Electronic Measurements (1)

Transducers - Part 1

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Definition

- **Transducer:** A device that converts energy from one form to another (a mercury thermometer).
- **Sensor:** Converts a physical quantity at the input to an electrical signal at the output, mainly for measurement purposes .
- **Actuator:** is a device that works opposite to a sensor. An actuator converts electrical signal to a physical event.
- Transducer is a term collectively used for both sensors and actuators.

Definition

Quantity being Measured	[redacted] (Sensor)	[redacted] (Actuator)
Light Level	Light Dependant Resistor (LDR) Photodiode Photo-transistor Solar Cell	Lights & Lamps LED's & Displays
Temperature	Thermocouple Thermistor Thermostat Resistive Temperature Detectors	Heater Fan

Examples of Energy Transformation

- Electromagnetic - EM fields ⟺ current

Examples:

Receiving Antennas

Transmitting Antennas

Examples of Energy Transformation

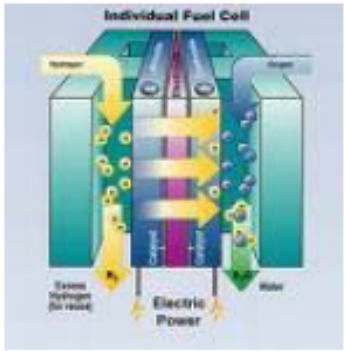
- Electrochemical - substance → voltage

Examples:

pH Probe

Measures the hydrogen ion concentration in solutions, converting it into a voltage signal.

Fuel Cell



A fuel cell is an electrochemical device that converts chemical energy from a fuel into electrical energy through a chemical reaction, usually involving hydrogen and oxygen

Examples of Energy Transformation

- Electromechanical - movement ⟺ voltage

Examples:

Motor/Generator

Phonograph Cartridge

converts the mechanical vibrations caused by the stylus moving along the record grooves into electrical signals. These signals are then sent to a pre-amplifier, amplified further, and finally converted into sound through speakers

Examples of Energy Transformation

- Electroacoustic - vibration ⟺ voltage

Examples:

Loudspeaker

Microphone

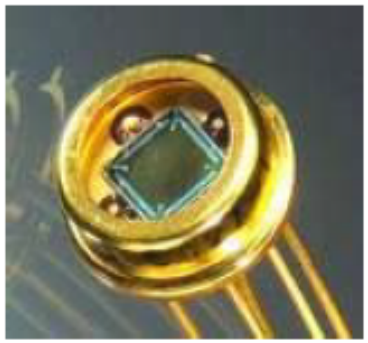
Examples of Energy Transformation

- Photoelectric - light ⟺ voltage

Examples:

Light Bulb

Photodiode



Examples of Energy Transformation

- Thermoelectric - temperature ⟺ voltage

Examples:

