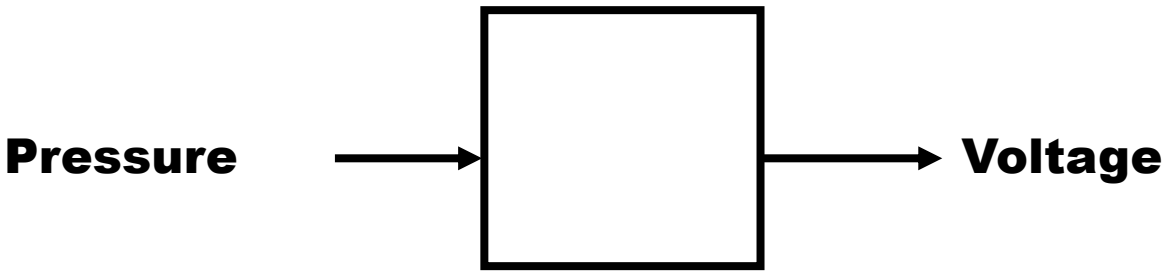
Transducers

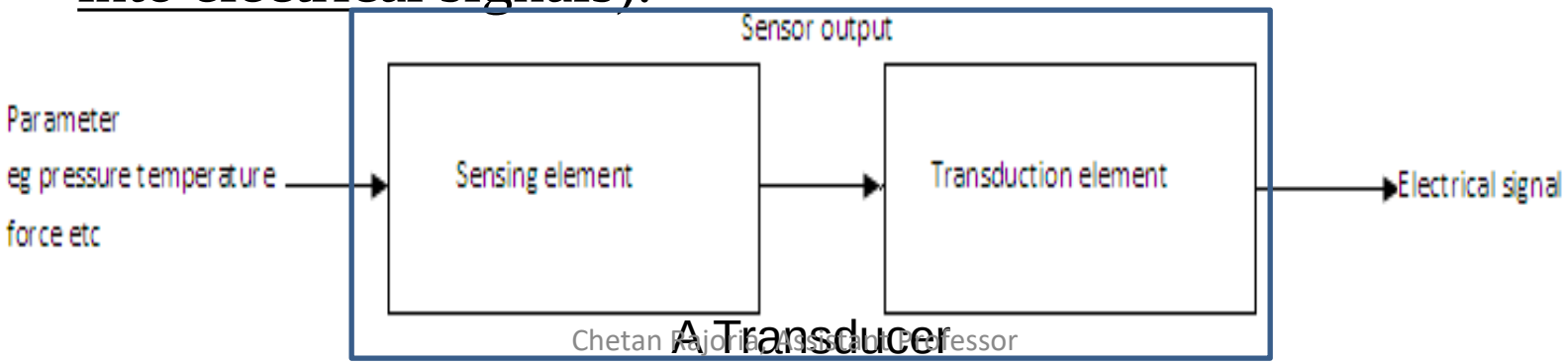
INTRODUCTION OF TRANSDUCERS

- A transducer is a device that convert one form of energy to electrical form. Typically it converts the measurand to a usable and detectable electrical signal.
- In other word it is a device that is capable of converting the physical quantity into a proportional electrical quantity such as voltage or current. This voltage or current can be used for measuring the initial physical quantity.
- Transducers have vast applications in the field of measurements.



BLOCK DIAGRAM OF TRANSDUCERS : Its main elements

- Transducer contains two main elements that are closely related to each other i.e. **the sensing element and transduction element**.
- The sensing element is called as the **sensor**. It is a device producing measurable response to change in physical conditions. (i.e. it reads the input signal).
- The transduction element convert the sensor output to suitable electrical form (i.e. it converts the sensor signal into electrical signals).



A Transducer

CHARACTERISTICS OF TRANSDUCERS

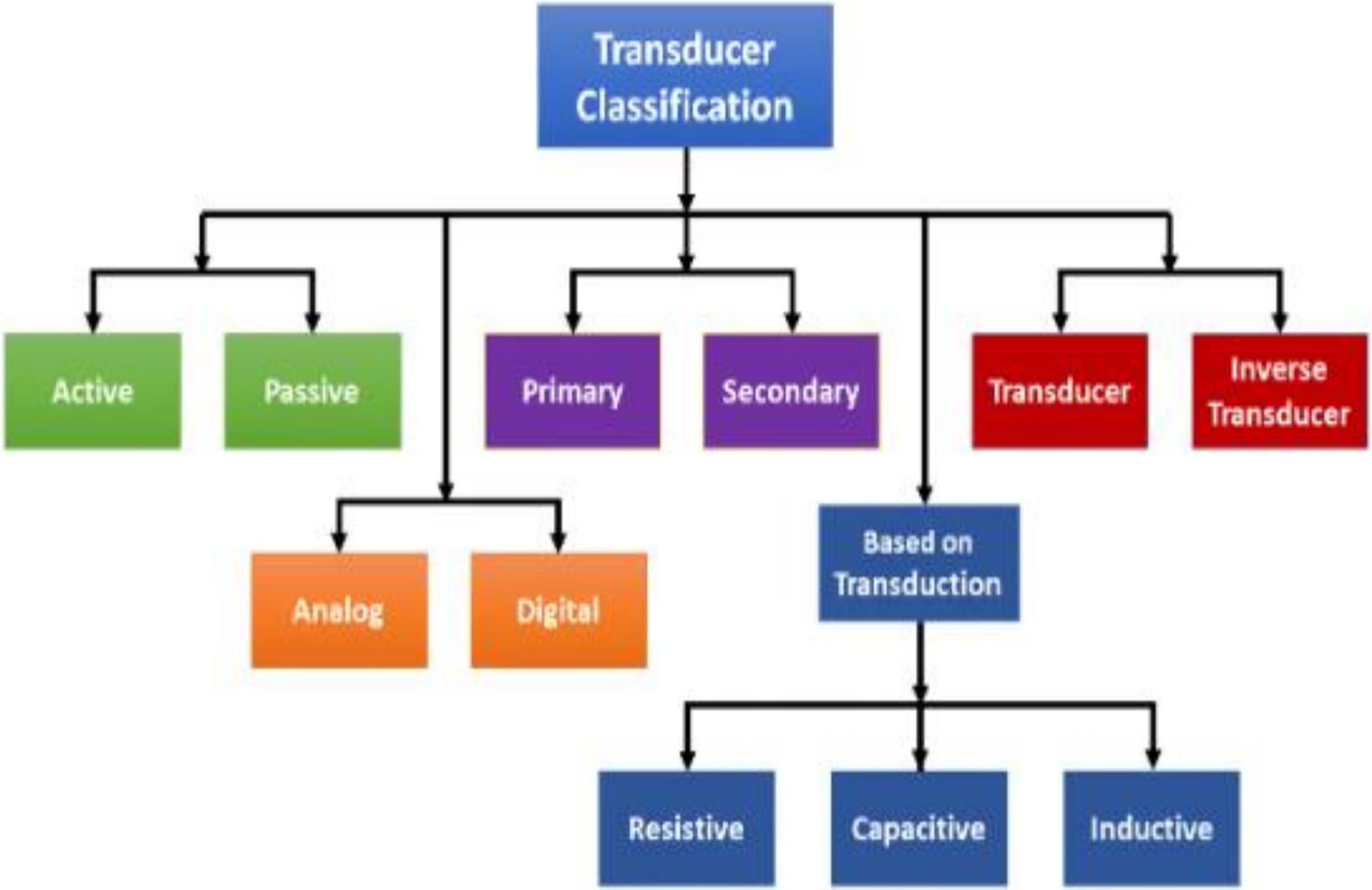
1. **Ruggedness** : Mechanically strong, suitable for rough and tough use.
2. **Linearity** : Output vs input variation should be linear.
3. **Repeatability** : Same outputs should be obtained for same inputs, every time (precision).
4. **Accuracy** : Result or output should be very close to the expected or verified output.
5. **High stability and reliability** : Outputs should not deviate without any change in input, and the device should be trust-worthy.
6. **Speed of response** : outputs should be attained as soon as the inputs are fed, without any time-lag.
7. **Sensitivity**: Outputs should be clear and visible even for smaller changes in inputs.
8. **Small size** : size of the device should be compact and small, so that it could be handled easily.

