Sensors and Transducers

The words ‘sensor’ and ‘transducer’ are often used interchangeably although they are different devices with different characteristics.

What is the difference between a sensor and a transducer? Sensors and transducers are both devices which react to a change in a physical quality in their surroundings.

The main difference between a sensor and a transducer is that a sensor senses the difference or change in the environment they are exposed to and gives an output in the same format where as a transducer takes a measurement in one form and converts it to another for example, a measurement which is not electrical and converts it into an electrical signal. This process is called “transduction”.

Transducers are sometimes referred to as sensors and vice versa - this can make telling the difference difficult.

WHAT IS A SENSOR?

A Sensor is defined as a device which measures a physical quality (light, sound, space) and converts them into an easily readable format. If calibrated correctly, sensors are highly accurate devices. Not all transducers are sensors but most sensors are transducers.

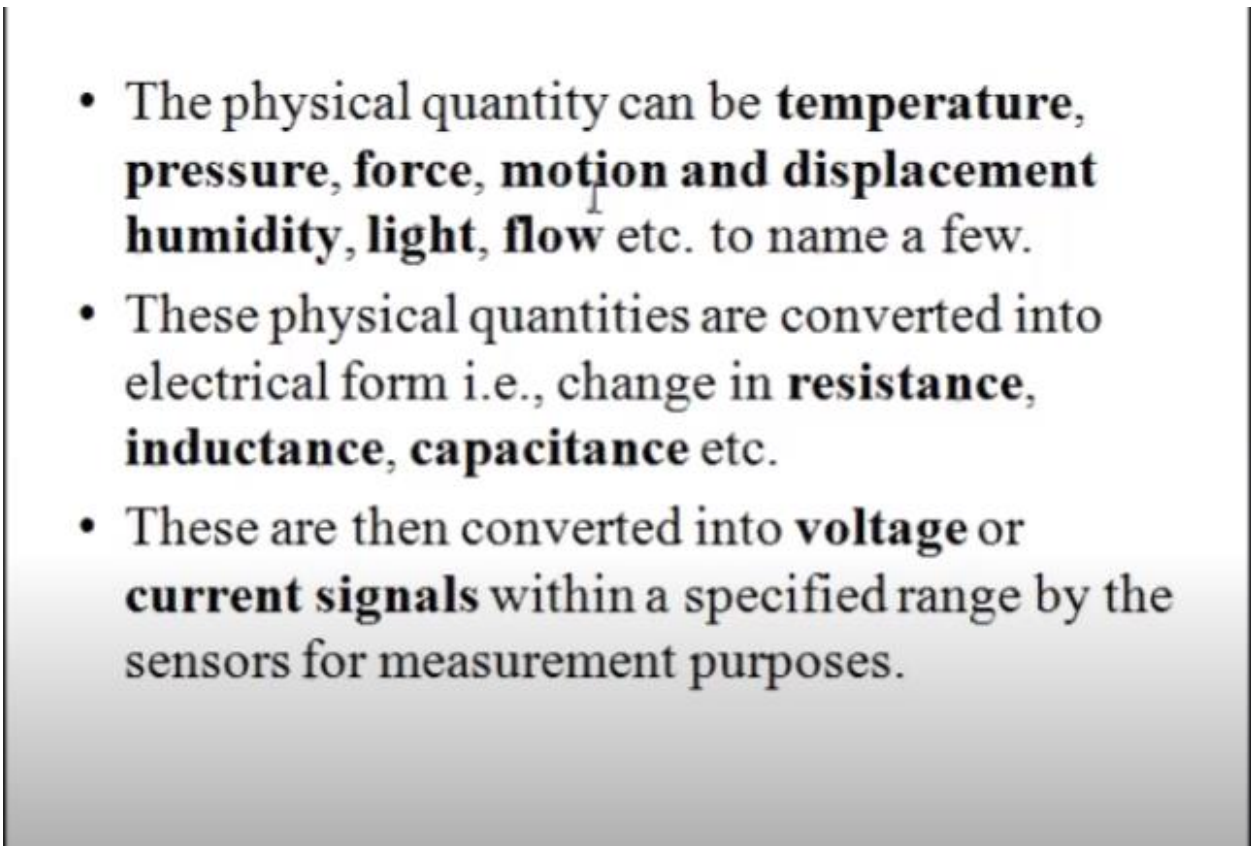
For example, a thermistor is a type of sensor; it will respond to the change in temperature but does not convert the energy into a different format to what it was originally sensed in.

WHAT IS A TRANSDUCER?

A transducer is an electronic device which converts energy from one form to another. There are six different types of measurements; mechanical, magnetic, thermal, electric, chemical and radiation, a transducer can take a measurement in one format and convert it to another. A thermistor on its own is a sensor but, when it is incorporated into a bigger circuit or device it will become an element of a transducer; for example, a thermometer is a transducer.

There are different types of transducer; an input transducer and an output transducer.

An input transducer takes measurement of a physical energy and converts it into a different signal to make it readable for a user. For example, a linear transducer takes the positional measurement and converts it into electrical signals to give an output.



An output transducer is also known as an actuator. Output transducers work the opposite way to input transducers, they take electrical signals and convert them into another form. For example, a light bulb can sometimes be referred to as an output transducer as it converts electricity into light.

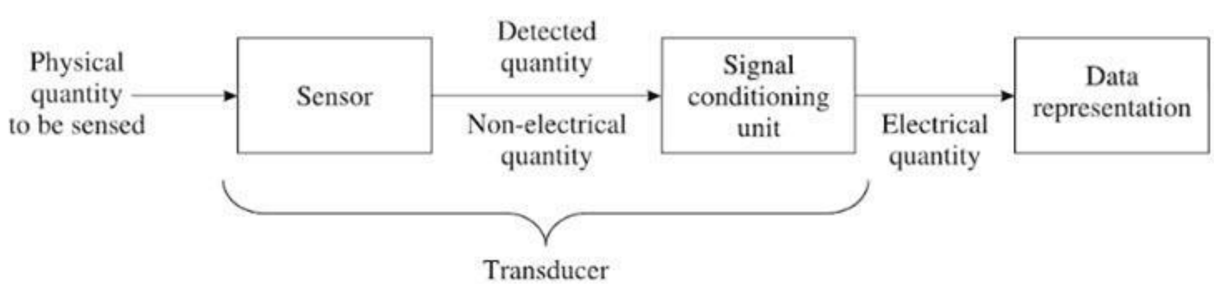
COMPARISON BETWEEN A SENSOR AND TRANSDUCER

	Sensor	Transducer
Working principle	Senses a physical measurement and makes it readable for the user but keeps it in the same format	Senses the physical measurement and converts it from one form to another - eg: Non- electrical to electrical.
Examples	Thermistor, motion sensor, pressure switch	Microphones, pressure transducer, linear transducer.
Uses / applications	Patient monitoring, infrared toilet flushes, liquid dispensing in drinks machines.	HVAC monitoring, engine controls, steering systems, ramp and bridge lifting systems.

