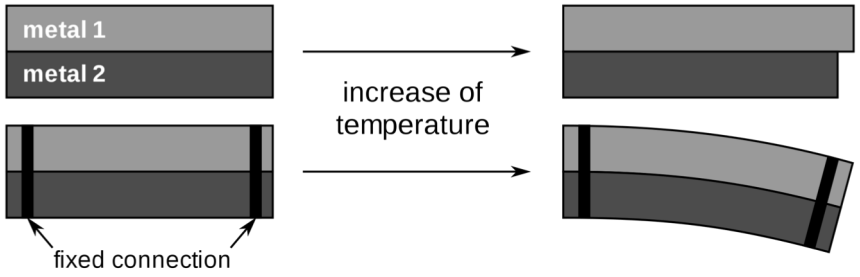
2. **Control**
   - **To control processes and operations**
     - **Temperature control using thermostat (refrigerator, geyser, iron etc.)**

Measurements

2. Control

- **To control processes and operations**
  - **Temperature control using thermostat (refrigerator, geyser, iron etc.)**

-Bimetal Thermostats use two different kinds of metal to regulate the temperature setting. When one of the metals expands more quickly than the other, it creates a round arc, like a rainbow. As the temperature changes, the metals continue to react differently, operating the thermostat.

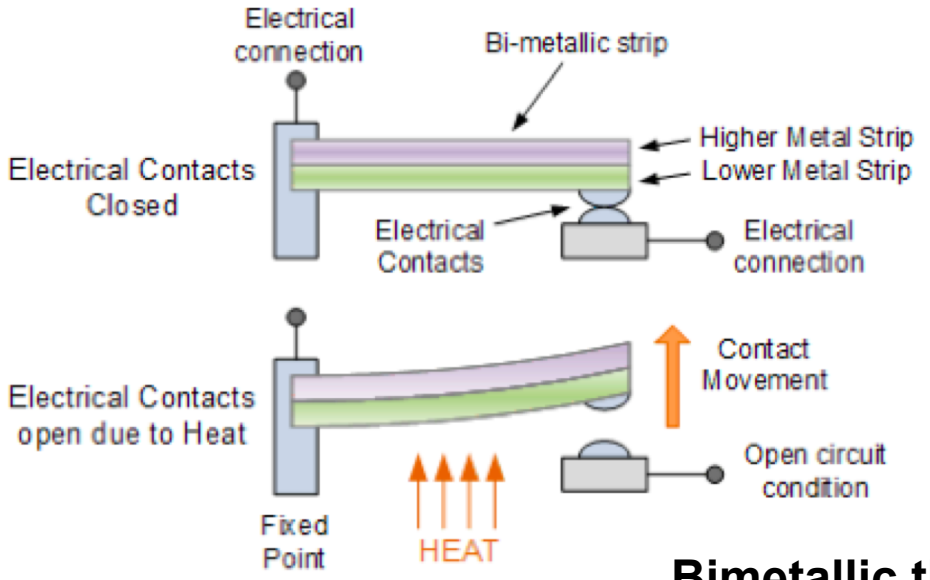


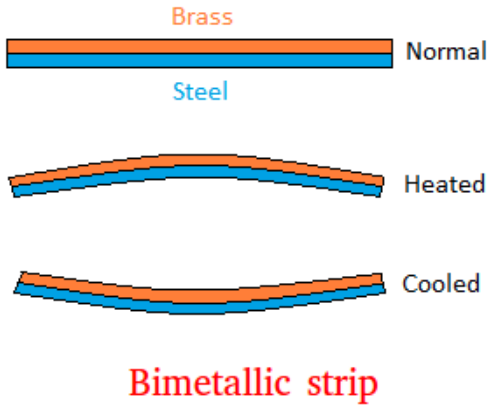
Bimetallic thermostat

Measurements

2. Control

- To control processes and operations
  - Temperature control using thermostat (refrigerator, geyser, iron etc.)





Bimetallic thermostat

Measurements

3. **Analysis**
    I. **Validate some predictions from theory**
    II. **Build empirical models/relationships between parameters and quantities**
    III. **Characterize materials, devices and components**

