Automation of programmed laboratory equipment and development of a virtual device for measuring imitance based on graphic LabVIEW

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Abstract

A virtual measuring instrument based on the LabVIEW hardware and software platform and a compatible NI USB 6009 unit has been proposed, developed and implemented for imitation control of vegetable juice quality indicators. A sinusoidal test signal in the form of alternating voltage with amplitude 10-20 mV. A structure has been developed that allows switching to the desired type of measurement, based on fixed instantaneous values of voltage and current of the conductometric cell, ie on measurements of rms voltage, measurements of rms current, module measurements, measurements of active and reactive components. A virtual device consisting of a personal computer with LabVIEW software, a NI USB 6009 unit and a juice conductivity cell was used to determine the content of heavy metals in this juice. In the same way, in production conditions at low cost, you can quickly control the quality of vegetables from which the juice is obtained.

Keywords

Immittance, conductometric cell, virtual tool, rms value, LabVIEW.

1. Introduction

Agricultural products, in particular vegetables, are an important component of Ukraine's export potential. Vegetables are a source of nutrients, including carbohydrates, fiber, protein, organic acids, as well as vitamins and minerals. Thanks to these substances and their compounds, vegetables have antioxidant, antibacterial, antifungal, antiviral and anticancer properties. However, at the same time, vegetables can contain toxins, nitrates and other harmful elements, which, depending on their content, are dangerous to human health, impair taste and nutritional value. Therefore, it is important to identify and quantify the useful and harmful elements present in vegetables. The task of quantitative assessment of useful and harmful elements in vegetables is becoming even more urgent, as the world markets have much stricter requirements for product quality. This brings to the fore a number of issues related to the development of rapid methods for assessing the quality and safety of products, with the development of a tool for studying the quality of vegetable products.

As it is important to produce safe food products, free, in particular, from heavy toxic metals, the development of a virtual device for assessing their presence in vegetables is gaining weight.

2. Analysis of published data and problem setting

Organoleptic and sensory analysis are often used to assess food quality [1]. However, they cannot be used to determine all the required quality characteristics with high accuracy. Measuring methods of quality control allow for more accurate quality control of materials [2]. Depending on what processes

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are the basis of the measurement method or what properties are used, measurement methods are classified into: physical; chemical; physico-chemical; microbiological; technological; biochemical; physiological (biological); commodity [2].

However, measuring methods of food quality control have a number of disadvantages, in particular: the long process of preparation of samples for measurement, the use of expensive instruments for measurement, highly qualified specialists.

According to the authors of the article, to study the quality of vegetables it is necessary to develop methods that would have a wide range of uses, high sensitivity, resolution, easy sample preparation and affordable and easy operation of the device in production conditions, significant analysis speed. Such requirements are mainly met by conductometric research methods. The conductometric method is based on measuring the electrical conductivity of objects of control. Currently, conductometry is used to quickly determine the concentration of solutions of salts, acids, bases, to control the composition of some industrial solutions. Preferably, these methods are used to control the individual quality indicators of substances in the liquid state or gaseous medium [3, 4]. Conductometry includes direct methods of analysis (used, for example, in salt meters) and indirect (for example, in gas analysis) using direct or alternating current (low and high frequency), as well as chronoconductometry, low-frequency and high-frequency titration [5]. Determination of the concentration is carried out by direct conductometry (calibration schedule - allows you to directly determine the concentration of electrolyte by measuring the conductivity of a solution with a known qualitative composition) or by conductometric titration (analysis method based on determining the content of the substance by breaking the titration curve). , variable as a result of chemical reactions in the titration process). To determine the composition of the liquid using the frequency dependence of the dielectric losses of the substance, as it is a characteristic of the material. Conductometric analysis is based on changes in the concentration of a substance or chemical composition of the medium in the interelectrode space; it is not related to the electrode potential, which is often close to the equilibrium value. Indicators that characterize the non-electrical properties of products are measured by converting the physico-chemical properties of substances and materials into an electrical signal using various primary transducers (sensors) [6-13].

