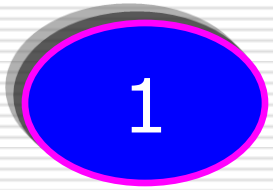

BASICS OF SENSOR, ACTUATOR & TRANSDUCER

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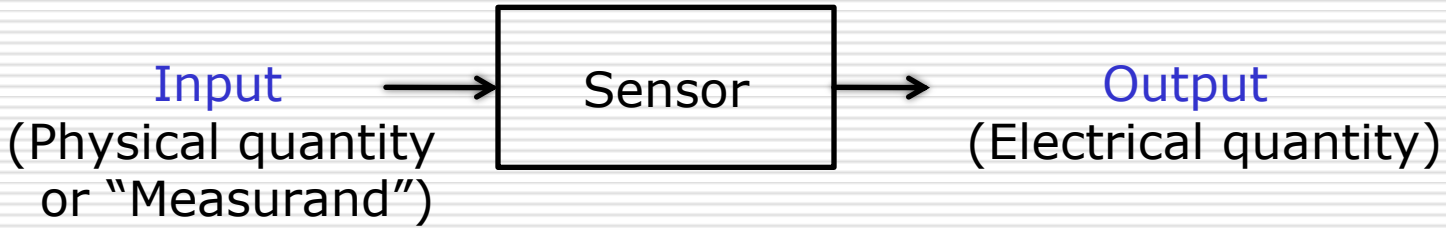
What is Sensor?

- Device that senses a ***physical quantity***
- This physical quantity becomes ***input to the sensor***
- Input is called sensed or measured quantity or ***"measurand"***
- Sensor output is a ***function*** of sensor input
- In the modern context of electrical/electronic measurement systems, MEMS and smart sensors, output of the sensor should be an ***electrical quantity.***



Sensor Input

- Input to the sensor is the *sensed or measured quantity, called as* ***measurand***
- Examples of the measurand are:
  - Temperature
  - Pressure and force
  - Torque
  - Displacement, velocity and acceleration
  - Strain
  - Flow, level and head
  - pH value
  - Humidity
  - Gas concentration
  - Voltage and current
  - Power and power factor
  - Frequency

