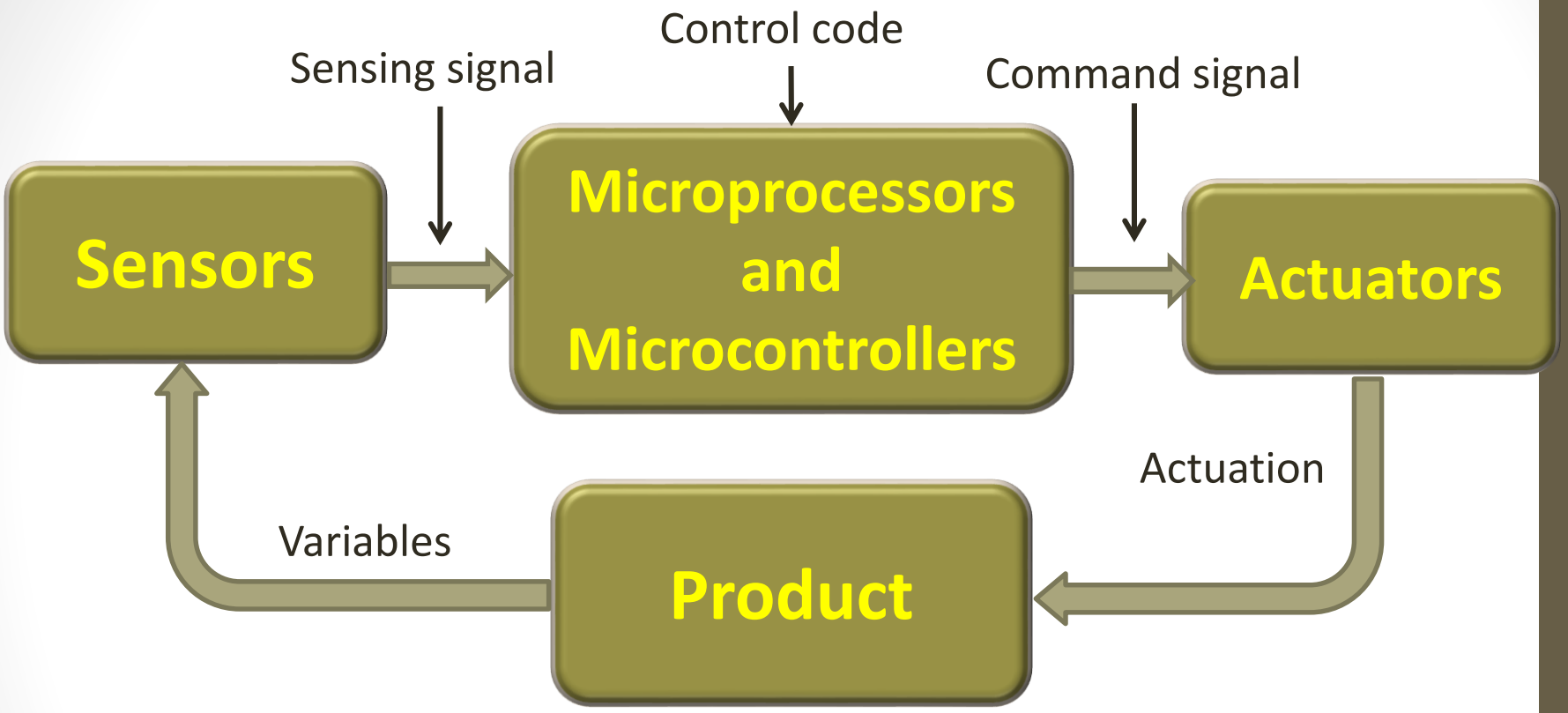
MKT 1121
Chapter-4

Mechatronics Technology Sensors

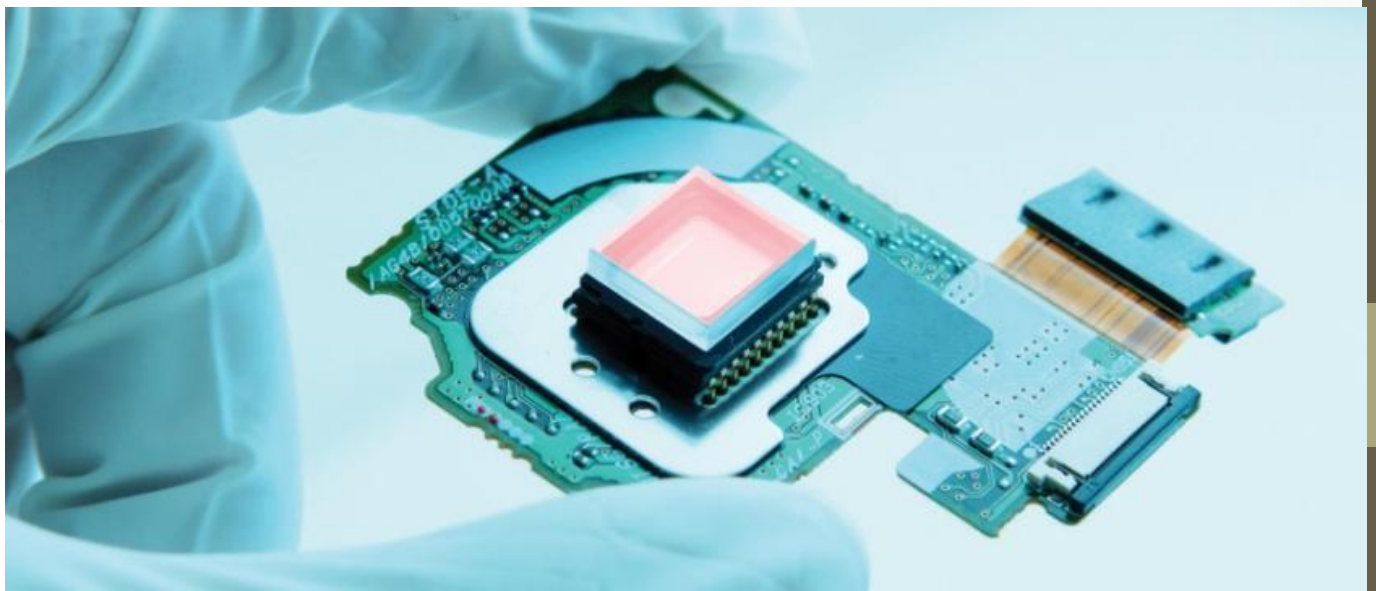
Mechatronic System



(Robot, Autonomous Guided vehicle, Numerical Controlled Machine, Vehicle engines, Consumer products, Conveyor systems, Assembly systems, Cranes, Defense equipment, Air craft engines, etc)

What is a SENSOR ?

