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DESIGN AND DEVELOPMENT OF WATER-IN-FUEL DETECTOR

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ABSTRACT
A simple and reliable device was designed and constructed with materials sourced locally. This project, "water-in-fuel detector" is as an automotive electronic project which involves the use of the electrical conductivity property of water for detecting non-polar hydrocarbon fuels. This work is justified by the excessive economic and social loss prompted by the presence of water and other contaminants in the automobile fuel systems and storage systems. The work further improves the safety of automobiles and the social status of the users of the device. Undoubtedly, the device can detect bulk water in the base of fuel containing vessels by giving an audio signal. The signal when analyzed will provide information on the integrity of the fuel and the personnel using the product.
Key words: Fuel, Water, conductivity, water-in-fuel detector, automobile, non-polar, hydrocarbon, microcontroller, capacitor, Compiler, Timer.

1.0 INTRODUCTION

Water-in-fuel detector is a device which detects water in fuels. Water-in-fuel sensors are fitted in fuel filters, fuel/water separator, fuel refining systems, fuel analysis and fuel management systems for engine protection in heavy vehicles such as trucks, automotive, industrial and agricultural diesel engines, aircraft applications, for fuel regulatory purposes [Ali, 2008].

A variety of sensing systems are currently used to measure existing free water or fuel-water emulsions by measuring the resistive properties of free water, its conductivity, the dielectric properties of the emulsions, or differences in the refractive index of light propagating through the fluid [David and Robert**,** 2010].

1.1 How does water comes into Fuel?

Water is normally present in small amount in liquid fuel, either dissolved in the fuel, in a separate liquid phase known as "free water", or in a fuel-water emulsion. The cause of water in fuel contamination can be linked to so many problems such as: Contaminated or poorly maintained fuel supply outlet, condensation in the fuel tank, fuel separation process, water ingress (through hole in vent cap/line, rain water entry, [EESIFLO, 2007]. In some cases in developing countries it have been found that fuel have been stolen and replaced with small amounts of water.

1.2 What happens when water is in fuel?

Water in fuel is an inescapable problem for all type of engines. The existence of free water or a fuel-water emulsion can be dangerous, especially in the aerospace industries where frozen water poses a significant risk to aircraft, passengers and crew. The result of water in fuel contamination is engine and fuel system damage. The cost can be extensive in terms of money and time with a drastic increase in downtime and maintenance costs [Gray, 1985].

It is therefore desirable to monitor the amount of water dissolved in fuel, to measure how close the fuel is to saturation and to indicate the risk of free water or fuel-water emulsion formation.

1.3 Objectives of the research

- To have a cleaner fuel for efficient, full–power engine performance
- To enhance the durability of automotive engine components
- To monitor the extent of degeneration of diesel fuel in storage tanks
- To salvage downtime

2.0 DESIGN OF THE WORK

The water-in-fuel detector is designed to give enough of a warning between to allow actions to take place otherwise nothing will be gained by having a warning. The output signals from the detector circuit are conditioned (signal conditioning) to produce outputs which can be measured as numerical values on a meter, [Fairchild Semiconductor**,** 2002]. This meter also makes it possible for fuels or some other liquids with very low resistance to be identifiable.

The objective of the design is to develop a device which will have the following characteristics; small in size and weight, low power consumption, minimum maintenance requirements, cost effective fabrication, highly efficient operation, high reliability, ease of operation, ease of reproduction, high aesthetic value, safe in operation, corrosion resistant, and an acceptable accuracy.

The design concept is based on the fact that water, no matter the state has a finite resistance value. The resistivity of water at 25^{0}C is 18.18±0.03MΩ-cm. This implies that water conducts electricity, although it does this with a very high resistance to current flow. The electrical conductivity of water is the prime property used in the design. It is worthy of note that water co-exists with fuels (petroleum products) which are non-polar in nature, with extremely higher resistance value when compared with it [Gray, 1985]. Thus, when there is water between the two probes used, current flows from the positive terminal of the battery, through the water and the probes and the circuit is thus activated.

