The Data Acquisition and Control System of EAST ME-SXR Diagnostic

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***Abstract*–A data acquisition and control system has been realized for a Multi-Energy Soft X-Ray (ME-SXR) diagnostic, which has been built for EAST (Experimental Advanced Superconducting Tokamak) electron temperature profile in the edge plasma region. The system has two functions: long-pulse data acquisition and electronics' automatic gain-control. It provides 96 high-speed channels with optional sampling rates from 250 KSPS to 1 MSPS, which can long-pulse acquires signals of ME-SXR. In the meanwhile, it transfers the data to the MDSplus server in real-time and users can access to the data during the discharge. The signals from the diode array detectors are in the microampere range, which should be amplified by the electronics with the transimpedance in 8 stages. In the past, electronics' gain settings were totally man-control. In order to realize auto-control, it makes data de-noising and calculates appropriate gains, according to the pulse situation and ME-SXR's reference signals in the last shot. The goal of the system is to ensure long-pulse data acquisition and electronics' automatic gain-control. The system has been demonstrated in the 2015 EAST campaign. The details are presented in the paper.**

I. Introduction

THE ME-SXR (Multi-Energy Soft X-Ray) diagnostic is used to measure EAST (Experimental Advanced Superconducting Tokamak) electron temperature profile in the edge plasma region using x-ray filters with different cut-off energies [1]. As shown in Fig. 1, ME-SXR diagnostic was built in 2014. It consists of four primary components: the AXUV20ELG diode arrays, five preamplifiers, a 2nd stage amplifier, and data acquisition (DAQ) [1]. The AXUV20ELG diode arrays is used to detect signals. The five preamplifiers are used to do signal conditioning. The 2nd stage amplifier is used to deliver the signals to the DAQ. DAQ is used to acquire the diagnostic data of ME-SXR. It was upgraded in 2015 with moving the preamplifiers to the outside of the vacuum chamber [1].

The diode arrays output 96 current signals to the DAQ via the five preamplifiers and the 2nd stage amplifier. For the 96 signals are in the microampere range, they should be amplified by the five preamplifiers. The transimpedance of the preamplifier has 8 stages, which is programmable. They can be controlled by a power and gain control chassis in the outside cabinet [1]. During the experiment, the preamplifiers' transimpedance is the only module needs to be adjusted and we call it gain-control. In the 2014 EAST campaign, the gain-control is manual and experimenters need to check transimpedance before a new discharge coming.

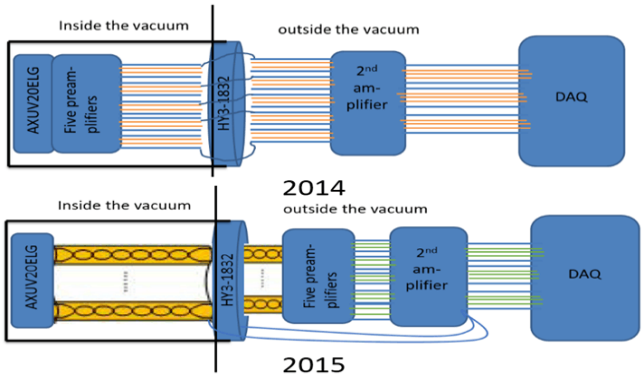

Fig. 1. The hardware architecture of ME-SXR [2]

Now the DAQ has been replaced by a new data acquisition and control system during the 2015 EAST campaign. The key requirements of the new data acquisition and control system are listed as follows:

1. 96 input channels with optional sampling rates are required. In order to facilitate the ME-SER diagnostic debugging and testing job, the experimenters suggest providing several options of sampling rates.
2. Real-time data access is essential. EAST has achieved 411s long pulse discharge with 0.28MA plasma current in the 2012 campaign [3]. For the long-pulse discharge, researchers need to know the plasma status in real time.
3. The automatic gain-control is necessary. An EAST campaign usually lasts several months with discharge incoming rising at more than 100 shots a day. In the past, gain setting was totally manual control in every shot. It's too hard and tried for experimenters.
4. The system should be in favor of automatic data analysis. In the future, more and more EAST diagnostic system will realize automatic data analysis and the ME-SXR diagnostic will be no exception.

