ELEMENTS OF IOT

Application Sensors & Actuators - Edge Networking (WSN) – Gateways - IoT Communication Model – WPAN & LPWA, IoT platform for available applications, Hardware Devices: Arduino, Raspberry pi and Smartwifi, etc, Wearable Development Boards, Softwares, Programs and Stacks available for building IoT applications, Installation of various packages necessary for project and list of tools.

1.SENSORS AND ACTUATORS

A transducer is any physical device that converts one form of energy into another. So, in the case of a sensor, the transducer converts some physical phenomenon into an electrical impulse that can then be interpreted to determine a reading. A microphone is a sensor that takes vibration energy (sound waves), and converts it to electrical energy in a useful way for other components in the system to correlate back to the original sound.

Another type of transducer that we will encounter in many IoT systems is an actuator. In simple terms, an actuator operates in the reverse direction of a sensor. It takes an electrical input and turns it into physical action. For instance, an electric motor, a hydraulic system, and a pneumatic system are all different types of actuators.

Examples of actuators

- Digital micromirror device
- Electric motor
- Electroactive polymer
- Hydraulic cylinder
- Piezoelectric actuator
- Pneumatic actuator
- Screw jack
- Servomechanism
- Solenoid
- Stepper motor

In typical IoT systems, a sensor may collect information and route to a control center where a decision is made and a corresponding command is sent back to an actuator in response to that sensed input. There are many different types of sensors. Flow sensors, temperature sensors, voltage sensors, humidity sensors, and the list goes on. In addition, there are multiple ways to measure the same thing. For instance, airflow might be measured by using a small propeller like the one you would see on a weather station. Alternatively, as in a vehicle measuring the air through the engine, airflow is measured by heating a small element and measuring the rate at which the element is cooling.

We live in a World of Sensors. You can find different types of Sensors in our homes, offices, cars etc. working to make our lives easier by turning on the lights by detecting our presence, adjusting the room temperature, detect smoke or fire, make us delicious coffee, open garage doors as soon as our car is near the door and many other tasks.
The example we are talking about here is the Autopilot System in aircrafts. Almost all civilian and military aircrafts have the feature of Automatic Flight Control system or sometimes called as Autopilot. An Automatic Flight Control System consists of several sensors for various tasks like speed control, height, position, doors, obstacle, fuel and many more. A Computer takes data from all these sensors and processes them by comparing them with pre-designed values. The computer then provides control signal to different parts like engines, flaps, rudders etc. that help in a smooth flight.

All the parameters i.e. the Sensors (which give inputs to the Computers), the Computers (the brains of the system) and the mechanics (the outputs of the system like engines and motors) are equally important in building a successful automated system. Sensor as an input device which provides an output (signal) with respect to a specific physical quantity (input). Sensor means that it is part of a bigger system which provides input to a main control system (like a Processor or a Microcontroller).

S.No	Sensor	Applications	Technology
1.	Inertial sensors	Industrial machinery, automotive, human activity	MEMS and Gyroscope
2.	Speed Measuring Sensor	Industrial machinery, automotive, human activity	Magnetic, light
3.	Proximity sensor	Industrial machinery, automotive, human activity	Capacitive, Inductive, Magnetic, Light, Ultrasound
4.	Occupancy sensor	Home/office monitoring	PassiveIR, Ultrasound most common
5.	Temperature/humidity sensor	Home/office HVAC control, automotive, industrial	Solid state, thermocouple
6.	Light sensor	Home/office/industrial lighting control	Solid state, photocell, Photo resistor, photodiode

7.	Power (current) sensor	Home/office/industrial powermonitoring/control Technology	Coil (Faraday's law), Hall effect
8.	Air/fluid pressure sensor	Industrial monitoring/control, automotive, agriculture	Capacitive, Resistive
9.	Acoustic sensor	Industrial monitoring/control, human interface	Diaphragm condenser
10.	Strain sensor	Industrial monitoring/control, civil infrastructure	Resistive thin films

In the first classification of the sensors, they are divided in to Active and Passive. Active Sensors are those which require an external excitation signal or a power signal. Passive Sensors, on the other hand, do not require any external power signal and directly generates output response. The other type of classification is based on the means of detection used in the sensor. Some of the means of detection are Electric, Biological, Chemical, Radioactive etc.

