International Journal on Science and Technology (IJSAT)
E-ISSN: 2229-7677 ● Website: www.ijsat.org ● Email: editor@ijsat.org

A Literature Review On Automotive Sensors and Actuators On a Car Engine

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ABSTRACT:

Automotive sensors are critical to the functioning and performance of modern automobiles. With the increasing complexity of internal combustion engines (ICE) and the incorporation of electronic control units (ECUs), sensors installed on or around the engine have become critical for monitoring, controlling, and optimizing engine performance. This study article goes into the numerous types of sensors found on engines, including their goals, operating principles, and role in improving engine performance, pollution control, and vehicle diagnostics. It also looks at future trends in engine sensor technologies as hybrid and electric powertrains become more prevalent. The study finishes with a full examination of difficulties, improvements, and the significance of sensor dependability to total car efficiency.

1. INTRODUCTION:

The automotive industry has undergone a revolutionary transformation over the past few decades, largely driven by advancements in electronic control systems. Engine-mounted sensors are key to this transition, as they continuously monitor the engine's status and ambient conditions to ensure peak performance, fuel efficiency, and low emissions. These sensors are the nervous system of modern automobiles, sending real-time data to the Engine Control Unit (ECU), which processes the data and modifies the vehicle's performance accordingly.

Internal combustion engines (ICEs) were powered only by mechanical methods before the introduction of electronic control. These technologies, while long lasting, lacked its flexibility and precision necessary by modern efficiency and emission regulations. The introduction of electronic sensors in engine systems allows for real-time modifications in ignition timing, air-fuel mixture, and exhaust gas recirculation, thereby improving the engine's performance, dependability, and environmental sustainability.

Sensors on an automobile engine differ in design and function, but they all serve the same purpose: to gather crucial information. Some of the most popular types include the oxygen sensor, which monitors exhaust gas composition, the throttle position sensor, which detects the angle of the throttle valve, the manifold absolute pressure (MAP) sensor, and the engine coolant temperature (ECT) sensor. These sensors, along with many more, provide the ECU with a steady stream of feedback, allowing for precise control of numerous subsystems.

The actuator is an important component of this control network. While sensors collect and communicate data, actuators turn ECU commands into physical actions, such as opening fuel injectors, altering the idle air control valve, or turning on ignition coils. The engine management system's operation relies heavily on the interaction between sensors and actuators.

This research paper aims to provide an in-depth analysis of the sensors positioned on or near the engine. It explores their many types, purposes, and interconnections, as well as how their wiring allows for effective data transfer. The study will investigate resistance-based sensors, Hall effect sensors, the role of reference voltage and grounding in sensor performance, and sensor testing processes using diagnostic tools.

SENSORS:

An automobile sensor is a device that monitors, detects, and reports on physical or environmental conditions within a vehicle's systems. These sensors transform physical data like as temperature, pressure, position, speed, and airflow into electrical signals that are transmitted to the vehicle's Electronic Control Unit. The ECU then uses this information to make real-time decisions that boost performance, safety, and efficiency.

This transmission of data from the Sensor to the Electronic Control Unit is done by the mode of Wiring. ECU or the Electronic Control Unit differs from car to car. These consists of pins that are connected to the wiring harness via adapters. For example: The Maruti Suzuki Swift (2010 model) has 91 different connections. This shows us the different attachments such as Sensors or Actuators linked with the Electronic Control Unit.

So as we know that the transfer is done through wiring, Sensors can vary in the wiring sequence. This means that different Sensors can have different number of wire connections attached to it.

SENSORS BASED ON THE NUMBER OF WIRES:

1- **2 WIRE SENSORS:**
   In this case, one wire will be negative (ground wire) and the other wire will be positive. The Electronic Control Unit has a Micro Controller Unit or the MCU that receives the signal from the Sensor. In this case the MCU will receive its signal from the positive wire.