II. System Architecture

According to the key requirements, the data acquisition and control system can be divided into two main functions: long-pulse data acquisition and electronics' gain auto-control. The system's architecture is as shown in Fig. 2. It is related to four

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systems. They are ME-SXR diagnostic, data acquisition console, data archive system, data analysis system. The data acquisition console [4] is used to control and monitor the whole EAST data acquisition, including this system. The data archive system is used to store all raw diagnostic data and provide the data to users. The data analysis system is used to integrate all the specific process programs for automatic data analysis [5].

A. *Long-pulse Data Acquisition*

The ME-SXR diagnostic needs 96 high-speed channels with optional sampling rates from 250 KSPS to 1 MSPS, which can keep continuous long-pulse data acquisition. DAQ administrator can control and monitor the data acquisition via the data acquisition console. Meanwhile, the diagnostic data will be transferred to the data archive system in real-time. The data will be stored into MDSplus [6], and users can access to the data during the current discharge in real-time.

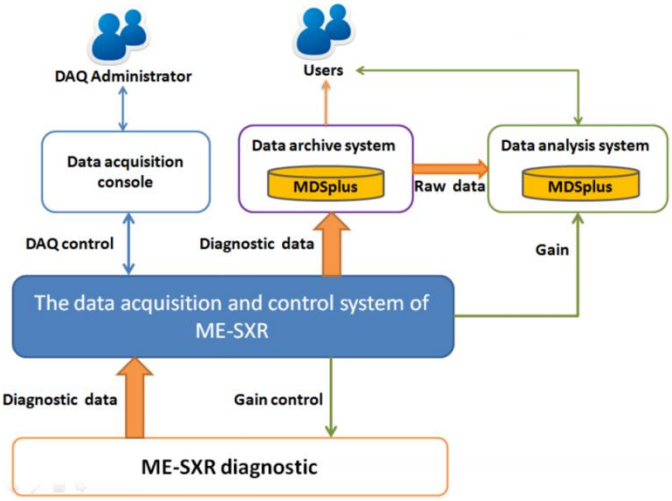

Fig. 2. System architecture

B. *Electronics' Automatic Gain-control*

Each preamplifier has 8 stages of transimpedance. The adjustment of transimpedance is made by three pins. So the five preamplifiers are adjusted by 15 pins, which can be controlled by the data acquisition and control system via 15 output digital signals. In order to realize auto-control, it makes data de-noising based on Savitzky-Golay filter and calculates appropriate gains, according to the pulse situation and ME-SXR's reference signals of the last discharge. Gains are useful for Te profiles data analysis, and the gains are transferred to the data analysis system in real-time for the future automatic data analysis.

III. System Implementation

A. *Hardware Structure*

The system has 96 input analog channels and 15 digital output channels. Fig. 3 shows the hardware structure of the data acquisition and control system, and all hardware choose National Instruments (NI) products based on PXI Express.

- Choosing PXIe-8135[7] as the controller, which is used to communicate with the data acquisition console and control all input/output cards.
- Choosing PXIe-6358[8] to acquire 6× 16 analog signals from the ME-SXR diagnostic. It meets the requirement of optional sampling rates from 250 KSPS to 1 MSPS.
- Choosing PXIe-6259[9] to output 15 digital signals for gain-control.

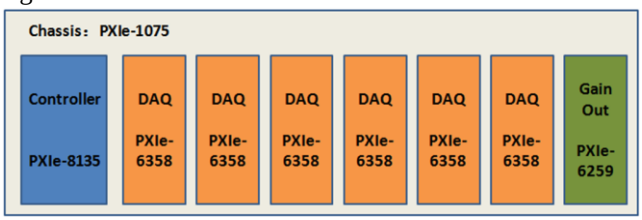

Fig. 3. Hardware architecture

B. *Software Structure*

For all hardware using NI products, it uses LabVIEW to implement the software. The chosen operating system is Windows 7 Professional, and its processor is an Intel (R) Core (TM) i7-3610QE CPU @2. 30 GHz.

