PC AND LABVIEW BASED VOLTAGE AND CURRENT SOURCE FOR ELECTROCHEMICAL INVESTIGATIONS

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The paper presents a computer-controlled voltage and current source and a response monitoring system for electrochemical investigations. The hardware of the measuring system includes the data acquisition USB card, as well as all the required circuits – the analog front end, signal conditioning circuits, and the power supplies. The software is based on the LabVIEW platform and designed to take control of the signal generation and measurements, cancel the noise in the signal and calibrate the device. The system supports the following measuring methods: potential measurement, potentiostatic and galvanostatic measurements, as well as cyclic voltammetry and impedance measurement. The system and its characteristics were thoroughly studied and were found to fulfill the requirements for most of the electrochemical or bioelectrochemical measurements, supercapacitor characteristics investigations, and much more. The whole system is open-source and can be easily upgraded to support different methods and purposes.

Keywords: voltage source, current source, electrochemistry instrumentation, LabVIEW, supercapacitors.

1. Introduction

Over time, the number of different components based on electrochemical solutions, such as accumulator batteries, capacitors, supercapacitors, various sensors, etc., has been constantly growing [1—3]. This progress would not be possible without different electrochemical investigations based on various material testing methods, characteristics measurements, and response monitoring [6]. There are a number of standard methods for testing electrochemical systems, but it is not a rare case that these methods are very expensive or not affordable to users. In this paper, a simple and affordable computer-supported system that allows most standard testing methods will be presented.

A computer-controlled response monitoring system for electrochemical investigations with a voltage and current source, cyclic voltammetry, and impedance meter described in this paper is a universal, easily customizable device intended for various investigation and research purposes. It can be used in physical electrochemistry, electrochemical corrosion, battery testing, fuel cell testing, solar cell testing, sensor development, and more [5]. Basically, it presents a complete solution for the Electrical Impedance Spectroscopy (EIS) system. The system is designed for electrochemical laboratories, institutes, and faculties, where it could be used instead of standard equipment, while maintaining the quality of results and measuring accuracy.

The idea behind the assembly of this system is modularity. The main system components are physically separated and can be easily changed/replaced. The system consists of three major modules: data acquisition module, analog front end module, and power supply unit (PSU), and each of them is physically separate from the rest. Therefore, it is easier to upgrade it in order to achieve even better characteristics, such as input and output impedance of voltage and current generators, frequency characteristics, measuring accuracy or add more input measuring channels if needed [6].

2. Hardware

Instead of classical measuring equipment, researchers begin using more and more frequently personal computers equipped with some general-purpose, inexpensive acquisition cards and appropriate software. If combined with an application-specific user interface, it easily makes a system suitable for collecting, measuring, and processing data and various experiments control [7].

In order to meet the requirements to the control and measurement system, a circuit has been designed. Its principal scheme is shown in Fig. 1.