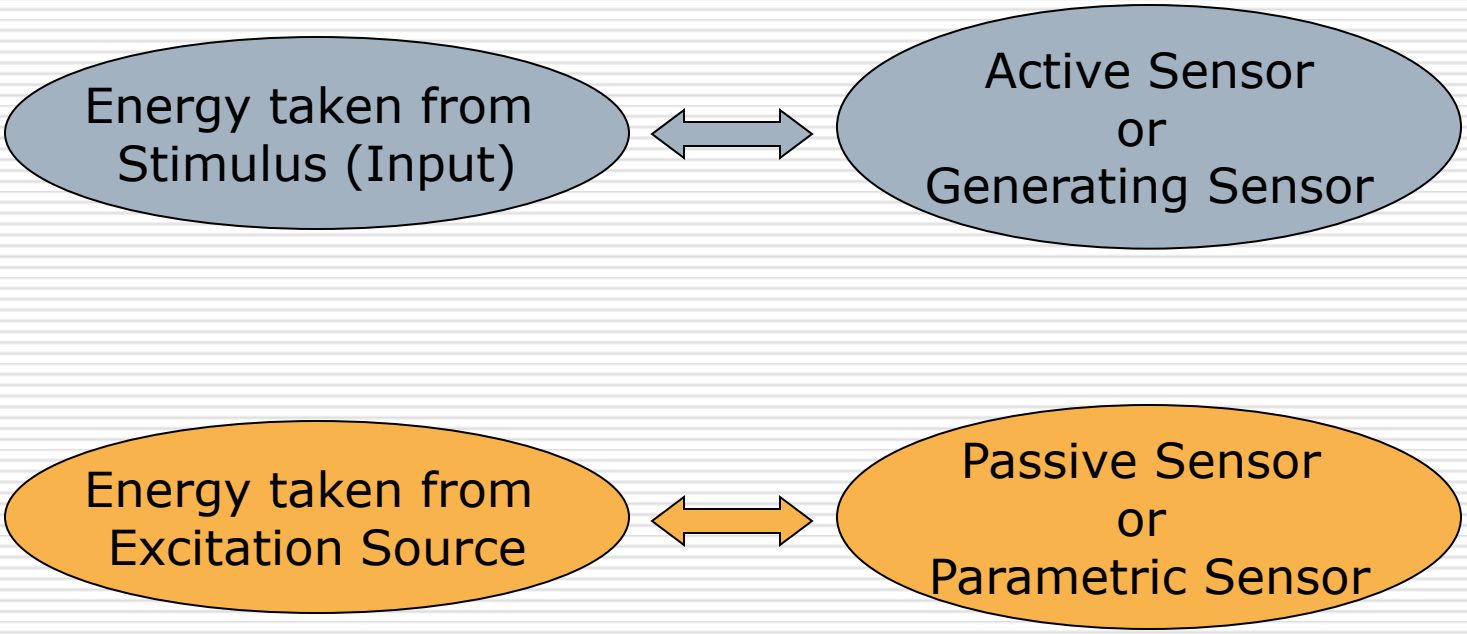
Sensor Output

- Generally speaking, the sensor output may be electrical, mechanical, hydraulic or even pneumatic
- But in the context of electrical/electronic measurement systems, MEMS and smart sensors, only those sensors that have an ***electrical output*** are relevant
- The electrical output of a sensor can be one of the two types:
  - Variation of an electrical parameter
  - An electrical signal
- Variation of electrical parameter means:
  - Variation of resistance (Δ R), or
  - Variation of inductance (Δ L), or
  - Variation of capacitance (Δ C)
- Electrical signal means:
  - Voltage signal, or
  - Current signal

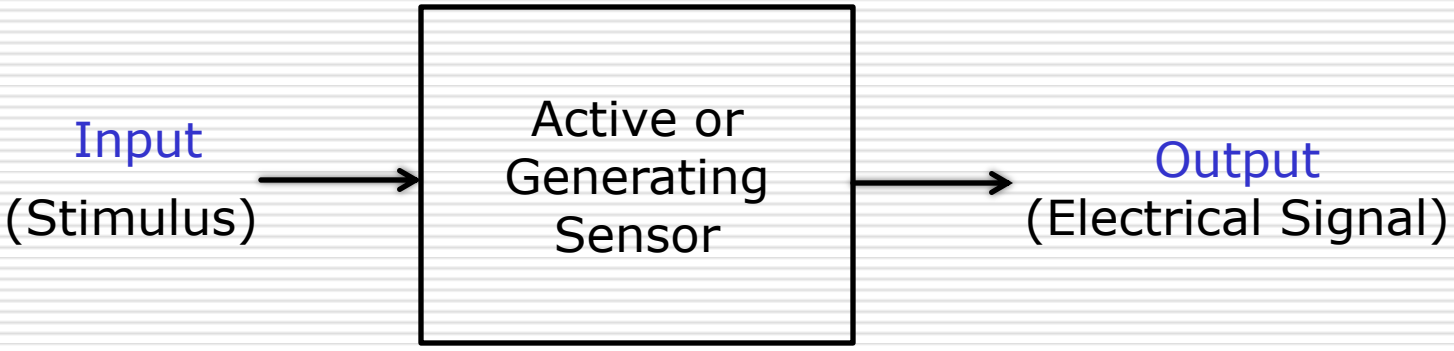
Operating Principles of Sensors

- Sensors work on various physical phenomena
- Almost all physical phenomena known to the scientists have been used in devising one or the other sensor
- Examples of simple sensors with phenomena used therein are:
  - Variation of metal resistance with temperature (RTD)
  - Variation of wire-resistance with physical dimensions (strain gauge)
  - Variation of inductance with reluctance (inductive displacement sensor)
  - Variation of capacitance with electrode dimensions and spacing (capacitive displacement transducers or sensors)
  - Variation of capacitance with dielectric constant (liquid level sensor)
  - Electro-magnetic induction (LVDT)
  - Thermo-electric effect (thermocouple)
  - Piezo-electric effect (piezo-electric pressure transducer)
- Examples of sensors based on other phenomena are:
  - Opto-electronic light sensor
  - Semiconductor-junction temperature sensor
  - Ultrasonic flow sensor
  - CCD imaging sensor
  - Biosensors

