Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 01, January-2018

Overview of MEMS Sensors in Automotive Industry

Prof. Upesh Mangalprasad Patel
Asstt. Professor,
Department of Electronics & Communicationn Engineering.
TGPCET, Nagpur.

Ms. Karishma Subhash Padole
Asstt. Professor,
Department of Electronics & Communicationn Engineering.
TGPCET, Nagpur.

***Abstract* — This paper is an overview of the primary automotive sensor devices using MEMS Technology used today and their related system applications. Considered by most engineers as cutting-edge or fringe technology, MEMS sensors have been embraced by the automotive industry in its quest to improve performance, reduce cost, and enhance the reliability of the family sedan. In fact, hundreds of millions of MEMS sensors have been used in automobiles over the past decade. This paper describes new automotive sensors that measure position, pressure, torque, exhaust temperature, angular rate, engine oil quality, flexible fuel composition, long-range distance, short-range distance, and ambient gas concentrations. In addition, new features are described for sensors that measure linear acceleration, exhaust oxygen, comfort/ convenience factors, and night vision. New automotive system applications are described for sensors that measure speed/timing, mass air flow, and occupant safety/security.**

Keywords* — *Accelerometers, actuators, automotive systems, gyroscope, microelectromechanical systems, micromachines, pressure sensors, sensors.

I. INTRODUCTION:

Microelectromechanical systems (MEMS) is the technology of microscopic devices, particularly those with mechanical moving parts along with electrical components. The ability of making micro structures on tiny silicon chip gives many advantages over traditional sensor technology. These micro moving parts of silicon chip can be used as sensor and actuators in many applications to gather the information, allow the system to measure the parameters and control the ambiance. Sensors are defined as “devices that transduce physical quantities such as pressure or acceleration into electrical signals that serve as inputs for control systems. There are different types of sensor working on the various principles like electrooptics, electromagnetic and piezoelectricity. These technologies have contributed to major improvements in vehicles such as more safety, less fuel consumption, less emission and better stability. Most of the sensors are now compulsory to install in modern day vehicles specially passenger vehicles [1,2].

Here, the most recent and main applications of the MEMS technology in the automotive sensors industry are introduced.

II. MEMS SENSORS:

MEMS Accelerometers

These are used to measure the static or dynamic force of acceleration. The major categories of accelerometers include silicon capacitive, piezo-resistive and thermal accelerometers. In case of piezo-electric effect, a voltage generated corresponds to the accelerative forces which are acting on microscopic crystal structures on the sensor.

Capacitive sensors are designed to operate by generating the electrostatic field and detecting the changes in the field caused when the object or target approaching the sensing area. In case of thermal MEMS sensors a large number of tiny thermocouples are connected in series.

MEMS Gyroscopes:

MEMS gyroscopes are used to detect and measure the angular rate of an object. These are works on the principle of vibrating objects undergoing rotation. These are very tiny sensors in which a small resonating mass is shifted as the angular velocity changes when the gyro is rotated. Further, this movement is converted into low current signals. Similar to the accelerometers these sensors also work on different sensing principles like silicon capacitive, piezo-resistive, etc. Some of the types of MEMS gyroscopes include tuning fork, resonant solids, vibrating wheels, vibrating plate gyroscopes.

MEMS Pressure Sensor:

MEMS pressure sensors measure the pressure difference across a silicon diaphragm. Three types of pressure measurements like gauge, absolute and differential pressure are possible with these sensors.

In this sensor design, diaphragm is etched from silicon using micro machining process and the measurement techniques include piezo-resistive and capacitive technologies. This sensor is integrated with diaphragm and a set of resistors on integrated chips so that a pressure is detected as a change in resistance when the membrane flexes.

MEMS Magnetic Field Sensor:

MEMS based magnetic sensor detects the magnetic field vector by measuring the amplitude of a mechanical Lorenz force. This MEMS device consists of a current loop on an SiO_2 plate and the amplitude of force is detected with a polysilicon piezoresistor Wheatstone bridge. Magnetic

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 01, January-2018

field sensors widely used to measure the magnetic fields and applications of such sensors include position sensing, current detection, speed detection, vehicle detection, geophysical prospecting, space exploration, etc. A new class of magnetic sensors is developed by MEMS technology [1, 2, 3].

