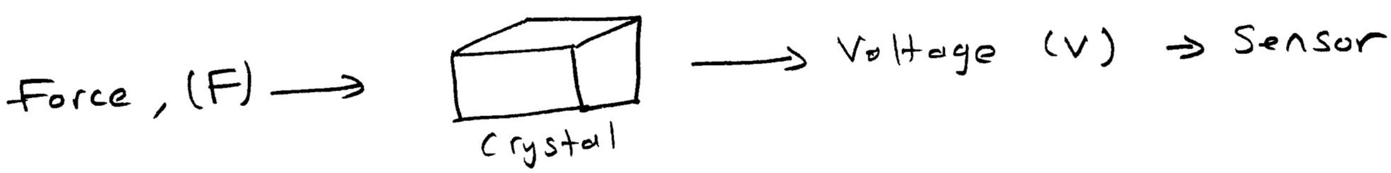
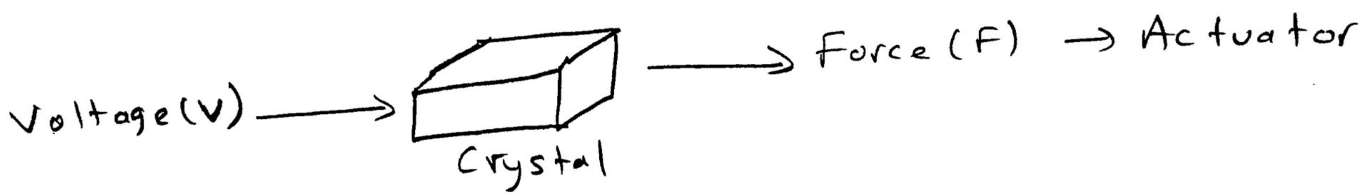
- SENSORS AND MEASUREMENTS -

- A sensor takes a physical quantity and converts it into a usable signal.
- An Actuator converts signal into a physical quantity

Piezoelectric Effect





Types of Sensors

- Motion Sensors
- Temperature Sensors
- Electrochemical sensors
- optical sensors
- Magnetic effect sensors
- Resistive Sensors
- Piezoelectric sensors
- Thermocouples
- Strain Gauges
- GMR (Giant Magnetoresistance) sensors
- Pyroelectric sensors