CLASSIFICATION OF TRANSDUCERS

- **The transducers can be classified according to their application, method of energy conversion, nature of the output signal, and so on.**

- **Following is the classification of transducers—**

I. Active and passive transducers.
II. Analog and digital transducers.
III. On the basis of transduction principle used : Capacitive / Inductive / Resistive
IV. Primary and secondary transducer
V. Transducers and inverse transducers.


Transducer Classification
Active
Passive
Primary
Secondary
Transducer
Inverse Transducer
Analog
Digital
Based on Transduction
Resistive
Capacitive
Inductive

ACTIVE AND PASSIVE TRANSDUCERS

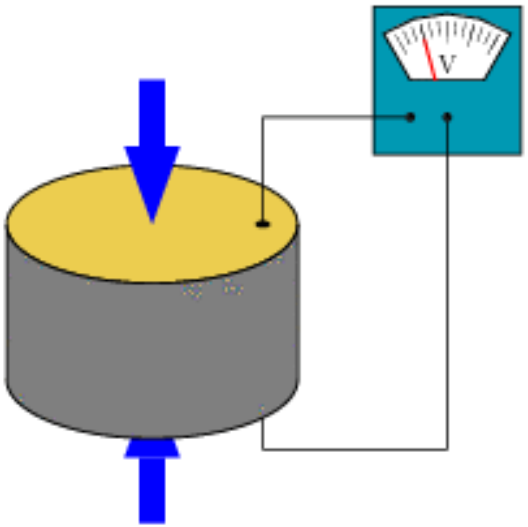
- **Active transducers :**
- These transducers do not need any external source of power for their operation. No battery or cell is required to make it working. Therefore they are also called as self generating type transducers.

I. The active transducer are self generating devices which operate under the energy conversion principle.

II. As the output of active transducers we get an equivalent electrical output signal e.g. temperature or strain to electric potential, without any external source of energy being used.

Example : A **Piezo-electric transducer** (details in next slide)

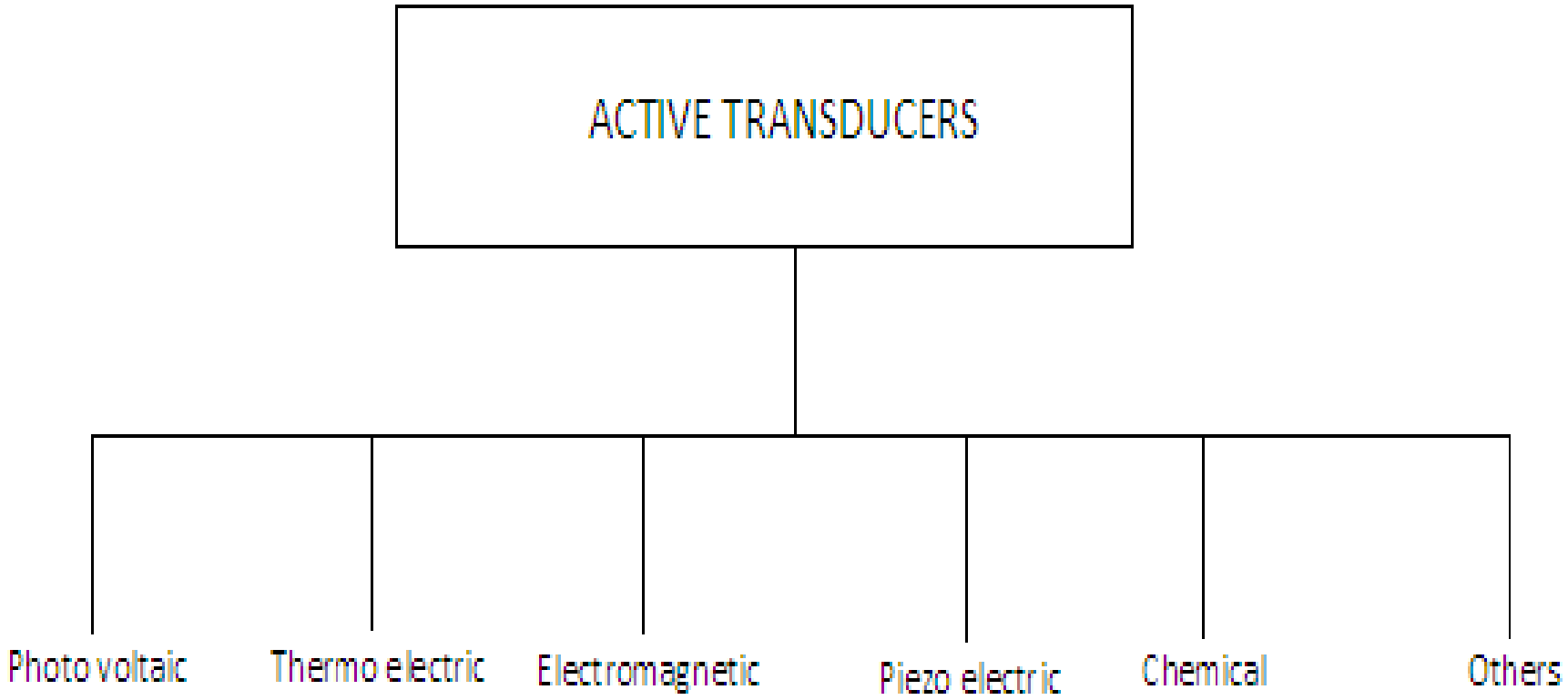
Piezoelectric Transducer



This type of transducer can convert the amount of applied external load (or pressure) directly into the electrical signals, in proportional amount. As the load is applied, a proportional change in voltage can be obtained, which can be read on a volt meter. Here, no external battery is required to make it working.

Examples of artificial piezo-electric material : Barium Titanate, Lithium Niobate, PZT (Lead-Zirconate-Titanate).
Some natural piezoelectric materials : Quartz, Topaz, Tourmaline crytal

Detailed Classification of Active Transducers



Active transducers

- Photo voltaic transducer : Creates EMF proportional to the emitting light on its light-sensor.
- Thermoelectric transducer : Works on the principle of '*Seeback's effect*' and produces EMF proportional to the temperature difference between hot and cold junction *(study thermocouple for details).*
- Electromagnetic transducer : A device that generates an EMF proportional to the disturbance of the magnetic field of the electromagnetic element (e.g. a magnet). *See slide no. 21 for details*.
- Piezoelectric transducer : *(already discussed on previous slide).*
- Chemical transducer : Produces EMF proportional to the changes in chemical composition of the substance used.

