Wirelessly Networked Quad-CZT Array for Uranium Enrichment Verification

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1. Introduction

Korea Institute of Nuclear Nonproliferation and Control (KINAC) have developed Quad-CZT 1st and Quad-CZT 2nd system for uranium enrichment verify-cation. Developed Quad-CZT systems consist of detector and laptop computer, which are connected by USB cable. Paradoxically, one of the most serious drawback of the condition is that operation time is limited to battery capacity of laptop computer and distance is limited to length of the cable. Moreover, it causes the long preparation time for set-up the detection.

As these reasons, Quad-CZT 3rd system is being developed to simplify equipment for improving port-ability. Firstly, detector and tablet PC are integrated into one device. In addition, tablet PC is detachable and it is able to receive the measurement data from detector under wireless network environment.

This paper will give an account of characteristic of Quad-CZT 3rd system

2. Description of the Equipment

2.1 Characteristics of Quad-CZT 3rd system

CZT semiconductor could not be made in large size because of physical properties. For this reason, there are low detection efficiency for gamma [2]. To enhance the efficiency of detector, four CZT semi-conductors are combined to operating as one detector.

As shown in Fig.1, two Quad-CZT systems need USB cable to connect the detector and laptop computer. On the other hand, the Quad-CZT 3rd system integrates the detector and tablet PC as shown at Fig. 2. Also, user handle tablet PC in separating or combining to detector optionally. When tablet PC is combined with Quad-CZT 3rd system through magnetic connection, power is supplied from the battery that equipped in the CZT system. By applying the embedded system, the efficiency of equipment operation has been enhanced.

(a) Quad-CZT 1st (b) Quad-CZT 2nd

Fig. 1. Developed Quad-CZT array system

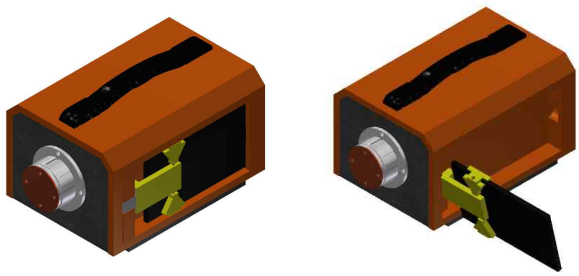

Fig. 2. Virtual Form of Quad-CZT 3rd system

In terms of hardware, total size of the system is 324 mm(W) × 206.2 mm(L) × 211 mm(H). Side of the system is designed to fix a tablet PC by using hinge as shown Fig. 2 Shielding is needed to minimize the interference from the other radiation and to get the accurate spectrum for uranium. So detecting element of CZT array is covered with plastic material and there is detachable shield to minimize the background influence when user measure a uranium pellets and gamma sources.

2.2 Schematic configuration of Quad-CZT 3rd system

Development of CZT system is divided into several parts such as detectors, data processing, high-voltage control, charge of battery, algorithm implementation for uranium enrichment analysis and design of hardware. The Fig. 3. means full block diagram of Quad-CZT 3rd system. First, some current is produced by interaction with detector and radiation. The current is converted to voltage in proportion to energy of radiation and then it exchanges some signal.

In the next step, the produced signal is amplified. The noise of the signal is removed on steps of data processing circuits. The data processing circuits are composed of matching impedance, baseline control, shaping circuits and generation module of difference amplifier signal.

The signal is moved to acquisition board of data. It consists of MCA (Multi-channel analysis), MCU (Master control unit) and communication module. In addition to that, MCA consist of ADC (Analog-digital converter) and FPGA (Field-programmable gate array). The analog signal is converted to digital signal on ADC and the digital signals is collected to digital circuit on the FPGA. FPGA produce gamma spectrum by gathering the digital signal. The XC7Z020 model was used on the FPGA which is manufactured by Xilinx. A characteristic of XC7Z020 is that user can materialize customization circuit by adding some IP on FPGA.

