New Data Acquisition System Implemented Based on MTCA.4 Form Factor for KSTAR Diagnostic System

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Introduction

- **The KSTAR Control System has been developed using EPICS (Experimental Physics and Industrial Control System) as a middleware of control and DAQ system**
- **From 2008, The KSTAR has various form factor DAQ systems for measuring the various plasma properties. : VME, cPCI, PXI, VXI and etc. [1]**
- **Using two types of database :**
  - ✓ **EPICS Channel Archiver : continuously produced machine operational data at a low rate**
  - ✓ **MDSplus : shot-based experimental pulse data with a large volume**
- **Development & Operating software : EPICS, MDSplus, Qt, Linux, Vxworks, Windows, CCS, etc**
- **Real-time Feedback Control on Plasma current(Ip), Radial Position(Rz) , and density (ne) using MD and MMW interferometer**

❖**Currently, over 21 types of diagnostics installed for plasma operation**
❖**Requirements and Technical issues :**
- **Raises maintenance and development issue the various form factor DAQ systems (H/W & S/W)**
- **Use as real-time control without interfering with data archiving**
- **Malfunction due to the Ageing of equipment**
- **Require new technology : data processing in DAQ system using FPGA or GPGPU**

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

ID	DAQ system	Diagnostic System	CH	Description of DAQ
1	MD (Magnet Diagnostics)	Rogowski Coil, Flux/Voltage Loop, Magnetic Field Probe, Diamagnetic Loop, Vessel Current Monitor, Halo Current Monitor	480	cPCI, 6 digitizers, 16-bit, max 100KSPS/56sec (DDS#1)
2	Probe	Probe	96	
3	HALPHA	H-Alpha Monitor	30	cPCI, 16-bit, 1 digitizers, max 500KSPS, 96ch
4	ECE-HR	ECE Heterodyne Radiometer	76	cPCI, 16-bit, 1 digitizers, max 500KSPS, 96ch
5	MMWI	MMW Interferometer	4	PXI, 16bit, 500KSPS
6	MMWI2	MMW Interferometer	2	uTCA.4 AMC725, AMC523 100MSPS, FPGA
6	TS	Thomson Scattering	198	VME, 8*QDC, 12bit / 5GSPS 8bit
7	MC	Mirnov Coil	43	KMCU-Z35(uTCA.4) & FMC, 16bit 2MSPS, 16ch x 4 (64ch)
8	SXR	Soft X-ray Array	288	cPCI, 16bit, 500KSPS, 4 digitizers (max 384ch)
9	ER	Reflectometer	8	PXI, 16bit, 100/200MSPS
10	IRTV_S1	Infra-red TV (survey)	1	FLIR camera, 120 FPS, 60 FOV
11	IRTV_D1	Infra-red TV (divertor)	1	FLIR SC6100 camera, Window
12	IRVB	Infrared imaging video bolometer	1	Camera, Window 2000
13	VBS	Visible Bremsstrahlung	17	PXI, 6 digitizer
14	VSS	Visible Spectroscopy	2	PCI, CCD, Window
15	HXR	Hard X-ray	4	PCI, 10MHz, Window
16	ECEI	Electron Cyclotron Emission Imaging	384	cPCI, 14bit, 2MSPS
17	CES	Charge Exchange Spectroscopy	3	CCD, Window
18	VFS	Visible Filter Scope	12	PCI, max 100KHz, Window
19	XICS	X-ray imaging crystal spectrometer	7	PCI, max 10KHz, Window
20	FILD	Fast ion loss detector	1, 64, 16	Camera system - 1ch / uTCA.4 KMCU-Z35, 16bit 2MSPS,16ch x4 : 64ch / PXI – 14bit, 16ch
21	MSE_K	Motional Stark effect for KSART diagnostic device	32	uTCA.4- KMCU-Z35 1, 16bit 2MSPS,16ch x 2 : 32ch

Upgrade of DAQ Systems

- **Adopt the MTCA.4 for standardization of a fast controller (DAQ) :**
  - ✓ **Developed the KSTAR Multi-function Control Unit at '15 ~'16 : ver KMCU-Z35 (High performance)**
  - ✓ **Developed new version of KMCU for suitable device at '16 ~ '17 : ver KMCU-Z30 (2 SFP+) [2]**
  - ✓ **At 2017, change 6 digitizer and one additional install with new version of KMCU-Z30 [3]**

