The Accuracy Comparison of Oscilloscope and Voltmeter Utilizated in Getting Dielectric Constant Values

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Abstract— Parallel plate capacitor is widely used as a sensor for many purposes. Researches which have used parallel plate capacitor were investigation of dielectric properties of soil in various temperature [1], characterization if cement's dielectric [2], and measuring the dielectric constant of material in various thickness [3]. In the investigation the changing of dielectric constant, indirect method can be applied to get the dielectric constant number by measuring the voltage of input and output of the utilized circuit [4]. Oscilloscope is able to measure the voltage value although the common tool for that measurement is voltmeter. This research aims to investigate the accuracy of voltage measurement by using oscilloscope and voltmeter which leads to the accuracy of values of dielectric constant. The experiment is carried out by an electric circuit consisting of ceramic capacitor and sensor of parallel plate capacitor, function generator as a current source, oscilloscope, and voltmeters. Sensor of parallel plate capacitor is filled up with cooking oil in various concentrations, and the output voltage of the circuit is measured by using oscilloscope and also voltmeter as well. The resulted voltage values are then applied to the equation to get dielectric constant values. Finally the plot is made for dielectric constant values along the changing of cooking oil concentration. The results show that the plot of dielectric constant values which are gained from the voltage measurement using voltmeter have better linearity compare to the other plot in which the voltage measurement utilize the oscilloscope. In conclusion, voltmeter is considered better equipment to measure a voltage compare to the oscilloscope in term of getting dielectric constant values of parallel plate capacitance sensor.

Keywords— Oscilloscope, voltmeter, accuracy, dielectric constant

INTRODUCTION

Parallel plate capacitor is one of capacitors which compose of two conductor plates separated in d and normally, in the space is put an isolator medium called dielectric. The common dielectric materials used in the capacitor are air, paper, ceramic, or electrolyte liquid [1, 5]. In the alternating current (AC) circuits, the parallel plate capacitor which act as capacitive sensor is put in series with the fix capacitor [6]. The capacitance value of capacitive sensor is affected not only by the dimensions of the sensor (plate distance, area of plate) but also by dielectric material in between those two plates [5].

Capacitance of capacitor represents the ability to save the electric charge. The kind of dielectric materials affects significantly to the capacitance values. Every material has own electric characteristics and the magnitude depend on the internal condition of the material such as moment dipole and its compositions. Compositions and volumes of the dielectric are also have impact to the capacitance values.

Measuring capacitance value can be performed directly by using capacitance meter or indirectly by measuring the output voltage of the capacitance. This indirect method has been done by [6] and the relationship between output voltage and the capacitance value has also been published by [4].

The usual equipment which is used to measure voltage is voltmeter. However, the oscilloscope is also has ability to do that task. The voltage values can be read on the oscilloscope's screen by counting the signal amplitudes and then multiply by volt per div which is show in the oscilloscope channel.

The accuracy of voltage measurement is important in getting the capacitance values gained by indirect measurement. The inaccurate results lead to the error values of capacitance. Further, the dielectric constant values will follow the error and give incorrect information.

Based on the descriptions above, we interest to investigate the difference of dielectric constant values that are got by measuring the voltage using voltmeter and oscilloscope. This research will recommend the better meter of voltage measurement to get the dielectric constant values. In this case we compare the oscilloscope and voltmeter. . From this research, it can later be used as a reference to recommend a better measuring tool in the measurement of dielectric materials.

REVIEW OF LITERATURE

Dielectric is an isolator material which cannot transfer electric charges or electrons cannot flow through the material. The examples of dielectric materials are mica, papers, water, oil, air, etc. Dielectric materials are commonly used in between two conductor plate in capacitor [7].

Construction of parallel plate capacitor is very simple. It constructs of two conductor plates which place parallel with dielectric material in between. Figure 1 show the diagram of that parallel plate capacitor.

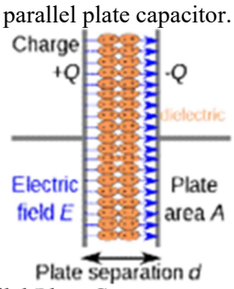

Figure 1. Parallel Plate Capacitor

If a parallel-plate capacitor with a cross-sectional area (A) separated by a dielectric at a distance (d), and the plate rated voltage (V), then there will be an electric field (E) working in the dielectric. Due to the electric field, the charge contained in the dielectric will be polarized [8].