The authors conducted experimental studies on the detection of heavy metals in vegetable juice and obtained data reflecting physical parameters (complex stresses) proportional to the immittance. The circuit consisted of a capacitive transducer (conductometric cell filled with model liquid - vegetable juice with various impurities), RLC-meter to send a test signal to the capacitive transducer; block of results processing and management [14].

However, the above-described measurements performed using a standard RLC meter are limited by the capabilities of the specified device in contrast to the virtual measuring instrument created using the LabVIEW platform. The latter is considered optimal for providing software support for automated control systems and research.

3. The purpose and objectives of the study

The purpose of this study is to improve the methodological and metrological support of quality control of vegetables and their juices by studying the electrical parameters using a virtual means of imitation control based on the hardware and computing platform LabVIEW.

To achieve this goal should solve the following tasks:

- to develop a virtual tool for researching the quality of vegetable products on alternating current;
- to measure immittance by means of the NI USB 6009 block.

The scientific novelty is the creation of a virtual device based on the LabVIEW platform, which allows for operational research of grown vegetable products in-situ on alternating current. The virtual instrument includes a test signal program and programs for processing the original voltage and current of the object of study to calculate the immittance.

Research methods. Theoretical bases of electrochemistry and qualimetry, measuring equipment, programming are used, in particular within the LabVIEW hardware and computer platform. The experiments were performed using modern measuring devices, including virtual ones, with automated processing of measurement results. Studies have used a simulated method to measure the electrical parameters of non-electrical objects, including vegetable juices.

4. Generation of test signal for imitation measurements

The creation of a virtual device for monitoring the content of heavy metals (Cu, Pb, Zn) in vegetable juice is based on the LabVIEW platform with the involvement of the NI USB 6009 unit [15]. The latter is connected to a PC via a full-speed USB interface and has 8 channels of input analog signals (A1) to generate and collect measured data; 12 digital I/O (DIO) channels and a 32-bit counter, as well as 2 analog signal generation (AO) channels, which perform the function of a test signal source (Figure 1).

The LabVIEW graphics platform manages the NI USB 6009 using the NI-DAQ (National Instruments - data acquisition) task. In the process of measurement the developed graphic software is used: the program of a test signal and the program of processing of results of measurements.

To measure and calculate the imitation of carrots generated a test signal - AC voltage with an amplitude of 10-20 mV. To do this, perform the following steps:

1. Generation of a test signal (sine wave);
2. Reading of complex values of immittance.

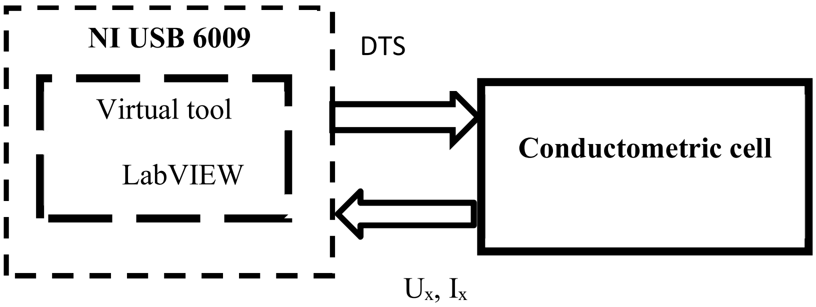

Figure 1: Block diagram of measuring the immittance of vegetable juice: DTS - the source of the test signal; U_x, I_x – current and voltage at the object of measurement

The NI USB 6009 unit is designed to generate a DC voltage of 5 V at a maximum current of 5 mA. According to the immittance measurement technique, the test signal is a sine wave. Because this unit does not generate AC voltage, the program used individual elements of the NI-DAQ task and the While Loop with Stop Button loop. In addition, the program records the Wait command, which specifies the interval between iterations of the loop. The number of sinusoidal points is set on the Points per cycle indicator (Figure 2-3).

