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Research Article

Measurement of Capacity and Tangens of the Angle of Dielectric Loss of Low Voltage Condensers in the Labview Program Environment

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Abstract The paper describes the use of the LabVIEW software environment for measuring the capacitance and tangent of the dielectric loss angle of low-voltage capacitors. The output signals of the measuring circuit via the NI Educational Laboratory Virtual Instrumentation Suite (NIELVIS) enter the LabVIEW software environment where they are measured.

Keywords Measurement, Capacitance, Dielectric losses, Software environment, Phase method

Introduction

LabVIEW is an ideal software tool for creating measurement, control, diagnostics and control systems of almost any complexity, based on the technology of virtual instruments. Currently, LabVIEW is increasingly used, because unlike similar software products, where simulation is performed, in LabVIEW "virtual" devices perform real measurement functions. This makes it possible to widely use this product in university laboratory practice, especially in subjects of a technical profile [1-3]. Therefore, the relevance of the development of a measuring instrument based on this software for measuring a number of physical quantities is justified.

Materials and Methods

A measuring device for measuring the capacitance and tangent of the dielectric loss angle of low-voltage capacitors is described below. The scheme and method (phase) for measuring are described in [4, 5], where a real device based on a microcontroller is used for measurement. [6] describes a measuring device for measuring the capacitance of a primary converter based on the LabVIEW software environment, where a phase measurement method was also used, whereby the primary converter's capacitance was measured with a relative error not exceeding 3%.

The instrument was developed using the LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) and the NI Educational Laboratory Virtual Instrumentation Suite (NI ELVIS). On the NIELVIS platform, the circuit in Figure 1 have been assembled.

The diagram shows: 1, 2- exemplary resistors; 3- electronic switch; 4, 5- operational amplifier OP27; 6- functional generator on the platform NI ELVIS; 7, 8- channels 0 and 1 of the oscilloscope on the NI ELVIS platform; 9- LabVIEW software environment; 10 - explored capacitive converter CC.

In the measuring circuit (MC) two measuring resistors are connected in series with the capacitive converter: the reference resistor (R_1) and the additional resistor (R_2). The resulting MC as a voltage divider is connected to the generator of sinusoidal signals on the NI ELVIS platform at a frequency of $f = 1$ *kHz*. The MC has two output voltages relative to a common point that are fed via the op amps to the NI ELVIS platform to the oscilloscope channels 0 and 1. From the platform NIELVIS data via the USB port is fed to a personal computer where in the LabVIEW software environment a phase angle shift between two voltages is measured. A block diagram of the program of the measuring device is shown in Figure 2.