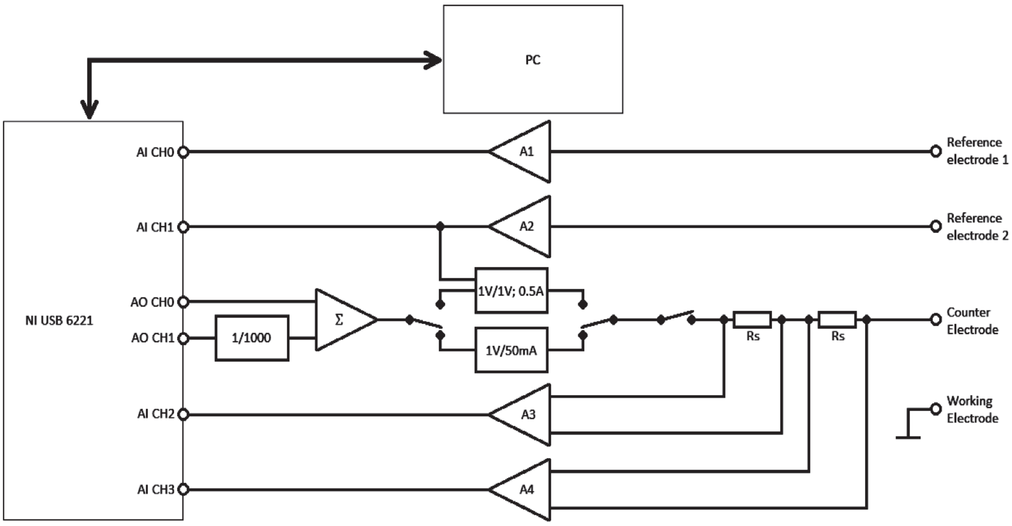

Fig. 1. Principal scheme of the system

2.1. Data acquisition module

For the purposes of the measurement and control system, a commercially available data acquisition card was used: NI USB-6211. It is a USB multifunctional input/output device from National Instruments. It offers a fairly high performance in its price range. It offers analog I/O, digital input, digital output, and two 32-bit counters. The device provides an onboard amplifier designed for fast settling times at high scanning rates. It also features signal streaming technology that gives you DMA-like bidirectional high-speed USB data streaming. The device is ideal for test, control, and design applications, including portable data logging, field monitoring, embedded OEM, in-vehicle data acquisition, and academic [8].

2.2. Analog front end module

The generation of voltage and current output signals, as well as the monitoring of the system's response to these signals, is performed through a set of electronic circuits, which form the analog front end (AFE). The input signals from reference electrodes 1 and 2 are buffered with amplifiers A1 and A2 and then sent to the acquisition module. This helps achieve the high input impedance of the system and thus improve its stability, due to the fact that electrodes by themselves can have large internal resistance.

The analog voltage outputs from the acquisition module (AO0 and AO1) can be used simultaneously, depending on the user requirements. However, the system behaves differently, depending on the analog output used. The voltage from the AO1 output is divided by 1000 and then sent to the summing amplifier, while the voltage from the AO0 output is sent directly. That means that the AO1 output can generate the output signals within ±10 mV range on the output of the summing amplifier. The signal is then brought to a series of relays (Re1, Re2), whose purpose is to switch between the potentiostat or galvanostat, used for the system output signal generation. The potentiostat amplifies the output voltage from the summing amplifier by 1 and therefore, the maximum output voltage of the whole system is ±10 V. However, its maximum output current is 500 mA, which is far higher than the outputs from the DA converter or any other internal amplifier. The galvanostat, on the other hand, has a ratio of 1 V/50 mA, which means that the maximum output current is 500 mA, provided that the control signal is at its maximum 10 V. Knowing that the AO1 output is divided by 1000 before the summing to form a control voltage, it can generate a system output voltage of up to ±10 mV in potentiostatic mode and a current up to 500 μA in the galvanostatic mode. As already mentioned, both analog outputs from the DA converter can be used simultaneously. That way, it is possible to keep both the voltage output range of AO0 (±10 V), and the resolution of AO1 at the same output channel from the system (counter electrode). In potentiostat mode, the absolute maximum resolution is $10\ mV/2^{16} = 0.15\ \mu V$, while in galvanostatic mode, it is $0.5\ mA/2^{16} = 7.63\ pA$. However, due to component tolerances, various environmental effects on the system, signal noises, etc., the electrical characteristics of the system indicate the resolution of the AO0 DA converter output.

3. Software

The software used for this particular system was based on the LabVIEW platform from National Instruments company, because it is considered to be the high standard in the area of modern virtual instruments [9].

LabVIEW is an object-oriented, graphical programming language. Therefore, a user interface is built using a set of various tools and objects. The user interface is known as the front panel. The code is then added by using graphical representations of functions to control the front panel objects shown on the block diagram.

For connection with the outside world, over the AD–DA converter, the NI data acquisition driver collection is used that comes with the data acquisition card NI USB-6211. The installation of these packages and the AD-DA converter makes a powerful development and measurement system that can be used for system control and signal processing.