Measurements

3. **Analysis**

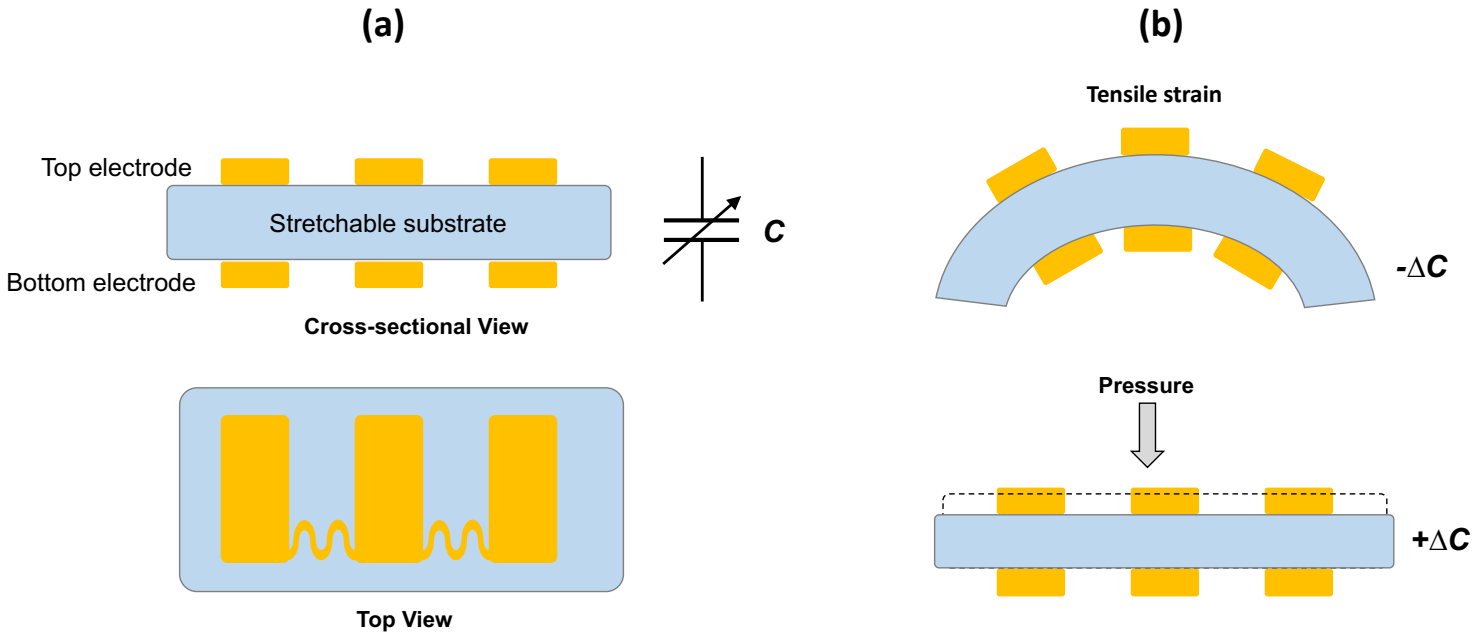
   I. Validate some predictions from theory

