

Embedded Based Control System for Irradiation Tests of Space Simulation Environment

Young-Gi Song*, Sang-Pil Yoon, Han-Sung Kim, Hyeok-Jung Kwon

Korea Multi-purpose Accelerator Complex, Korea Atomic Energy Research Institute, Gyeongju 38180, Korea

*Corresponding author: ygsong@kaeri.re.kr

1. Introduction

The proton beam can be the main source of radiation that simulates radiation effects such as single event effects (SEE), total ionizing dose effects (TID), and disposition damage (DD) experienced by electronic equipment (EE parts) in space environments. Therefore, satellites, electronic components and equipment (EE parts) mounted on the spacecraft will perform acceleration tests on radiation received during the mission at proton beam irradiation test facilities on the ground. Devices at the irradiation test facility for space component testing consist of proton beam flux, beam profile measurement, and remote systems that control internal devices such as electronics, beam shutters, and collimator processing signals to the beam diagnosis device. The flux of the proton beam supplied to the DUT in the irradiation test facility of the space component enables real-time monitoring by the beam diagnosis device. During the experiment, when the target irradiation amount is set through the user interface and the target irradiation amount is reached, the beam shutter is driven to block the proton beam. This paper describes the construction of a control system that monitors proton beam flux in real time and automatically blocks the beam in the irradiation test facility.

2. Target control system

When irradiating beams in irradiation test facilities, AC current transformer and faraday cup are used as beam diagnostic equipment to measure beam current. The beam user is required to monitor the accumulated amount of irradiation in real time. The configuration diagram of the system for integrated control of these devices is shown in the Fig 1, and the main functions are summarized as follows.

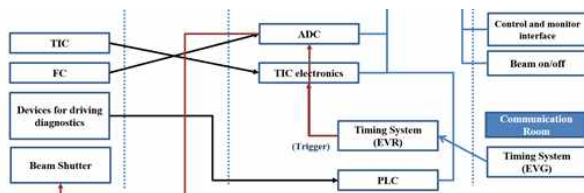


Fig. 1. Configuration for target control system

- Integrated control by EPICS IOC
- Signal processing and storage by EPICS IOC.
- Synchronization of the accelerator timing system.
- Remote control integrated control by EPICS IOC.

The beam charge amount is measured and a control system is implemented to measure the beam flux per pulse in real time and block the beam for the accumulated flux.

2.1 Establishment of development environment

As hardware for beam measurement, Digilent zybo-z7-20 shown in Fig 2 and Analog Device AD7605 ADC are adopted. A development environment is established with Vivado Design Suite and Petalinux for the development of ADC devices and EPICS IOC servers on Zynq SoC [1]. The Zynq uses an AXI interface between PS and PL. on the PL side, there are AXI Master (High Performance) ports, AXI General Purpose (GP) ports, AXI Slaves GP, and AXI Master ACP ports. The PS connected to the PL uses a GPIO controller. The Petalinux tools offers everything necessary to customize, build and deploy Embedded Linux solution on Xilinx processing systems. We customize the boot loader, linux kernel, linux application.

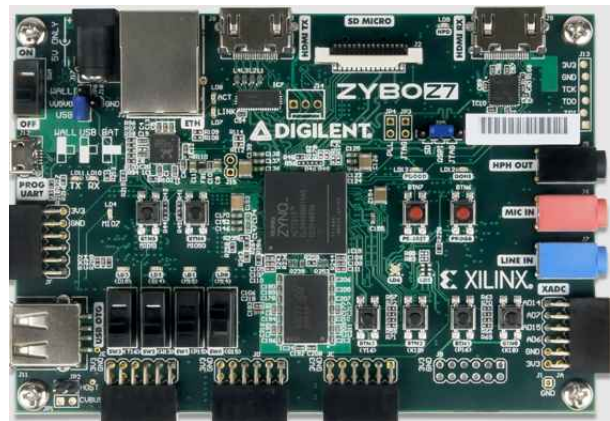


Fig. 2. Zybo z7-20 board based on zynq 7000 SoC

2.2 Development of PL

The operation of the control system accumulates data by acquiring data from the ADC for a predetermined time (1.3 ms) and averaging the data for a set time when the external trigger is input. If this accumulated data is greater than a predetermined value, an output signal is generated and a beam shutter is driven.

- Download and install the install program from the xilinx site.
- When Vitis is installed, Vivado is also included

inside. When installing petalinux, it is recommended to install version accordingly.

- Device tree generator
- Download and install the Petalinux
- Build PL with AXI peripheral
- Create IP and zynq project
- External peripheral connection

The PIN connection between ADC and FPGA was designed as Fig 3.

