SENSORS: Types and Characteristics

Academic Resource Center

I- Physical Measurements as input (Measurement Units)

Physical Quantity	Name	Symbol	English or other
Length	Meter	m	feet , yard or mile
Mass	Kilogram	kg	lbm, slug or ton
Time	Second	S	
Electric current	Ampere	A	
Temperature	Kelvin	K	Rankine, Fahreinheit, or Celcius
Amount of substance	Mole	mol	
Luminous intensity	candela	Cd	violle

Acceleration	Name	Symbol
Acceleration	m/s^2	m/s^2
Area	m^2	m^2
Capacitance	Farad	F=[s^4.A^2]/[m^2.kg]
Force	Newton	N=[kg.m/s^2]
Power	Watt	W=[kg.m^2/s^3]
Pressure	Pascal	Pa=[kg/m.s^2]
Speed	m/s	m/s
Voltage	Volt	V=[kg.m^2/A.s^3]
Energy	Joule	J=[kg.m^2/s^2]

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II-Characteristics of different types of sensors

a) **Active vs. Passive**: Does sensor draw energy from the signal ?

b) **Digital vs. Analog**: Is the signal discrete or continuous?

c) **Null and deflection methods**

d) **Input – Output configuration**

Active vs. Passive Sensors

- 1) **Active sensors**: Require an external source of power (excitation voltage) that provides the majority of the output power of the signal
- 2) **Passive sensors**: The output power is almost entirely provided by the measured signal without an excitation voltage

Digital vs. Analog Sensors

- 1) **Digital sensors**: The signal produced or reflected by the sensor is binary
- 2) **Analog sensors**: The signal produced by the sensor is continuous and proportional to the measurand

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Null and Deflection Methods

- 1) **Deflection**: The signal produces some physical (deflection) effect closely related to the measured quantity and transduced to be observable.
- 2) **Null**: The signal produced by the sensor is counteracted to minimize the deflection. That opposing effect necessary to maintain a zero deflection should be proportional to the signal of the measurand

Input-Output Configuration

- 1) Method of inherent insensitivity: Use whenever possible
- 2) Method of high gain feedback:
- 3) Method of calculated output corrections
- 4) Method of signal filtering
- 5) Method of opposing inputs

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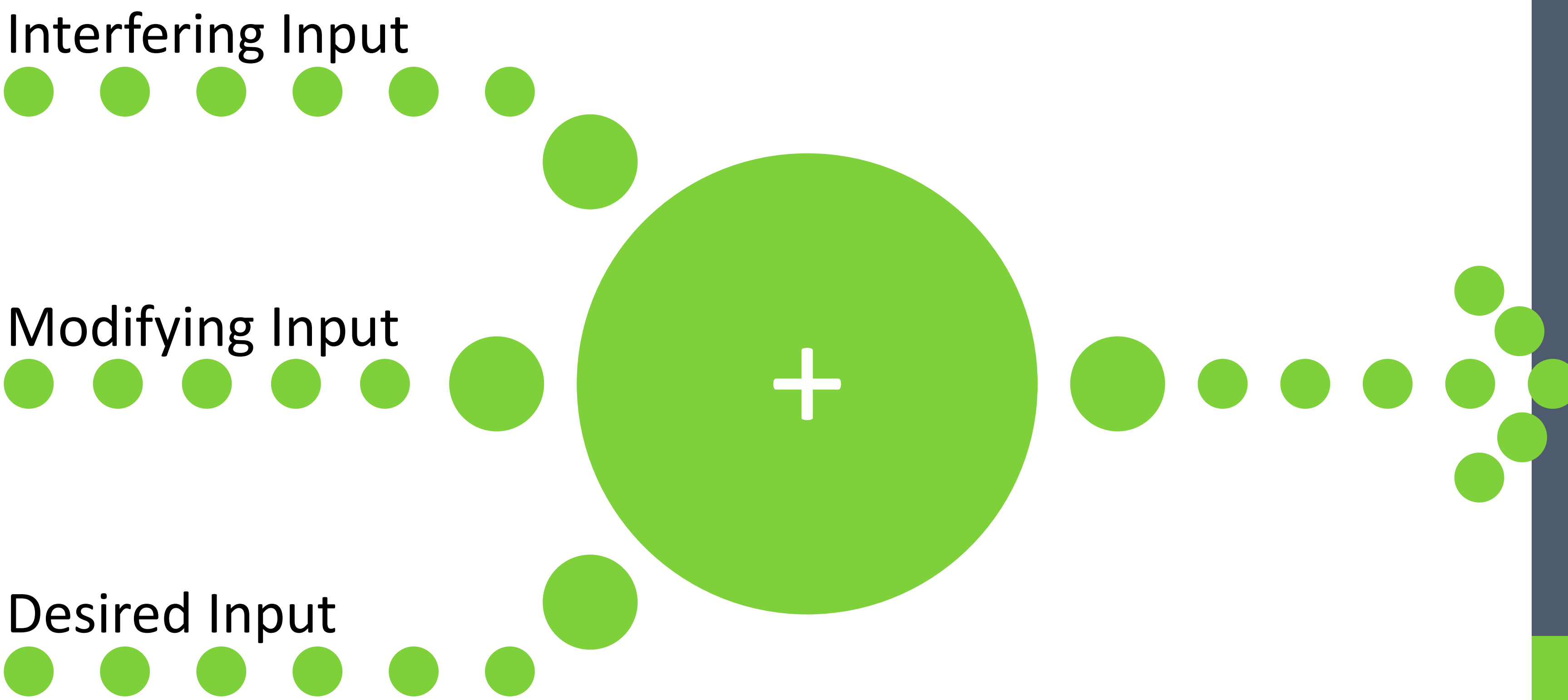