Energy Source for Sensor



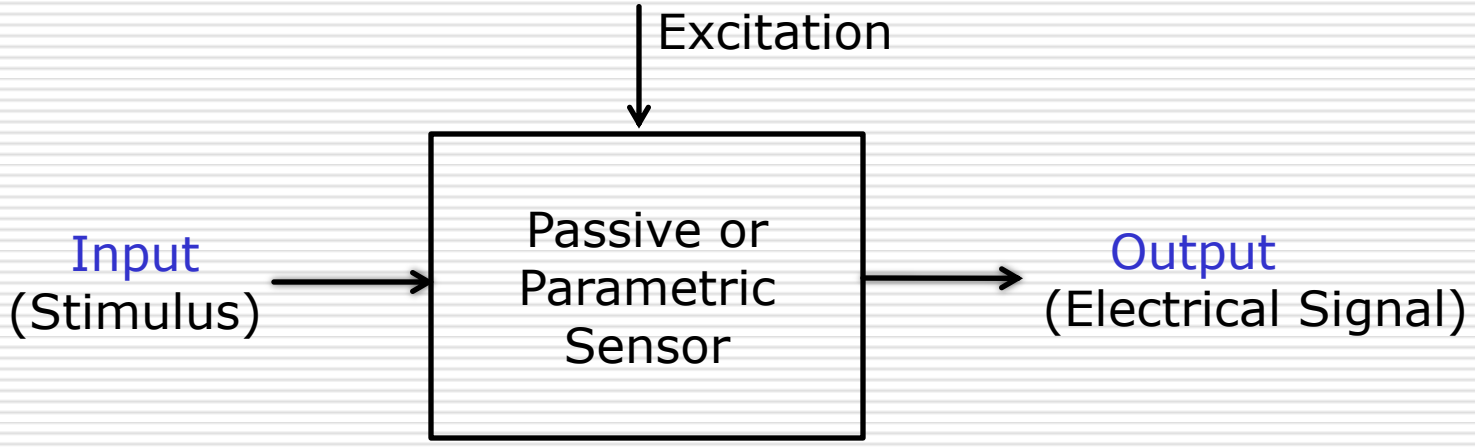
Active or Generating Sensor



Output = Certain function of Input
Linear function is preferred by users

- The source of stimulus supplies energy to the sensor
- The sensor does not need an external excitation
- Output of the sensor is an electrical signal (V or I)
- Examples: Thermocouple (temperature sensor)
  Piezoelectric pressure sensor

Passive or Parametric Sensor



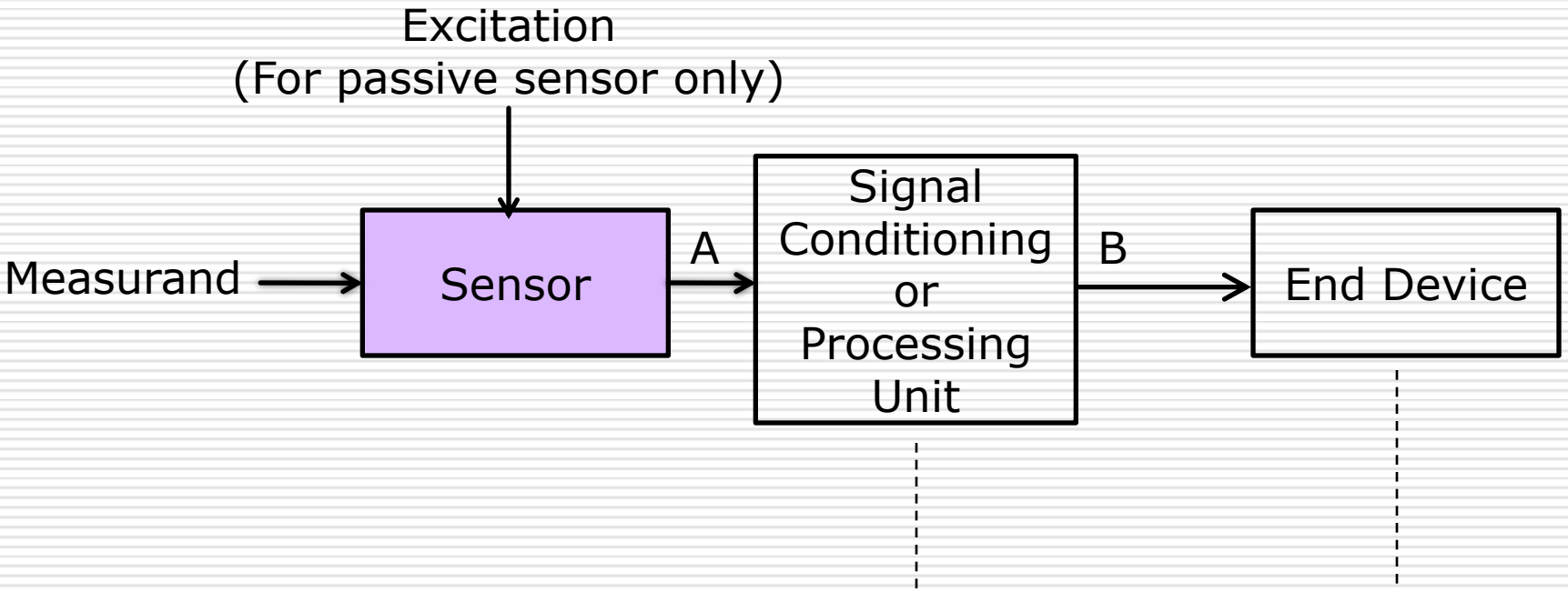
Output = Certain function of Input and Excitation
Linear function is preferred by users

