Unit IV

Magnetic Sensors : Introduction, Villari effect Widemann effect – Hall effect – Construction, Performance characteristics, Application, Introduction to smart sensors. Film Sensors : Introduction, Thick-film sensors Microelectromechanical sensors, Micromachini Nano sensors, Applications : Industrial weighing systems : Link-lever mechanism Load cells – Pneumatic, elastic and their mounting, different designs of weighing systems. Conveyor type, weigh feeder type.

Magnetic Sensor

→ A magnetic sensor is a sensor that detects the magnetic magnitude of magnetism and geomagnetism generated by a magnet or current.

→ It serves a strong impact in changing properties of certain materials.

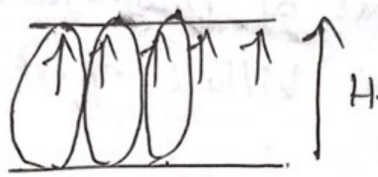
→ It produces effects which are mechanical or electrical in nature.

Types

1. Magnetic field sensor
2. Magneto elastic sensors
3. Magnetic elastic sensors
4. Torque / Force sensors
5. Magneto resistive sensors
6. Hall effect sensors (or) magneto galvanic sensors
7. Distance (or) proximity sensors.
8. Wiegand and pulse wire sensors.
9. Superconducting Quantum Interface Devices (SQUIDs).
10. Magnetostriction

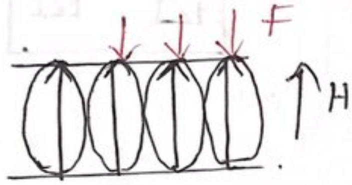
VILLARI EFFECT

→ If External magnetic field is applied to ferromagnetic material in Vertical

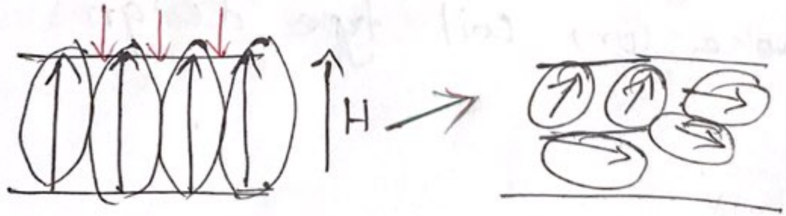


direction, the dipoles gets arranged in the same direction.

→ Apply force to ferromagnetic material.



→ This changes the direction of dipoles. Even though the external magnetic field tries to align the dipoles, the force changes the structure and direction of dipole (random fashion)



Villari effect

For a hollow Shaft of inner and outer diameters D_i and D_o, the angle of torsion ϕ, the length of Shaft l, torque produced is given by.

$$T = \frac{C\pi\phi}{32l}\left(D_o^4 - D_i^4\right)$$

The maximum Stress on the surface of the Shaft is

$$S_m = \frac{16 D_o T}{\pi\left(D_o^4 - D_i^4\right)}$$

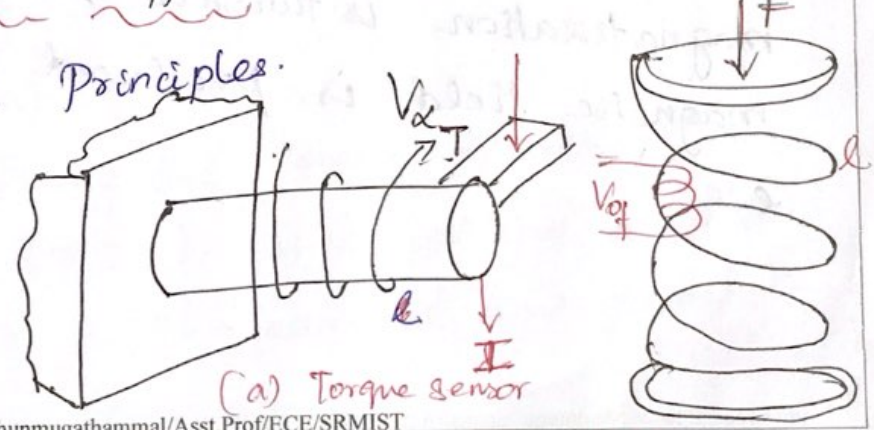
and maximum strain $\mathcal{E}_m$ is

$$\mathcal{E}_m = \frac{S_m}{Y}(1+\nu) = \frac{16 D_o (1+\nu)T}{\pi\left(D_o^4 - D_i^4\right)Y}$$

ν = Poisson ratio.

