Design and Development of a Dielectric Spectroscopy Sensor for Liquids using Microcontroller Based System

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Abstract— A Dielectric spectroscopy sensor has been developed to measure liquid dielectric constant using P89v51RD2 microcontroller based system. The signal generator IC XR2206 is employed, which follows principle of frequency variation with change in capacitance of capacitor. The dielectric cell as a capacitor is designed in which liquid acts as a dielectric medium. The frequency from signal generator is measured using microcontroller internal timer T0 and displays it on 2 lines and 8x7 matrix Liquid Crystal Display. The keil compiler is used to execute necessary software designed in c programming language. The ECEFlash flash programmer is used to program into microcontroller IC. The designed system is accurate, portable, easily operated, and low cost.

Key Words— Dielectric Constant Sensor, P89v51RD2 microcontroller, Keil, Frequency measurement.

INTRODUCTION

THE term dielectric is related to a substance which can acts as an insulator by sustaining an electric field. A good dielectric material bears special properties of storing and dissipating electric energy when subjected to electromagnetic field. The dielectric constant gives physio-chemical composition and structure of material [1]. With recent development the application area of dielectric measurement is extensively increased, and there is need for accurate dielectric measurements of liquids in the range of DC to microwave frequency [2], [3]. By using fully featured microcontroller the system is designed, which consist of XR2206 function generator. The frequency from function generator, which is proportional with variation in dielectric cells capacitance, measured using microcontroller's internal timer/counter T0. And with proper conversion, display it on LCD. The experimental hardware and software details of the designed system are presented in this paper.

EXPERIMENTAL DETAILS

Principle

By definition dielectric constant ε is the ratio of the electrical capacitance of a cell when the liquid forms the dielectric medium (C_s) to the capacitance of the cell when air forms the dielectric medium (C_0) at a given temperature.

$$\varepsilon = (C_s) / (C_0) \quad (1)$$

The dielectric cell assembly consist of two circular discs of stainless steel. The cell has to be first standardised with standard liquid like benzene. The dielectric constant of unknown liquid (ε_x) can be determined by measuring the capacitance of the cell in air (C_0), the capacitance of cell in standard liquid (C_r) and the capacitance of the cell in liquid whose dielectric constant has to be measured (C_x) using the relation

$$\varepsilon = 1+[(C_0 - C_x) / (C_0 - C_r)] \times (\varepsilon_r-1) \quad (2)$$

Where ε_r is the dielectric constant of the standard liquid [4], [5].

The IC XR2206 function generator chip is used to acts as an oscillator. The frequency of oscillations depends on the values of timing resistor R and timing capacitor C. When the value of R kept constant, the dielectric cell acts as a capacitor C which varies with dielectric medium. Accordingly the frequency of oscillator also changes. And by measuring frequency of oscillator one can compute the capacitance of the cell and thus the dielectric constant of the medium.

Hardware design

The hardware designe of designed dielectric spectroscopy sensor for liquid using microcontroller consist of specialy designed dielectric cell, the function generator XR2206, and P89v51RD2 microcontroller with LCD display.

XR 2206 (Function Generator):

The XR2206 is a monolithic function generator IC capable of producing high quality square, sine, triangle, ramp and pulse waves of excellent stability and accuracy. It has facility to select wide range of operation frequency 0.01 Hz to above 1 MHz. The square wave out- put is used to measure the desired frequency [6]. The signal o/p from pin no.11 is interfaced to microcontroller external timer/counter for to count the frequency of oscillations. The delay is set internally at 1 second, for which pulses are count.

