**Relevance/Objective:**

- To understand input and output information and source of sensors.

**Learning Outcome: -**

- Students will be able to identify sensors sensing methodology and input information

**Relevant CO:**

- Explain basic working principles & applications of electronics in automotive systems.

---

**Introduction**: - Modern vehicles can have up to one hundred microcontroller-based electronic control units (ECUs). These are fitted to enhance safety, performance, and convenience. As the complexity and safety-critical nature of automotive control systems increases, more and more sensors are needed.

**Theory:**

**Temperature Sensor**

Temperature is an important parameter for automotive engineers. The first temperature sensors to be applied to motor vehicles were probably those based on bimetallic strips or mercury thermometers and used to monitor engine coolant. Thermistor-based temperature sensors have been used in automotive applications since the late 1940s to send signals to dashboard gauges, and later to electronic control modules. In modern vehicles temperature transducers are used in connection with electronic fuel control systems, and to measure the temperature of inlet air and exhaust gas.

They are also used for environmental control, to regulate heating or air conditioning in the passenger compartment, and for ice warning systems. The majority of automotive temperature sensors are thermistors, though other forms of transducer are increasingly used.

The engine/powertrain management system uses a number of temperature inputs to enhance the performance of the engine, control emissions, and optimize efficiency. The most common applications are as follows:

- Coolant temperature sensing
- Intake air temperature sensing
- Transmission oil temperature sensing

• Cylinder head temperature sensing


Figure : coolant temperature sensor

The coolant temperature sensor measures the temperature of the coolant and interfaces with the electronic engine control module (ECM). This sensor provides feedback to the ECM regarding the temperature of the coolant at a single point on the engine. Similarly, the cylinder head temperature sensor provides the temperature of the metal at a single point on the engine. The ECM uses temperature measurement and previous engine calibrations to achieve optimal operation of the engine management system

**Exhaust Gas Oxygen Sensor**

Exhaust gas oxygen (EGO) sensors have been the most successful exhaust gas transducers for controlling the performance of the internal combustion engine. In this section the main principles of the exhaust gas oxygen (EGO) sensor are introduced, with particular reference to the zirconia type. This is the most widely used sensor for controlling engine performance and is usually fi tted close to the exhaust outlet.


Figure : oxygen sensor

**Vehicle Speed Sensor**

Vehicle speed sensors are usually either inductive or optical sensors. The most common inductive sensors consist of a rod magnet on top of a magnetic pin that is surrounded by a fixed coil. This sensor is mounted a fixed distance from a ferromagnetic rotor with teeth. As the rotor turns and a tooth comes into the proximity of the rod, the magnetic flux in the coil changes. This change in flux results in a voltage pulse across the coil. The vehicle's engine control module counts these voltage pulses and computes the vehicle's speed. Optical sensors also generate pulses at a frequency corresponding to the rotor rotation, but instead of measuring magnetic flux, the optical sensor measures either reflected light or light allowed to pass through slits. When using an optical sensor the rotor either has light and dark marks for the optical sensor to detect the reflected light using photosensors, or a series of slits that allows light from an infrared source to pass through and be detected by a phototransistor on the other side.


Figure : vehicle speed sensor

**Engine RPM Sensor**

This sensor consists of a magnet around which a coil is wound. By moving a piece of metal towards the sensor, the magnetic field will change. The same happens when we pull the metal away from the sensor. The changing magnetic field in the coil of the sensor will generate a voltage. If the metal object moves towards it, the voltage will be positive, if the metal object moves away from it, the voltage will be negative. The signal coming from the sensor is therefore a varying positive and negative voltage. An alternating voltage. We see a new sinus for every tooth of the trigger wheel.

The voltage generated by this sensor differs. At starting speed this will be approximately 1 Volt (measured in the AC position). This can be as high as 100 volts if the engine makes a lot of revs.