Any example

Measurements

3. Analysis

I. Validate some predictions from theory



Measurements

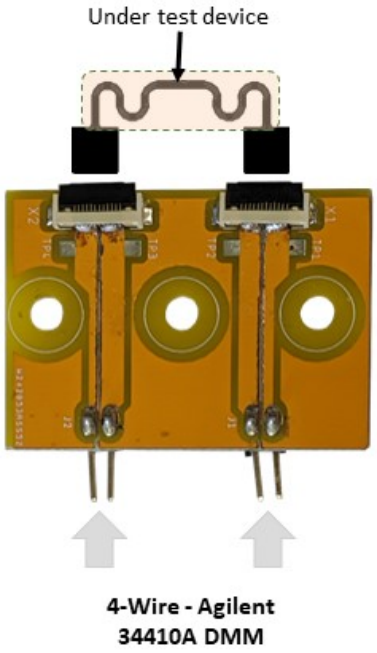
3. **Analysis**

   II. Build empirical models/relationships between parameters and quantities

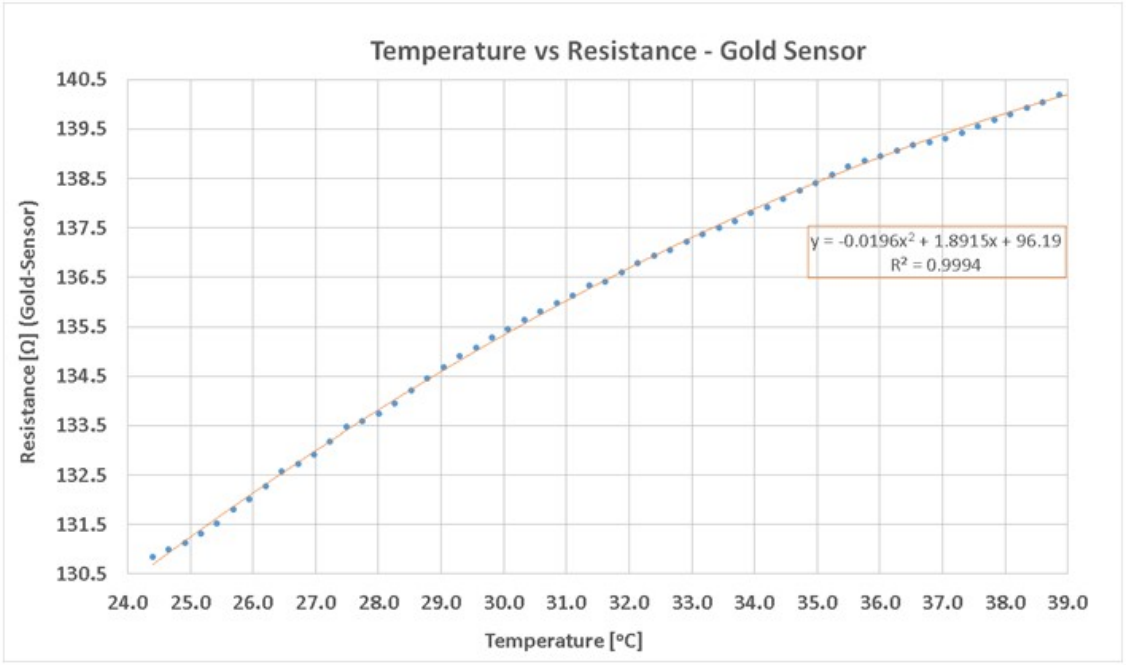
Measurements

3. Analysis

II. Build empirical models/relationships between parameters and quantities



4-Wire - Agilent 34410A DMM



R^2 is a measure of the goodness of fit of a model

Measurements

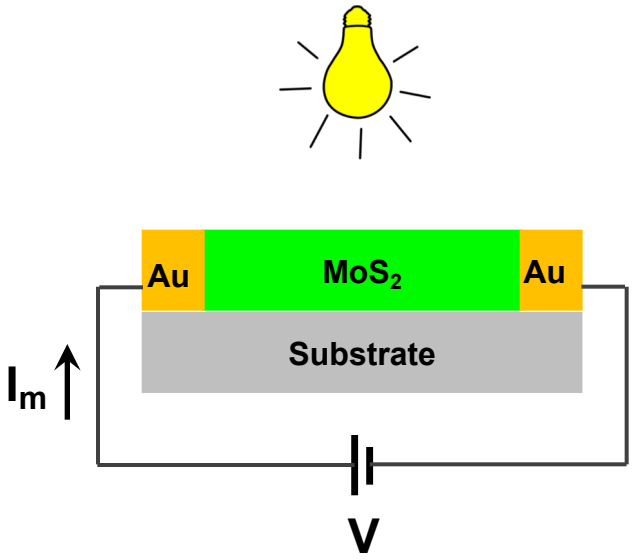
3. **Analysis**

   III. Characterize materials, devices and components

Measurements

3. Analysis

III. Characterize materials, devices and components



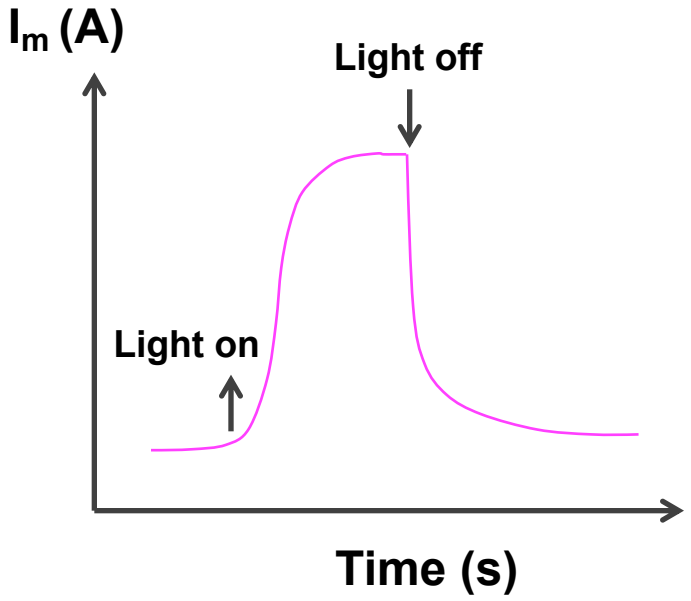
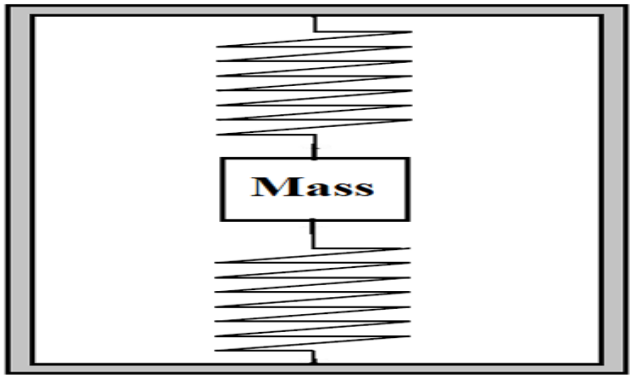
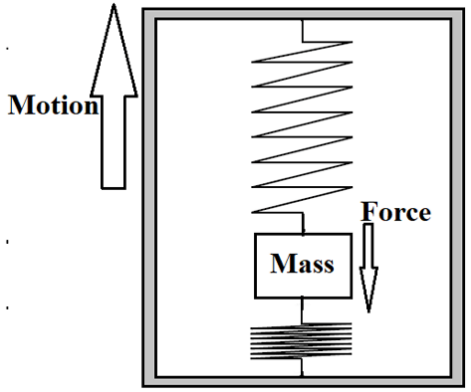


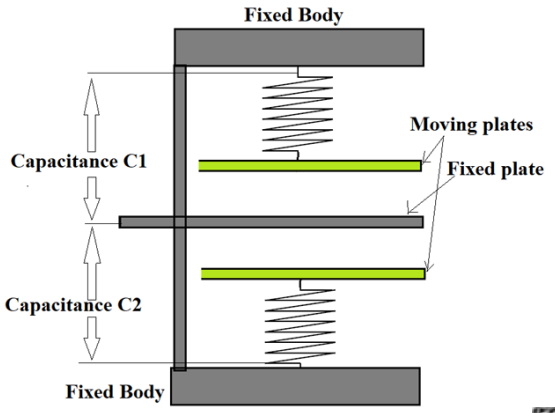
Photo responsive material: Molybdenum disulfide