As shown in Fig. 4, the data acquisition and control system can be divided into four modules: communication, data-acquisition, data-process and gain-control.

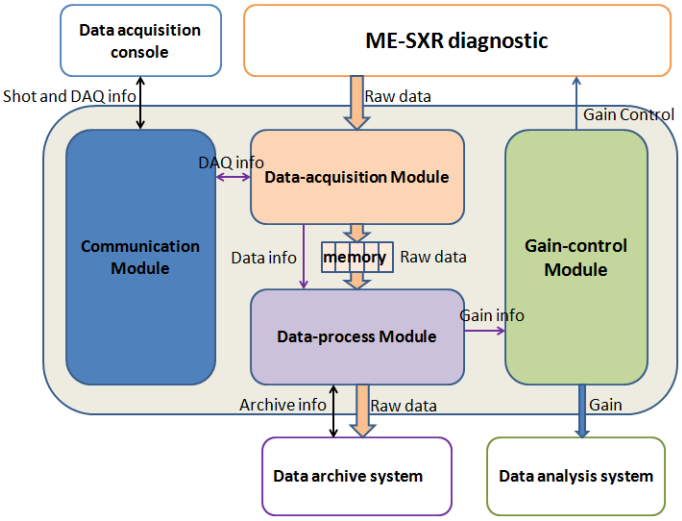

Fig. 4. Software architecture

Communication module is used to communicate with the data acquisition console. It receives shot and DAQ info from the data acquisition console and forwards the info to the data-acquisition module. The shot and DAQ info includes pulse start message, pulse interrupt signal and DAQ status.

Data-acquisition module is used to acquire data according to the requirements from the data acquisition console and sends data info to data-process module. It analysis DAQ info, configures acquisition setting and acquires data. The sampling rate can be adjusted from 250KSPS to 1MSPS according to the acquisition configuration information. In order to realize real-time data access, there is a shared memory area between the data-acquisition module and the data-process module. The data-acquisition module writes raw data into memory slice by slice orderly. Meanwhile, the data will be read out by the data-process module.

Data-process module is used to preprocess raw data and send data to the data archive system. It reads out the slice data from the shared memory orderly and preprocesses them according to the data info from the data-acquisition module. Finally it sends data to the data archive system. In addition, it processes the gain's reference signals via data de-noising based on Savitzky-Golay filter and maximization.

Gain-control module is used to adjust the preamplifiers' gain. It calculates the gains when a new pulse is coming via comparing the maximum values of the reference signals with two threshold ranges. The definition of these threshold ranges is according to the historical record and manual operation experience. The gain-control algorithm is shown as in Fig.5. Defining two threshold ranges named A and B, according to the historical record and manual operation experience. After getting the maximum values of the five reference signals from the data-process module, it compares them with the two ranges. If the maximum value is in the range A, the gain of the corresponding preamplifier remains unchanged; otherwise it's needed to compare with the range B. If in the range B, it stays the same; if under the range B, it needs to increase one stage of transimpedance; if above the range B, it needs to reduce one stage of transimpedance. Finally exports 15 gain control digital signals to the five preamplifiers. For the data analysis code needing the gain, it stores and uploads the values of 15 gain control signals to the data analysis system. Soon afterwards the data process program will be integrated into the data analysis system.