Capacitance sensor circuit consisting of parallel capacitor plates are arranged in series with the capacitor components as shown in the Figure 2 below.

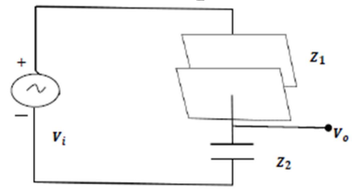

Figure 2. The circuit of capacitance sensor

Figure 2 shows the trajectory of a voltage divider with Vi is the input voltage and Vo is a voltage signal sensor, Z_1 and Z_2 are the impedances of dielectric materials. So we get the equation for the circuit above, namely:

$$\frac{V_o}{V_i} = \frac{Z_2}{Z_1 + Z_2} \quad (1)$$

If a capacitor is connected to an oscilloscope and voltmeter as a voltage meter, it will produce a voltage output signal form, so that the capacitance-voltage is calculated following the equation (2) below.

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$$C_1 = \frac{C_2}{\left(\frac{V_i}{V_o} - 1\right)} \quad (2)$$

Capacitors are initially has a capacitance of Co (before given dielectric material), then after being added the dielectric material the value of capacitance becomes:

$$\kappa = \frac{C}{C_o} \quad (3)$$

or,

$$C = \kappa \frac{\varepsilon_o A}{d} \quad (4)$$

METHODS

a. Equipments and Materials

The equipment used in this study are oscilloscope and voltmeter as a voltage meter, capacitance meter, capacitors, project board, function generator, digital scales, measuring cups and connecting cables. Materials used in this research are bulk cooking oil, refined (bottled) cooking oil and margarine.

b. Collecting Data

Data collection was done with filled containers with samples (bulk cooking oil, refined cooking oil, margarine and oil mixture to the margarine. Mixing is done with the volume of oil remains (50ml) by adding margarine as much as 1g - 15g with intervals of addition 1g each. Data is collected in three repetitions at room temperature (29°C). All data collection was done in the same way, using a frequency of 200 kHz. So we get the value of the input voltage and output voltage values.

c. Preparation of Assessment Tools

Preparation of research equipments arrange to get the best possible results, in which two conductive plates placed side by side but not touching each other, and among them there are measuring samples as dielectrics. Each plate is connected to the output and input of voltage meter (voltmeter and oscilloscope) and also connected to the function generator. Further the read voltage values were applied to the equation to get the capacitance value of a material that can later be used to determine the value of the dielectric constant of each tested sample.

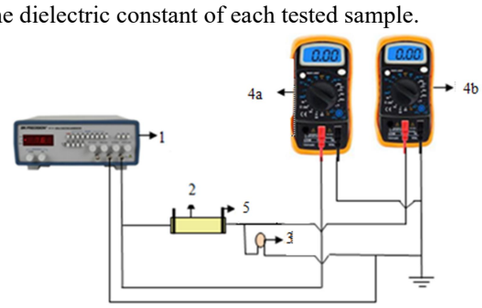

Figure 3. Measurement circuit using a voltmeter

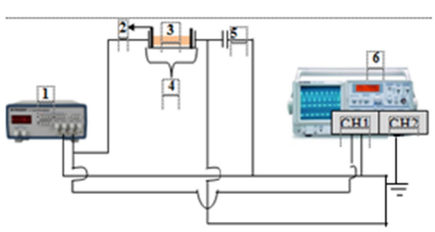

Figure 4. Measurement circuit using an oscilloscope

d. Data Analysis

Measurement data in the form of input voltage value and output voltage value are inputted to the equation (2) to gain the capacitance value of a material. By inserting a fix capacitance value in equation (3) it is known the value of the dielectric constant of the material. Data retrieval is performed three times, so do the average value of the dielectric constant. So we get the value of the dielectric constant with the accuracy of the tool using the equation:

$$\kappa = (\bar{\kappa} \pm \Delta k) \quad (5)$$

Furthermore, the addition of margarine mass is plotted as the x-axis and the value of the dielectric constant is plotted as the y-axis. So it can be seen the graph of the relationship between the two variables. To determine whether there is a relationship between the mass of margarine addition to the value of the dielectric constant, then the linearity is tested by using SPSS. Furthermore, the measured results obtained from the oscilloscope are compared to the results measured by a voltmeter.

