Design and Integration of the Real-Time Remote Wireless Sensing System for pH Flexible Biosensor

Jie Ting Chen[1], Jung Chuan Chou[1, 2*], Yi Hung Liao[3]

[1] Graduate School of Electronic and Optoelectronic Engineering, National Yunlin University of Science and Technology, Yunlin, Taiwan, R. O. C.

E-mail: m10013337@yuntech.edu.tw

[2] Department of Electronic Engineering, National Yunlin University of Science and Technology, Yunlin, Taiwan, R. O. C.

E-mail*: choujc@yuntech.edu.tw

[3] Department of Information Management, TransWorld University, Yunlin, Taiwan R. O. C.

E-mail: liaoih@twu.edu.tw

NSC Project：NSC 100-2221-E-224-017 and NSC 101-2221-E-224-046.

Abstract

In this study, the wireless sensor network (WSN) with Zigbee technique was integrated with the pH flexible biosensor. The wireless sensing system was accomplished by the graphical language laboratory virtual instrumentation engineering workbench (LabVIEW). The wireless sensing system can be classified with two parts, which are the pH detection system of front end and transmission platform of back end. The pH detection system embraces ruthenium dioxide polyethylene terephthalate (RuO_2/PET) biosensor, silver-silver chloride electrode (Ag/AgCl) reference electrode and readout circuit. The transmission platform was transmitted the detection signals with real-time, which displayed the results in the computer. In addition, the wireless sensing system was used to detect pH values in buffer solutions.

Keywords：Wireless Sensor Network, Zigbee, pH Flexible Biosensor, LabVIEW

1. Introduction

The wireless sensor network (WSN) was consisted of network nodes with sensor, that designed to communicate via wireless radio. The recent development of wireless sensor network was provided advantages of low cost, low power consumption, small size, flexibility and distributed intelligence that compared with wired ones [1]. The sensors were combined with the WSN that has been widely in various applications. The applications of WSN techniques have been proposed in healthcare of patient monitoring [2, 3]. The monitored signals include heart rate (HR), electrocardiogram (ECG), blood glucose, activity for ambulatory health monitoring. Environment monitoring [4, 5] has become an important area of management and protection that provided real-time system and control communication from WSN. In literature [6], a wearable healthcare system was integrated with WSN for detecting falls of an elder person. The healthcare system can reduce the cost of medical care, and improves primary care services. About the application of intelligent life was proposed in literature [7]. This literature was developed a smart medication system which utilized the WSN techniques. The functions of medication system are medication reminding, pill-dispensing assisting and medication recording.

In 1970, P. Bergveld [8] presented a chemical sensor, ion sensitive field effect transistor (ISFET), that was fabricated by semiconducting process and electrochemistry technique. The physical difference in the ISFET structure is replaced the metal gate of the metal-oxide-semiconductor field effect transistor (MOSFET) by the series combination of the reference electrode, electrolyte and chemical sensitive insulator or membrane [9]. Afterward, Spiegel et al. [10] proposed the extended gate ions sensitive field effect transistor (EGISFET) in 1983. The EGISFET was improved to become separative extended gate field effect transistor (SEGFET) [11]. The SEGFET structure only needs to change sensing electrode, and the MOSFET device of that can be used repeatedly. The structure is shown in Fig. 1 [12]. The SEGFET holds the advantages of small size and fast response time. An extended metal wire is used as connection between metal gate and field effect transistor (FET), and the sensing film is deposited on the metal gate area to measure various detections of environment.

We achieved the WSN integrated with the pH flexible biosensor, which detected pH value in buffer solutions. Some advantages of the WSN are presented a low cost technique for collecting detection signals, the cable cost and space expansion can be increased. Consequently, the WSN for homecare, healthcare, and environmental monitoring in our life is required. The proposed system includes the pH detection system and transmission platform.