- Excitation is usually a constant voltage or, sometimes, a constant current
- Without excitation, output of the passive sensor is a parametric change, i.e. a change in its resistance, capacitance or inductance
- Output of the excited passive sensor is an electrical signal
- Excitation source supplies energy to the sensor
- Examples: Resistance temperature detector/ sensor
  Variable-gap capacitive displacement sensor

Electrical Excitation Circuits for Passive Sensors

- Voltage applied across sensor
- Current driven through sensor
- Potential divider circuit
- Wheatstone bridge circuits:
  - Quarter sensor-bridge
  - Half sensor-bridge
  - Full sensor-bridge

Sensor in Measurement System



- Incompatible magnitude and/or form of electrical signal A
- This unit conditions or processes electrical signal A into signal B to make it compatible with the End Device

- Indicating device
- Display device
- Storage device
- Communication device
- Data processor

Signal Conditioning or Processing

- Sensor is used as ***input element*** of a measurement system
- Signal conditioning/ processing unit (SCU) is placed after the sensor and before the end device
- SCU is meant for conditioning/ processing the electrical output of sensor to make it compatible to end device
- SCU consists of electronic circuits:
  - Analog electronic circuits
  - Converter circuits

Analog Electronic Circuits used for Signal Conditioning

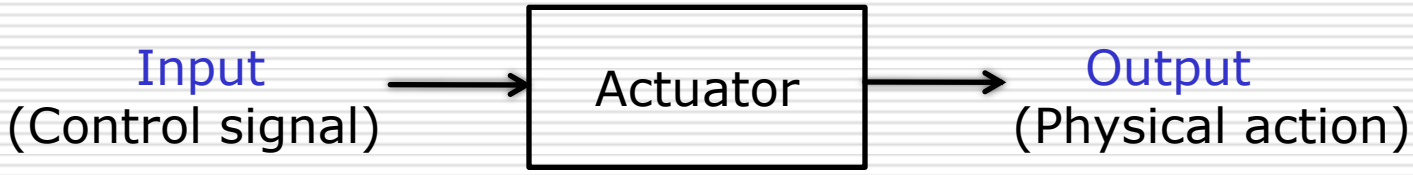
- Amplifiers
  - D.C. coupled
  - A.C. coupled
  - Differential
  - Instrumentation
- Operational circuits
  - Adder
  - Subtractor
  - Multiplier
  - Divider
  - Integrator
  - Differentiator
- Active filters
  - Low pass
  - High pass
  - Band pass
  - Band reject (notch)
- Modulators/Demodulators
  - Pulse width modulator (PWM)
  - Amplitude detector (demodulator)
  - Phase sensitive amplitude detector