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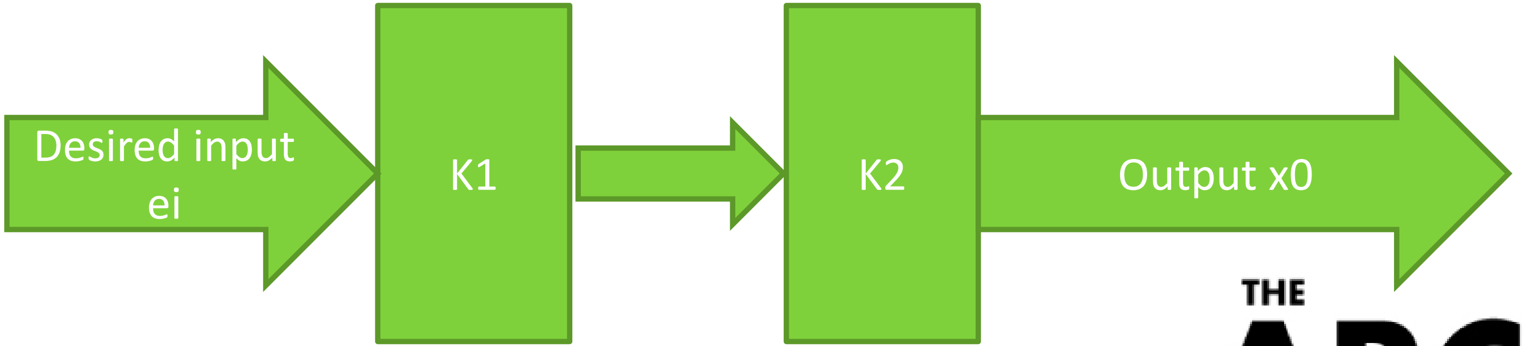
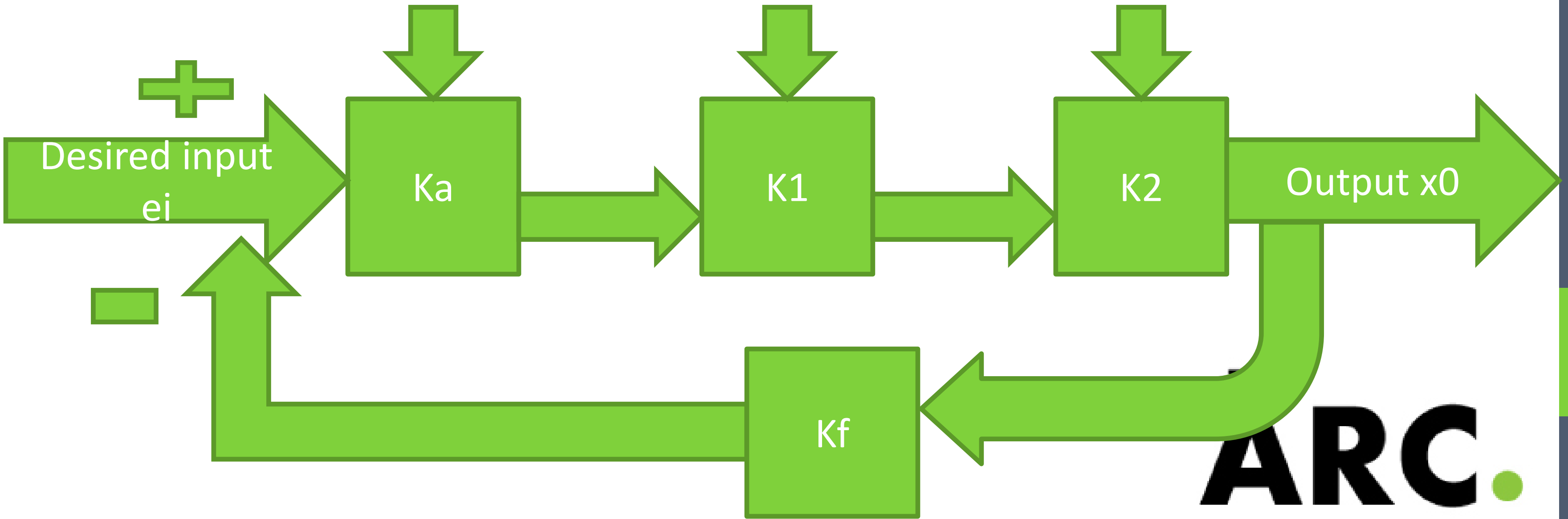
- **Interfering Input:** Quantities to which the Instrument is unintentionally sensitive
- **Modifying Input**: Quantities that cause a change in the input – output relations of the instrument
- **Examples are**: Temperature, atmospheric pressure, magnetic fields, humidity, etc.