Hotplate

Thermistor

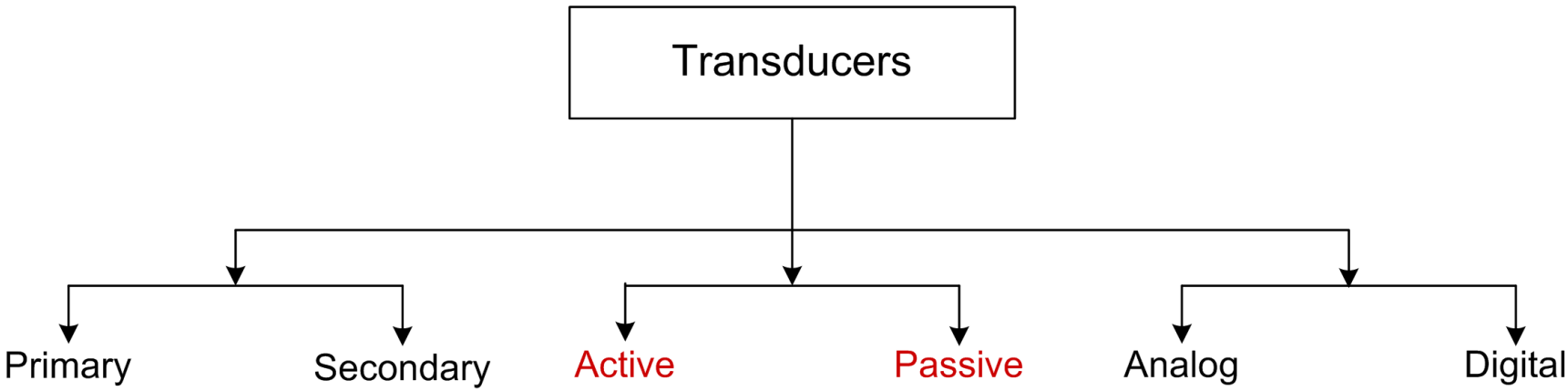
Electrical Transducers

- Electrical transducers , widely known as sensors, are the first stage in most of the measurement systems (see, lecture 2).
- The quantities which cannot be measured directly, such as pressure, displacement, temperature, humidity, fluid flow, etc., are required to be sensed and changed into electrical signal first for easy measurement.

Advantages of Electrical Transducers

- An amplifier may be used for amplifying the electrical signal according to the requirement.
- Friction effect is minimised.
- Mass-inertia effect are also minimised, because in case of electrical or electronics signals the inertia effect is due to the mass of the electrons, which can be negligible.
- The output can be indicated and recorded remotely from the sensing element.
- Power requirement is very low for controlling the electrical or electronic system

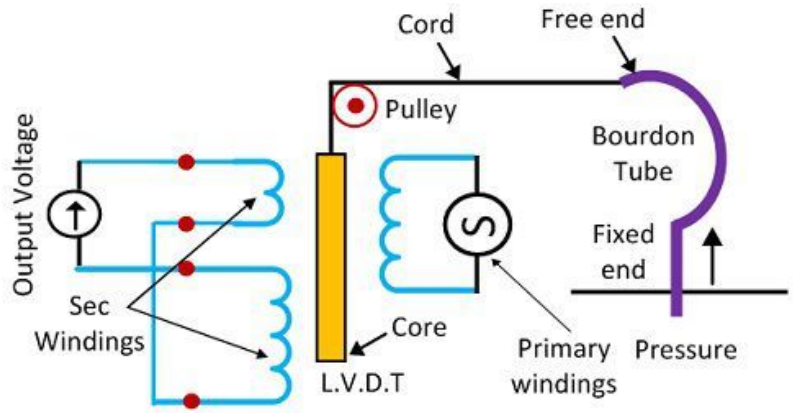
Classifications of Transducers



Primary and Secondary Transducers

- **Primary Transducer:** A Transducer which is directly connected to the measurable quantity is known as a primary transducer (bourdon tube in pressure measurement).
- **Secondary Transducer:** A Transducer which is not directly connected to the measurable quantity or input is known as a secondary transducer (linear variable differential transformer LVDT in pressure measurement).

Generally, a mechanical device acts as a primary transducer and electrical device acts as a secondary transducer.



https://www.youtube.com/watch?v=o_hEmYip248

Active and Passive Transducers

Active Transducer

- Converts measurand input into electrical signal (voltage/current).
- Examples: thermocouple, photo-voltaic cell, and piezoelectric crystal.
- No external power supply is required .
- They develop theirs owns voltage or current, hence known as a self-generating transducer.

Passive Transducer

- Converts measurand into variation in resistance, or capacitance, or inductance.
- Examples: LDR, potentiometer, resistive, inductive and capacitive transducers.
- External power supply is required .
- Their internal parameters like capacitance and inductance changes with the input signal.