Wiedemann Effect

→ Design Principles.



(a) Torque sensor

(b) Force sensor.

With a current I passing in direction as shown in fig and a torque is produced in the rod of fig 4.4 a, an output voltage V_{ot} is obtained that gives a measure of the torque.
fig 4.4 b, V_{of} is the output voltage for the force in the balanced condition.

Wiedemann effect has a inverse effects
→ When a ferromagnetic rod which is circularly magnetized is twisted, a longitudinal magnetic field is produced in it.
→ When such a rod with longitudinal magnetization is twisted, a circular magnetic field is produced in it which

ess

Flim Sensors

→ Sensors are produced by film deposition of different thickness on appropriate substrates.

THICK FILM SENSORS

Used for producing capacitor, resistor and conductors.

Step 1. : Selection and preparation of substrate.

Step 2 : Preparation of initial coating material in paste or paint form.

Step 3 : Pasting or painting the substrate by coating material or screen printing it.

Step 4 : Fixing the sample produced in step 3 in an oxidising atmosphere at a programmed temp format.

Substrate Alumina (96% or 99.5%) and beryllia (99.5%). These fired at 625°C. Others are made up of low carbon Steel.

For thin film alumina & beryllica can also be used. Besides, special class, quartz fused Silica and sapphire are often used.

Thick film (~20μm) used for sensing Temp, pressure, gas Concentration & humidity.

Temp: (1) Themopiles (gold & gold platinum alloy)

(2) Thermistors (oxides of maganese, ruthenium & Cobalt)

(3) Temperature dependent resistances based on gold, platinum & nickel

Pressure: device made of Al_2O_3 (Alumina) and $Bi_2Ru_2O_7$ (or) Piezoresistive devices

Concentration of gases: Gases such as methane (CH_4), CO and C_2H_5OH

Humidity :- (1) resistive films made from RuO_2 (2) Capacitive films made from glass ceramic Al_2O_3.

Thin film Sensors.

Film deposition Techniques

Techniques used for thin film deposition.

(a) Thermal evaporation.
 (1) resistive heating
 (2) Electron beam heating

(b) Sputter deposition.
 (1) DC with magnetron.
 (2) Rf with magnetron.

(c) CVD

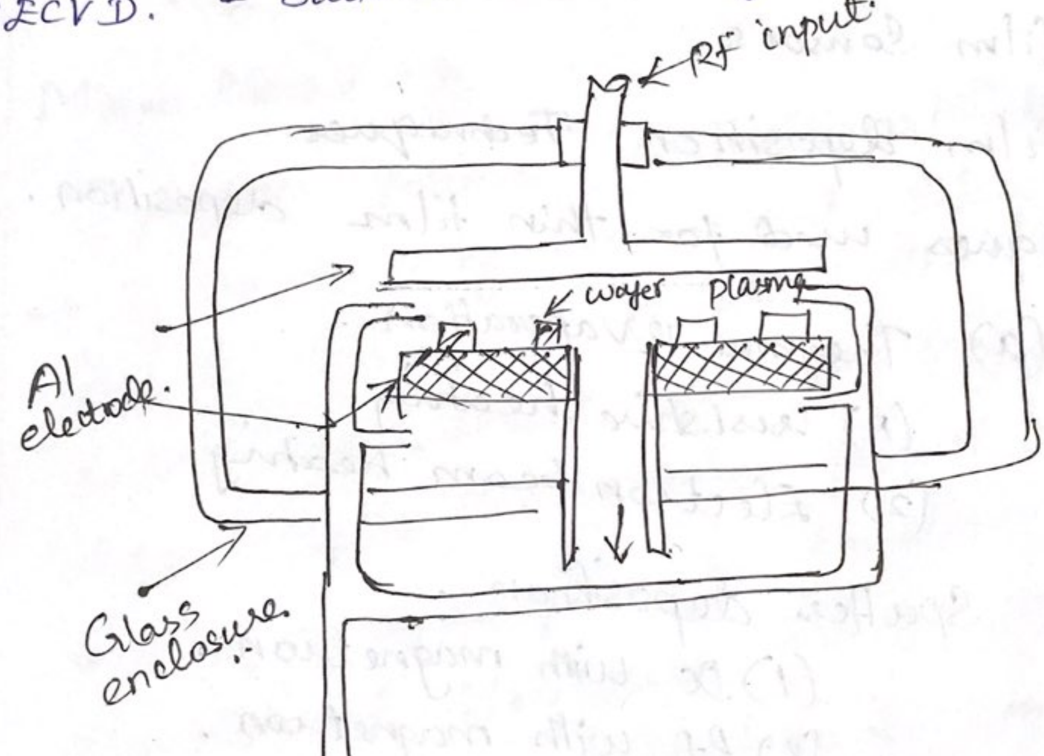
(d) plasma enhanced Chemical Vapour Deposition (PECVD)