Applications have been made for various electrochemical investigation methods. Therefore, in order to choose among the different methods, one needs to run the appropriate application. This ensures that no access code is present and that the system is well optimized and stable. Besides that, the front panels are minimalistic, so the user can quickly set all the necessary parameters and monitor the results.

4. Realization

A prototype of the developed system (Fig. 2) was made and the parameters were adjusted. Using the 5½ digit voltmeter PRIMA B7-21A and the lock-in laboratory multi-meter KEITHLEY 193A SYSTEM DMM, the system was calibrated for the selected range. Then the complete system was tested and tuned by using the accompanying software. Setting the offset and gain constants was reduced to the input constants of the LabVIEW application. Measurement errors were below 0.1% in all ranges.

Signal-to-noise ratio measurements of the system have been performed as well. The system was thoroughly tested under various conditions using the RTB 2002, a premium 2-channel oscilloscope from Rohde&Schwarz.

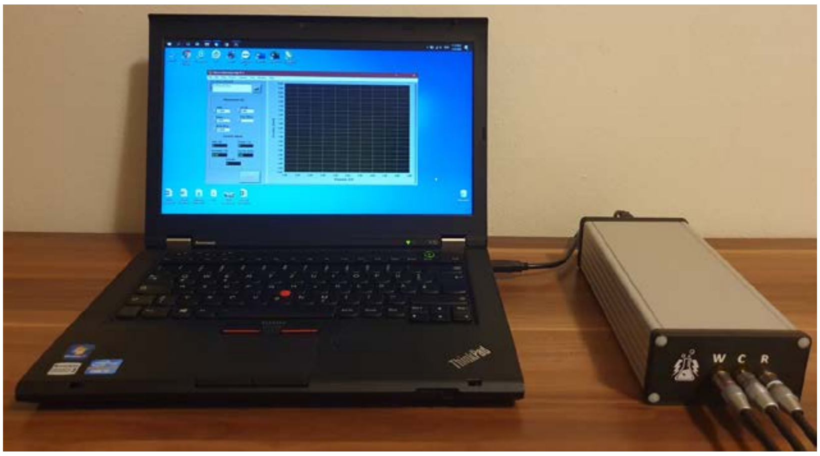

Fig. 2. Photograph of the prototype system

5. Conclusion

The default version of the system was thoroughly tested under many different conditions and with material samples. The obtained results were compared with test results of some commercial devices. The obtained results prove that this low-cost system matches the most significant characteristics of more expensive devices for most of the investigation methods.

The appropriate hardware (data acquisition device with desired external analog front end) in conjunction with a personal computer equipped with the software developed in the LabVIEW environment is a very powerful, customizable measurement system applicable in scientific research. Due to its characteristics, the system can be adopted to meet low cost requirements or, conversely, to suit as a more expensive, faster and more precise, device. Thanks to open architecture, it can successfully replace large number of specialized and very often high-cost measuring devices for a fraction of their price. The presented system can be further used in new areas of science or expanded by adding new methods and virtual instruments.

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Джерело напруги та струму на основі ПК та LabVIEW для електрохімічних випробувань

Представлено кероване комп'ютером джерело напруги та струму та систему контролю відгуку для електрохімічних досліджень. Апаратне забезпечення вимірювальної системи включає в себе USB-карту для збору даних, а також усі необхідні для цього схеми — аналоговий інтерфейс, схеми формування сигналів та джерела живлення. Програмне забезпечення базується на платформі LabVIEW і призначене для контролю над генерацією та вимірювання сигналу, скасування шуму в сигналі та калібрування пристрою. Підтримувані методи включають вимірювання потенціалу, потенціостатичні та гальваностатичні вимірювання, а також циклічну вольт-амперометрію та вимірювання імпедансу. Проведено ретельне випробування системи, встановлено, що її характеристики відповідають вимогам, які висуваються до більшості електрохімічних або біоелектрохімічних вимірювань, досліджень характеристик суперконденсаторів тощо. Вся система є відкритим кодом і може бути легко оновлена для підтримки різних методів та цілей.

Ключові слова: джерело напруги, джерело струму, електрохімічні прилади, LabVIEW, суперконденсатори.
