# Advanced Measurement Systems & Sensors (0640732)

Lecture (1)

# Advanced Measurement Systems & Sensors: An Introduction

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Philadelphia University-Jordan

# Course Title: Advanced Measurement Systems & Sensors

- **Instructor:** Prof. Kasim M. Al-Aubidy.
- **Email:** *qmlone@yahoo.com*
- **Semester:** First, 2015-2016
- **Time:** (15:00-18:00) Monday.
- **Office Hours:** (12:00-15:00) Monday & Wednesday.
- Appointments to discuss the course should be made by email.
- **Course Material:**
  http://www.philadelphia.edu.jo/academics/kaubaidy/page.php?id=7

# Course Description:

The invention of a microprocessor has brought highly sophisticated instruments into our everyday life. Sensors are essential components in any mechatronics system that uses a digital signal processor. This course concentrate on methods of sensing, physical principles of sensors operations, practical designs, and interface electronic circuits. It covers design and selection of best suited sensors for a specified problem, regarding range, accuracy, dynamic behavior, environment requirements etc. It also covers necessary calculations regarding the sensor characteristics, performance and the required signal processing.

- **Primarily through:**
  - **Lectures:** 45 hours/semester, 3 hours/week.
  - **Homework and assignments:**
  - **Semester project:** 2 projects for each student

  » We will also discuss student projects.

# Intended Learning Outcomes:

**A. Knowledge and understanding**

A1- Describe the concepts of different measurement systems used in industry.

A2 - Describe the function, suitability of different sensors and transducers.

A3- Know and understand in depth the concepts of Input/ Output Signal conditioning

**B. Intellectual skills**

B1- Analyze, Design and/or select the suitable sensors for a given system.

B2- Analyze & design the signal conditioning circuits.

B3– Conduct research in the measurement & sensors field to generate novel techniques.

**C. Professional and practical skills:**

C1- Carry out calibration and error estimation of measuring devices

C2- Design and assessment of the sensors used in industrial systems.

C3– Improve system performance

**D. General and transferrable skills**

D1- Critical thinking. D2- Team work. D3- Self learning.

## Prerequisites:

- Students are expected to be familiar with electronic circuits, control systems, systems modeling and simulation techniques, systems design and implementation.

- Some basic familiarity with microprocessors, microcontrollers, interfacing and artificial intelligence.

## Grades:

- Assignments, Project & Presentation: 30%,
- Mid Exam: 30%
- Final Exam: 40%

## Projects:

- Define your own project and write a proposal.
- Experimental investigation requires a programming project and a final report.
- Final report contents: Project title, Objective, Introduction, Hardware design, Software design, Conclusion, References.
- Team projects are allowed, but they must be significant!

# Timetable:

| Week | Basic and support material to be covered | HW/Project |
|---|---|---|
| 1 | **Introduction:** Mechatronics systems and Measurement systems. Sensors, Signals, and Systems; | |
| 2 | **Sensor Characteristics:** Sensor Classification; Units of Measurements. Transfer Function, Sensitivity, Calibration. | |
| 3 | **Sensor Characteristics:** Nonlinearity, Repeatability, Resolution; Dynamic Characteristics; Accuracy; Reliability; Application Characteristics; Uncertainty | Project Selection |
| 4 | **Physical Principles of Sensing:** Electric Charges, Fields, Capacitance, Magnetism, Induction, Resistance, Piezoelectric Effect, Hall Effect, Thermoelectric Effects, Temperature and Thermal Properties of Materials, Heat Transfer, Light, Dynamic Models of Sensor Elements. | HW1 |
| 5 | **Interface Electronic Circuits:** Input C/Cs of Interface Circuits, Amplifiers, Light-to-Voltage Converters, Excitation Circuits, ADC. | Assignment1 |
| 6 | **Interface Electronic Circuits:**, ADC, Bridge Circuits, Noise in Sensors and Circuits. | |
| 7 | **Motion Detectors:** Ultrasonic Detectors, Microwave Motion Detectors, Capacitive Occupancy Detectors, Optoelectronic Motion Detectors. | Project (Phase1) |