What are Transducers?

Before understanding what, a transducer is or diving into the different types of Transducers, consider the following setup of a measuring system. In this block diagram of a simple measuring system, there are three basic elements:

- Sensor
- Signal Conditioning Unit
- Data Representing Device



Sensor in detail

A Sensor is a device that is used to detect changes in any physical quantity like Temperature, Speed, Flow, Level, Pressure, etc. Any changes in the input quantity will be detected by a Sensor and reflected as changes in output quantity.

Both the input and output quantities of a Sensor are Physical i.e. non-electrical in nature.

Signal Conditioning Unit

The non-electrical output quantity of the Sensor makes it inconvenient to further process it. Hence, the Signal Conditioning Unit is used to convert the physical output (or non-electrical output) of the sensor to an electrical quantity.

Some of the best-known Signal conditioning units are:

- Analog to Digital Converters
- Amplifiers
- Filters
- Rectifiers
- Modulators

Data Representation Device

A Data representation device is used to present the measured output to the observer. This can be anything like

- A Scale
- An LCD Display
- A Signal Recorder

Transducer

In the above example, consider a Strain Gauge as the Sensor. Any changes in the strain will reflect as changes in its resistance. Now, in order to convert this change in resistance into equivalent voltages, you can use a simple Wheatstone Bridge circuit, which acts as the Signal Conditioning Unit.

The combination of Strain Gauge (Sensor) and Wheatstone Bridge (Signal Conditioning Unit) is Known as a Transducer.

Generally speaking, a Transducer is a device that converts one form of energy into another by the principle of Transduction. Usually, a signal in one form of energy is converted to a signal in another form by a Transducer.

From the above example, a Transducer is a device that converts a Physical Quantity into an Electrical Quantity.

Classification of Sensors:

- Passive Sensors
  - Measure a physical property from the environment
- Active Sensors
  - Provide their own signal and use the interaction of the signal with the environment
  - Consist of an emitter and a detector
  - **Active sensor** requires an external power source to operate, and they transmit and detect the energy at the same time. While **passive sensors** do not require any external power source to produce output signal and they not only transmit energy but only detects the energy, transmitted from an energy source

Sensor Fusion

- Combining multiple sensors to get better information about the world

- Sensor fusion is a complex process
    - Different sensor accuracy, Different sensor complexity, Contradictory information, Asynchronous perception
- Cleverness is needed to put this information together
- Use the interaction with the world, keep in mind the task
    - Camera: great deal of processing
    - Movement: if everything else is static: movement means people
    - Color: If you know the particular color people wear
    - Temperature: can use sensors that detect the range of human body heat

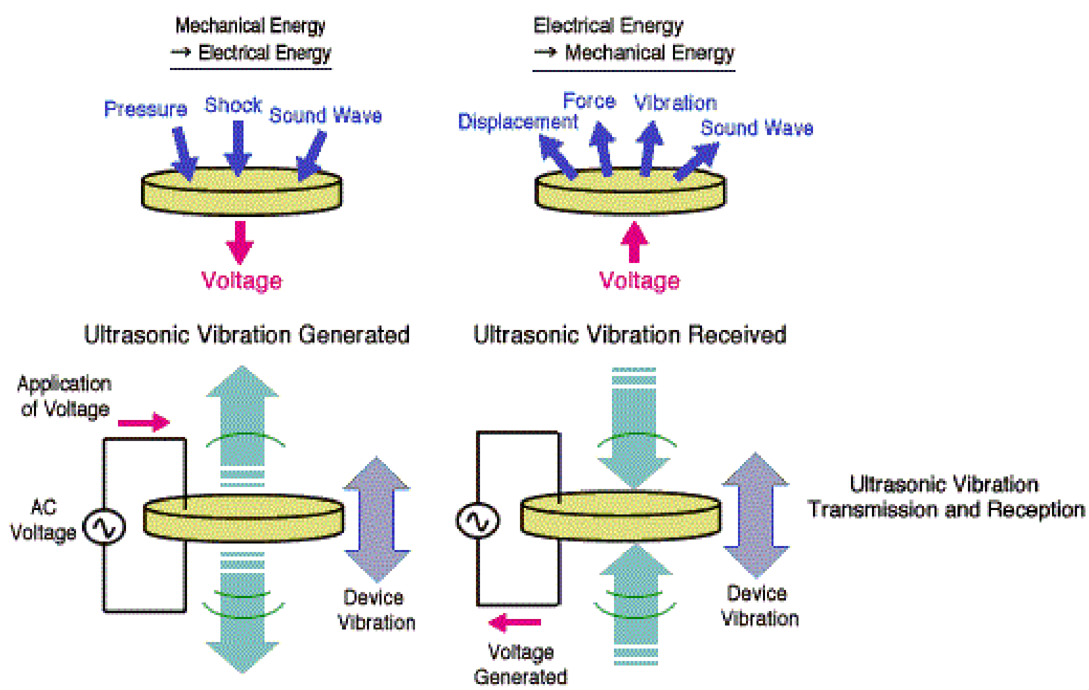
Distance: If any open-range becomes blocked

Piezoelectricity

Piezoelectricity, also called the piezoelectric effect, is the ability of certain materials to generate an AC (alternating current) voltage when subjected to mechanical stress or vibration, or to vibrate when subjected to an AC voltage, or both.

- The most common piezoelectric material is **quartz**.
- Certain ceramics, Rochelle salts, and various other solids also exhibit this effect.

A **piezoelectric transducer** comprises a "crystal" sandwiched between two metal plates. When a sound wave strikes one or both of the plates, the plates vibrate. The crystal picks up this vibration, which it translates into a weak AC voltage. Therefore, an AC voltage arises between the two metal plates, with a waveform similar to that of the sound waves.



Conversely, if an AC signal is applied to the plates, it causes the crystal to vibrate in sync with the signal voltage.