- **Passive Transducers :**

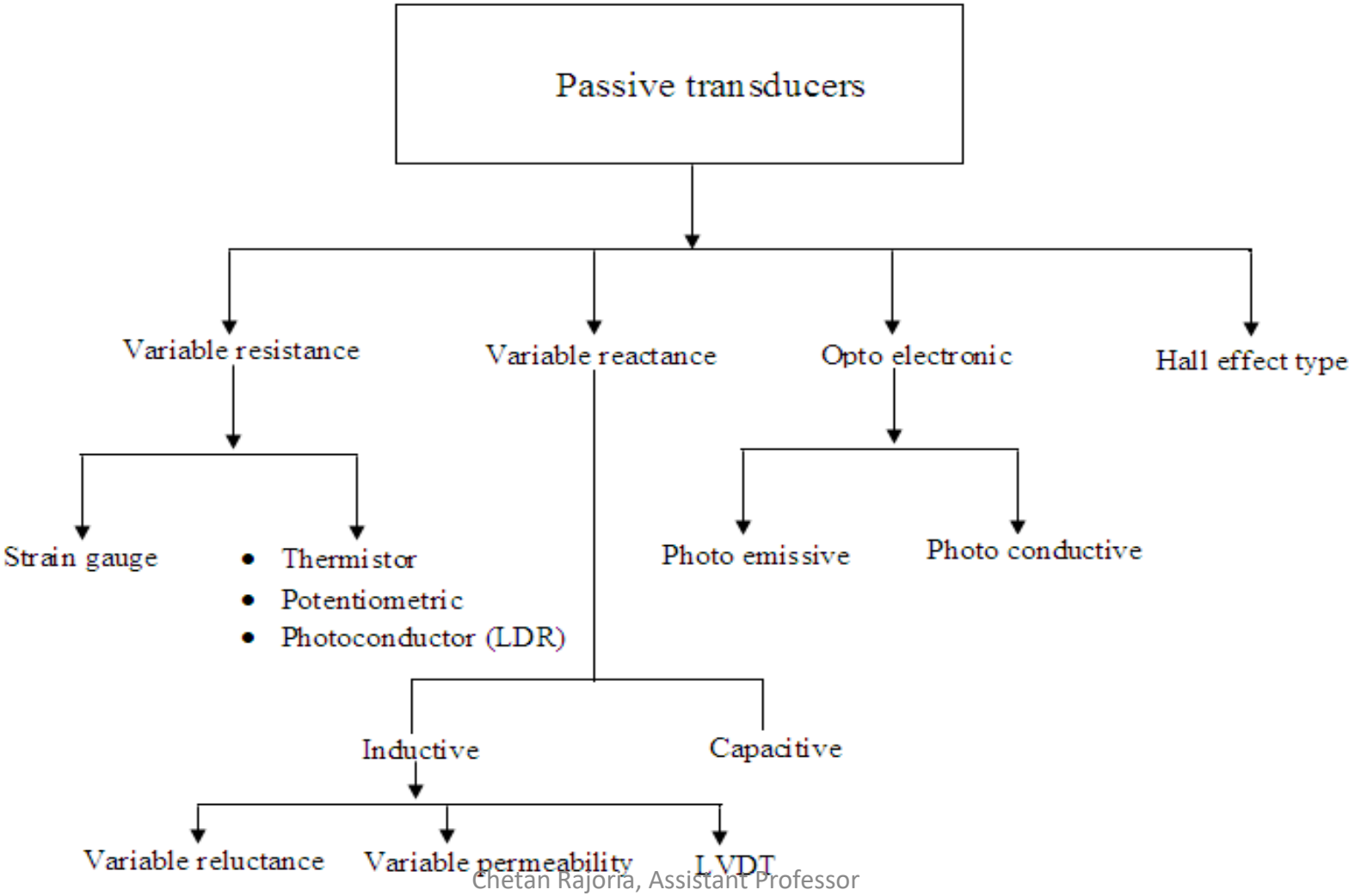
I. These transducers **need external source of power** for their operation. So they are not self generating type transducers.

II. A DC power supply or an audio frequency generator is used as an external power source.

III. These transducers produce the output signal in the form of variation in resistance, capacitance, inductance or some other electrical parameter in response to the quantity to be measured.

Example : **LVDT** (**L**inearly **V**ariable **D**ifferential **T**ransformer)
(details on slide no 28)

Detailed Classification of Passive Transducers



Passive Transducers

- **Variable resistance type transducers** : The resistance of a specific wire changes with the change in input signal. This change in resistance can be used for measurement purpose. There are various type of transducers based on this concept : (1) *strain gauges*, (2) Thermistors, (3) Potentiometric type, etc. *(see slide no. 25 for details).*
- **Opto-Electronic type transducers** : The electrical signals are changed with the proportional change in optical signals. These are of two types: (1) Photo Emissive type and (2) Photo Conductive type *(see slide no. 24).*
- **Hall Effect type transducers** : Their working are based on an electromagnetic physical phenomenon known as "*Hall Effect*".
- **Variable reactance type transducrs** : This type includes two further categories : (1) Inductive type and (2) Capacitive type
  - **Inductive type transducers** : These are based on the variable inductance of a coil *(slide 19)* . Inductance (in *Henry* or *micro-Henry*) can be changed in various ways. They are of many types, like - (1) Variable reluctance type, (2) Variable permeability type, (3) *LVDT (slide 27)*
  - **Capacitive type transducers** : These are based on the variable capacitance of a capacitor. Capacitance (in *micro-Farads* or *Farads*) can be changed by various ways like- by changing the gap between the plates, or by moving one of the plates along its plane. *(slide 18)*