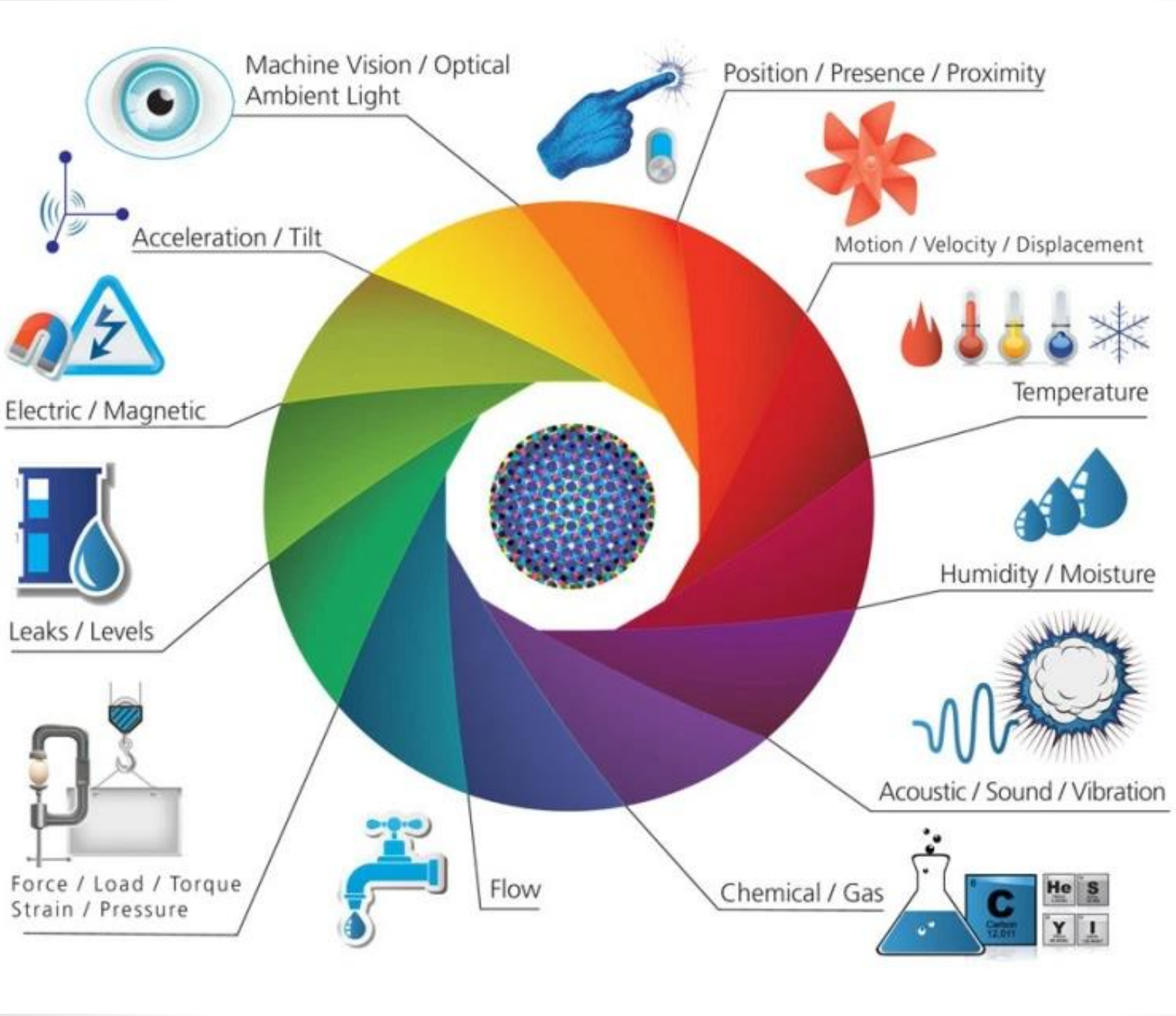
It is a device that detects a change in a physical stimulus and turns it into a signal which can be measured or recorded.



Sensors measure changes in physical quantities, **(Input).**

The changes occur in response to some excitation, for example heat or force and convert that into an electrical signal.

They perform an "**Output**" function are used to control some external device.


Machine Vision / Optical
Ambient Light
Position / Presence / Proximity
Acceleration / Tilt
Motion / Velocity / Displacement
Electric / Magnetic
Temperature
Leaks / Levels
Humidity / Moisture
Acoustic / Sound / Vibration
Force / Load / Torque
Strain / Pressure
Flow
Chemical / Gas

SENSORS

Role of a sensor

- **Detection**: detect the presence of an external phenomenon
- **Selection**: select or filter out a single property of the external stimulus
- **Signal Processing**: amplitude, power modulation, linearization, ADC conversion etc.
- **Communication**: pass the signal to the destination (control system, recording system, user)