As a result, the metal plates vibrate also, producing an acoustic disturbance.

Some Important Sensors, their Working Mechanism and Applications

Sonar sensor: Ultrasonic sensors work by emitting sound waves at a frequency too high for humans to hear. They then wait for the sound to be reflected back, calculating distance based on the time required. This is similar to how radar measures the time it takes a radio wave to return after hitting an object

https://www.youtube.com/watch?v=AwVIilqNZ8U

A Light Dependent Resistor (LDR) or a photo resistor is a device whose resistivity is a function of the incident electromagnetic radiation. Hence, they are light sensitive devices. They are also called as photo conductors, photo conductive cells or simply photocells. Working Principle of LDR. ... These devices depend on the light, when light falls on the LDR then the resistance decreases, and increases in the dark. When a LDR is kept in the dark place, its resistance is high and, when the LDR is kept in the light its resistance will decrease.

IR sensor:

An infrared sensor is an electronic device, that emits in order to sense some aspects of the surroundings. An IR sensor can measure the heat of an object as well as detects the motion. There are some sensors measure only infrared radiation, rather than emitting it that is called as a passive IR sensor. There are Active IR sensors also. Usually in the infrared spectrum, all the objects radiate some form of thermal radiations. These types of radiations are invisible to our eyes, that can be detected by an infrared sensor. The emitter is simply an IR LED (Light Emitting Diode) and the detector is simply an IR photodiode which is sensitive to IR light of the same wavelength as that emitted by the IR LED. When IR light falls on the photodiode, the resistances and these output voltages, change in proportion to the magnitude of the IR light received.

How air conditioner remote controls work

Most air conditioner remote controls rely on infrared technology (IR). It works based on the concept of Active sensor. A remote control emits pulses of infrared light and those pulses are detected by a receiver, usually situated on the air conditioning unit itself. The infrared beams of light are invisible to the naked eye. The limitation of infrared technology is that it can only be used over a relatively short distance and in the line of sight. An IR remote control device won't work if there's an object blocking the beam. The signal can also be disrupted due to the presence of other types of electronic equipment in the same room.

PIR and Motion Sensors:

https://www.youtube.com/watch?v=6Fdrr_1guok

Introduction of PIR sensor and working mechanism

https://www.seeedstudio.com/blog/2019/08/03/pir-sensor-introduction-and-how-pir-motion-sensor-works-with-arduino-and-raspberry-pi/

How infrared cameras work

All objects emit infrared energy, known as a heat signature. An infrared camera (also known as a thermal imager) detects and measures the infrared energy of objects. The camera converts that infrared data into an electronic image that shows the apparent surface temperature of the object being measured.

An infrared camera contains an optical system that focuses infrared energy onto a special detector chip (sensor array) that contains thousands of detector pixels arranged in a grid.

Each pixel in the sensor array reacts to the infrared energy focused on it and produces an electronic signal. The camera processor takes the signal from each pixel and applies a mathematical calculation to it to create a color map of the apparent temperature of the object. Each temperature value is assigned a different color. The resulting matrix of colors is sent to memory and to the camera's display as a temperature picture (thermal image) of that object.

Pulse Oximeter:

Pulse oximeter work by emitting Infra-red and LED and having it passed through tissue bed which included blood to a receiver which is on the other side of a pulse oximeter. Hemoglobin contains oxygen. Hemoglobin which is fully saturated and de-saturated will absorb different spectrum in different amounts of light. Fully saturated hemoglobin (SpO2) will absorb more infra-red light radially and de-saturated hemoglobin will absorb red light and by passing this information how much light is absorbed both infrared and red light, the machine will able to calculate the amount of fully-saturated hemoglobin in the patients' blood. By calculating oxygen saturation, heart rate can also be calculated from the same data by separata calculation.

Resistance Temperature Detector:

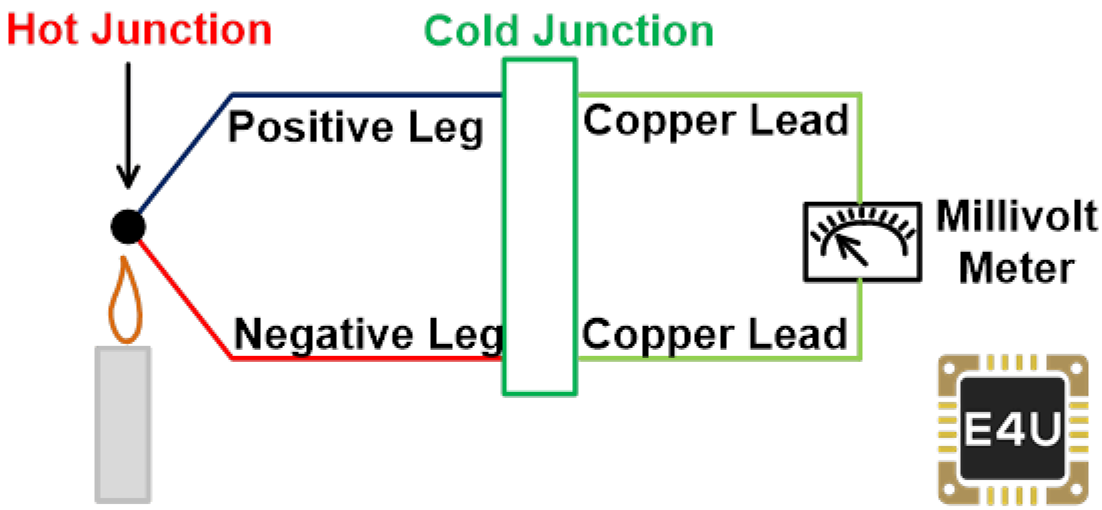
A **Resistance Temperature Detector** (also known as a **Resistance Thermometer** or **RTD**) is an electronic device used to determine the temperature by measuring the resistance of an electrical wire. This wire is referred to as a temperature sensor. If we want to measure temperature with high accuracy, an **RTD** is the ideal solution, as it has good linear characteristics over a wide range of temperatures. Other common electronics devices used to measure temperature include a thermocouple or a thermistor.

In **RTD** devices; Copper, Nickel and Platinum are widely used metals. These three metals are having different resistance variations with respective to the temperature variations. That is called resistance-temperature characteristics.

What is a Thermocouple?