The created device allows to generate electric voltage in the range 0… 5 V. At the same time, the program deduces a sinusoidal signal with voltage shift and allows the user to choose the number of points per cycle. Increasing the dots per cycle increases the resolution of the output signal, but decreases its frequency. The approximation period of the output signal is equal to the number of points per cycle multiplied by the time norm (Figure 2-3).

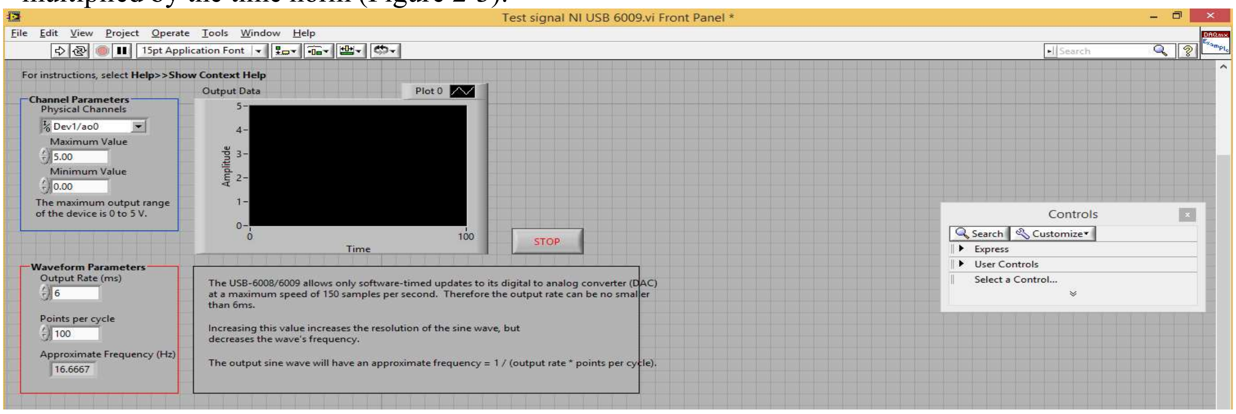

Figure 2: Test signal, front panel

In practice, the frequency of the sinusoidal test signal was set indirectly through the interval and number of points. It was evaluated in the program approximately.Steps to implement or execute code.

1. Open Test signal NI USB-6009 VI.
2. Adjust the front (front) panel controls: Physical channel; Maximum value; Minimum value; Output speed; Number of points per cycle.
3. Run the Test signal NI USB-6009 VI (Figure 2).

All steps are performed in the LabVIEW software package. The obtained experimental data are processed using the tools of the graphics platform LabVIEW.

The virtual device for measuring the immittance of non-electric objects has: PC with installed software, NI USB 6009 unit, which is used to generate a sinusoidal signal and apply it to a container with graphite electrodes filled with juice or modeling solution. The same unit is used to measure immittance.