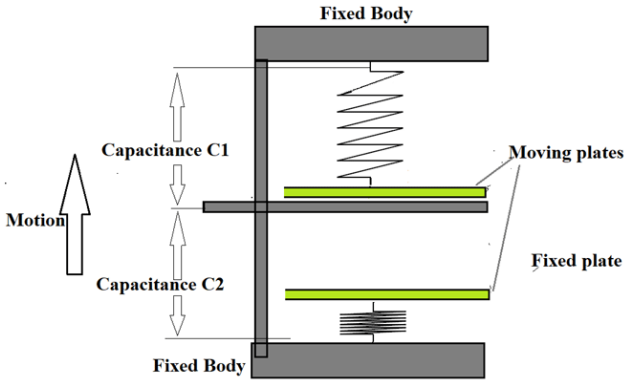
MEMS Technology

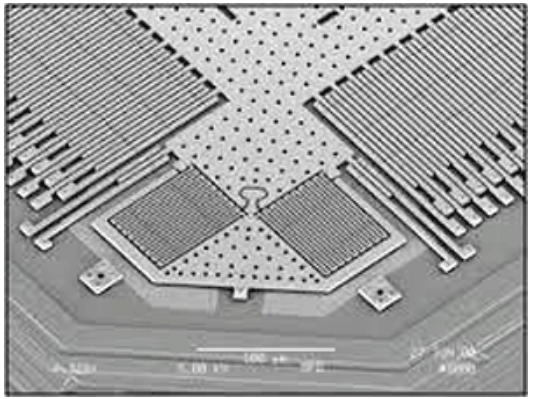
MEMS Stand for: Micro Electro-Mechanical Systems







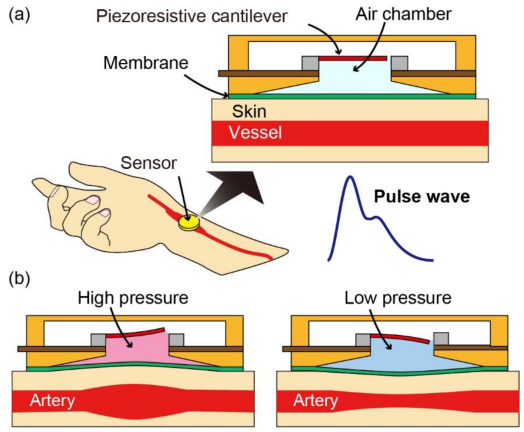




Measurements

3. Analysis

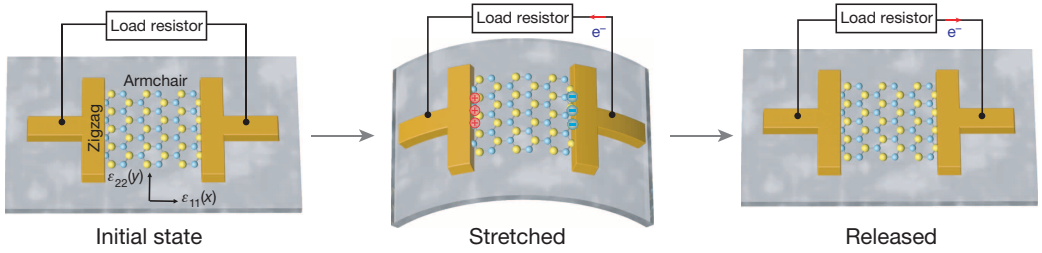
III. Characterize materials, devices and components