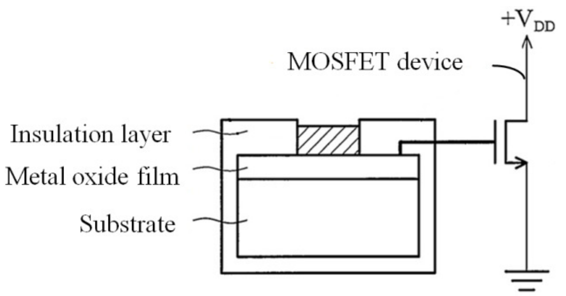


Figure 1: Structure of SEGFET [12].

2. Experimental

2.1 pH detection system

This study detected hydrogen ion and used potentiometric electrochemical method measured the output signal of the potential difference between reference electrode and biosensor. This pH detection system comprises: test solutions in the container; a reference electrode providing stable reference potential in test solutions; a pH flexible biosensor; a readout circuit device amplifying the detection signals.

The pH flexible biosensor was imitated the structure of SEGFET and used 99.99% purity ruthenium metal target via radio frequency (R.F.) sputtering, which deposited ruthenium dioxide (RuO_2) thin film on PET substrate. The sensing membrane with an area is 3 mm × 3 mm. The screen printing technique produced conductive wire and insulation layer. The insulating layer has an aperture for exposing a part of the biosensor, which forms a sensing window. The cross-sectional of pH flexible biosensor is shown in Fig. 2 [13].

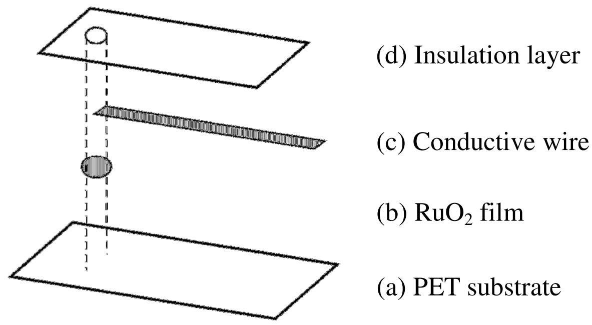


Figure 2: pH flexible biosensor cross-sectional view [13].

2.2 Transmission platform

The transmission platform was consisted wireless measurement devices and graphical language. The popular near field communications are such as Zigbee, Bluetooth, and Wi-Fi. In this study, the wireless measurement device used National Instruments (NI) WSN system of Zigbee module to transmit the detection signals. Wireless measurement device consists of the measurement node (Model: NI WSN-3202, National Instruments Corp., U.S.A.), and a gateway (Model: NI WSN-9791, National Instruments Corp., U.S.A.). The measurement nodes had directly connected via 2.4 GHz radio transmitted signals to the gateway. Measurement node installed with four 1.5 V AA alkaline battery cells. Each measurement node offers four analog input channels and four digital Input/Output channels. The gateway must be connected to a host controller running graphical language (Model: LabVIEW 2011, National Instruments Corp., U.S.A.) that can process, analyze, and display measurement signals. The wireless sensing system is shown in Fig. 3. The transmission distance of a single measurement node indoor is about 10 meters to 15 meters.