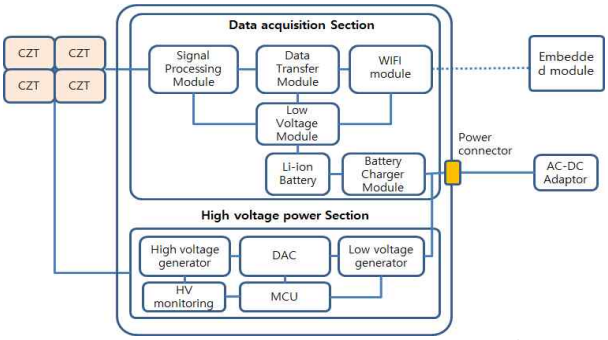

Fig 3. Configuration schematic of Quad-CZT 3rd System

The generated spectrums are transferred to packet of MCU and it is sent to external PDA like tablet PC. The selected MCU is AT91SAM3X8E which produced by ATMEL. Typically, MCU controls the system and interacts with communication module to transfer spectrums. In other words, collected data on FPGA is transformed and transmitted to wireless communication module (Wi-Fi module). Also, AT91SAM3X8E is adapted for GPIF™ (General Programmable Interface) that user can freely configure. So AT91SAM3X8E can interact with various processor like ASIC(application-specific integrated circuit), image sensor, FPGA and other communication module.

Finally, these spectrum data are transferred to application of tablet PC through wirelessly network module by SPI interface. Because processing speed of SPI(Serial Programming Interface) method is about 10 times faster than the UART(Universal Asynchronous Receiver Transmitter), spectrum can be updated on the application of tablet PC in real time. Now, wirelessly networked Quad-CZT 3rd system is being upgraded to check the spectrum of gamma source every second.

Furthermore, it has special feature that is easy to use due to design to treat various error situation by proper AT(attention) command.

2.3 Application program for Uranium Enrichment measurement equipment

The operating application of Quad-CZT 3rd System is developed. The application program runs on Android OS and this program have four functions that background measurement, energy calibration, reference measurement and uranium enrichment measurement as shown fig.5.

The menu options are described as below:

1. After measuring background, the result is applied to measurement of samples.
2. Calibration menu is selected to correspond channel with peak energy of gamma source to get the accurate identification of isotopes.
3. To get a simple spectrum of gamma source, the menu is chosen.
4. The menu is used to verify enrichment of uranium by calculating efficiency of enrichment based on two or three known uranium samples.

Fig 5. Application program for Uranium Enrichment measurement equipment (Quad-CZT 3rd System)

3. Conclusions

Quad-CZT 3rd system is developed in order to overcome an inconvenience for USB connection of already developed Quad-CZT 1st system and Quad-CZT 2nd system. Quad-CZT 3rd system is operated under wireless network for uranium enrichment verification. Further, the CZT system is applied to embedded equipment which is combination of CZT detectors and gamma analysis device. Portability of the CZT system is enhanced due to embedded system. And availability will be increased because constraints of UBS connection are resolved. Finally, a variety of experiments will be conducted to improve performance of a Quad-CZT 3rd system at field or NDA laboratory.

Additionally, Development of Quad-CZT 3rd system would be expected to utilize safeguard inspections on nuclear facility because of convenience and accessibility. Moreover, it will be looking forward to inspection equipment of IAEA.

REFERENCES

[1] Ae-Ri Lee, Jung-Ki Shin, Uk Ryang Park, Yongkwon Kim, Sung-Woo Kwak, and Heejun Chung, Comparing the Performance of Portable Gamma Spectrometry Systems based on the Quad-CdZnTe Array" 2016 IEEE NSS-MIC-RTSD

[2] Z. Xiaoqing, C. Zeng, D. M. Jamal, P. Hao, Improving the Spatial Resolution in CZT Detectors using Charge Sharing Effect and Transient Signal Analysis: Simulation Study, Nuclear Inst. And Method in Physics Research, Vol.808, p. 60, 2015.