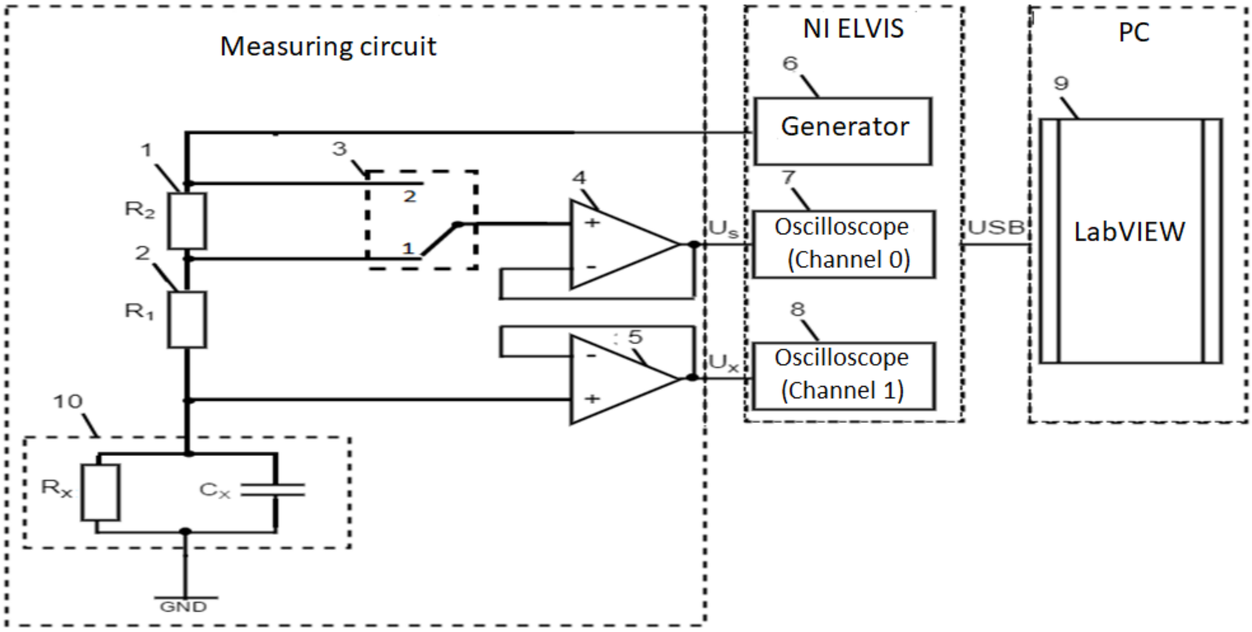


Figure 1: Measuring circuit

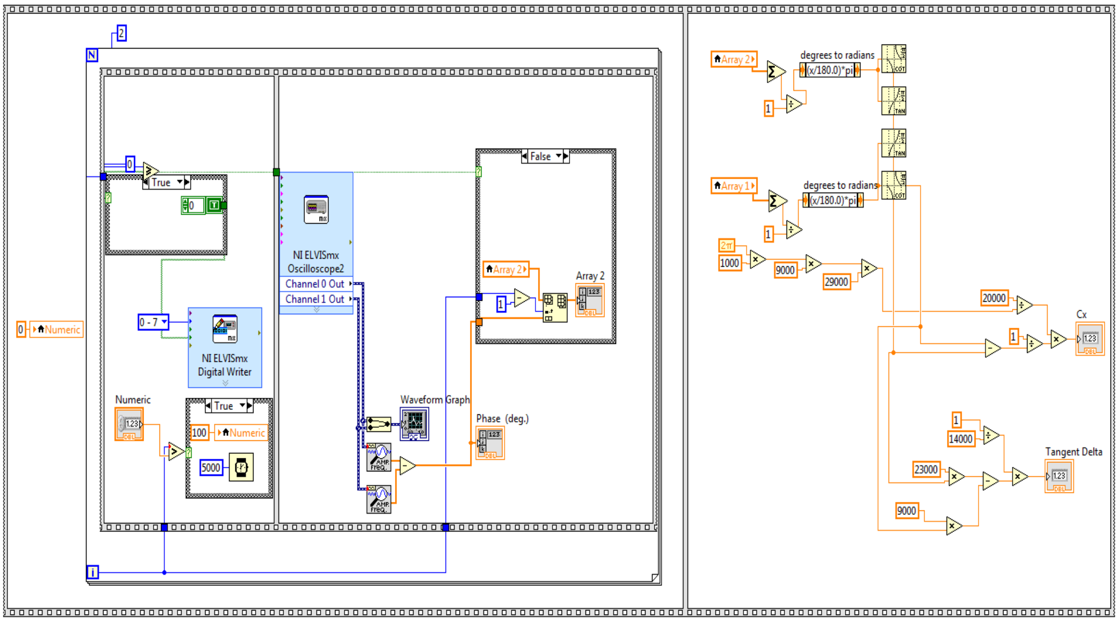


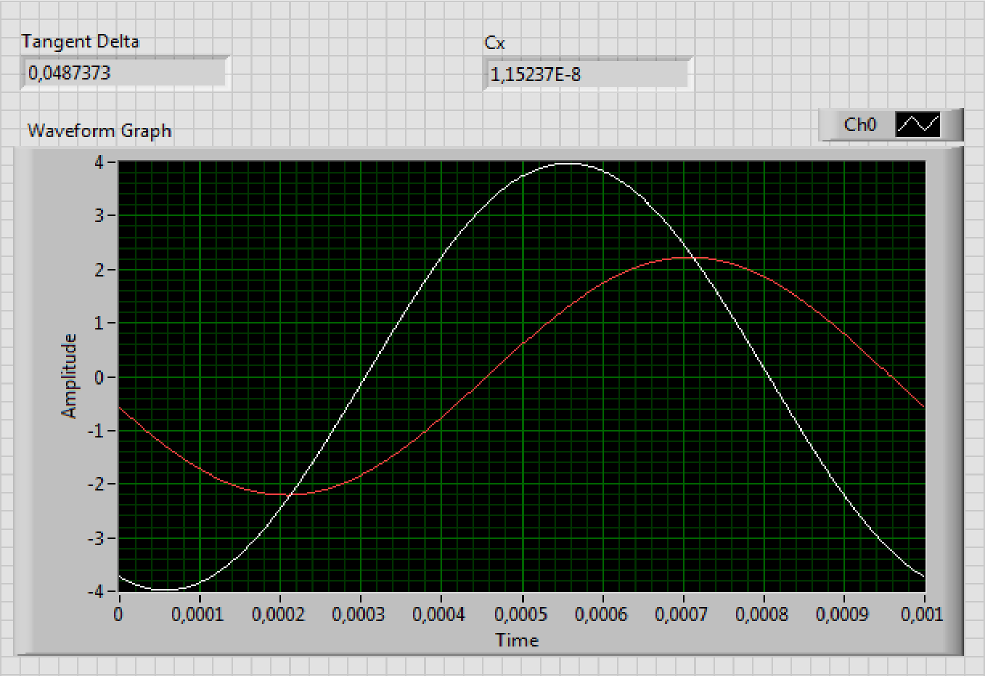
Figure 2: Block diagram of the program of the measuring device

To receive signals in the LabVIEW environment, the utility "NI ELVIS OSCILLOSCOPE" was used, which was tuned to a two-channel mode with a maximum frequency of 500,000 results / second. Further, the detected signal is fed to the input of the "Phase detection" function, the output of which is the phase angle of the signal in degrees [7]. To obtain a phase shift angle φ_1 of the two signals, the phase angle of the signal $\dot{U}_X$ is subtracted from $\dot{U}_S$ (the electronic switch is in position 1). Next, the NI ELVIS platform signals the switch and switches it to position 2, after which the phase angle φ_2 is calculated. After obtaining the results of φ_1 and φ_2, the capacitance C_X and tangent of the dielectric loss angle $tg\delta$ are calculated by the following formulas:

$$C_X = \frac{R_2}{\omega R_1 \left(R_1 + R_2\right)} \cdot \frac{1}{ctg\varphi_1 - ctg\varphi_2}, \tag{1}$$

$$tg\delta = \frac{1}{R_2}\left[\left(R_1 + R_2\right) \cdot ctg\varphi_2 - R_1 \cdot ctg\varphi_1\right]. \tag{2}$$

On the front panel of the device there is a digital indicator for displaying the measurement result C_X, $tg\delta$ and a graph of the signals, where the user can see the type of signals and their phase shift in real time. The appearance of the device panel is shown in Figure 3.