- **Method of high gain feedback**
  - Open loop system
  - x0= (K1.K2).ei
  - Any modification to K1 or K2 will affect the response of changing the desired output

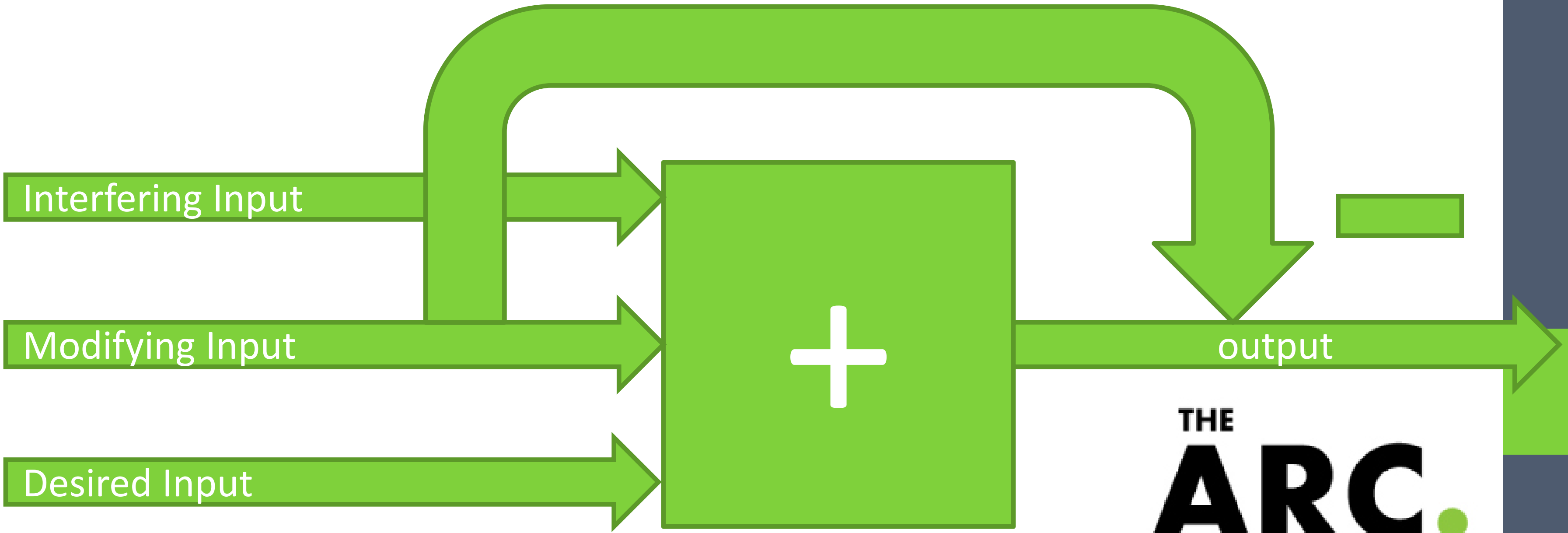


- Closed loop system
- x0 = [(KaK1K2)/(1+KaK1K2Kf)].ei
- If Ka is very large “high gain”, then Ka.K1.K2.Kf >> 1
- x0= [1/Kf].ei
- Kaf is not affected by the undesired inputs like K1 and K2