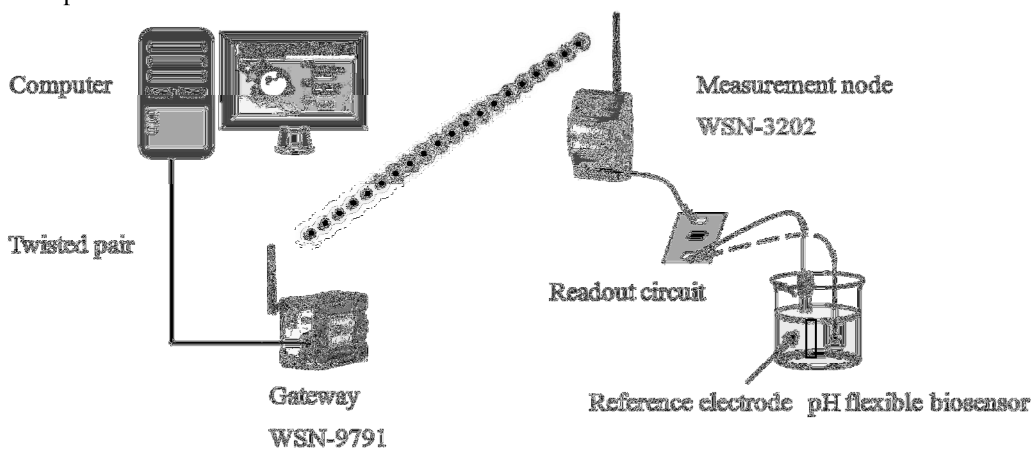


Figure 3: Schematic diagram of wireless sensing system.

3. Description of graphical language

The LabVIEW used a kind of program language: graphical language. The graphical language is a method of graphic designed to replace the traditional text program function. This study used the graphical language LabVIEW to implement the real-time remote wireless sensing system, and the main functions were described below. Before running graphical language LabVIEW, the wireless measurement devices should be finished the installation.

3.1 Framework of gateway interface

This section describes the gateway operation in program. As shown in Fig. 4, the 'WSN Open Gateway' creates a reference to the gateway. User can confirm the gateway internet protocol (IP) address is correct, and that the 'WSN Discover All Nodes' was started to search the measurement nodes via the WSN network. 'WSN Get Node Info' was returned information about the specified measurement node. Finally, the step was set parameter and scanned amount of node identification (ID).

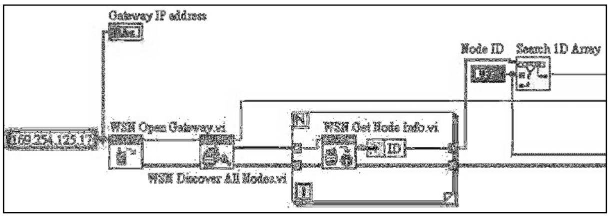


Figure 4: Program framework of gateway interface.

3.2 Framework of measurement node interface

If the measurement node will be working normally that should create the shared variable node. The shared variable node represents to transmit information between different virtual instruments. As shown in Fig. 5, the analog inputs (AI0-AI3) are the shared variable nodes relative to the four analog channels of measurement node. The 'WSN Open Node Reference' creates a reference to the specified measurement node, and then closes the reference. The collection information will output to next step.

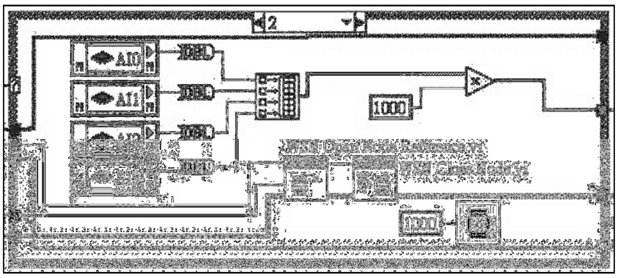
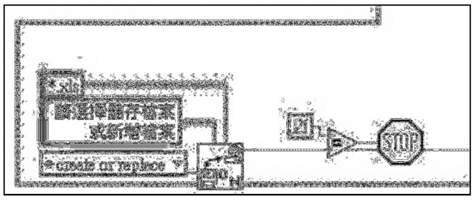


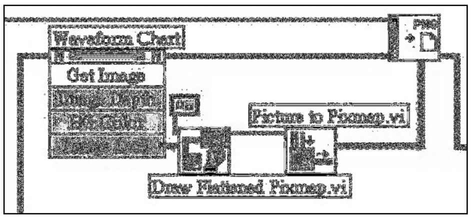
Figure 5: Program framework of measurement node interface.

3.3 Framework of storage and display interface

In this section, all functions are processed the measurement signals. The descriptive programs of storage and display framework are shown in Fig. 6. In Fig. 6 (a), the function is referred to select saving path. In addition, after terminating measurement, the program will auto storage two files: an excel files of measured data (*.xls) and a graph (*.png). In Fig. 6 (b), the function of 'Waveform Chart' can display the result of measurement with real-time which will be written into selected saving path file. The saving path is retained in beginning, which provides a function to auto-save the completed measurement curve for the '*.png' formation.