Digital Sensors

Button

Bumper Switch Sensor

Lever

Limit Switch Sensor

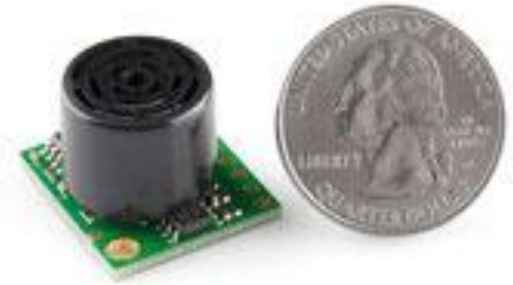
Ultrasonic sensor

Motion

Analog Sensors

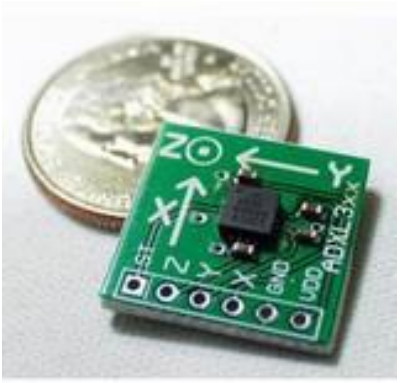
Proximity sensors

Proximity sensors measure the distance from the sensor to an obstructing object in front of the sensor. There are two types, Infrared and Sonar



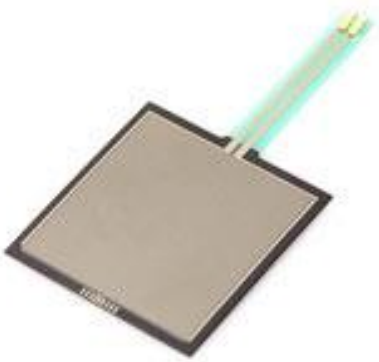
Accelerometers

Accelerometers sense motion and are used to detect changes in position, tilt, and orientation



Pressure sensors

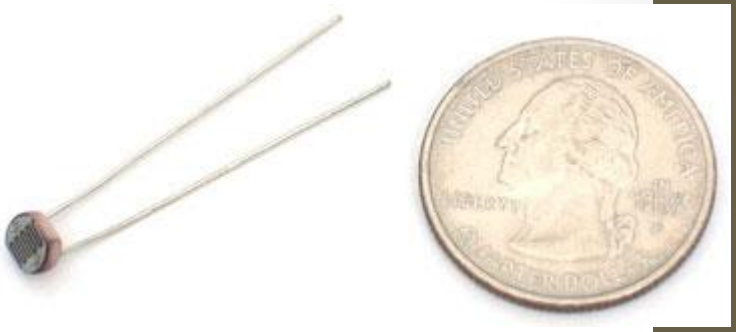
Measure the amount of pressure, for example of a finger press, or the weight of someone standing on a surface



Analog Sensors

Light sensors

Detect the amount of light striking the sensor, which is called a photocell, photoresistor,



Temperature sensors

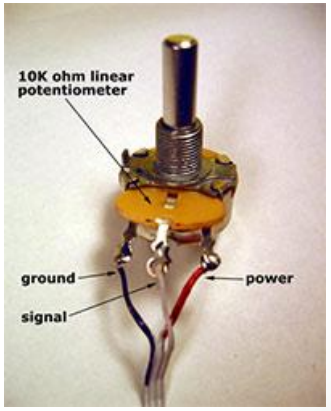
measure the air temperature in Fahrenheit or Celsius.

Ribbon sensors

Measure the position of a finger touch across a surface

Potentiometers

Measure rotation or linear travel, and are used in car stereos, dimmers, equalizers, etc



Factors in Selecting Sensors

- Phenomena sensed
- Operating distance
- Invasiveness (measurement/measurand)
- Form of output signal
- Performance characteristics
- Ergonomic factors
- Economic factors
- …

Phenomena Sensed

- Position, dimension: liquid level, area, volume
- Proximity: range or binary
- Static mechanical: mass, pressure, torque…
- Dynamic mechanical: velocity, flow rate…
- Thermal: temperature
- …

Operating Distance

- Why not sense it at the source?
  - Physically impossible
  - Hazardous
  - ???
- What changes with distance?
  - Noise
  - Signal strength
  - ???
- EX: bar code reader

Invasiveness

- Measurement might interact with the value of the measurand

- Measurand can alter the quality of measurement

Form of Output Signal

- Binary Output

  Single bit: ON or OFF, 1 or 0, Detected or NOT Detected etc.