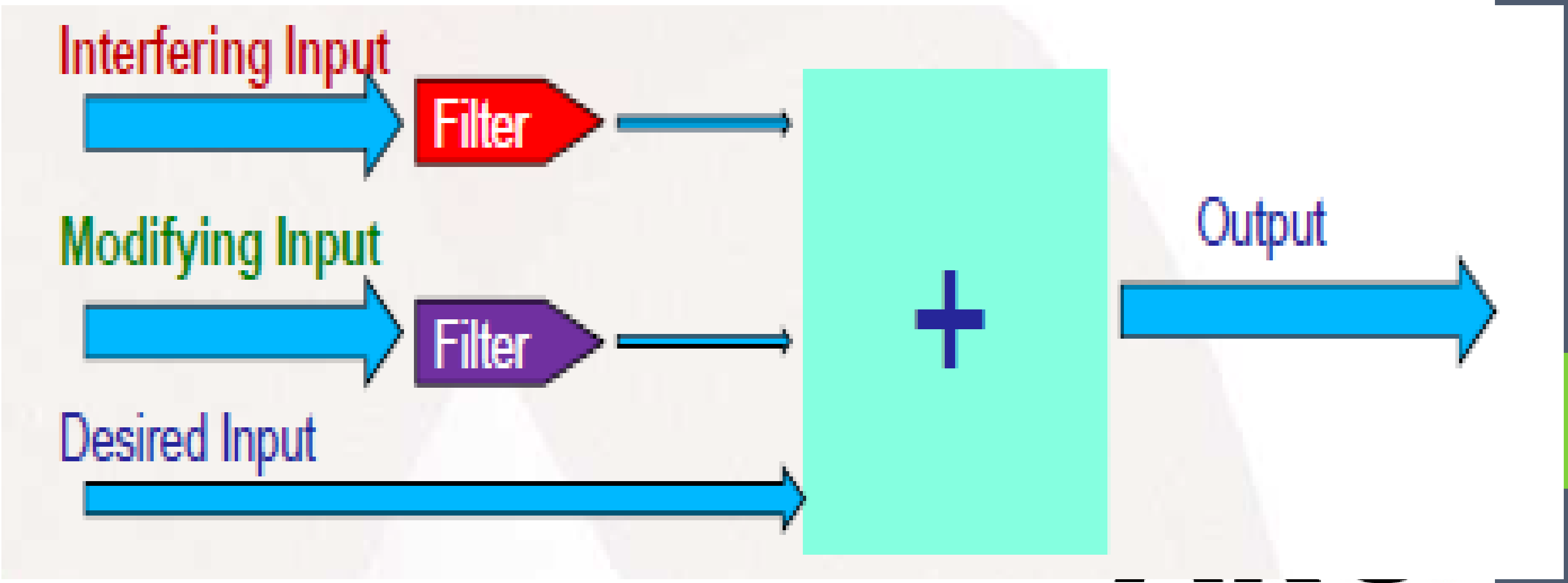


- **Ka:** Modifying Input A
- **K1:** Modifying Input 1
- **K2:** Modifying Input 2
- **Kf:** Modifying Input F

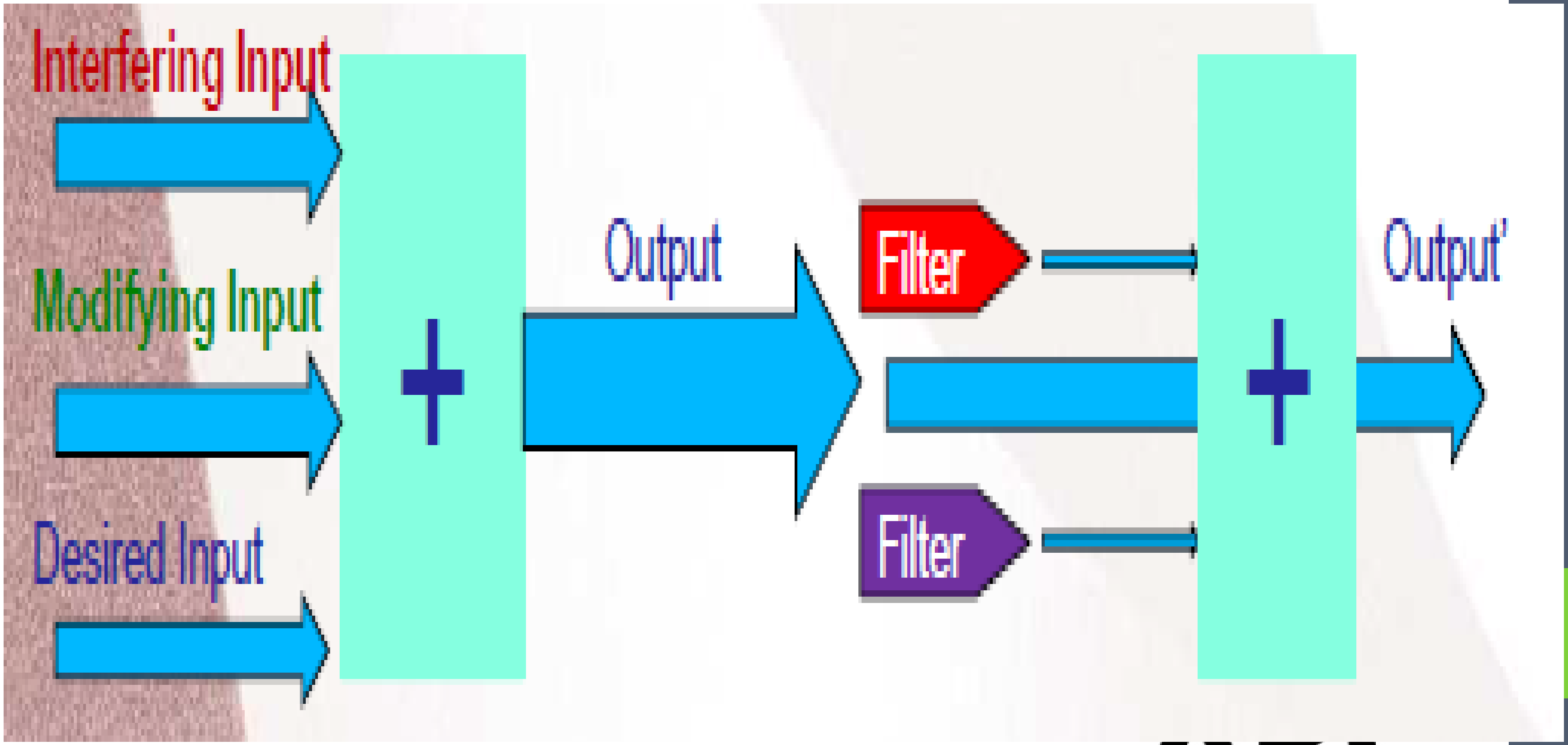
- **Method of calculated output corrections:** measure or estimate the magnitudes of the interfering or modifying input and subtract from signal to calculate the correct output

