Fuel Gauge Sensing Technologies for Automotive Applications

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Abstract— **The paper describes the existing fuel gauge techniques being used in automobiles i.e. the traditional fuel gauge system and the smart fuel gauge system and also discusses their operating principle and a comparison is done between the two existing techniques based on performance, complexity and cost of development. Some issues with respect to the existing techniques are identified and so a better alternate sensing technology has been suggested, described and justified.**

***Index Terms*— automobile fuel gauge, fuel gauge, float sensor, fuel indicator, capacitive level sensing**

I. Introduction

A fuel gauge (or gas gauge) is an instrument used to indicate the level of fuel contained in a tank. Commonly used in cars, these may also be used for any tank including underground storage tanks. The systems consist of two important circuitry that is for sensing and indication of fuel level. The sensing unit usually uses a float type sensor to measure fuel level while the indicator system measures the amount of electric current flowing through the sensing unit and indicates fuel level. There are various techniques to implement sensing and indicating systems.

II. Existing fuel gauge techniques description

The main reason for stretching a vehicles mileage is the fuel gauge present on the dashboard of the car which makes the driver think that they are running low on fuel while there is plenty of fuel still left. Therefore the traditional system used is notoriously inaccurate; however some embedded systems were incorporated into the traditional systems in order to obtain better accuracy. Presently the most common and traditional fuel indicator system makes use of the resistive float type sensors to measure the level of fuel in the tank and this system consists of two units i.e. 1) The "sender unit" responsible to measure the level of fuel in the tank, 2) The "gauge unit" responsible to display the measured fuel level to the driver. Another technique is known as the Smart fuel gauge system, which is similar to the traditional technique but also makes use of embedded systems such as microcontrollers or microprocessors for providing better accuracy.

III. Operating principles of the existing techniques

As discussed in section 2, the traditional fuel indicator consists of two units i.e. the sending unit and the gauge. The Fig (1) shows the commonly used traditional fuel measurement system. The sending unit is located in the fuel tank of the car and it consists of afloat, usually made of foam, connected to a thin, metal rod. The end of the metal rod is mounted on a variable resister or potentiometer. The variable resistor consists of a strip of resistive material over it which moves across the variable resistor changing the resistance and flow of current depending on the movement of the float with respect to the level of fuel present in the fuel tank.

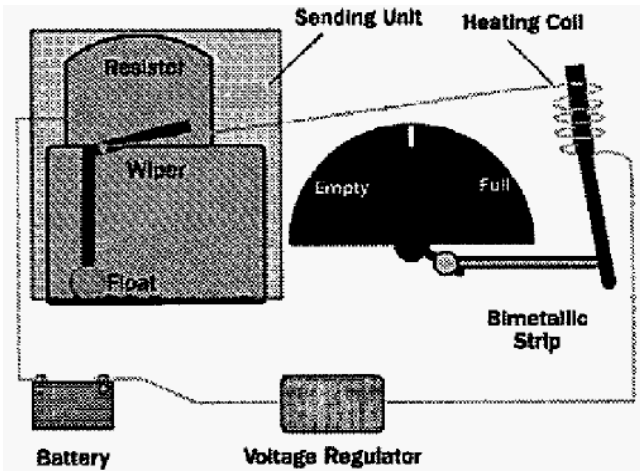

Figure1. Traditional Fuel Measurement System [1]

The Fig (1) shows that the fuel in the in the fuel tank is almost empty and the float has moved to the bottom of the tank moving the strip on the resistor thus increasing the resistance to maximum and current flow through the resistor becomes minimum thus displaying fuel empty on the gauge[1]. The gauge consists of a bimetallic strip i.e. a strip made of different kinds of metal and whose thermal co-efficient of expansion differs from each other. When resistance is decreases, current increases and thus the strip is heated during which one metal expands less than the other, so the strip curves, and this bending action is what moves the needle move on the fuel gauge. As resistance increases, less current passes through the heating coil, so the bimetallic strip cools. As the strip cools, it straightens out, pulling the gauge from full to empty. The smart fuel gauge system techniques has been implemented in some newer cars in which, instead of sending the current directly to the gauge, an intermediate microprocessor is used to read the output of the resistor and then communicate with the dashboard for displaying the fuel on the gauge corresponding to the read output voltage from

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the sending unit and these systems actually help improve the accuracy of the gauge.

