Jupiter Publications Consortium

Vol. 2 Iss.3, pp. 1-6, 22nd November, 2016
ISSN Print : 2454-1435 © 2016 IJRMMAE
ISSN Online : 2454-1443 © 2016 IJRMMAE
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International Journal of Research in Mechanical, Mechatronics and Automobile Engineering (IJRMMAE)

SENSORS FOR AUTOMOTIVE VEHICLES – A REVIEW

Dr. S. SELVI
Associate Professor, Dept. of Mechanical Engineering
Institute of Road and Transport Technology, Erode – 638 316.
selvimech@yahoo.com

Received 10, November 2016 | Accepted 22, November 2016

Abstract : Automotive manufacturers are continuously increasing the use of electronics systems mainly to improve the vehicle performance, safety and passenger comfort. Sensors and actuators integrated with automotive control computers called as Engine Control Unit [ECU] or Engine Control Management [ECM] which helps to optimize the vehicle performance while improving reliability and durability. Variety of sensors covering a wide range of functions is used in the current vehicles.

Keywords: Sensors, Actuators, ECU, ECM

1. Introduction

Today's automotive vehicles are installed with a wide range of sensors capable of providing on-line and on-road data to ensure performance, comfort and safety to the driver and passengers. The measurement of inlet manifold absolute pressure in early ignition and fuelling control systems was one of the first automotive applications of sensors, and continues to this day to be an important parameter [1]. Many other sensors including oxygen sensor, throttle position sensor, velocity sensor, position sensor, knock, air mass flow, exhaust gas recirculation and temperature sensors have been subsequently used to enhance powertrain performance.

The trend towards the increasing use of sensors on vehicles has created new challenges and opportunities for sensor design and development. Fig, 1 provides some examples of sensors used on today's vehicles.

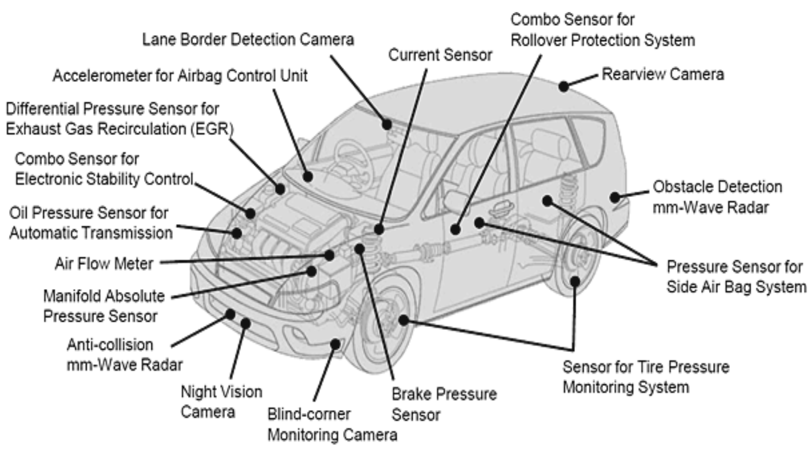

Fig. 1 Sensors in Car

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Computerized engine control systems rely on inputs from a variety of sensors to regulate engine performance, emissions and other important functions. The sensors must provide accurate information otherwise drivability problems, increased fuel consumption and emission failures can result.

2. Sensor Technology

Sensors are essential components of automotive electronic control systems. Automotive sensors must satisfy accuracy, robustness, manufacturability, interchangeability, serviceability and low cost of manufacturing. Because of the key role, sensors and actuators play a major role in automotive, aeronautical, defense and robotics technology [2]. A *sensor* is a device which is capable of converting any physical quantity to be measured and convert them to an electronic signal. A sensor is the interface between the monitored device or a unit and the control system.

The evolution of microcontroller and sensor technology is allowing automobile industry to create complex systems that can provide higher levels of vehicle control and safety through ECU or ECM. Currently, each vehicle has an average of 50-100 sensors on board [3]. Because cars are rapidly getting "smarter" the number of sensors is projected to reach as many as 200 sensors per car. These numbers translate to approximately 22 billion sensors used in the automotive industry per year by 2020.

