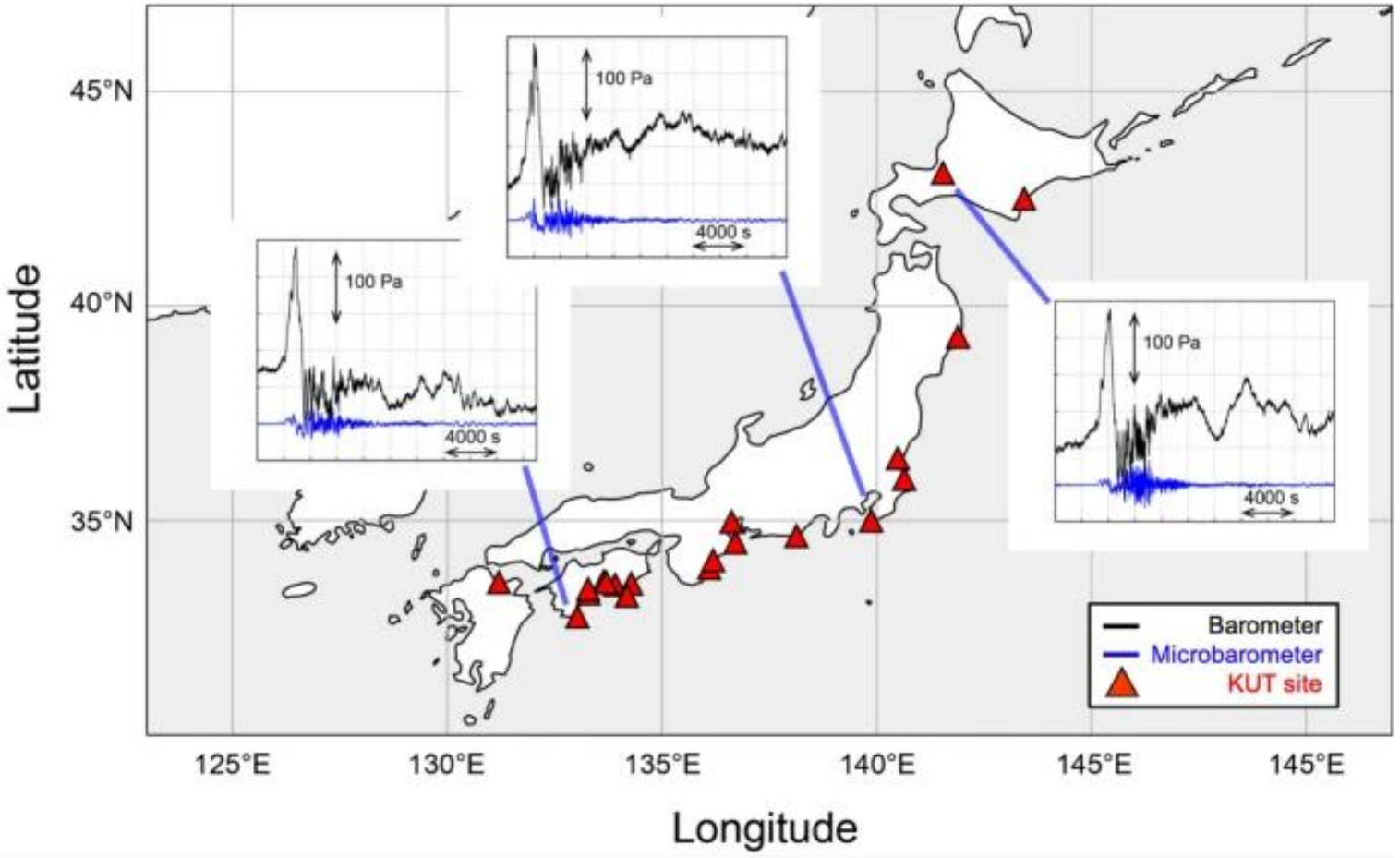
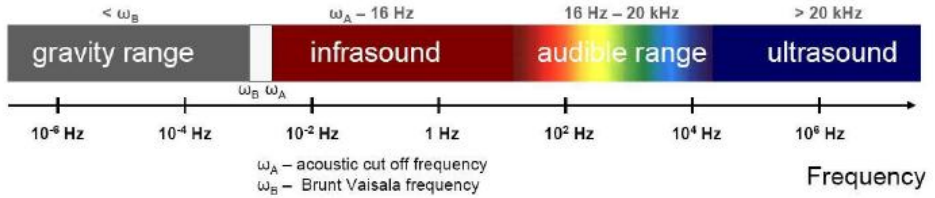
Jacob Fraden
Handbook of Modern Sensors
Physics, Designs, and Applications
Physics, Designs, and Applications
Fifth Edition

