ISBN: 978-3-95450-193-9 doi:10.18429/JACoW-ICALEPCS2017-TUPHA080

# NEW DATA ACQUISITION SYSTEM IMPLEMENTED BASED ON MTCA.4 FORM FACTOR FOR KSTAR DIAGNOSTIC SYSTEM

Taegu Lee†, Woongryol Lee, Taehyun Tak, Gill Kwon and Jaesic Hong,
National Funsion Research Institute (NFRI),
113 Gwahangno, Yuseong-gu, Daejeon 305-333, KOREA

*Abstract*

In Korea Superconducting Tokamak Advanced Research (KSTAR), various diagnostics systems were developed with various form factor digitizer such as VME, CPCI, PXI, VXI. and PCIe. The DAQ systems are measuring the various plasma properties such as plasma current, magnetic current, electron density, electron temperature, plasma image, impurity, and so on.

These complicated form factors installed on KSTAR have difficulties with hardware management, software management and performance upgrades. In order to control real-time systems using several diagnostic signals, the real-time control system is required to share the data without delay between the diagnostic measurement system and the real-time control system without branch one signal. Therefore, we developed the Multifunction Control Unit (KMCU) as the standard control system MTCA.4 form-factor and implemented the various diagnostic DAQ system using KMCU V2, that is KMCU-Z30. This paper will present the implementation of KSTAR diagnostic DAQ systems configured with KMCU based on MTCA.4 and their operating results.

## INTRODUCTION

Korea Superconducting Tokamak Advanced Research has operated and installed various diagnostic devices, and has executed to add and upgraded the DAQ systems according to KSTAR upgrade and installation plan every year since 2008 [1]. As shown in the Table 1, the KSTAR has many diagnostics and various DAQ systems. We had some technical issues and requirements during the operation that is maintenance of hardware and software, and software development. There is a need to incorporate new technologies such as data processing using FPGA and data analysis using GPU into the DAQ system. To overcome these technical issues, we have developed a standard system with MicroTCA.4 form-factor [2][3]. The KMCU-Z35 supports simultaneous two point streaming data transmission but the newly KMCU-Z30 supports simultaneous three point streaming data transmission [2][3]. In 2017, the KSTAR diagnostic DAQ systems were rebuilt with KMCU-Z30, which has several advantages.

## UPGRADE DATA ACQUISITION SYSTEMS

The new DAQ systems were set up with KMUC-Z30 MTCA.4 form-factor controller and digitizers of the D-TACQ [4] in the 64 bit Linux OS platform. It is standalone operation capability for a small size diagnostic.

### *H/W Upgrade the DAQ Systems*

In 2017, three DAQ systems were changed from KMCU-Z35 to KMCU-Z30, and four diagnostic DAQ systems were changed to the KMCU-Z30 of MTCA.4 form-factor. In addition, a new DAQ system was newly added to measure MSE data composed of MIT polychrometer device. As shown in Figure 1, eight KMCU-Z30s are used for the MD DAQ system with ACQ424ELF and are connected to the host PC via PCIe uplink. And the Probe DAQ system was built using the front SFP+ with aurora link, AFHBA400, to operate independently in the same chassis.

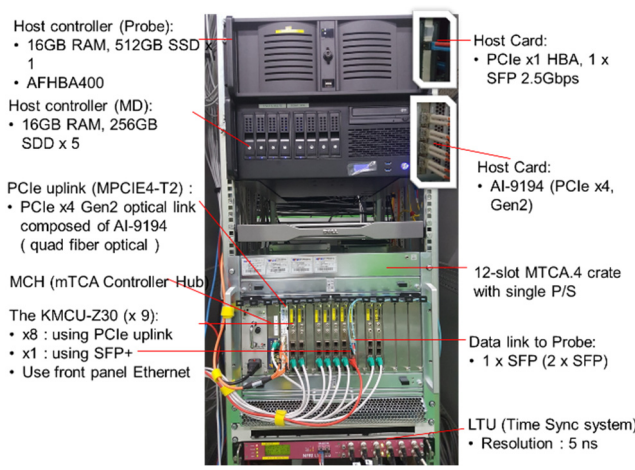


Figure 1: Configuration of MD (with PCIe uplink) & Probe DAQ system (with SFP+) in single create.

As shown in Figure 2, the H-Alpha DAQ systems were configured via the aurora link with a KMCU-Z30 installed in a VT812 chassis.