# Timetable:

| Week | Basic and support material to be covered | HW/Project |
|---|---|---|
| 8 | **Position, Displacement, and Level:** Potentiometric Sensors, Capacitive Sensors, Inductive and Magnetic Sensors, Optical Sensors, Ultrasonic Sensors, Radar Sensors, Thickness and Level Sensors, Pointing Devices. | Mid Exam |
| 9 | **Velocity and Acceleration:** Accelerometer Characteristics, Capacitive Accelerometers, Piezoresistive, Piezoelectric Accelerometers, Thermal Accelerometers, Gyroscopes, Gravitational Sensors. | HW2 |
| 10 | **Force, Strain, and Tactile Sensors:** Strain Gauges, Tactile Sensors, Piezoelectric Force Sensors.<br>**Pressure Sensors:** Mercury Pressure Sensor, Piezoresistive Sensors, Capacitive Sensors, VRP Sensors, Optoelectronic Pressure Sensors, Indirect Pressure Sensor, Vacuum Sensors, | Assignment2 |
| 11 | **Flow Sensors:** Pressure Gradient Technique, Thermal Transport Sensors, Ultrasonic Sensors, Electromagnetic Sensors, Breeze Sensor, Coriolis Mass Flow Sensors, Drag Force Sensors, Dust and Smoke Detectors, | |
| 12 | **Acoustic Sensors**: Resistive Microphones, Condenser Microphones, Fiber-Optic Microphone, Piezoelectric Microphones, Electret Microphones, Dynamic Microphones, Solid-State Acoustic Detectors, | Assignment3 |

# Timetable:

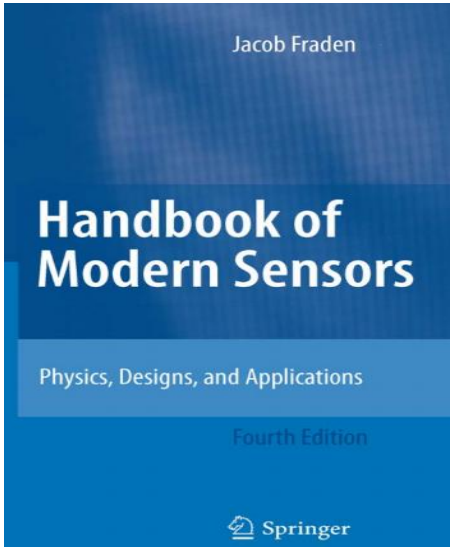
| Week | Basic and support material to be covered | HW/Project |
|---|---|---|
| 13 | **Humidity and Moisture Sensors:** Concept of Humidity, Capacitive Sensors, Electrical Conductivity Sensors, Optical Hygrometer, Oscillating Hygrometer.<br>**Light Detectors:** Introduction, Photodiodes, Phototransistor, Photoresistors, Cooled Detectors, Image Sensors, Thermal Detectors, Gas Flame Detectors. | |
| 14 | **Temperature Sensors:** Coupling with Object, Temperature Reference Points, Thermoresistive Sensors, Thermoelectric Contact Sensors, Optical Temperature Sensors, Acoustic Temperature Sensor, Piezoelectric Temperature Sensors. | Project (Phase2) |
| 15 | **Chemical Sensors:** Chemical Sensor Characteristics, Biochemical Sensors, Multisensor Array. | HW3 |
| 16 | **Intelligent Sensors and Sensor Networks:** Smart sensor systems, wireless sensor networks (Definition – Different types- new trends) | |
| 17 | Mini Projects | Final Exam |

# Text Books:

1. **Handbook of Modern Sensors: Physics, Designs, and Applications**, By: Jacob Fraden, Springer, 2010,

   ISBN 978-1-4419-6465-6.

