Development of a portable impedance meter for diagnostics of biological objects plant origin

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Abstract. The article proposes a technical solution for a multi-frequency meter of electrical impedance parameters based on a precision impedance converter AD5933 from analog devices. The technical solution can be used in the development of portable devices for the diagnosis of biological objects.

Due to the presence of electric charges (ions) in the cellular and intercellular fluid, plant tissue is a conductor of electric current, which means it has an active resistance [1]. It is also known that all the most important manifestations of the life activity of a plant cell are associated with membranes and changes in their permeability, that is, with the properties of the electrical capacity of plant tissue [1]. This means that the parameters of the total electrical resistance of plants (bioimpedance) characterize the state of plant physiology and pathology. This is the basis of the method of electrical impedance spectroscopy (EIS) for the diagnosis of biological objects, while the impedance is measured depending on the frequency of the applied alternating voltage [2]. The EIS method is used in methods of diagnosis and rejection of green cuttings that are potentially unsuitable for rooting [3,4], a method for determining the removable ripeness of berries [5], a method for detecting fungal diseases of garden strawberries [6] developed at SibFTI SFNCA RAS. The EIS method also allows using equivalent electrical circuits to obtain electrical parameters of the cell structure: characteristic frequency, electrical capacitance and resistance, which in practice can be used to assess the state of plant physiology and pathology [7]. For the implementation of methods in the field, the task of creating portable impedance parameter meters with functions for calculating diagnostic indicators is relevant.

To solve this problem, a technical solution of a multi-frequency meter of electrical impedance parameters based on a chip of a precision impedance converter AD5933 from analog devices has been developed at the SibFTI SFNCA RAS at the stage of research [8,9]. The block diagram of the resonance meter is shown in Figure 1.
The impedance meter uses a ready-made evaluation module board containing the AD5933 chip and analog signal processing facilities from the diagnostic object and calibration resistor R1. The EVAL-AD5933 evaluation module is also equipped with software for a personal computer (PC). Ferroelectric memory is used to collect data on a variety of samples and accumulate the results. Unlike EEPROM memory, which has a very limited resource in terms of the number of writes/reads, ferroelectric memory operates at the maximum interface speed, that is, without delay, and has a resource in terms of the number of write/read cycles by 7 orders of magnitude more. [10] provides data on the guaranteed resource by the number of recording cycles of at least 1012 cycles and the storage period of recorded data of about 38 years. The impedance meter works as a result of executing a program loaded into the memory of the PIC16F876A microcontroller.

The microcontroller program performs the following functions:

a. Control of the AD5933 impedance converter via the I2C interface. To do this, all input values are prepared in advance in hex format, for example, using a calculator, or, conveniently, in the MATHCAD package. The register loading procedure is performed according to the rules specified in the passport data AD5933 [8].

b. Storing the results of the discrete Fourier transform of REAL and IMAGINARY calibration and measurement in ferroelectric memory for each sample.

b. Transfer of accumulated calibration and measurement data via RS232C serial interface to the PC COM port.

The procedure for working with the impedance meter is as follows. The diagnostic sample is connected by the operator to the input of the device using electrodes. The calibration and measurement process is started sequentially at 10 fixed Fi frequencies by pressing the corresponding control button S. The obtained values of the calibration resistor R1 and the impedance parameters of the diagnosed sample for each of the 10 fixed excitation frequencies of the plant tissue section between the electrodes (active and reactive resistances, phase shift angle) are stored in a ferroelectric memory and can be displayed on the screen of an alphanumeric liquid crystal indicator for monitoring. For
subsequent data processing, the device is connected by cable to the COM port of the PC. Under the control of a virtual device implemented in the LabVIEW 8 demo, the gain of the signal path of the AD5933 impedance converter is calculated, measurement data is processed and stored in the same order according to samples in a format convenient for opening in the EXEL package. Data processing consists in obtaining diagnostic parameters, for example, the coefficient of dispersion in the implementation of the methods [3, 4, 5], the characteristic frequency in the methods [6, 7], at which the reactive (capacitive) resistance has a maximum, the values of the resistance of the intercellular fluid and the capacity of cell membranes when using the method of equivalent electrical circuits [7].

The proposed technical solution can be used as a base for the implementation of various methods of bioimpedance diagnostics of various biological objects.

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