  Multiple bits: 01101101

  - Series
  - Parallel

- Analog Output

Performance Characteristics

- Linearity
- Range of operational accuracy
- Repeatability
- Reliability
- ???

Other Factors

- Cost
- Packing
- Ease of installation and repairing
- ???

Categorization

- Sensors can be categorized based on several factors most of which contribute to the selection of them
  - Phenomena sensed, invasiveness, etc.
- Active vs. Passive Sensors

Active vs. Passive Sensors

- **Active**: inject energy to the environment in order to measure the desired phenomenon
  - Range measurement: ultrasonic, later, IR
- **Passive**: use the energy present in the environment
  - Light intensity and temperature measurement

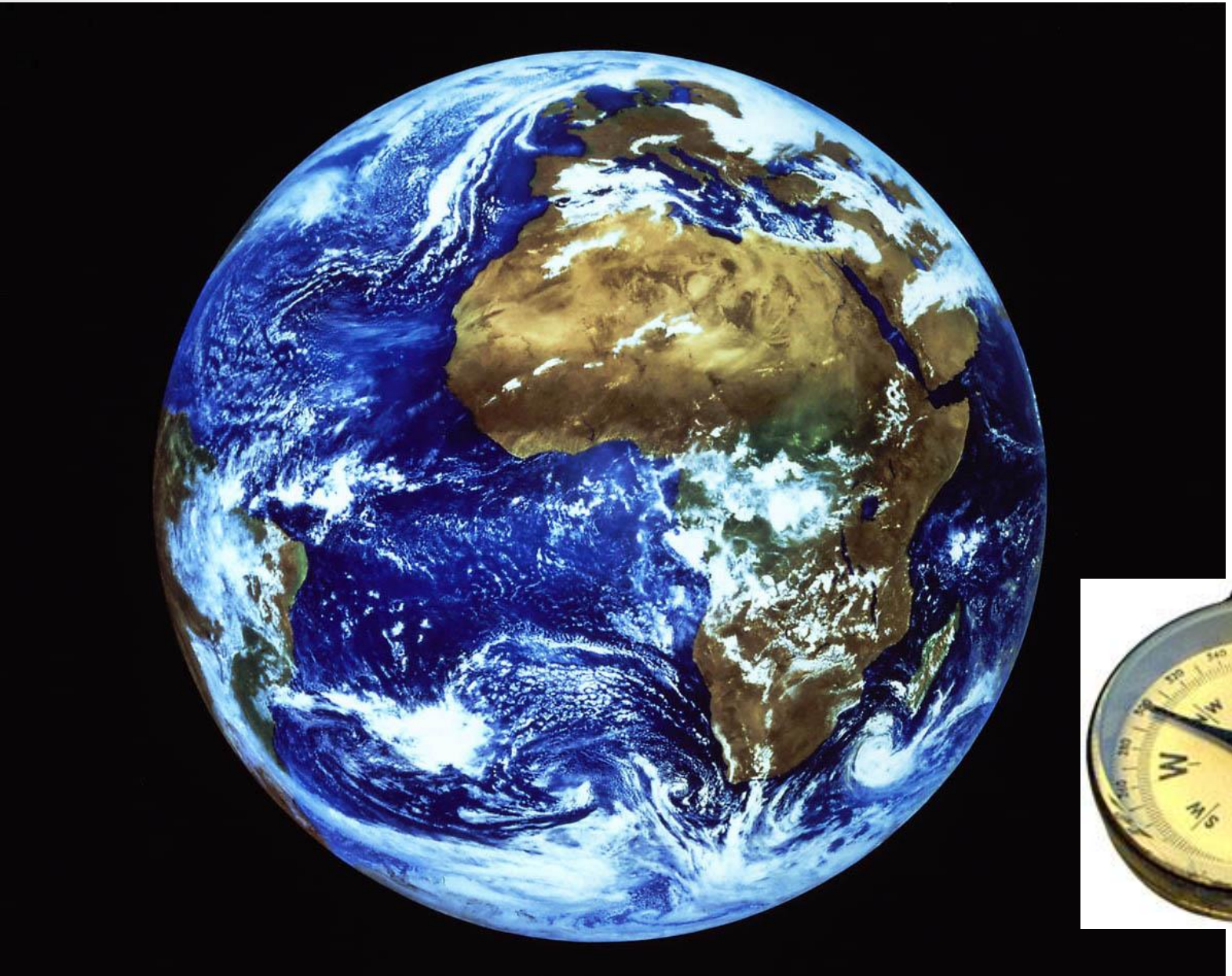

FUJINON ASPHERICAL LENS
SUPER EBC f=23mm 1:2

?

•Cameras are ***active sensors*** when the photographer uses flash. It illuminates its target and measures the reflecting energy back to the camera.