APPLICATIONS OF MEMS SENSOR:

a. Accelerometer for crash detection and airbag control : Crash sensing for air bag control represents the largest automotive use of inertial MEMS sensors. In this application, an accelerometer continuously measures the acceleration of the car. When this parameter goes beyond a predetermined threshold, a microcontroller computes the integral of the acceleration (i.e., the area under the curve) to determine if a large net change in velocity has occurred. If it has, the air bag is fired.

The decision to fire front air bags has to be made in dozens of millisecond the decision to fire side air bags must be made even more quickly because the car door is closer to the occupant than the steering wheel or dashboard. MEMS accelerometers can perform robust self-testing, allowing the air bag module processor to determine if the sensor's data are reliable or if the air bag module must be serviced.

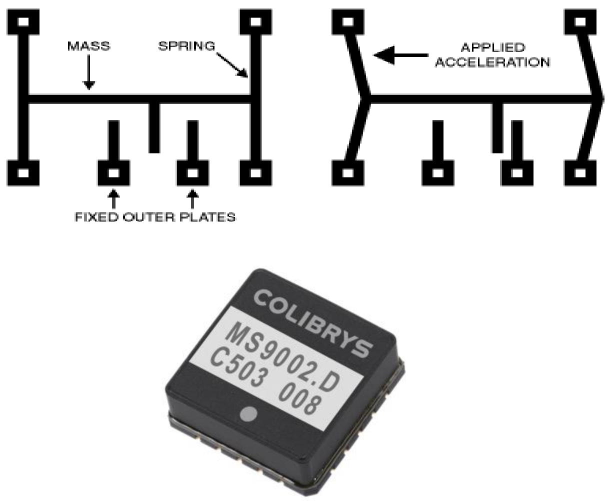

Figure 1: MEMS Accelerometer design.

b. Side Impact Sensor: It is a type of pressure sensor used to detect the side impact or crash. The side impact MEMS sensor measures the quick increase of pressure within the cavities of passenger car door to determine the airbag deployment.

Figure 2: Front Impact Sensor

c. Front Impact Sensor: The front impact sensor measures acceleration data for impact detection using MEMS technology**.** This feature enables passenger safety from crash impact.

Figure 3 : Front Impact Sensor

d. Brake Vacuum Sensor: It is used to measure pressure of brake booster in start/stop systems using MEMS sensor technology. The operating voltage is 5V (4.5 - 5.5 V) and operating temperature is between -40 to +150° C. It operates in pressure range of ± 1.05 bar (programmable for each customer) with burst pressure of 5 Bar. It has accuracy over lifetime about 1.5%.

Figure 4: Brake Vacuum Sensor

e. Vehicle Dynamic Control: Vehicle dynamic control (VDC) systems help the driver regain control of the automobile when it starts to skid. If the VDC works properly, the driver may not even be aware that the system intervened. A VDC system consists of a gyroscope, a low-g accelerometer, and wheel-speed sensors at each wheel (the wheel-speed sensors may also be used by the ABS).

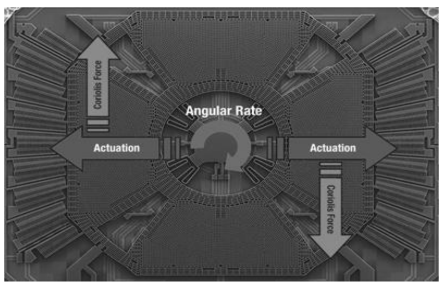

Figure 5: 3 axis gyroscope design on chip

f. Rollover Detection: This system is useful for SUV, LUV, vans, pickup trucks, and sport utility vehicles, which are more likely to roll over because of their higher centre of gravity. The roll over detection system consists of a gyroscope to read the roll rate. The roll rate is integrated to determine the roll angle of the vehicle, but roll rate data alone are not enough to predict if a vehicle is (or will be) rolling over.

An accelerometer reading for vertical acceleration (Z axis) is also required because large roll angles can be encountered in banked curves with no possibility of rollover roll angle and roll rate of the vehicle to determine if it is tipping over. If it is, the system fires the side curtain air bags to protect the occupants.