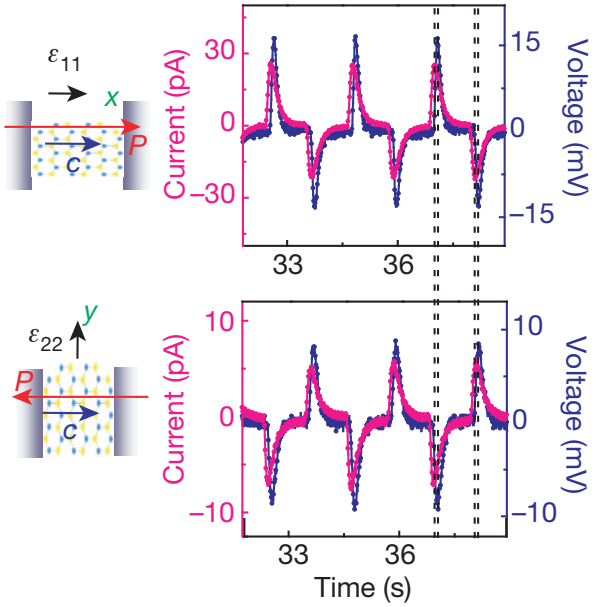
Bio-NEMS/MEMS Sensor

NEMS – NanoElectroMechanical Systems

MEMS-Micro Electro-Mechanical Systems

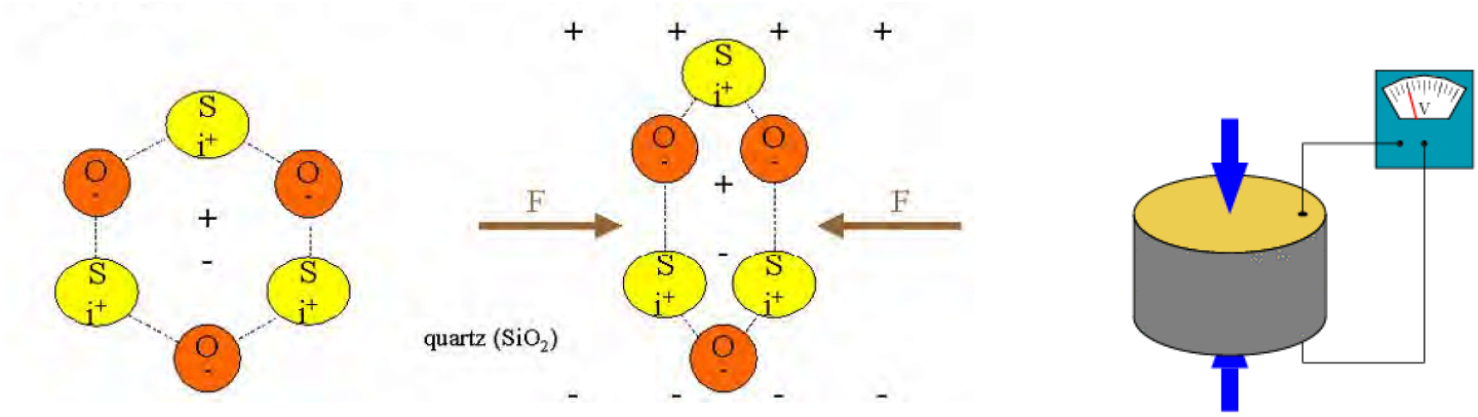


Piezoelectric: Monolayer molybdenum disulfide



Z. L. Wang et al., NATURE, VOL 514, 2014.

Measurements



No center of symmetry!

Piezoelectric Materials

Piezoelectric *materials convert mechanical energy to electrical energy and vice versa, while* ***piezoresistive*** *devices convert mechanical energy to resistance values and that's it. They do not work in reverse like their piezoelectric counterparts*

https://www.youtube.com/watch?v=_XABS0dR15o

Concepts
Piezoresistive Vs Piezoelectric

- The **piezoresistive** effect is a change in the electrical resistivity of a semiconductor or metal when mechanical strain is applied.
- In contrast to the piezoelectric effect, the **piezoresistive** effect causes a change only in electrical resistance, not in electric potential.

- **Piezoelectric** components convert mechanical energy to electrical energy and vice versa, while **piezoresistive** devices convert mechanical energy to resistance values and that's it. They do not work in reverse like their **piezoelectric** counterparts.

Instruments

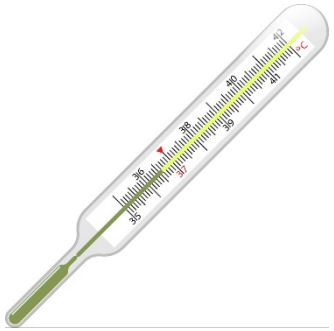
Instruments

- **Makes measurements**

An instrument can be defined as a device or a system which is designed in such a way that it maintains a functional relationship between a prescribed property of a substance and a physical variable, and communicates this relationship to a human observer by some ways and means.

Mercury in glass thermometer maintains a linear relationship between

- **Prescribed property of mercury**
- **Physical variable i.e., temperature**

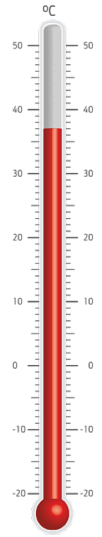


Instruments

- **Functional relationship between a prescribed property of a substance and a physical variable**
  - **For example, mercury-in-glass thermometer: a linear relationship between**

    thermal expansion of mercury (prescribed property) and

    Temperature (physical variable)



Temperature

Instruments

- **Measurement system**
  - **Simplest form: single element**
    - **Liquid in glass thermometer**