2.1 Design Consideration

A new idea was considered for development, and this idea was thoroughly evaluated according to the following criteria: Innovation, function, product aesthetics, design concept, industrial manufacturability, inter-disciplinary approach, economic viability, visualization, presentation, sustainability, ergonomics, suitability, realization, quality and safety**,** [Richard 1999].

Table 1.0 Electrical Data

Input	**Value**	**Unit**
Power consumption	30-225	mW
Minimum power dissipation	600	mW
Supply voltage	4.5-15	v
Supply current	10-15	mA
Output current	200	mA
Frequency	5-250,000	Hz
Operating temperature	0-70	^{0}C

2.2 Components of the design

The design comprise of a detector system, alarm system and system on/ off state indicator. The alarm system is further divided into the audible alarm and visual alarm system. The detector system always works with the alarm system, because without the alarm system, the output signal from the detector system will be a latent signal [John, 1992]. The components for the system includes; Resistors (56kΩ, 10kΩ, 470Ω,), electrolytic capacitors (0.01µF, 0.01µF, 1µF/15v, 27pF, 10µF), batteries (6F22, 9v), copper probes, NE555N timer ICs, printed circuit boards, single throw switches, jumper cables, four pieces of seven segment display common anode type, npn transistors 2N222 type, microcontroller AT89C52 type, 12Mhz crystal oscillator, reset switch, jumper cables, IC 7805 voltage regulator and light emitting diodes.

2.3 Design of the modular units

The design of the system is shown simplified with the aid of the following circuit diagrams produced with Express PCB software, version 7.0.2.