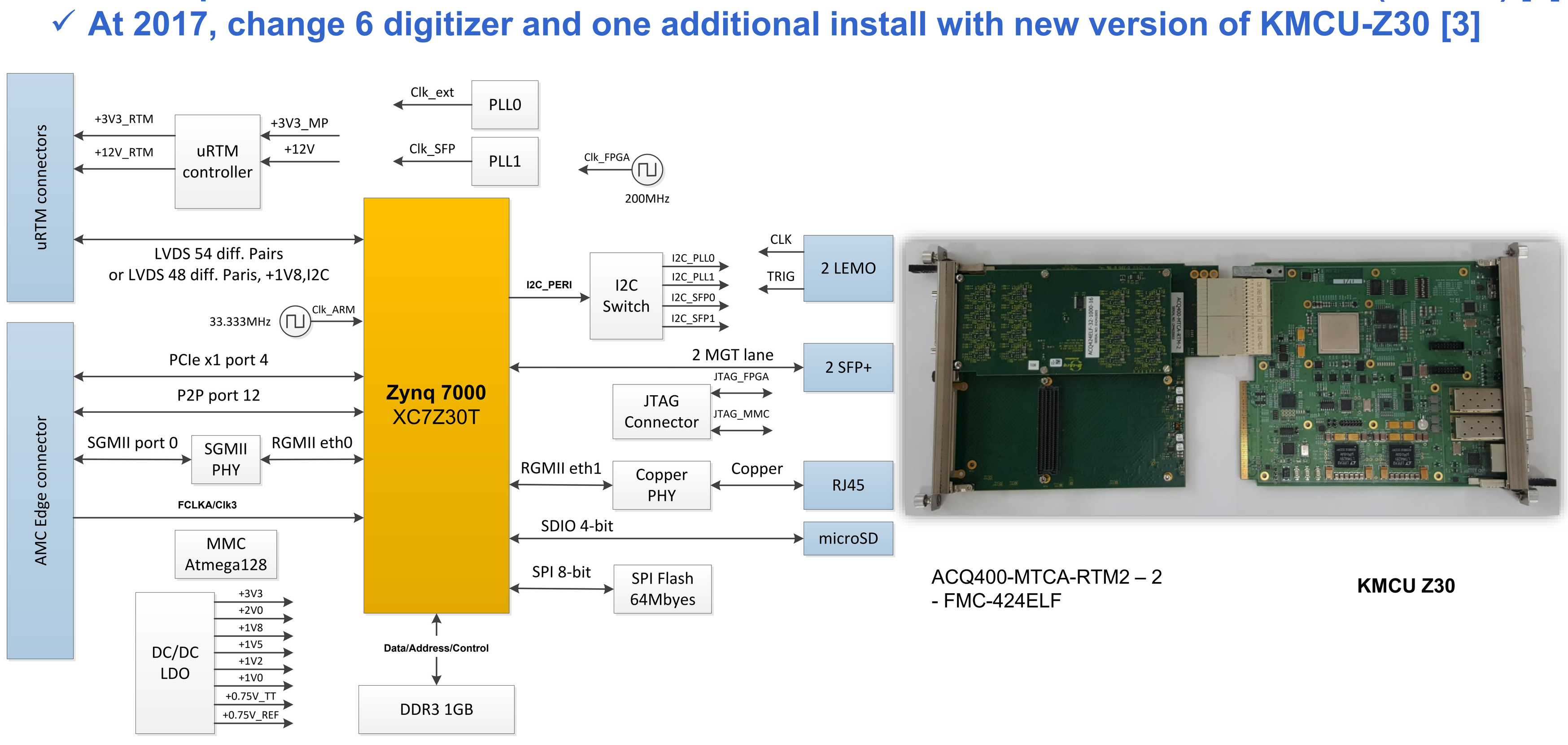

Figure 1. A Block diagram of KMCU-Z30 (changed FPGA, 2 SFP front interface and Backplane (PCIe x4 -> PCIe x1 Gen2) and KMCU-Z30 & ACQ400-MTCA-RTM2 with digitizer [3]

➢ Upgrade of DAQ Systems

- Several DAQ systems were upgraded and newly developed using KMCU-Z30 (various configuration)