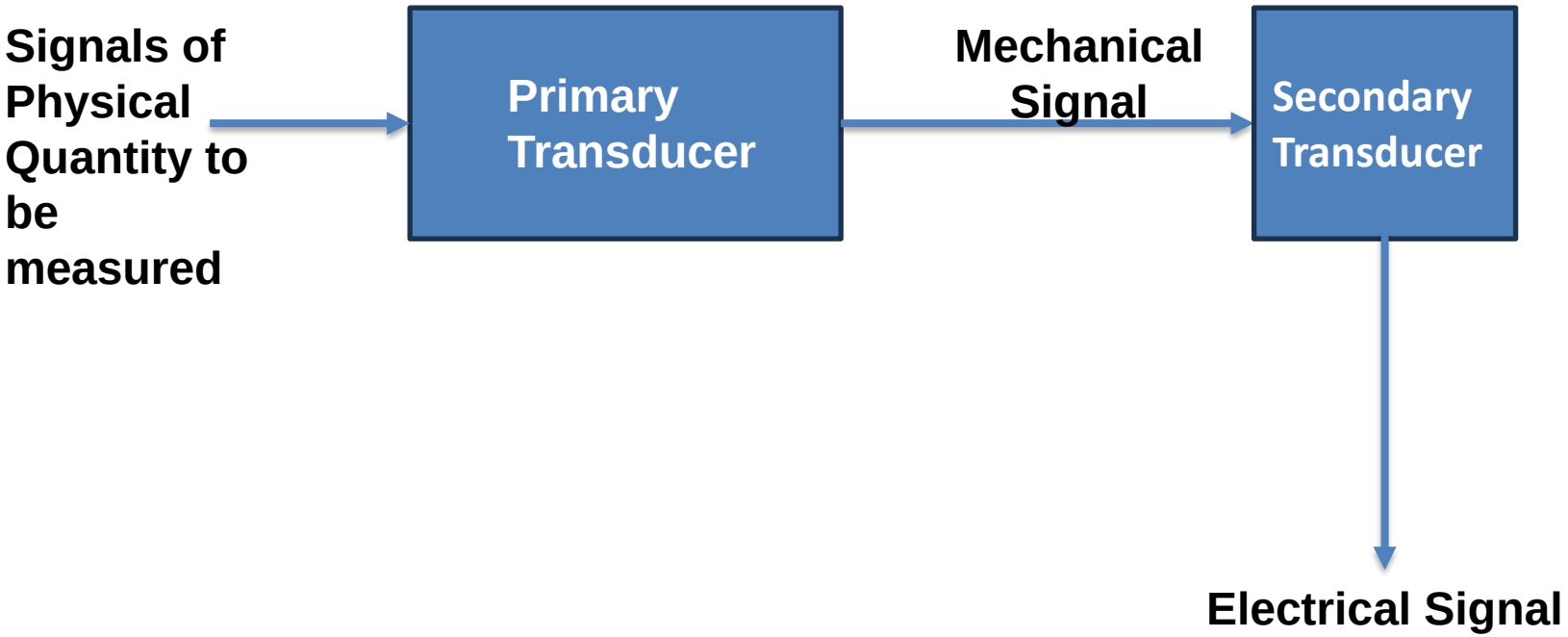
PRIMARY AND SECONDARY TRANSDUCERS

• Some transducers contain the mechanical as well as electrical device. The mechanical device converts the physical quantity to be measured into a mechanical signal. Such mechanical device are called as the primary transducers, because they deal with the physical quantity to be measured.

•The electrical device then convert this mechanical signal into a corresponding electrical signal. Such electrical device are known as secondary transducers. *(see the block diagram on the next slide).*

•Means, if *only one conversion of signal* is there, then the transducer is called primary type. Or if there are *two, three of more conversions of signals*; such transducers are called secondary type, tertiary type, etc.

PRIMARY AND SECONDARY TRANSDUCERS



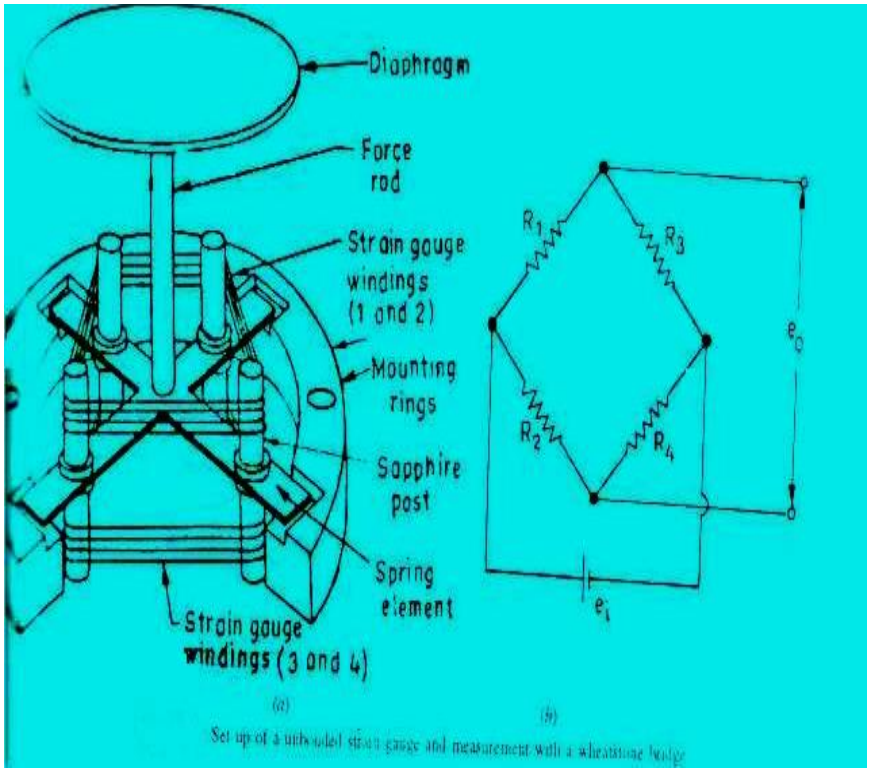
Example : A Strain Gauge

CONTD

•One of the example of **passive transducer** is an **Unbonded type strain gauge**. It also consists an example of secondary transducer. This was covered in detail, in "measurement of strain" topic (strain gauges).

•Ref fig in which the diaphragm act as primary transducer. It convert pressure or force (the quantity to be measured) into displacement (the mechanical signal).

•The displacement is then converted into change in resistance using strain gauge wire. Hence strain gauge acts as the secondary transducer.



CLASSIFICATION OF TRANSDUCERS
Transducer and Inverse Transducer

TRANSDUCER:

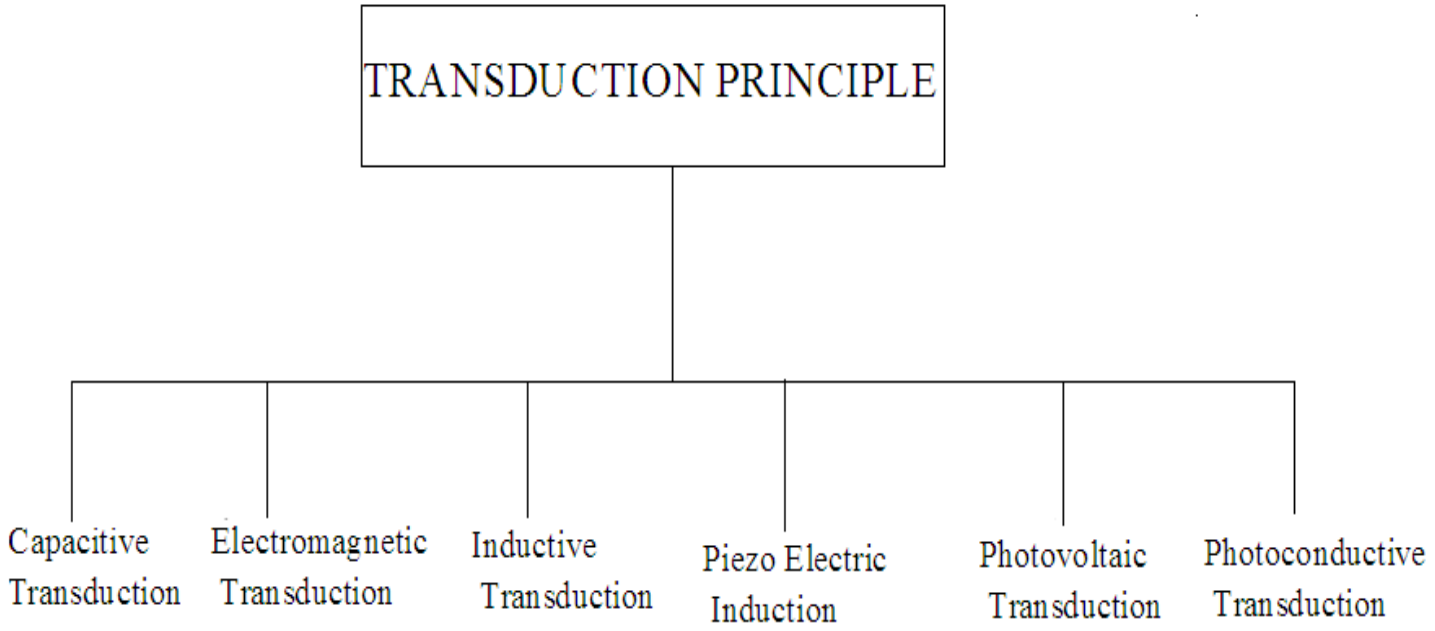
•Transducers convert non electrical quantity to electrical quantity (e.g microphone : converts voice (sound) signals into electrical signals. There are many other examples too, like strain gauge, potentiometer, etc.)