(e) Metallo - Organic deposition (MOD).

(f) Langmuir - Blodgett technique of monolayer deposition

Thermal evaporation and sputter deposition are decades old. Sputter deposition → Magnetic field ⊥ to applied electric field is applied. This increases ionization property.

PECVD. - Suitable Technolog.



It is the process of deposition of solid material onto a substrate in a state of raised temperature. Deposition occurs either by decomposition or chemical reaction of compounds. for sensor development, the materials deposited, though not many are

Single crystal silicon (epitaxy)
Poly crystalline Silicon (polysilicon)
SiO_2 and Si_2N_3.

Micro Machining:

Deposition follows conventional technology.
-> It is matching conventional silicon, the use of Silicon-on-insulator (SOI) as the initial requirement, and the use of deep profile lithographic process. This technique is adaptable to developing three-dimensional structures and physical sensors are being produced by the process of micromachined silicon.

HALL EFFECT.

- Also called Galavomagnetic Effect sensor
- Absewed in metals and Semiconductors.
- When a curent is sent through a very long strip of extrinsic homogeneous Semiconductor in x direction across the plane XY perpenticular to it, magnetic field is applied to produce a flux density Bz, an Electric field Ey in direction of y is Produced which is called Hall effect.

With electrodes across strip in y direction, Hall voltage (V_H) can be collected is given by

$$V_H \simeq B_z I_x$$

Galvano magnetic effects, because of Lorentz force on the charge carrier transport phenomena in Condensed medium Lorentz force is

$$f = eE + e[v \times B]$$

e – Charge carrier
E – Electrical field
V – Carrier Velocity
B – Magnetic Induction.
I – Total current density.
μH – Hall mobility.
Δn – Carrier Concentration.

I_0 - Current density. due to E field

Δn - Carrier Concentration.

$I = I_0$ and $B = 0$

σ = Conductivity.

D = Diffusion Co-efficient

$$I = I_0 + \mu_H [I_0 \times B]$$

$$I_0 = \sigma C - eD \nabla n$$

Transport Co-efficients μ_H (or) D are dependent on Electric & Magnetic field and are determined by Carrier Scattering process.

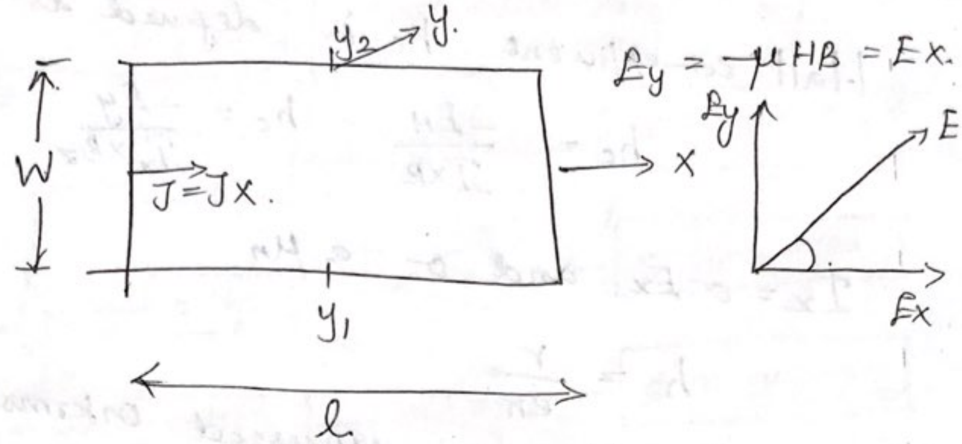
Hall mobility μ_H is product of drift mobility of carrier μ and hall scattering factor r, which is given by appropriate ratio of relaxation time averages of energy distribution.