Converter Circuits used for Signal Conditioning

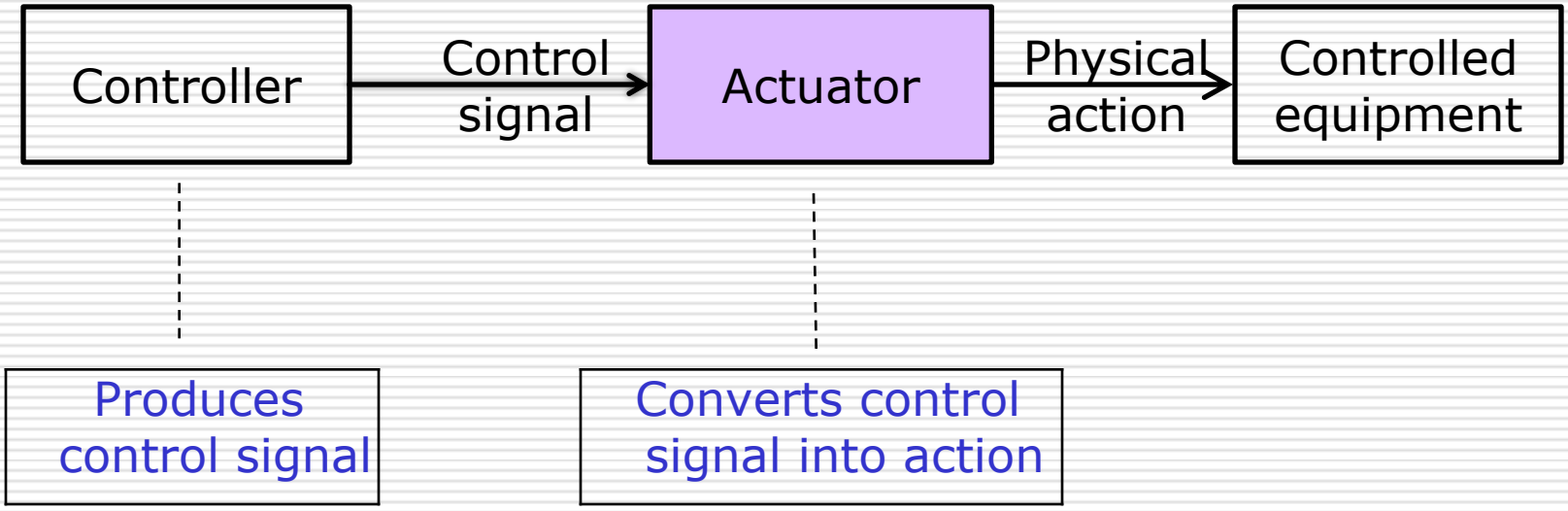
- Analog to Digital Converter (ADC)
  - Integrating ADC (Slow)
  - Instantaneous ADC (Fast)
  - Incremental ADC (Faster)
  - Flash ADC (Fastest)
- Output of ADC
  - Binary-output
  - BCD-output
- Voltage to Frequency Converter (VFC)

What is Actuator?

- Device that converts a control signal into a physical action in a control system
- The control signal appears as the input to the actuator
- In the modern context of electronic and computer-based controls, the control signal is an electrical signal
- Output of the actuator is a physical action.