Figure : engine RPM sensor

**Light Sensor**

The light sensor is a passive device that converts the light energy into an electrical signal output. Light sensors are more commonly known as Photoelectric Devices or Photo Sensors because they convert light energy (photons) into electronic signal (electrons). Phototransistors, photoresistors, and photodiodes are some of the more common type of light intensity sensors.

Photoelectric sensors use a beam of light to detect the presence or absence of an object. It emits a light beam (visible or infrared) from its light-emitting element. A reflective-type photoelectric sensor is used to detect the light beam reflected from the target. A beam of light is emitted from the light emitting element and is received by the light receiving element. Both the light emitting and light receiving elements are contained in a single housing. The sensor receives the light reflected from the target.

A phototransistor, on the other hand, uses the level of light it detects to determine how much current can pass through the circuit. So, if the sensor is in a dark room, it only lets a small amount of current to flow. If it detects a bright light, it lets a larger amount of current flow. A photoresistor is made of cadmium sulphide whose resistance is maximum when the sensor is in dark. When the photoresistor is exposed to light, its resistance drops in proportion to the intensity of light. When interfaced with a circuit and balanced with potentiometer, the change in light intensity will show up as change in voltage


Figure : Light sensor

**Distance Sensor**

An ultrasonic sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal. Ultrasonic waves travel faster than the speed of audible sound (i.e. the sound that humans can hear). Ultrasonic sensors have two main components: the transmitter (which emits the sound using piezoelectric crystals) and the receiver (which encounters the sound after it has travelled to and from the target).

In order to calculate the distance between the sensor and the object, the sensor measures the time it takes between the emission of the sound by the transmitter to its contact with the receiver. The formula for this calculation is D = ½ T x C (where D is the distance, T is the time, and C is the speed of sound ~ 343 meters/second). For example, if a scientist set up an ultrasonic sensor aimed at a box and it took 0.025 seconds for the sound to bounce back, the distance between the ultrasonic sensor and the box would be:

**D = 0.5 x 0.025 x 343**

or about 4.2875 meters.


Figure : Distance sensor

**Work:**

| Sensor Name | Input data | Output data | Observation & Comments |
| --- | --- | --- | --- |
| Temperature sensor | | | |

| | | | |
|---|---|---|---|
| Exhaust Gas Oxygen Sensor | | | |
| Vehicle Speed Sensor | | | |

| | | | |
|---|---|---|---|
| Engine RPM Sensor | | | |
| Light Sensor | | | |

| | | | |
|---|---|---|---|
| Distance Sensor | | | |

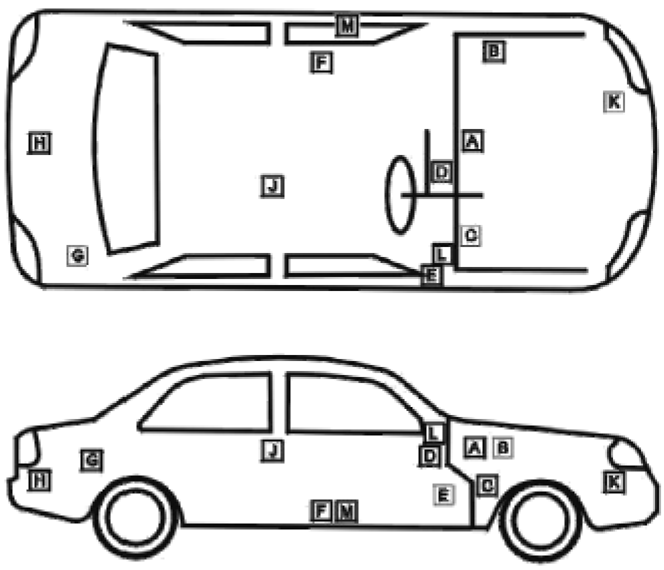
**Assignment Question:**

- Describe working principle of Temperature, Exhaust Gas Oxygen, Vehicle Speed, Engine RPM, Light & distance sensor.