$$r = \frac{[\tau^2]}{[\tau]^2} \quad \mu_H = r\mu$$

r = 1 for degenerate semiconductor / metals

r = 1.93 for scattering with ionized impurities.

r = 1.18 for accoustic phonons.



Basic Scheme of Hall device.

E_y is Hall field represented as E_H and this field would produce voltage across the width of strip.

Transverse voltage called Hall voltage V_H is given by.

$$V_H = \int_{y_2}^{y_1} E_H \, dy = -\mu_H B_z E_x W.$$

The effect leading to phenomena called Hall effect

$$\tan \theta_h = \frac{E_y}{E_x} = \mu_H B_z$$

Hall effect has varying intensity in different materials.

Hall co-efficient h_c is defined as

$$h_c = \frac{-E_H}{I \times B} \quad h_c = \frac{-E_y}{I_x \times B_z} = \frac{\mu_n E_x}{I_x}$$

$I_x = \sigma E_x$ and $\sigma = e\mu_n$

$$h = \frac{r}{en}$$

Hall voltage can be expressed interms of Hall co-efficient h_c

$$V_H = -h_c J_x B_z W$$

$$h_c = \frac{1}{e} \frac{r_p n_p - r_n n_n (\mu_n/\mu_p)^2}{(n_p + n_n (\mu_n/\mu_p)^2}$$

Intrinsic carrier density n_i equals n_p and n_n

$$n_i^2 = A T^{3/2} \exp\left[\frac{-E_g}{2kT}\right]$$

A - Co-efficient
T - Absolute Temperature.
k - Boltzmann constant.

SMART SENSOR

It is an Analog / Digital transducer combining with processing unit and Communication Interface. It consists of

Transduction element signal conditioning electronic and Controller / processor that support some intelligence in a single package.

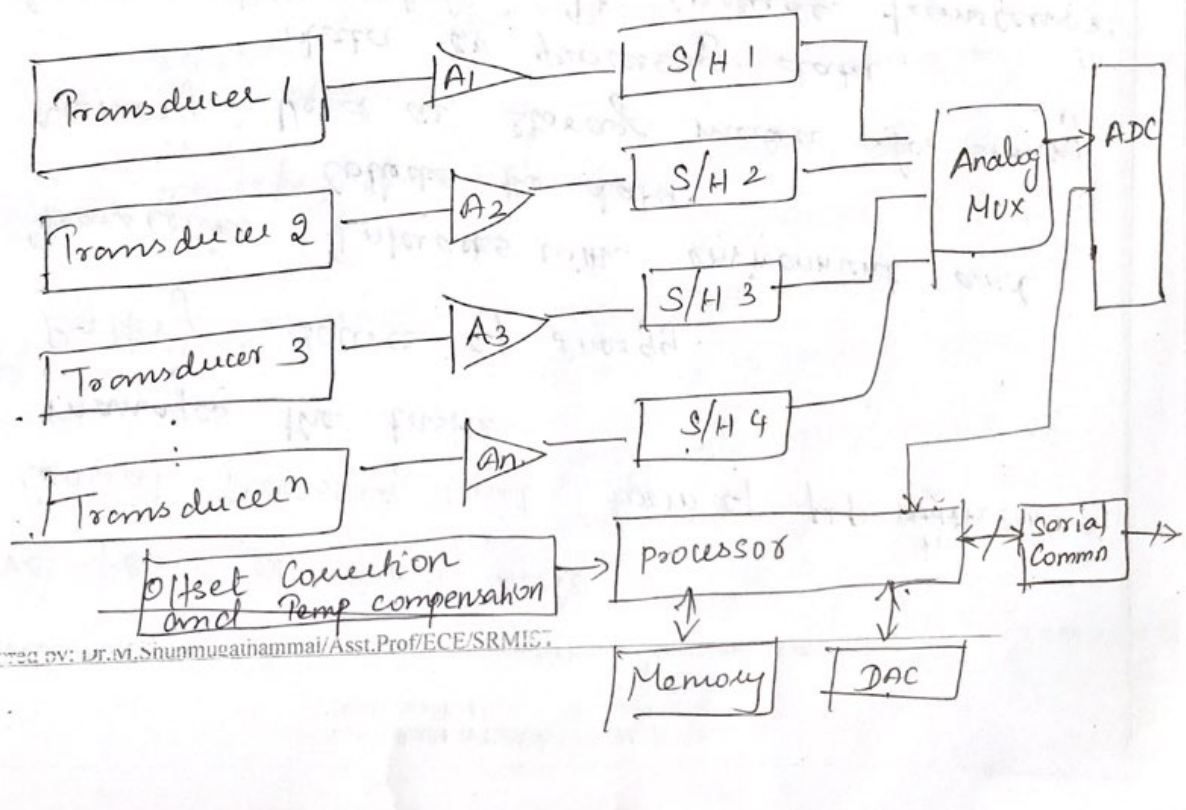
It has electronics and transduction element together on one Silicon chip called System-on-chip.

