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ScienceDirect

Procedia Engineering 120 (2015) 956 – 960

Procedia Engineering

www.elsevier.com/locate/procedia

EUROSENSORS 2015

A new, low-cost potentiostat for environmental measurements with an easy-to-use PC interface

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Abstract

A potentiostat is an electronic device for investigating the mechanisms of redox reactions and other electrochemical processes. These highly sensitive instruments allow studying the electrochemical properties of a certain analyte in solution. Nowadays, there are many high-end systems on the market that are usually supplied with a dedicated software package. However, there are only few instruments available in the low price segment. Therefore, our goal was to develop "EcoStat" a low-cost, digitally controlled potentiostat, which has several improvements compared to other inexpensive instruments; e.g. lower noise and a more stable output signal due to a digital PI controller. Furthermore, the data acquisition, visualization and filtering are managed by a comfortable, easy-to-use PC interface called "POTCON". Additionally, EcoStat was evaluated with three other commercial potentiostats and showed a good performance compared to high-end instruments.

Peer-review under responsibility of the organizing committee of EUROSENSORS 2015

Keywords: cyclic voltammetry; digital PI controller; EcoStat; *Escherichia coli*; potentiostat.

1. Introduction

A potentiostat is an electronic device to study electrochemical experiments on a mostly three electrode system. The potential of a working electrode is maintained at a constant level with respect to the reference electrode by balancing the current at an auxiliary or counter electrode. Commercially available potentiostats often exceed the

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Peer-review under responsibility of the organizing committee of EUROSENSORS 2015
doi:10.1016/j.proeng.2015.08.820

practical needs and the financial possibilities of the users. Therefore, many laboratories have started to design their own potentiostats [1,2].

Our aim was to quantify analyte concentrations in environmental samples. Therefore, we designed the "EcoStat" system. The prefix "Eco" is related to the low price as well as to its application for *Escherichia coli* detection in drinking water [3].

2. Methodology and Results

We have encountered that the analog P-controller, which is mostly used in potentiostats [1,2], is a source for high signal noise. Therefore, EcoStat uses a configurable, digital PI controller for better accuracy of the applied signals on the electrode.

For additional noise reduction, EcoStat is strictly separated into an analog (Fig. 1 and 2) and a digital board.

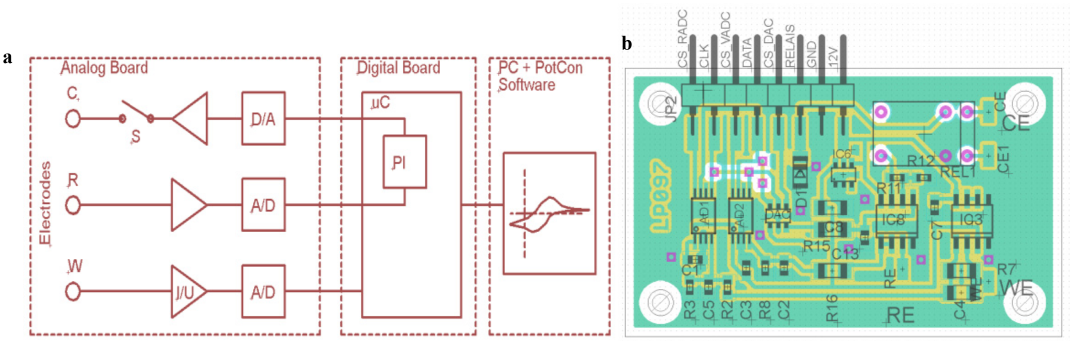

Fig. 1 (a) Block diagram of the EcoStat device. (b) PCB board.

