Available online at www.elixirpublishers.com (Elixir International Journal)

Electrical Engineering

Elixir Elec. Engg. 43 (2012) 6751-6754

ISSN: 2229-712X

Embedded based capacitance fuel level sensor

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ARTICLE INFO

Article history:
Received: 24 November 2011;
Received in revised form:
25 January 2012;
Accepted: 7 February 2012;

Keywords
Embedded System,
Ladder network,
Reed sensor.

ABSTRACT
This paper proposes a new idea of the Fuel level sensor is to monitor, measure and indicate the fuel level in the tank of vehicles by using microcontroller based Embedded System. At present methods of fuel level measurement is Resistor Ladder network, Reed sensor with float and Linear Hall Effect sensor. The proposed method of measurement of fuel level is based on the variation in the capacitance based on the difference in dielectric properties between fuel and free air without any moving parts.

Introduction

The capacitance level detectors consist of two conductors (plates) that are electrically isolated from one another by a nonconductor (dielectric). When the two conductors are at different potentials (voltage, the system is capable of storing an electric charge. The storage capability of a capacitor is measured in farads. Figure 1. shows the capacitor plates have an area (A) and are separated by a gap (D) filled with a non-conducting material (dielectric – Fuel Diesel in this case) of dielectric constant (K). The dielectric constant of a vacuum is 1.0. The dielectric constants of a variety of materials are listed in the table for reference.

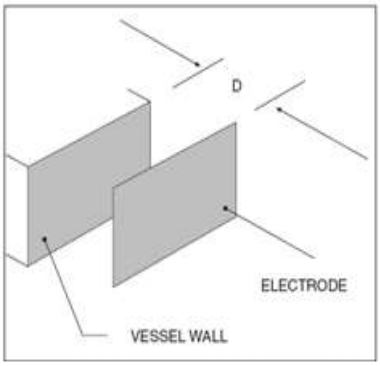

Figure 1. Construction of Capacitor plates

The dielectric constant of a substance is proportional to its admittance. The lower the dielectric constant, the lower the admittance of the material. Capacitance C is calculated as

$$C = kA/D \quad (1)$$

Where k = dielectric constant of medium
D = distance between the plates in mm
A = area of the plates mm^2

If a change in fuel level results in the total dielectric of the capacitance of probe. This capacitor (probe) is part of oscillator circuit which generates the frequency input to microcontroller based on the level of the fuel present in the tank. The resultant capacitance is proportional to the level of the fuel in the tank.

Figure 2. Physical View of Capacitive Fuel Level Sensor

The capacitance fuel level sensor is used for measuring the fuel level in the fuel tanks of vehicles without any moving parts. A controller, Power supply and signal conditioning circuit comprises of the design.

Proposed Design

The proposed design is for measuring fuel level of Diesel tank of capacity 350 Liters and 475mm height. The figure 2. shows the physical view of the Capacitance Fuel Level sensor proposed. The Electronic circuit with microcontroller is mounted on the top the unit. The Capacitive Sensors can directly sense a variety of things like motion, chemical composition, electric field, pressure, acceleration, fluid level and fluid composition.

The Capacitance fuel level sensors are built with conductive sensing electrodes in a dielectric, with excitation voltages on the order of five volts and detection circuits which turn a capacitance variation into a voltage, frequency, or pulse width variation. Capacitance level sensing is based around the difference in dielectric properties between the fuel and free air.

It works by measuring the change in capacitance between two conducting surfaces-inner and outer tubes (profiles).

The electronic signal conditioning circuit measures the change in capacitance and converts this value to analogue output corresponding to fuel level in the tank.

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This can be done by controller that internally calculates the change in frequency to the change in capacitance value and to produce the analogue voltage.

The calibration of sensor is also done by the controller, which frequently monitors the change in capacitance of profiles. In the proposed design 5% accuracy of fuel measurement can be achieved.

The figure 3. shows the sample Capacitive fuel level sensor which contains no moving parts when compared to other Reed and Linear Hall IC sensors.

