SENSORS

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INTRODUCTION

- Measurement is an important subsystem in any major system, whether it may be a mechanical system or an electronic system.

- A measurement system consists of sensors, actuators, transducers and signal processing devices.

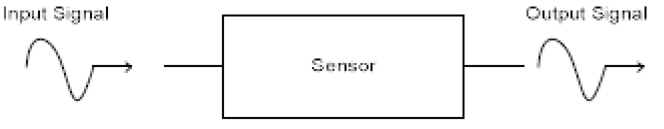
- The use of these elements and devices is not limited to measuring systems.

- These are also used in the systems which perform specific tasks, to communicate with the real world.

- The communication can be anything like reading the status of a signal from a switch or to trigger a particular output to light up an LED.

<u>SENSORS?</u>

- American National Standards Institute – A device which provides a usable output in response to a specified measurand.



- A sensor acquires a physical quantity and converts it into a signal suitable for processing (e.g. optical, electrical, mechanical)

- Nowadays common sensors convert measurement of physical phenomena into an electrical signal

- Active element of a sensor is called a transducer

Transducer?

A device which converts one form of energy to another

When input is a physical quantity and output electrical → Sensor

When input is electrical and output a physical quantity → Actuator

Sensors

Physical parameter ↓ Electrical Output

Actuators

Electrical Input ↓ Physical Output

e.g. Piezoelectric:

Force -> voltage

Voltage-> Force

=> Ultrasound!

Microphone, Loud Speaker

Commonly Detectable Phenomena

- Biological
- Chemical
- Electric
- Electromagnetic
- Heat/Temperature
- Magnetic
- Mechanical motion (displacement, velocity, acceleration, etc.)
- Optical
- Radioactivity

SENSORS BASED ON THEIR DETECTION PROPERTIES

Types	Properties
Thermal sensor	Temperature, heat, flow of heat etc
Electrical sensor	Resistance, current, voltage, inductance, etc
Magnetic sensor	Magnetic flux density, magnetic moment, etc
Optical sensor	Intensity of light, wavelength, polarization, etc
Chemical sensor	Composition, pH, concentration, etc
Pressure sensor	Pressure, force etc
Vibration sensor	Displacement, acceleration, velocity, etc
Rain/moisture sensor	Water, moisture, etc
Tilt sensors	Angle of inclination, etc
Speed sensor	Velocity, distance etc

Physical Principles: Examples

- **Amperes's Law**
  - A current carrying conductor in a magnetic field experiences a force (e.g. galvanometer)
- **Curie-Weiss Law**
  - There is a transition temperature at which ferromagnetic materials exhibit paramagnetic behavior
- **Faraday's Law of Induction**
  - A coil resist a change in magnetic field by generating an opposing voltage/current (e.g. transformer)
- **Photoconductive Effect**
  - When light strikes certain semiconductor materials, the resistance of the material decreases (e.g. photoresistor)

Choosing a Sensor

Environmental Factors	Economic Factors	Sensor Characteristics
Temperature range	Cost	Sensitivity
Humidity effects	Availability	Range
Corrosion	Lifetime	Stability
Size		Repeatability
Overrange protection		Linearity
Susceptibility to EM interferences		Error
Ruggedness		Response time
Power consumption		Frequency response
Self-test capability		

Need for Sensors

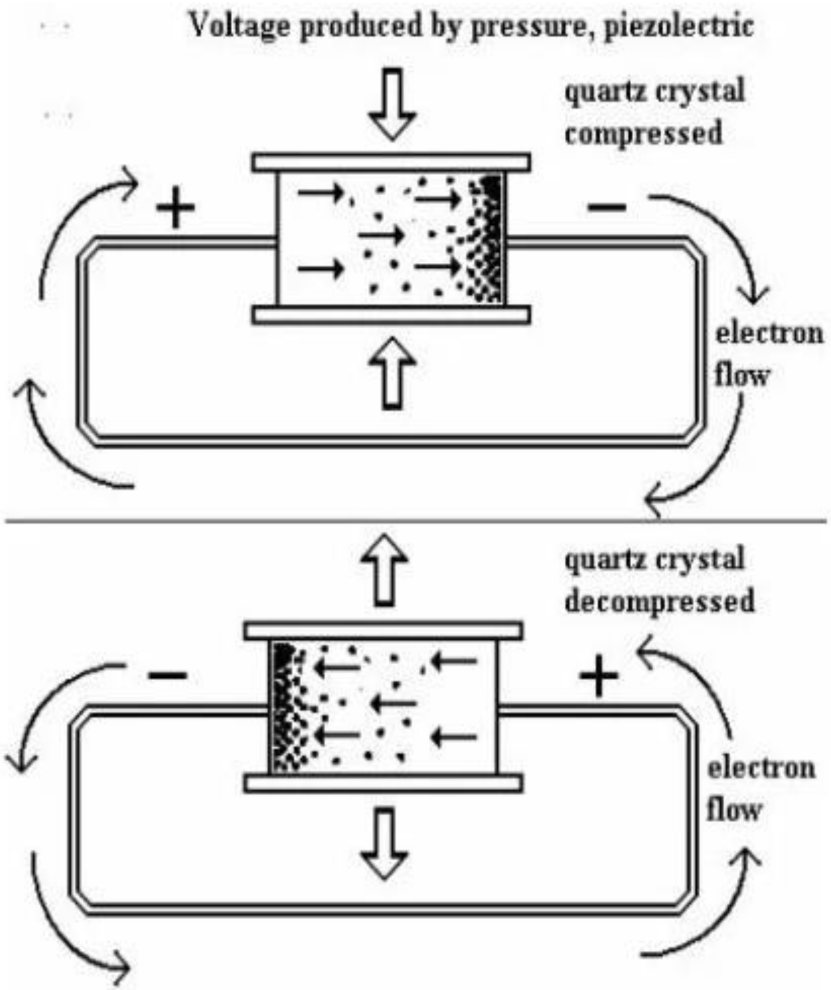
- Sensors are pervasive. They are embedded in our bodies, automobiles, airplanes, cellular telephones, radios, chemical plants, industrial plants and countless other applications.

