Instrumentation and data acquisition Spring 2010

Lecture 1: Introduction and Terminology

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Outline

- Introduction
- Terminology
- An example of instrumentation system

Course homepage and contact info

- Course homepage
  - 1 studiekreds, 1 selvstudium
  - http://kom.aau.dk/~zt/cources/Instrumentation/
- Lecturer
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About the course

- **Purpose**
  - To understand - in theory and practice - how to acquire, process and output data with computers.
  - Terminology
- **Key words**
  - Instrumentation
  - Data acquisition

Instrumentation

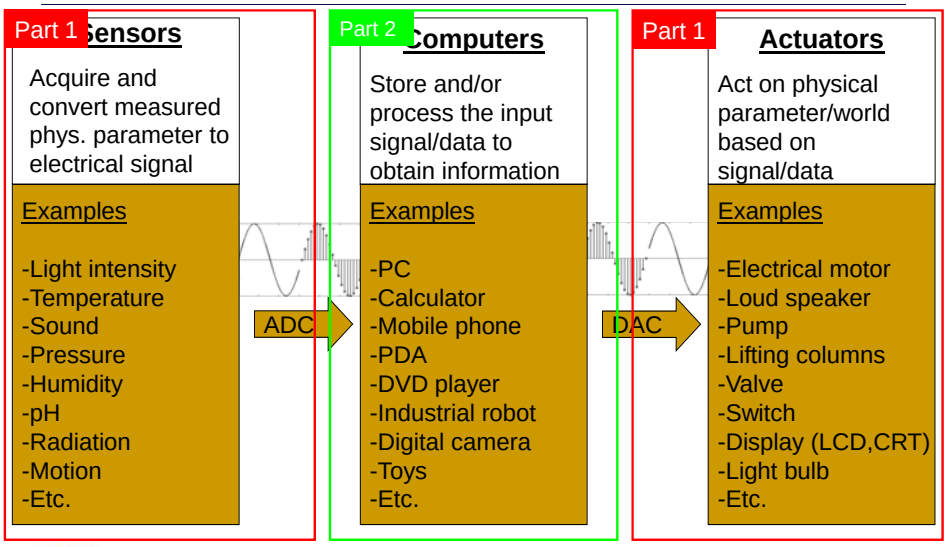
- Instrumentation is the branch of science that deals with measurement and control in order to increase efficiency, safety, etc.
- An instrument is a device placed in the field to measure/ manipulate variables such as flow, temperature or pressure.
  - Core: to measure and/or control something
- Instrumentation is the key to both gathering information from the field and changing the field parameters (physical values).

Data acquisition

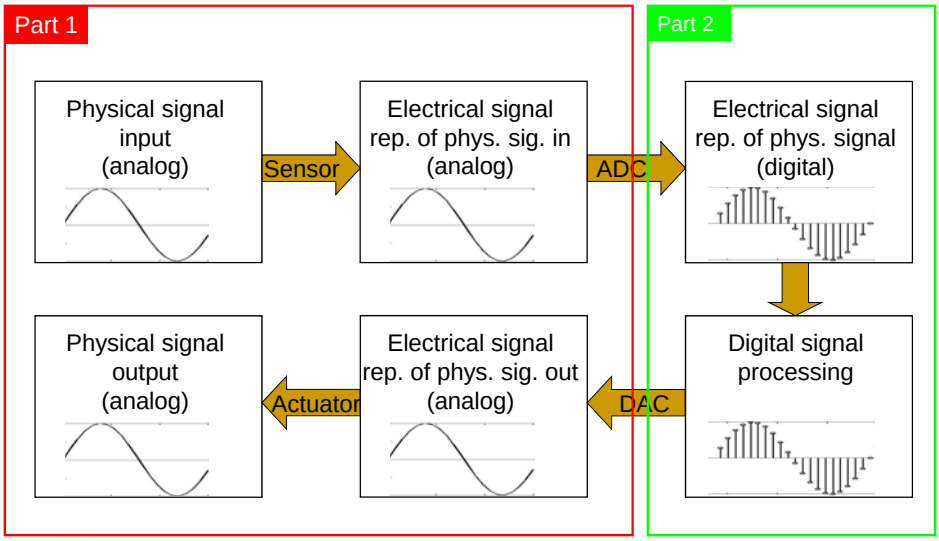
wikipedia.org

- "Data acquisition is the sampling of the real world to generate data that can be manipulated by a computer."
- "Data acquisition typically involves acquisition of signals and waveforms and processing the signals to obtain desired information "
- "The components of data acquisition systems include appropriate sensors that convert any measurement parameter (a physical property or phenomenon) to an electrical signal (such as voltage, current, change in resistance or capacitor values, etc)."