   *http://link.springer.com/book/10.1007%2F978-1-4419-6466-3*



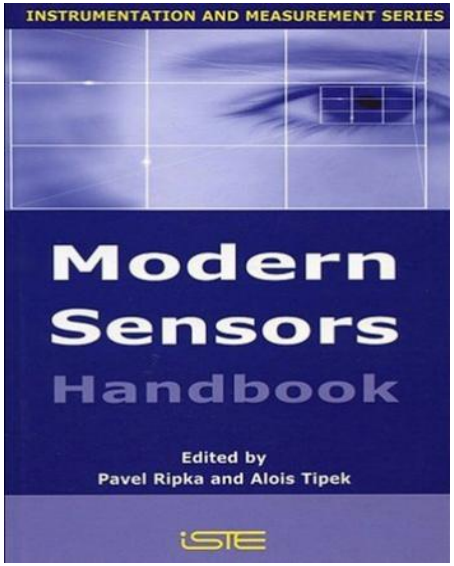

- ✓ This book comprises most of the lecture notes for the course and is required reading for all students.
- ✓ All selected material in this book is examinable.

2. **Modern Sensors Handbook**,

   Edited by: Pavel Ripka & Alois Tipek,

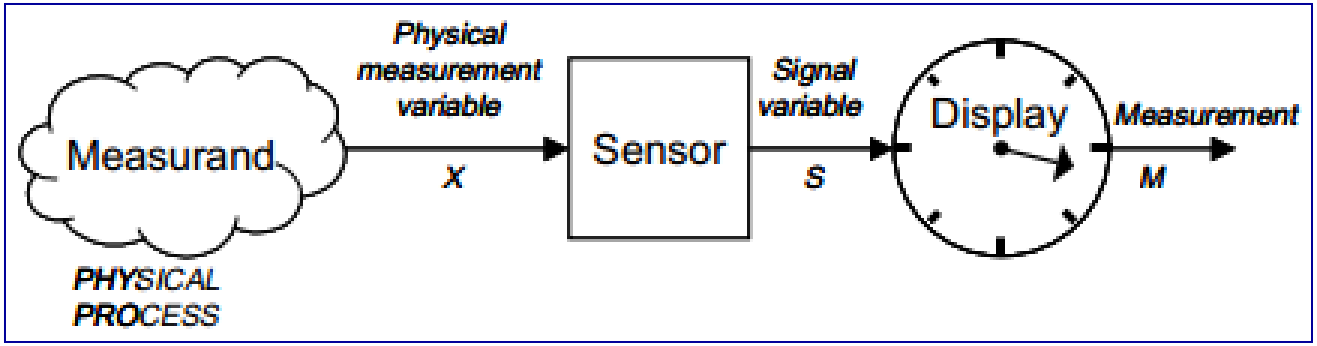
   ISTE Ltd UK, 2007, www.iste.co.uk

   ISBN 978-1-905209-66-8




- ✓ This book is optional, but provides further detail on the practical aspects of the course.

# Measurements:




- It is a process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity.
- An observable variable (X) is obtained from the measurand.
- The sensor generates a signal variable (S) that can be manipulated (Processed, transmitted or displayed).

**Measurement:**

- The process of comparing an unknown quantity with a standard of the same quantity (measuring length) or standards of two or more related quantities (measuring velocity).
- The measurement is the process by which one can convert physical parameters to meaningful numbers.

**Why we need Measurements?**

- The advancement of science and technology is dependent upon a parallel progress in measurement techniques.
- In order that the results are meaningful, there are two basic requirements:
  - ✓ The standard used for comparison purposes must be accurately defined.
  - ✓ The apparatus used and the method adopted must be proved.

- There are two major functions in all branches of engineering:
  - Design of equipment and processes.
  - Proper operation and maintenance of equipment and processes.
  - ✓ Both of these functions require measurements.

**Methods of Measurements:**

1. **Direct Method:** The unknown quantity is directly compared against a standard.
2. **Indirect Method:** Measurement by direct methods are not always possible, feasible and practicable. These methods in most of the cases are inaccurate because of human factors. They are also less sensitive.