RESULTS AND DISCUSSION

Measurements were conducted by the full filling containers sized of 10cm x 3cm x 2,3cm. The frequency used is 2200 kHz, either when using a measuring instrument voltmeter or oscilloscope.

The first measurement was done on bottled palm cooking oil. With the same treatment, the dielectric value obtained by oscilloscope is 3.409, while the dielectric value gotten by using voltmeter is 3.113. Furthermore, the value of the dielectric constant of packaging cooking oil generated by using an oscilloscope is 7.066, but the one by using a voltmeter is 10.370. In addition, the dielectric value of margarine is 14.466 and 15.184 which are obtained by oscilloscope and voltmeter respectively.

Measurement is then performed on each additional mass of margarine for every resulted data. The results of each measurement instruments are shown in the graph of Figure 5 and Figure 6 below:

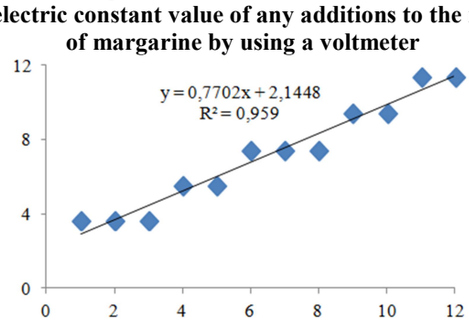

Figure 5. Graph of the relationship between the addition of margarine masses against the value of the dielectric constant of palm cooking oil packaging

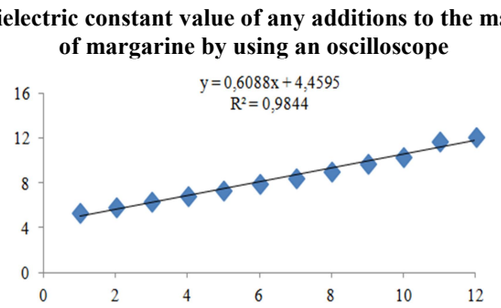

Figure 6. Graph the relationship between the addition of margarine masses against the value of the dielectric constant of palm cooking oil packaging

Figure 5 shows the relationship of dielectric constant value with the addition of masses of margarine. The data on the graph shows the addition of 1g - 12g to 1g every span the addition, the resulting value of the dielectric constant increase. Also there is a very strong correlation between increased in mass margarin the dielectric constant value, the linearity resulting equation is equal to 0.991 or 99.1% value of the dielectric constant of palm cooking oil packing masses influenced by the addition of margarine.

The image above shows the relationship between the value of the constant dielktrik against margarine increased in mass by using an oscilloscope. From the data obtained, the resulting changes in the dielectric constant increase in value at the time of the mass penambhan margarine. However, these changes did not occur on any additions, changes in the value of the dielectric konstaanta each additional 2g - 3g. In contrast with the results obtained in measurements using a voltmeter, linearity obtained from the graph by using an oscilloscope is 0,959, it does show that linearity relationship between the independent variable on the dependent variable is 9.959% of the equation linear line as shown in Figure 4. From these data, the correlation value of the oscilloscope is smaller than the voltmeter. The correlation of the independent variables on the dependent variable is declared strong when getting close to 1 [9].

CONCLUSION

Oscilloscope and voltmeter measuring devices can be used to determine the characteristics of a material by using a capacitive method. The greater the correlation value is obtained, the stronger the influence of independent variables on the dependent variable, and the greater the linearity of the resulting graphs. Then it shows the accuracy of the used tool and we can see which one is better. In this study, we can state that the measuring instrument voltmeter has a higher accuracy compared to oscilloscope. So it is advisable for readers and future research to use voltmeter as a gauge in measuring electrical properties of a material using a capacitive method.

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