A thermocouple is defined as a thermal junction that functions based on the phenomenon of the thermoelectric effect, i.e. the direct conversion of temperature differences to an electric voltage. It is an electrical device or sensor used to measure temperature. A thermocouple can measure a wide range of temperatures. It is a simple, robust, and cost-effective temperature sensor used in various industrial applications, home, office, and commercial applications.
A thermocouple consists of two plates of different metals. Both plates are connected at one end and make a junction.

The junction is placed on the element or surface where we want to measure the temperature. This junction is known as a hot junction. And the second end of the plate is kept at a lower temperature (room temperature). This junction is known as cold junction or reference junction.



Working of Thermocouple

We know the temperature difference between the two different metals induces the potential differences between two points of the thermocouple plates. If the circuit is closed, a very small amount of current will flow through the circuit. A voltmeter is connected in the circuit. The voltage measured by the voltmeter is a function of a temperature difference between two junctions. Hence, by measuring the voltage, we can calculate the temperature of the hot junction.

What is a Thermistor?

A thermistor (or thermal resistor) is defined as a type of resistor whose electrical resistance varies with changes in temperature. Although all resistors' resistance will fluctuate slightly with temperature, a thermistor is particularly sensitive to temperature changes. Thermistors act as a passive component in a circuit.

The working principle of a thermistor is that its resistance is dependent on its temperature. We can measure the resistance of a thermistor using an ohmmeter. If we know the exact relationship between how changes in the temperature will affect the resistance of the thermistor – then by measuring the thermistor's resistance we can derive its temperature.

How much the resistance changes depend on the type of material used in the thermistor. Thermistors are made with polymer or ceramic materials.

Thermistor Types

There are two types of thermistors:

- Negative Temperature Coefficient (NTC) Thermistor
- Positive Temperature Coefficient (PTC) Thermistor

NTC Thermistor

In an NTC thermistor, when the temperature increases, resistance decreases. And when temperature decreases, resistance increases. Hence in an NTC thermistor temperature and resistance are inversely proportional. These are the most common type of thermistor. The thermistors are non-linear sensors.

PTC Thermistor

A PTC thermistor has the reverse relationship between temperature and resistance. When temperature increases, the resistance increases. And when temperature decreases, resistance decreases. Hence in a PTC thermistor temperature and resistance are proportional.

Although PTC thermistors are not as common as NTC thermistors, they are frequently used as a form of circuit protection. Similar to the function of fuses, PTC thermistors can act as current-limiting device.

Uses of Thermistors

Thermistors have a variety of applications. They are widely used as a way to measure temperature as a thermistor thermometer in many different liquid and ambient air environments. Some of the most common uses of thermistors include:

- Digital thermometers (thermostats)
- Automotive applications (to measure oil and coolant temperatures in cars & trucks)
- Household appliances (like microwaves, fridges, and ovens)
- Circuit protection (i.e. surge protection)
- Rechargeable batteries (ensure the correct battery temperature is maintained)
- To measure the thermal conductivity of electrical materials

- Useful in many basic electronic circuits (e.g. as part of a beginner Arduino starter kit)
- Temperature compensation (i.e. maintain resistance to compensate for effects caused by changes in temperature in another part of the circuit)
- Used in wheatstone bridge circuits.

Proximity sensor

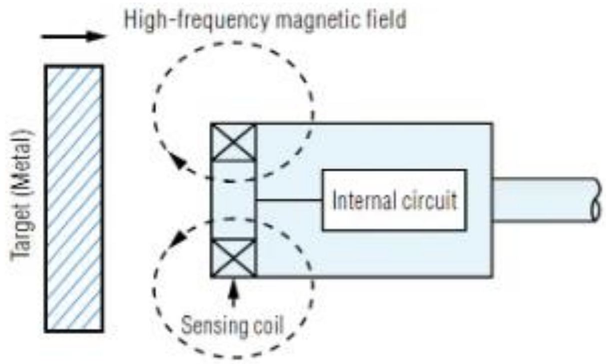
Comprised of an infrared LED and an IR light detector, a proximity sensor detects how close the phone is to an outside object, such as your ear. This sensing is done to reduce display power consumption while you're on a call by turning off the LCD backlight. It also disables the touch screen to avoid inadvertent touches by the cheek.

Inductive proximity sensor

A inductive proximity sensor can detect metal targets approaching the sensor, without physical contact with the target. Inductive Proximity Sensors are roughly classified into the following three types according to the operating principle: the high-frequency oscillation type using electromagnetic induction, the magnetic type using a magnet, and the capacitance type using the change in capacitance.

Working:

A high-frequency magnetic field is generated by coil L in the oscillation circuit. When a target approaches the magnetic field, an induction current (eddy current) flows in the target due to electromagnetic induction. As the target approaches the sensor, the induction current flow increases, which causes the load on the oscillation circuit to increase. Then, oscillation attenuates or stops. The sensor detects this change in the oscillation status with the amplitude detecting circuit, and outputs a detection signal.



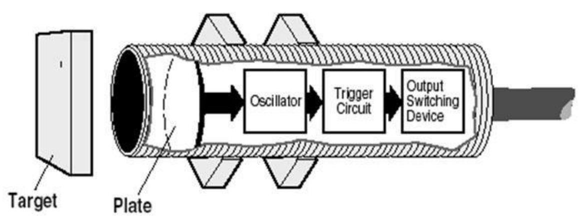
What is a Capacitive Sensor?

Capacitive proximity sensors are non-contact devices that can detect the presence or absence of virtually any object regardless of material. They utilize the electrical property of capacitance and the change of capacitance based on a change in the electrical field around the active face of the sensor.

Capacitive sensing technology is often used in other sensing technologies such as:

Flow, pressure, liquid level, spacing, thickness, ice detection, shaft angle or linear position, dimmer switches, key switches, x-y tablet, accelerometers

Principle of operation



A capacitive sensor acts like a simple capacitor. A metal plate in the sensing face of the sensor is electrically connected to an internal oscillator circuit and the target to be sensed acts as the second plate of the capacitor. Unlike an inductive sensor that produces an electromagnetic field a capacitive sensor produces an electrostatic field.

The external capacitance between the target and the internal sensor plate forms a part of the feedback capacitance in the oscillator circuit. As the target approaches the sensors face the oscillations increase until they reach a threshold level and activate the output.

How Does a Microwave Motion Detector Work?