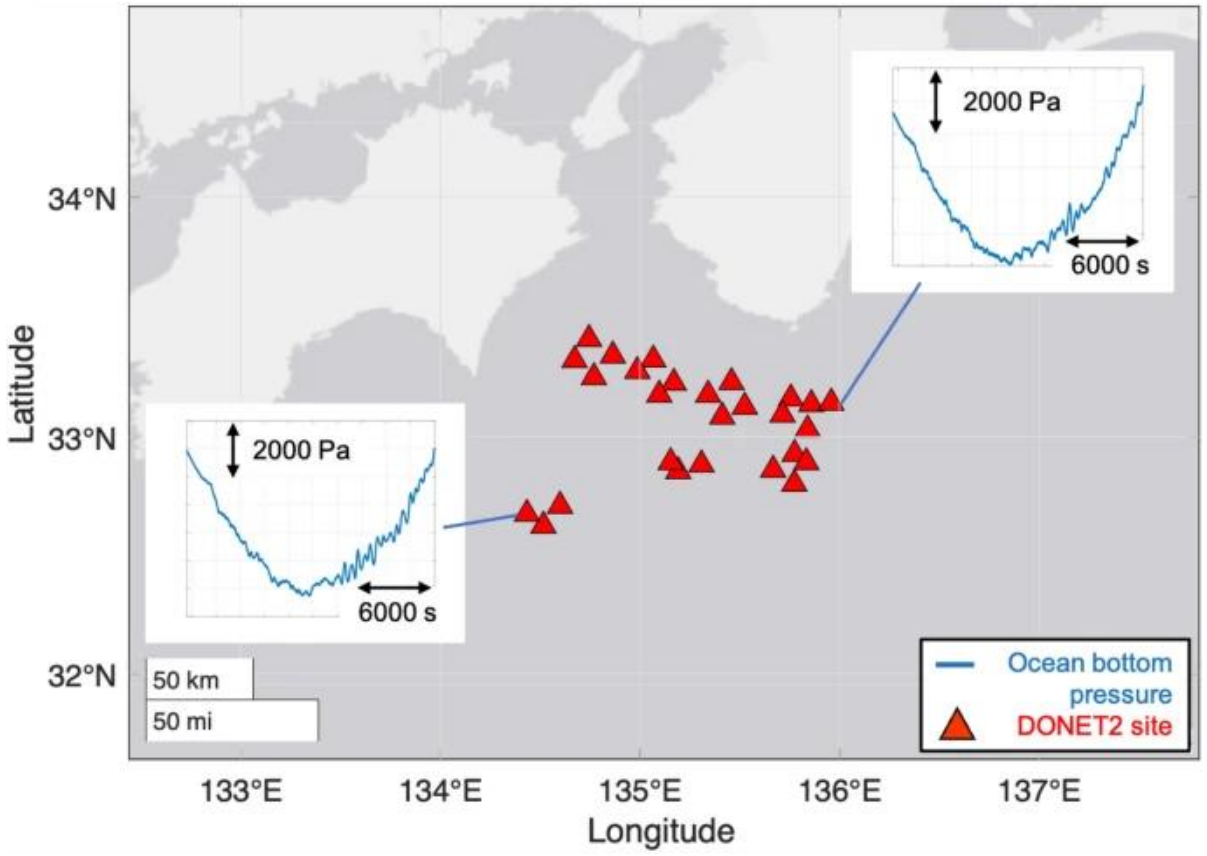
Classification



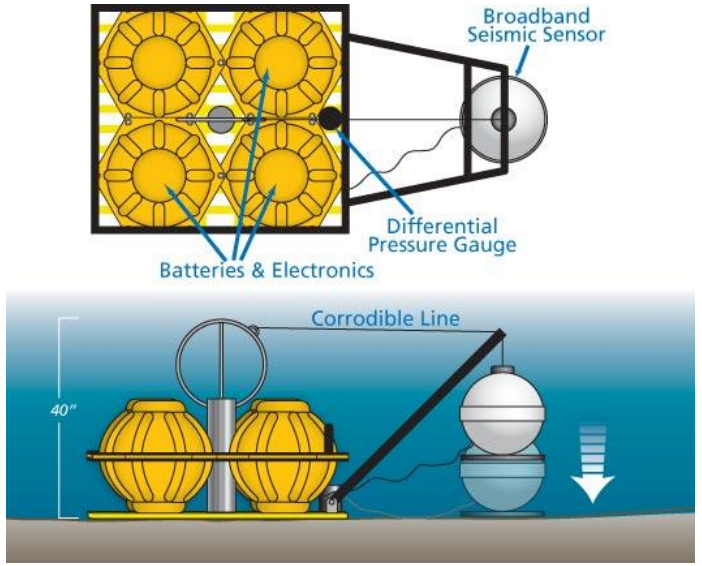


Location of Kochi University of Technology (KUT) infrasound sensors and their observed data after the Tonga volcanic eruption. The KUT installed more than 30 infrasound sensors to form a Japan-wide infrasound observation network. Every site has a SAYA INF01-type comprehensive sensor that contains a membrane-type infrasound sensor, a barometer, a thermometer, and a three-component accelerometer of small MEMS (micro electromechnical system) sensor chips. These observation sites are 7700 to 8400 km away from Tonga volcano, and the pressure fluctuations were monitored approximately 7 hours after the eruption. Examples of time series of pressure perturbation are shown; the observed signals had similar waveforms regardless of their locations.

Nishikawa et al., 2022



Location of DONET2 (Dense Oceanfloor Network system for Earthquakes and Tsunamis) sites. These 27 ocean bottom pressure gauges are installed for the early detection of tsunamis by observing the vertical movement of the sea surface through the observation of changes in water pressure.



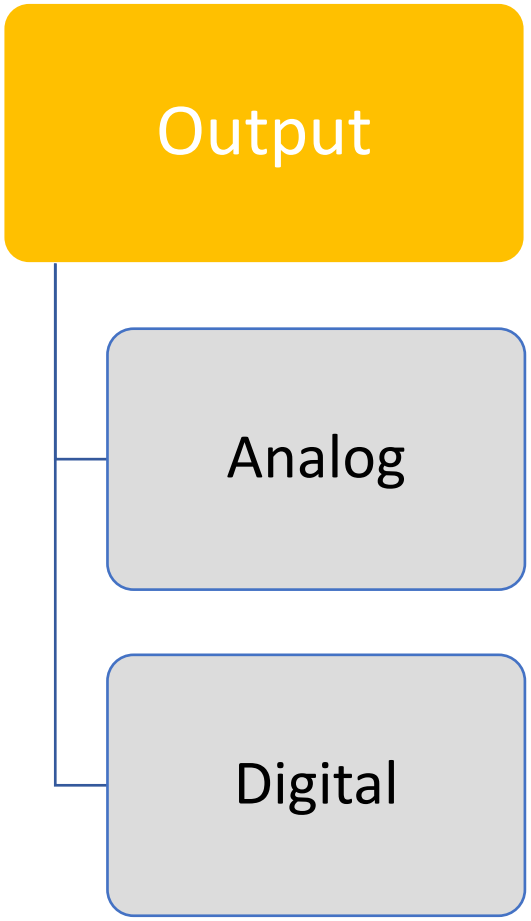
A long-term ocean-bottom seismograph designed to work for more than a year. The four yellow "hardhats" protect equipment from the high pressure at depth. A pressure gauge measures earthquake waves in the water. The seismometer is housed in a metal sphere that drops gently into place after the entire seismograph has been installed on the sea floor. (Jack Cook, WHOI)

Reading assignment ….