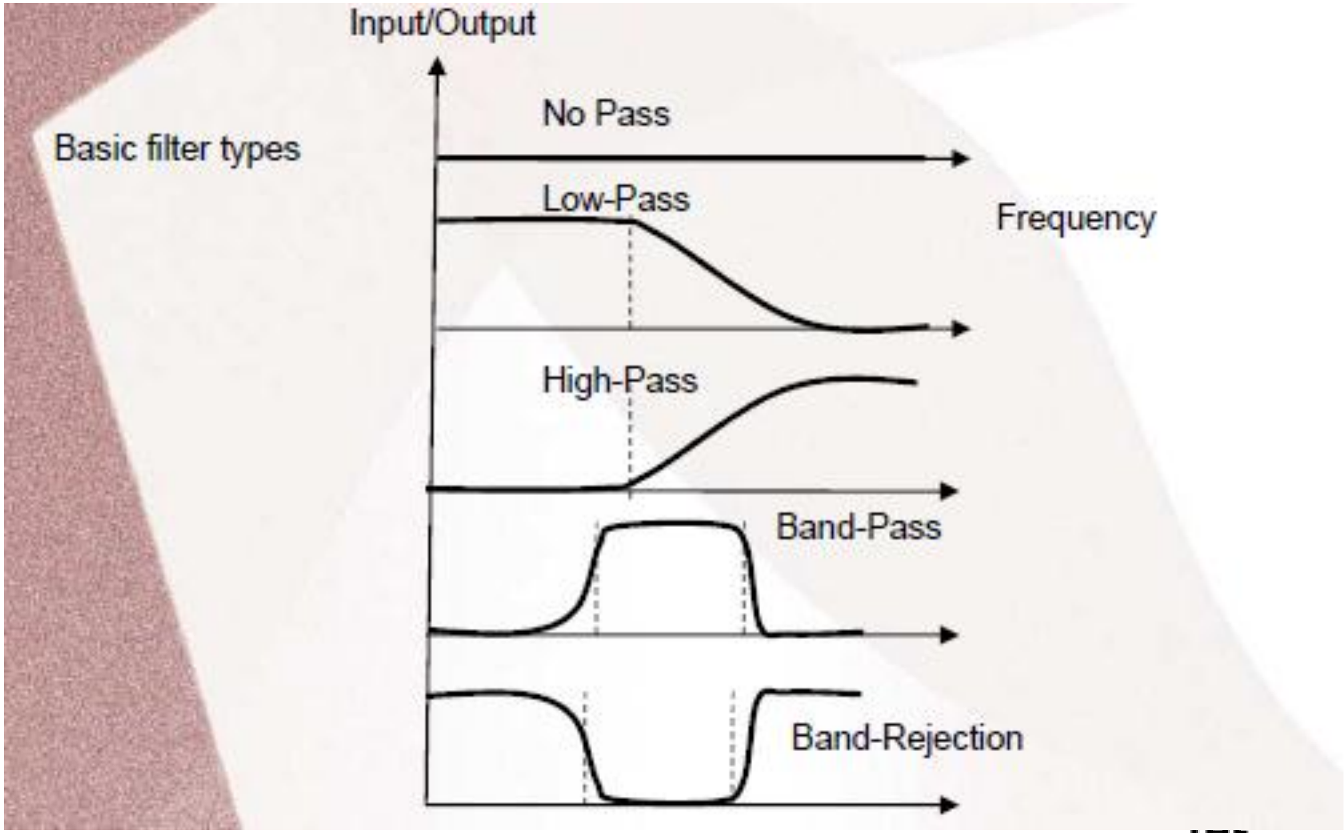


- **Method of signal filtering:** Introduce elements into the instrument to block or reduce the interfering or modifying inputs
  - Input Filtering:



- Output Filtering:




Input/Output
Basic filter types
No Pass
Low-Pass
Frequency
High-Pass
Band-Pass
Band-Rejection

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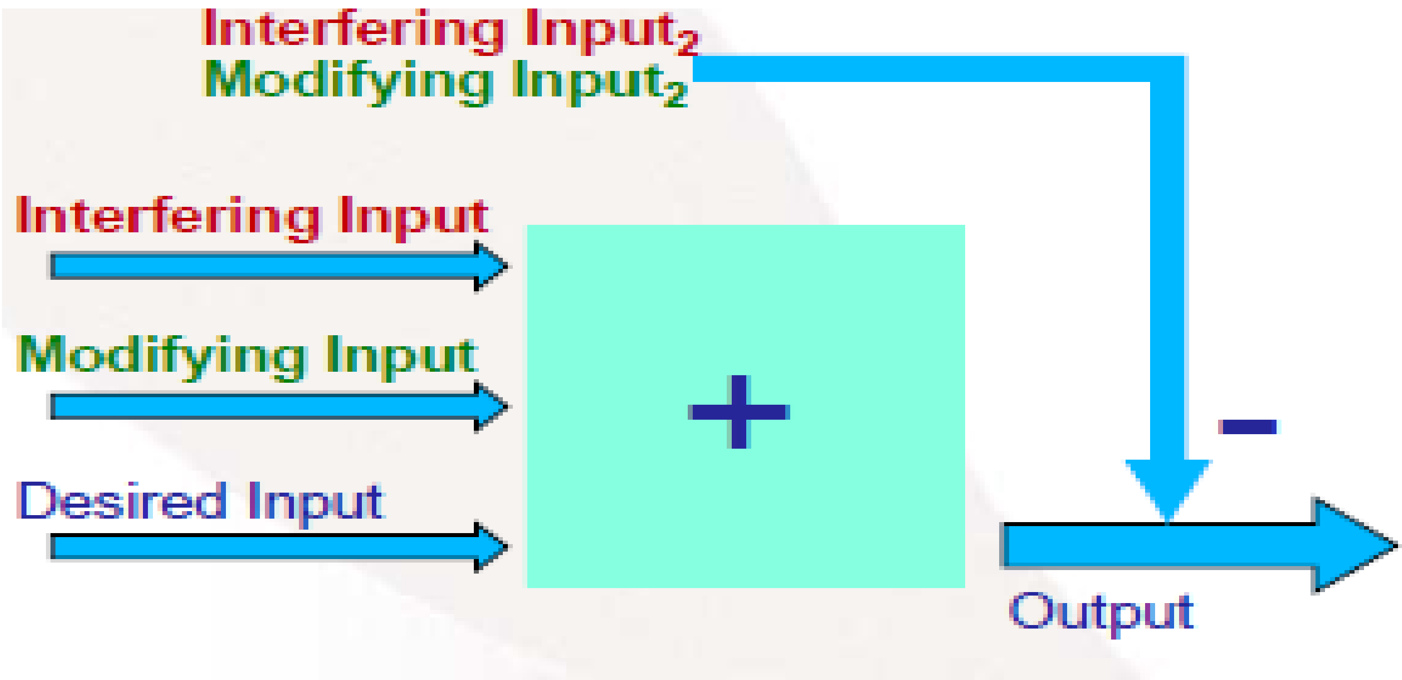
- **Method of opposing inputs**: Intentionally introduce interfering or modifying inputs to cancel the undesired effects of other interfering inputs



Sensors and their principles of operation

- The purpose of a sensor is to detect a physical quantity and translate it into a signal through a relationship of the type:

$$I_{out} = f(I_{in})$$

- The sensitivity is defined

$$\eta = \frac{dI_{out}}{dI_{in}}$$

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- **Variable resistance transducer elements:**