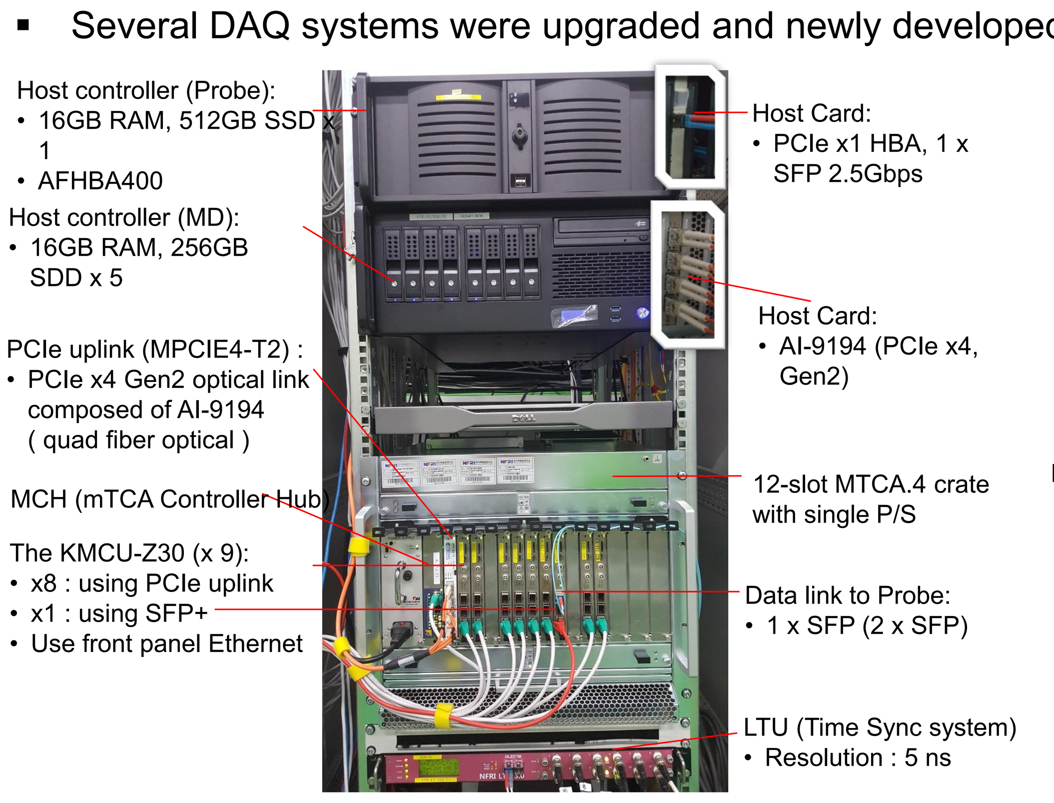

Figure 2. Configuration of MD (with PCIe uplink) & Probe DAQ system (with SFP+) in single create

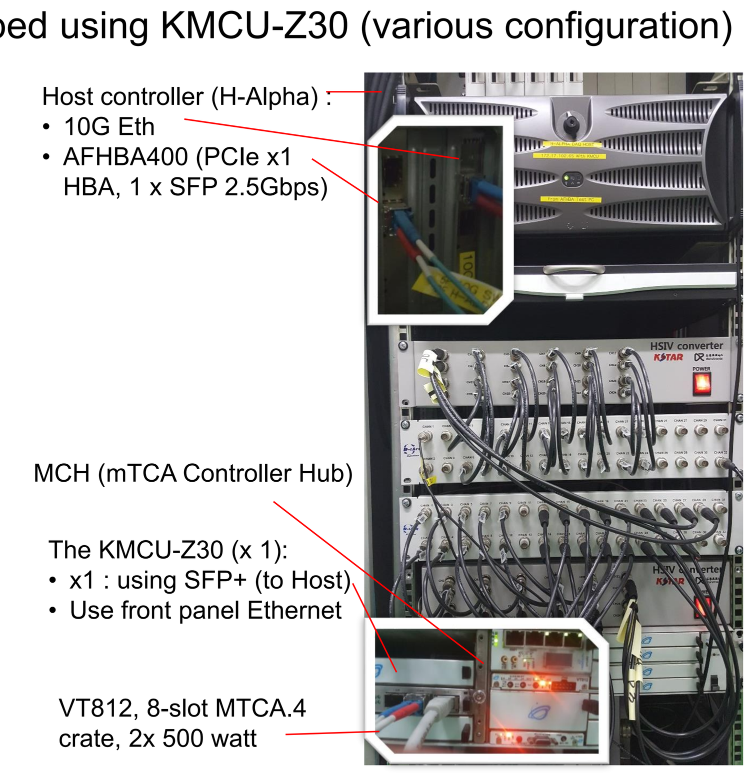

Figure 3. Configuration of H-Alpha DAQ system with SFP+ (AFHBA400)