* Work supported by Korea Ministry of Science and ICT
† glory@nfri.re.kr

ISBN: 978-3-95450-193-9 doi:10.18429/JACoW-ICALEPCS2017-TUPHA080



Table 1: Lists of digitizer of used in 2016 for measuring KSTAR data

| Diagnostic System | No of Ch | Description of DAQ |
|---|---|---|
| MD (Magnet Diagnostics) | 480 | cPCI, 6 digitizers, 16 bit, max 100 KSPS/56 sec (DDS#1) |
| Probe | 96 | |
| H-Alpha Monitor | 30 | cPCI, 16 bit, 1 digitizers, max 500 KSPS, 96 ch |
| ECE Heterodyne Radiometer | 76 | cPCI, 16 bit, 1 digitizers, max 500 KSPS, 96 ch |
| MMW Interferometer | 4 | PXI, 16 bit, 500 KSPS |
| MMW Interferometer with FPGA | 2 | uTCA.4 AMC725, AMC523 100 MSPS, FPGA |
| Thomson Scattering | 198 | VME, 8 * QDC, 12 bit / 5 GSPS 8 bit |
| Mirnov Coil | 43 | KMCU-Z35(uTCA.4) & FMC, 16 bit 2 MSPS, 16 ch x 4 (64 ch) |
| Soft X-ray Array | 288 | cPCI, 16bit, 500 KSPS, 4 digitizers (max 384 ch) |
| Reflectometer | 8 | PXI, 16 bit, 100/200 MSPS |
| Infra-red TV (survey) | 1 | FLIR camera, 120 FPS, 60 FOV |
| Infra-red TV (divertor) | 1 | FLIR SC6100 camera, Window |
| Infrared imaging video bolometer | 1 | Camera, Window 2000 |
| Visible Bremsstrahlung | 17 | PXI, 6 digitizer |
| Visible Spectroscopy | 2 | PCI, CCD, Window |
| Hard X-ray | 4 | PCI, 10 MHz, Window |
| Electron Cyclotron Emission Imaging | 384 | cPCI, 14bit, 2 MSPS |
| Charge Exchange Spectroscopy | 3 | CCD, Window |
| Visible Filter Scope | 12 | PCI, max 100 KHz, Window |
| X-ray imaging crystal spectrometer | 7 | PCI, max 10 KHz, Window |
| Fast ion loss detector | 1, 64, 16 | Camera system – 1 ch / uTCA.4 KMCU-Z35, 16 bit 2MSPS, 16 ch x4 : 64 ch / PXI – 14 bit, 16 ch |
| Motional Stark effect | 22 | uTCA.4- KMCU-Z35 1, 16 bit 2MSPS, 16 ch x 2 : 32 ch |

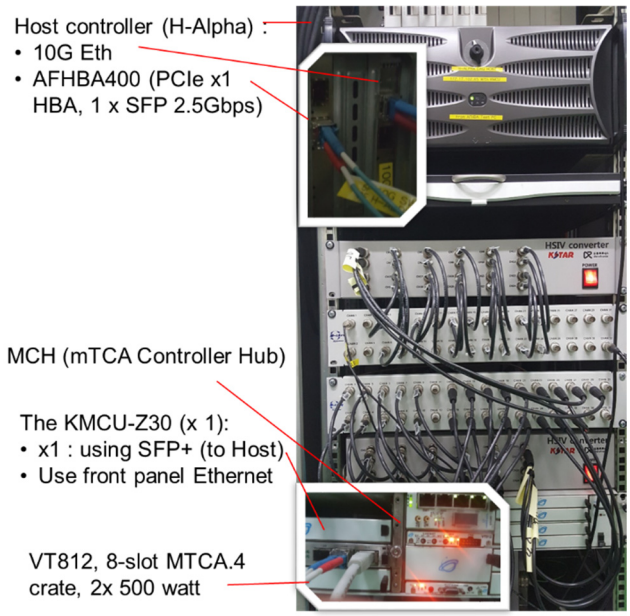


Figure 2: Configuration of H-Alpha DAQ system with SFP+ (AFHBA400).

As shown in Figure 3, the configuration of MSE-K DAQ system duplicate streaming data transmission from single digitizer, ACQ425ELF, to two host systems. One host system was built to reliably store raw data and the other was configured for real-time analysis using the GPU. The KMCU-Z30 are simultaneous streaming data transmission to the two hosts without interference.