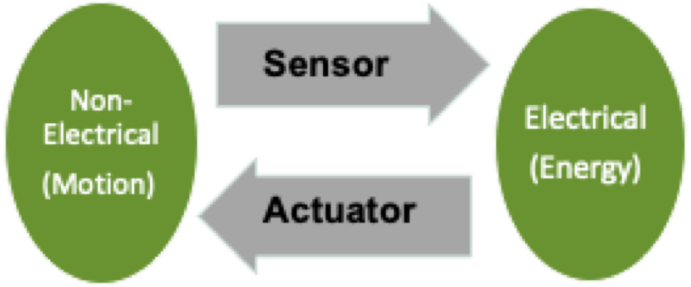
Temperature

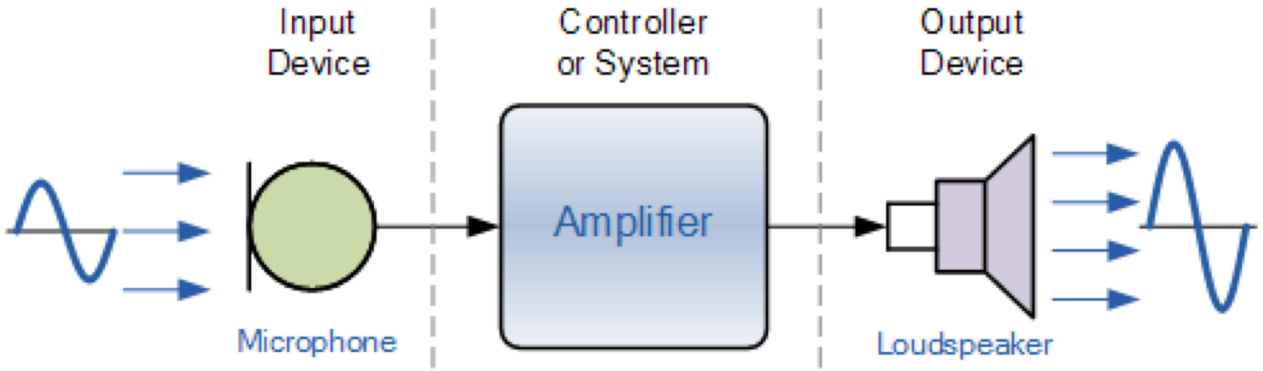
Instrument

- **Transducer**

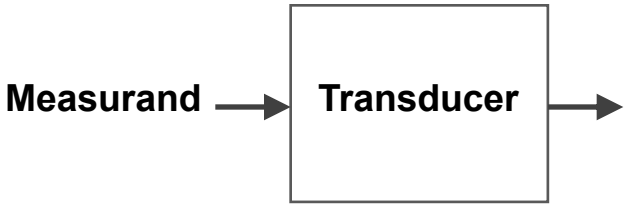
Instrument

- **Transducer**





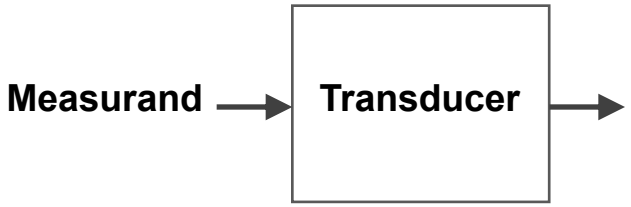
Instrument



- **Transducer**
  - **Conversion of the physical variable to be measured into a suitable signal (preferably electrical one)**

Instrument

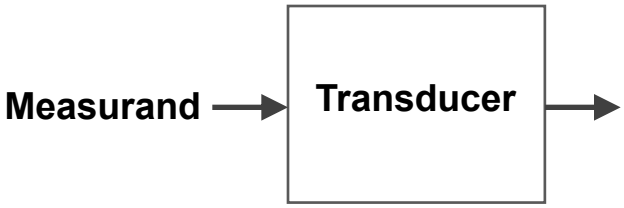
- **Measurement system**



- **Transducer**
  - **Output as a function of the measurand**
  - **Output is in a suitable form; electrical**
  - **Piezoelectric strain sensor, thermocouple etc.**

Instrument

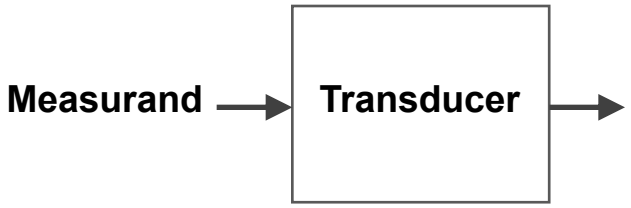
- **Measurement system**



- **Is transduction perfect?**
  - **It also extracts energy from the measurand, so disturbs measurement**