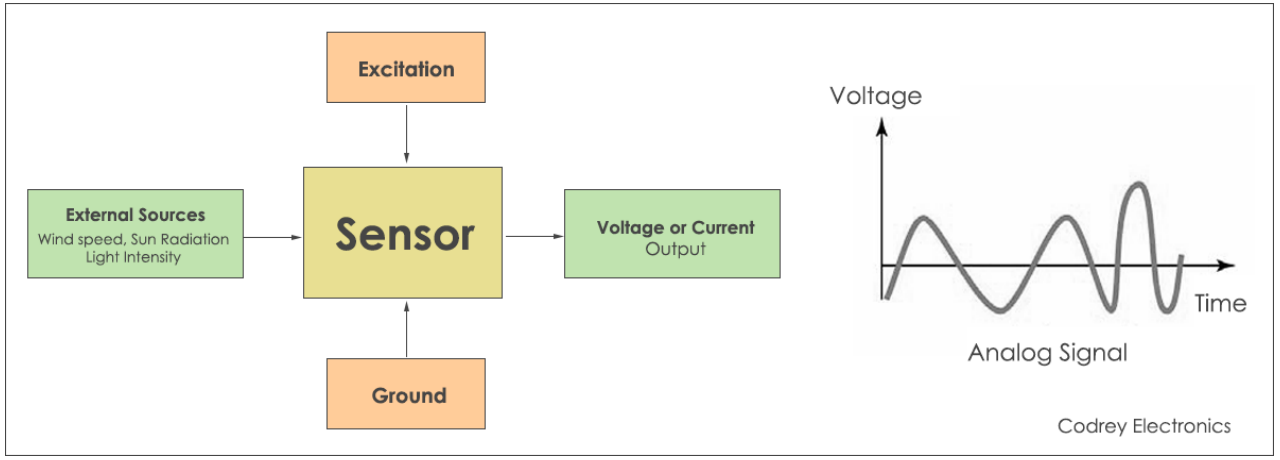
DONET I & II and S Net Cable Configurations

Underwater communication networks

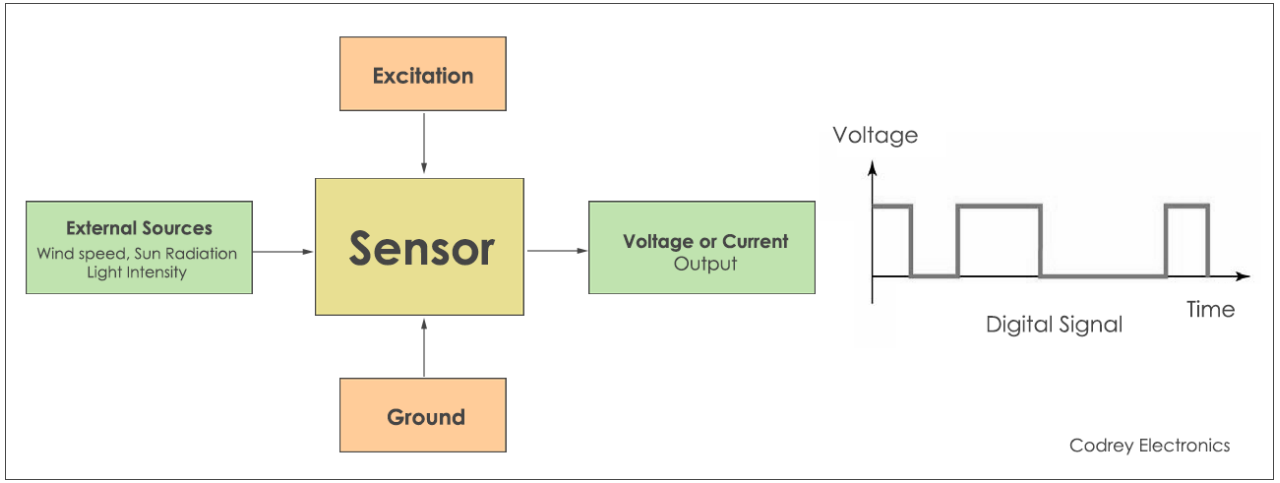
Types of Sensors



Sensor Classes (Based on Output)