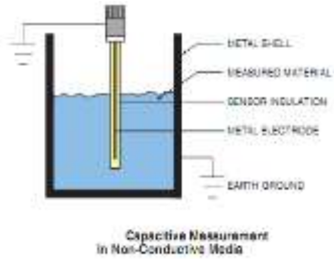

Figure 3. Capacitive Fuel level sensor

The capacitive fuel level sensor can be used for level detection of fluids. The sensor detects the liquid level in a reservoir by measuring the changes in capacitances between conducting plates which are immersed in the liquid, or applied to the outside of a non-conducting tank.

Proposed design procedures

1. Design electrode plates to measure the desired variables. Maximize capacitance with large area, close-spaced plates.
2. Surround this sensor with appropriate guard or shield electrodes.
3. Calculate sensor capacitance, stray capacitance and output signal swing.
4. Choose an excitation high enough for noise. An excitation frequency increases, external and circuit generated noise decreases.

Design circuit to meet accuracy, specifications and provide immunity to environmental challenges.

4. Block diagram and Schematic circuit diagram of proposed design

The figure 4. shows a block diagram of Capacitive Fuel level sensor which contains Power supply, Oscillator, Microcontroller, Input probe circuit, Buffer circuit and Digital to Analog converter.

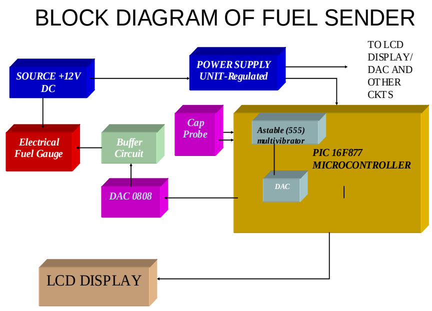

Figure 4. Capacitive Fuel level sensor

The figure 5 shows the capacitance probe circuit and figure 6 shows the microcontroller circuit to indicate the levels in Liters.

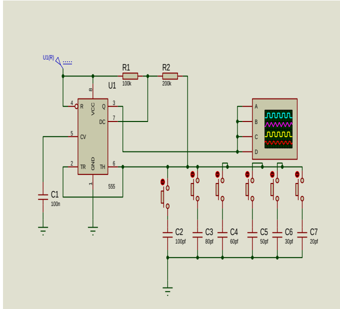

Figure 5. **Capacitive Fuel Level sensor probe**

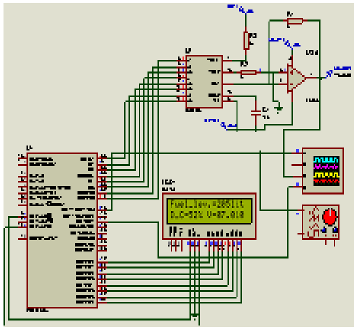

Figure 6. Capacitance Fuel level sensor

The Output frequency from the oscillator circuit fed to the input port of the microcontroller. The microcontroller internally converts the frequency input into level of fuel in liters and generates PWM signals which can be given directly to LCD display as shown in schematic diagram.

The LCD display is displaying the Duty cycle variations and Level of fuel in the tank.

The capacitance fuel level sensor is used for measuring the fuel level in the tanks of vehicle to give accurate results. The information received from microcontroller is further converted into voltage output as shown in the schematic above.

This part comprises of DAC 0808 and operational amplifier LM358 which can be directly connected to Fuel gauge for indication purpose in the front panel of driver. Further the Capacitance fuel level sensor can be used for giving and indicating KMPL of the vehicle. This is future improvement and implementation.

Results and conclusion

The change in output capacitance with frequency generated is shown in figure 7.

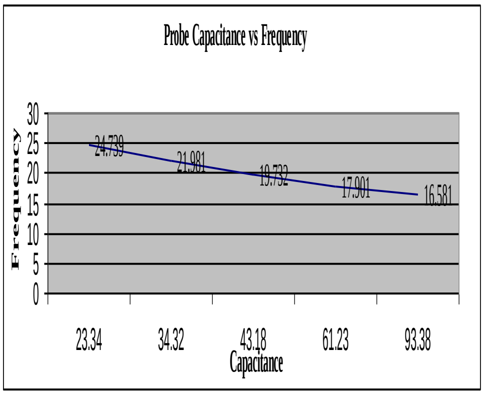

Figure 7 Relationship between Capacitance and Frequency generate

The signal input frequency generation is done by using Oscillator circuit. Controller gives the linear analogue voltage to the change in frequency which is shown in figure 8.