The next classification is based on conversion phenomenon i.e. the input and the output. Some of the common conversion phenomena are Photoelectric, Thermoelectric, Electrochemical, Electromagnetic, Thermo-optic, etc. The final classification of the sensors are Analog and Digital Sensors. Analog Sensors produce an analog output i.e. a continuous output signal with respect to the quantity being measured.

Digital Sensors, in contrast to Analog Sensors, work with discrete or digital data. The data in digital sensors, which is used for conversion and transmission, is digital in nature.

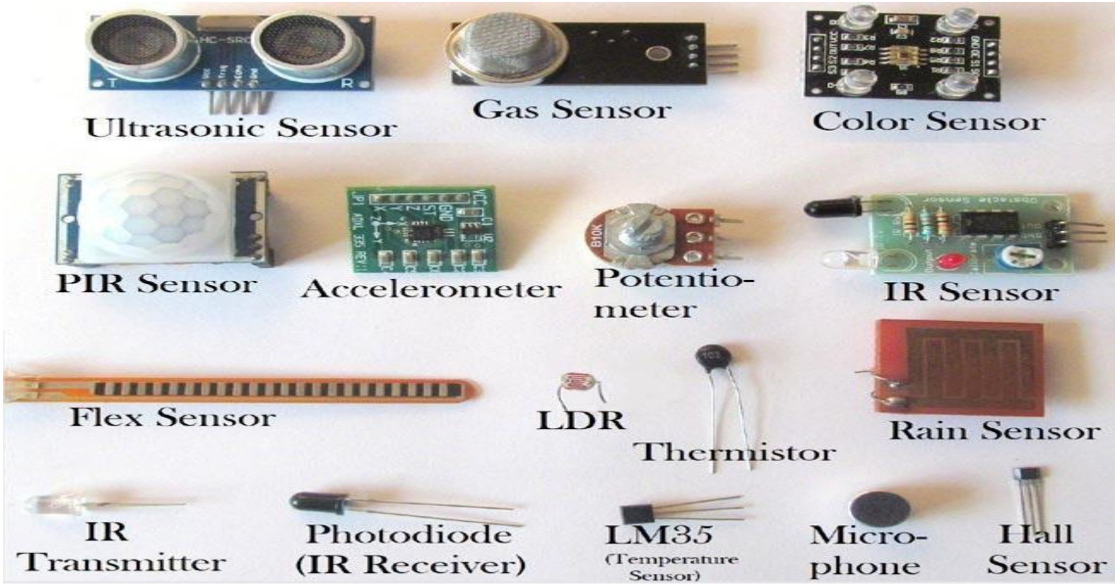


Fig 1.Examples of Sensors

1.IR LED

It is also called as IR Transmitter. It is used to **emit Infrared rays**. The range of these frequencies are greater than the microwave frequencies (i.e. >300GHz to few hundreds of THz). The rays generated by an infrared LED can be sensed by Photodiode explained below. **The pair of** IR LED and photodiode is called IR Sensor**.**

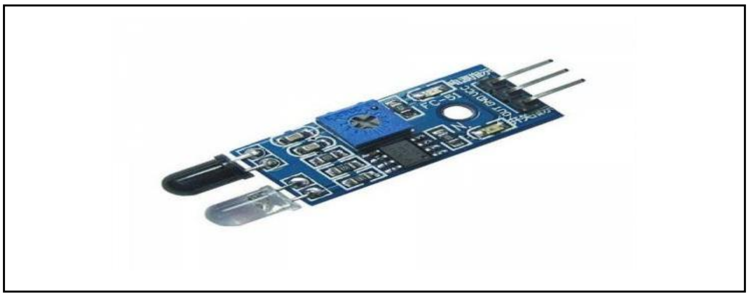
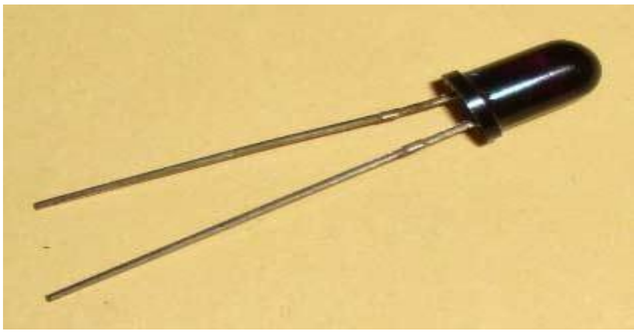