Tangent Delta
0,0487373

Cx
1,15237E-8

Figure 3: The front panel of the program of the measuring device

Results

Measurement of C_X **.**

For the selected measuring range of the $C_x=0.001\ldots0.1\ \mu F$ and the frequency of the measuring current $f=1$ *kHz*, the resistance values of the resistors of MC $R_1=9$ *kOhm*, $R_2=20$ *kOhm* (for this measurement R_x - is absent) were chosen, the relevance of which was proved in [8]. Values of C_x were set at the P513 capacities box. Five measurement points were selected: $C_{x1}=0.001\ \mu F$, $C_{x2}=0.005\ \mu F$, $C_{x3}=0.01\mu F$, $C_{x4}=0.05\ \mu F$ and $C_x=0.01\ \mu F$. To assess the error of measurement at each point were carried out by $n=30$ measurements and according to the indications of the device N_i were determined:

- average value $N_0 = \sum N_i / 30$ of measurement results;
- the average square deviation $\sigma(N_i) = \sqrt{\frac{\Sigma(N_i - N_0)^2}{n-1}}$ of the results of individual measurements

from the average value;

- the result of measuring of the device with a confidence probability of 0.9 $N_X = N_0 \pm 2\cdot\sigma\left(N_i\right)$;
- systematic measurement error $\Delta_{sys} = N_0 - N_n$;

- the relative error in measuring the capacitance at a given point in the scale of the measuring device $\delta W = \left(\Delta / N_0 \right) \cdot 100$.