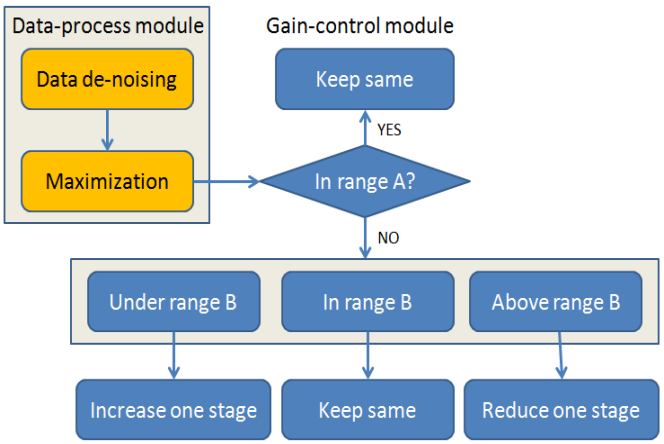

Fig. 5 Gain-control algorithm

IV. Result

A. Long-pulse data acquisition result

The 2015 EAST campaign crosses the year 2015 and 2016. The data acquisition and control system for the ME-SXR diagnostic system has running about 5 months with over 6000 shots in the 2015 EAST campaign. The data acquisition and control system has run continuously and stability during the experiment. It has met the requirement of long-pulse quasi-steady data acquisition.

Users can access the data during the discharge through several methods such as WebScope [10], which is an online tool for displaying EAST data. Users can use WebScope to display more new diagnostic data with refreshing during the discharge. It has met the requirement of real-time data access.

B. Electronics' automatic gain-control result

In the 2015 EAST campaign, the gain auto-control has going on more than 6000 shots. The control results are all correct with confirming by the experimenters. The Fig. 6 shows a gain auto-control result between shot 64786 and 64787. From the figure, we can see in shot 64786 some signals exceed the full-scale of the data acquisition card. But in the next shot 64787 these signals are in the scale range. It's the effect of the automatic gain–control. It works well in the whole experiment and gets a good evaluation from the experimenters.

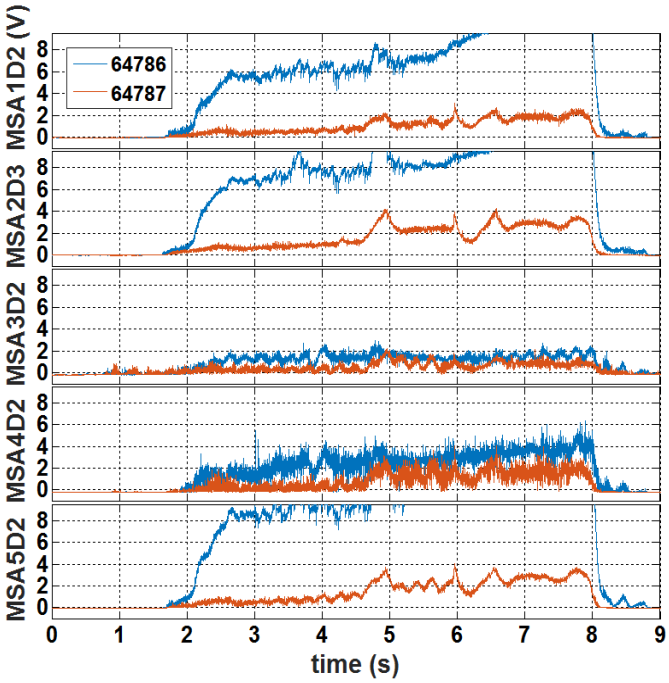

Fig. 6 Signal contrast before and after gain adjustment (shot@64786/64787)

V. Conclusion

During the 2015 EAST campaign, the data acquisition and control system has realized continuous data acquisition with optional sampling rate and automatic gain-control in the long-pulse quasi-steady state. It meets the four requirements: input channels with optional sampling rates, real-time data access, automatic gain's setting and extension for automatic data analysis. It provides 96 input channels with optional sampling rates for long-pulse acquiring the diagnostic data. Users can access to the data in real time during the discharge. The automatic gain-control has freed experimenters from the tired manual operation. And the gains are ready for data analysis.

Soon afterwards, the ME-SXR diagnostic system will realize automatic data analysis. Finally, it will realize automation including acquisition, control and analysis. Other similar diagnostic systems may refer to this system and make the experiment more relaxed.

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