Microwave sensors, also known as Radar, RF or Doppler sensors, detect walking, running or crawling targets in an outdoor environment. A microwave motion detector works by continuously sending out microwave signals. These signals will return to the sensor in consistent intervals based on the objects in the room. If motion occurs, the timing of these signals will change, and the sensor will send a signal to the system.

When a microwave motion detector is operating in an environment with absolutely no motion, the sensor will only detect one consistent pattern. This is because the microwave signals will bounce off of any objects or structures in the area and return to the sensor in the same way every single time. If this is the case, the sensor will assume that no motion is present and that everything is fine.

But if a person or an object were to suddenly enter into the area, then the microwave signals would return to the sensor at a different time interval. This is due to the fact that the signals would bounce off the person or object and change their previous pattern. This change in signal path would be recognized by the microwave sensor, and an alarm would occur. However, this change must be significant enough for an alarm to occur. Small changes, such as an insect or falling leaves probably wouldn't set off the motion detector.

Laser Sensor Working Mechanism:

- Receiver lens concentrates the light reflected off the target, and produces an image on a light receiving element.
- The concentrated light reflects at several different angles, when distance changes.

- With the change in angle of the concentrated light, the position of the image changes correspondingly.
- I have provided the three visuals at different distances in the figure shown below.
- From the three figures given below, you can easily understand the working principle of a laser sensor.

Smoke Sensors:

Ionization smoke alarms are generally more responsive to flaming fires.

How they work: Ionization-type smoke alarms have a small amount of radioactive material between two electrically charged plates, which ionizes the air and causes current to flow between the plates. When smoke enters the chamber, it disrupts the flow of ions, thus reducing the flow of current and activating the alarm. Example: Americium 241 (95 Protons and 146 Neutrons)

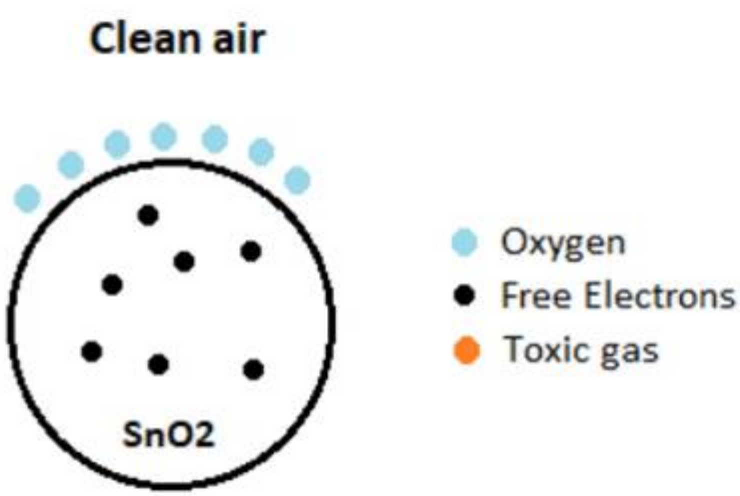
Photoelectric smoke alarms are generally more responsive to fires that begin with a long period of smoldering (called “smoldering fires”).

How they work: Photoelectric-type alarms aim a light source into a sensing chamber at an angle away from the sensor. Smoke enters the chamber, reflecting light onto the light sensor; triggering the alarm.

For each type of smoke alarm, the advantage it provides may be critical to life safety in some fire situations. Home fatal fires, day or night, include a large number of smoldering fires and a large number of flaming fires. You cannot predict the type of fire you may have in your home or when it will occur. Any smoke alarm technology, to be acceptable, must perform acceptably for both types of fires in order to provide early warning of fire at all times of the day or night and whether you are asleep or awake.

Gas Sensor Working

The ability of a Gas sensor to detect gases depends on the **chemiresister** to conduct current. The most commonly used chemiresistor is Tin Dioxide (SnO_2) which is an n-type semiconductor that has free electrons (also called as donor). Normally the atmosphere will contain more oxygen than combustible gases. The oxygen particles attract the free electrons present in SnO_2 which pushes them to the surface of the SnO_2. As there are **no free electrons** available output current will be zero. The below gif shown the oxygen molecules (blue color) attracting the free electrons (black color) inside the SnO_2 and preventing it from having free electrons to conduct current.



When the sensor is placed in the toxic or combustible gases environment, this reducing gas (orange color) reacts with the adsorbed oxygen particles and breaks the chemical bond between oxygen and free electrons thus **releasing the free electrons**. As the free electrons are back to its initial position, they can now conduct current, this conduction will be proportional the number of free electrons available in SnO2, if the gas is highly toxic more free electrons will be available.

These sensors are normally available as modules (shown right), these modules consist of the gas sensor and a comparator IC. Now let's see the pin description of the gas sensor module which we will generally use with an Arduino. The gas sensor module basically consists of 4 terminals

- **Vcc** – Power supply
- **GND** – Power supply
- **Digital output** – This pin gives an output either in logical high or logical low (0 or 1) that means it displays the presence of any toxic or combustible gases near the sensor.
- **Analog output** – This pin gives an output continuous in voltage which varies based on the concentration of gas that is applied to the gas sensor.

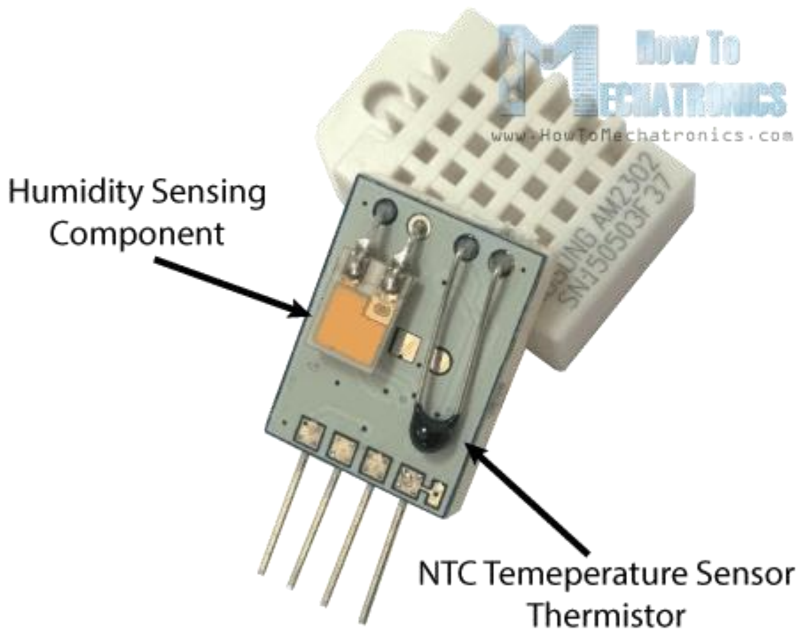
As discussed earlier the output of a gas sensor alone will be very small (in mV) so an external circuit has to be used in order to get a digital high low output from the sensor. For this purpose, a comparator (LM393), adjustable potentiometer, some resistors and capacitors are used.