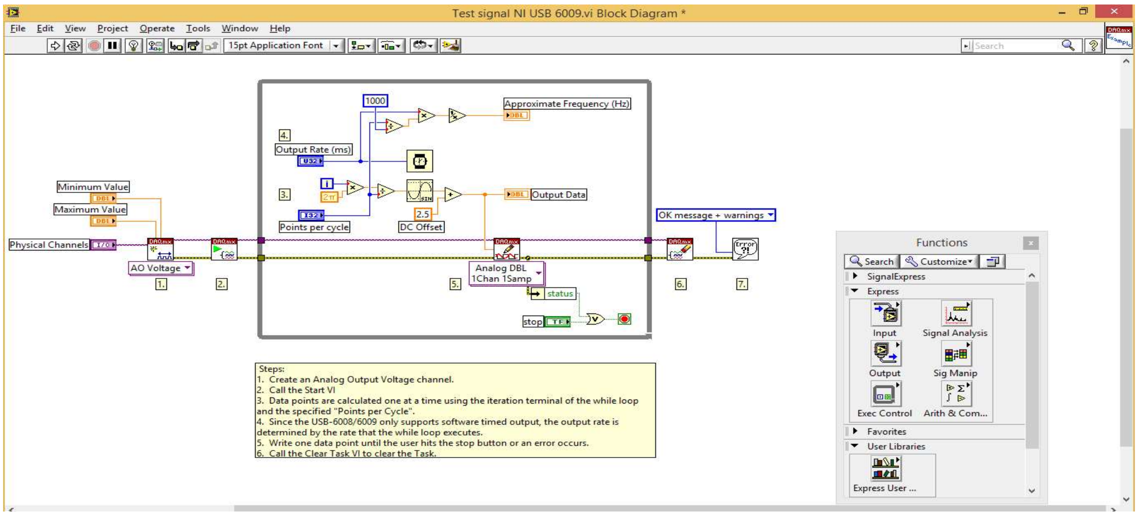

Figure 3: Test signal, block diagram

5. Measurement of immittance by means of the NI USB 6009 block

A typical immittance measurement requires one transducer to measure the voltage at the load terminals and a second transducer to measure the current flowing through the object. However, the actual calculation of the immittance depends on the resistive and reactive components (capacitors and / or inductors) in the circuit. Reactive components lead to a phase shift (up to 90 degrees) between voltage and current signals. This phenomenon is represented by three different representations of imitance: the active component, the module and the reactive component. These three components have phase connections that can be visualized in the immittance triangle shown in Figure 4.

There are various methods used to measure the active impedance component. The first method is to take the average time value of the instantaneous product of voltage and current to calculate the active power and then divide it by the square of the current value. Another way is to use the impedance angle depicted in the immittance triangle. The cosine of the impedance angle, directly proportional to the active resistance in the circuit, is called the impedance coefficient.

Immittance measurement through complex power. Reactive components cause a phase shift (up to 90 degrees) between voltage and current. Current and voltage signals have a phase shift in the range of 0 and 90 degrees. To measure the reactive component, the following capabilities are required: the ability to obtain a voltage and current signal; simultaneous receipt of both measuring signals; both measuring instruments must receive signals simultaneously. The LabVIEW software and hardware platform includes a number of virtual devices that work with DAQ hardware devices. For a single-phase circuit, the voltage and current signals have the following expressions:

$$u(t) = U\sqrt{2}sin\omega t, \quad (1)$$

$$i(t) = I\sqrt{2}\sin(\omega t - \varphi). \quad (2)$$

Ratio - active power relative to the square of the current value [16]:

$$R = \frac{\frac{1}{T}\int_t^{t+T} u(t)*i(t)dt}{I^2}. \quad (3)$$

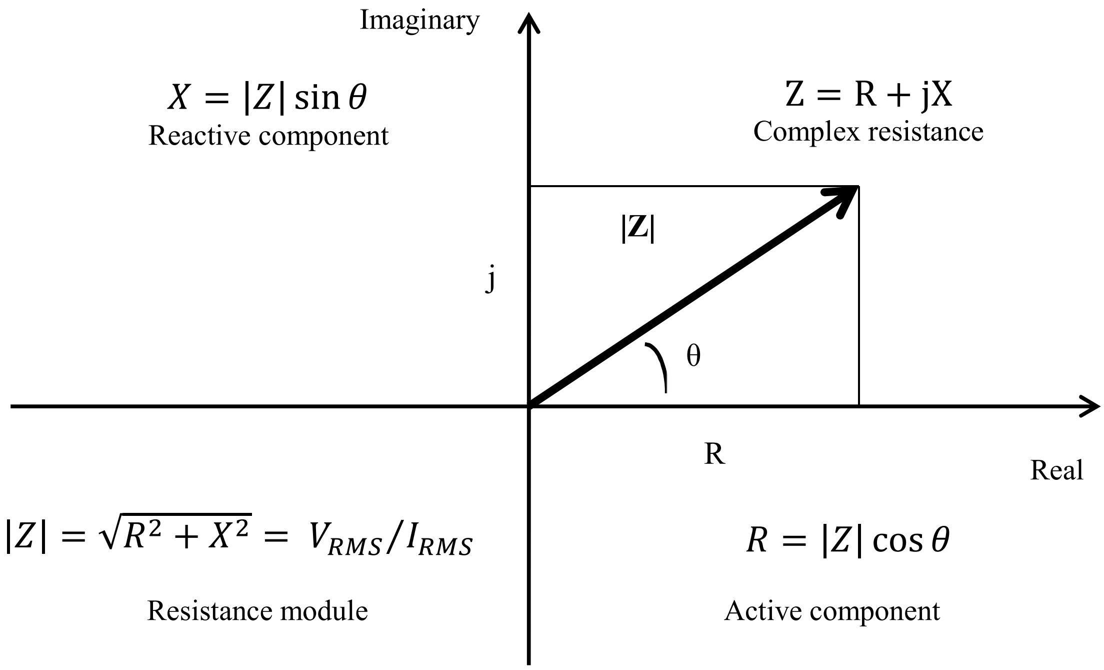

Figure 4: Imitation triangle

This operation of calculating the specified ratio requires two operations, namely to multiply the instantaneous values of current and voltage; calculate and give the result of indirect measurement and divide it by the square of the current value. The modulus of complex resistance, | Z |, which is defined as the division of the root mean square (current) values of voltage and current, is obtained by the ratio [16]:

$$|Z| = U_c/\mathrm{I_c}. \tag{4}$$

Taking into account these connections, two measuring contacts are defined: one for voltage and the other for current.

To calculate the RMS values of voltage and current used virtual instruments, which are in the subpalette of functions "VI Express" Signal analysis, by dividing the RMS values of voltage and current, the modulus of impedance Z is obtained (Figure 5).

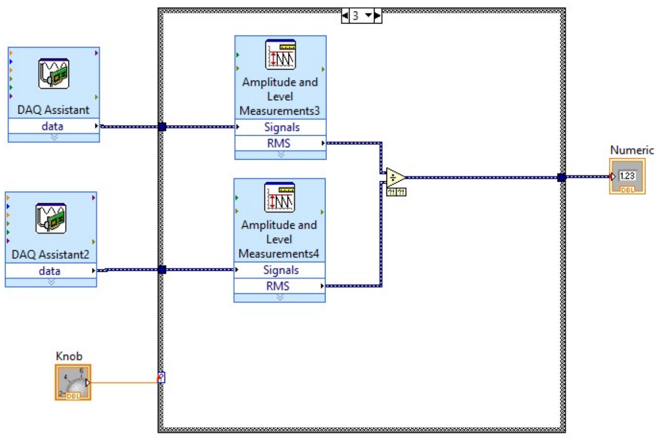

Figure 5: Block diagram for calculating the modulus of impedance Z

By multiplying the instantaneous values of voltage and current and passing through a low-pass filter (Express Filter VI), we obtain the active power, and then the active component R (Figure 6).

The reactive component is determined by the ratio:

$$X = \sqrt{Z^2 - R^2}. \tag{5}$$

The device (Figure 5-7) used:

- Filter to obtain the integral of the product of the voltage and current values of the object of study;
- MEAN to calculate the average value for the period at the output of the filter;
- Amplitude and Level Measurement to obtain the current value;
- DAQ Assistant to obtain the original voltage and current values of the object of study.