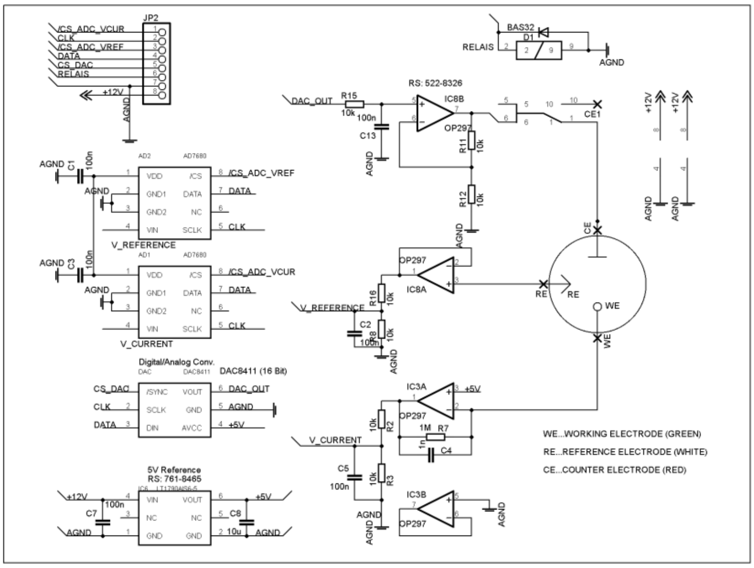

Fig. 2 Schematics of the analog board.

The digital PI controller forces the reference electrode voltage to a set point by manipulating the counter electrode voltage. The set point can be held constant (constant voltage mode) or can be varied over time for cyclic voltammetry. In cyclic voltammetry typically saw-tooth or triangle slopes with rising and falling source voltages are used. Furthermore, increasing the resolution of the A/D converters from 12 to 16 bits enables a wider measurement range as well as an improved accuracy. The digital part comprises an ATMEGA328 controller (Atmel Corp., USA).

EcoStat transmits the recorded unfiltered measurement data to the PC in real time. Data can be exported and saved as .png, .csv or in the proprietary .pot format. Filtering (e.g. by floating mean filter) is done by the POTCON software (Fig. 3a) and can be adjusted easily, even on reloaded .pot files.

The device was designed to work with screen-printed electrodes as shown in Fig. 4. As an example, the measurements of a ferricyanide solution are shown in Fig. 3a. With EcoStat we were able to obtain similar results compared to the datasheet of the electrodes (Fig. 3b).

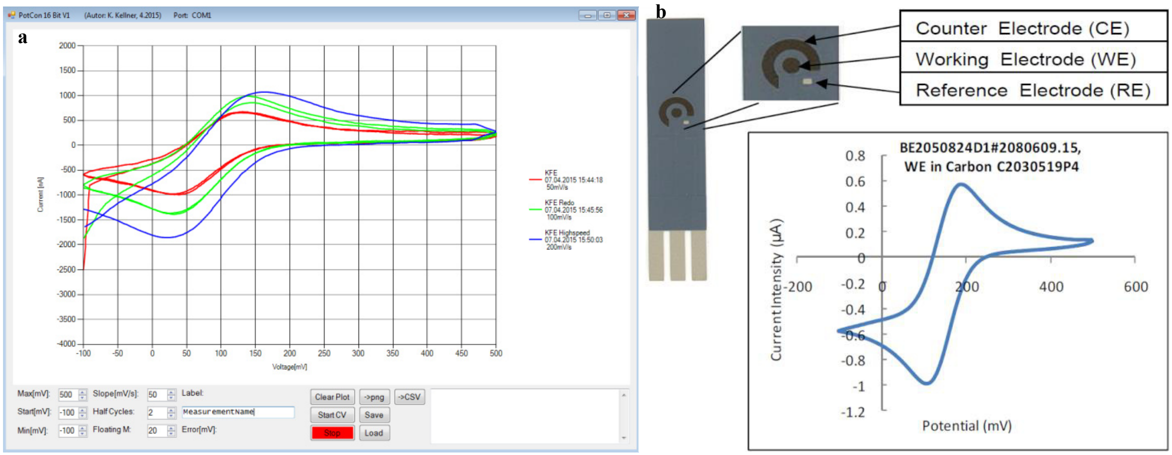

Fig. 3 (a) PC- User interface “POTCON”; measurements of 0.05 mL of 0.5 mM ferricyanide solution, pH 7.5. (b) Datasheet excerpt of the screen printed electrode BE2050824D1 and standard curve: 0.05 mL of 0.5 mM ferricyanide solution, pH 7.5 with 50 mV/s (Source: Gwent Electronic Materials Ltd., UK).

