

Development of Two-Channel Measuring Device For Dielectric Polarization Characterization

Ju Song Kim*, Ryong Il Ri, Su Rim Kim

Faculty of Electrical Engineering, Kim Chaek University of Technology, Democratic People's Republic of Korea

*Corresponding Author

DOI: <https://doi.org/10.51584/IJRIAS.2025.100900072>

Received: 08 September 2025; Accepted: 16 September 2025; Published: 17 October 2025

ABSTRACT

Many researches have been widely carried out to develop techniques and devices for evaluating the quality of materials and monitoring production processes, based on measuring dielectric polarization properties, which are closely related to dielectric material properties, including molecular structure and composition of dielectric materials, molecular bonding properties. Since the polarization characteristics of dielectric materials may be influenced by some error factors, including the measuring conditions such as temperature, humidity, etc. and the measuring skill, it is more advantageous to simultaneously measure the dielectric polarization characteristics of both samples if the comparison between them is required. This paper aims both to develop a device capable of simultaneously conducting the experiments of dielectric polarization characteristics for two dielectric samples and to verify its performance accuracy.

Keywords: Dielectric polarization characteristics, Electrical capacitance, Two-channel simultaneous measurement, Real-time measurement

INTRODUCTION

Most of materials encountered during human survival and production activities are non-conductive materials, also called dielectric materials from the viewpoint of electro-physical property.

Dielectric polarization is one of typical electro-physical phenomena observed in dielectric materials under the action of the external electric field, and closely related to the material properties such as molecular structure and composition of the dielectric material, molecular binding and mobility, etc.

Therefore, many researches have been widely used for many years all over the world to develop and introduce the techniques and devices for evaluating the quality of dielectric materials or for monitoring production lines by measuring dielectric polarization characteristics. [1-4]

Up to now, experimental and measuring devices for characterizing dielectric polarization tend to be designed so that they could measure only one dielectric material sample at a time. However, in educational and scientific experiments or engineering practices, there exist a number of cases that the polarization characteristics of two samples should be compared with each other, for example, the comparison of electrical, mechanical, thermal properties plastic or rubber materials before and after the addition of fillers to them, and the comparison of physical and chemical properties of dielectric materials before and after the treatment of them using electrical, magnetic, thermal, optical and acoustic energy. [5]

As well known, the polarization characteristics of dielectric materials can be influenced by a number of error factors, including temperature, humidity and other measurement conditions, so it is more advantageous to simultaneously measure the dielectric polarization characteristics of both samples if any comparative analysis is required.

In view of these practical requirements, this paper aims to how to design the two channel measuring device capable of simultaneously conducting the experiments of dielectric polarization characteristics of two dielectric samples to be compared.

Measurement principle of the device.

The so-called two channel dielectric measuring device is based on the principle that the oscillation frequency of the dedicated oscillators depends on the values of the resistance and capacitance connected to them.

There are several types of dedicated oscillators used to the measurement of electrical capacitance based on the above-mentioned manner, including NE555, MAX038 and so on. Among them, the authors selected MAX038, which is much wider in the oscillation frequency range than NE 555.

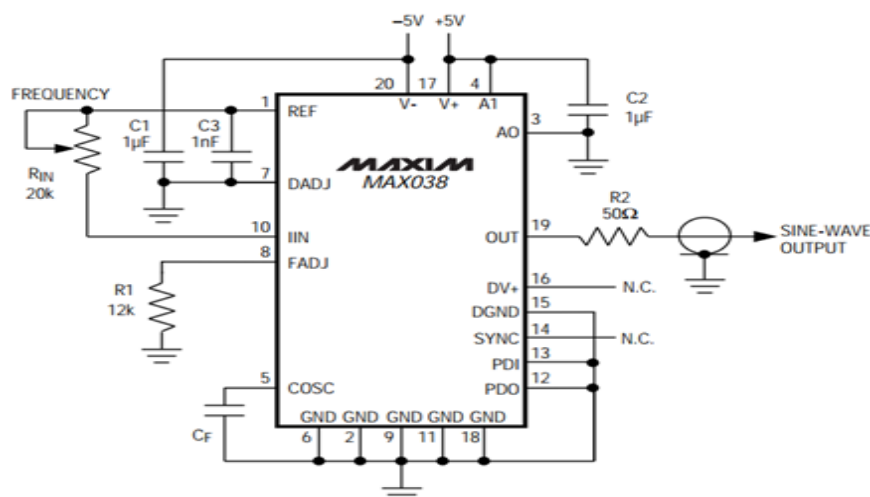
According to the measurement principle mentioned above, it is quite obvious that the narrower the oscillation frequency range is, the narrower the capacitance measurement range is, and that the lower the maximum oscillation frequency is, the more difficult it is to measure small values of capacitance of dielectric samples. [11, 12]

For this reason, it is natural to select the waveform oscillators with the wide oscillation frequency range and the maximum frequency so as to make it possible to broaden the capacitance measurement range and to measure very small capacitance. Fig 1 shows the circuit of the waveform oscillator MAX038 with a capacitor and a resistor connected in parallel to it.