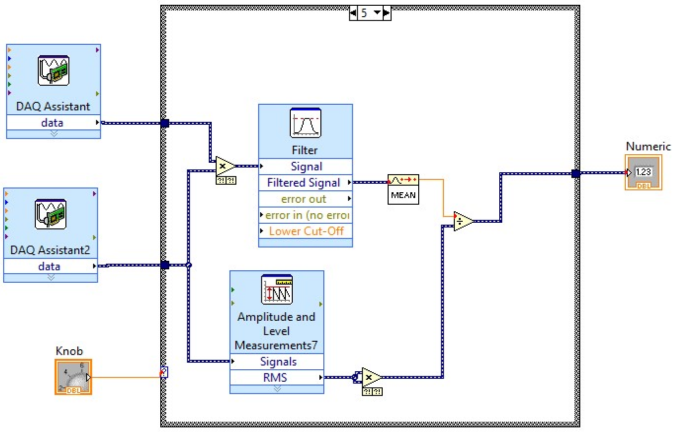

Figure 6: Block diagram for calculating the active component of the impedance Z

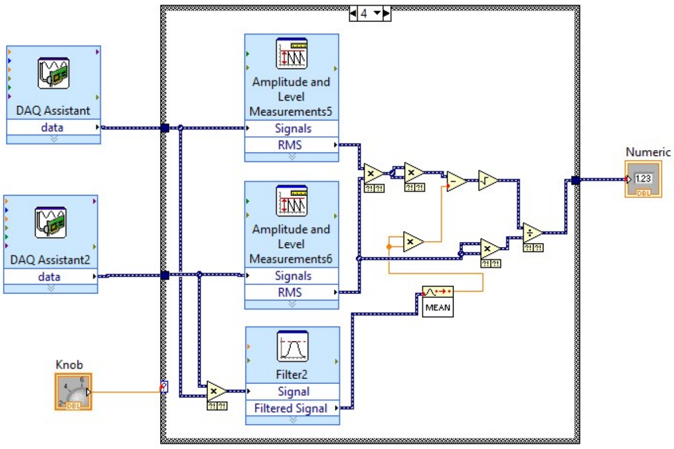

Figure 7: Block diagram for calculating the reactive component of the impedance

The window for setting the amplitude measurements is shown in Figure 8.

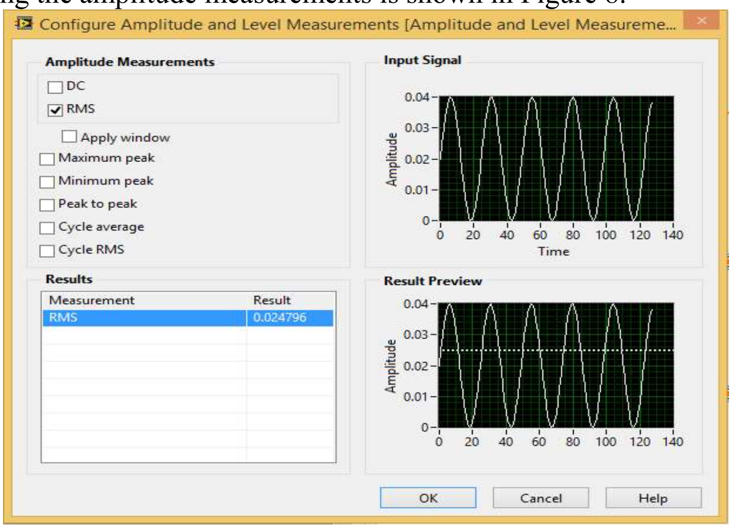

Figure 8: Amplitude measurement setting window

This analysis of the measured values of voltage and current is used to calculate the modulus of admittance. The RMS option is selected in this window. The output is the root mean square value of the voltage or current signal.

The window for setting the electric filter is shown in Figure 9.