- Without the use of sensors, there would be no automation !!

ULTRASONIC SENSORS

- An ultrasonic sensor uses ultrasonic waves for the purpose of sensing.
- Ultrasonic waves are very high frequency waves.
- Depends on the elastic properties and the density of the materials.
- Propagates as a longitudinal waves in fluids.
- Propagates as a transverse as well as a longitudinal waves in solids.
- The total time taken by the ultrasonic waves to travel from the transmitter to the object and again from the object to the receiver of the sensor is given by the output of the sensor.
- Ultrasonic sensors are used in many applications such as robotics, driverless cars, for measuring distance, and also in radar systems etc.

Effects used in US Sensors



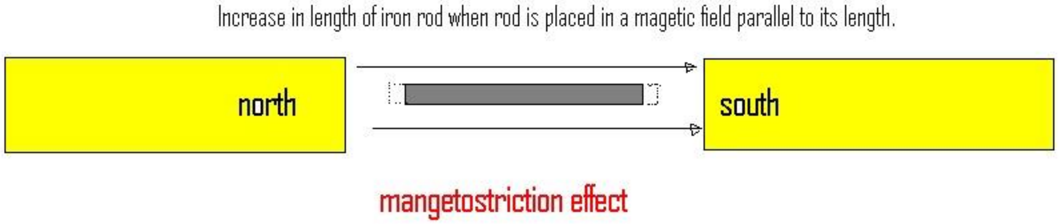
Piezoelectric Effect:
The ability of certain materials to generate an electric charge in response to applied mechanical stress.

Inverse peizoelectric effect:
This can be formed by applying electrical energy to make a crystal expand. The main function of this effect is to convert electrical energy into mechanical energy.

Piezoelectric sensors: used with high frequency sound in ultrasonic transducers for medical imaging and industrial nondestructive testing.

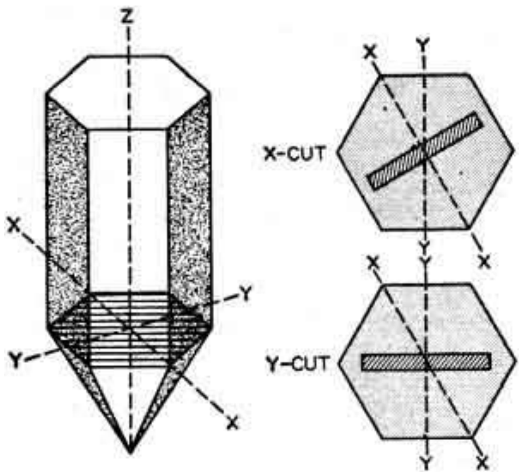
Magnetostriction Effect

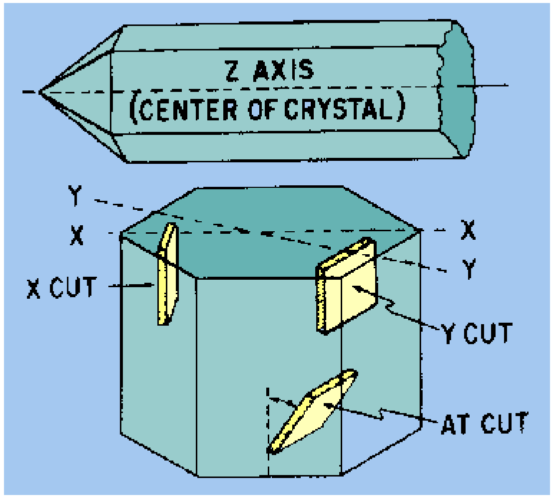
- Property of a ferromagnetic materials which causes them to expand or contract in response to a magnetic field.
- This effect allows magnetostrictive materials to convert electromagnetic energy into mechanical energy.
- As a magnetic field is applied to the material, its molecular dipoles and magnetic field boundaries rotate to align with the field. This causes the material to strain and elongate.