•Cameras are ***passive sensors*** when the photographer does not use the flash. Because the camera is not sending the source of light, it uses naturally emitted light from the sun.

Compass



Passive Sensors

- Thermometer, thermocouple…
- Proximity Switch,
- Light intensity, Cameras …
- Accelerometer, gyro
- Compass
- ???

Active Sensors

- Range finders: Ultrasonic, laser, IR
- Retina Scanners
- MR: Magnetic Resonance
- ???

Transducers

- Transducer: a device, as a microphone, that converts a signal from one form of energy to another.

- Both sensors and actuators can be perceived as transducers

- Common use is Transducer → Sensor

Transducer

Antenna: elektromagnetic wave <--> electric current

Lamp: electrical energy --> visible light

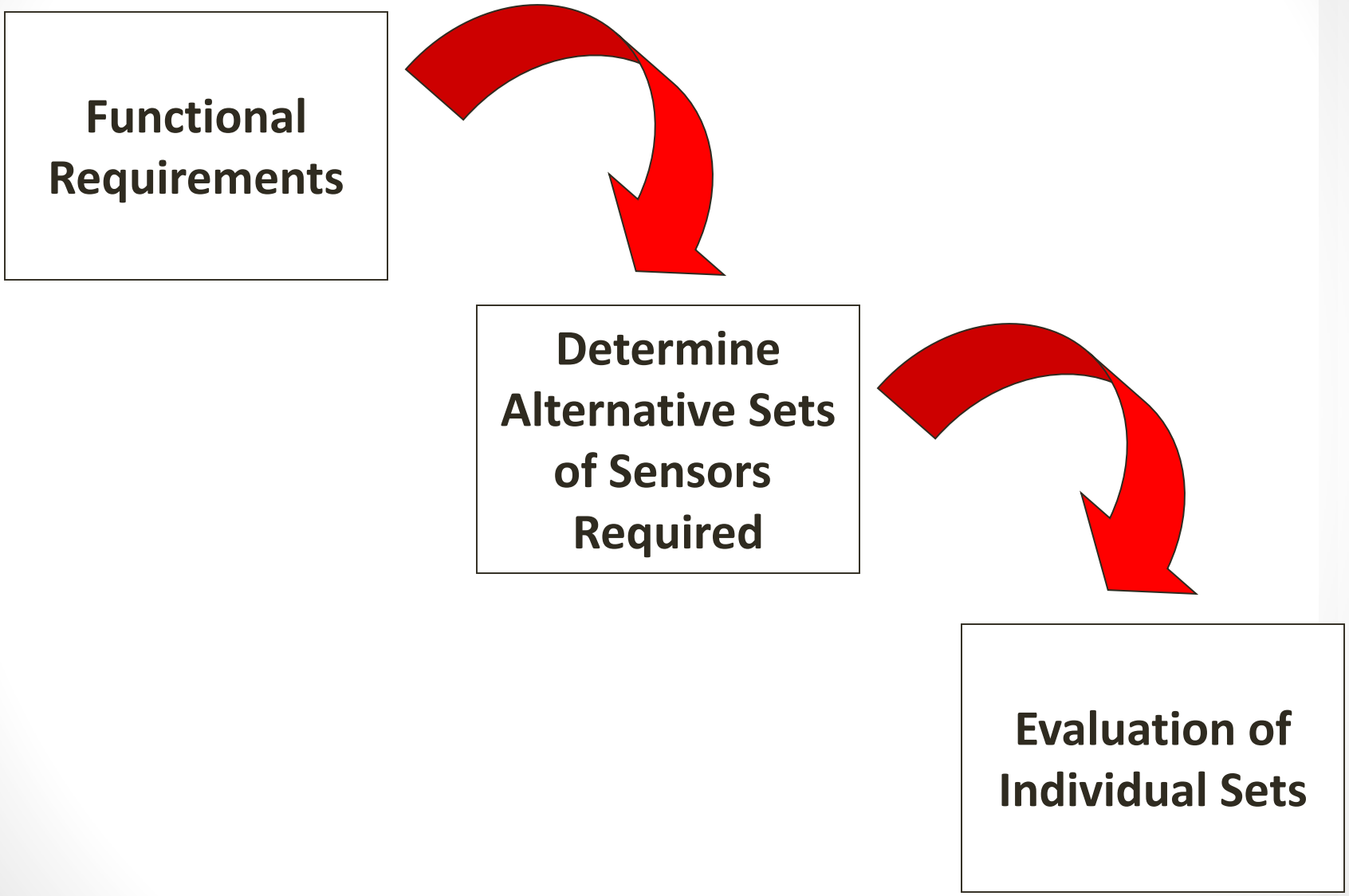
Magnetic reader head: Magnetic fields --> electrical energy