In the waveform oscillator MAX038, its oscillation frequency is dependent on the values of resistance and capacitance connected to it, and therefore, if an electrode system with a dielectric sample to be measured is connected to MAX038 in the place of the above-mentioned capacitor, the capacitance value can be calculated from the measurement value of the corresponding oscillation frequency of MAX038.

In MAX038, the upper limit value of the oscillation frequency is known to be 20MHz, which is large enough to measure small values of capacitance of dielectric samples.

Fig 1. The circuit of the waveform oscillator MAX038 with a capacitor and a resistor connected in parallel to it



In the case of connecting a dielectric sample electrode to MAX038, the capacitance value of the sample can be calculated in terms of Eq.1.

$$C_s = \frac{V_{in}}{R_{in} \times f_{out}} \quad (1)$$

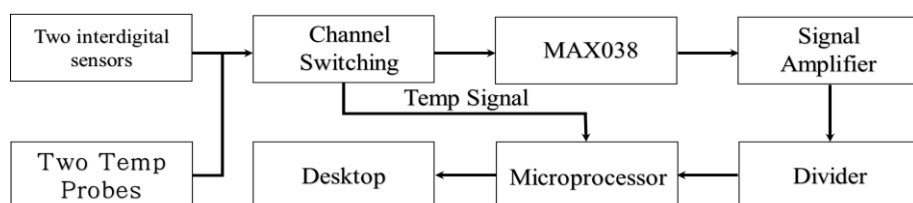
where f_{out} is the output oscillation frequency (MHz) of MAX038; V_{in} is the input voltage (V); R_{in} is the parallel resistance value(Ω); C_s is the sensing capacitance of the capacitance-sensing electrode of a dielectric sample(pF).

Device design

Hardware configuration and its driving software

As aforementioned, the so-called two-channel experimental device for characterizing dielectric polarization of dielectric samples considered was designed so that the electrical capacitance signal coming from the input sensor in an RC parallel circuit connected MAX038 could be converted and generated out. [6-8]Fig 2 represents the schematic block diagram of two-channel capacitance measuring device

Fig 2. Schematic block diagram of two-channel capacitance measuring device



Since the capacitance values of dielectric sample to be measured tend to be varied with temperature, the

www.rsisinternational.org

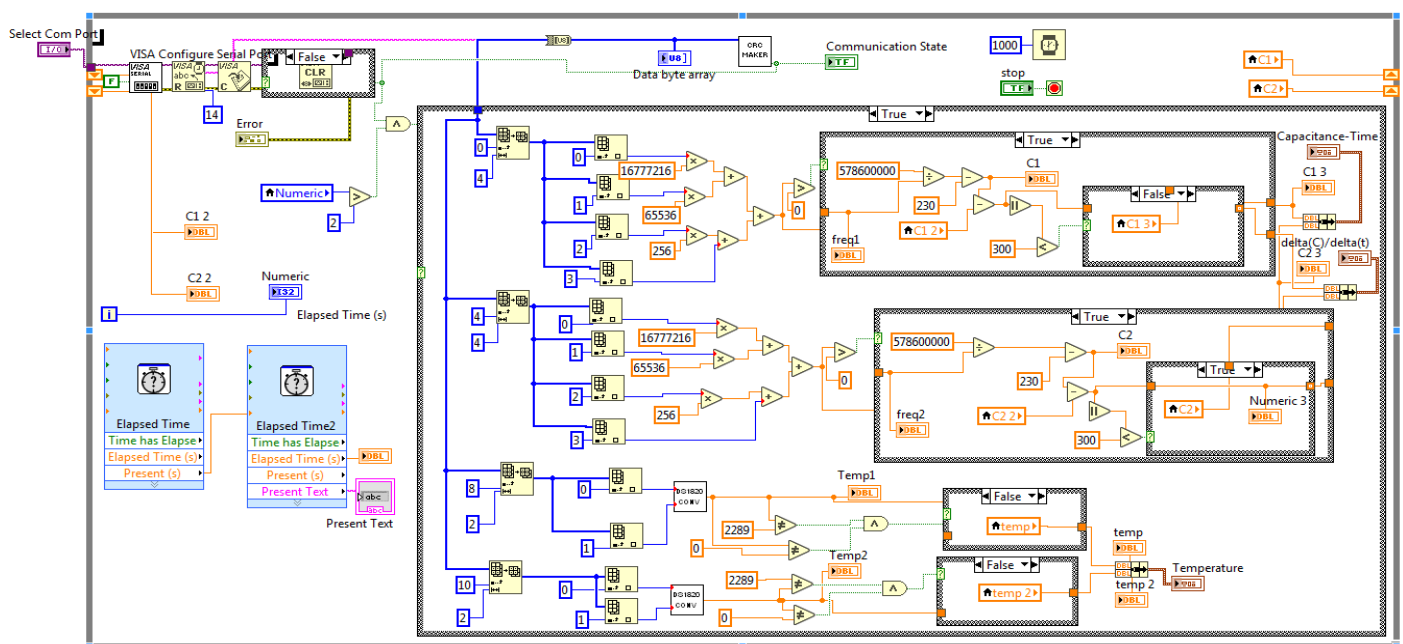
Fig 4 shows the block diagram of the device software, where the channel switching for sensing two capacitance values of two dielectric samples to be simultaneously measured was realized in a defined time interval by using a relay.