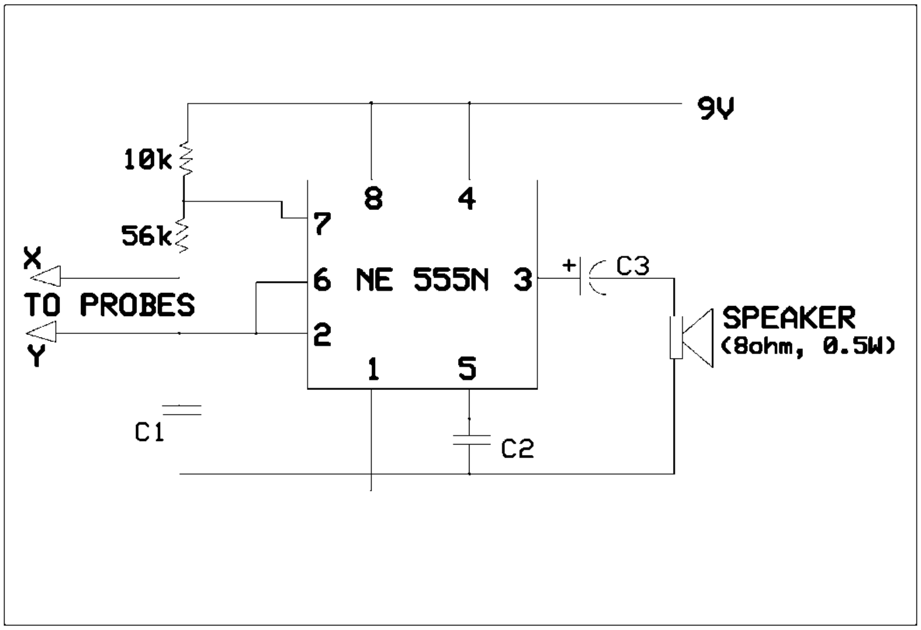

Fig.1: Circuit diagram of the detector system

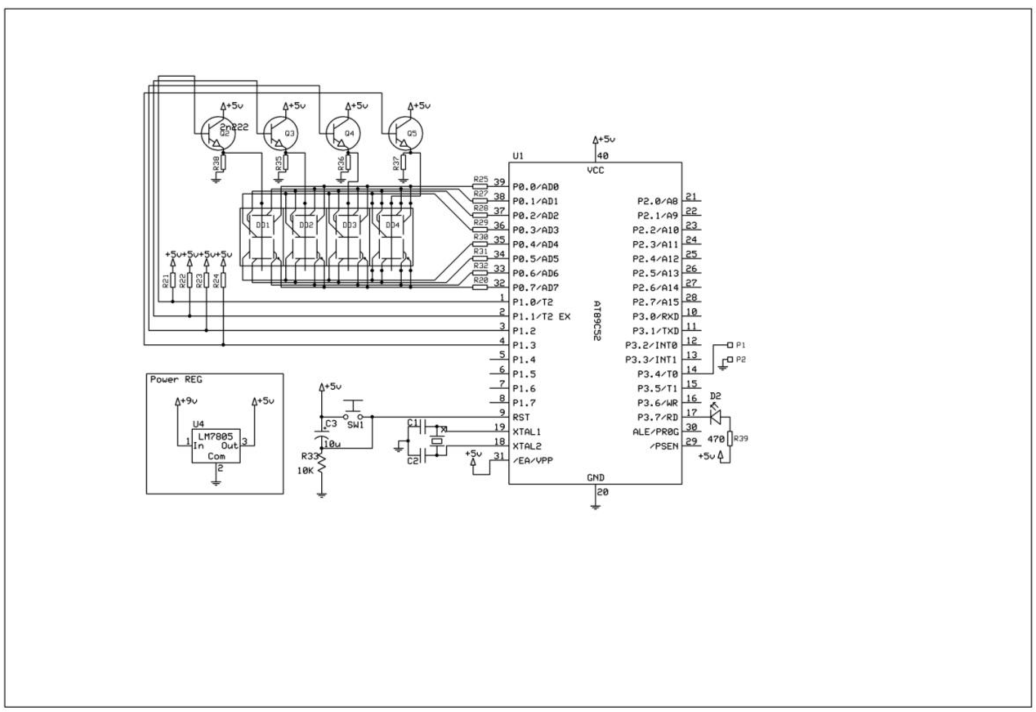

Fig 2.0 Circuit diagram of the visual alarm system

2.4 Working of the circuits

The detector circuit first does the detection of water in the fuel with the aid of the probes. It is a frequency generating system. The circuit is closed by the water finite resistance and thus current flows through the circuit. The 555 timer integrated circuit is the brain of the detector circuit. It has pin 1 as the ground pin and pin 8 as the supply pin. The pin 3 is the output from the integrated circuit (see the datasheets). Once the ground and supply pins are connected accordingly to a voltage source, frequency signals emanate from pin 3 this is the same frequency that goes to the buzzer. The buzzer tone can be heard only if this frequency is within the range of audible frequencies (20-20000Hz). However it is only polar fluids like water that can give this range of frequency which can be heard from the buzzer. [Hiller, 2008]. The non-polar fuels have very high almost infinite resistance and thus cannot give a frequency that is within the audible range. Thus this facilitates the development of the visual display alarm (frequency meter).