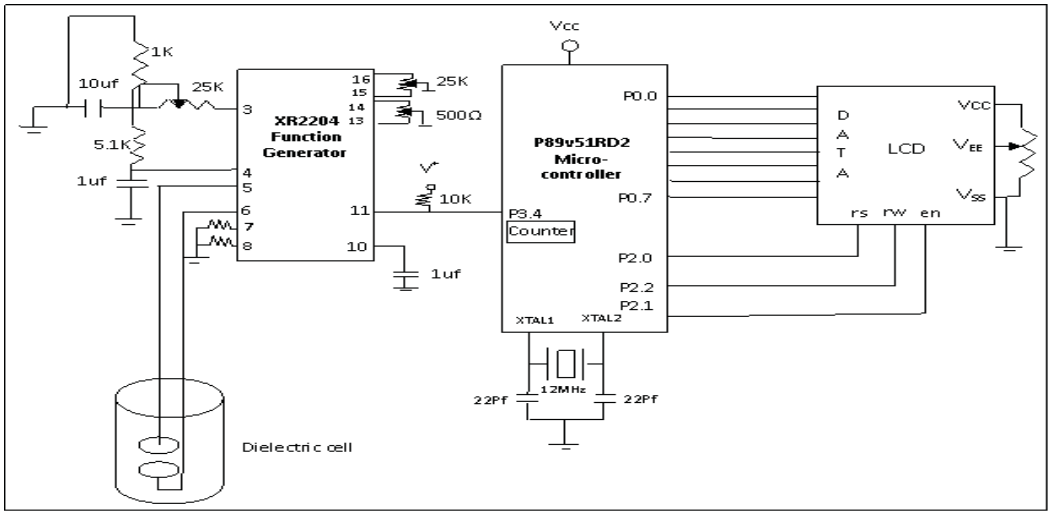

Fig. 1. The Interfacing circuit diagram of Dielectric Spectroscopy Sensor for Liquids Using Microcontroller Based System.

P89v51RD2 Microcontroller:

The Philips 89v51RD2 microcontroller is an 80C51 µc with 64 kB flash and 1024 bytes of data RAM. It has following features

- 5v operating voltage from 0 MHz to 40 MHz
- Support 12-clock (default) or 6-clock mode selection via software or ISP
- SPI(Serial Peripheral Interface) and enhanced UART
- PCA(Programmable Counter Array) with PWP and capture/compare function
- Four 8-bit I/O ports with three high current Port 1 pins(16 ma each)
- Three 16-bit timers/counters
- Eight interrupt sources with four priority levels
- TTL & CMOS compatible logic level
- Power down mode with external interrupt wake –up
- Idle mode
- DIP 40 Packages

The microcontroller internal timer /counter used to count frequency feed to port P3.4 externally. The Port 3 pin P3.4 is the timer T0. For Timer 0, when C/T=1, pin P3.4 provides clock pulse and the counter counts up for each clock pulse coming from function generator XR2206. The data count stored in TL register is converted to ASCII to be displayed on an LCD [7], [8].

LCD Display Unit:

The 2 lines & 8x7 matrix LCD is used to display counted frequency in KHz. The microcontroller Port0 (P0.0 to P0.7) is used as a data port to LCD and Port 2 (P2.0= RS, P2.1=En, P2.2=R/W) is used for command pins. The Vcc and Vss provide +5V and ground, respectively, for controlling LCD contrast V_{EE} is used.

Software Implementation

Keil compiler is used to convert source code to object code.