(a)



(b)

Figure 6: Program framework of (a) storage interface and (b) display interface.

4. Results and Discussion

The real-time remote wireless sensing system was used to detect pH buffer solutions in this study. After built the experiment instruments, users can operate the system in user interface. At the first step, users select instrument with wireless sensor network and choose the signal channels. The next step is to key the measurement time and time interval. If users decide the correct parameters, the final step is to start the graphical language LabVIEW of real-time remote wireless sensing system. The diagram of user interface is shown in Fig. 7.

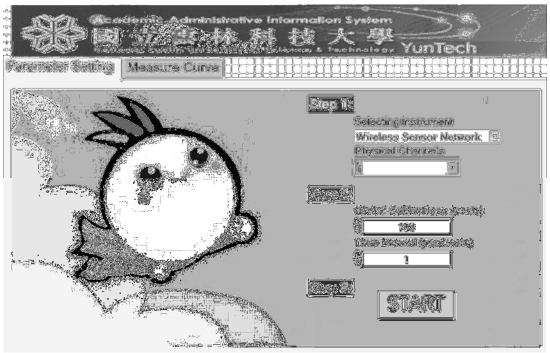


Figure 7: Diagram of user interface.

In this study, we built the pH detection system to detect pH value, and integrated with the wireless sensor network, transmitted signals with real-time and displayed the results. The pH flexible biosensor was based on RuO_2/PET. The pH detection system was measured in buffer solutions with pH 1, pH 3, pH 5, pH 7, pH 9, pH11. Figure 8 was shown the measure result in buffer solution with pH 3. The experiment results show the average response voltage about −467.8 mV, and the error is around 2 mV. The response voltage is stable in detect process. Setting the immovable measurement time is 180 seconds, if the measurement time needed to change, the parameter settings can be changed in user interface.

Figure 9 was shown the sensitivity of the pH flexible biosensor is 58.23 mV/pH and linearity is 0.994. The linear range is between pH1 and pH 11.

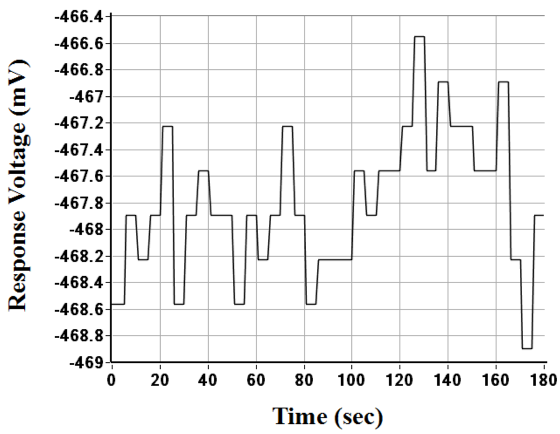


Figure 8: Measurement curve of the pH detection system with pH 3 buffer solution.

The measurement results show that the proposed system was used to measure pH buffer solution, which obtained better sensitivity and linearity. In addition, the measured results were compared with other literatures as shown in Table 1.

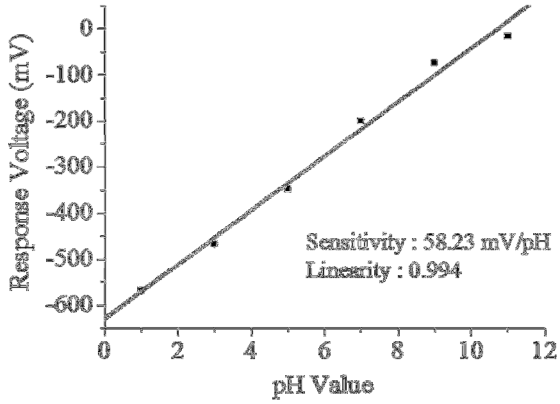


Figure 9: Diagram of measurement results of the pH flexible biosensor.