Acquire, process and output data

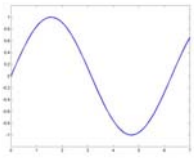


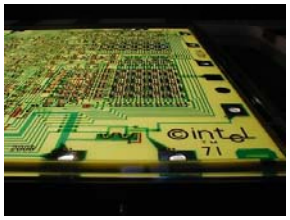
Conversion between analog and digital signals



Components

- Sensor
  - “a device that measures a physical quantity and converts it into a signal which can be read by an observer or by an instrument.” (wikipedia.org)
- Actuator
  - One who actuates, or puts into action.
- ADC/DAC
- Computer
- Signal





Sensor and transducer

- both widely used in the description of measurement systems.
- 'sensor' is `a device that detects a change in a physical stimulus and turns it into a signal which can be measured or recorded;
- 'transducer' is 'a device that transfers power from one system to another in the same or in the different form'.
- A sensible distinction is to use 'sensor' for the sensing element itself and 'transducer' for the sensing element plus any associated circuitry. All transducers would thus contain a sensor and most (though not all) sensors would also be transducers.

Sensor classification

Table 1: Stimulus

Stimulus	
Acoustic	Wave (amplitude, phase, polarization), Spectrum, Wave velocity
Electric	Charge, Current, Potential, Voltage, Electric field (amplitude, phase, polarization & spectrum), Conductivity, and Permitivity
Magnetic	Magnetic field (amplitude, phase, polarization, spectrum), Magnetic flux, Permeability
Optical	Wave (amplitude, phase, polarization, spectrum), Wave velocity, Refractive index, Emissivity, Reflectivity, Absorption
Thermal	Temperature, Flux, Specific heat, Thermal conductivity
Mechanical	Position (linear, angular), Acceleration, Force, Stress, Pressure, Strain, Mass, Density, Moment, Torque, Shape, Roughness, Orientation, Stiffness, Compliance, Crystallinity, Structural

http://www.mfg.mtu.edu/cyberman/machtool/machtool/sensors/intro.html

Further readings: Sensor Fundamentals

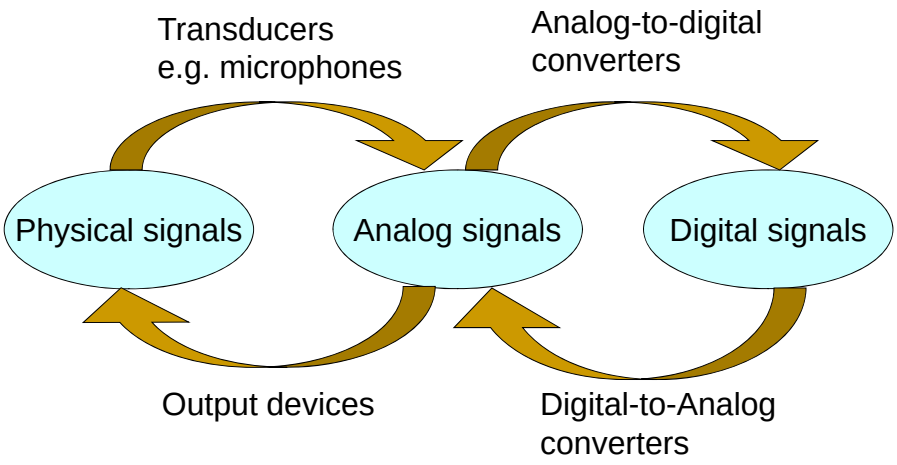
Measurement

- Things to be measured
  - Pressure, temperature, level, flow, humidity, speed, motion, position, weight, density, conductivity, pH, light, quality, quantity, and more.
- Devices to process or do the measuring
  - Sensors, transducers, transmitters, indicators, displays, recorders, data loggers, and data acquisition systems.