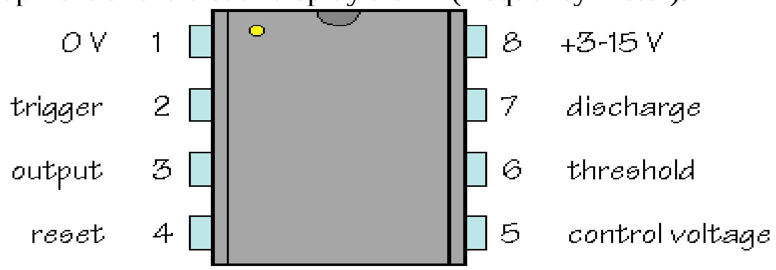

Fig. 3.0 The 555 timer IC Pin Configurations

The frequency meter measures frequencies as low as 5Hz and as high as 250 kHz, which covers the audible frequency and some other frequencies from the non-polar fuels, thus a more thorough detection can be made. The frequency meter is connected to pin 3 of the 555 timer IC parallel to the buzzer that is the two are in series with the circuit. The brain of the frequency meter is the famous AT89C52 microcontroller. The pins 20 and 40 are known as the ground and supply pins respectively, pin 14 is the output pin which is connected to the circuit to be measured. The frequency meter counts the number of electric pulses during a time of one second. This is achieved by the use of a counter which counts the pulses and a timer so that at every 1000millisecond, the processor stops counting, calculate the frequency and display it on the seven segments displays and then starts counting again from zero.
For the microcontroller pin configurations go to www.alldatasheets.com

3.0 Implementation, Simulation/Testing

Proteus version 7.7 was used for the simulation of this work. Proteus is design simulation software developed by **Labcenter electronics.**

