PC AND LABVIEW BASED VOLTAGE AND CURRENT SOURCE FOR ELECTROCHEMICAL INVESTIGATIONS

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The computer-controlled voltage and current source, and response monitoring system for electrochemical investigations is presented. The hardware of the measuring system includes the data acquisition USB card, as well as all needed circuits for the purpose – the analog front end, signal conditioning circuits, and the power supplies. The software is based on the LabVIEW platform and it is designed to take control of the signal generation and measurements, cancel the noise in the signal and calibrate the device. The supported methods are the potential measurement, potentiostatic and galvanostatic measurements, as well as the cyclic voltammetry and impedance meter. The system is thoroughly tested and it is established that the system characteristics 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, and many more, are constantly growing [1-3]. Their 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 omputer-controlled response monitoring system for electrochemical investigations with voltage and current source, cyclic voltammetry, and impedance meter, described in this paper, is 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 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.

An 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 separated from the other. 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, the personal computers equipped with some general-purpose, inexpensive, acquisition cards and related software are becoming more and more used. When combined with application-specific user interface, a system suitable for collecting, measuring, and processing data and various experiments control can be easily achieved [7].

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

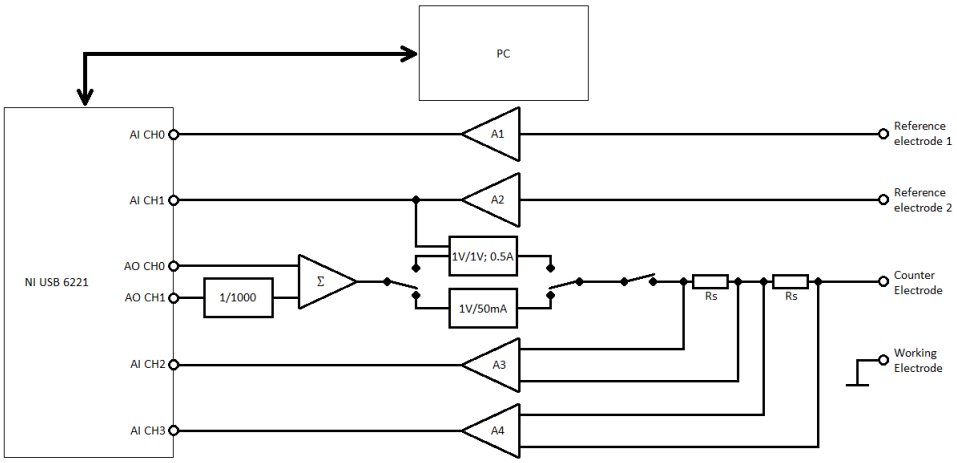

Figure 1. The principal scheme of the system

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 – the USB Multifunction input/output device, from National Instruments company. It offers a fairly high performance, compared to other successors in the same 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 streaming of data across USB. 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. That way, the high input impedance of the system is achieved, and therefore the stability of the system is improved, due to 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, there is a difference in system behavior, depending on the analog output used. Voltage from output AO1 is divided by 1000 and then sent to the summing amplifier, while the voltage from output AO0 is sent directly. That means that the output AO1 can generate the output signals within ±10mV range on the output of the summing amplifier. Following the previous, the signal is 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 ±10V. However, it's maximum output current is 500mA, which is far higher than the outputs from the DA converter or any other internal amplifiers. The galvanostat, on the other hand, has a ratio of 1V/50mA, which means that the maximum output current is 500mA in case that the control signal is at its maximum 10V. Knowing that the output AO1 is divided by 1000 before the summing to form a control

voltage, in potentiostatic mode, it can generate system output voltage up to ±10mV, while in the galvanostatic mode, the currents up to 500μA can be generated. 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 (±10V), and the resolution of the AO1, on the same output channel from the system (counter electrode). In potentiostat mode, the absolute maximum resolution is $10mV/2^{16}=0.15\mu V$, while in galvanostatic mode, it is $0.5mA/2^{16}=7.63pA$. However, due to component tolerances, various environmental effects to the system, signal noises, etc. in electrical characteristics of the system, the resolution of the AO0 DA converter output is stated.