Fig 2. LED sensor

2.Photo Diode (Light Sensor)

It is a semiconductor device which *is* used to detect the light rays and mostly used as IR Receiver. Its construction is similar to the normal PN junction diode but the working principle differs from it. As we know a PN junction allows small leakage currents when it is reverse biased so, this property is used to detect the light rays. A photodiode is constructed such that light rays should fall on the PN junction which makes the leakage current increase based on the intensity of the light that we have applied. So, in this way, a



photodiode can be used to sense the light *rays* and maintain the current through the circuit. Check here the working of Photodiode with IR sensor.

Fig 3.Photo diode

3.Proximity Sensor

A Proximity Sensor is a non-contact type sensor that detects the presence of an object. Proximity Sensors can be implemented using different techniques like Optical (like Infrared or Laser), Ultrasonic, Hall Effect, Capacitive, etc.

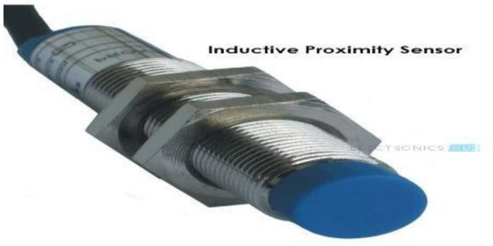


Fig 4.Proximity sensor

Some of the applications of Proximity Sensors are Mobile Phones, Cars (Parking Sensors), industries (object alignment), **Ground Proximity in Aircrafts, etc. Proximity Sensor in Reverse Parking is implemented in this Project:** Reverse Parking Sensor Circuit**.**

4.LDR (Light Dependent Resistor)

As the name itself specifies that the resistor that depends upon the light intensity. It works on the principle of photoconductivity which means the conduction due to the light. It is generally made up of Cadmium sulfide. When light falls on the LDR**,** its resistance decreases and acts similar to a conductor and when no light falls on it, its resistance is almost in the range of MΩ or ideally it acts as an open circuit**.** One note should be considered with LDR is that it won‘t respond if the light is not exactly focused on its surface.

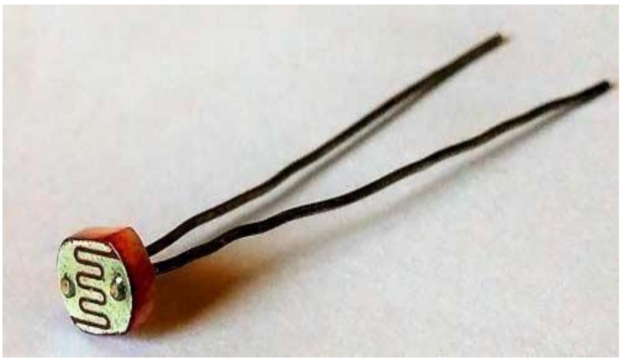


Fig 5.LDR

With a proper circuitry using a transistor it can be used to detect the availability of light. A voltage divider biased transistor with R2 (resistor between base and emitter) replaced with an LDR can work as a light detector.

5.Thermistor (Temperature Sensor)

A thermistor can be used to detect the variation in temperature**.** It has a negative temperature coefficient that means when the temperature increases the resistance decreases. So, the thermistor's resistance can be varied with the rise in temperature which causes more current flow through it. This change in current flow can be used to determine the amount of change in temperature. An application for thermistor is, it is used to detect the rise in temperature and control the leakage current in a transistor circuit which helps in maintaining its stability. Here is one simple application for Thermistor to control the DC fan automatically.