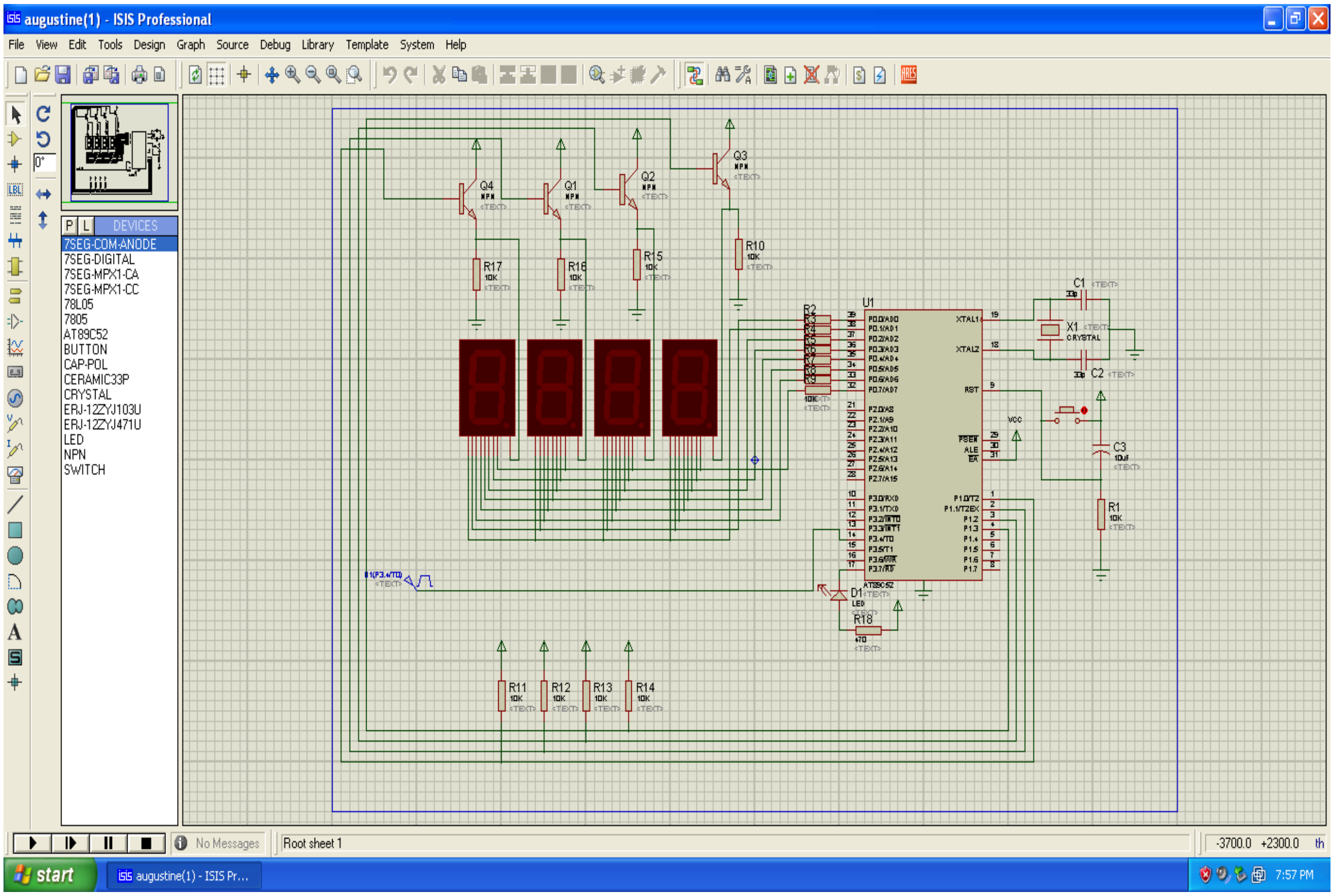

Fig 4.0 Simulation window of the frequency meter with Proteus

The microcontroller in this circuit was programmed with c codes. The **µvision4** c compiler was used for this purpose. The compiler was used to generate the hex files which were burnt into this chip. The chip (microcontroller) without these hex files is dormant, meaning that it cannot execute any task. The program for this chip was carefully written and properly debugged before the hex files was the burnt to the chip. Below are the exact c codes for the microcontroller.

```
# include <REGX52.h>
# include <math.h>


unsigned int temp,calc_del;
unsigned char a,b,c,d,e,dcnt;
float sample[5];
unsigned char scale=9;
unsigned char dig[4],ord[4],pt[4];
unsigned long f,idl;
unsigned char bcd[10];
bit sleep=0;

delay(unsigned int y){
 unsigned int i;
 for(i=0; i<y; i++);
 }
```

```
Setup_interrupts(){
EA=1;
EX0=0;
EX1=0;
ET0=1; //Enable the/counter 0 interrupt
TR0=1; //Enable Timer/counter 0 to count
TMOD=0*25; //counter 0 in mode 1 (16 bit counter), timer 1 in mode 2(auto reload from TH1
TL0=0; //empty the counting registers
TH0=0; //empty the counting registers
TH1=100; //start timer 1 from 0
ET1=1; //enable timer 1 interrupt
TR1=1; //Enable Timer/counter 1 to count
PT0=1;
PT1=0;
}

void int_to_digits (unsigned long number){ //store the digits of an integer number in the variable a,b,c,d
float itd_a, itd_b;
itd_a=itd_a=number/10.0;
dig[3]=floor((modf(itd_a, & itd_b)*10)+0.5);
itd_a=itd_b/10.0;
dig[2]=floor((modf(itd_a, & itd_b)*10)+0.5);
itd_a=itd_b/10.0;
dig[1]=floor((modf(itd_a, & itd_b)*10)+0.5);
itd_a=itd_b/10.0;
dig[0]=floor((modf(itd_a, & itd_b)*10)+0.5);
}

Count_pulses() interrupt 1 //counter 0 interrupt
{
if (scale<200)
scale++;
//ex_pulses++;
}

calc_and_disp() interrupt 3{
if (sleep !=1){
P0=(bcd[dig[3-dcnt]]-pt[3-dcnt]);
P1=ord[3-dcnt];
dcnt++;
if (dcnt>3){
dcnt=0;
}
}
}

void main (){
Setup_interrupts();
P3_4=1;
P3_7=0;
P0=0;
P1=1;
bcd[0]=136;
bcd[1]=190;
```

```
bcd[2]=196;
bcd[3]=148;
bcd[4]=178;
bcd[5]=145;
bcd[6]=129;
bcd[7]=184;
bcd[8]=128;
bcd[9]=144;
ord[0]=1;
ord[1]=2;
ord[2]=4;
ord[3]=8;
dcnt=0;
while(1){
calc_del++;
if (calc_del>((2248/scale))){ // update data
calc_del=0;
f=(TL0+(TH0*256));
sample[4]=sample[3];
sample[3]=sample[2];
sample[2]=sample[1];
sample[1]=sample[0];
sample[0]=f;
TL0=0;
TH0=0;
if(TH0<10){
        if (scale>9){
        scale--;
        }
}
// calculate F to display
f=floor((sample[0]+sample[1]+sample[2]+sample[3]+sample[4])/5)*scale;
if (f<1000){
pt[0]=128;
pt[1]=0;
pt[2]=0;
pt[3]=0;
} else if ((f>999) & (f<10000)){
f=f/1;
pt[0]=128;
pt[1]=0;
pt[2]=0;
pt[3]=0;
} else if ((f>9999) & (f<100000)){
f=f/10;
pt[0]=0;
pt[1]=128;
pt[2]=0;
pt[3]=0;
} else if ((f>99999) & (f<1000000)){
f=f/100;
pt[0]=0;
pt[1]=0;
pt[2]=128;
```



```
pt[3]=0;
} else if ((f>999999)){
f=f/1000;
pt[0]=0;
pt[1]=0;
pt[2]=0;
pt[3]=128;
}
int_to_digits(f);
// goto sleep or shutdown
if (f==0){
idl++;
}else{
idl=0;
sleep=0;
}
if (idl>399){
sleep=1;
P0=127;
P1=ord[3-dcnt];
dcnt++;
if (dcnt>3){
dcnt=0;
}
}
if (idl>999){ //power down
P3_7=1;
P1=0;
P0=0;
PCON=1;
}
}
}
}
```

