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Design of a digital fuel gauge with distance-to-zero indicator

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Abstract. The fuel gauge in automobiles measures the amount of fuel in the tank through the sensing unit located in the tank and the analog indicator on the dashboard of the vehicle shows the quantity of fuel per time. This work is designed to ensure the display of the exact volume of fuel in the vehicle in digital form instead of the usual analog fuel indicator. It will also help to prevent inaccurate measurement of fuel at the filling station by showing the quantity of fuel during refuelling. So, a digital fuel gauge system has been designed and constructed to measure the exact quantity of fuel in the tank and display this measured quantity digitally in litres, by making use of an ultrasonic sensor and programmable microcontroller and the result obtain is $\pm 0.96\%$ accurate.

Keywords: Fuel gauge, Automobile, Indicator, Digital, Ultrasonic Sensor

1. Introduction

Today, though everything is going digital, most of the fuel meters in vehicles today are analog-based [1] and the few ones which are digitally based, only display the amount of fuel in percentage values or in bars. The most common fuel indicator system makes use of the type known as resistive float. In this type fuel indicator, measurement of the fuel level in the tank is leveraged on sensors. And it comprises two modules: the sensing module which measures the level of fuel in the tank and the gauge which displays to the driver, the measured fuel level with a deflecting needle oscillating between empty (E) and full (F) [2]. This fuel meter is not that accurate and it provides insufficient knowledge on the amount of fuel present in the tank. This creates a problem of determining the actual fuel available when refilling the fuel tank as well detecting any form of discrepancy in fuel purchased [3].

The concept of this paper is to produce an advanced fuel measuring system which indicates the exact quantity of fuel available in litres. With increase in the variety of sensor usage [4, 5], this paper explores the ability of an ultrasonic sensor to determine the actual amount of fuel in car tank and also calculate how much distance that can be covered with corresponding amount of fuel in the tank. These values, with the help of a micro-controller, are displayed on the LCD screen.

Ultrasonic sensor helps to determine how far (i.e. distance) is the surface of the liquid (i.e. fuel) to the top of fuel tank when measuring the quantity of fuel in the tank. These sensors principle of operation depends on echoes from radio or sound waves which is usually analog [6]. Besides that, it is also called



a transceiver. This means the sensor can transmit and receive signals [7]. Ultrasonic sensors work at high frequency to calculate distance travelled by the signal send and echo received by the sensor. These sensors are also capable of evaluating the time interval between the sent signal and the received echo to calculate the actual distance to an obstacle (surface of the fuel in this case) [8].

2. Related works

Trupti Wable et al. [9] proposed a fuel metering system using PIC16F877A micro controller. The system had a fuel level sensor and gear level connected to the microcontroller, so as to read the amount of fuel in the vehicle's tank and also to get information on the current state of the gear level. The fuel sensor used was the float-type sensor. The LCD screen was interfaced with the PIC microcontroller so that it displays the fuel level and also the gear level. The LCD screen shows the amount of fuel present in the fuel tank digitally. Also, in this system there was a GSM module for sending message to the owner in the event of fuel theft. But this system lacked an indicating system to alert or warn the driver in the event of low fuel in the vehicle's tank.

Nitin Jade et al. [10] proposed a fuel gauging system consisting of sensor, computing unit and indicator. The computing unit was made up of an Electronic Control Unit (ECU), Central Processing Unit (CPU) and a modulator. The sensor used to measure fuel is the density sensor. By using the vibrational frequency of the micro tube, the density of the fluid can be measured. Based on the factors that influence mileage, a number of sensors were put in place to retrieve information on those factors. ECU receives information from each individual sensor. The CPU collects data from ECU and processes it and then sends to modulator which modulates the signals and displays them on the indicator. The indicator was the LCD screen and it displayed the amount of fuel left in bars. But the limitation of this system is that it is not suitable for low and medium class vehicles. This is because as a greater number of sensors were used, the system became expensive and it is only suitable for luxurious vehicles. The failure of any of the sensors can stop the system from working.

Avinashkumar et al. [11] proposed a digital fuel indicator using PIC microcontroller which also indicates distance to zero. The system consists of the PIC16F877A microcontroller, the float type sensor, analog-to-digital (A/D) converter and the LCD screen. It measured the changes in the voltage at different fuel levels and computed distance to zero by considering a fixed mileage. In [11], the resistance position changes as the fuel level in the tank changes through the float type sensor placed inside the fuel tank. The resistance position is converted to digital value through analog-to-digital converter unit. The LCD is interfaced with the PIC microcontroller to show the value of the fuel tank in digits. The distance to zero was calculated by coding the microcontroller with respect to two inputs which are speed and fuel level. However, this system also lacks an indicator to alert or warn the driver in the event of low fuel in the vehicle's tank.

2.1 Existing Fuel Gauge Systems

The most common fuel gauge device is the resistive float type sensor. It comprises the sensing unit and the gauge unit. The former is mainly for fuel level measurement while the latter is mainly display of the measured fuel level.

In Figure 1, the gauge made of a bimetallic strip with different thermal co-efficient of expansion. The operation of this is linear such that as the resistance reduces, current increases which in turn cause temperature to be increased and thereby heating up the strip. During the heating process one metal expands more than the other causing the strip to become curved and change the position of the needle on the fuel gauge. In the reverse case, increase in resistance allows low current passage through the heating coil which causes the bimetallic strip to cool. As the strip cools, it straightens out, pulling the gauge from full to empty [12].

