Measurement of nonelectrical Physical quantities (Introduction to sensors and transducers)

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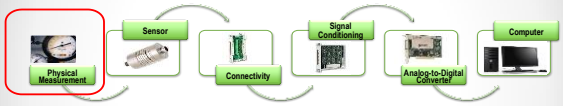
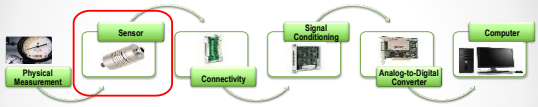
2017

Measurement of non-electrical quantities



- Results is influenced by all components in measurement chain
- The main source of uncertainty and imprecisions: sensor

Sensor



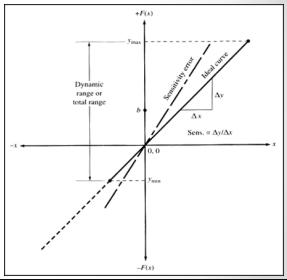
- Sensor: device converting physical quantity to electrical signal
- Active sensors: generate voltage and current (DC or time varying)
- Passive sensors: change electrical properties, e.g. resistance, capacitance, …
- The main source of uncertainty and imprecisions: sensor

Properties and parameters of sensors

- Sensitivity
  - Slope of conversion characteristic(DY/DX)
  - Minimal value of measured quantity causing a measurable change of sensor output
  - Change of measured quantity causing a standard change of sensor output
  - Example: sensor of blood presure: 10 mV/V/mm Hg means 10mV change on output at 1V power voltage change or 1mm Hg blood presure change
- Sensitivity Error
  - Difference of real and ideal transfer characteristics (at specific conditions), e.g., real sensitivity is 8,1 mV/V/mm Hg instead of required and supposed value 10 mV/V/mm Hg

Properties and parameters of sensors

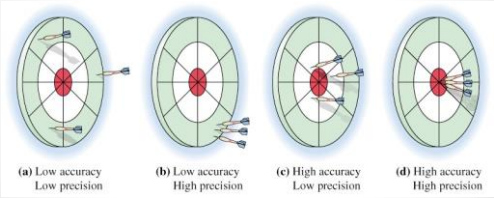
- Range
  - max and min measurable values, e.g. -400 až +400 mm Hg (mercury column)
  - Range do not need to be symmetrical around zero
- Dynamic range
  - The difference max-min, e.g. 800mm Hg



Properties and parameters of sensors

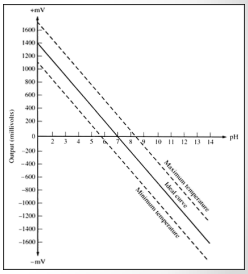
- Precission
  - Coincidence of repetitive measurements – it speaks about dispersion of results not about correctness of results
- Resolution
  - The smallest detectable change on output
- Accuracy
  - the difference between real and measured value (consonance)

Accuracy versus precision



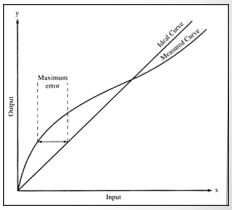
Properties and parameters of sensors

- Offset
  - DC shift of output value in towards zero
  - Often is connected with conditions of measurement, e.g. temperature



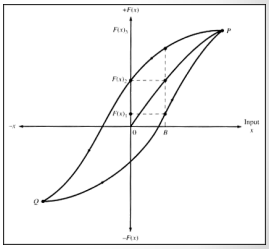
Properties and parameters of sensors

- Non-linearity
  - The difference between the modelled (required) transfer characteristics by a function and real characteristics of sensor (the shape of curve)
  - Influenced by the conditions of measurement
  - Static - $Nonlinearity\ (\%) = \frac{D_{y(max)}}{IN_{f.s.}} \times 100$



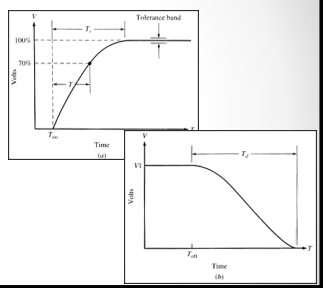
Properties and parameters of sensors

- Hysteresis
  - The results is influenced by the value of previous measurement and by the direction of measured quantity change



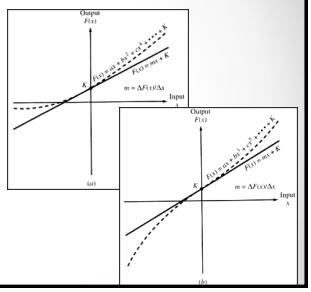
Properties and parameters of sensors

- Response time
  - The delay between change of measured quantity and equivalent change of output quantity cause usually by the sensor inertia



Properties and parameters of sensors

- Dynamic linearity(non.linearity)
  - Express ability of sensor to follow fast changes of measured quantity
  - The error is manifested by changes of amplitude and phase in course of measured quantity in results of measurement
  - It can be described by a polynomial.
  - It is also manifested by appearing new higher harmonics in spectrum of measured quantity course



Properties and parameters of sensors

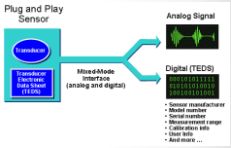
- Output signal
  - Analog DC or time varying signal, which amplitude describes the measured quantity value with linear or nonlinear transfer characteristic
    - Active
    - Passive – must be converted by a convenient electronic network to voltage or current
  - Time varying signal, which a time parameter (frequency, phase, duty cycle, time position of pulse, etc.) describes the measured quantity value with linear or nonlinear transfer characteristic
  - Digital data – sensor consists not only with transducer (quantity conversion) but also with additional electronic, AD convertors and communication interface (e.g. TEDS).