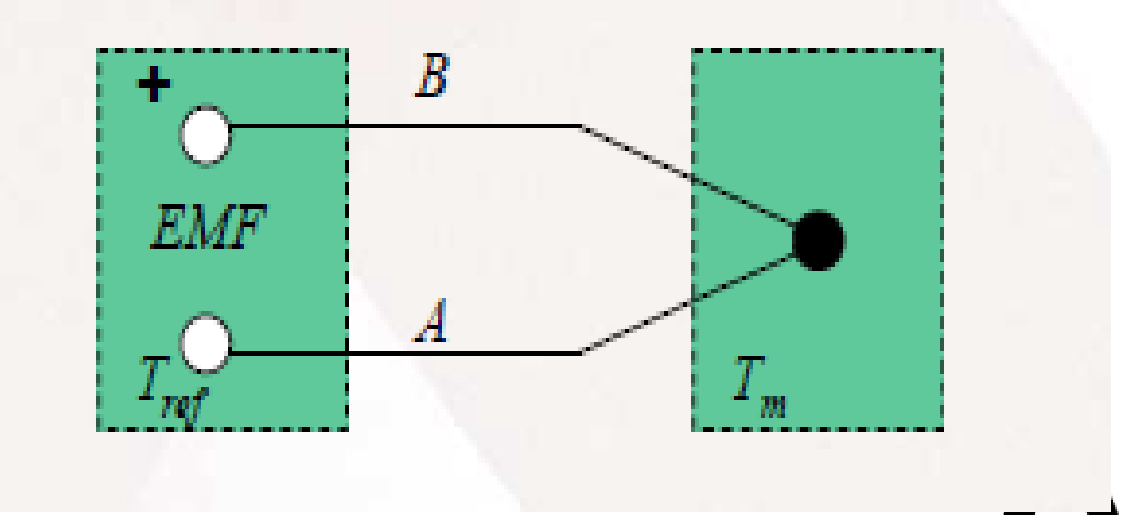
$$R = \frac{\rho L}{A}$$

- Sliding contact
- Potentiometer
- Strain gages
- Thermistors
- Photoconductive light detectors
- Piezo-resistive strain gages
- Resistance temperature detectors

- **Thermocouples:**

- When two dissimilar materials come in contact an EMF is generated, the magnitude of the EMF is dependent on temperature. (Seebeck Effect)