The main aim of integrating the electronics and the sensor is to make intelligent sensor.

Smart sensor has an ability to make some decision.

Sensor + Integrated Circuit = Smart sensor

General Architecture of smart sensor.



Five parts of Sensor node.

1. Central processing Unit : form of μP which manages the tasks.
2. Battery : Source of Energy.
3. Transceiver : Interacts with environment and Collects the data.
4. Memory : Used as storage media for storing data or processing data.
5. Communication module : It includes transceivers and forward queries and data to and from central module.

TOP SMART SENSORS.

1. Temperature Sensor – Thermisters, RTD, IC.
2. Proximity Sensor – ultrasonic, photo electric, Capacitive proximity.
3. Pressure sensor – Air Pressure sensor, water pressure sensor, Low pressure sensor.
4. Gas and smoke Sensor – LPG Sensor, Alcohol sensor photo electric smoke sensor.
5. Accelerometer Sensor
   - → Linear Hall-effect Accelerometer.
   - → Piezoelectric Accelerometer.
   - → Capacitive Accelerometer.

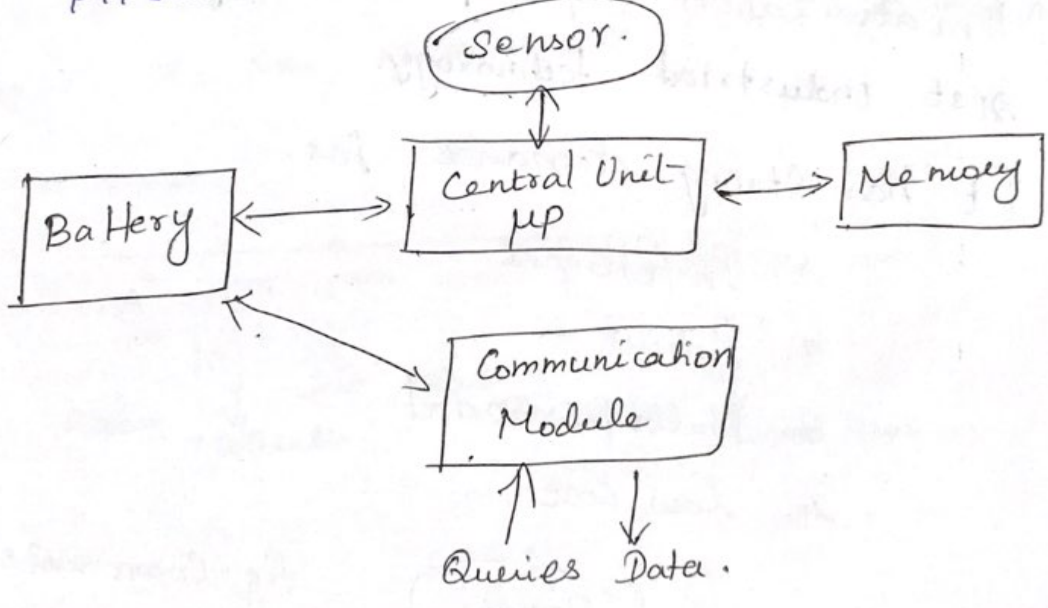
6. Level Sensors:
Liquid Level Sensors, Capacitive level Sensors, Heat type level sensors.