The results of the measurements are shown in Table. 1.

Table 1: The results of the measurement of C_X

i	C_{X1}, μF	C_{X2}, μF	C_{X3}, μF	C_{X4}, μF	C_{X5}, μF
1	0.0010091	0.005004	0.009988	0.049934	0.099592
2	0.0010028	0.005012	0.010038	0.049965	0.099902
3	0.0010011	0.004997	0.010002	0.049962	0.098918
…	...	...	...	...	,,,
29	0.001010	0.004997	0.009978	0.049901	0.099881
$n = 30$	0.001002	0.004992	0.010029	0.049831	0.099976
N_0	0.001002	0.005004	0.010010	0.049902	0.099702
$\sigma(N_i)$	0.000007	0.000013	0.000021	0.000052	0.000290
N_X	$0.001 \pm 13 \cdot 10^{-6}$	$0.005 \pm 26 \cdot 10^{-6}$	$0.01 \pm 41 \cdot 10^{-6}$	0.049 ± 10^{-4}	$0.099 \pm 58 \cdot 10^{-5}$
Δ_{sys}	$2.4 \cdot 10^{-6}$	$3.49 \cdot 10^{-6}$	$10.44 \cdot 10^{-6}$	$-98 \cdot 10^{-6}$	$-298 \cdot 10^{-6}$
δW	0.24%	0.06%	0.1%	0.19%	0.29%

Measurement of $tg\delta$.

For the selected measuring range of $tg\delta = 0.0005 \ldots 0.005$ and the frequency of the measuring current $f = 1$ *kHz*, we chose $C_x = 0.01$ μF, the resistance values of the resistors of MC, $R_1 = 9$ *kOhm*, $R_2 = 14$ *kOhm*, the relevance of which was proved in [8]. In the beginning, we measured $tg\delta$ without connecting a parallel resistance R_x. As a result, we get the value of $tg\delta_1$ of capacities box P513, by means of which we calculate its internal resistance R_{X1} by the formula

$$R_{X1} = \frac{1}{\omega C_X tg\delta_1}.$$

Then, in parallel connecting the resistance to the capacitor C_x, step by step we reduce the total resistance at five points: $R_{X2} = R_{X1}/2$, $R_{X3} = R_{X1}/3$, $R_{X4} = R_{X1}/4$, $R_{X5} = R_{X1}/5$.

At each selected point, we measure $tg\delta$ by LabVIEW ($tg\delta_{dev}$) and by formula

$$tg\delta_i = \frac{1}{\omega C_X R_{X1} / i}, \text{ where } i = 2, 3, 4, 5,$$

by the values $tg\delta_{dev}$ and $tg\delta_i$ we define:

- systematic measurement error $\Delta_{sys} = tg\delta_{dev} - tg\delta_i$;
- the relative error in measuring the capacitance at a given point in the scale of the measuring device $\delta W = \left(\Delta / tg\delta_i \right) \cdot 100$.

The results of the measurements are shown in Table. 2.

Table 2: The results of the measurement of $tg\delta$

i	$tg\delta_i$	$(tg\delta_{dev})$	Δ_{sys}	δW
$i=2$	0.02	0.01985	-0.00015	0.75%
$i=3$	0.03	0.02988	-0.00012	0.4%
$i=4$	0.04	0.03982	-0.00018	0.45%
$i=5$	0.05	0.04969	-0.00031	0.62%

Conclusions

Experiments show that in the LabVIEW software environment, using the NI Educational Laboratory Virtual Instrumentation Suite (NI ELVIS) platform, it is possible to measure the capacitance and tangent of the dielectric loss angle of low-voltage capacitors with a relative error not exceeding 0.29% and 0.75%, respectively. The device can also be used for digital measurement of the informative parameter of a differential capacitor.

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