The purpose of LM393 is to get the output from the sensor, compare it with a reference voltage and display whether the output is logically high or not. Whereas the purpose of the potentiometer is to set the required threshold value of the gas above which the digital output pin should go high.

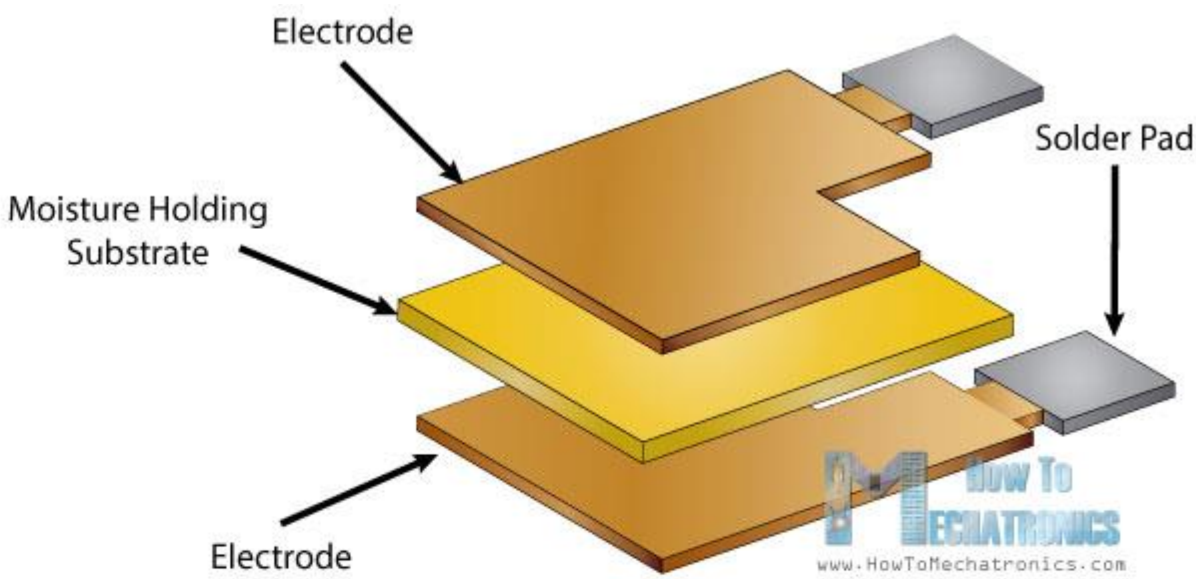
Humidity Sensor (DHT22):

The DHT22 sensor can measure temperature and humidity. Its temperature measuring range is from -40 to +125 degrees Celsius with +-0.5 degrees accuracy, while the DHT11 temperature range is from 0 to 50 degrees Celsius with +-2 degrees accuracy. The DHT22 sensor has better humidity measuring range, from 0 to 100% with 2-5% accuracy, while the DHT11 humidity range is from 20 to 80% with 5% accuracy.

Ok now let’s see how these sensors actually work. They consist of a humidity sensing component, a NTC temperature sensor (or thermistor) and an IC on the back side of the sensor.

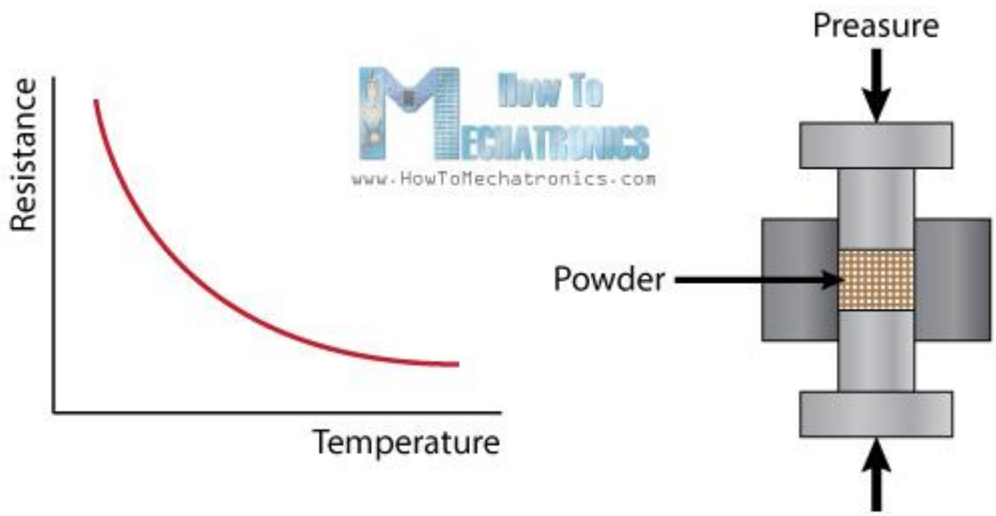


For measuring humidity, they use the humidity sensing component which has two electrodes with moisture holding substrate between them. So as the humidity changes, the conductivity of the substrate changes or the resistance between these electrodes’ changes. This change in resistance is measured and processed by the IC which makes it ready to be read by a microcontroller.



On the other hand, for measuring temperature these sensors use a NTC temperature sensor or a thermistor.

A thermistor is actually a variable resistor that changes its resistance with change of the temperature. These sensors are made by sintering of semi conductive materials such as ceramics or polymers in order to provide larger changes in the resistance with just small changes in temperature. The term “NTC” means “Negative Temperature Coefficient”, which means that the resistance decreases with increase of the temperature.



Working Principle of Touch Sensor

Touch sensors work similar to a switch. When they are subjected to touch, pressure or force they get activated and acts as a closed switch. When the pressure or contact is removed, they act as an open switch.

Capacitive touch sensor contains two parallel conductors with an insulator between them. These conductors plates act as a capacitor with a capacitance value.

When these conductor plates come in contact with our fingers, our finger acts as a conductive object. Due to this, there will be an uncertain increase in the capacitance.