Actuators

- The devices the controller operates:
  - Pneumatic valves, solenoid valves, rotary valves, motors, switches, relays, variable frequency drives.
- Mechanics: plasma actuators, pneumatic actuators, electric actuators, motors, propellers, hydraulic cylinders, linear actuators
- Human

ADC and DAC



Pros and cons of DSP

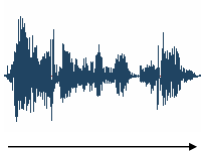
- Pros
  - Easy to duplicate
  - Stable and robust: not varying with temperature, storage without deterioration
  - Flexibility and upgrade: use a general computer or microprocessor
- Cons
  - Limitations of ADC and DAC
  - High power consumption and complexity of a DSP implementation: unsuitable for simple, low-power applications
  - Limited to signals with relatively low bandwidths

What is a signal ?

- A flow of information.
- (mathematically represented as) a function of independent variables such as time (e.g. speech signal), position (e.g. image), etc.
- A common convention is to refer to the independent variable as time, although may in fact not.

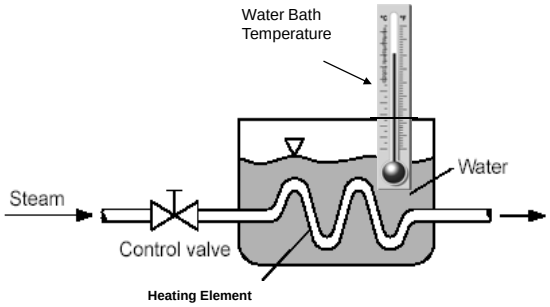
Example signals

- Speech: 1-Dimension signal as a function of time $s(t)$;.
- Grey-scale image: 2-Dimension signal as a function of space $i(x,y)$
- Video: 3 x 3-Dimension signal as a function of space and time $\{r(x,y,t), g(x,y,t), b(x,y,t)\}$.



Example of a temperature process

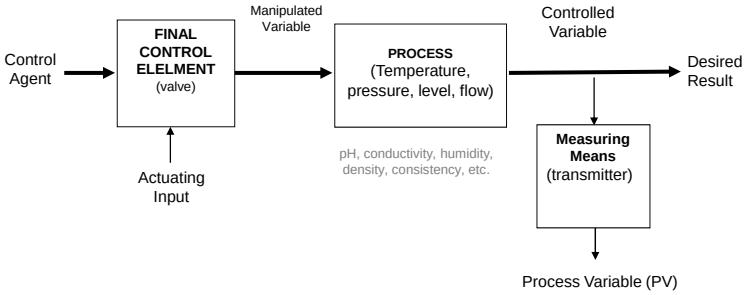
- Objective: maintain a constant water bath temperature at a desired point
- Sensor: thermometer
- Steam (Control Agent) is used to vary the temperature by opening and closing the control valve



Leo SaLemi, 2008

Basic model of a process

- The process is maintained at the desired point by changing the final control element based on the value of the process variable
- The measuring means provides the standardized signal that represents the condition of the process, i.e. is the process at the desired point?



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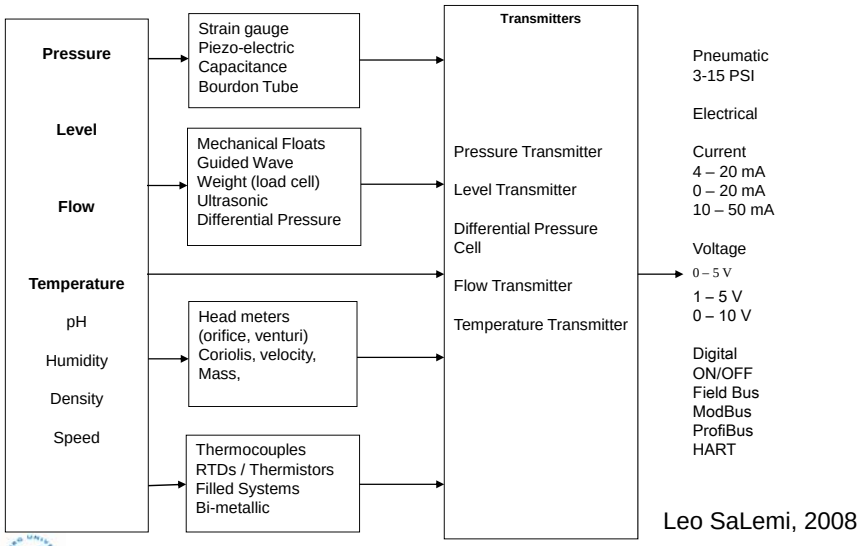
Measuring means