3. Characteristics of Sensors

A good sensor should have the following characteristics:

- High Sensitivity - How much the output of the device changes with unit change in input
- Linearity - The output should change linearly with the input.
- High Resolution - Smallest change in the input that the device can detect.
- Wide range and span
- Less Noise and Disturbance.
- Less power consumption.
- Low cost

4. Sensors - Types

A Hall effect sensor is a transducer that varies its output voltage in response to a magnetic field. Hall Effect sensors are used for proximity switching, positioning, speed detection, and current sensing applications [4]. Hall sensors are commonly used to time the speed of wheels and shafts, such as for internal combustion engine ignition timing, tachometers and anti-lock braking systems. Fig. 2 shows the simple view of the sensor.

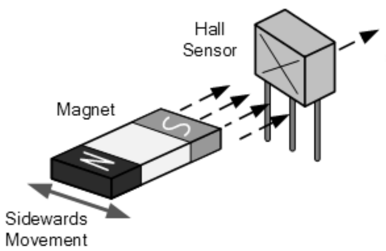

Fig. 2 Hall Effect sensor

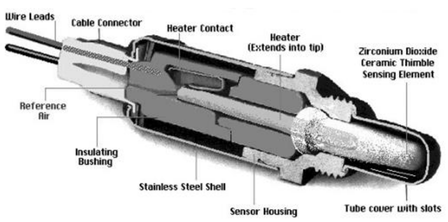

Fig. 3 Heated Oxygen Sensor

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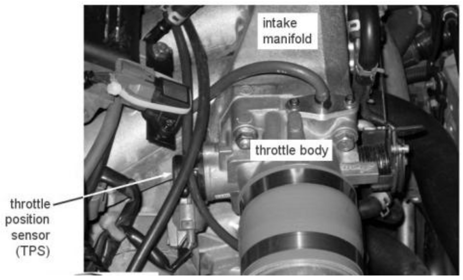
4.1 Oxygen Sensor

It is one of the key sensors in this system often referred to as the "O2" sensor because O2 is the chemical formula for oxygen. It may also be referred to as the H2O2 for Heated Oxygen Sensor because it has an internal heater circuit to bring the sensor up to operating temperature following a cold start [5]. The O2 sensor [Fig. 3] is mounted in the exhaust manifold to monitor how much unburned oxygen is in the exhaust. Monitoring oxygen levels in the exhaust is a way of gauging the fuel mixture. It tells the computer if the fuel mixture is burning rich (less oxygen) or lean (more oxygen).

4.2 Throttle Position Sensor (TPS)

It is a sensor used to monitor the throttle position of a vehicle. The sensor is usually located on the butterfly spindle/shaft so that it can directly monitor the position of the throttle. More advanced forms of the sensor are also used.

(a) TPS in BMW Car



(b) TPS in Audi A4

Fig. 4 Throttle position sensor

4.3 Coolant temperature sensor

This sensor [Fig. 5] is used to measure the temperature of the engine coolant of an internal combustion engine. The readings from this sensor are then fed back to the Engine control unit (ECU), which uses this data to adjust the fuel injection and ignition timing. On some vehicles the sensor may also be used to switch on the electric cooling fan.

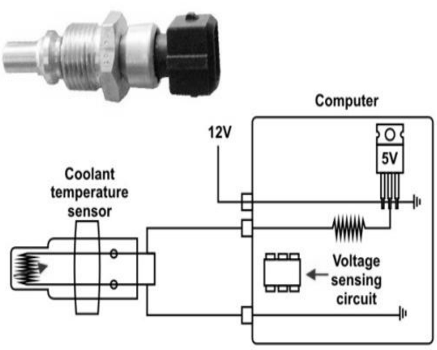


Fig. 5 Coolant temperature sensor

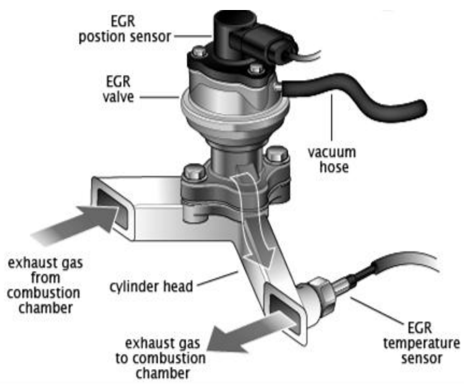


Fig. 6 EGR temperature sensor

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4.4 Exhaust Gas Recirculation Sensor

The sensor is installed in between the exhaust and intake manifold, and monitors the temperature of the exhaust gases which is shown in Fig.6. To reduce engine emissions, modern vehicles have exhaust gas recirculation systems. These systems route gases from the exhaust to the intake, which reduces the combustion temperatures in the engine. Reduced combustion temperatures minimize nitrous oxide emissions and prevent engine knocking.