INVERSE TRANSDUCER:

• Inverse transducers convert electrical quantity to a non electrical quantity (e.g loudspeaker : converts electrical signals into sound signals)

CLASSIFICATION OF TRANSDUCERS
According to Transduction Principle

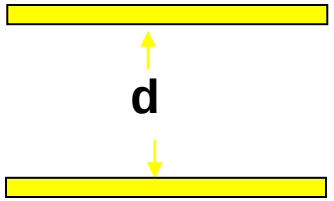
The method or principle of converting the input signal into another or output signal is called the transduction. There may be various transduction principles adopted by different types of transducers. *(A few of these have already been covered in previously discussed classifications). Please note that active as well as passive both types will come in this classification.*



CLASSIFICATION OF TRANSDUCERS
According to Transduction Principle

CAPACITIVE TRANSDUCER:

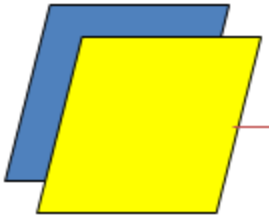
•In capacitive transduction transducers **the measurand is converted to a change in the capacitance of a capacitor.**



• A typical capacitor is comprised of two parallel plates of conducting material separated by an electrical insulating material called a dielectric. The plates and the dielectric may be either flattened or rolled.

Area=A

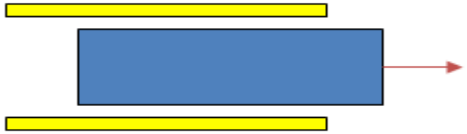
• The purpose of the dielectric is to help the two parallel plates maintain their stored electrical charges.



• The relationship between the capacitance and the size of capacitor plate, amount of plate separation, and the dielectric is given by

$C = \varepsilon_0 \varepsilon_r A / d$

Either A, d or ε can be varied.



d is the separation distance of plates (m)

C is the capacitance (F, Farad)

ε_0 : absolute permittivity of vacuum

ε_r : relative permittivity

A is the effective (overlapping) area of capacitor plates (m2)

CLASSIFICATION OF TRANSDUCERS
According to Transduction Principle

INDUCTIVE TRANSDUCER:

- In inductive transduction, the measurand is converted into a change in the self inductance of a single coil. It is achieved by displacing the core of the coil that is attached to a mechanical sensing element.
- The details of this concept are given in the coming slides-

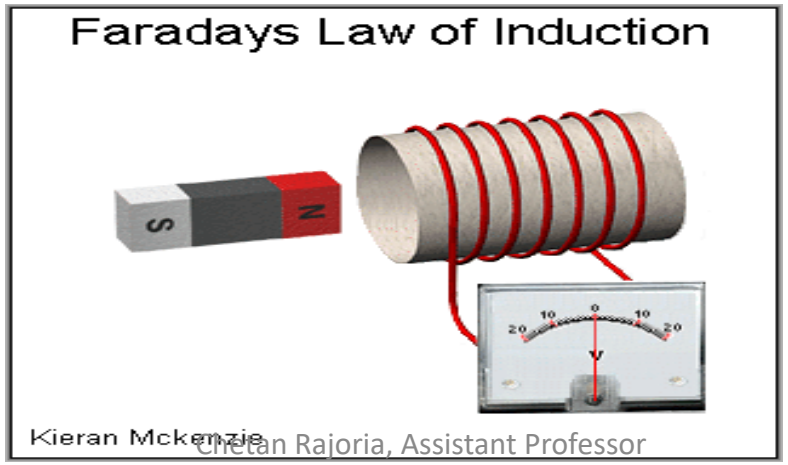
CLASSIFICATION OF TRANSDUCERS According to Transduction Principle

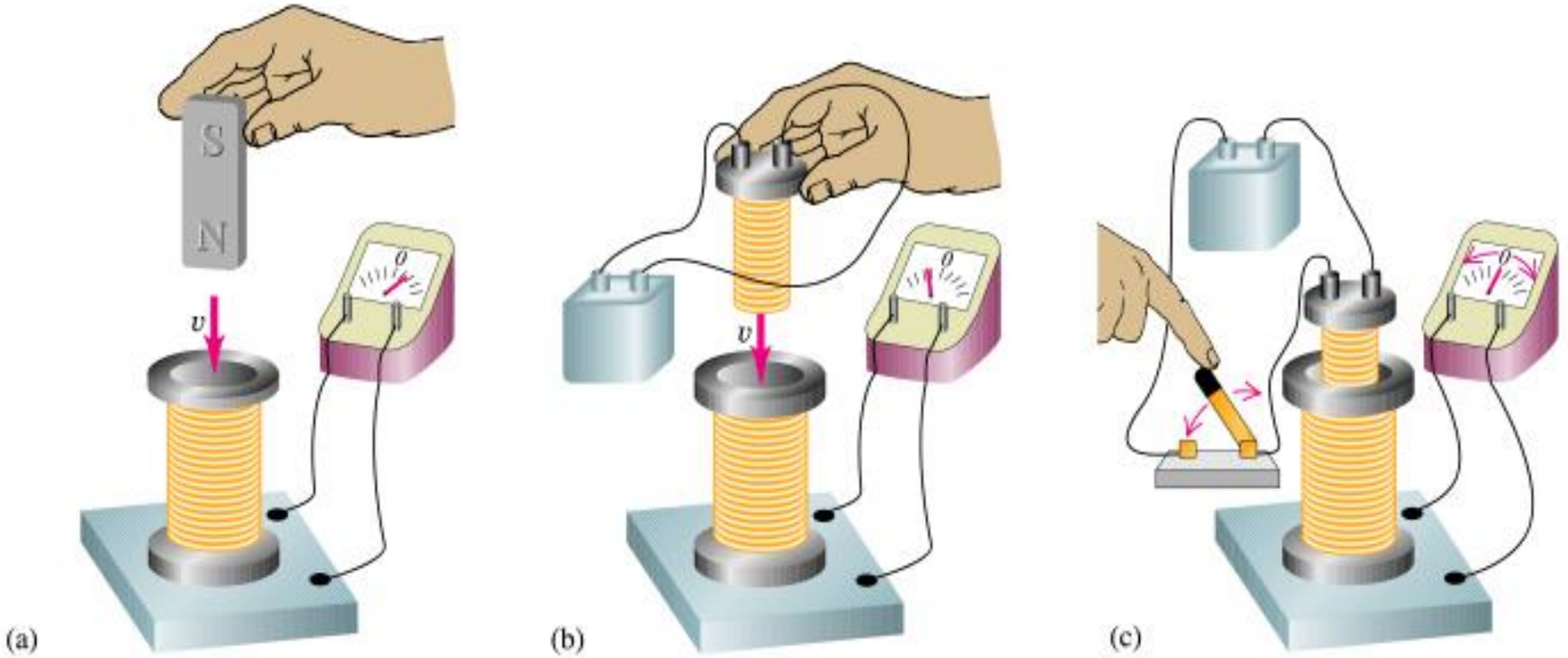
ELECTROMAGNETIC TRANSDUCTION:

•In electromagnetic transduction, the measurand is converted to voltage induced in conductor by change in the magnetic flux, in absence of excitation.