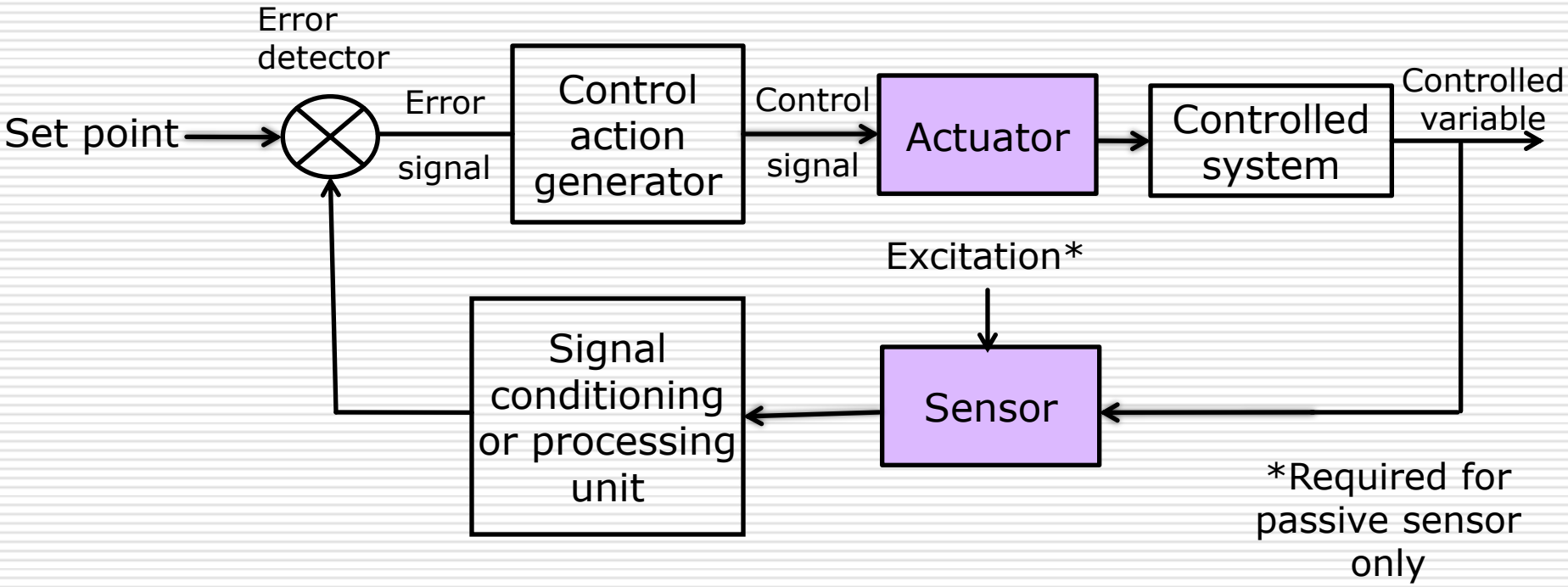


Actuator in Open-Loop Control System



Note that ***actuator*** is the output element of a control system, whereas ***sensor*** is the input element of a measurement system

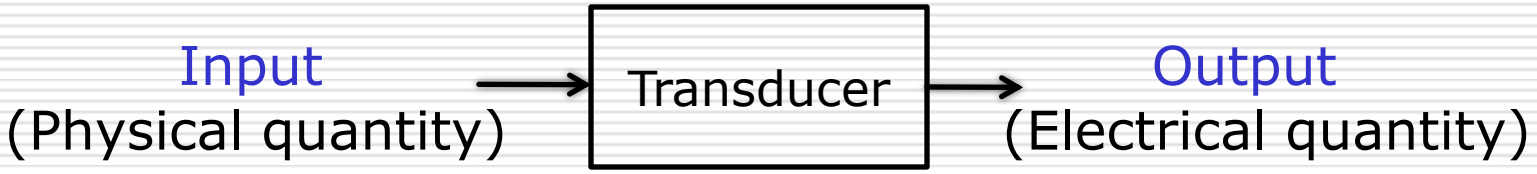
Sensor & Actuator in Closed-Loop Control System



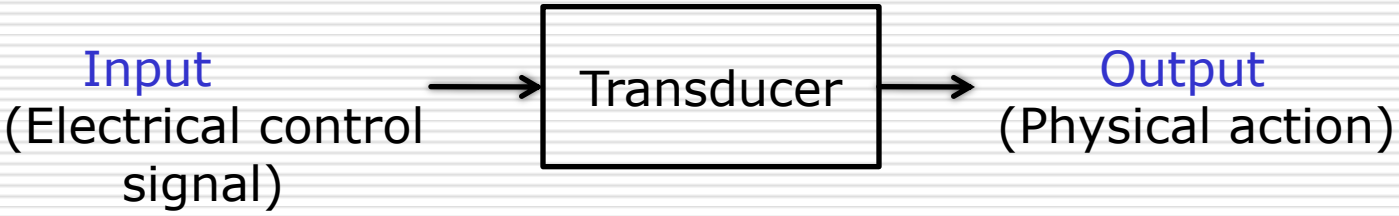
Note that a closed-loop control system uses ***an actuator*** in the forward path and ***a sensor*** in the feedback path

What is Transducer?

- Device that converts one form of energy into another form of energy ***for the purpose of either measurement or control***
- When used for the purpose of ***measurement***, a transducer converts a physical quantity into an electrical quantity:



- When used for the purpose of ***control***, a transducer converts an electrical control signal into a physical action:



Transducer-Sensor-Actuator Relationship

- Transducer: Converts one form of energy into another form of energy for the purpose of measurement or control.
- Sensor: Converts a physical input quantity into an electrical output signal for the purpose of measurement and used as an ***input element*** of the measurement system.
- Actuator: Converts an electrical control signal into an action for the purpose of control and used as an ***output element*** of the control system
- Thus,
  Sensor is an ***Input Transducer***, while
  Actuator is an ***Output Transducer***.