$$\varepsilon_{AB}(T_m) - \varepsilon_{AB}(T_{ref}) = EMF$$



- **Variable inductance transducers**

$$L = \frac{\mu_0 n^2 A_a}{h_a}$$

Inductance
DC circuits

$$X_L = 2\pi f L$$

Reactance
AC circuits

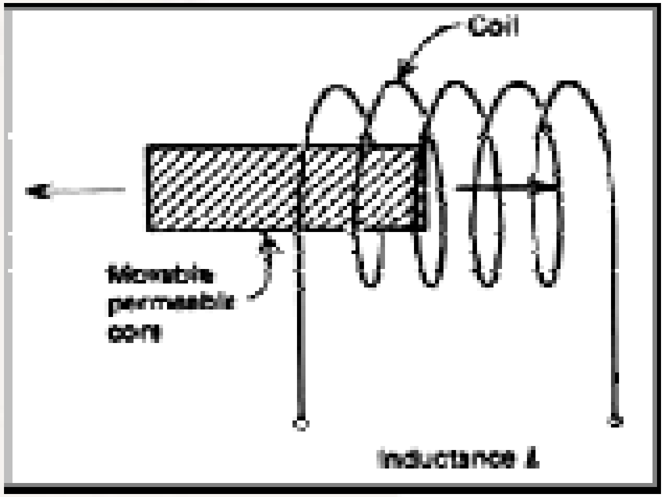
$$Z = \sqrt{X_L^2 + R^2}$$

Impedance

- **Variable reluctance transducer:**

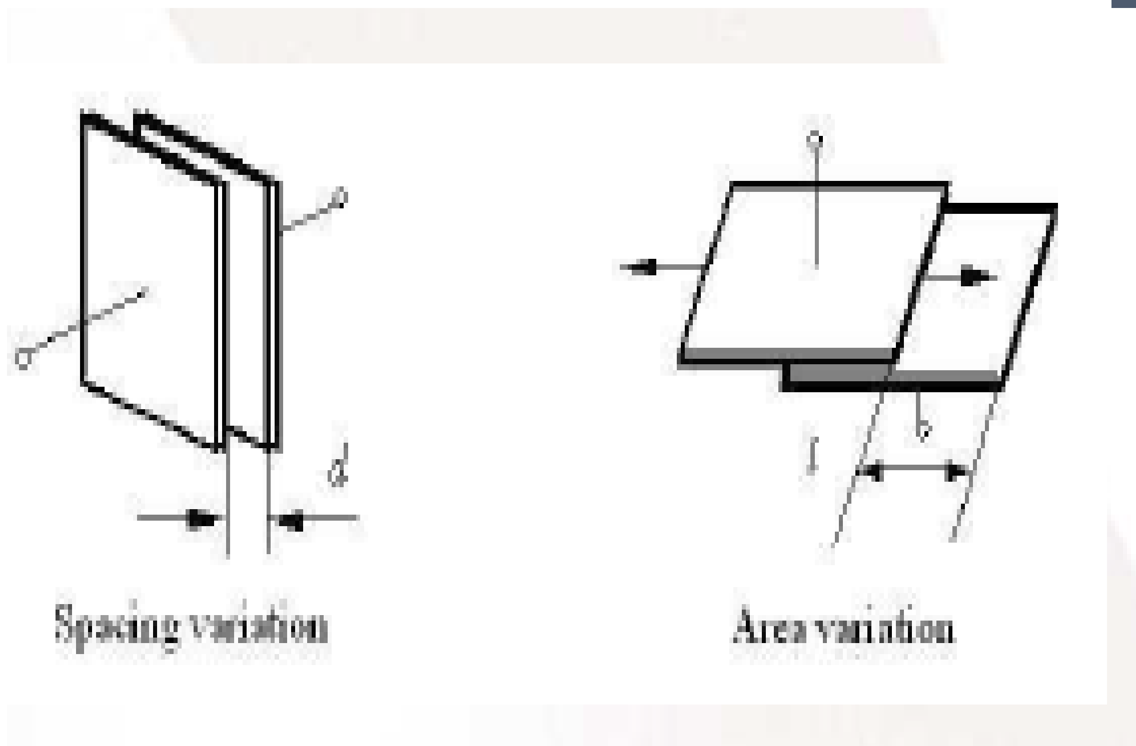
$$V = -n\frac{d\Phi}{dt}$$

- Inductance device with a permanent magnet to produce V

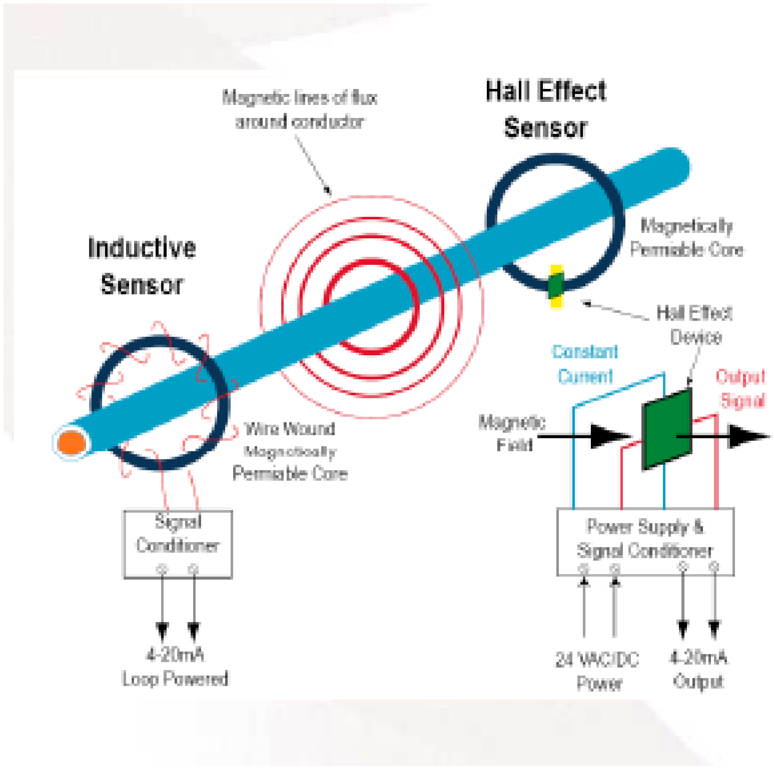


- **Capacitance transducer**

$$C = \frac{\varepsilon_0 K A}{d}$$



- **Other sensors:**
  - Piezoelectric sensors
  - Semiconductors sensors
  - Pn-junctions
  - Photodiodes
  - Photon detectors
  - Hall-effect sensor


Magnetic lines of flux around conductor
Hall Effect Sensor
Inductive Sensor
Magnetically Permiable Core
Hall Effect Device
Constant Current
Output Signal
Magnetic Field
Wire Wound Magnetically Permiable Core
Signal Conditioner
Power Supply & Signal Conditioner
4-20mA Loop Powered
24 VAC/DC Power
4-20mA Output

REFERENCES

Dr. Jose Garcia Lecture 2 MMAE 415: Aerospace Laboratory II
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