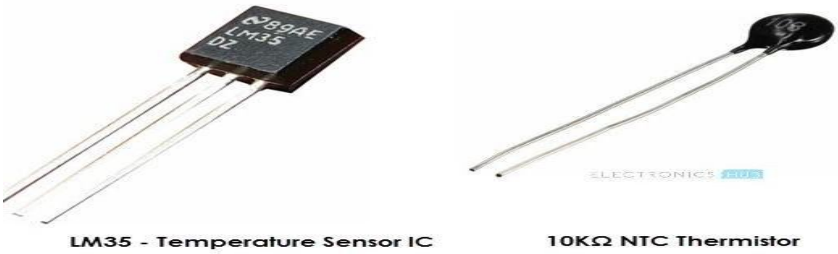


Fig 6.Thermistor

6.Thermocouple (Temperature Sensor)

Another component that can detect the variation in temperature is a thermocouple**.** In its construction, two different metals are joined together to form a junction. Its main principle is when the junction of two different metals are heated or exposed to high temperatures a potential across their terminals varies. So, the varying potential can be further used to measure the amount of change in temperature.

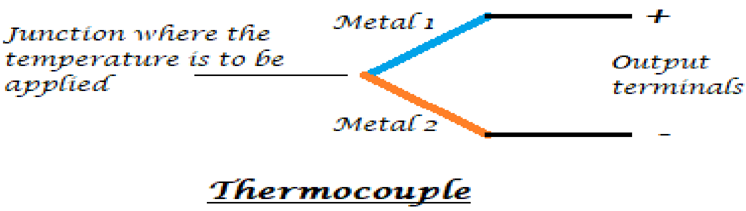


Fig 7.Thermo couple

7.Strain Gauge (Pressure/Force Sensor)

A strain gauge is used to detect pressure when a load is applied**.** It works on the principle of resistance, we know that the resistance is directly proportional to the length of the wire and is inversely proportional to its cross-sectional area (R=ρl/a). The same principle can be used here to measure the load. On a flexible board, a wire is arranged in a zig-zag manner as shown in the figure below. So, when the pressure is applied to that particular board, it bends in a direction causing the change in overall length and cross- sectional area of the wire. This leads to change in resistance of the wire. The resistance thus obtained is very minute (few ohms) which can be determined with the help of the Wheatstone bridge. The strain gauge is placed in one of the four arms in a bridge with the remaining values unchanged. Therefore, when the pressure is applied to it as the resistance changes the current passing through the bridge varies and pressure can be calculated.

Strain gauges are majorly used to calculate the amount of pressure that an airplane wing can withstand and it is also used to measure the number of vehicles allowable on a particular road etc.

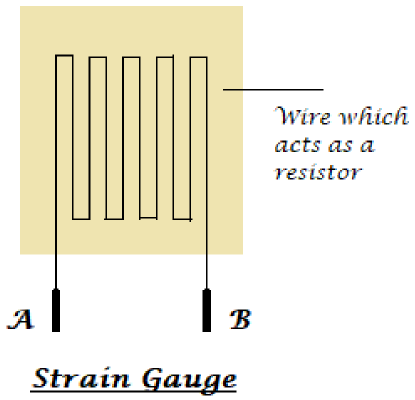
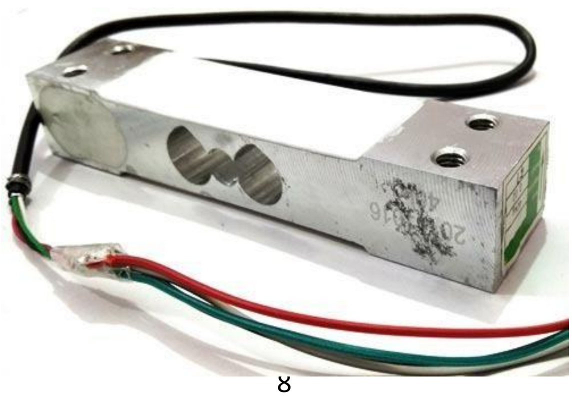


Fig 8.Strain Guage

8.Load Cell (Weight Sensor)

Load cells are similar to strain gauges which measure the physical quantity like force and give the output in form of electrical signals. When some tension is applied on the load cell it structure varies causing the change in resistance and finally, its value can be calibrated



using a Wheatstone bridge. Here is the project on how to measure weight using Load cell.

Fig 9.Load Cell

9.Potentiometer

A potentiometer is used to detect the position. It generally has various ranges of resistors connected to different poles of the switch. A potentiometer can be either rotary or linear type. In rotary type, a wiper is connected to a long shaft which can be rotated. When the shaft has rotated the position of the wiper alters such that the resultant resistance varies causing the change in the output voltage. Thus the output can be calibrated to detect the change its position.