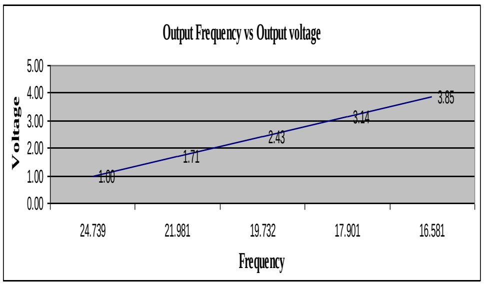

Figure 8 Relationship between Frequency and Output voltage

The output of the sensor is checked for four fuel levels ¼th , ½ , ¾th and Full fuel levels. The table 3. shows fuel level in liters. The other outputs are calculated and verified and found correct.

Future developments

It can be used for indication of BIO Fuels, to indicate the KMPL in vehicles, to monitor the average fuel consumption in vehicles, can be used in vehicles with different sizes and shapes of tank.

References

[1] PIC microcontroller manual
[2] OKI Reed switches catalogue
[3] RRE & Medar Reed switches manuals
[4] JCSES International Journal for computer sciences and Engineering systems Vol 2. No.3 Jul 2008
[5] Allegro & Melexis Hall IC Application notes

Table 1. Dielectric constant for different materials

S. No	Material	Dielectric constant
1	Air	1
2	Diesel	4
3	Petroleum	2.0 to 2.2
4	Transformer Oil	2.2
5	Thrichloroethylene	3.4
6	Acetic Acid	4.1
7	Glass	3.7
8	Castor Oil	4.7
9	Paper Dry	2.0
10	Mineral Oil	2.1
11	Water	4 to 88
12	Teflon	2.0
13	Quartz	4.0
14	Rubber (chlorinated)	3.0
15	Rubber (hard)	2.8
16	Rubber (isomerized)	2.4 to 3.7
17	Raw Rubber	2.1 to 2.7
18	PVC Powder	1.4
19	Polyester resin	2.8 to 4.5
20	Sugar	3.0
21	Silk	2.5 to 3.5
22	Teflon PTFE	2.0

Table 2. Sample calculation for capacitance probe

Capacitance of rod when the tank is Empty				
Parameters	Values	UOM	Values	UOM
Inner rod Dia (a)	5	mm	0.005	m
Outer rod inner dia Dia (b)	15.5	mm	0.0155	m
Length of rods	475	mm	0.475	m
Permittivity(Eo) free air	8.85×10^{-12}	Farad/m	8.85×10^{-12}	Farad/m
Capacitance for full tank is Empty = C=2*pi*E*L/Ln(b/a)			2.33×10^{-11}	Farad
			23.34	Pico Farad
Capacitance calculation when tank is Full with Fuel				
Parameters	Values	UOM	Values	UOM
Inner rod Dia (a)	5	mm	0.005	m
Outer rod inner dia Dia (b)	15.5	mm	0.0155	m
Length of rods	475	mm	0.475	m
Permittivity(Eo) free air	8.85×10^{-12}	Farad/m	8.85×10^{-12}	Farad/m
Permittivity of Diesel (Er)	4.00	Farad/m	4.00	Farad/m
Permittivity(E=Eo*Er)	3.54×10^{-11}	Farad/m	3.54×10^{-11}	Farad/m
Capacitance for full tank with Fuel = C=2*pi*E*L/Ln(b/a)			9.34×10^{-11}	Farad
			93.38	Pico Farad

Table 3. FUEL IN 350 LITRES TANK CONVERSION CHART

FUEL LEVEL	HEIGHT OF TANK IN MM	FUEL LEVEL IN LITRES	Duty cycle in %
EMPTY	25	11	10
¼	120	88	36.97
½	235	177	59.1
¾	365	265	77.05
FULL	475	350	90