Quartz Crystal

Quartz is piezoelectric: a crystal develops positive and negative charges on alternate prism edges when it is subjected to pressure or tension.
The charges are proportional to the change in pressure. Because of its piezoelectric property, a quartz plate can be used as a pressure gauge, as in depth-sounding apparatus.





X- axis: Electrical Axis
Y-axis: Mechanical Axis
Z- axis: Optical Axis

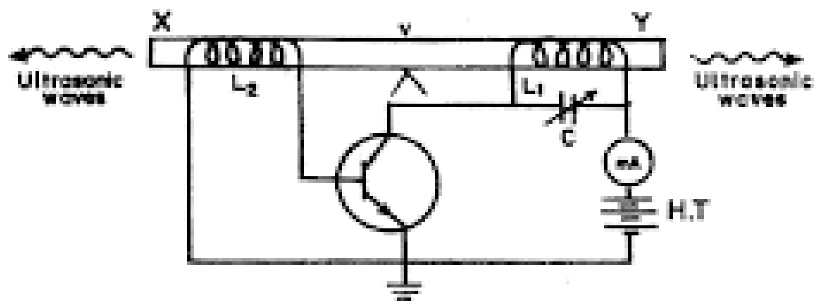
- The X-Cut crystal is a cut that has a face perpendicular to the Y-axis. It produces longitudnal waves of the order of few KHz.

- The Y-Cut crystal is a cut that has a face perpendicular to the X-axis. . It produces transverse waves of the order of MHz.

US Waves production using FM rod

Construction

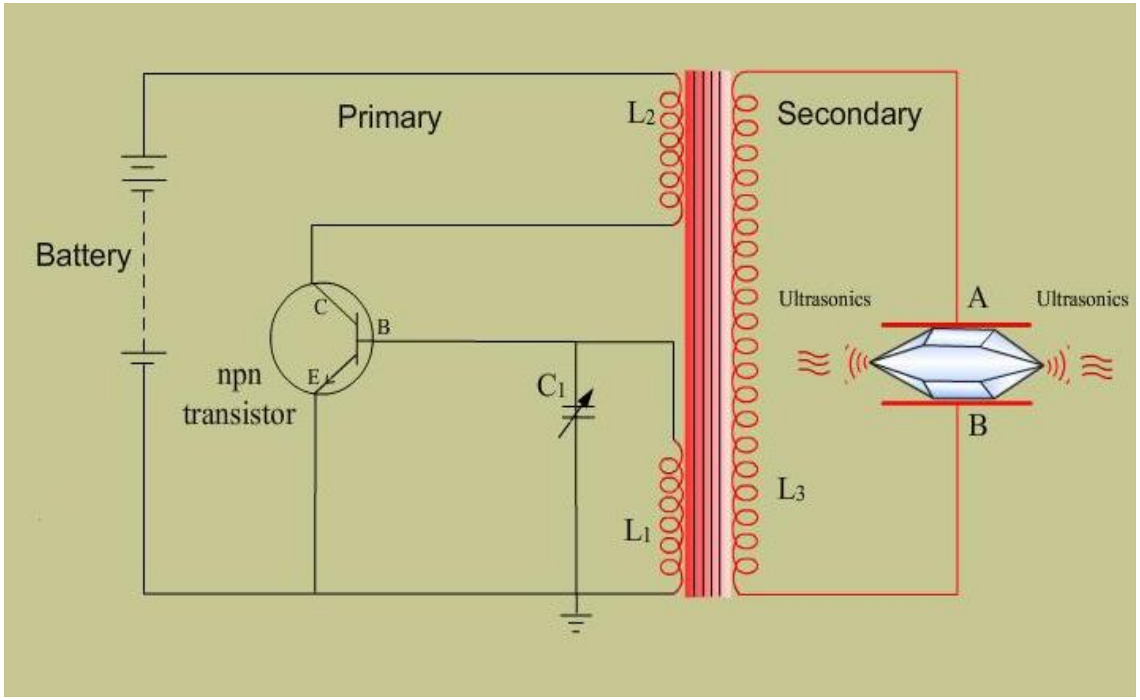
The experimental arrangement is shown in Figure



The magnetostriction coefficient is given as the ratio of change in length to the original length. Magnetostriction coefficient $\lambda = \frac{\delta L}{L}$.

The frequency of the oscillation is given as $f = \frac{1}{2L}\sqrt{\frac{Y}{\rho}}$ where, Y is the young's modulus; ρ is the density of the crystal and L is the length of the rod.

US waves production using Quartz crystal



The frequency of the thickness vibration of the crystal can be given as (along X-axis):

$f = \frac{1}{2t}\sqrt{\frac{Y}{\rho}}$ where, Y is the young's modulus; ρ is the density of the crystal and t is the thickness of the crystal.