Instrument

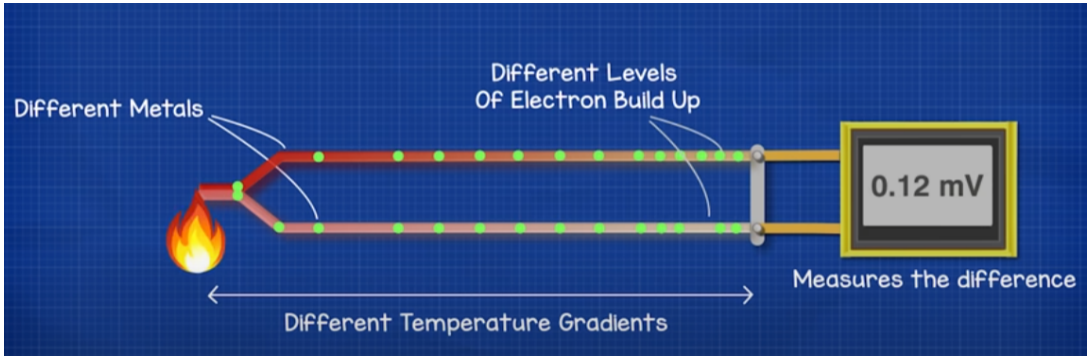
- **Measurement system**

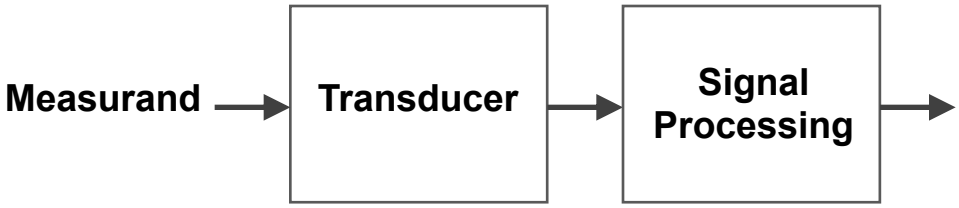


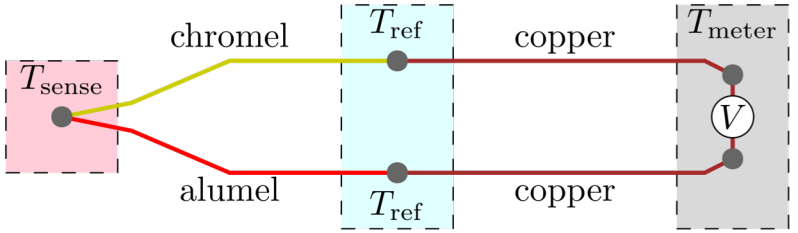
- **CH 5, Ch 6-11**

Instrument

- **Measurement system**







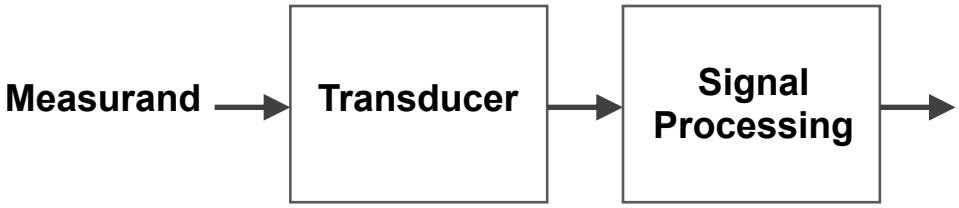
Thermocouple: temperature sensor

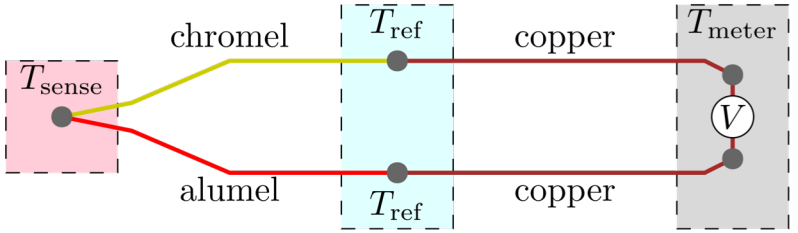
- **Signal processing**
  - **Improve the quality of the output**
  - **Amplify, attenuate, integrate, differentiate, digital conversion, filter etc.**
  - **Amplify the typically low output (mVs) of thermocouples**

https://www.youtube.com/watch?v=v7NUi88Lxi8

Instrument

- **Measurement system**



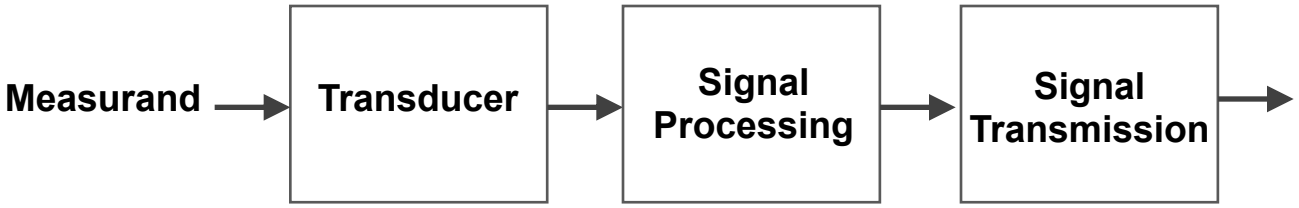


Thermocouple: temperature sensor

- **Signal processing**
  - **More about it in Ch 16**

Instrument

- **Measurement system**



- **Signal transmission**
  - **Transducer is at a distance from observation/application point**
    - **for convenience**
    - **physical inaccessibility or environmental unsuitability for display/recording unit**

Signal Conditioner & Transmitter

The signal generated by the transducer may need to be amplified, attenuated, integrated, differentiated, modulated, converted to a digital signal, and so on. The signal conditioner performs one or more such tasks. Since electrical signals have distinct advantages in this

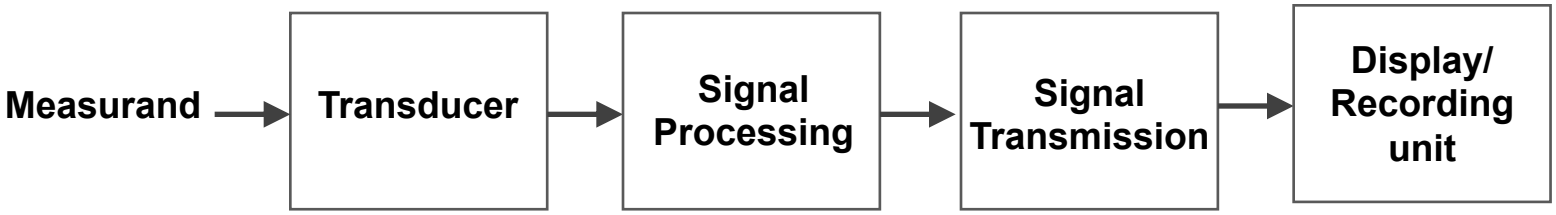
Signal transmitters are necessary for remote measurements. Remote measurements and control, called telemetry, is a highly-developed subject.

List few applications where telemetry is needed?

- Oil and gas pipeline monitoring.
- Monitoring health of underground cable network.

Instrument

- **Measurement system**



- **Display/recording unit**
  - **Communicate to human observer**
  - **Record**
    - **analysis**

Display/ Recording Device

The purpose of this element of an instrument is obvious—to communicate the information about the measurand to the human observer or to present it in an intelligible form. This

Instrument cluster of car has a mix of display and recoding devices.