3.2 PC interface software design

Fig 5 shows the LabVIEW software block diagram for receiving signals from a microprocessor through a communication port and displaying them to a PC.

The personnel computer displays the derivative values of the capacitance in relation to time as well as the oscillation frequency of MAX038 and the capacitance values of dielectric samples so that the change of electro-physical properties of dielectric samples considered could be visually observed.

Fig 5. Block diagram of LabVIEW software for the PC interface



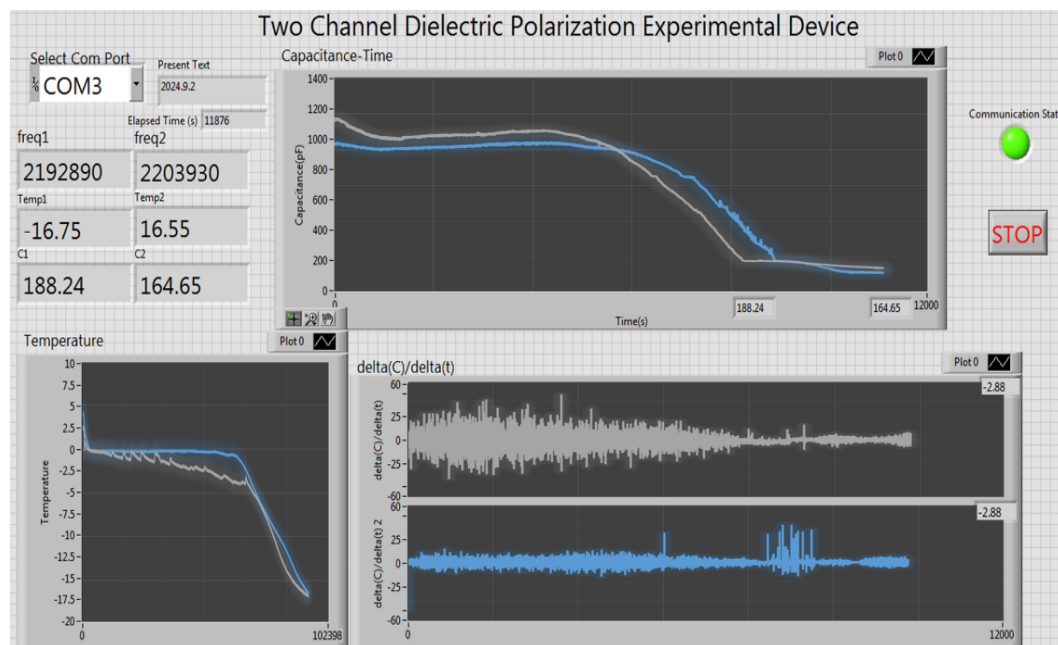
The switching noise generated when switching the capacitance sensing electrode gives some negative influences to the performance of the capacitance-measuring device.

Therefore, the switching and output parts of the circuit are electromagnetically isolated from each other, thereby minimizing the influence of such a switching noise.

And also, LabVIEW software control was used to overcome the distortion of the oscillation signals and the generation of the harmonic waves at the moment when the relay is on and off. For this, LabVIEW program was designed so that the value of capacitance to be measured and displayed 500ms ahead of time when the relay is on could be made to be read and that to be measured behind 500ms to be neglected; and also the measurement value of capacitance could be displayed 500ms behind of time when the relay is off.