Some of Stimulus forms

- chemical
- Thermal
- magnetic
- optic
- mechanical
- Biological

→ **Sensor** →

Some of converted forms

- Electrical
- magnetic
- optical
- Thermal

You can measure the following Quantities

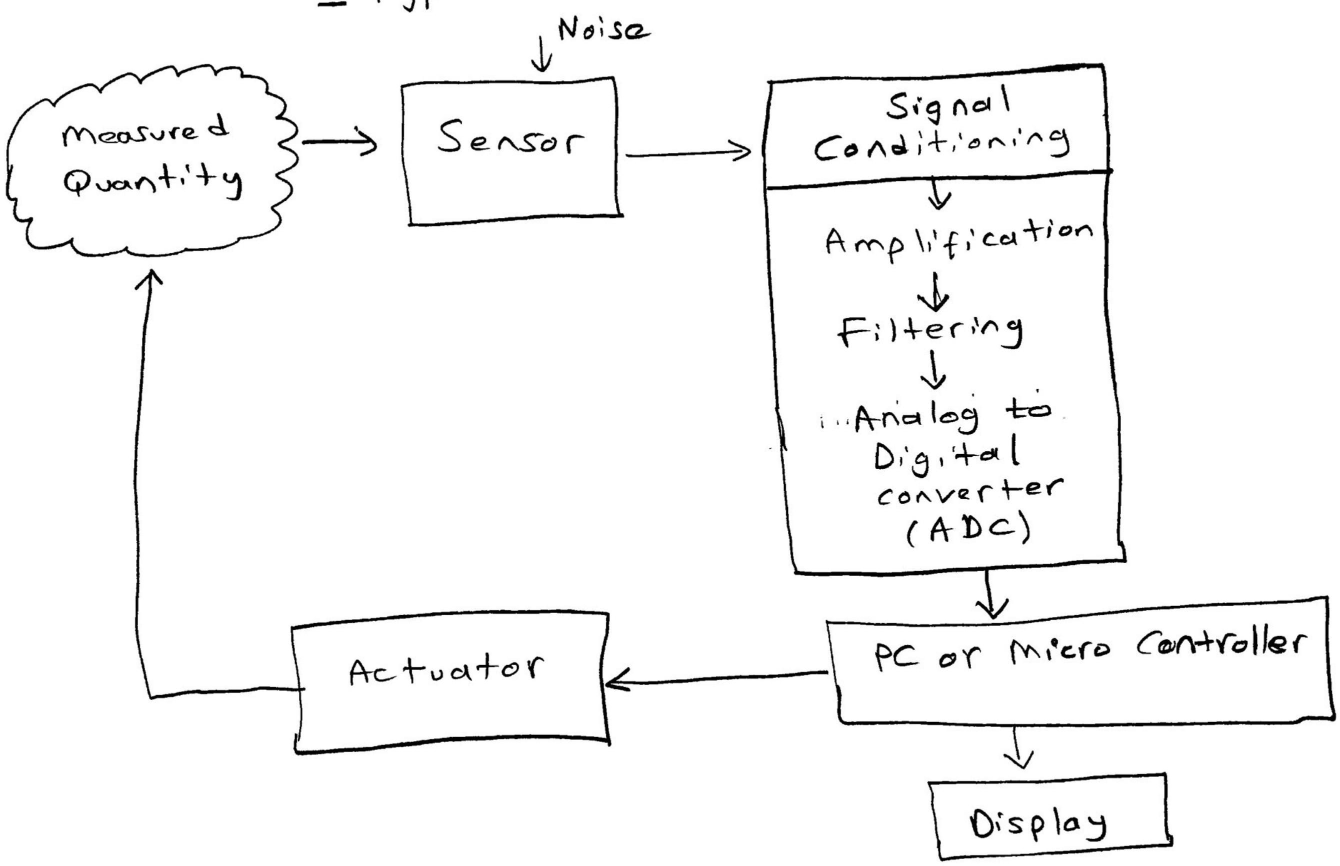
Electric signal → Voltage, charge, Conductivity,

Thermal signal → Temperature, Flux, Heat, Thermal conductivity

Mechanical signal → Velocity, Force, strain, Pressure, Torque

Optical signal → Reflectivity, Refractive index, Transmission, Absorption

Typical Measurement System



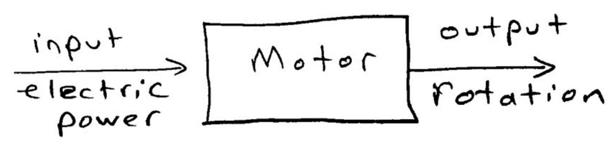
Performance Parameters of Sensors

- Sensitivity
- Repeatability
- Linearity
- Response time
- Stability
- Operation range

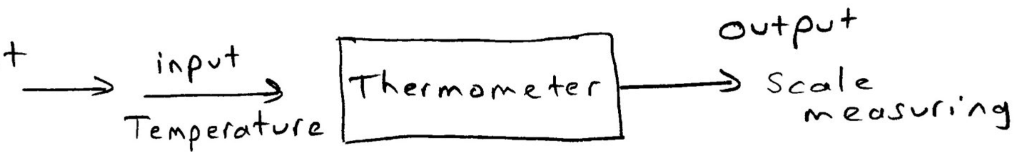
Following Environmental Factors may effect the system performance of Sensors