Active and Passive Transducers

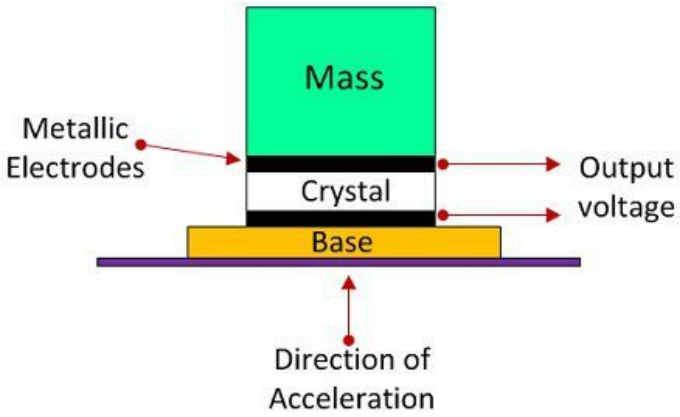


Figure: Piezo electrical crystal, active transducer

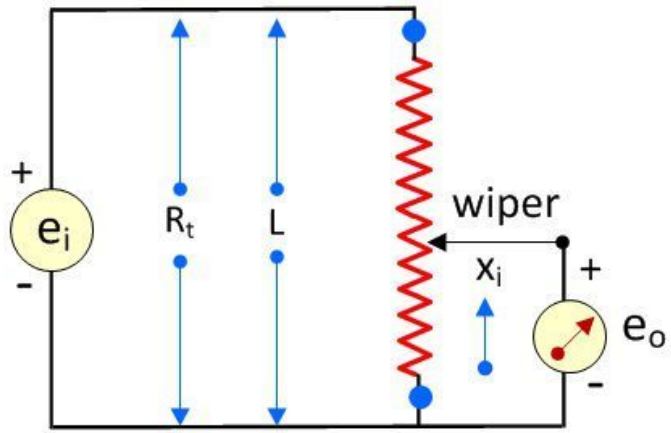


Figure: linear potentiometer (POT), passive transducer

Capacitive touch sensors work by detecting the change in capacitance when a human finger (or another conductive object) comes close to or touches a conductive surface. The human body acts as a dielectric, altering the capacitance at the point of contact.

Analog and Digital Transducers

- **Analog Transducer:** converts the input quantity to an analog output which is continuous in time.
  Examples: thermocouple, thermistor, and strain gauge SG (variation in mechanical displacement, tension or compression, can be sensed as change in electric resistance).
- **Digital Transducer:** converts the input quantity to electrical output which is in a digital form (or pulses).
  Examples: shaft/rotary encoder (converts the angular position of a shaft to analog or digital signal), digital tachometer (measures the rotational speed of a disk or shaft), Hall effect sensors (detects the presence and magnitude of a magnetic field using the Hall effect), limit switches (used in control systems as safety interlock).

Specifications of Transducers

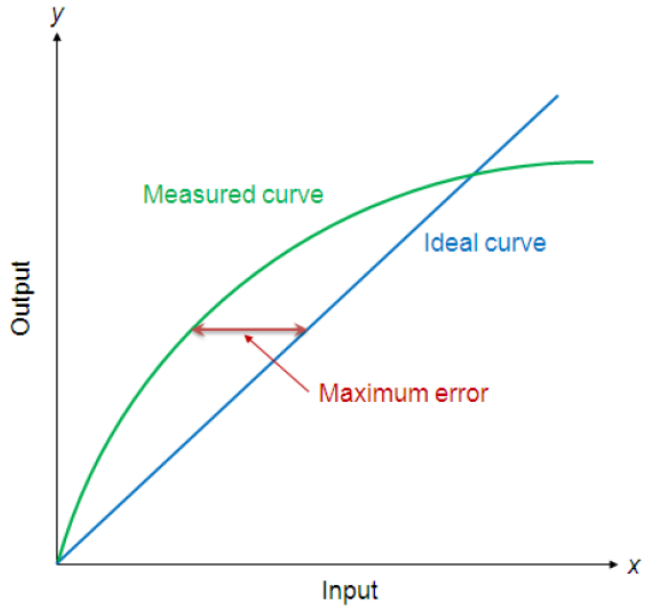
- Transducers or measurement systems are not perfect systems.
- Design engineer must know the capability and shortcoming of a transducer or measurement system to properly assess its performance.
- There are a number of performance related parameters of a transducer or, generally, measurement system.
- These parameters are called as transducer specifications.
- **Transducer specifications:** inform the user about the deviations from the ideal behavior of the transducer.

