Introduction to Sensors

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Organization

- Brief Introduction
- Sensor/Transducer Fundamentals
- Binary sensors
- The Evolution of Horology

Why do we need sensors?

- To measure the system outputs for feedback control
- To measure system inputs (desirable inputs, unknown inputs, and disturbances) for feedforward control
- To measure output signals for system monitoring, diagnosis, evaluation, parameter adjustment, and supervisory control
- To measure input and output signal pairs for system testing and experimental modeling (i.e., for system identification)

What is a Transducer?

Fundamental mechanism for both sensing and actuation is energy transduction – conversion of signal/energy. Primary forms are grouped into two categories:

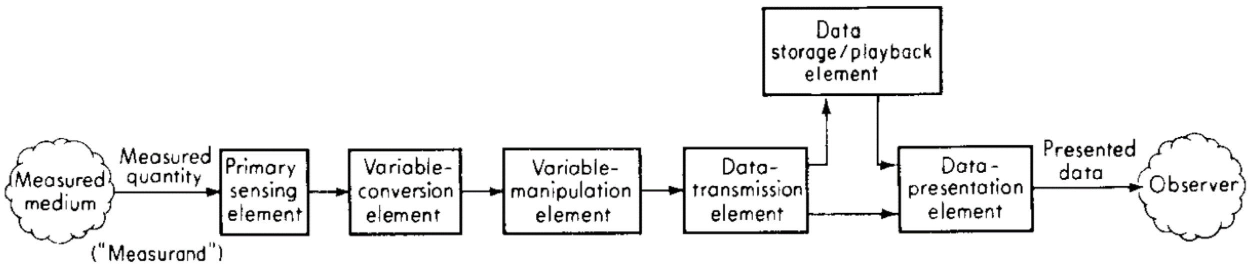
Multicomponent transduction, utilizes "action at a distance" behavior between multiple bodies. eg:
Electromagnetic transduction, typically based upon the Lorentz equation and Faraday's law, and electrostatic interaction, typically based upon Coulomb's law.

Deformation-based / Solid-state transduction, mechanics-of-material phenomena: crystalline phase changes or molecular dipole alignment.

Piezoelectric effects, shape memory alloys, and magnetostrictive, electrostrictive materials.

Micro-scale systems currently dominated by electrostatic and electromagnetic interactions.

Functional Elements of a Sensing/Actuation Instrument



Doebelin

Active and Passive Transducers

Bourdon Pressure Gauge: A Passive Transducer

Servomotor: An Active Transducer

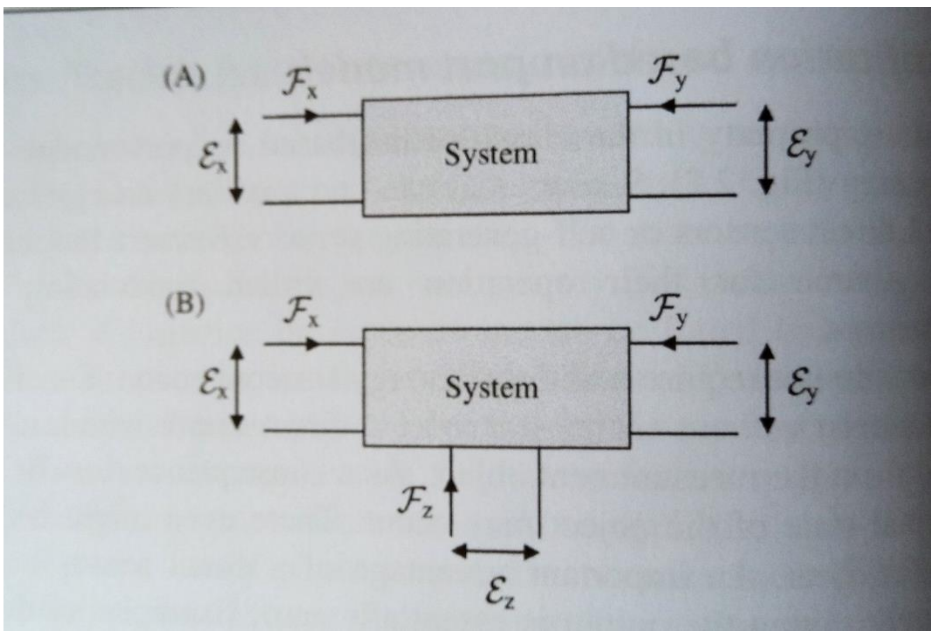
Sensor Characteristics

1. **Sensitivity**
2. **Range**
3. **Precision**
4. **Resolution**
5. **Accuracy**
6. **Offset**
7. **Linearity**
8. **Hysteresis**
9. **Response Time**
10. **Dynamic Linearity**

Concept of Port

- Energy enters or leaves the system through a pair of terminals making up a ‘port’.
- A direct sensor (which does not require additional energy) can be described by a two-port model or four terminal model.
- A Modulating or interrogating sensor on the other hand can be conceived as a system with three ports: an input port, an output port and a port through which the auxiliary energy is supplied.

Port Structure



(A) Two-Port and (B) Three-Port System

Various Energy Conversions in a Transducer

	output domain					
input domain	Radiant	Thermal	Magnetic	Mechanical	Chemical	Electrical
Radiant	Luminescense	Radiation heating	Photomagnetism	Radiation pressure	Photochemical process	Photoconductivity
Thermal	Incandescense	Thermal conductivity	Curie-Weiss law	Thermal expansion	Endothermal reaction	Seebeck effect; pyroelectricity
Magnetic	Faraday effect	Ettinghausen effect	Magnetic induction	Converse magnetostriction		Hall effect
Mechanical	Photo-elastic effect	Friction heat	Magnetostriction	Gear	Pressure induced reaction	Piezoelectricity
Chemical	Chemo-luminescense	Exothermal reaction		Explosive reaction	Chemical reaction	Volta effect
Electrical	Injection luminescense	Peltier effect	Ampère's law	Converse piezoelectricity	Electrolysis	Ohm's law

Design Variations of Transducers

		Interrogating input	
		Design controlled	Environment controlled
LIP input	Design controlled	Source	Direct sensor
	Environment controlled	Modulating sensor	Multiplying devices

LIP: Latent Information Parameters
By default all input ports are also LIP ports

Direct Sensor: Piezo Accelerometer
Modulating Sensor: Strain Gauge
Multiplying Devices: Hall Sensor

Classification of Transducer by Indices

- Direct Input Transducer
  – Thermocouple [th, el, 0]
- Modulating Input Transducer
  – Hall Sensor [ma, el, el]
- Direct Output Transducer
  – LED [el, ra, 0]
- Modulating Output Transducer
  – LCD [ra, ra, el]