Different WSN techniques and analytical apparatus were presented to be used for pH detection [14-16]. The WSN system of literature [14] was based on graphical language LabVIEW with the Bluetooth wireless technique for handheld devices. But the measurement system was limit to extend more sensor devices. In this study the measurement node had four channels, and the 16 bits A/D resolution of NI WSN system can process more signal transfer quickly. However, a measurement node offered four analog input channels. If we expected to extend more channels to transmit analog signals, we just needed to add another node to install in NI WSN system. In this study has wide measurement range in requirement of sensitivity better than the literatures [15-16]. In addition, the graphical language LabVIEW is the simpler and more flexible than literature [16]. The graphical language is easily customized and controlled with different sensor devices.

We presented a wireless sensing system based on the transmission platform. In the future, this system can be developed in the applications of other sensors or biosensors such as temperature, glucose, Na^+ etc., and can provide health care living.

Table 1: WSN system in this study is compared with other literatures [14-16].

References	In this study	[14] (2009)	[15] (2012)	[16] (2011)
Method of Transmission	Zigbee, Twisted Pair	Bluetooth, RS-232	Bluetooth, RS-232	2.4GHz Wireless Transceiver, RS-232
A/D Resolution	16 bits	12 bits	10 bits	8 bits
Analytical Apparatus	LabVIEW	LabVIEW	LabVIEW	ASCII
Application	pH	pH, Uric Acid, and Glucose	pH, Potassium, Sodium, Chloride	pH, Temperature, Chlorine
pH range	pH 1 – 11	pH 1 – 13	pH 2 – 12	pH 4 – 10
Sensitivity	58.23 mV/pH	50.27 mV/pH	57 mV/pH	-
Linearity	0.994	-	0.993	-

Note: - means not available.

5. Conclusions

In this study, the wireless sensing system has been successfully prepared for detecting pH value. The system was designed and integrated with pH detection system and transmission platform. The system provides real-time monitoring and rapid detection, and the detection range from pH 1 to pH 11 with sensitivity 58.23 mV/pH, linearity 0.994. Moreover, the wireless sensing system was designed by using graphical language LabVIEW which can design different functions according to user's needs. In the future, the system can apply to healthcare at home, provide user with better quality of life and better health in a cost effective manner.

6. Acknowledgment

This study was supported by National Science Council, The Republic of China under contracts NSC 100-2221-E-224-017 and NSC 101-2221-E-224-046.