7. Motion Detection Sensors.
Ultrasonic, Passive Infrared Sensor, Microwave

8. Optical Sensor.
photo detector, Pyrometer, Infrared, Proximity

9. Gyroscope sensors.
Ring laser, optical, Digital, Vibrating.

10. Water quality sensor.
PH sensor, Turbidity Sensor, water conductivity Sensor



MEMS : Micro Electro Mechanical System

Any Engineering system that performs electrical and mechanical functions with components in micrometers is a MEMS. ($1\mu m$ = 1/10 of human air)

Available MEMS products.

Micro Sensors

Micro Actuators.

Read/Write heads

Inkjet Printer heads

Micro device components.

Miniaturization : Principle driving force for 21st industrial technology.

It has strong demand for.

1. Intelligent.
2. Robust.
3. Multi functional
4. Low cost.

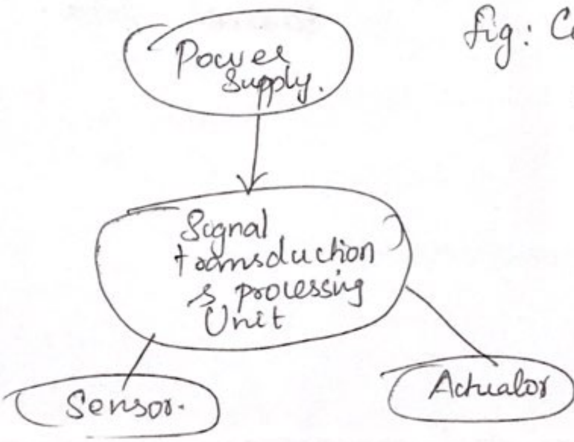


fig: Components of Microsystem.

Scaling Laws in Miniaturization

1. Scaling in geometry.
2. Scaling on Rigid body dynamics.
3. Scaling in Electro Static forces.
4. Scaling in Electro magnetic forces.
5. Scaling in Electricity.
6. Scaling in fluid mechanics.
7. Scaling in Heat Transfer.

NANO SENSORS.

Nano Sensors are Sensors, which performs mechanical and Electronic functions and it is in the size of nanometer ($1\ nm = 10^{-9} m$).

NANO SENSORS.