Potentiometer

Fig 10.Potentiometer

10.Encoder

To detect the change in the position an encoder can also be used. It has a circular rotatable disk-like structure with specific openings in between such that when the IR rays or light rays pass through it only a few light rays get detected. Further, these rays are encoded into

a digital data (in terms of binary) which represents the specific position.

Fig 11.Encoder

11 Hall Sensor

The name itself states that it is the sensor which works on the Hall Effect. It can be defined as when a magnetic field is brought close to the current carrying conductor (perpendicular to the direction of the electric field) then a potential difference is developed across the given conductor. Using this property a Hall sensor is used to detect the magnetic field and gives output in terms of voltage. Care should be taken that the Hall sensor can detect only one pole of the magnet.

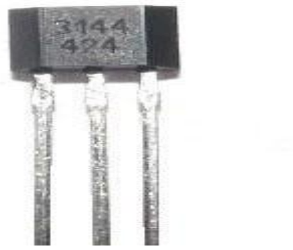


Fig 12.Hall sensor

The hall sensor is used in few smartphones which are helpful in turning off the screen when the flap cover (which has a magnet in it) is closed onto the screen. Here is one practical application of Hall Effect sensor in Door Alarm.

12. Flex Sensor

A FLEX sensor is a transducer which changes its resistance when its shape is changed or when it is bent. A FLEX sensor is 2.2 inches long or of finger length. Simply speaking the sensor terminal resistance increases when it‘s bent. This change in resistance can do no good unless we can read them. The controller at hand can only read the changes in

voltage and nothing less, for this, we are going to use voltage divider circuit, with that we can derive the resistance change as a voltage change.

Fig 13. Flex sensor

13.Microphone (Sound Sensor)

Microphone can be seen on all the smartphones or mobiles. It can detect the audio signal and convert them into small voltage (mV) electrical signals. A microphone can be of many types like condenser microphone, crystal microphone, carbon microphone etc. each type of microphone work on the properties like capacitance, piezoelectric effect, resistance respectively. Let us see the operation of a crystal microphone which works on the piezoelectric effect. A bimorph crystal is used which under pressure or vibrations produces proportional alternating voltage. A diaphragm is connected to the crystal through a drive pin such that when the sound signal hits the diaphragm it moves to and fro, this movement changes the position of the drive pin which causes vibrations in the crystal thus an alternating voltage is generated with respect to the applied sound signal. The obtained voltage is fed to an amplifier in order to increase the overall strength of the signal.

Fig 14.Microphone

14.Ultrasonic sensor

Ultrasonic means nothing but the range of the frequencies. Its range is greater than audible range (>20 kHz) so even it is switched on we can‗t sense these sound signals. Only specific speakers and receivers can sense those ultrasonic waves. This ultrasonic sensor is *used to calculate the distance between the ultrasonic transmitter and the target and also used to measure the velocity of the target***.**

Ultrasonic sensor HC-SR04 can be used to measure distance in the range of 2cm-400cm with an accuracy of 3mm. Let‗s see how this module works. The HCSR04 module generates a sound vibration in ultrasonic range when we make the ‗Trigger‗ pin high for about 10us which will send an 8 cycle sonic burst at the speed of sound and after striking the object, it will be received by the Echo pin. Depending on the time taken by sound vibration to get back, it provides the appropriate pulse output. We can calculate the distance of the object based on the time taken by the ultrasonic wave to return back to the sensor.

Fig 15.Utrasonic sensor

There are many applications with the ultrasonic sensor. We can make use of it avoid obstacles for the automated cars, moving robots etc. The same principle will be used in the RADAR for detecting the intruder missiles and airplanes. A mosquito can sense the ultrasonic sounds. So, ultrasonic waves can be used as mosquito repellent.

15.Touch Sensor

In this generation, we can say that almost all are using smartphones which have widescreen that too a screen which can sense our touch. So, let's see how this touchscreen works. Basically, there are two types of touch sensors *resistive based and a capacitive based touch screens.* Let's know about working of these sensors briefly.