7. References

1. L. R. Garcia, P. Barreiro, and J. I. Robla, Performance of ZigBee-Based Wireless Sensor Nodes for Real-Time Monitoring of Fruit Logistics, J. Food Eng., Vol. 87, pp. 405-415, 2008.
2. H. J. Lee, S. H. Lee, K. S. Ha, H. C. Jang, W. Y. Chung, J. Y. Kim, Y. S. Chang, D. H. Yoo, Ubiquitous Healthcare Service Using Zigbee and Mobile Phone for Elderly Patients, Int. J. Med. Informatics, Vol. 78, pp. 193-198, 2009.
3. A. Milenkovic, C. Otto, E. Jovanov, Wireless Sensor Networks for Personal Health Monitoring: Issues and an Implementation, Comput. Commun., Vol. 29, pp. 2521-2533, 2006.
4. M. F. Othman, K. Shazali, Wireless Sensor Network Applications: A Study in Environment Monitoring System, Procedia Engineering, Vol. 41, pp. 1204-1210, 2012.
5. W. S. Jang, W. M. Healy, M. J. Skibniewski, Wireless Sensor Networks as Part of a Web-Based Building Environmental Monitoring System, Autom. Constr., Vol. 17, pp. 729-736, 2008.
6. R. Paoli, F. J. Fernández-Luque, G. Doménech, F. Martínez, J. Zapata, R. Ruiz, A System for Ubiquitous Fall Monitoring at Home via a Wireless Sensor Network and a Wearable Mote, Expert Syst. Appl., Vol. 39, pp. 5566-5575, 2012.
7. W. W. Chang, T. J. Sung, H. W. Huang, W. C. Hsu, C. W. Kuo, J. J. Chang, Y. T. Hou, Y. C. Lan, W. C. Kuo, Y. Y. Lin, Y. J. Yang, A Smart Medication System Using Wireless Sensor Network Technologies, Sens. Actuators, A, Vol. 172, pp. 315-321, 2011.
8. P. Bergveld, Development of an Ion-Sensitive Solid-State Device for Neurophysiological Measurements, IEEE Trans. Biomed. Eng., Vol. BME-17, pp. 70-71, 1970.
9. S. Swaminathan, S. M. Krishnan, L. W. Khiang, Z. Ahamed, G. Chiang, Microsensor Characterization in an Integrated Blood Gas Measurement System, Proceedings of IEEE Asia Pacific Conference on Circuits and Systems, Vol. 1, pp. 15-20, 2002.
10. J. Van Der Spiegel, I. Lauks, P. Chan, and D. Babic, The Extended Gate Chemical Sensitive Field Effect Transistor as Multi-Species Microprobe, Sens. Actuators, B, Vol. 4, pp. 291-298, 1983.
11. J. C. Chou, J. M. Chen, An Equivalent Circuit Model for Simulating the Separative Extended Gate Field Effect Transistor, Sens. Lett., Vol. 6, pp. 924-928, 2008.
12. L. L. Chi, J. C. Chou, W. Y. Chung, T. P. Sun, S. K. Hsiung, Study on Extended Gate Field Effect Transistor with Tin Oxide Sensing Membrane, Mater. Chem. Phys., Vol. 63, pp. 19-23, 2000.
13. J. C. Chou, W. C. Chen, C. C. Chen, Flexible Sensor Array with Programmable Measurement System, Proceedings of International Conference on Chemical and Biomolecular Engineering, Japan,

pp. 340-344, 2009.
14. Y. H. Liao, J. C. Chou, Potentiometric Multisensor Based on Ruthenium Dioxide Thin Film with a Bluetooth Wireless and Web-Based Remote Measurement System, IEEE Sens. J., Vol. 9, pp. 1887-1894, 2009.
15. J. F. Cheng, J. C. Chou, T. P. Sun, S. K. Hsiung, H. L. Kao, Study on a Multi-Ions Sensing System for Monitoring of Blood Electrolytes with Wireless Home-Care System, IEEE Sens. J., Vol. 12, pp. 967-977, 2012.
16. W. Y. Chung, C. L. Chen, J. B. Chen, Design and Implementation of Low Power Wireless Sensor System for Water Quality Monitoring, Proceedings of The 5th International Conference on Bioinformatics and Biomedical Engineering, China, 4 Pages, 2011.

酸鹼可撓式生醫感測器與即時遠端無線感測系統之設計與整合

陳玠廷[1]、周榮泉[1,2]、廖義宏[3]
[1]國立雲林科技大學電子工程系暨電子與光電工程研究所
[2]國立雲林科技大學電子工程系
[3]環球科技大學資訊管理系

摘要

本論文係利用無線感測網路(WSN)之 ZigBee 技術整合酸鹼可撓式生醫感測器，此無線感測系統經由圖形化程式語言-實驗室虛擬儀器工程平台(LabVIEW)被實現。此無線感測系統可分為前端之酸鹼值檢測系統與後端之傳輸平台二個部分，此酸鹼值檢測系統包括二氧化釕/聚乙烯對苯二甲酸酯(RuO_2/PET)生醫感測器、銀/氯化銀(Ag/AgCl)參考電極與讀出電路，傳輸平台即時傳送檢測訊號並顯示結果於電腦中。此外，無線感測系統被用於檢測緩衝溶液中之酸鹼值。

關鍵字：無線感測網路、ZigBee、酸鹼可撓式生醫感測器、實驗室虛擬儀器工程平台