•The electromagnetic transducer are self generating active transducers

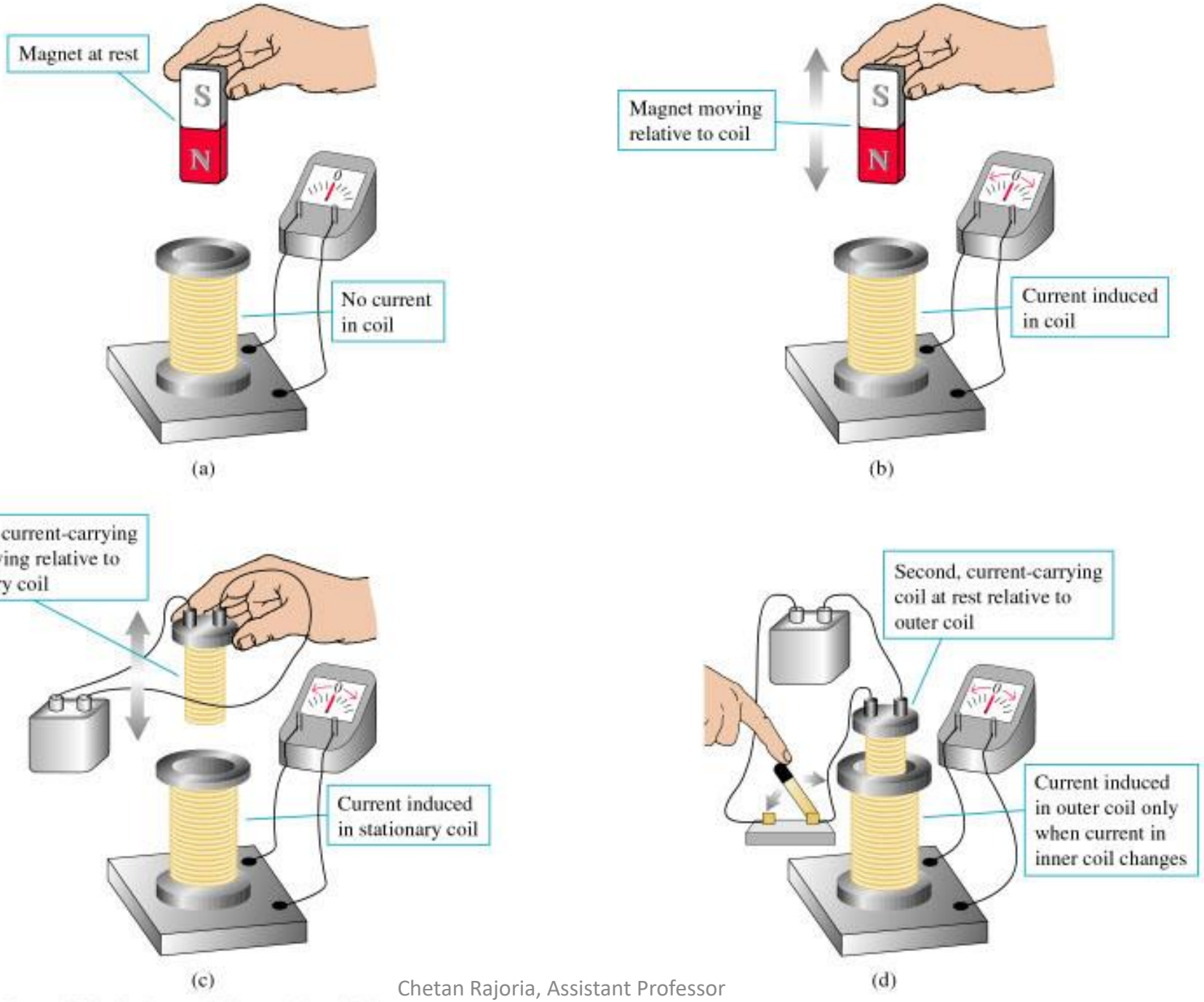
•The motion between a piece of magnet and an electromagnet is responsible for the change in flux





Current induced in a coil.

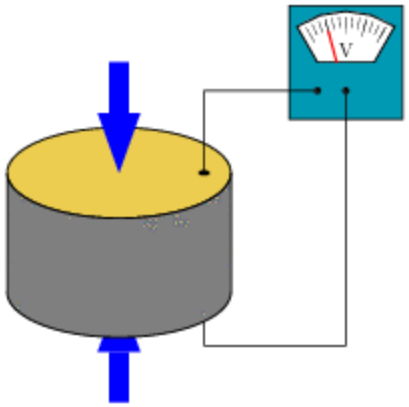
The current in a coil can be induced in various ways : Fig (a) : By inserting a magnet as a core inside, Fig (b) by inserting a coil already having current in it, inside another coil, Fig (c) Just by turning the current on/off in the core coil.



CLASSIFICATION OF TRANSDUCERS According to Transduction Principle

PIEZO ELECTRIC INDUCTION :

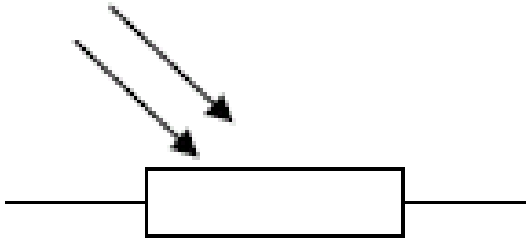
•In piezoelectric induction the measurand is converted into a change in electrostatic charge q or voltage V generated by crystals when mechanically it is stressed as shown in fig. *(already discussed on slide no .8).*



CLASSIFICATION OF TRANSDUCERS According to Transduction Principle

PHOTO CONDUCTIVE TRANSDUCTION :

•In photoconductive transduction the measurand is converted to change in resistance of semiconductor material by the change in light incident on the material.



PASSIVE TRANSDUCERS

- **Resistive transducers** :
  - Resistive transducers are those transducers in which the resistance change due to the change in some physical phenomenon.
  - The resistance of a metal conductor is expressed by a simple equation.
  - $R = \rho L/A$
  - Where R = resistance of conductor in Ω

    L = length of conductor in m

    A = cross sectional area of conductor in m^2

    ρ = resistivity of conductor material in Ω-m.

RESISTIVE TRANSDUCER

There are 4 type of resistive transducers.

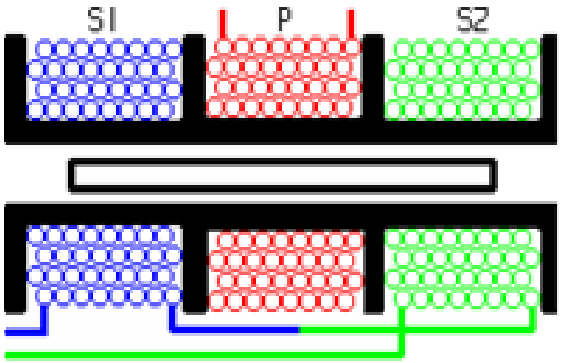
1. **Potentiometers (POT) :** A device used for pressure measurement. Change in pressure causes mechanical movement of the rider of a Rheostat, which in turn causes change in its resistance, detected by a Wheatstone bridge).
2. **Strain gauge** (bonded and unbonded) : Change in length of a wire causes change in its electrical resistance, detected by a Wheatstone bridge.
3. **Thermistors** (semiconductor based RTDs*)
4. **Resistance thermometer** (RTDs*)

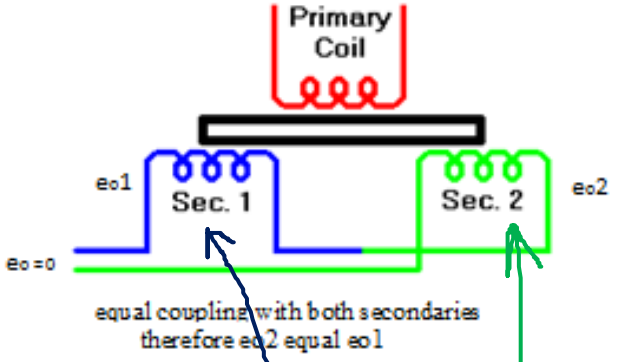
(*RTD = Resistive Temperature Detectors. A device used for temperature measurement. **Principle** : Change in temperature of a wire can cause change in its electrical resistance, which can be detected using a Wheatstone bridge).