Properties and parameters of sensors

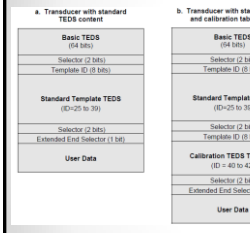
- Sensors parameters
  - Parameters of sensors have usually wide dispersion of parameters even for the same type and production series
  - Consequence:
    - Application engineer need usually knows specific parameters of particular sensors to implement correct constant to calculation formula. Otherwise the result of measurement may be deteriorated by an error.
    - Exchanging a sensor in DAQ system require to change constant in calculation formula (software)

Transducer electronic data sheet

- Standard IEEE 1451 (smart sensors) – any type and principal of transducer, plug and play sensors
- Data are saved in EEPROM
- 1451.0 - Basic Standard for a Smart Transducer Interface for Sensors and Actuators - Common Functions, Communication Protocols, and Transducer Electronic Data Sheet (TEDS) Formats
- 1451.1 Network-Capable Application Processor (NCAP) Information Model
- 1451.2 Transducer to Microprocessor Communications Protocols and Transducer Electronic Data Sheet (TEDS) Format
- 1451.3 Digital Communications and TEDS Formats for Distributed Multidrop Systems
- 1451.4 Mixed-Mode Communication Protocols and TEDS Formats
- 1451.5 Wireless Communication Protocols and TEDS Formats
- 1451.7 Radio Frequency Identification (RFID) Systems Communication Protocols and Transducer Electronic Data Sheet Formats



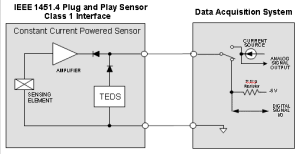
Data sheets



- Example of data content

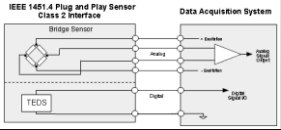
Basic TEDS	Manufacturer ID	43 (Acme Accelerometer Company)
	Model Number	7115
	Version Letter	B
	Serial Number	X001881
Standard and Extended TEDS (fields will vary according to transducer type)	Calibration Date	Jan 29, 2002
	Sensitivity @ ref. condition (S ref)	1.0094E-03 mV/g
	Physical measurement range	± 50 g
	Electrical output range	± 5 V
	Reference frequency (f ref)	100.0 Hz
	Quality factor @ fref (Q)	300 E-3
	Temperature coefficient	-0.85 %/°C
	Reference temperature (T ref)	23 °C
	Sensitivity direction (x,y,z)	x
User Area	Sensor Location	Strut 3A
	Calibration due date	April 15, 2002

Class 1 and 2



- Positive voltage (current) sensors controls output voltage according to measured quantity value by changing the output resistance
- Negative voltage – sends serial data from TEDS trough open collector digital output

- Class 2 has independent connection wires for analog output signal and digital serial communications



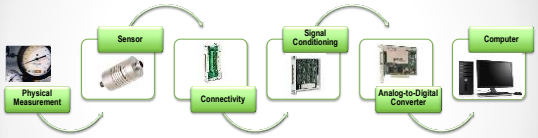
Basic TEDS

Template ID

	Bit Length	Allowable Range
Manufacturer ID	14	17 – 16381
Model Number	15	0-32767
Version Letter	5	A-Z (data type Chr5)
Version Number	6	0-63
Serial Number	24	0-16777215

Type	Template ID	Name of Template
Transducer Type Templates	25	Accelerometer & Force
	26	Charge Amplifier (w/ attached accelerometer)
	43	Charge Amplifier (w/ attached force transducer)
	27	Microphone with built-in preamplifier
	28	Microphone Preamplifiers (w/ attached microphone)
	29	Microphones (capacitive)
	30	High-Level Voltage Output Sensors
	31	Current Loop Output Sensors
	32	Resistance Sensors
	33	Bridge Sensors
	34	AC Linear/Rotary Variable Differential Transformer (LVDT/RVDT) Sensors
	35	Strain Gage
	36	Thermocouple
	37	Resistance Temperature Detectors (RTDs)
	38	Thermistor
	39	Potentiometric Voltage Divider
Calibration Templates	40	Calibration Table
	41	Calibration Curve (Polynomial)
	42	Frequency Response Table

Data acquisition system (DAQ)



- Complex system ensuring sensing signal connection, HW preprocessing, digitizing, software processing, presentation and archiving.