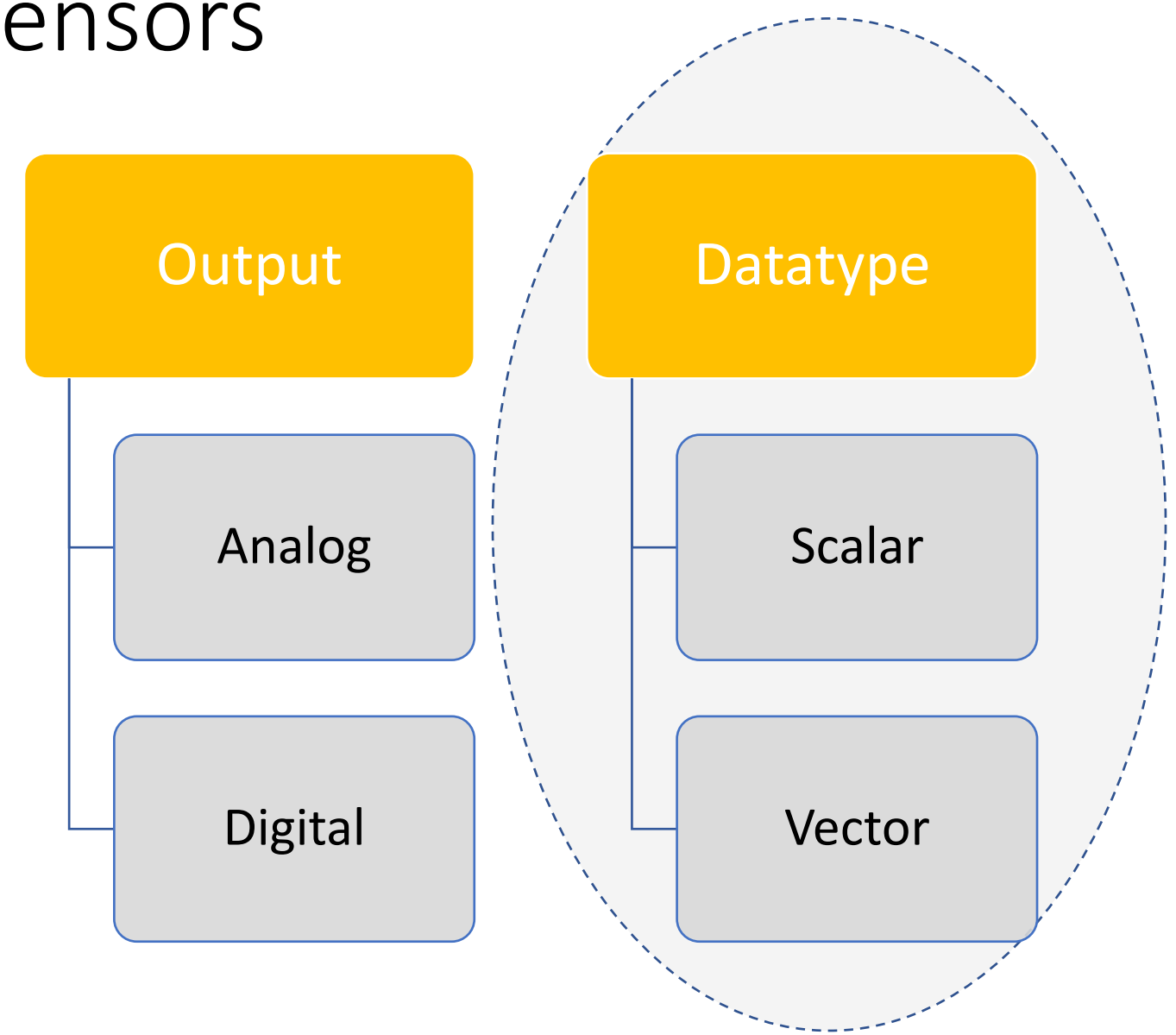


Analog Sensor



Digital Sensor

Types of Sensors



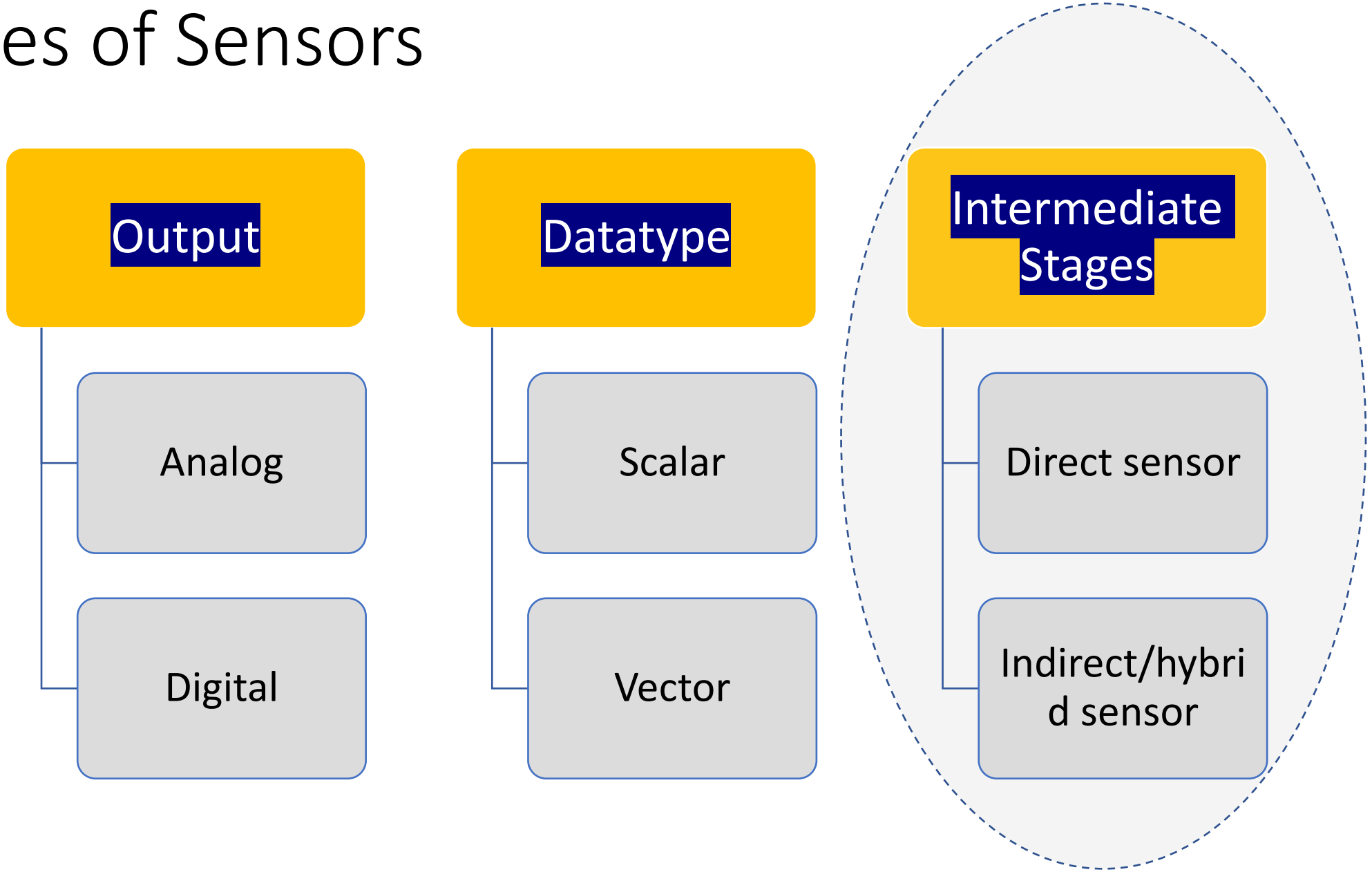
Sensor Classes (Based on Data Type)

- Scalar Sensor: Produces output voltage which is proportional to the magnitude of the quantity measured
  Physical quantities: temperature, color, pressure, etc

- Vector Sensor: Produces output voltage which is proportional to the magnitude, direction and the orientation of the quantity measured (Camera sensor)

  Physical quantities: Sound, image, velocity, acceleration

Types of Sensors



Types of Sensors

- Direct Sensor:
  Converts a stimulus into an electrical signal or modifies an electrical signal by using an appropriate physical effect