**Introduction**:

The combination of IT and vehicle-based and highway-based electronic systems has become known as automotive telematics. All telematic systems rely heavily on sensors and measurement techniques, and this is especially true of those applications that are safety critical.Modern vehicles can have up to one hundred microcontroller-based electronic control units (ECUs). These are fitted to enhance safety, performance, and convenience. As the complexity and safety-critical nature of automotive control systems increases, more and more sensors are needed.

**Theory:** For any such system to operate satisfactorily, the need for effective, accurate, reliable, and low-cost sensors is very great. Electronic measurement systems can be applied very widely within a motor vehicle, as shown in figure. The complexity can range from the interactive control of engine and transmission to optimize economy, emissions, and performance to the simple sensing of water temperature and fuel level.




KEY:

- A: Engine management system: controls ignition, fuelling, exhaust gas recirculation
- B: Antilock/antiskid control
- C: Vehicle security
- D: Steering motion sensor
- E: Door sensors
- F: Climate control system
- G: Fuel tank sensing
- H: Crash sensor
- J: Electronic transmission control
- K: Bulb outage & ice alert sesors
- L: Electronic instrument cluster, traffic & road information system
- M: Data and power bus (CAN bus)

Figure  Car sensor location

**Task**

**Kindly understand and fill below mentioned table with respect to vehicle/physical sensor model which you have seen during lab.**

| Name | Function | Location | Sensing Method |
|---|---|---|---|
| Manifold Absolute Pressure Sensor | | | |
| Throttle Position Sensor | | | |

| | | | |
|---|---|---|---|
| Mass Air flow sensor | | | |
| Intake Air temp sensor | | | |
| Knock sensor | | | |
| Cranck shaft sensor | | | |

| | | | |
|---|---|---|---|
| Cam shaft sensor | | | |
| Coolant temp sensor | | | |
| Vehicle speed sensor | | | |
| EGO sensor | | | |

| | | | |
|---|---|---|---|
| Rain sensor | | | |
| Proximity sensor | | | |
| Coolant pressure sensor | | | |
| Engine Oil Pressure sensor | | | |

| | | | |
|---|---|---|---|
| Tire pressure sensor | | | |
| Air Bag sensor | | | |
| ABS sensor | | | |

**Group activity:**

**Following activity needs to be conduct within 3 - 4 students team.**

1) Prepare a chart of various pressure monitoring sensors used in vehicle with functional location and sensing methodology details.

2) Prepare a chart of various temperature measuring sensors used in vehicle with functional location and sensing methodology details.
3) Prepare a chart of various liquid level measuring sensors used in vehicle with functional location and sensing methodology details.
4) Prepare a chart of various safety related sensors used in vehicle with functional location and sensing methodology details.

**Introduction:**

A stepper motor, also known as step motor or stepping motor, is a brushless DC electric motor that divides a full rotation into a number of equal steps

**Theory:**

The motor's position can be commanded to move and hold at one of these steps without any position sensor for feedback (an open-loop controller), as long as the motor is correctly sized to the application in respect to torque and speed. Switched are very large stepping motors with a reduced pole count, and generally are closed-loop commutated.

**Mechanism**

1) Brushed DC motors rotate continuously when DC voltage is applied to their terminals. The stepper motor is known for its property of converting a train of input pulses (typically square waves) into a precisely defined increment in the shaft's rotational position. Each pulse rotates the shaft through a fixed angle.
2) Stepper motors effectively have multiple "toothed" electromagnets arranged as a stator around a central rotor, a gear-shaped piece of iron. The electromagnets are energized by an external driver circuit or a micro controller. To make the motor shaft turn, first, one electromagnet is given power, which magnetically attracts the gear's teeth. When the gear's teeth are aligned to the first electromagnet, they are slightly offset from the next electromagnet. This means that when the next electromagnet is turned on and the first is turned off, the gear rotates slightly to align with the next one. From there the process is repeated. Each of the partial rotations is called a "step", with an integer number of steps making a full rotation. In that way, the motor can be turned by a precise angle.
3) The circular arrangement of electromagnets is divided into groups, each group called a phase, and there is an equal number of electromagnets per group. The number of groups is chosen by the designer of the stepper motor. The electromagnets of each group are interleaved with the electromagnets of other groups to form a uniform pattern of arrangement.