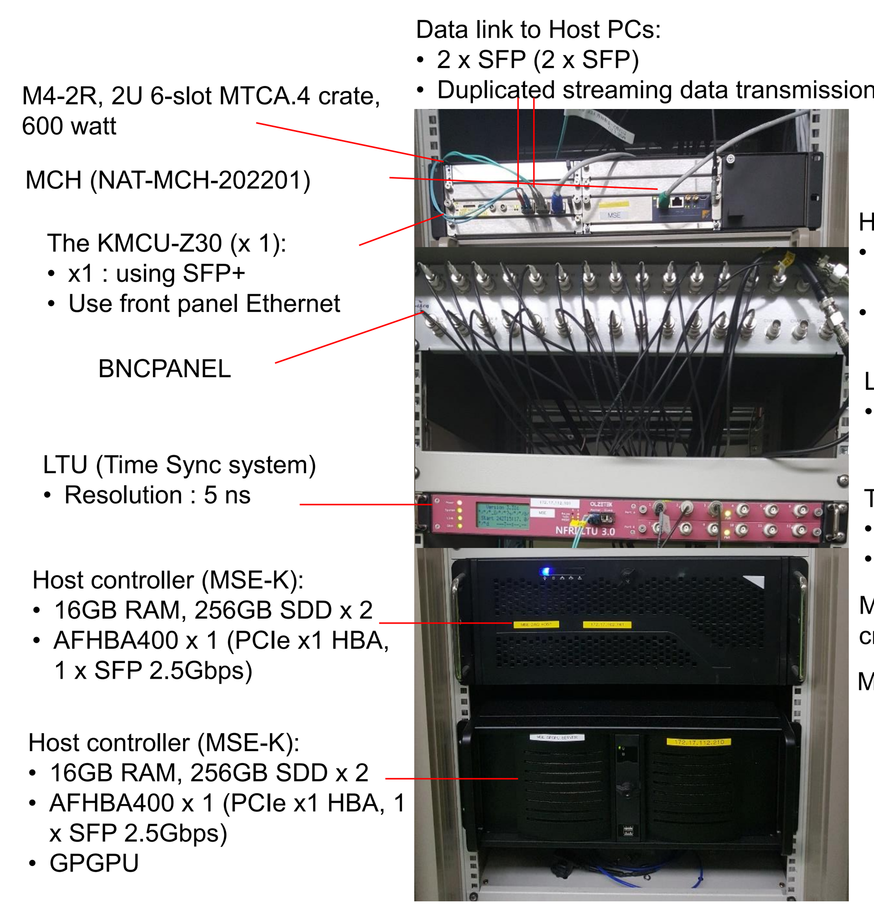

Figure 4. Configuration of MSE-K DAQ system, duplicated streaming data transmission from single digitizer to two systems (can do three way streaming data transmission with PCIe-uplink)

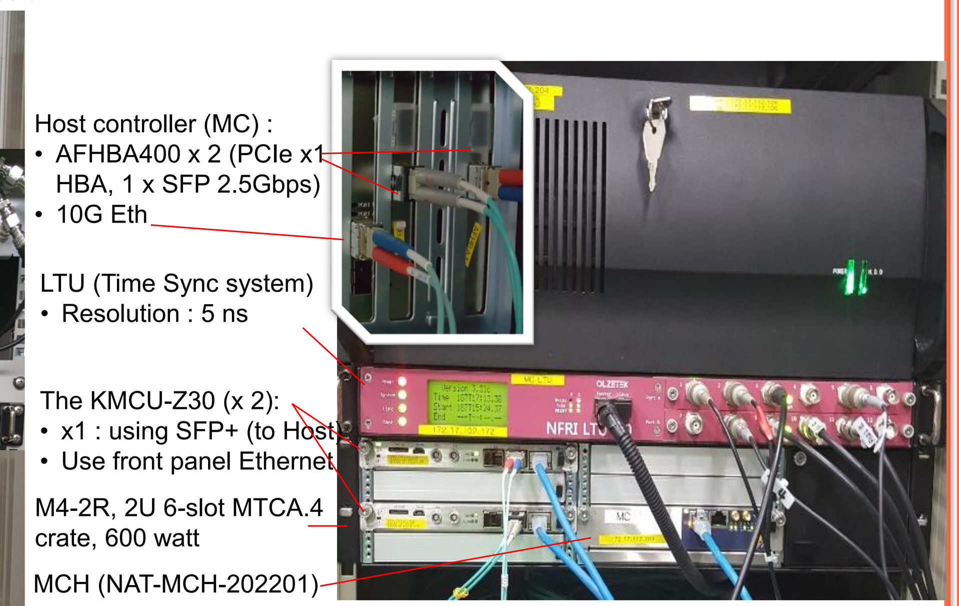

Figure 5. Configuration of MC DAQ system, two KMCU controlled with two AFHBA in single host