2- **3 WIRE SENSORS:**
   In this case, similar to previous case, one wire will be positive and the other will be negative. The third wire is for Reference Voltage. Reference Voltage is the voltage provided by the Electronic Control Unit to the Sensor in order to turn on the Sensor.

3- **4 OR MORE WIRE SENSOR:**
   Basically, a Sensor has 2 or 3 wires. But in case of 4-5-6 or more wire Sensors, the given Sensor will have more purposes to solve. Means there are more than one Sensors located within a single Sensor.

For Example: In case of a 4 wire Boost Pressure Sensor, one wire is positive and second wire is negative. The third and fourth wire has two different operations. One wire will give information about the Air Pressure and the other wire will give information about Intake Air Temperature.
So, this is how a more wire Sensor has more jobs to do.

TYPES OF SENSORS IN A CAR ENGINE:

Basically, there are 4 main categories of sensors that are located on an Engine –

1- Sensors related to Engine Starting.
2- Sensors related to Air Flow.
3- Sensors related to Heat.
4- Sensors related to Speed.

SENSORS RELATED TO ENGINE STARTING:

1- **Crankshaft Sensor:**
The sensor is located near the crankshaft, detects both the crankshaft's position and rotational speed (RPM). It uses a magnetic or Hall-effect sensor to determine the position of a toothed reluctor wheel. This information is essential for ignition timing, fuel injection timing, and misfire detection. Without this sensor, the engine may fail to start or misfire while running.

2- **Camshaft Sensor:**
The camshaft sensor works in coordination with the crankshaft sensor to monitor the camshaft's position. It controls the precise timing of valve opening and shutting, which is critical for engines with variable valve timing (VVT). The sensor increases fuel efficiency and lowers emissions by allowing the ECU to adjust valve timing based on engine load and speed.

3- **Fuel and Air pressure Sensor:**
A fuel pressure sensor measures the pressure of fuel in the fuel rail or fuel line and delivers the results to the Engine Control Unit (ECU). This allows the ECU to maintain the appropriate fuel pressure for combustion.
An air pressure sensor, often known as the MAP sensor, detects the actual pressure within the intake manifold. This data is used to compute air density and find the appropriate air-fuel ratio.

SENSORS RELATED TO AIR:

1- Mass Air Flow Sensor:
The Mass Air Flow (MAF) sensor is an essential part of an automobile's engine management system. It detects the amount of air entering the engine's intake system and transmits this data to the Engine Control Unit (ECU). Accurate air measurement is required to maintain the ideal air-fuel ratio for combustion, performance, and emissions control.

2- Boost Pressure Sensor:
The boost pressure sensor, commonly referred to as the turbo pressure sensor or manifold boost sensor, is an essential component in turbocharged or supercharged engines. It measures the

pressure of air pushed into the intake manifold by the turbocharger or supercharger. This information enables the Engine Control Unit (ECU) to control boost levels, modify fuel injection, and ensure engine safety.

3- **O2 Sensor:**
The oxygen sensor, located in the exhaust manifold, measures the amount of oxygen in exhaust gasses. The ECU uses this information to maintain the optimal air-fuel ratio (14.7:1) for combustion. A rich or lean mixture can cause greater emissions or engine damage. Hence, the oxygen sensor is critical for emission control.

SENSORS RELATED TO HEAT:

1- **Engine Coolant Temperature (ECT) Sensor:**
The ECT sensor is installed in the engine's coolant tubes and measures the temperature of the coolant. This sensor aids the ECU in controlling fuel mixture, ignition timing, and cooling fan operation. A cold engine demands a richer fuel mixture, whereas a warm engine works better with a leaner mix. Accurate ECT readings are critical for avoiding overheating and preserving engine performance.

2- **Intake Air Temperature Sensor:**
The Intake Air Temperature Sensor is located after the Air Filter. This Sensor measures the Temperature of the air entering the Engine. The data is sent to the ECU which further alters the fuel supply and EGR valve based on the temp.