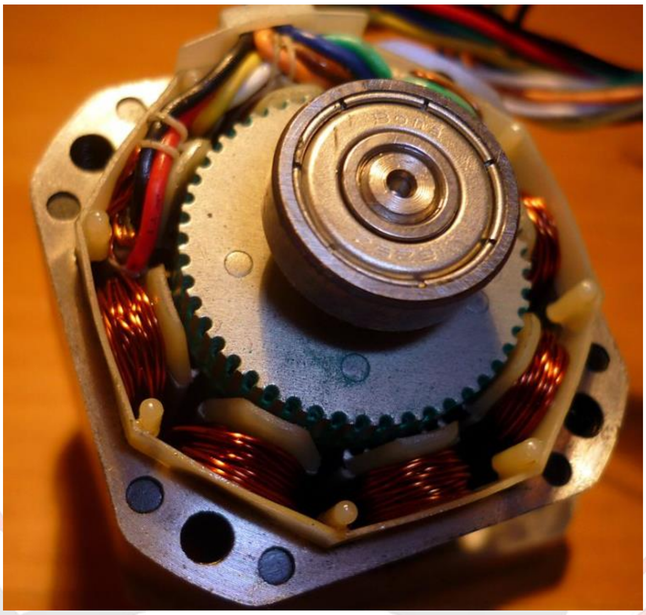


Figure: A Stepper motor

**Stepper Motor system**

A stepper motor system consists of three basic elements, often combined with some type of user interface (host computer, PLC or dumb terminal)

**Indexers**: The indexer (or controller) is a microprocessor capable of generating step pulses and direction signals for the driver. In addition, the indexer is typically required to perform many other sophisticated command functions.

**Drivers:** The driver (or amplifier) converts the indexer command signals into the power necessary to energize the motor windings. There are numerous types of drivers, with different voltage and current ratings and construction technology. Not all drivers are suitable to run all motors, so when designing a motion control system, the driver selection process is critical.

Stepper motors

The stepper motor is an electromagnetic device that converts digital pulses into mechanical shaft rotation.

**Types:**

1. Permanent magnet stepper
2. Variable reluctance stepper
3. Hybrid synchronous stepper

Permanent magnet motors use a permanent magnet (PM) in the rotor and operate on the attraction or repulsion between the rotor PM and the stator electromagnets.

Pulses move the rotor in discrete steps, CW or CCW. If left powered at a final step a strong detent remains at that shaft location. This detent has a predictable spring rate and specified torque limit; slippage occurs if the limit is exceeded. If current is removed a lesser detent still remains, therefore holding shaft position against spring or other torque influences. Stepping can then be resumed while reliably being synchronized with control electronics.

Variable reluctance (VR) motors have a plain iron rotor and operate based on the principle that minimum reluctance occurs with minimum gap, hence the rotor points are attracted toward the stator magnet poles. Whereas hybrid synchronous are a combination of the permanent magnet and variable reluctance types, to maximize power in a small size.

**Advantages:**

- Low cost for control achieved
- High torque at startup and low speeds
- Ruggedness
- Simplicity of construction
- Can operate in an open loop control system
- Low maintenance (high reliability)
- Less likely to stall or slip
- Will work in any environment
- Can be used in robotics in a wide scale.
- High reliability
- The rotation angle of the motor is proportional to the input pulse.
- The motor has full torque at standstill (if the windings are energized)
- Precise positioning and repeatability of movement, since good stepper motors have an accuracy of 3–5% of a step and this error is non-cumulative from one step to the next.
- Excellent response to starting/stopping/reversing.
- Very reliable since there are no contact brushes in the motor. Therefore, the life of the motor is simply dependent on the life of the bearing.