Specifications of Transducers

- **Range $\downarrow \uparrow$:** The range of a sensor indicates the limits between which the input can vary. For example, a thermocouple for the measurement of temperature might have a range of 25-225 °C .
- **Span $\uparrow$:** The span is difference between the maximum and minimum values of the input. Thus, the above-mentioned thermocouple will have a span of 200 °C .

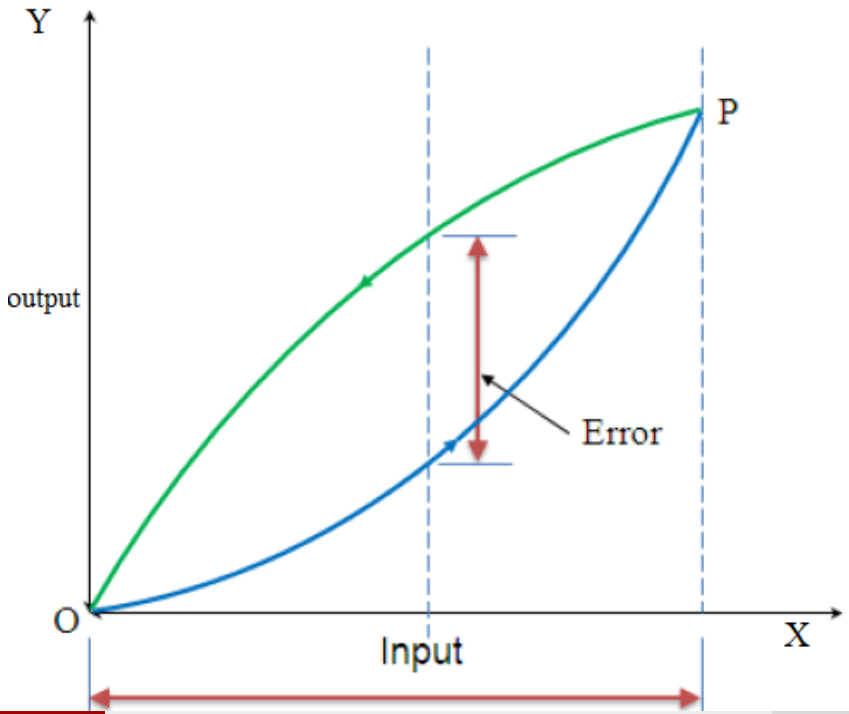
Specifications of Transducers

- **The nonlinearity ↓:** Indicates the maximum deviation of the actual measured curve of a sensor from the ideal curve.
- Nonlinearity (%) = Maximum deviation in input / Maximum full scale input.
- It dependent upon environmental factors, including temperature, vibration, acoustic noise level, and humidity. Therefore it is important to know under what conditions the specification is valid.



Specifications of Transducers

- **Hysteresis ↓:** Is an error of a sensor, which is defined as the maximum difference in output at any measurement value within the sensor's specified range when approaching the point first with increasing and then with decreasing the input parameter .
- The hysteresis error value is normally specified as a positive or negative percentage of the specified input range.



Specifications of Transducers

- **Response time $\downarrow$:** Lecture 1
- **Accuracy:** Lecture 1 (High degree of accuracy is necessary)
- **Sensitivity:** Sensitivity of a sensor is defined as the slope of the output characteristic curve $\Delta Y/\Delta X$. In other words, it is the ratio of change in output value of a sensor to the change in input value that causes the output change. For example, a general purpose thermocouple may have a sensitivity of $\uparrow 41\ \mu V/^{\circ}C$.

Lecture References

- Purkait, Prithwiraj. Electrical and electronics measurements and instrumentation. McGraw-Hill Education, 2013. (Hint: chapter 11)
- Kishore, K. Lal. Electronic Measurements and Instrumentation. Pearson Education India, 2009. (Hint: chapter 7)