**Instruments:**

- An instrument consists of a single unit which gives an output reading or signal according to the unknown variable applied to it.
- In more complex situations, a measuring instrument consists of several separate elements. These elements may consist of transducer elements which convert the measurand to an analogous form. The analogous signal is then processed by some intermediate means and then fed to the end devices to present the results for the purposes of display and or control.
- These elements are:
  - A detector.
  - An intermediate transfer device.
  - An indicator.

**Functions of Instruments:**

- Indicating function.
- Recording function.
- Controlling Function.

**Classification of Instruments:**

1. **Absolute instruments:** These instruments give the magnitude of the quantity under measurement in terms of physical constants of the instrument. Example: Galvanometer.
2. **Secondary Instrument:** These instruments are constructed that the quantity being measured can only be measured by observing the output indicated by the instrument.

**Modes of Operation:**

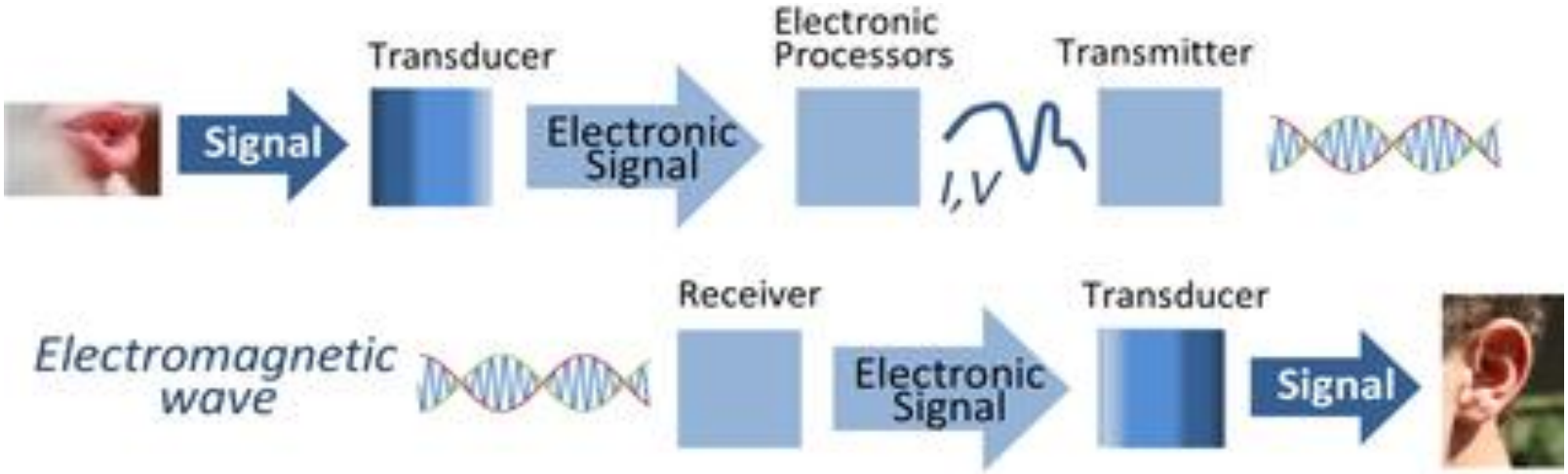
- **Analog Signal:** signals that vary in a continuous fashion and take an infinite number of values in any given range.
- **Digital signal:** signals that vary in discrete steps and thus take only finite different values in a given range.

**What is Transducer?**

- A device that receives a signal in the form of one type of energy and converts it to a signal in another form.
- A device that changes one form of energy into another.

**Example: Speaker**

- A speaker changes electrical energy from an amplifier into mechanical energy or sound waves. The electrical energy in the amp causes the speaker cone to move in and out creating air waves that our ears perceive as sound.
- A microphone is the reverse of a speaker. It is a transducer that converts acoustic energy (in the form of sound waves from a human voice) and turns it into electrical energy (electrical impulses).