- The motor's response to digital input pulses provides open-loop control, making the motor simpler and less costly to control.
- It is possible to achieve very low-speed synchronous rotation with a load that is directly coupled to the shaft.
- A wide range of rotational speeds can be realized, as the speed is proportional to the frequency of the input pulses.

**Disadvantage:**

- Resonance effect often exhibited at low speeds and decreasing torque with increasing speed.

**Rating and specifications:**

Stepper motors' nameplates typically give only the winding current and occasionally the voltage and winding resistance. The rated voltage will produce the rated winding current at DC: but this is mostly a meaningless rating, as all modern drivers are current limiting and the drive voltages greatly exceed the motor rated voltage.

Datasheets from the manufacturer often indicate Inductance. Back-EMF is equally relevant, but seldom listed (it is straightforward to measure with an oscilloscope). These figures can be helpful for more in-depth electronics design, when deviating from standard supply voltages, adapting third party driver electronics, or gaining insight when choosing between motor models with otherwise similar size, voltage, and torque specifications.

A stepper's low-speed torque will vary directly with current. How quickly the torque falls off at faster speeds depends on the winding inductance and the drive circuitry it is attached to, especially the driving voltage.

Steppers should be sized according to published torque curve, which is specified by the manufacturer at particular drive voltages or using their own drive circuitry. Dips in the torque curve suggest possible resonances, whose impact on the application should be understood by designers.

**Applications:**

- Adaptive headlight systems
- Steering wheel vibration

- Cluster gauges
- Fuel pump
- Adjustment for mirror, door, sunroof and seats

## Actuators

Actuators are a subdivision of transducers. They are devices which transform an input signal (mainly an electrical signal) into motion. Like include electrical motors, pneumatic actuators, hydraulic pistons, relays, piezoelectric actuators, thermal bimorphs, and electro active polymers.

**Vehicle Common actuators:**

**Actuators in automotive for the vehicle interior**

1. **Steering wheel**
   The regulation of the steering wheel position according to the driver, is a widespread movement which improves the comfortableness of driving. Through a linear actuator, is possible to draw the steering wheel closer or further in search of the most suitable position.

2. **Headrest**
   Rotational actuators for the automatic adjustment of the headrest.

3. **Seats**
   Here we can find rotational actuators for the lumbar regulation of the seat and actuators for the automatic regulation of its height and position.

4. **Sunroofs**
   Automotive actuators for opening and closing the sunroof or roof panel. We are talking about movable panels coupled onto a moving flap that allows, through a translational movement, to move the roof. The mobile panel moves driven by two control cables located on the sliding shoe. This movement of the sunroof is once again provided by the gear motor.

5. **Headlights**

   Headlights washing systems: lineal actuators that allow the displacement of the cleaning mechanism of the lights.

6. **Height regulation systems**

   Gear motor that performs an angular movement.This adaptive headlights can be used as for the regulation of the height of the lights or for the orientation of the blades of the air conditioning.

7. **Lid of the gasoline deposit**

   Electric actuator for opening and closing the lid of the deposit.

8. **Engine block**

   Automotive actuators for activating control valves of gases and fluids. This drive mechanism can be found on the windshield and tends to have an internal relay inside its engine. This mechanism closes or opens the contacts that provide voltage to the wiper's motor. Some wiper systems have intermittent relays that relay on a timer to help manage the movements.

9. **Trunk**

   The number of brands that incorporate automated drives for opening and closing the tailgate is increasingly growing. To operate this movement, it is usual to opt for mechanical transmission from hydraulic actuators. These products offer superior durability, since there is no wear by friction between its components.

   On the other hand, some automotive manufacturers opt for pneumatic conveying for their tailgate opening systems. Here the energy from the air pressure is in charge of starting the up and down movement.

**task:**

1. Read and note down given sample of vehicle accessories motorized actuator.
2. Compare specification of any two sample vehicle accessories motorized actuator and write comment in your own words.