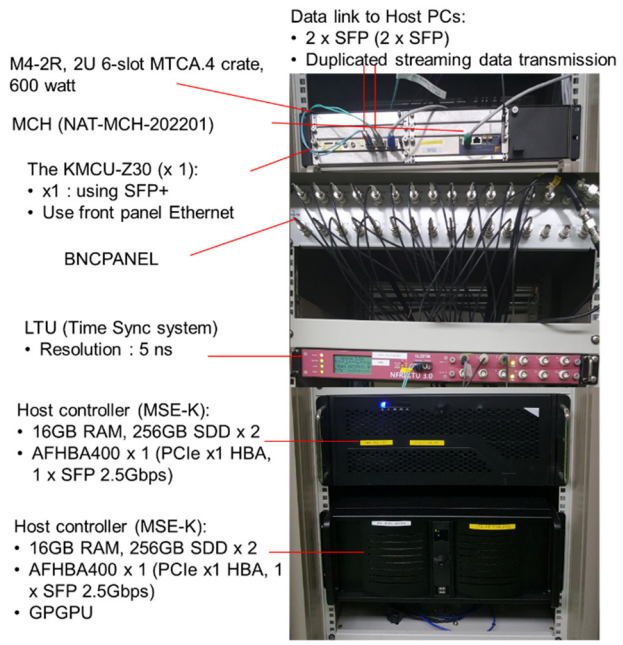


Figure 3: Configuration of MSE-K DAQ system, duplicated streaming data transmission from single digitizer to two systems (can do three way streaming data transmission with PCIe-uplink).

ISBN: 978-3-95450-193-9 doi:10.18429/JACoW-ICALEPCS2017-TUPHA080

Figure 4 shows a configuration using two KMCU-Z30s in one host with aurora PCIe link. The MC DAQ system has 10G Ethernet cards for quick storing of huge raw data to MDSplus [5] DB in central storage. More detailed products of DAQ systems are shown in Table 2.

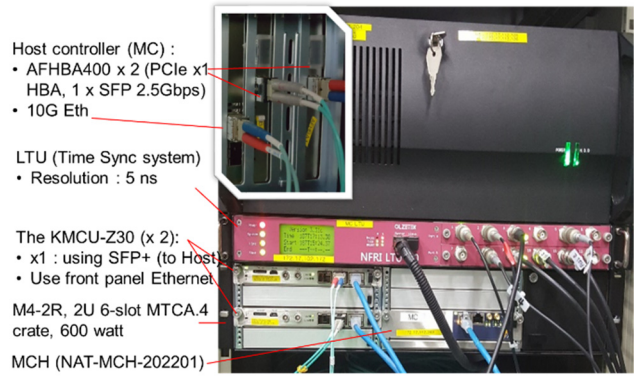


Figure 4: Configuration of MC DAQ system, two KMCU controlled with two AFHBA in single host.

The data acquisition sequence of KSTAR is synchronized with experimental cycle using the LTU [6][7]. The LTU parameters of triggers and clock signals are configured with a pre-programmed scenario before plasma shot. It receives a shot start signal from a Central Timing unit (CTU) and is under control of a CTU in TSS [6][7].

### *S/W Development for Standard DAQ System*

The DAQ systems of KMCU-Z3x of MTCA.4 form-factor was set up with EPICS [8] middleware based on Linux O/S. The KMCU EPICS IOC was developed with SFW (Standard Frame-Work) [9] for control standardization DAQ system. The SFW is a development package for KSTAR control system. It supports synchronized operation with KSTAR discharge experiment by using internal sequence handler. It provides MDSplus interface and system status manipulator. We can make shorten of system development time and increase the system reliability by using the SFW. The KMCU IOC can be use for each DAQ system IOC by change name of IOC using script. And edit the EPICS IOC to suit the purpose of the diagnostic DAQ system, such as number of channels, MDSplus node name for storing each channel data and etc. The KMCU IOC is streaming data (1 MB) archiving from KMCU-Z3x to host kernel buffer (1 MB * 66). It is extraction one point of data per each channel from 1MB data for raw and voltage data display on real-time. After shot, the DAQ system archives raw data from Local SSD to MDSplus DB in Central Storage.

The GUI to control of DAQ system was developed to use KSTAR Widget Toolkit (KWT) based on Qt library [10].

Table 2: Lists of digitizer of changed with KMC-Z30 in 2017 for measuring KSTAR data