A capacitance measuring circuit continuously measures the capacitance of the sensor. When this circuit detects a change in capacitance it generates a signal.

Resistive touch sensors calculate the pressure applied on the surface to sense the touch. These sensors contain two conductive films coated with indium tin oxide, which is a good conductor of electricity, separated by a very small distance.

Across the surface of the films, a constant voltage is applied. When pressure is applied to the top film, it touches the bottom film. This generates a voltage drop which is detected by a controller circuit and signal is generated thereby detecting the touch.

Applications

Capacitor sensors are easily available and are of very low cost. These sensors are highly used in mobile phones, iPods, automotive, small home appliances, etc.… These are also used for measuring pressure, distance, etc.… A drawback of these sensors is that they can give a false alarm.

Resistive touch sensors only work when sufficient pressure is applied. Hence, these sensors are not useful for detecting small contact or pressure. These are used in applications such as musical instruments, keypads, touch-pads, etc.. where a large amount of pressure is applied.

Examples

Some of the examples of touch sensors available in the market are TTP22301, TTP229, etc.…

Accelerometer

By measuring the amount of acceleration due to gravity, an accelerometer can figure out the angle it is tilted at with respect to the earth. By sensing the amount of dynamic acceleration, the accelerometer can find out how fast and in what direction the device is moving.

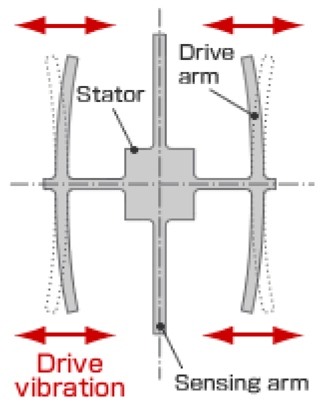
Accelerometer Working:

An accelerator looks like a simple circuit for some larger electronic device. Despite its humble appearance, the accelerometer consists of many different parts and works in many ways, two of which are the piezoelectric effect and the capacitance sensor. The piezoelectric effect is the most common form of accelerometer and uses microscopic crystal structures that become stressed due to accelerative forces. These crystals create a voltage from the stress, and the accelerometer interprets the voltage to determine velocity and orientation. The force caused by vibration or a change in motion (acceleration) causes the mass to "squeeze" the piezoelectric material which produces an electrical charge that is proportional to the force exerted upon it. Since the charge is proportional to the force, and the mass is a constant, then the charge is also proportional to the acceleration.

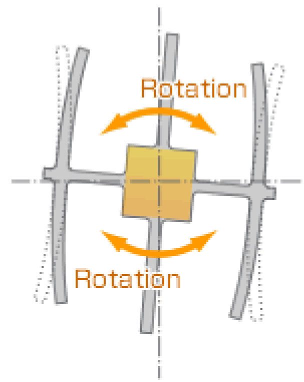
The capacitance accelerometer senses changes in capacitance between microstructures located next to the device. If an accelerative force moves one of these structures, the capacitance will change and the accelerometer will translate that capacitance to voltage for interpretation.

Gyro Sensors

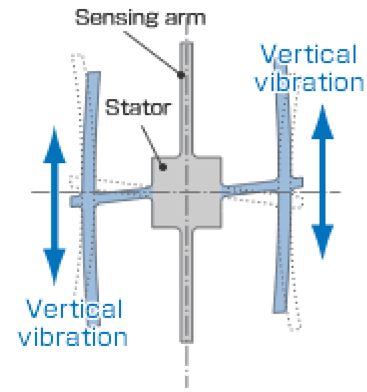
Vibration gyro sensors sense angular velocity from the Coriolis force applied to a vibrating object.
Here, we explain how this works, using as an example Epson 's double-T structure crystal element.



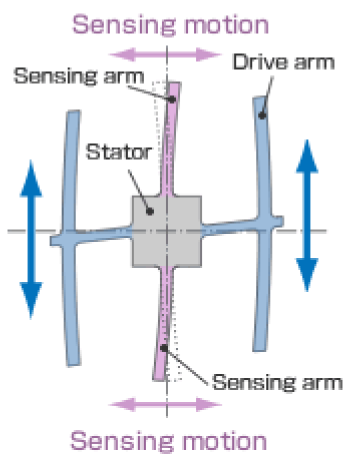
1. Normally, a drive arm vibrates in a certain direction.



2. Direction of rotation



3. When the gyro is rotated, the Coriolis force acts on the drive arms, producing vertical vibration.



4. The stationary part bends due to vertical drive arm vibration, producing a sensing motion in the sensing arms.

5. The motion of a pair of sensing arms produces a potential difference from which angular velocity is sensed. The angular velocity is converted to, and output as, an electrical signal.

Door Sensors or Elevator Sensors:

Door sensors (sometimes known as photoelectric or infrared beam, electric safety door edges, door detector, electric proximity edges, or electric doorman) is an elevator device that detects a passenger or an object on the doorway which prevents the doors from closing (usually installed for accessibility). If a person or an object blocks the doorway and the sensors detects the person or object, the door will reopen then stays open and will not closed until the person moves away or the object is removed from the doorway. If the doors are being held open for a more than the specified period, the elevator will go into nudge mode and the doors will close slowly with a continuously beep. The door sensors will not work on the fire service mode; hence the fireman's elevator still need mechanical safety edges when the sensor not working. Door sensors are also possible to detect an object or obstacle blocking the doorway.

For all the elevators with the door sensors may need an independent power supply to make the sensors work. Door sensors are usually work with a pair, the transmitter unit (or TX unit) which present the infra-red beams to the receiver unit (or RX unit) to receive the infra-red beams and make the sensors working.

Finger Print Sensor

Many modern IoT applications rely on fingerprint sensors for added safety and security, and to easily identify users. Fingerprint sensors are widespread in smartphones and other wearables, as well as in smart industry and smart home applications for entry identification and data security. The two most common fingerprint sensors in use today are optical sensors and capacitive sensors. Here’s how they work.

Optical vs. Capacitive Fingerprint Scanner

Whether you want to secure your phone or identify yourself before you enter a building, fingerprint sensors can add security and identification easily. There is two common ways that fingerprint sensors are being used today and that is optical and capacitive.

How Does a Fingerprint Optical Scanner Work?