The resistive touch screen has a resistive sheet at the base and a conductive sheet under the screen both of these are separated by an air gap with a small voltage applied to the sheets. When we press or touch the screen the conductive sheet touches the resistive sheet at that point causing current flow at that particular point, the software senses the location and relevant action is performed.

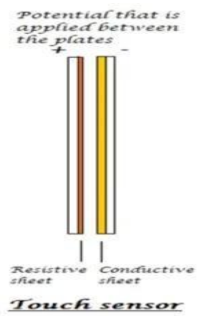


Fig 16.Touch sensor

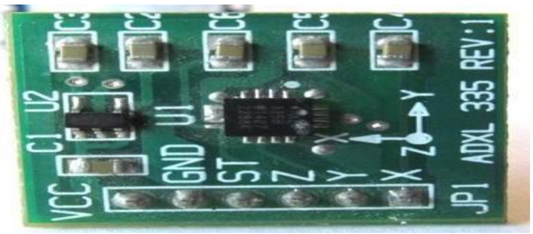
16.PIR sensor

PIR sensor stands for **Passive Infrared sensor**. These are used to detect the motion of humans, animals or things. We know that infrared rays have a property of reflection. When an infrared ray hits an object, depending upon the temperature of the target the infrared ray properties changes, this received signal determines the motion of the objects or the living beings. Even if the shape of the object alters, the properties of the reflected infrared rays can differentiate the objects precisely. Here is the complete working or PIR sensor.

Fig 17.PIR Sensor

17.Accelerometer (Tilt Sensor)

An accelerometer sensor *can* sense the tilt or movement of it in a particular direction**.** It works based on the acceleration force caused due to the earth's gravity. The tiny internal parts of it are such sensitive that those will react to a small external change in position. It has a piezoelectric crystal when tilted causes disturbance in the crystal and generates



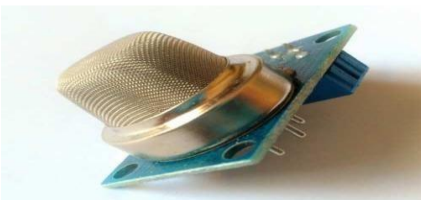
potential which determines the exact position with respect to X, Y and Z axis.

Fig 18.Accelerometer

These are commonly seen in mobiles and laptops in order to avoid breakage of processors leads. When the device falls the accelerometer detects the falling condition and does respective action based on the software.

18.Gas sensor

In industrial applications gas sensors plays a major role in **detecting the gas leakage**. If no such device is installed in such areas it ultimately leads to an unbelievable disaster. These gas sensors are classified into various types based on the type of gas that to be detected. Let's see how this sensor works. Underneath a metal sheet there exists a sensing element which is connected to the terminals where a current is applied to it. When the gas particles



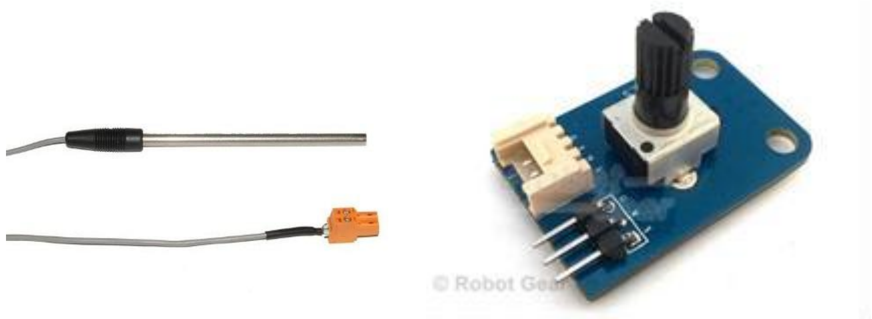
hit the sensing element, it leads to a chemical reaction such that the resistance of the elements varies and current through it also alters which finally can detect the gas.

Fig 19.Gas Sensor

So finally, we can conclude that sensors are not only used to make our work simple to measure the physical quantities, making the devices automated but also used to help living beings with disasters.