or

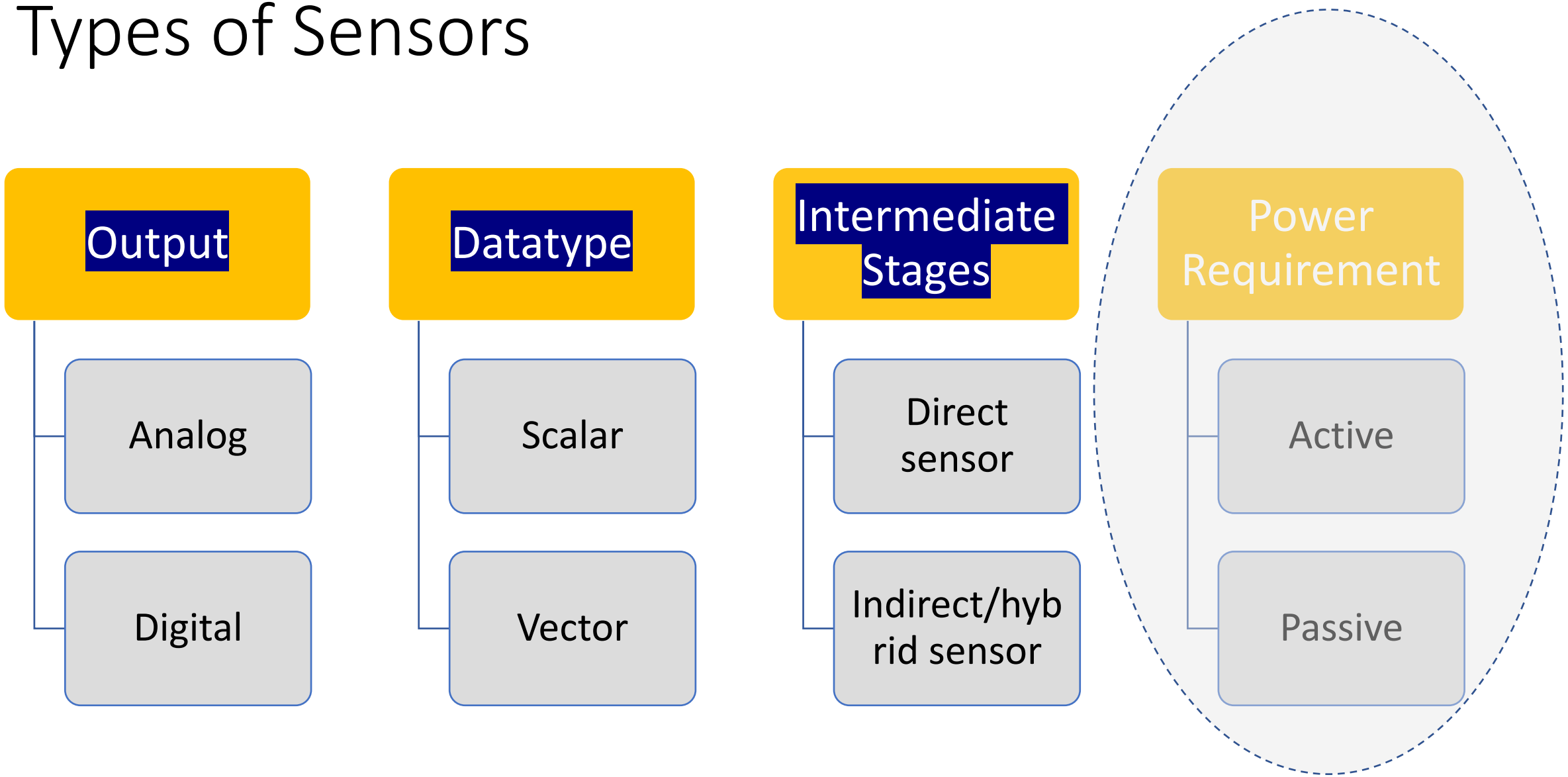
- The direct sensors are those that employ certain physical effects to make a direct energy conversion into a generation or modulation of an electrical signal
  Example: Thermocouple

What is photoelectric effect?

- Indirect/hybrid Sensor:
  Includes one or more transducers for multiple conversion steps before a direct sensor generates an electrical output.

Example: rotary encoder

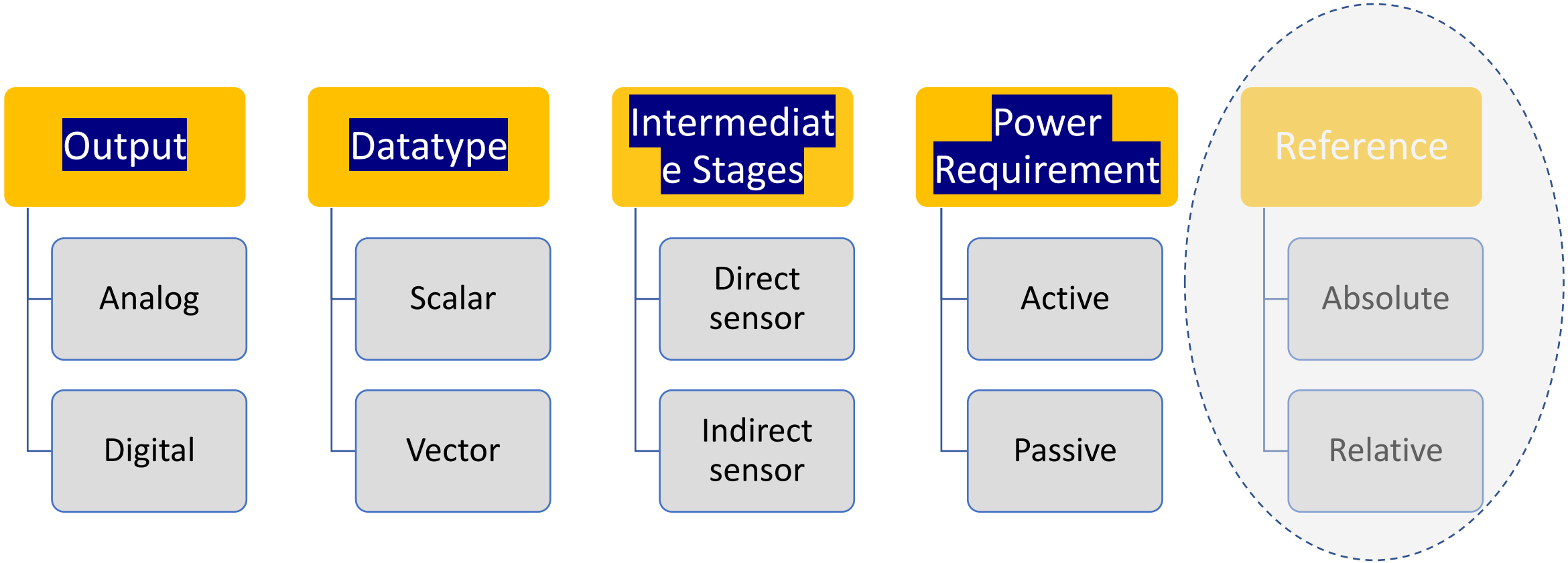
Types of Sensors



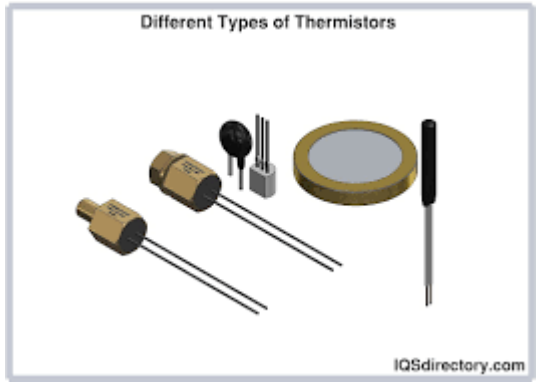
Types of Sensors

- Passive Sensor:
  Does not need any additional energy source and directly generates an electrical signal in response to external stimulus.
  Most passive sensors are direct sensors as defined earlier.
  Example: Thermocouple, photodiode, piezoelectric sensor
- Active Sensor:
  Requires external power for its operation, which is called an excitation signal.
  Example: LiDAR, GPS, infrared sensor