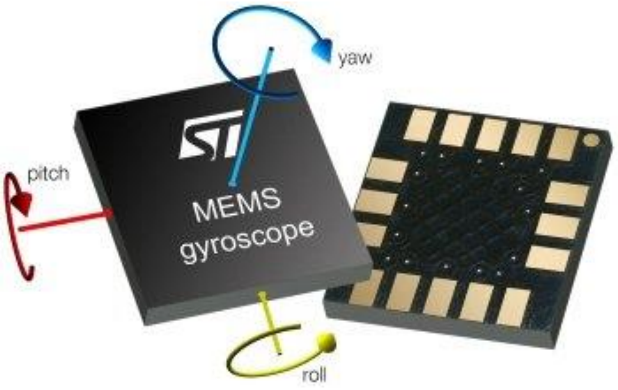

Figure 6: Gyroscope chip

g. Tire Pressure Monitoring Systems: Correct tire pressure and temperature are essential for obtaining optimal product performance. TPMS has played important role in safely driving now a days. The inflated tyre or heating issue can be monitor using this system. Power consumption of this sensors is low and accuracy is great and reliable. These pressure monitoring systems are connected with main computer of vehicle with wireless data transfer.

Figure 7: Tyre Pressure Monitoring System

h. Position sensor: The position of specific point of interest can be calculated by bending detection of cantilevers or more complex MEMS flexures via different techniques: optical, capacitive, piezoelectric, etc.

i. Speed Sensor: The wheel speed sensors are useful for ABS (antilock brake system) control the braking mechanism of vehicle. This is one of the most common safety feature in almost all supplied vehicles. Now these sensors are manufactures using MEMS sensor technology.

j. Crankshaft speed sensor: The optimum engine control is based on ongoing, exact information from the drive train provided by sensors. The electronic engine management system measures the speed, position and, optionally, the rotational direction of the crankshaft via the crankshaft speed sensor. It is used to determine the speed at which crankshaft is rotating. The sensor required here is to achieve the matching timing between the valves and pistons. It is useful in fuel injection mechanism in vehicle engine.

k. Camshaft position sensor: The engine control unit uses the camshaft position sensor to record the exact position of the camshaft. This increases power and supports emissions reduction at the same time. This gives the driver optimal engine control. The crank sensor can be used in combination with a similar camshaft position sensor to monitor the relationship between the pistons and valves in the engine, which is particularly important in engines with variable valve timing. This method is also used to "synchronise" a four stroke engine upon starting, allowing the management system to know when to inject the fuel. It is also commonly used as the primary source for the measurement of engine speed in revolutions per minute.

Figure 8: Camshaft Position Sensor

III. CONCLUSION:

The inertial MEMS content of cars is substantial and growing. As the capabilities of these sensors grow, designers are finding more uses for them to improve the safety and reliability of automobiles. Today, manufacturers primarily use inertial MEMS sensors to implement safety features (e.g., air bag control), but performance and convenience applications are quickly becoming a major market. Due to yearly advancement in MEMS technology the applications requirement will not be limited to only inertial MEMS sensors. Future will come with some new applications of such MEMS technology as the autopilot systems are becoming common in automotive industry.

IV. REFERENCES:

[1] Amir Piltan, Khaje Nasir Toosi University of Technology, Reza Ghodsi, Central Connecticut State University. “MEMS Technology in Automotive Industry: Trends and Applications”.

[2] David S. Eddy and Douglas R. Sparks, Application of MEMS Technology in Automotive Sensors and Actuator.

[3] T. Fujimori et al., “Tiny (0.72 mm^2) Pressure Sensor Integrating MEMS and CMOS LSI with Back-End-Of-Line MEMS Platform,” the 15th International Conference on Solid State Sensors, Actuators & Microsystems Transducers 2009, June 21-25, pp.1924-1927 (2009).

[4] H.Ishikawa et al., “The Latest Trend in Sensors for Automobiles,” CMC Publishing Co., Ltd. (2008) in Japanese.

[5] M. Madou, Y. Zhang, C. Wang, and S. Akbar, “MEMS chemical sensors for automotive applications,” in Proc. Sensor Expo Detroit,1997, pp. 329–335.

[6] C. Spangler and C. Kemp, “A smart automotive accelerometer with on-chip airbag deployment circuits,” in Tech. Dig. IEEE Solid-State Sensor and Actuator Workshop, Hilton Head Island, SC, 1996, pp. 211–214