**Sensors and Actuators:**

**What is a Sensor?**

- It is a transducer whose purpose is to sense or detect some characteristic of its environs.
- It is a transducer used to detect a parameter in one form and report it in another form of energy.

  **Example:** A pressure sensor detects pressure (a mechanical form of energy) and converts it to electrical signal for display.

**What is an Actuator?**

- An actuator is a transducer that accepts energy and produces the kinetic energy of action.
- The energy supplied to an actuator might be electrical or mechanical (Pneumatic, Hydraulic).

  **Example:** Electrical motor and a Hydraulic cylinder are both actuators, converting electrical energy and fluid power into motion for different purposes.

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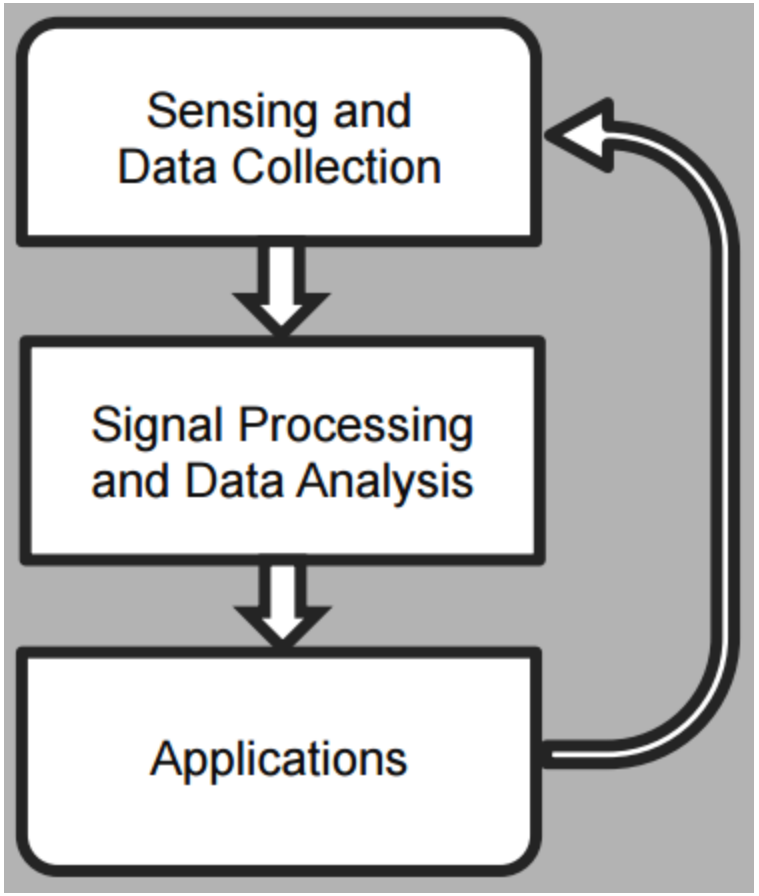
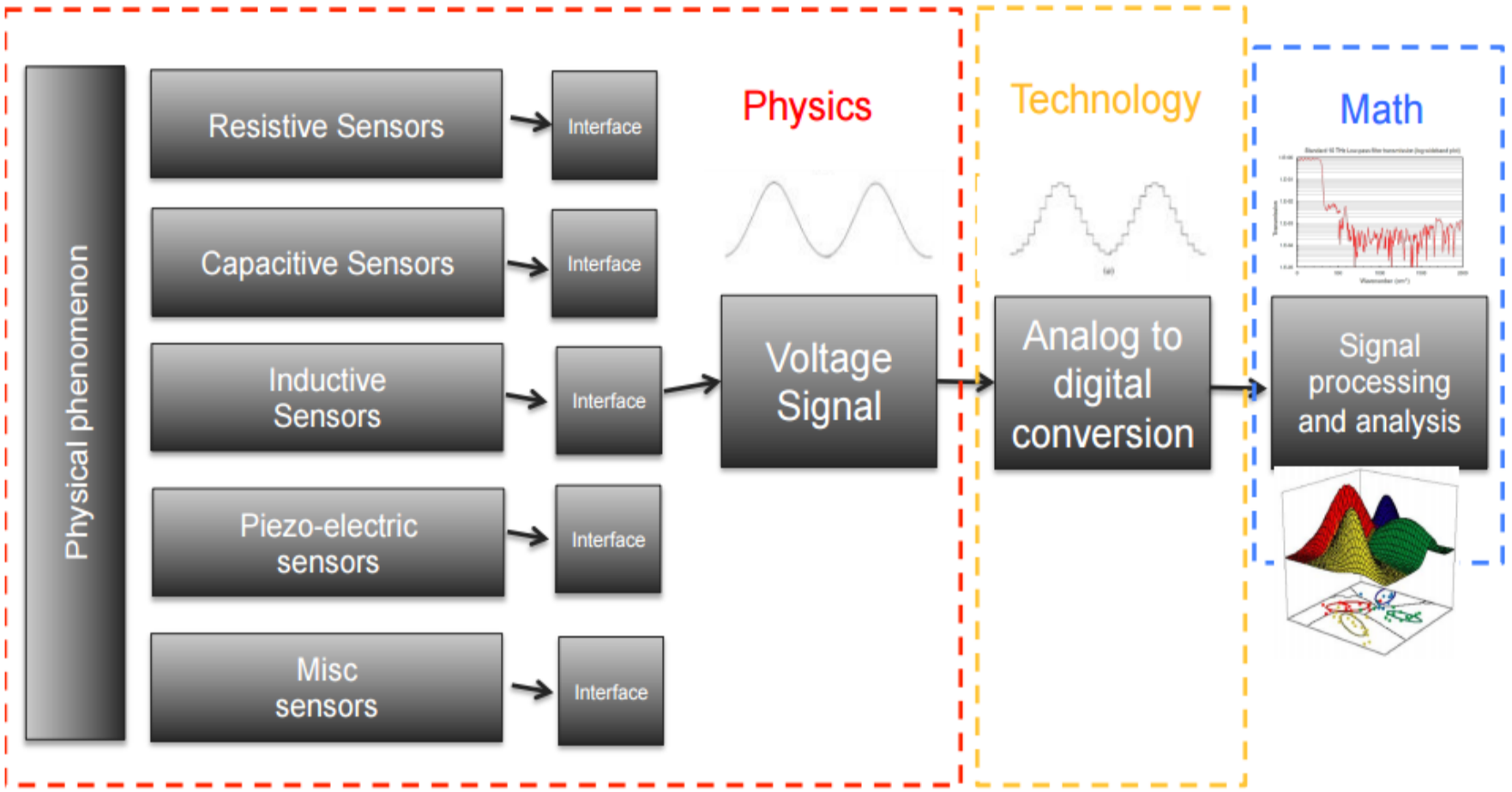
- Sensing alone are not enough, there is a need to do some thing with signals generated from the sensors.

- What we will do this semester?




Physical phenomenon
Resistive Sensors
Capacitive Sensors
Inductive Sensors
Piezo-electric sensors
Misc sensors
Interface
Interface
Interface
Interface
Interface
Physics
Voltage Signal
Technology
Analog to digital conversion
Math
Signal processing and analysis

References:


1. Jacob Fraden, “Handbook of Modern Sensors; Physics, Design, and Applications”, Fourth Edition, Springer Press 2010.
2. Robert Bishop , “The Mechatronics Handbook”, Second Edition, CRC Press 2002.
3. Pavel Ripka and Alois Tipek (editors), “Modern Sensors Handbook”, ISTE Ltd, 2007.
4. Devdas Shetty & Richard Kolk, “Mechatronics System Design”, 1997.
5. http://www-personal.umich.edu/~bkerkez/courses/cee575/lectures/1_Intro.pdf