3- **Boost Intake Temperature Sensor:**
The Boost Intake Temperature Sensor can be different or combined with the boost pressure Sensor. This Sensor is used to measure the temperature of the air after the Boost by the turbocharger or supercharger.

4- **Ambient Temperature Sensor:**
The Ambient Sensor is used to measure the surrounding temperature.

5- **Exhaust Temperature Sensor:**
The Exhaust Temperature Sensor is used to measure the temperature of Exhaust gases.

6- **Fuel Temperature Sensor:**
The Fuel Temperature Sensor is used to measure the temperature of the Fuel before entering the fuel rail. This will also alter the fuel supply due to advance firing of the fuel in combustion chamber.

SENSORS RELATED TO SPEED:

1- **Acceleration Pedal Sensor:**

The accelerator pedal sensor, is an essential component for modern drive-by-wire systems. It replaces the typical mechanical throttle linkage that connects the accelerator pedal and the throttle body. This sensor sends real-time data to the Engine Control Unit (ECU), showing the driver's demand for engine power depending on pedal position. It controls engine speed, acceleration, and throttle response.

2- **Speed Meter Sensor:**
The speed meter sensor, also known as the Vehicle Speed Sensor (VSS), provides real-time data on the vehicle's speed. This sensor is critical for engine control and driver display systems, as well as transmission, cruise, and ABS systems.

3- **Throttle Position Sensor:**
The Throttle Position Sensor (TPS) is a component of the electronic throttle control system that monitors the position of the throttle valve in the throttle body. It assists the ECU in determining the amount of air entering the engine, which has a direct impact on engine power, acceleration, and fuel delivery.

RESISTANCE TYPE SENSORS:

Resistance-type sensors are among the most widely used and fundamental components in vehicle electronics. These sensors work on the idea that a material's resistance varies in response to physical conditions such as temperature or pressure. Resistance-type sensors are often found in automotive engines to monitor temperature-pressure characteristics, which are critical for maintaining optimal combustion, emissions control, and fuel-air pressure.

For example: Rail pressure sensor, boost pressure sensor, mass air flow sensor, engine coolant temperature sensor, acceleration pedal sensor.

HALL-EFFECT TYPE SENSORS:

The Hall Effect sensor functions using electromagnetic principles. When an electric current travels through a thin strip of conductive material and is subjected to a perpendicular magnetic field, it generates a tiny voltage (Hall voltage) across the conductor—at right angles to both the current and the magnetic field. The voltage is related to the strength of the magnetic field.

In practical automotive applications, a Hall sensor is installed near a revolving target wheel or gear that contains either permanent magnets or ferrous teeth. As the wheel rotates, the magnetic field at the sensor fluctuates, creating changes in the Hall voltage. These voltage variations are interpreted as signals that describe position, speed, and direction.

For example: Crankshaft sensor, camshaft sensor.

IDENTIFICATION OF SENSOR WIRING:

Identification done only in case of OPEN CIRCUIT. For a 2 Wire Sensor, we need to check the ground wire. With the help of the multimeter, the ground wire can be identified by checking the continuity. Place the black probe of the multimeter on the body ground and the other probe on either of the two connections for the sensor. Any one of the two wires will show the continuity beep. This will show us that the beeped wire is Ground for the sensor. So, the second wire will be positive. If it beeps on both wires, it means that there is an issue within the wiring, ecu or sensor.

Now in case of 3 Sensor, first process is similar. We need to check the ground wire by checking the continuity with the body ground. After the ground wire is identified, change the setting on the multimeter from continuity range to 20v. now place the red probe on remaining wires.

In case of Resistance type Sensors, there will be some voltage on remaining wires. Note down the voltage on all three wires according to their location. For example, in case of rail pressure sensor, the voltages during Open Circuit are: GROUND – 5V – 5V .