Instrument

- **Measurement system**
  - **Control unit**
    - **In some cases, instead of presentation/recording, the output is fed to a control system**
    - **Room temperature control: $T_a = T_d$**

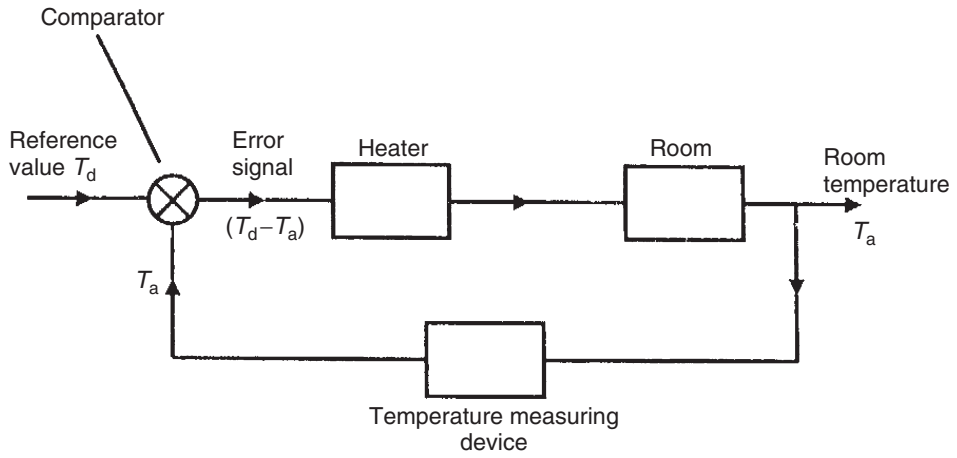


Figure 1.2
Elements of a simple closed-loop control system.

Ref: Measurement and Instrumentation, Theory and Application, Alan S Morris, Reza Lengari

Instruments

A generalised instrument can be schematically represented as shown in Fig. 1.1. It consists of

1 A transducer
2 A signal conditioner and transmitter, and
3 A display/recording device.

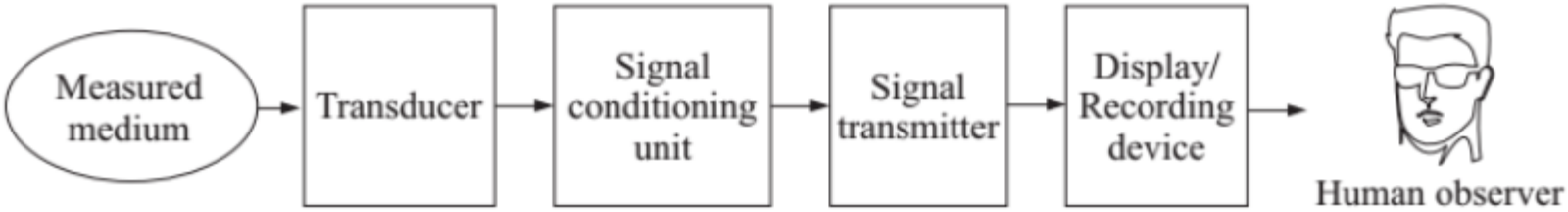


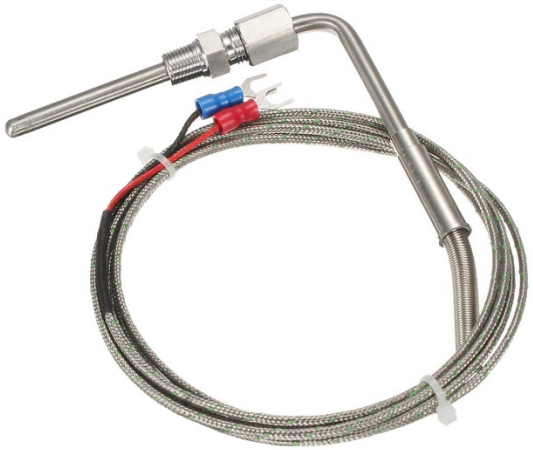
Fig. 1.1 A generalised instrument.

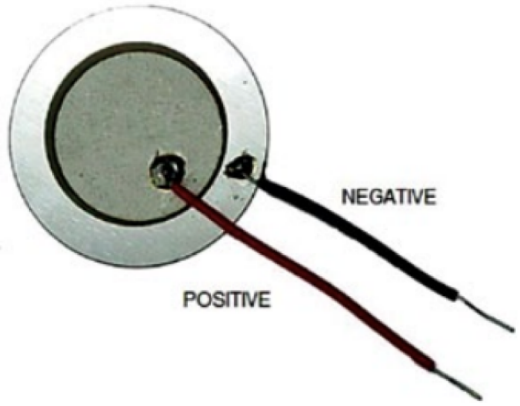
Summary of Transducers

- A transducer senses the physical signal to be measured and converts it into a suitable signal preferably an electrical signal.

- Transducer extracts some energy from the measured medium, hence disturbing that medium. Perfect measurement is theoretically impossible.

- Example → thermocouple: it senses a change in temperature and resultantly produces a voltage across its terminals.





Application

- Home
  - Thermometer
  - Barometer
  - Watch
- Road vehicles
  - speedometer
  - fuel gauge
- Industry
  - Automation
  - Process control
  - Boiler control

Questions

Thanks!