4.5 Manifold Absolute Pressure [MAP] & Mass Airflow [MAF] sensor

The manifold absolute pressure sensor provides instantaneous manifold pressure information to the engine's electronic control unit. The data is used to calculate air density and determine the engine's air mass flow rate, which in turn determines the required fuel metering for optimum combustion and influence the advance or retard of ignition timing. A fuel-injected engine may alternatively use a mass airflow sensor (MAF) to detect the intake airflow. A typical naturally aspirated engine configuration employs one or the other, whereas forced induction engines typically use both; a MAF sensor on the intake tract pre-turbo and a MAP sensor on the charge pipe leading to the throttle body.

Fig. 7 Manifold Absolute Pressure sensor

Fig.8 Mass Airflow Sensor

4.6 Knock Sensor

The main purpose of a knock sensor is to reduce the ignition system to inhibit any damage to the engine. Knocks to an engine may occur because of overheating of the engine and poor fuel quality [6]. Any knock to an engine manifests as a small vibration that is detected by the knock sensor. This sensor works by converting the vibration to an electrical signal, which is then transmitted to the computer controlling the ignition system where the change in vibration to this voltage signal alters the timing adjustments on the ignition.

Fig.9 Knock sensor in BMW

Fig. 10 Knock sensor in Mercedes

4.7 Vehicle Speed sensor [VSS]

The Vehicle Speed sensor or VSS [Fig.11] measures transmission/transaxle output or wheel speed. The ECM uses this information to modify engine functions such as ignition timing, Air/Fuel ratio, transmission shift points, and to initiate diagnostic routines. It is typically located at the transmission or transaxle.

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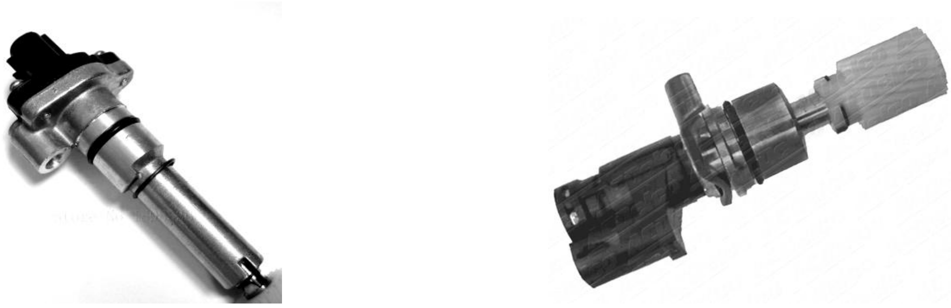

(a) Toyota Lexus VSS (b) Ford Taurus VSS

Fig. 11 Vehicle Speed sensor

4.8 Fuel Pressure Sensor [FPS]

The fuel pressure sensor signals the pressure in the fuel rail to the ECU [Fig.12]. The rail contains a pressurized supply of diesel fuel ready for the injectors to use; when the pressure in the rail drops the sensor signals this to the ECU and pressure (via the fuel pump) is restored. The ECU controls the supply of fuel to the rail from the high pressure pump; it does this by means of a fuel pressure control valve.

Fig. 12 Fuel Pressure Sensor

Conclusion

- Sensor design and development is one of the fast growing areas to meet the demands
of the future vehicles.
- Smart, intelligent and driverless cars are becoming popular which needs the sixth
sense provided by sensors.
- Within 5 to10 years, sensors that can be designed to operate at high temperatures and
pressure will provide new means of monitoring engine combustion processes.
- A review of various types of currently used automotive sensors is presented.

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