For details of potentiometer you can study "Pressure measurement"
For details of Thermistors and RTDs, you can study "Temperature measurement".
For details of Strain gauges, you can study "Strain measurement".

LINEAR VARIABLE DIFFERENTIAL TRANSFORMER(LVDT)

- AN LVDT transducer comprises a transformer on to which three coils are wound.
- The primary coil is excited with an AC current, the secondary coils are bound such that when a ferrite core is in the central linear position, an equal voltage is induced in to each coil.
- The secondary are connected in opposite so that in the central position the outputs of the secondary cancels each other out.



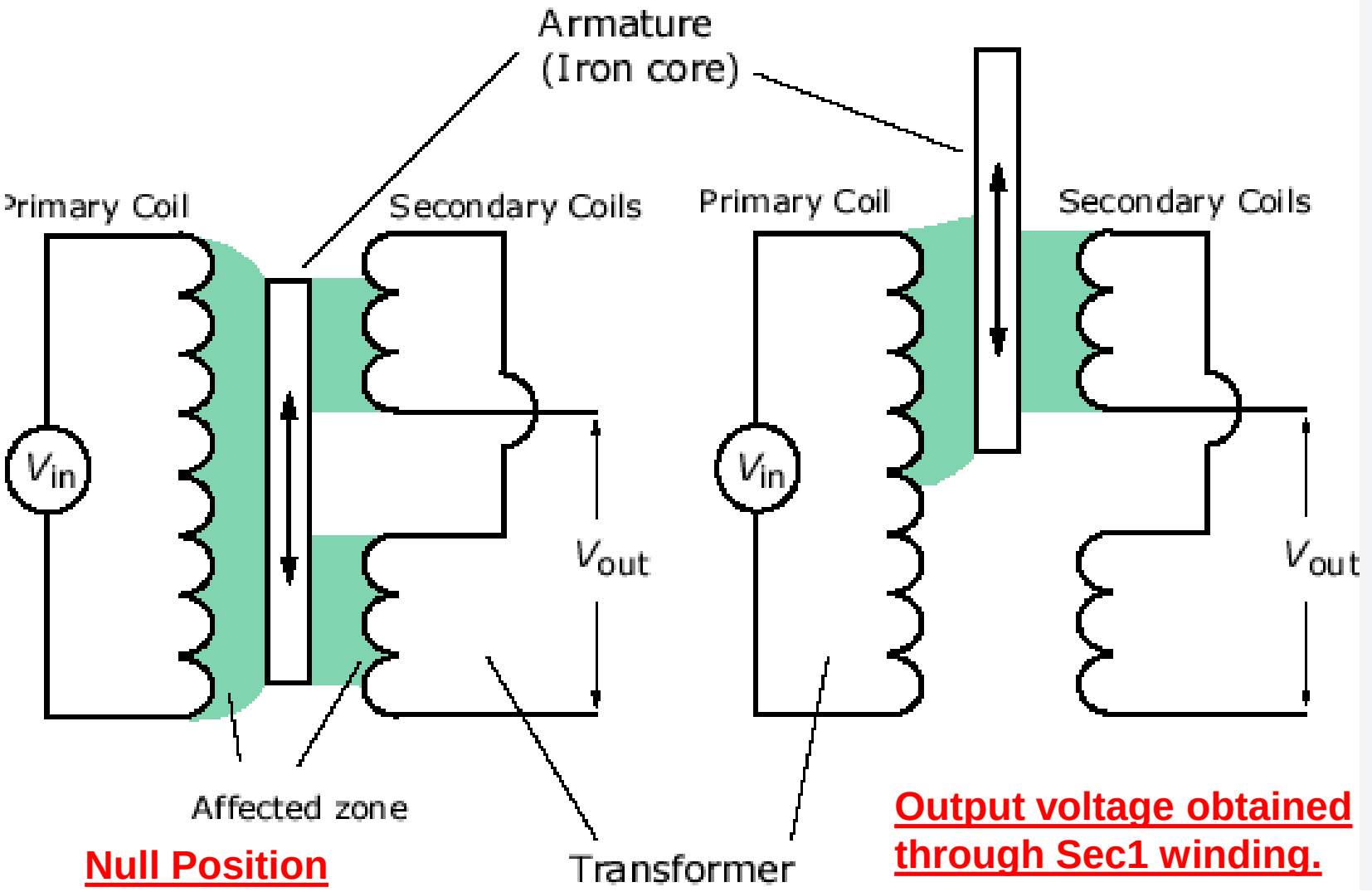


Secondary coil is bounded into two equal parts – Sec1 and Sec2. Both parts in opposite direction – one clockwise other anticlockwise.