Now Close the Circuit. After closing the circuit, again check the voltage on the positive wires. If there is a drop in the voltage of a wire, the it is the signal wire. And the wire with no major voltage change will be your positive or Reference voltage. Taking same example: in case of rail pressure sensor, the voltages during Closed Circuit are: GROUND – 0.50V – 5V . This shows that middle one is signal wire.\

In case of Hall Effect Type Sensors, the positive voltages depend on the position of the teeth. In Open Circuit, Ground can be identified and also the positive voltages. If the position of the teeth is correct, then the positive voltages will be similar.

Now close the circuit. After closing the circuit, the voltage will not change. This is because the teeth is still on its original position. We need to check this while the engine is running. One the engine is running, the voltage on one wire will remain constant and will fluctuate on the other one. The constant one will be the reference and the fluctuating one will be the signal voltage. The fluctuation is caused due to the motion of the teeth. Once the teeth leave’s the sensor, the voltage on signal wire becomes 0V. due to fast moving teeth, the fluctuation occurs.

ACTUATORS:

Actuators are critical components in modern automobiles, converting electrical information from the Engine Control Unit (ECU) into mechanical movement or control actions. While sensors monitor engine conditions, actuators carry out the commands, adjusting, moving, or regulating systems to ensure peak performance, efficiency, and pollution control. The engine's actuators are crucial for managing fuel supply, air intake, exhaust management, and other functions.

Actuators also need a command from the Electronic Control Unit in order to actuate or work. These Actuators work on the negative command from the ECU. The negative command from the Electronic Control Unit controls the working of the Actuator.

For Example: Diesel Rail Valve, EGR Valve.

TYPES OF ACTUATORS IN A CAR:

1. **Fuel Injectors:**

   These are electronically controlled valves that provide precise amounts of fuel to the combustion chamber. Fuel injectors are controlled by the ECU, ensuring proper atomization and timing for optimal combustion.

2. **Idle Air Control (IAC) Valve:**

   This actuator adjusts the engine's idle speed by directing airflow around the throttle plate. The ECU controls the IAC valve based on engine load and temperature.

3. **EGR Valve (Exhaust Gas Recirculation) :**

   To reduce NOx emissions, the EGR valve recirculates a portion of the exhaust gases back into the intake manifold. The ECU regulates it based on load and RPM. It also plays an important role in engine cooling. Increased temperature will open the EGR valve to recirculate 2-5% of exhaust gases back to intake in order to reduce oxygen amount to reduce the blast.

4. **Ignition Coil:**

   The ignition coil transforms low-voltage battery electricity to high-voltage pulses for spark production. In today's coil-on-plug ignition systems, the ECU controls it directly.

5. **Variable Valve Timing (VVT) Solenoids:**

   These actuators optimize engine efficiency and power by adjusting intake and exhaust valve timing at varying RPM levels. They receive signals from the ECU via sensor inputs.

IDENTIFICATION OF WIRES IN ACTUATORS:

In case of Actuators, in Open Circuit, there will be minimum voltage on either of wires. Actuators are mostly 2 wired. The voltage will be around 1V.

Once the Circuit is Closed, the voltage on both the wires will become equal. Now when the engine is running and continuously being accelerated or decelerated, the voltage on one wire will increase to a constant value. This will be our reference voltage. In the other wire, the voltage will increase but continuously fluctuate due to acceleration or deceleration.

2. CONCLUSION:

Engine-mounted sensors are critical in current automotive engineering. They lay the groundwork for fuel efficiency, emissions reduction, safety, and performance improvement. As car technology advances, sensor technologies will become more sophisticated, linked, and integrated into the automotive ecosystem.

ACKNOWLEDGEMENT:

The author would like to express his sincere gratitude to CT University, Ludhiana for providing the necessary resources and support to carry out this research. I am especially thankful to our faculty mentors and the academic staff who guided me in reviewing and understanding the sensors and actuators on an engine.

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