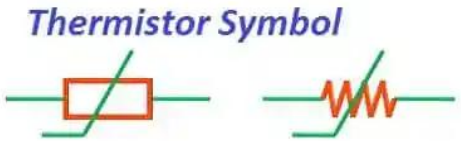
Types of Sensors



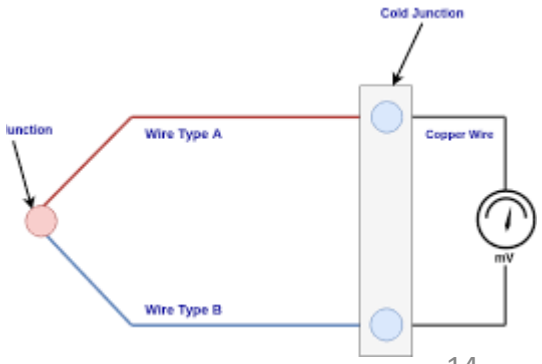
Types of Sensors



- Absolute Sensor:
  Detects a stimulus in reference to an absolute physical scale that is independent of the measurement conditions
  Example: Thermistor

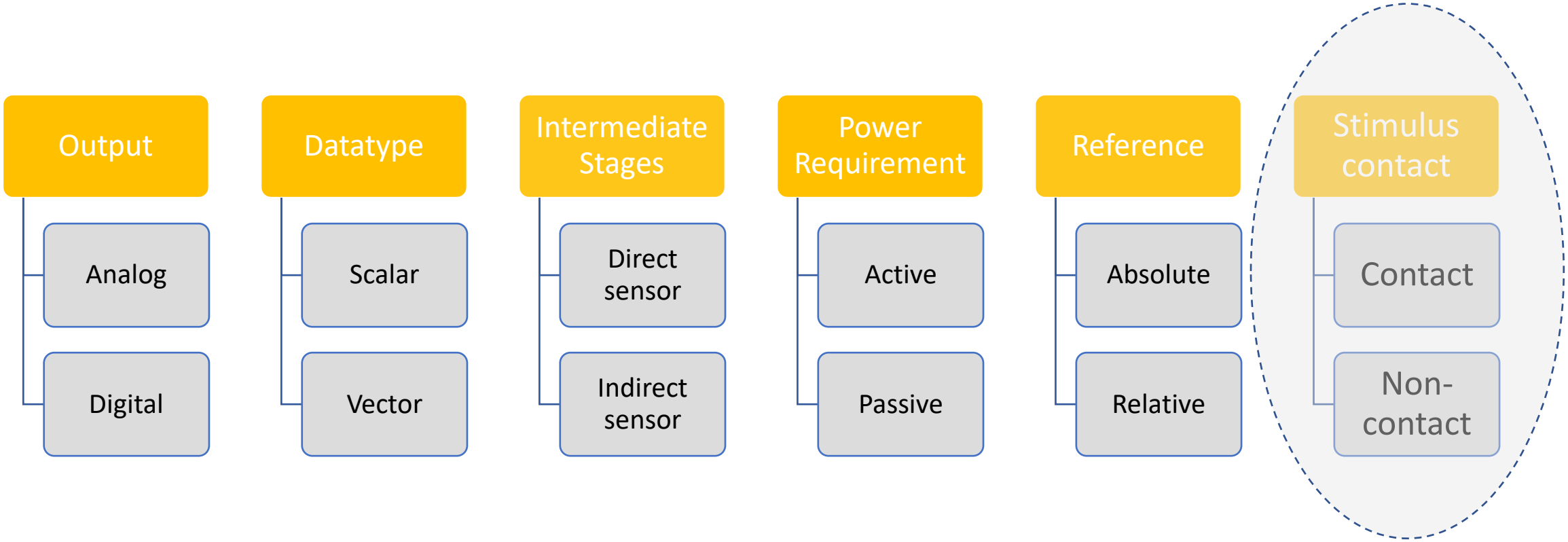


- Relative Sensor:
  Stimulus is sensed with respect to a fixed or variable reference that is not an absolute value independent of measurement conditions
  Example: Thermocouple