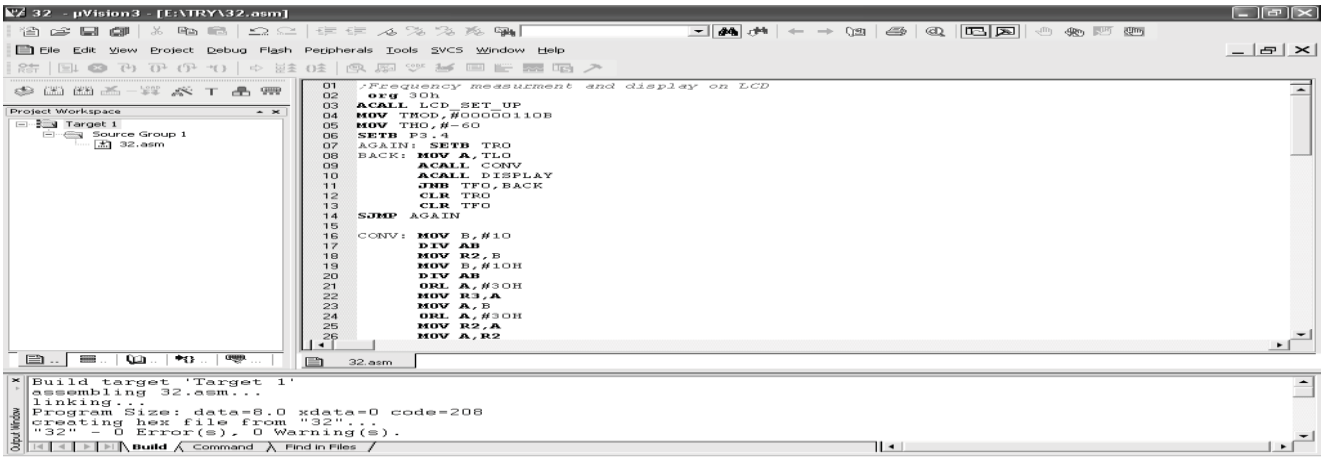

Fig. 2. The Keil simulator designed software.

It analyses and executes each line of source code. The ECE Flash programmer is used to put programme into microcontroller IC. The keil simulator designed software picture is shown in Fig. 2.

EXPERIMENTAL SETUP

The Fig.3 shows the designed experimental setup, in which interfacing of XR2206 function generator along with dielectric cell and LCD to the microcontroller system. The essential softwares are programmed and execute on personal computer with the help of keil compiler. The executed programme put into microcontroller IC by interfacing to the personal computer.

Fig. 3. The Experimental Setup of developed system

EXPERIMENTAL RESULTS

The designed dielectric spectroscopy sensor using microcontroller based system is verified with sample liquids at 30°C. The experimental dielectric constant value and literature reference values for sample liquids are mentioned in Table 1 [9], [10]. The SPSS (Statistical Package for Social Science) version 20.0 is used to show reliability test. The statistical analysis of dielectric constant of experimental value and literature reference value are analysed with reliability and ANOVA model which are shown in Table 2 and Table 3.

Table 1- Observation Table for Dielectric Constant of Sample Liquids at 30 ^{0}C

Sample	*Frequency in KHz*	*Capacitance in nf*	*Observed value of* (ε_x)	*Reference value of* (ε_x)
Benzene	405.0	24.69	2.26	2.26
2-Butoxy ethanol	345.0	28.99	9.89	9.30
2-Ethoxy ethanol	301.0	33.22	17.39	16.98
Isopropanol	290.0	34.50	19.63	18.30
Acetone	283.8	35.24	20.95	20.70
Ethanol	268.0	37.31	24.64	24.30

Table 2- Reliability Statistics for Observed and Literature Dielectric ConstantValue

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
0.999	0.999	2

From Table 2 observed that Cronbach's alpha is 0.999 for observed dielectric constant value and literature dielectric constant value. This indicates a high level of internal consistency for scale with this specific sample given by this designed system. In general the Cronbach's alpha is 0.70 is statistically accepted and Cronbach's alpha is greater than 0.80 is sign of good reliability is present in the dataset. Here the Cronbach's alpha is greater than 0.80 means that in given dataset by designed system is good reliability and high level of internal consistency.

Table 3- ANOVA Table for Observed Dielectric Constant Value and Literature Dielectric Constant Value

ANOVA						
		Sum of Squares	*df*	*Mean Square*	*F*	*Sig*
Between People		655.020	5	131.004		
Within People	Between Items	0.053	1	0.053	0.440	0.536
	Residual	0.606	5	0.121		
	Total	0.659	6	0.110		
Total		655.679	11	59.607		
Grand Mean = 15.3733						

Table 3 shows that the significance level value of ANOVA i.e. sig. value is 0.536, which is greater than 0.05. And, therefore, there is no statistically significant difference in the means of observed dielectric constant value and literature dielectric constant value. Hence it stated that designed dielectric spectroscopy sensor for liquids using microcontroller based system shows very good comparable results of literature dielectric constant values.

CONCLUSIONS

The features of microcontroller employed in the present design, to measure dielectric constant of liquids with the help of function generator in the form of corresponding frequency. The developed sensor system is portable, low cost and easily operable without any programming expertise.

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