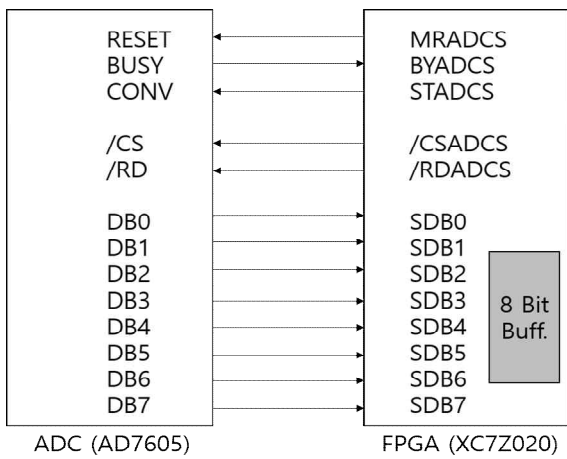


Fig. 3. PIN connection between AD7605 and FPGA

3. Build PS

The sampling data is saved at the trigger receiving edge (trigger is only at the start point). The storage time is about 1.3 ms. The actual required data is data for some sections after trigger occurs, To acquire data before and after, about 1.3 ms of data is obtained. Interrupt occurs after saving is completed, and data is overwritten when the next trigger comes in. Accumulated by averaging the data of the actual necessary section of the stored data. Digital out is generated by comparing the accumulated value and the threshold value.

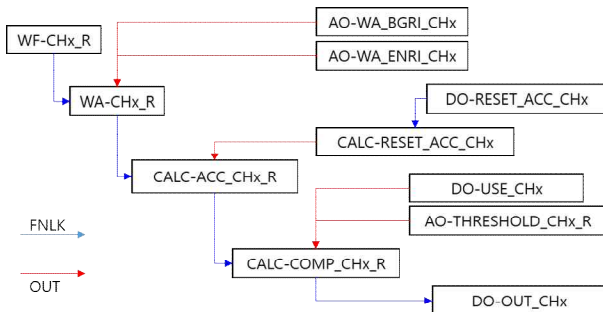


Fig. 4. Design of data accumulation and comparison processing using EPICS record

The data is accumulated and compared in the EPICS of high level application. After generating waveform when interrupt occurs in EPICS, the following calculation is processed. Data accumulation and comparison processing use Calcord and waveProc records [2] as shown in Fig. 4.

Figure 5 shows the user interface implemented using the EPICS CSS [3]. For precise analysis of data, EPICS waveProc record was applied. In the test, it was possible to measure beams of 50uS and 100uS.

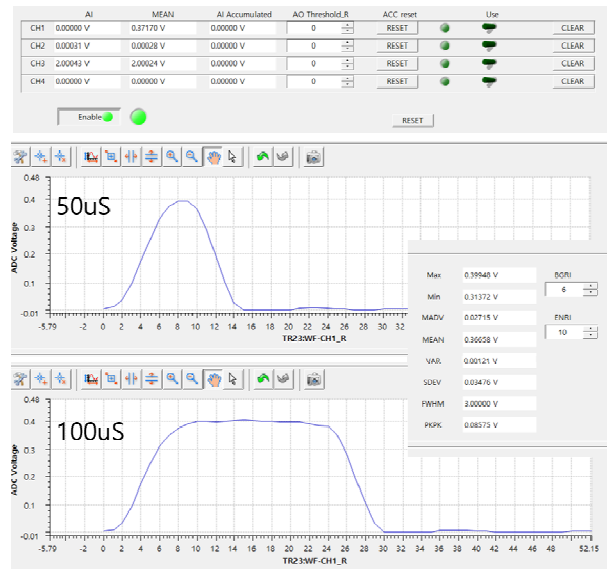


Fig. 5. User interface using EPICS CSS

4. Conclusion

A control system to be used in a beam irradiation test for simulating a space environment was developed using SoC (System on Chip)-based zynq board. It is designed to collect beam data in real time with ADC chips and simultaneously analyze and accumulate data to block beams. In the future, a part of increasing the ADC sampling clock in consideration of beam size and repetition will be further studied.

Acknowledgement

This research was supported by the National Research Foundation of Korea (NRF-2021M2D1A1045615).

REFERENCES

- [1] Vitis download
<https://www.xilinx.com/support/download/index.html/content/xilinx/en/downloadNav/vitis.html>
- [2] Experimental Physics and Industrial Control System (EPICS). URL:<http://www.aps.anl.gov/epics>.
- [3] waveProc
<https://epics.anl.gov/modules/soft/waveProc/index.html>