Optical fingerprint sensors have been around for a while. The way an optical scanner works is by shining a bright light over your fingerprint and taking a digital photo. The light-sensitive microchip makes the digital image by looking at the ridges and valleys of the fingerprint, turning them into 1's and 0's, and creates the user's own personal code. Figure 1 shows how the light source reads the fingerprint and where that information goes. The disadvantage to this, while highly unlikely, is that a digital photo can be replicated.

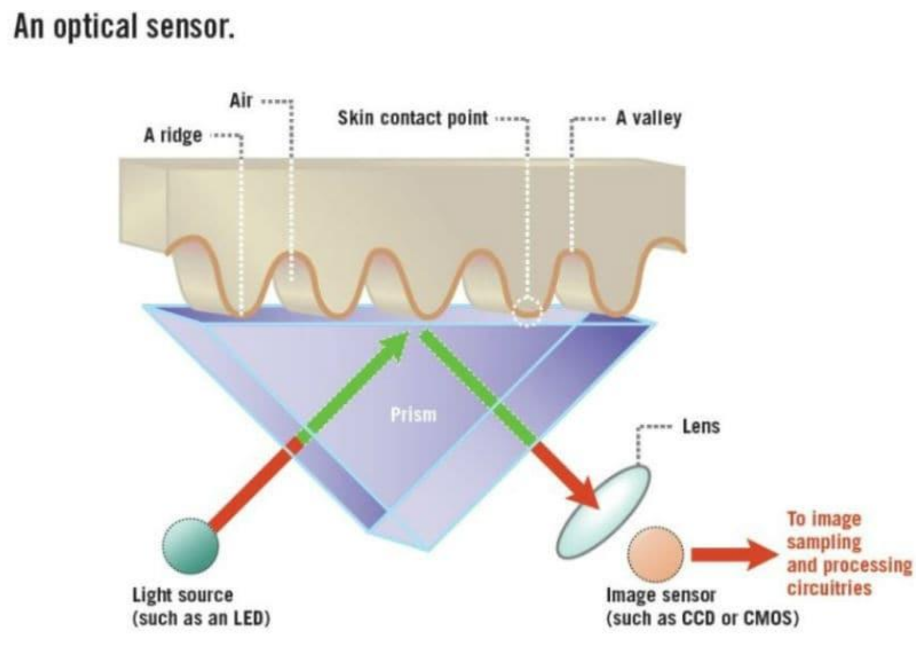


Image is showing how Light source taking a digital image of a fingerprint. (Source: Android Authority/Robert Triggs)

Capacitive Fingerprint Sensors

In today's world, capacitive fingerprint scanners are more common and found on phones. Similar to the capacitive touchscreen, it measures your finger by using human conductivity, creating an electrostatic field, and creating a digital image based on the electrostatic field.

To go into more detail, the capacitive fingerprint scanner uses tiny capacitor array circuits that track the detail of a fingerprint. It uses the ridges of your fingerprint that is placed over the conductive plates which changes the charge stored in the capacitor, while the valleys (air gaps) leave the charge on the capacitor unchanged. An operational amplifier integrator circuit tracks these changes that can then be recorded by an analog-to-digital converter, where this digital data can be analyzed.

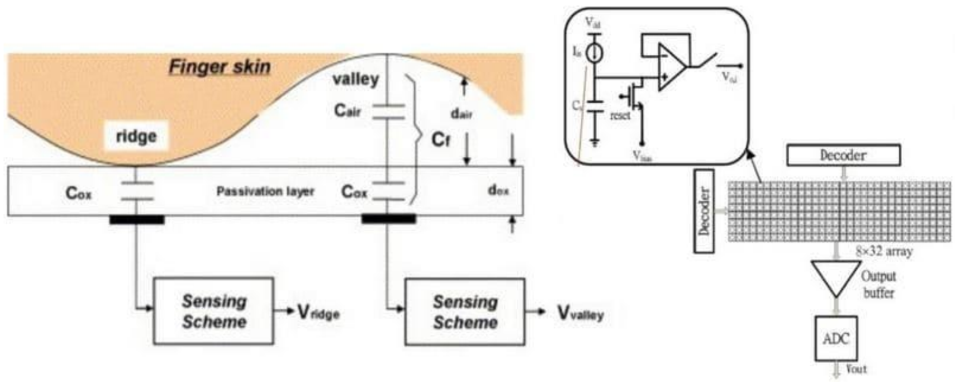


Image is showing How a capacitive fingerprint scanner captures digital images (Source: Android Authority/Robert Triggs)

This technology is a lot harder to bypass since an image cannot get passed capacitive fingerprint sensor and other materials will record different changes in charge on the capacitor. While it is more expensive, it’s also more complex and secure.

As we become more advanced and IoT keeps growing, accurate data collection via sensors becomes more important. Smartphones are the best example on how sensors are quickly changing the way we go about our days. After all, it was only a few years ago that phones didn’t have touchscreen or fingerprint applications on them.

For clear understanding: https://www.youtube.com/watch?v=l4tzkD3G_K0

How LiDAR works:

The LiDAR instrument fires rapid pulses of laser light at a surface, some at up to 150,000 pulses per second. A sensor on the instrument measures the amount of time it takes for each pulse to bounce back.

Light moves at a constant and known speed so the LiDAR instrument can calculate the distance between itself and the target with high accuracy. By repeating this in quick succession the instrument builds up a complex 'map' of the surface it is measuring. With airborne LiDAR other data must be collected to ensure accuracy. As the sensor is moving height, location and orientation of the instrument must be included to determine the position of the laser pulse at the time of sending and the time of return. This extra information is crucial to the data's integrity. With ground-based LiDAR a single GPS location can be added for each location where the instrument is set up.

Distance = (Speed of Light x Time of Flight) / 2

Water Level Sensor

Capacitance level sensors are made available for wide range of solids, aqueous, organic liquids and slurries. This technique is frequently stated as the radio-frequency signals applied to a capacitance circuit. The capacitive sensors are designed to sense material with dielectric constants as low as 1.1 for coke and fly ash, and as high as 88 for water or other liquids.

Principle of operation: The principle of capacitive level measurement is based on the change of capacitance. There are two plates in capacitive sensor: one plate acts as an insulated electrode and the other plate acts as a tank wall. The capacitance depends on the liquid level. An empty tank has low capacitance while a filled tank has higher capacitance. A simple capacitor consists of two electrode plates separated by a small thickness of an insulator such as solid, fluid, gas, or vacuum. The Value of Capacitance depends on dielectric constant used, area of the plate and also on the distance between the plates.