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

ID	DAQ system	Description of previous DAQ	Description of New DAQ
1	Magnet Diagnostics	cPCI, 6 digitizers, 16-bit, max 100KSPS/56sec (DDS#1)	uTCA.4- KMCU-Z30 - 8, MTCA.4 Optical PCI Express 4x Link (MPCIE4-T2 & AI-9194) - 1 ACQ400-MTCA-RTM2 – 8 : RTM with 2 x ELF sites FMC-424ELF : 16bit 1MSPS,32ch x 16 : 512ch,
2	Probe	cPCI, 6 digitizers, 16-bit, max 100KSPS/56sec (DDS#1)	uTCA.4- KMCU-Z30 1, AFHBA400 –1 : PCIe 1x HBA, Single SFP 2.5Gbps ACQ400-MTCA-RTM2 – 1 : RTM with 2 x ELF sites FMC-424ELF :16bit 1MSPS,32ch x 2 : 64ch
3	HALPHA	cPCI, 16-bit, 1 digitizers, max 500KSPS, 96ch	uTCA.4- KMCU-Z30 - 1, AFHBA400 –1 : PCIe 1x HBA, Single SFP 2.5Gbps ACQ400-MTCA-RTM2 – 1 : RTM with 2 x ELF sites FMC-424ELF :16bit 1MSPS,32ch x 2 : 64ch
4	VBS	PXI (SCXI), 6 digitizer	
5	MC	KMCU-Z35(uTCA.4) & FMC, 16bit 2MSPS, 16ch x 4 (64ch)	uTCA.4- KMCU-Z30 - 2, AFHBA400 –2 : PCIe 1x HBA, Single SFP 2.5Gbps ACQ400-MTCA-RTM2 – 2 : RTM with 2 x ELF sites FMC-425ELF :16bit 2MSPS, 16ch x 4 : 64ch
6	FILD	uTCA.4 KMCU-Z35, 16bit 2MSPS,16ch x4 : 64ch	uTCA.4- KMCU-Z30 - 1, AFHBA400 –1 : PCIe 1x HBA, Single SFP 2.5Gbps ACQ400-MTCA-RTM2 – 1 : RTM with 2 x ELF sites FMC-425ELF :16bit 2MSPS, 16ch x 2 : 32ch
7	MSE_K	uTCA.4- KMCU-Z35 1, 16bit 2MSPS,16ch x 2 : 32ch	uTCA.4- KMCU-Z30 - 1, AFHBA400 –1 : PCIe 1x HBA, Single SFP 2.5Gbps ACQ400-MTCA-RTM2 – 1 : RTM with 2 x ELF sites FMC-425ELF :16bit 2MSPS, 16ch x 2 : 32ch
8	MSE_M (for MIT diagnostic)	-	uTCA.4- KMCU-Z30 - 1, MTCA.4 Optical PCI Express 4x Link (MPCIE4-T2 & AI-9194) - 1 ACQ400-MTCA-RTM2 – 1 : RTM with 2 x ELF sites FMC-424ELF : 16bit 2MSPS, 16ch x 2 : 32ch,

➢ Software Spec

- Developed the KMCU IOC device/driver for control standardization DAQ with SFW
  - ✓ Simply create new EPICS IOC using script
  - ✓ Edit the EPICS IOC to suit the purpose of the diagnostic DAQ system (number of channels, MDSplus node name for storing each channel data, etc.)
- Standard software framework(SFW) composed of an EPICS library(sfwLib) [7]
  - ✓ Provides essential functions to support common records
- Streaming data (1MB) archiving from KMCU-Z30 to host kernel buffer(1MB * 66)
- Extraction of 1 point data per each channel from 1MB data for raw and voltage data display on real-time
- Storing data in local SSD during a shot
- After shot, DAQ system archives raw data from Local SSD to MDSplus DB (Central Storage)
- OPI panel has been developed by using in-house KWT [6]

Operation Results & Plan

- New developed DAQ systems has been upgraded and successfully operated during KSTAR experimental campaigns.
  - ✓ Constructed the DAQ systems with various configurations using new standard equipment
- Successfully data archiving with new KMCU-Z30 in 2017.
  - ✓ Technical issues in these system : too slow to save data, difficult handling large signals in MDSplus
- 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.
- To reduce the cost of chassis and MCH, we plan to use 1U commercial chassis without MCH.

References

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