IV. Comparison of the Existing Techniques

According to the details described in section 3, the two existing techniques are the traditional float type measurement technique and the microcontroller based fuel measurement technique which are similar to each other while differing in their accuracy, complexity and cost of development. The traditional float type resistive measurement technique has bad accuracy issues compared to that of the microcontroller based technique and the reason for this is its mechanism, it is noticed that the gauge tends to stay on full for quite a while after filling up and this is because when the tank is full, the float is at its maximum raised position while its upward movement is limited either by the rod its connected to or by the top of the tank and therefore this means that the float is submerged and it won't start to sink until the fuel level drops to almost the bottom of the float, hence the needle on the gauge won't start to move until the float starts to sink. Something similar can happen when the float nears the bottom of the tank. Often, the range of motion does not extend to the very bottom as shown in Fig (1), so the float can reach the bottom of its travel while there is still fuel in the tank. This is why, on most cars, the needle goes below empty and eventually stops moving while there is still gas left in the tank. The newer cars have a microprocessor that reads the variable resistor in the tank and communicates that reading to another microprocessor in the dashboard thus displaying the fuel level and a fuel light indicator signal with respect to the fuel level such as a red light when low on fuel and green light when tank is full. In this technique, the Carmakers can tinker with the gauge movement a little while compensating for the shape of the tank by comparing the float position to a calibration curve and this curve correlates the position of the float with the volume of fuel left in the tank. This allows the gauge to read more accurately, especially in cars with complicated gas-tank shapes. The microprocessor can also provide some damping to the needle movement i.e. when the car goes around a turn, or up a hill, the fuel can slosh to one side of the tank and quickly change the float position and if the needle were to respond quickly to all of these changes, it would be bouncing all over the place, instead the software calculates a moving average of the last several readings of the float position. This means that changes in needle position occur more slowly; therefore this may have been noticed when filling up car tank that the tank is fulfilled long before the needle reaches full, however the cost of implementing this technique is more expensive and complex compared to that of the traditional technique, therefore the trade off in the microprocessor based technique is the cost and complexity for gaining accuracy and its vice versa for the traditional technique i.e trade off accuracy for reducing cost of development and complexity of the system.

V. Suggestion of Alternate Sensing Technology

Excluding the existing techniques, an alternative level sensing technology such as capacitive sensing can be used to measure the fuel level in the tank .along.

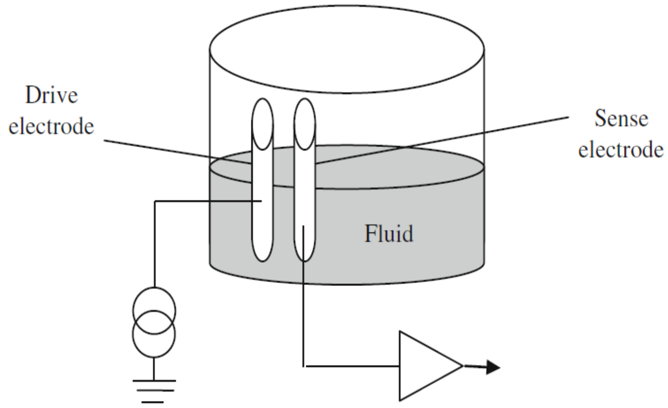

Figure2. Capacitive Level Sensing [2]

In a capacitive fuel level sensing system, the capacitive sensors have two conducting terminals electrodes and the gap between the two rods is fixed the fuel level can be found by measuring the capacitance between the two conductors immersed into the fuel as shown in the Fig (2). Since the capacitance is directly proportional to the dielectric constant between the parallel rods or plates, therefore the fuel rising between the two parallel rods leads to increase or change in the net capacitance value of the measuring tank as a function of fluid height [2]. If the dielectric behaves even slightly as a conductor then this can reduce the performance of the capacitor. The dielectric material used should ideally be an insulator while chemically fuel will have other contents mixed in it increasing the conductivity of electrons to some extent, therefore a common method used to overcome this problem is placing an insulating layer on each of the rods in order to preserve the performance of the measuring system. Capacitive type fuel level measurement system can make use of multiple capacitors or ulti-plate capacitors which has an advantage of an increased capacitance value and accuracy. Multicapacitor systems share the common dielectric constant, which is essentially the fluid itself in capacitive type fluid level measurement systems. If a capacitor is constructed with "n" number of parallel plates, then the overall capacitance will be increased by a factor of (n-1) as illustrated with an example in [2].Another upcoming level sensing technology is using ultrasonic sensors that can compete with the capacitive sensing technology in terms of accuracy and its details has been illustrated in [4].

VI. Justification for the Alternate Technology

In mobile fluid tanks, such as automotive fuel tanks, acceleration will induce slosh waves in the storage tank and this phenomenon of fluid fluctuation is called sloshing. The magnitude of sloshing is dependent on the value of the acceleration or deceleration that may be caused by braking, speeding, and irregular terrain. These dynamic effects of the fuel tanks can be compensated by incorporating a tilt sensor i.e. inclinometer along with the capacitive sensing technology in the fuel gauging apparatus. In this system, a signal from the fuel quantity capacitive sensor is transmitted to the display gauge only when the vehicle is tilted less than a

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predetermined degree, therefore the signal from the fuel sensor is passed to the display through the microprocessor only when the vehicle is in level condition and not accelerating or decelerating, thus when the level condition is met, the amount of fuel left in the tank measured by the capacitive fuel sensor is stored in the microprocessor memory and is displayed on the fuel gauge and same is updated again when the vehicle reaches the next level condition while the tilt of the vehicle being continuously monitored by the inclinometer and an correction factor matrix is stored in the microprocessor memory that is applied to the capacitive fuel level sensor signal at each level condition of the vehicle to compensate for fuel sloshing and displaying the correct and accurate measurements of the fuel level as illustrated with an example in [2].

VII. CONCLUSION

The existing traditional and the microcontroller based float type measurement techniques are far from exact and are on the conservative, however the microcontroller based technique is more accurate compared to the traditional technique but still lacks accuracy due to fuel sloshing in the tank unless float sensor is calibrated with respect to the size and curves of the tank. A more efficient and reliable sensing technology is the capacitive level sensing system that makes use of inclinometer as well as a microprocessor which has corrective action code inbuilt that is applied to the fuel sensor signal based on the inclinometer measurements to provide highly accurate measurement of the level of fuel in the tank .

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