Optical Nanosensors

1. Proximity
2. Ambient light

Biological Nanosensors

1. Antibody/Antigen interaction
2. DNA interaction.
3. Enzymatic Interaction.

Chemical Nanosensors

1. Chemical composition.
2. Molecular Concentration.

Physical Nanosensors

1. Pressure
2. force.
3. Mass.
4. Displacement

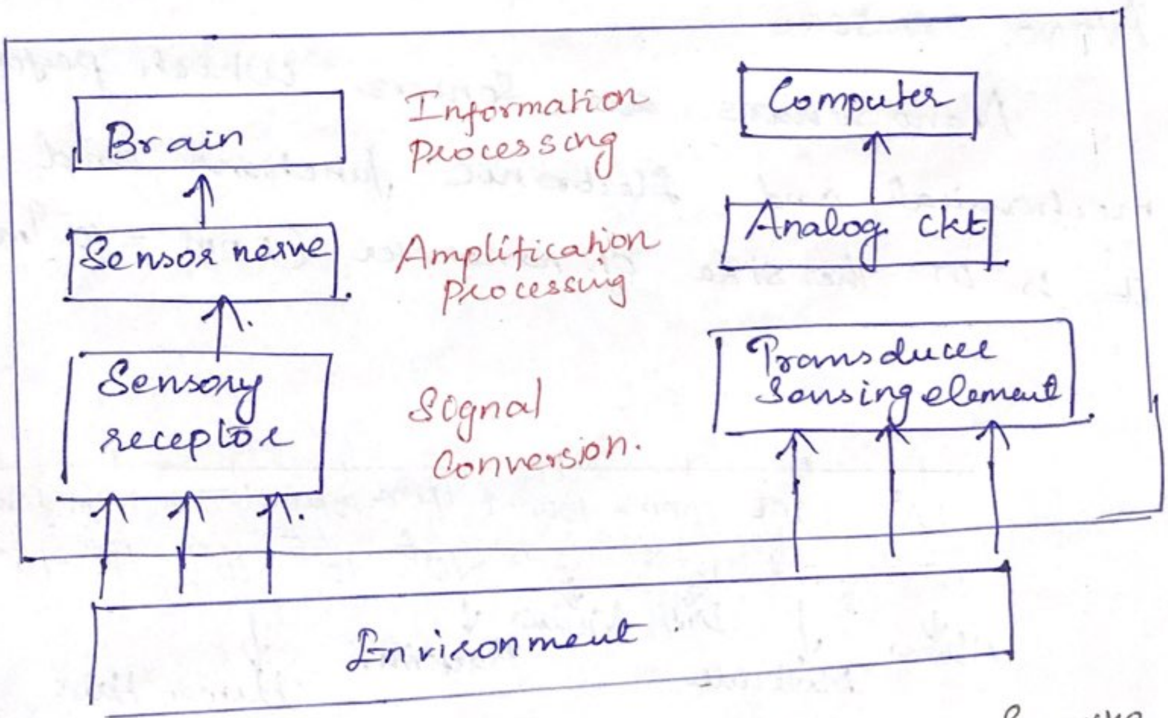


fig: Analogy between human Sensing System and Artifical sensors.

BIO SENSORS

Bio-recognition element

Molecular | Cell Based | Tissue Based

Optical | Mechanical | Electro chemical

Principle of operation.

Fluorecense Surface plasma resonance. Adsorbance. Reflectance.	Piezoelectric Surface accoustic wave. Cantilever resonance freq	Amperometric Potentiometric Impedimetric

Biosensor is an analytical device incorporating a Biological or biologically derived sensed element either intimately associated with (or) integrated with in a physics chemical transducer the usual aim is to produce a digital electronic signal which is proportional to the concentration of a specific analyse or group of analyzer.

LOAD CELLS.

Load cell is an electromechanical device, A load cell is a force transducer that converts force or weight acting on it in to an electrical signal.

Load cell can be used to measure force torque and pressure.

Load cell can measure a wide range of force from 25 grams to 30,000,00 lbs.

- Mechanical type load cells.
  a) Hydraulic
  b) Pneumatic.
- Electrical type load cells.
  a) Resistance based (strain gauge load cell)
  b) Capacitance based.
  c) Inductance based (LVDT load cell)

Among many kinds of load cells, the most common type is strain gauge load cells.

$$\text{Gauge factor } F_g = \frac{\Delta R/R}{\Delta L/L}$$

Material	Gauge factor.
Conventional foil gauge	1.5 to 3.5
Constantan strain gauge	1.9 to 2.1
Ni Chrome (or) Platinum Iridium.	upto 3.5

Load cell Types.

→ Stype
→ Button
→ Shear
→ Beam.

CONVEYOR SYSTEMS.

It is a common piece of mechanical handling equipment that moves materials from one location to another. Conveyors are especially useful in applications involving the transportation of heavy (or) Bulky materials.

Designing a Conveyor System.

- Capacity requirement
- Length of travel
- Material characteristics
- Processing Requirements.
- Life expectancy
- Costs

Main elements of a Conveyor.

1. Conveyor drive
2. Conveyor motor.
3. Auxilary equipment
4. Control of conveyors.

Types

1. Chute Conveyor
2. Wheel conveyor
3. Roller conveyor.
4. • Gravity roller conveyor
   • Live (powered) roller.
5. Chain conveyor.
6. Flight chain
7. Apron chain
8. Closed belt.
9. Slat conveyor.
10. Continuous flow Conveyor.