3. Software

The software platform used for this particular system is LabVIEW based, from National Instruments company, because of it's regards as a high standard in the area of modern virtual instruments [17,18].

LabVIEW is object-oriented, graphical programming language. Therefore, an 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. In this paper, the Front Panels, as well as Block Diagrams, are shown showed for the most common electrochemical methods.

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 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, choosing between different methods is done by running the appropriate application. In that way, it is ensured that no access code is present and that the system is well optimized and running stable. Besides that, the front panels are made in a minimalistic style, so the user can quickly set all needed parameters and monitor the results.

4. Realization

A prototype of the developed system (Fig. 2) and parameter adjustments were made. Using the 5½ digit voltmeter PRIMA B7-21A and lock-in laboratory multi-meter KEITHLEY 193A SYSTEM DMM 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 achieved less than 0.1 % in all ranges.

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

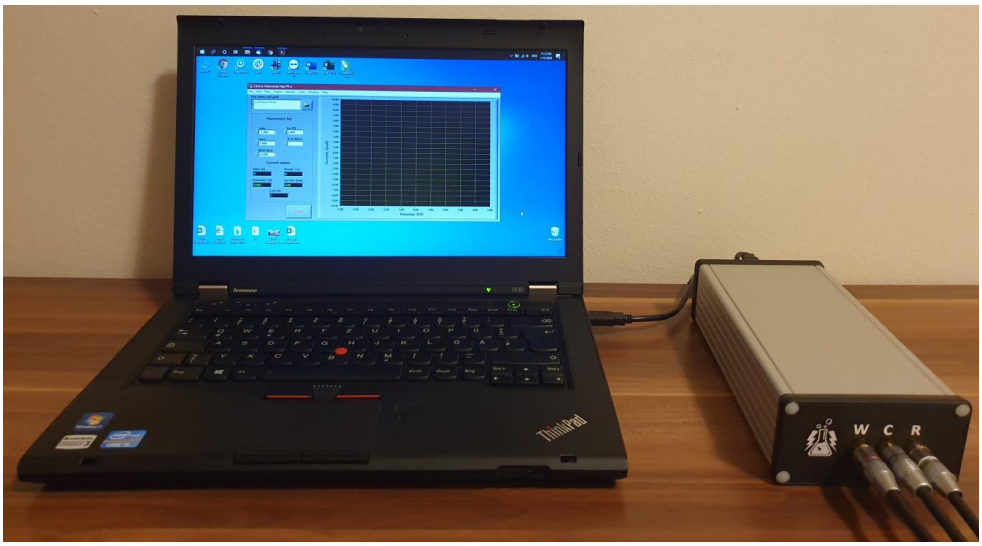

Figure 2. The photo of realised system

5. Conclusion

The default version of the system is thoroughly tested in many different conditions and with material samples, and the obtained results were compared with test results of some commercial devices. The obtained results proved that it is possible to match the most significant characteristics of more expensive devices for most of the investigation methods, using low-cost device.

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

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

Представлено керовану комп'ютером джерело напруги та струму та систему контролю реакції для електрохімічних досліджень. Апаратне забезпечення вимірювальної системи включає в себе USB-карту для збору даних, а також усі необхідні для цього схеми - аналоговий фронт, схеми кондиціонування сигналів та джерела живлення. Програмне забезпечення базується на платформі LabVIEW і призначене для контролю над генерацією та вимірюванням сигналу, скасування шуму в сигналі та калібрування пристрою. Підтримувані методи - це вимірювання потенціалу, потенціостатичні та гальваностатичні вимірювання, а також циклічна вольтамперометрія та вимірювач імпедансу. Система ретельно випробувана і встановлено, що характеристики системи відповідають вимогам для більшості електрохімічних або біоелектрохімічних вимірювань, досліджень характеристик суперконденсаторів та багато іншого. 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