4.0 Design Calculations

The 555 timer which acts as the pulse generator was used in its astable mode in the device. Astable circuits produce pulses. The 555 timer puts out a continuous stream of rectangular pulses having a specified frequency. Below is a form of the astable circuit used.

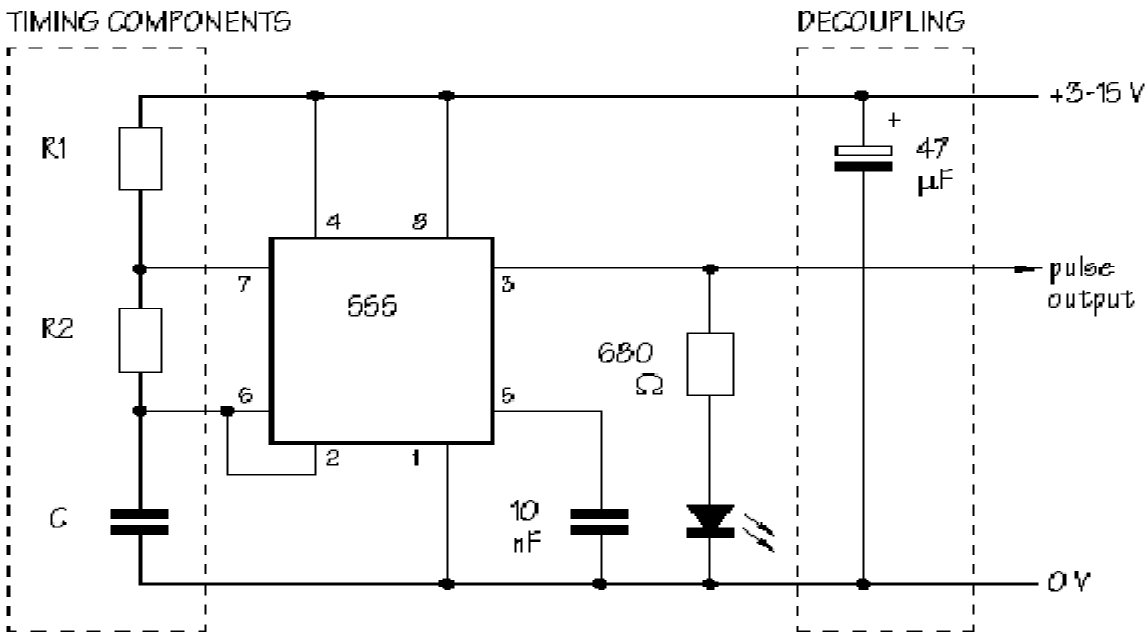

Fig 5.0 A schematic form of the astable circuit used

The design formula for the frequency pulses;

$f=1.44/((R_1+2R_2)\ x\ C$ was used for the calculation. The high and low times of each pulse can be calculated from;

High time = $0.69(R_1 + R_2)$ x C

Low time = $0.69(R_2$ X C), the duty cycle of the wave form usually expressed as a percentage given by:

Duty cycle = high time/low time

Thus in the astable mode, the frequency pulse stream depends on the values of R_1, R_2 and C.