- Temperature
- Humidity
- Electro Magnetic Interference
- Sun light

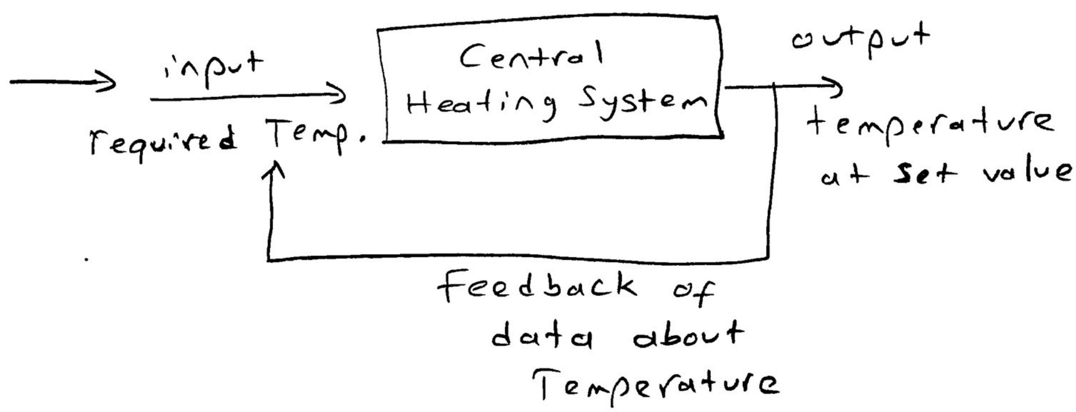
A system →



A measurement System



A Control System



Capacitive Sensors

Capacitance of a parallel plate is given as

$$C = \frac{\varepsilon_r \varepsilon_o A}{d}$$

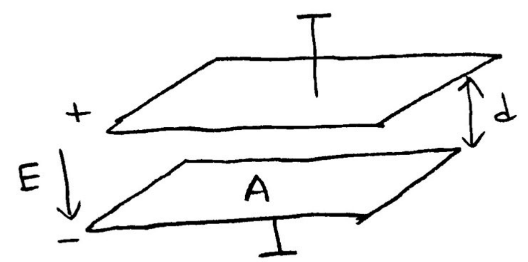
Note that $C = \frac{q}{V}$

$$1 \text{ Farad} = \frac{1 \text{ Coulomb}}{\text{Volt}}$$

$q \rightarrow$ charge

$V \rightarrow$ Voltage

$C \rightarrow$ capacitance



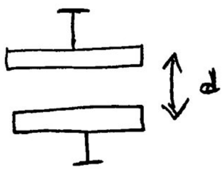
$\varepsilon_r \rightarrow$ Relative permittivity of the dielectric between plates

$\varepsilon_o \rightarrow$ Permittivity of free space 8.85 pf/m

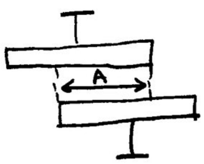
$A \rightarrow$ Area of the overlap between plates

$d \rightarrow$ Plate separation

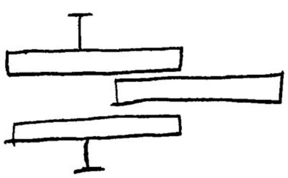
Forms of capacitive sensing element



– plate moves and d changes

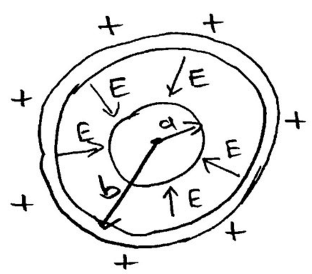


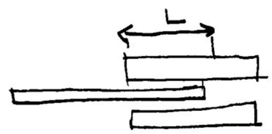
– plate moves and A changes



– plate moves and dielectric changes

A cylindrical capacitor formed by two coaxial cylinders can be used as displacement sensor





$$C = 2\pi \varepsilon_0 \frac{L}{\ln\left(\frac{b}{a}\right)}$$

Resistance Temperature Detectors (RTD)

Resistance of materials changes with temperature variations

$$R = R_0 \left[1 + \alpha \left(T - T_0\right)\right]$$

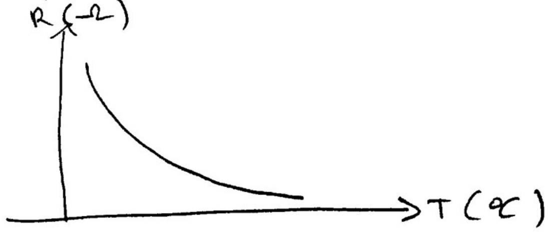
R_0 → Resistance at reference temperature T_0 (0°C or 25°C)

α → Temperature constant.