Lookup: Seebeck effect

Types of Sensors

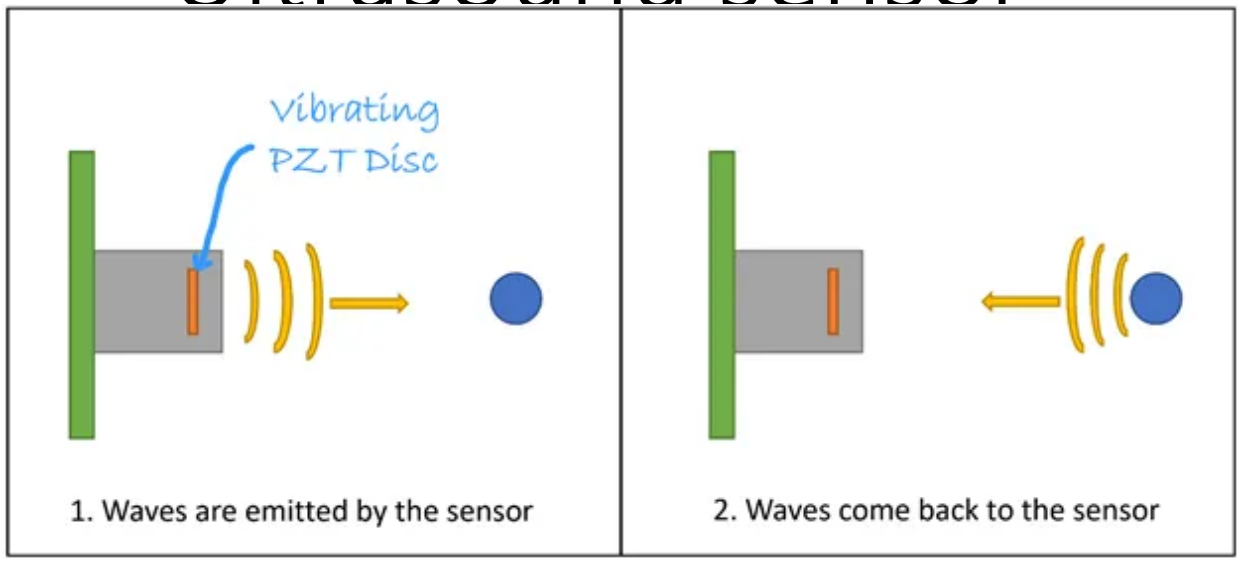


Types of Sensors

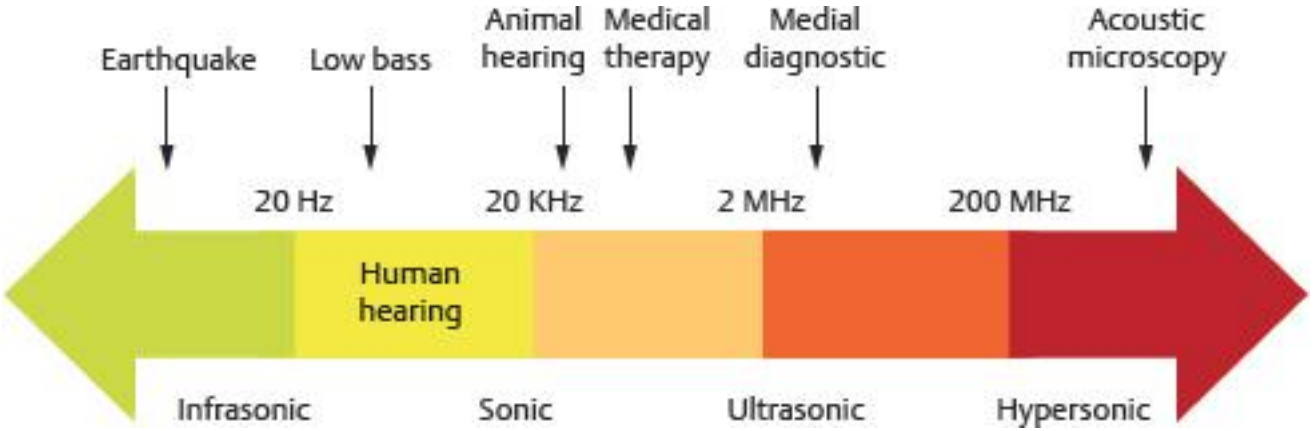
- Contact sensor:
  Requires physical contact with the stimulus
  Example: strain gauges, temperature sensors

- Non-contact sensor:
  Requires no physical contact
  Example: optical and magnetic sensors

Ultrasound sensor



- convert alternating current (AC) into ultrasound and vice versa
- piezoelectric transducers or capacitive transducers
- Piezoelectric crystals change their sizes and shapes in response to voltage being applied.
- capacitive transducers (example::microphone) use electrostatic fields between a conductive diaphragm and a backing plate



HC-SR04 Ultrasonic Sensor

- Ultrasound is high-pitched sound wave with inaudible frequencies – Frequency of over 20000 Hz
- Consists of 2 ultrasonic transducers – one acts as a transmitter and another as a receiver
- Transmitter converts electrical signal to 40 KHz ultrasonic sound pulses
- Receiver listens for the pulses and produces output pulses with width corresponding to distance
- Non contact range of 2 cm to 400 cm with an accuracy of 3 mm

HC-SR04 Ultrasonic Sensor

- Trig (Trigger): Pin to trigger ultrasonic sound pulses
- Echo: Output pulse produced at this pin when reflected signal is received

What is acoustic impedance? And what is its unit of measurement?

Outline

- Definitions
- **Sensor Classification**
- **Sensor Characteristics**
- **Sensor Working Principles**

Classification: Field of applications

Agriculture	Automotive	Civil engineering, construction	Domestic, appliances	Distribution, commerce, finance	Environment, meteorology, security
Energy, power	Information, telecommunication	Health, medicine	Marine	Manufacturing Recreation, toys	Military
	Space	Scientific measurement	Transportation (excluding automotive)	Other	

Classification : Stimuli

Stimulus	Stimulus	
Acoustic	*Mechanical*	Position (linear, angular)
Wave amplitude, phase		Acceleration
Spectrum polarization		Force
Wave velocity		Stress, pressure
Other		Strain
Biological		Mass, density
Biomass (types, concentration states)		Moment, torque
Other		Speed of flow, rate of mass transport
Chemical		Shape, roughness, orientation
Components (identities, concentration, states)		Stiffness, compliance
Other		Viscosity
Electric		Crystallinity, structural integrity
Charge, current		Other
Potential, voltage	*Radiation*	Type
Electric field (amplitude, phase, polarization, spectrum)		Energy
Conductivity		Intensity
Permittivity		Other
Other	*Thermal*	Temperature
Magnetic		Flux
Magnetic field (amplitude, phase, polarization, spectrum)		Specific heat
Magnetic flux		Thermal conductivity
Permeability		Other
Other		
Optical		
Wave amplitude, phase, polarization, spectrum		
Wave velocity		
Refractive index		
Emissivity, reflectivity, absorption		
Other		

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Classification : Sensing element material

- Inorganic/Organic
- Conductor /Insulator
- Semiconductor
- Liquid gas or plasma
- Biological substance
- Other….