Hall effect sensor: Magnetic field level --> electrical energy

Microphone: sound (air pressure->coil displacement) --> electric current

Speaker: electric current --> sound (coil displacement --> air pressure)

Determining the Sensors Needed



Proximity sensor comparison

Technology	Sensing range	Applications	Target materials
Inductive 	<4-40 mm	Any close-range detection of ferrous material	Iron Steel Aluminum Copper etc. 
Capacitative 	<3-60 mm	Close-range detection of non-ferrous material	Liquids Wood Granulates Plastic Glass etc. 
Photoelectric 	<1mm- 60 mm	Long-range, smalll or large target detection	Silicon Plastic Paper Metal etc. 
Ultrasonic 	<30 mm- 3 mm	Long-range detection of targets with difficult surface properites. Color/reflectivity insensitive.	Cellophane Foam Glass Liquid Powder etc. 

Performance and Terminology

1. Range / Span
2. Errors and Accuracy
3. Nonlinearity
4. Hysteresis
5. Dead band and Saturation
6. Output impedance
7. Repeatability
8. Sensitvity
9. Resolution
10. Frequency Response
11. Response time
12. Calibration

Range and Span (Example)

Span: The arithmetic difference between the highest and lowest values of the input that being sensed.

Range: Lowest and highest values of the stimulus

Input full scale (IFS) = Span

Output full scale (OFS): Difference between the upper and lower ranges of the output of the sensor.

Range and Span (Example)

- Example: a sensors is designed for: −30 °C to +80 °C to output 2.5V to 1.2V

- Range: −30°C and +80 °C

- Span: 80 − (−30)=110 ° C

- Input full scale = 110 ° C

- Output full scale = 2.5V-1.2V=1.3V

Errors and Accuracy

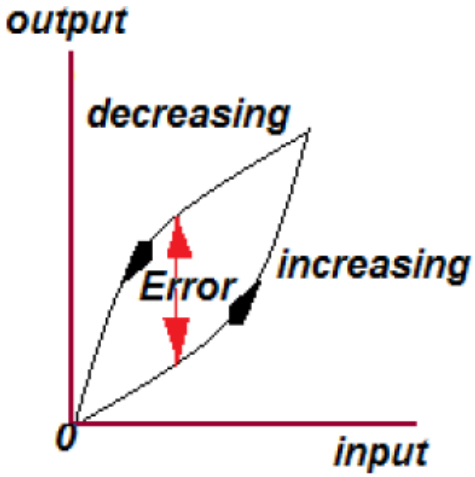
- **Error:** It is the difference between the result of the measurement and the true value of the quantity being measured error= measured value –true value

- **Accuracy:** Accuracy can be defined as the amount of uncertainty in a measurement with respect to an absolute standard. Accuracy specifications usually contain the effect of errors due to gain and offset parameters.