(Tungsten and Platin can be used)

Thermistors

Temperature and Resistance relation is not linear



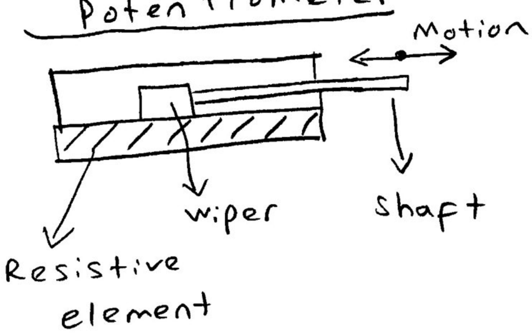
$$R = R_o \, e^{\beta\left(\frac{1}{T} - \frac{1}{T_o}\right)}$$

T → Temp in Kelvin

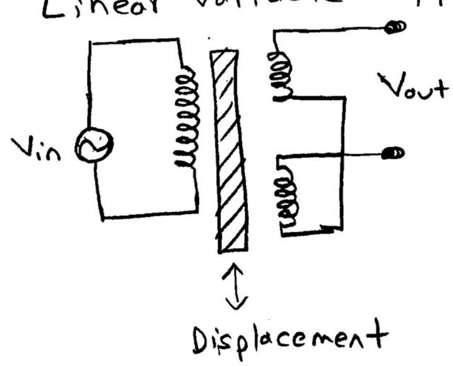
β → material dependent const.

Some Forms of Displacement Sensors

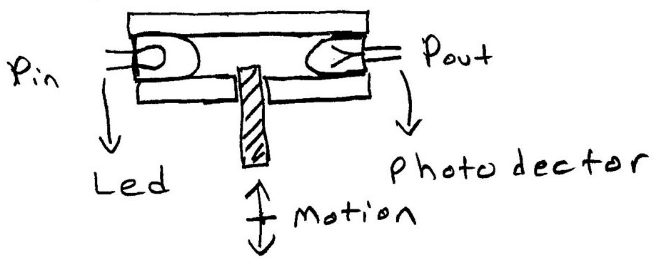
Potentiometer



Linear variable differential Transformer (LVDT)



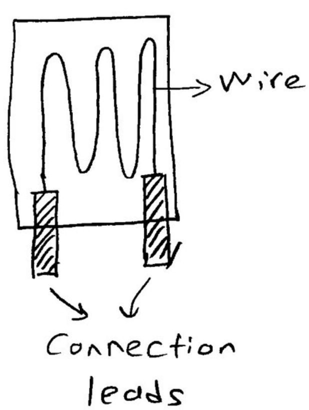
Optoisolator



Pin	Pout	Displacement
10mW	8mW	10cm
10mW	6mW	8cm
10mW	4mW	6cm

Strain Gauge:

Strain Gauge can be used to measure stress, pressure etc.



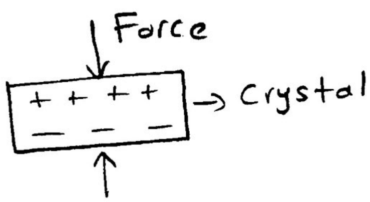
when strain occurs its Resistance R changes, Fractional changes in R is proportional to strain ε

$$\frac{\Delta R}{R} = G\varepsilon$$

$G \rightarrow$ gauge factor

Piezoelectric Sensors

Piezoelectric materials generate electric charges when it stretched or compressed.



Net charge on the surface

$q = kx$ → x: displacement, k: constant

$q = SF$ → F: Force, S: charge sensitivity

Quartz has charge sensitivity → 2.2 pC/N

Barium titanate charge sensitivity → 130 pC/N