| Diagnostic System | Description of New DAQ |
|---|---|
| MD (Magnet Diagnostics) | uTCA.4- KMCU-Z30 - 8,<br>MTCA.4 Optical PCI Express 4x Link (MPCIE4-T2 & AI-9194) - 1<br>ACQ400-MTCA-RTM2 – 8 : RTM with 2 x ELF sites<br>FMC-424ELF : 16 bit 1MSPS, 32 ch x 16 : 512 ch, |
| Probe | uTCA.4- KMCU-Z30 1,<br>AFHBA400 –1 : PCIe 1x HBA, Single SFP 2.5 Gbps<br>ACQ400-MTCA-RTM2 – 1 : RTM with 2 x ELF sites<br>FMC-424ELF :16 bit 1MSPS, 32 ch x 2 : 64 ch |
| H-Alpha Monitor /Visible Bremsstrahlung | uTCA.4- KMCU-Z30 - 1,<br>AFHBA400 –1 : PCIe 1x HBA, Single SFP 2.5 Gbps<br>ACQ400-MTCA-RTM2 – 1 : RTM with 2 x ELF sites<br>FMC-424ELF :16 bit 1MSPS, 32 ch x 2 : 64 ch |
| Mirnov Coil | uTCA.4- KMCU-Z30 - 2,<br>AFHBA400 –2 : PCIe 1x HBA, Single SFP 2.5 Gbps<br>ACQ400-MTCA-RTM2 – 2 : RTM with 2 x ELF sites<br>FMC-425ELF :16 bit 2MSPS, 16 ch x 4 : 64 ch |
| Fast ion loss detector (FILD) | uTCA.4- KMCU-Z30 - 1,<br>AFHBA400 –1 : PCIe 1x HBA, Single SFP 2.5 Gbps<br>ACQ400-MTCA-RTM2 – 1 : RTM with 2 x ELF sites<br>FMC-425ELF :16 bit 2MSPS, 16 ch x 2 : 32 ch |
| Motional Stark effect (KSTAR) | uTCA.4- KMCU-Z30 - 1,<br>AFHBA400 –1 : PCIe 1x HBA, Single SFP 2.5 Gbps<br>ACQ400-MTCA-RTM2 – 1 : RTM with 2 x ELF sites<br>FMC-425ELF :16 bit 2MSPS, 16 ch x 2 : 32 ch |
| Motional Stark effect (MIT) | uTCA.4- KMCU-Z30 - 1,<br>MTCA.4 Optical PCI Express 4x Link (MPCIE4-T2 & AI-9194) - 1<br>ACQ400-MTCA-RTM2 – 1 : RTM with 2 x ELF sites<br>FMC-424ELF : 16 bit 2MSPS, 16 ch x 2 : 32 ch, |

ISBN: 978-3-95450-193-9 doi:10.18429/JACoW-ICALEPCS2017-TUPHA080



## RESULT OF OPERATION

We constructed the DAQ systems with various configurations using new standard equipment. After DAQ system was upgraded with KMCU-Z30, its stability and usability were improved. Only FILD DAQ systems had some faults in the campaign. The digitizer is located in the KSTAR Tokamak Hall, which is not convenient for electrical equipment. So we could not stop the digitizer from stopping.

New developed DAQ systems has been upgraded and successfully operated during KSTAR experimental campaigns.

## SUMMARY AND FUTURE PLAN

The DAQ systems were newly set up in KSTAR operation in 2017, so the new system was built to operate with improvement of its performance and function. The DAQ system has a lot of advantages in its hardware and software.

Next campaign, we will use segment record for handling large signals in MDSplus. We will use the duplicated data for real-time data analysis with GPGPU in MSE system. For upgrade performance of Ethernet, will be install 10G Eth card in DAQ systems.

## ACKNOWLEDGMENT

This work is supported by Ministry of Science and ICT. We would also like to thank all the member of KSTAR control research team.

## REFERENCES

[1] Mikyung Park, et.al.., “Data acquisition system implemented with various platform for KSAR diagnostic systems”, Fusion Eng.Des. 85 (2010) 350-355.

[2] Woongryol Lee et al., “MicroTCA Based Data Acquisition System for KSTAR Tokamak”, 20th IEEE-NPSS Real Time Conference, (2016)

[3] Woongryol Lee et al., “New control systems at KSTAR compatible with ITER standard technologies” [Paper submitted for publication; the name of the periodical does not appear]

[4] D-TACQ, http://www.d-tacq.com

[5] MDSplus, http://www.MDSplus.org

[6] Mikyung Park, et al.., “Development of a Prototype Time Synchronization System for KSTAR with a VME-bus System”, Fusion Eng. Des. 81 (2006) 1817-1821

[7] Mikyung Park. Other, “The Upgrade of KSTAR Timing System to Support Long Pulse Operation and High speed Data Acquisition”, Proceedings of IAEA TM (2011).

[8] EPICS, http://www.aps.anl.gov/epics

[9] Woongryol Lee, Other, “Design and implementation of a standard framework for KSTAR control system”, 9th IAEA TM on Control., (2013).

[10] S.Baek, et.al.., “KSTAR widget toolkit using Qt library for the EPICS-based control system” Proceedings of ICALEPCS (2009).