200 mV measurement on a ±1 volt single-ended range
Temperature = 25 °C
Resolution = 2 V ÷ 2^{16} = 30.5 µV
Sensitivity = 30.5 µV × 1.36 LSB rms = 41.5 µV rms
Gain Error = 0.024% × 200 mV = ±48 µV
Offset Error = ±245 µV
Linearity Error = 0.0076% of range = 76 µV
Total Error = 48 µV + 245 µV + 76 µV = 369 µV

Therefore a 200 mV reading could fall within a range of 199.631 mV to 200.369 mV.

Hysteresis



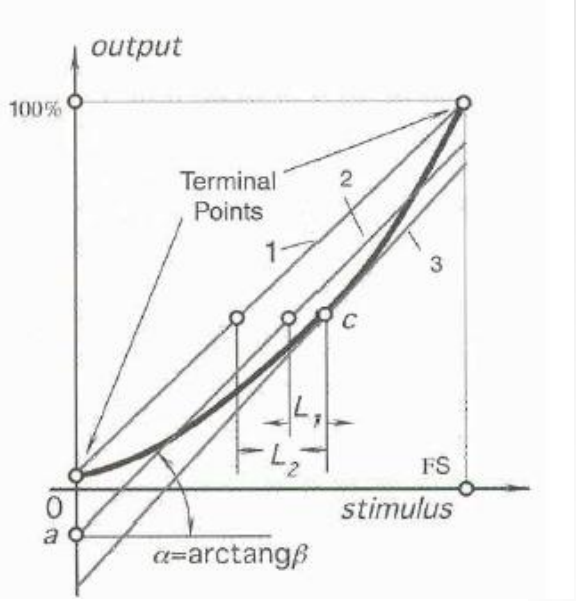
• Hysteresis is the deviation of the sensor's output at any given point when approached from two different directions

• Caused by electrical or mechanical systems – Magnetization – Thermal properties – Loose linkages

• If temperature is measured, at a rated temperature of 50 °C, the output might be 4.95V when temperature increases but 5.05V when temperature decreases.

• This is an error of ±0.5% (for an output full scale of 10V in this idealized example).

Nonlinearity



• Nonlinearity is defined as the maximum deviation from the ideal linear transfer function.

• Nonlinearity must be deduced from the actual transfer Function or from the calibration curve

• A few methods to do so:

• a. by use of the range of the sensor
– Pass a straight line between the range points (line 1)

• b. use a linear best fit (least squares) through the points of the curve (line 2)

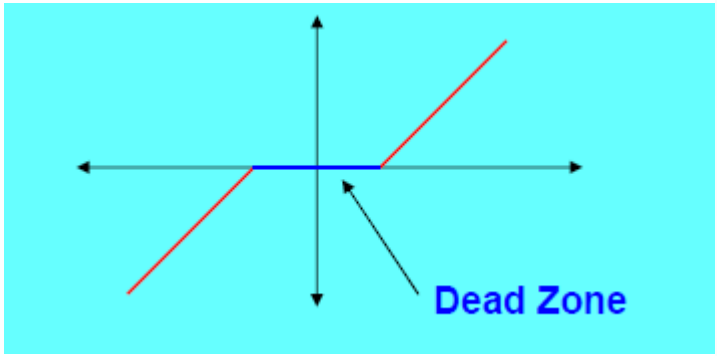
• c. use the tangent to the curve at some point on the curve
Take a point in the middle of the range of interest
-Draw the tangent and extend to the range of the curve (line 3)

Deadband

• **Deadband**: the lack of response or insensitivity of a device over a specific range of the input.

• In this range which may be small, the output remains constant.

• A device should not operate in this range unless this insensitivity is acceptable.



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