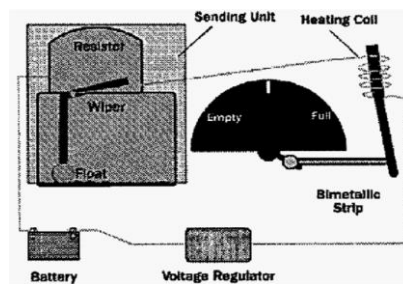


Figure 1. Traditional Fuel Measurement System (Bimetallic strip type)

2.2 Capacitance Level Sensing

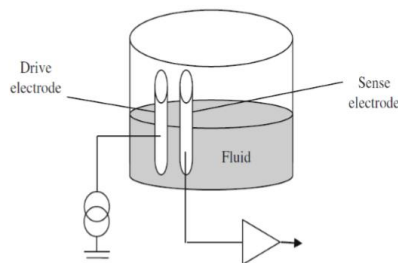


Figure 2. Traditional Fuel Measurement System (Capacitor type)

Another type of fuel measuring device is capacitive type. In this type, two conducting electrodes are placed at a fixed distance to each other as shown in Figure 2. From the mathematical relationship between capacitance of two parallel electrodes and dielectric, therefore, as the fuel level increases upward the two parallel electrodes, the value of the capacitance changes with respect to the fuel level [13].

3. Materials and method

In the design of this device, the different stages involved are discussed as follows:

Power supply: The power supply feeds the Arduino microcontroller. It is a DC power supply and it is either supplied by a 9-V DC battery or a regulated power supply. The regulated power supply consists of a step-down transformer which steps down the voltage level from 240V AC to 12V AC. The 12V AC is then rectified to 12V DC with Bridge rectifier. The ripples of the rectified DC waveform are eliminated by utilizing a capacitor. This is then regulated to 9V using voltage regulator LM7809.

In this work, the sensor used is the ultrasonic sensor. The ultrasonic sensor, which is directly connected to the fuel tank of the vehicle, will sense/find the level of fuel in the tank in litres.

The Arduino microcontroller, with the signal from the sensor, makes the required calculations concerning the amount of fuel in the tank and the corresponding distance to be covered by the vehicle. The Arduino is interfaced with the Liquid Crystal display (LCD) which displays the amount of fuel in the tank and the corresponding distance to cover. The block diagram of this system design is given in Figure 3.

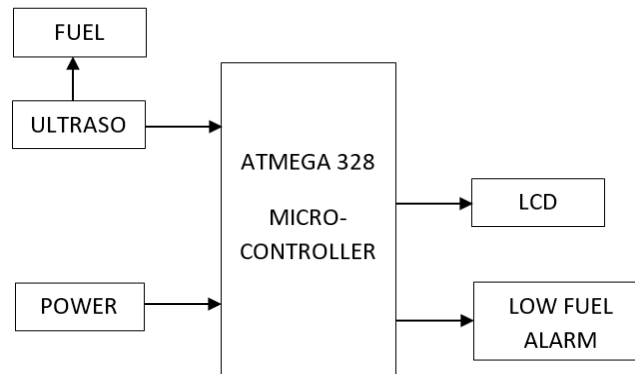


Figure 3. Block Diagram of the Design

3.1 System Implementation and Testing

The implementation of the work is divided into two different parts, namely:

- Software Implementation; and
- Hardware Implementation

3.1.1 Software Implementation

The coding of the Arduino Nano microcontroller was carried out through the Arduino Integrated Development Environment (IDE) software on a personal computer (PC). The Arduino codes used were written in C language, compiled and uploaded to the Arduino Nano board via its mini USB port.

3.1.2 Hardware Implementation

The hardware implementation of this project was grouped into three stages. These stages are as follows:

- Breadboarding of the components;
- Mounting and Soldering of the components on Vero board; and
- Packaging of the entire circuit.

4. Results

After testing the overall system, the results obtained are shown in the Table 1. From Table 1, it is clear that as the fuel level in the tank increases, the measured distance by the ultrasonic sensor reduces. This means that the fuel level in the fuel tank determines how far the ultrasonic signal can travel, hence, the fuel surface in the fuel tank obstructs the ultrasonic signal. It can also be seen from Table 1 that the displayed value by the proposed design is approximately equal to actual quantity of fuel in the tank and directly proportional to the calculated distance with respect to fuel in the tank. On the average, the percentage accuracy of the proposed design is $\pm 0.96\%$.

Table 1. Overview Results of System Testing

Actual Quantity of Fuel in the Tank (Litres)	Measured Distance from the Ultrasonic Sensor to the Surface of the Fuel (cm)	Displayed Value of the Fuel in the Tank (litres)	Calculated Distance to Zero (km)
0	34	0.00	0.00
4	24	4.07	40.72
10	10	9.94	99.43
11	8	10.91	109.12
14	2	14.10	141.04

5. Conclusion

In conclusion, the implementation of the digital fuel gauge gives the driver an actual value of the volume of fuel in the tank in litres. The designed system also gives the driver an estimate of the distance that can be travelled with the volume of fuel in the tank. The implementation of this designed system i.e. digital fuel gauge will alert the driver in the event of a low fuel in the vehicle's tank.

Furthermore, it will assist in curbing fuel theft due to inaccurate measurement of fuels at some filling stations because the driver will be able to see the exact value of the fuel in the tank before refilling and after refilling at the fuel station.

6. Recommendations

The following recommendations are made for further works;

- A GSM SMS technology can be incorporated with the digital fuel gauge in order to detect fuel theft or leakages from the tank. The GSM at the start of the vehicle and from time to time sends messages to the user intimating him/her about the volume of the fuel in the tank. This will help the user notice any fuel theft; and
- A hall effect sensor could be integrated with the digital fuel gauge system to measure the speed of the vehicle and make a more accurate calculation on the distance that can be covered with the available fuel in the tank.

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