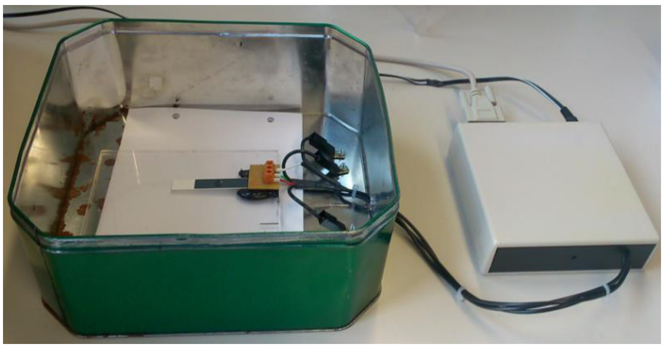

Fig. 4 Measurement setup: EcoStat potentiostat (right) connected with the screen-printed electrode in a shielded box (left).

The accuracy of EcoStat was evaluated and compared with the open-source potentiostat "CheapStat" [1] as well as with two high-end instruments (VersaStat4 and Reference 600). At the commercial instruments all software based filters were switched off, whereas, hardware based filters might still have some influence on the measurement data. For the evaluation we performed two technical experiments with different dummy cells (10 MΩ and 1k Ω-1µF). The data were graphically analyzed in Microsoft Excel in order to compare the four devices (Fig. 5). By using a 10 MΩ dummy cell a straight, rising line should be detected (Fig. 5a), whereas with the second dummy cell (1kΩ-1µF), a rectangular shape should be realized (Fig. 5b). The results showed a very good performance of the high end potentiostats (VersaStat4 and Reference 600). With the self-built EcoStat it was possible to obtain very satisfying measurement data with good accuracy and lowered signal noise in comparison to the open source device CheapStat.

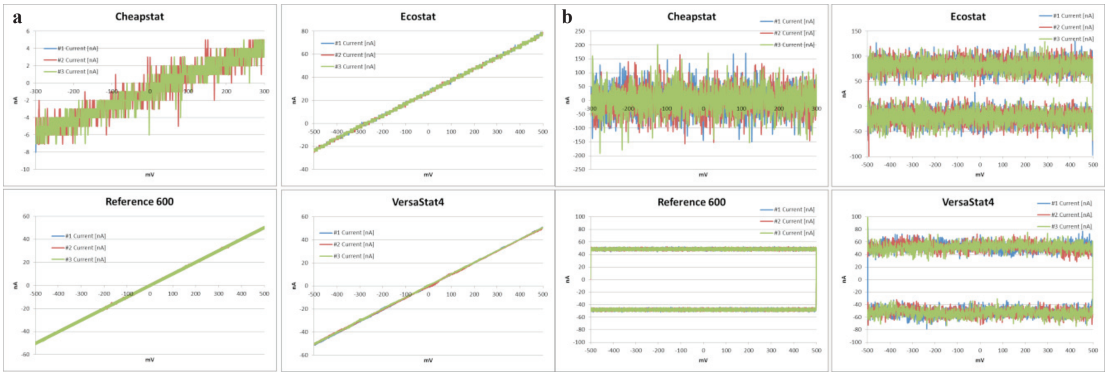

Fig. 5. Results of each three measurements with each of the four potentiostats with (a) the 10MΩ and (b) the 1kΩ-1µF dummy cell.

3. Conclusions and future outlook

"EcoStat" has several improvements compared to other cheap instruments: e.g. the output signal is more stable due to a digital PI controller, a 16 bits resolution of the converter leads to a wider measurement range and an improved accuracy; the data acquisition, visualization and filtering are managed by a comfortable and easy-to-use PC interface called "PotCon". In our developed potentiostat the data is transferred to the PC in real time, can be exported or saved in various file formats as well as reloaded into the software for later signal processing and filtering.

Since EcoStat showed excellent results in comparison to other instruments it represents a cheap and accurate alternative, performing electrochemical analysis for environmental applications.

Acknowledgements

The authors thank the province of Lower Austria and the European Regional Development Fund for financial support (project ID: WST3-T-91/026-2012).

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