Sensor Characteristics

Sensor specifications

- Sensitivity
- Stimulus range (span)
- Stability (short and long term)
- Resolution
- Accuracy
- Selectivity
- Speed of response
- Environmental conditions
- Overload characteristics
- Linearity
- Hysteresis
- Dead band
- Operating life
- Output format
- Cost, size, weight Other

https://www.signaguard.com/case-studies-in-bridge-health-monitoring/

Range and Span

- **Range**
  Minimum and Maximum value of a physical quantity that a sensor can measure
  Example: A Resistance Temperature Detector (RTD) for the measurement of temperature has a range of -200 to 800˚C

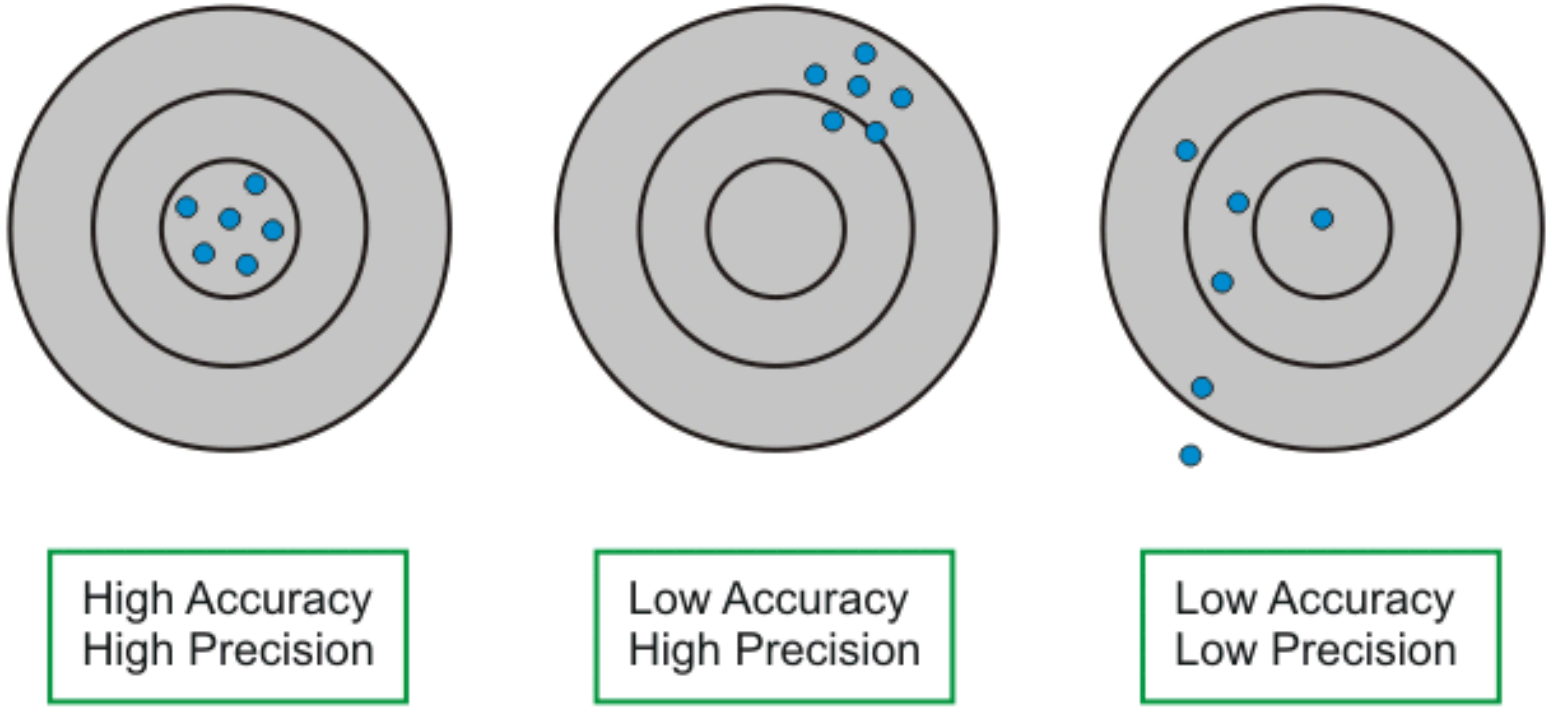
- **Span**
  Difference between maximum and minimum values of input measured
  In the above example, span of RTD = 800 – (-200) = 1000˚C

Accuracy and Resolution

- **Accuracy** is the capacity of a sensor to give results close to the **TRUE VALUE** of the measured quantity
  - Measured by absolute and relative errors
    ABSOLUTE ERROR = RESULT – TRUE VALUE (measured value to a known absolute true value)
    RELATIVE ERROR = ABSOLUTE ERROR / TRUE VALUE (how close is the value to a standard value in relative terms)
- **Resolution** is the minimal change of the input necessary to produce a detectable change at the output

Precision

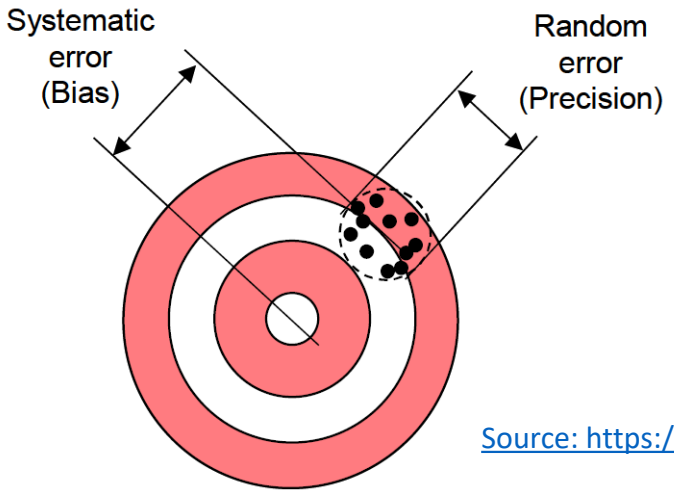
- Capacity of a sensor to give same reading when repetitively measuring the same quantity under the same prescribed conditions



Source: https://www.electrical4u.com/characteristics-of-sensors/

Errors

- Systematic Errors
  Due to interfering or modifying variables (e.g., temperature), loading, attenuation, etc.
- Random Errors
  A signal that carries no information such as environmental noise



Source: https://www.philadelphia.edu.jo/academics/kaubaidy/uploads/Sensor-Lect2.pdf

Specifications

- Power Supply: DC 5V
- Working Current: 15mA
- Working Frequency: 40Hz
- Ranging Distance : 2cm – 400cm/4m
- Resolution : 0.3 cm
- Measuring Angle: 15 degree
- Trigger Input Pulse width: 10uS
- Dimension: 45mm x 20mm x 15mm

Specifications

- Power Supply: 3.3V – 5V
- Operating Current: 8mA
- Working Frequency: 40Hz
- Ranging Distance : 3cm – 350cm/3.5m
- Resolution : 1 cm
- Measuring Angle: 15 degree
- Trigger Input Pulse width: 10uS TTL
- Dimension: 50mm x 25mm x 16mm