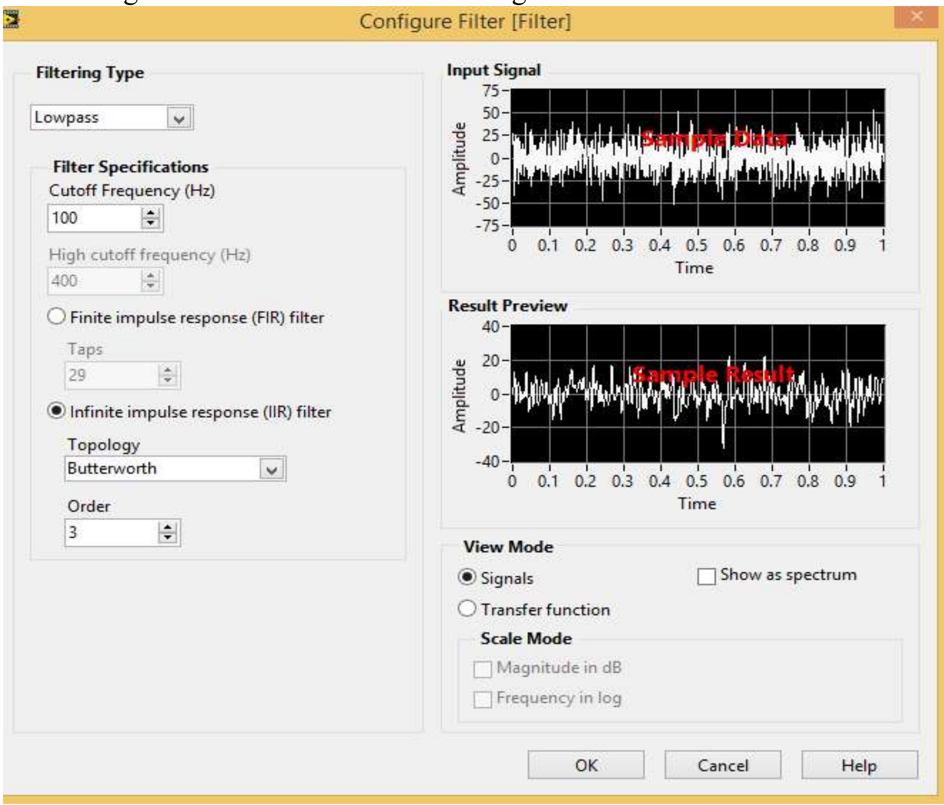

Figure 9: Electric filter settings window

The design of the virtual filter in the composition: the filter, the RMS meter and the average value at the output of the filter, is used to calculate the active component of the impedance. In the window you can select the filter settings, operating frequency range, etc.

Calculation of immittance using the Euler equation. To represent voltage and current signals with complex values, we use the laws of electrical engineering [16]. Yes, AC voltage or current:

$$i=I_m \sin(\omega t+\varphi_i), \tag{6}$$
$$u=U_m \sin(\omega t+\varphi_u), \tag{7}$$

are as follows:

$$i = I_m \cos(\omega t + \varphi_i) + j * I_m \sin(\omega t + \varphi_i), \tag{8}$$
$$\dot{u} = U_m \cos(\omega t + \varphi_u) + j * U_m \sin(\omega t + \varphi_u). \tag{9}$$

Using Euler's equation:

$$i = I_m e^{j(\omega t+\varphi_i)}, \tag{10}$$
$$\dot{u} = U_m e^{j(\omega t+\varphi_u)}, \tag{11}$$

write the impedance of the measuring object:

$$Z = \frac{U_m e^{j(\omega t+\varphi_u)}}{I_m e^{j(\omega t+\varphi_i)}}. \tag{12}$$

Therefore, to measure the impedance, it is necessary to measure the amplitudes and phases of the voltage and current signals [16]. The window for adjusting the measurement of the amplitude and phase of the measuring signals of voltage and current is shown in Figure 10.