19. Resistive Sensors

Resistive sensors, such as the potentiometer, have three terminals: power input, grounding terminal, and variable voltage output. These mechanical devices have varied resistance that can be changed through movable contact with its fixed resistor. Output from the sensor varies depending on whether the movable contact is near the resistor's supple end or



ground end. Thermistors are also variable resistors, although the resistance of the sensor varies with temperature

Fig 20 Resistive Sensors

20.Voltage generating sensors

Voltage-generating sensors, such as piezo electrics, generate electricity by pressure with types of crystals like quartz. As the crystal flexes or vibrates, AC voltage is produced. Knock sensors utilize this technology by sending a signal to an automobile's on-board computer that engine knock is happening. The signal is generated through crystal vibration within the sensor, which is caused by cylinder block vibration. The computer, in turn, reduces the ignition timing to stop the engine knock.

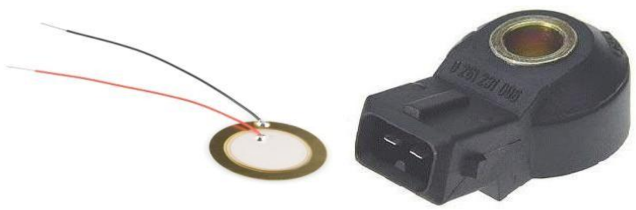


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Fig 21.Voltage Generating Sensors

21.Switch Sensors

Switch sensors are composed of a set of contacts that open when close to a magnet. A reed switch is a common example of a switch sensor and is most commonly used as a speed or position sensor. As a speed sensor, a magnet is attached to the speedometer cable and spins along with it. Each time one of the magnet's poles passes the reed switch, it opens and then

closes. How fast the magnet passes allows the sensor to read the vehicle's speed.

Fig 22.Switch Sensors

2.Edge Networking

Embedded systems are already playing a crucial role in the development of the IoT. In broad strokes, there are four main components of an IoT system:

1. The Thing itself (the device)
2. The Local Network; this can include a gateway, which translates proprietary communication protocols to Internet Protocol
3. The Internet
4. Back-End Services; enterprise data systems, or PCs and mobile devices

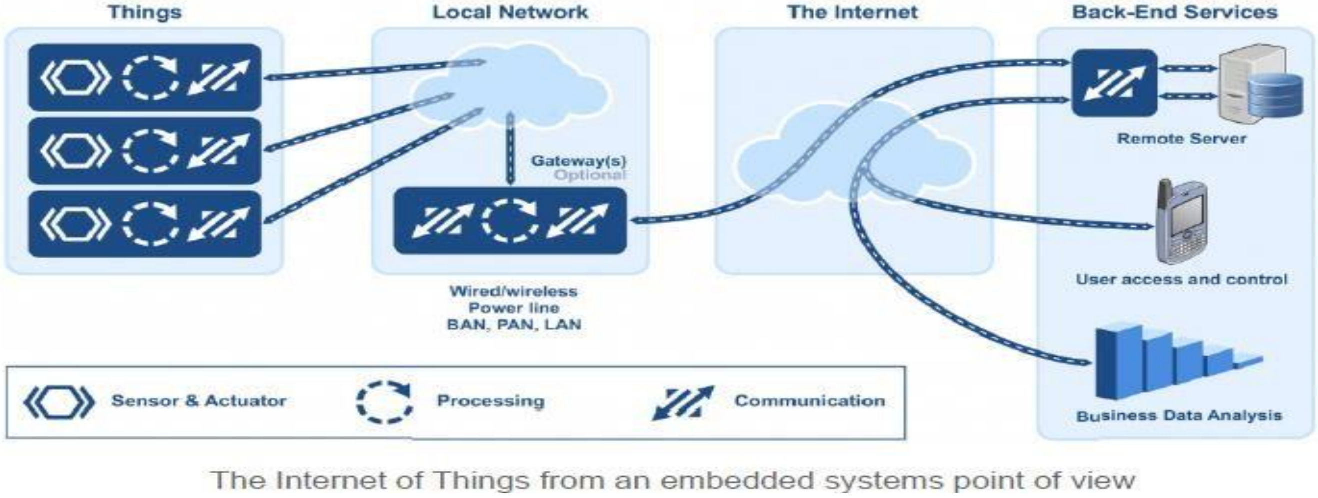

Fig 23.Embedded Point of View

We can also separate the Internet of Things in two broad categories:

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1. Industrial IoT, where the local network is based on any one of many different technologies. The IoT device will typically be connected to an IP network to the global Internet.