The first step in the calculation was to make the value of R_1=10KΩ, this left us with the task of selecting values for R_2 and C. After several trials the following values were finally chosen for the detector.

R_1 =10kΩ, R_2 =56kΩ + the resistance of water, C =0.01 µF

For the electrical resistance of water, 182kΩ was chosen from a very wide range of values. Thus R_2 becomes, R_2 = 56+ 182 = 238kΩ, substituting the values of $R_{1,}$ R_2 and C into the design equation,

$f = 1.44/(10 + [2x236]) \times 10^3 \times 0.01 \times 10^{-6} = 296.3$ Hz.

This is the frequency of the pulse stream from the 555 timer IC.

High time = $0.69(10+238) \times 10^3 \times 0.01 \times 10^{-6} = 0.0017$s

Low time = $0.69(238 \times 10^3 \times 0.01 \times 10^{-6}) = 0.0016$s

Duty cycle = 0.0017/0.0016 = 1.0625

5.0 Conclusion and Recommendations

As can be seen from above, this device can be employed in a very vast field of applications. The device enables the user to know when there is water coexisting with fuel in a tank (automotive fuel tank or any fuel storage tank), or fuel systems with the fluids in a separate phase. The alarm will be activated for a reasonable amount of water at the base of the tank or bottom of the fuel filter, however for very little amount of water, the frequency meter display takes care of that. The frequency is calculated and displayed and this corresponds to the resistance of the fluid.

However the device requires further development in other solve some other problems such as the detection of water in many other fuels especially alcohol blended fuels. In addition, further development is required to enhance the accuracy of the display and to ensure a wider area of

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applications like oil regulatory uses, fuel quality monitoring etc. Also the calibration of the meter for fuel identification is left as a further work for interested persons.

REFERENCES

Ali M.O, (2008); “Design of Economical equipment for water and fuel level Detection in Jordan”, Science Publications, Jordan.

David J. I. and Robert M. N, (2010); “Engineering Circuit Analysis International Students Version 10th Edition”, Wiley Publishers, USA.

EESIFLO, (2007); “water in diesel fuel”, nova press, Sweden.

Fairchild Semiconductor, (2002); “LM555 Single Timer”, Fairchild Semiconductor, USA.

Gray R. C. (1985); “Water-In-Fuel Sensor Circuit and Method”, United States Patents, Scottsdale, Arizona.

Hiller V. A. W, (2008); “Automotive Electronics”, McGrahill Publishers, USA.

Ibrahim K. (2008); “Frequency Measurement”, Creative Press, USA.

John O. M. (1992); “Outline of Theory and Problems of Basic Circuit Analysis” , McGraw-Hill publishers, USA.

Karthekeya Automotive, (2008); “Water-in-Fuel Sensor” Karthekeya Automotive, USA.

Lang M. A. (2009); “Dan Nitrox Workshop Proceeding”, Drivers Alert Network Press, Durham.

Motorola Inc., (2008); “water in fuel sensor” Motorola, USA.

National Semiconductor, (2002); “OP Amp Circuit Collection”, National semiconductor, Arizona.

Paul T. (2004); “Physics for Scientists and Engineers; Electricity, Magnetism, Light and Elementary Modern Physics, Freeman publishers, USA.

Philips Semiconductor, (1994); “Timer NE/SA/SE5555/SE55C” USA.

Richard C. D, (1999); “Handbook of Design, Manufacturing and Automation”, Wiley Publisher, USA.