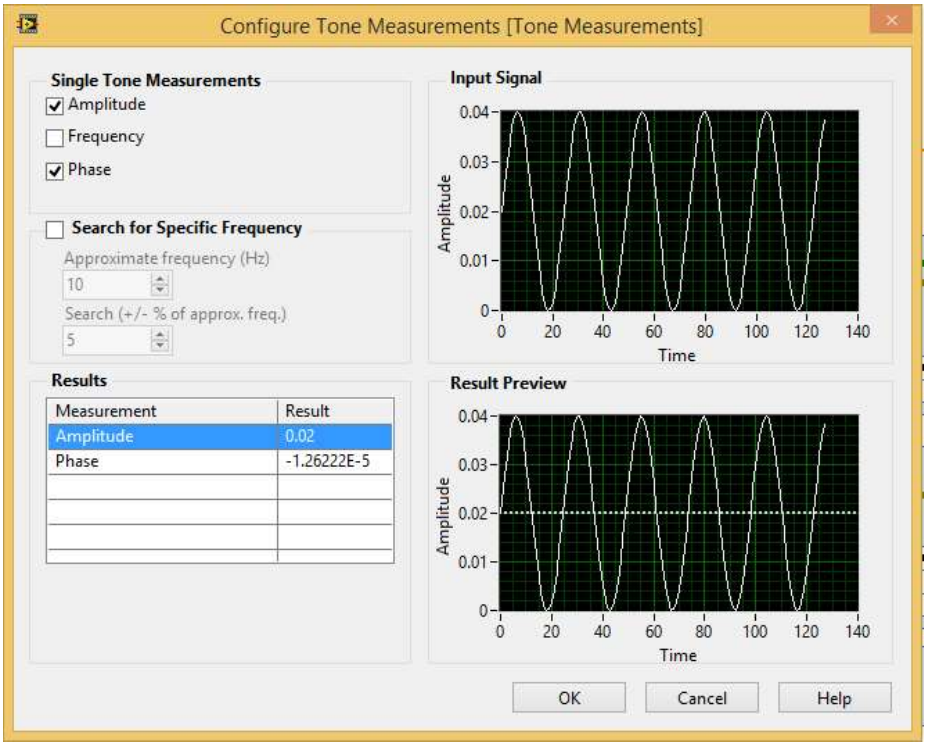

Figure 10: Amplitude and phase measurement window for measuring voltage and current signals

In the created device (Figure 11) are used:

- Tone Measurement – to obtain the amplitude and phase of the measured values of voltage and current;
- DAQ Assistant - to obtain the original values of voltage and current of the object of study;
- Adapter for converting measurement data to numeric;
- Elements of transformation of complex numbers.

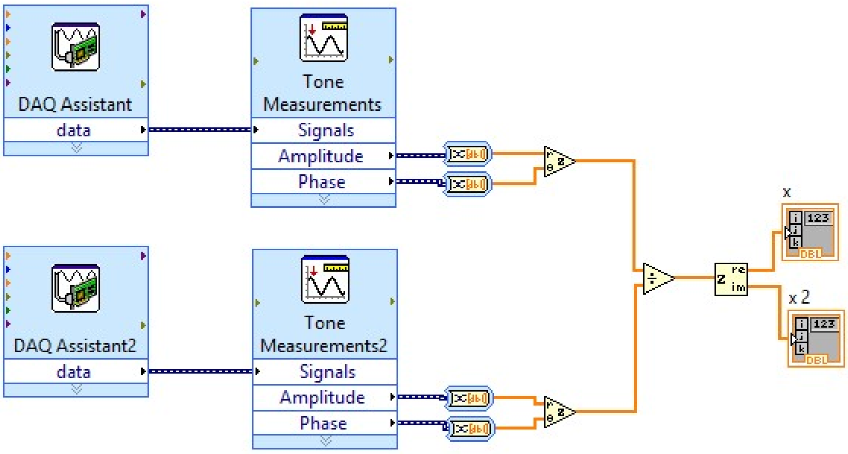

Figure 11: Immittance measurement program according to Euler's equation

6. Conclusions

For imitative control of vegetable juice quality indicators, a virtual measuring instrument based on the hardware and software platform LabVIEW and a compatible NI USB 6009 unit has been proposed, developed and implemented.

A sinusoidal test signal in the form of an alternating voltage with an amplitude of 10-20 mV was generated to measure and calculate the imitance of the object. Because the NI USB 6009 unit is not able to generate AC voltage, the program uses some elements of the NI-DAQ task with the While Loop with Stop Button cycle. To do this, create a generation channel Create Channel (start generation Start, write voltage generation, clear task Clear Task), as well as Wait, which regulates the sine wave period.

Reading and processing of complex components of imitation is carried out in 2 ways:

- Using Euler's equation;
- By module and active immittance component (Amplitude & Level measurement → RMS (root mean square) was used to obtain the immittance module value, and Filter i mean was used to obtain the active immittance component). In this case, the reactive component of immittance is calculated algebraically.

A structure has been developed that allows switching to the desired type of measurement, based on the recorded instantaneous values of voltage and current of the conductometric cell, ie on SCR voltage measurements, SCR current measurements, module measurements, measurements of active and reactive components.

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