In addition, the device program readout section was designed to collect and integrate the input data at certain time intervals and display the average values so as to ensure the smoothness of the characteristic curves to be displayed shown in the PC interface programmed by using LabVIEW (Fig 6).

Fig 6. The PC Interface programmed by LabVIEW



Accuracy evaluation of the device

The capacitors of known capacitance values of 10pF and 500pF were connected to the input of MAX038 instead of the capacitance-sensing electrode, respectively and their capacitance values were calculated and compared with the known capacitance values in order to evaluate the accuracy of the developed two-channel capacitance measuring device.

As can be seen from Table 1, the measurement error of the device is found to be less than 0.1%, which hints us at that the two-channel capacitance measuring device suggested by authors is quite reliable in its performance accuracy and can be effectively used for the measurement and experiment of dielectric polarization characteristics if dielectric material samples.

Table 1. The comparison of the measured capacitance with known one

Measurement number	1	2	3	4	5
Capacitance(pF)					
10	9.99	9.97	10.001	10.03	9.98
500	499.96	500.03	499.99	500.01	499.98

CONCLUSION

This paper has been dealt with how to design two-channel experimental device for dielectric polarization characterization of dielectric materials, which can simultaneously measure the variation of dielectric polarization properties for two dielectric samples considered.

Experimental studies have demonstrated that the negative effects on the operating characteristics of the device, including the switching noise generated during the two-channel switching, can be solved programmatically,

and that the designed two-channel capacitance device works comparatively correctly with the accuracy of about 0.1%.

REFERENCES

1. A.Marcellis and G.Ferri, Analog circuit and system for voltage-mode and current-mode sensor interfacing application, New Delhi:Springer, 2011
2. Aleksandra Vukovic Rukavina, "Hand-held unit for liquid-type recognition, based on interdigital capacitor", Measurement 51(2014). 289-296
3. Ge, M.; Chen, G.; Liu, C.; Zheng,D.; Liu, W. "Study of the pore structure characteristics of soybean grain piles using image processing technology", Int.Agrophysics, 2023, 16, 8519-8531.
4. Haynes WM.ED.2016. "Permittivity(Dielectric Constant) of water at various frequencies'. In CRC Handbook of Chemistry and Physics, 96th ed. Boca Raton, FL: CRC Press. 6-14.
5. Isabelle Bord, Pascal Tardy, Francis Menil, "Influence of the electrodes configuration on a differential capacitive rain sensor performances", Sensors and Actuators B 114(2006), 640-645
6. Jianyi Li, "Permittivity Measurement of Low-Loss Substates Based on Split Ring Resonatos'. World Journal of Engineering and Technology, 5, 62-68, DOI: <https://doi.org/10.4236/wjet.2017.54B007>
7. Khatti J.; Grover, K.S. "Prediction of compaction parameters for fine-grained soil: Critical comparison of the deep learning and standalone models", Rock Mech,Geotech. Eng. 2023, 15, 3010-3038.
8. S. Kharkovsky and R, Microwave and Millimeter Wave Nondestructive Testing and Evaluation," IEEE Instrumentation and Measurement Magazine, vol. 10 (2), pp. 26-38, April 2007.
9. S.H.Mirjahnamardi, A.M.Albishi, and O.M.Ramahi, "Permittivity reconstruction of nondispersive materials using transmitted power at microwave frequencies", IEEE Transactions on Instrument and Measurement, Vol.69, No.10, pp.8270-8278, 2020
10. Sergio L.S.Severo, "Non-resonant Permittivity Measurement Methods", Journal of Microwaves, Optoelectronics and Electromagnetic Applications, Vol.16, No.1, March 2017, 297, DOI: <https://dx.doi.org/10.1590/2179-10742017v16i1890>
11. T.Islam, J.A.Anwar Ulla Khan and M.Z.U.Rahman, "A Digital Hygrometer for Trace Moisture Measuremntn", IEEE Trans. Instrum.Meas., vol.61, pp.5599-5605, Oct 2014
12. Wu, Z.D.;Zhang, Q.; Yin, J.; Wang, X.M.; "Interactions of Multiple Biological Fields in Stored Grain Ecosystems." Sci. Rep. 2020, 10, 9302
13. Xiujun Li, Gerard C.M.Meijer, "An Accurate Interface for Capacitive Sensors", IEEE Transactions on Instrumentation and Measurement, Vol.51, No.5, Oct 2002