LVDT contd…

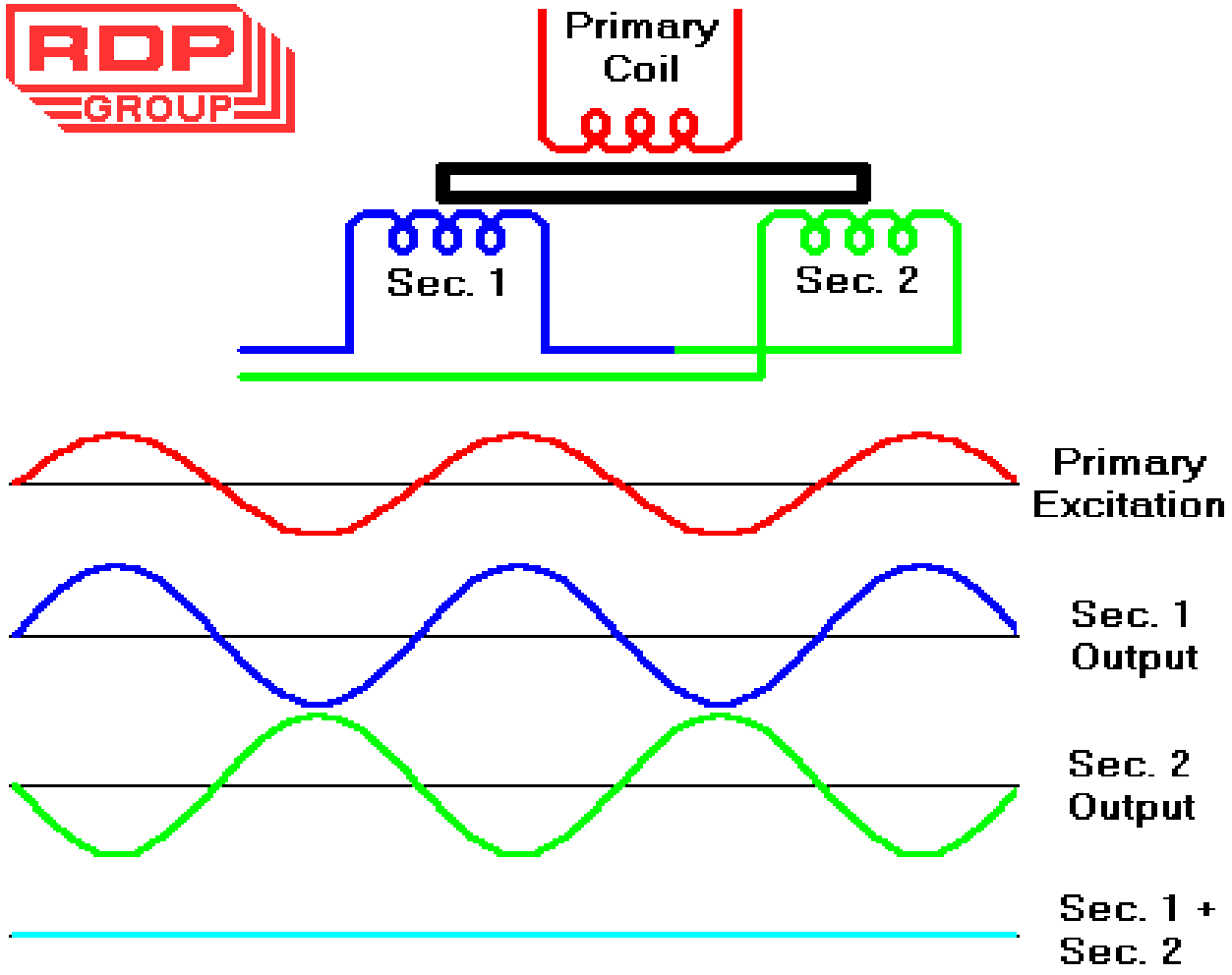
- The excitation is applied to the primary winding and the armature assists the induction of current in to secondary coils.
- When the core is exactly at the center of the coil then the flux linked to both the secondary winding will be equal. Due to equal flux linkage the secondary induced voltages (eo1 & eo2) are equal but they have opposite polarities. Output voltage eo is therefore zero. This position is called “null position”

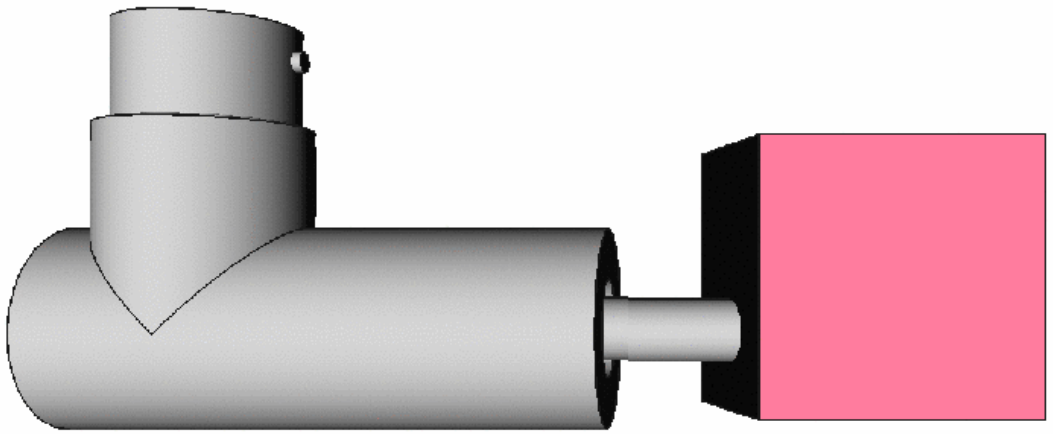
- Now if the core is displaced from its null position toward sec1 then flux linked to sec1 increases and flux linked to sec2 decreases. Therefore $e_{o1} > e_{o2}$ and the output voltage of LVDT e_o will be positive
- Similarly if the core is displaced toward sec2 then the $e_{o2} > e_{o1}$ and the output voltage of LVDT e_o will be negative.



Null Position

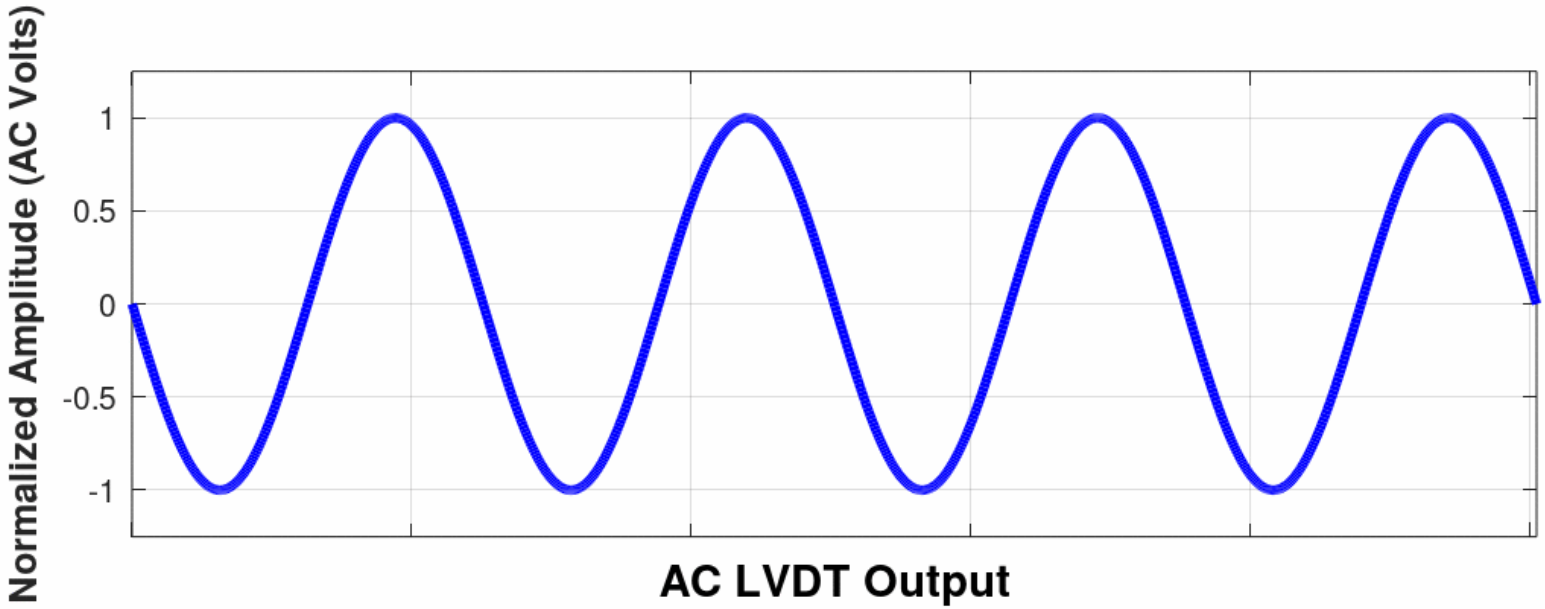
Output voltage obtained through Sec1 winding.


Primary
Coil
Sec. 1
Sec. 2
Primary
Excitation
Sec. 1
Output
Sec. 2
Output
Sec. 1 +
Sec. 2



LVDT Housing

Measured Object



THANK YOU