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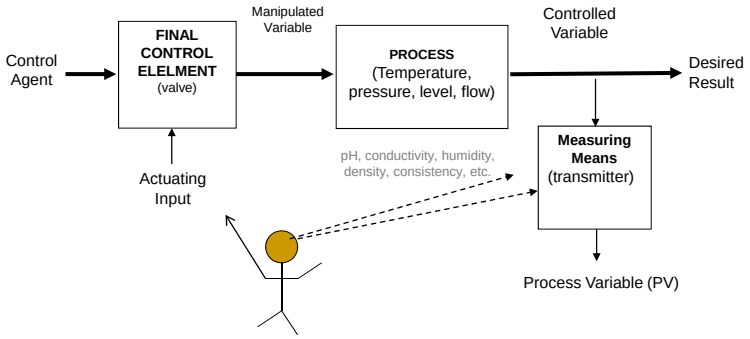
Open loop control

Open loop (or manual control) is used when very little change occurs in the Process Variable



Corrective action is provided by manual feedback

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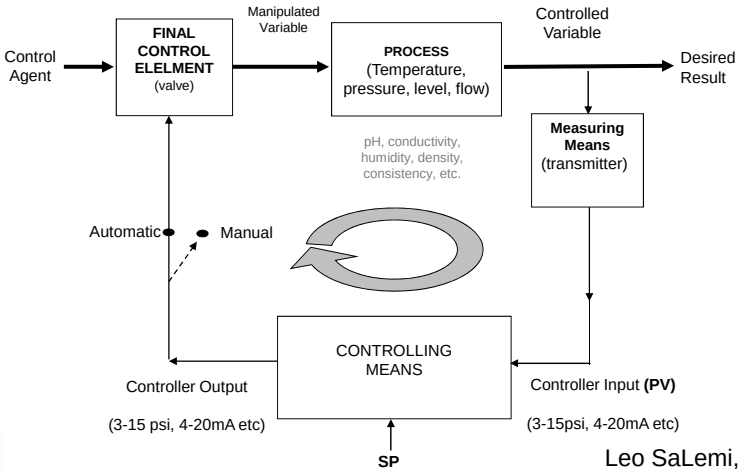
Closed loop control

Closed loop or feedback control provides a corrective action based on the deviation between the Process Variable (PV) and the Desired Point (SP).



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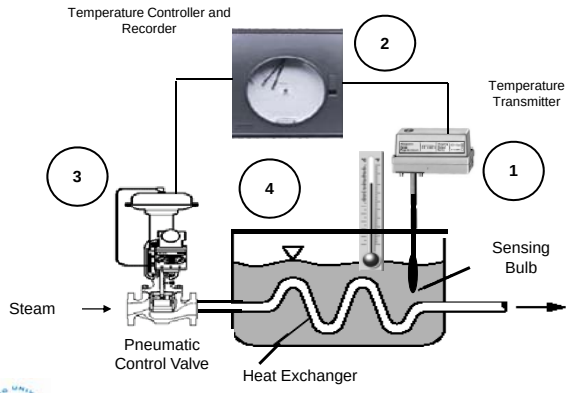
Single loop feedback control

The TIC compares the PV to the SP and opens and closes the FCE to maintain the process at equilibrium.



1. Measuring Means
2. Controlling Means
3. Final Control Element
4. Temperature Process

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Summary

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- An example of instrumentation system