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THE DESIGN OF CSNS INSTRUMENT CONTROL

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Abstract

To meet the increasing demand from user community, China is now building a world-class spallation neutron source, called CSNS(China Spallation Neutron Source). It can provide users a neutron scattering platform with high flux, wide wavelength range and high efficiency. CSNS construction is will completed in this year. There are three neutron instruments in CSNS, which are GPPD, SANS and RM. CSNS Experimental Control System is in charge of the operation of NS target and instruments.

The instrument control system of CSNS is based on EPICS and White Rabbit network, offering device operation, timing synchronization, synchronization of DAQ and physical software, metadata collection and generation of experiment summary. This paper will introduce the structure of instrument control.

INTRODUCTION

Neutron scattering becomes a more and more important method probe the structure of the microscopic world. In physics, chemistry, biology, life science, material science, new energy, as well as in other applications, Neutron scattering is the widely used as a complementary way to X-ray in advance research.

To meet the increasing demand from user community, China is now building a world-class spallation neutron source, called CSNS (China Spallation Neutron Source) [1]. It can provide users a neutron scattering platform with high flux, wide wavelength range and high efficiency. CSNS construction will be completed this year, and got first neutron in August, 2017.

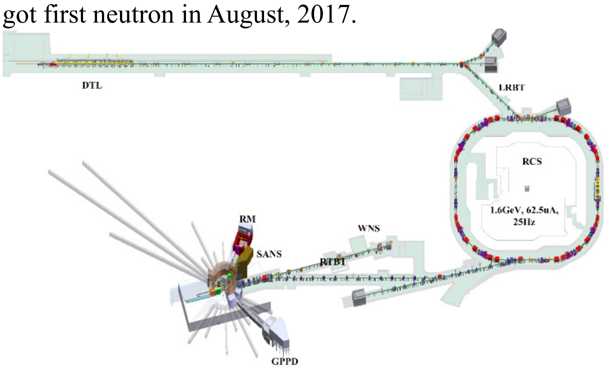

Figure 1: The Layout of CSNS.

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The experimental control system of CSNS is in charge of target and instrument control [2]. The task of instrument control includes:

1. Provide local control to instrument device.
2. Ingrate all devices belonged to the instrument into one system, including sample environment, slit， chopper, etc.
3. Provide facility information, mainly on accelerator information.
4. Provide the trigger signal (T0) when proton hit the target and time synchronization for device to get timestamp.
5. Interact with security systems, including neutron shutter and personal safety protection system.
6. According to experiment requirement, coordinate all system, mainly focus on DAQ and physical software.
7. Record status information of device, producing experiment summary file for offline.
8. Provide remote monitor and optional remote control for whole neutron instrument.
9. Provide statistics of instrument operation.

CSNS instrument control is based on EPICS control system [3], integrating commercial hardware, Labview and other components. Some customized hardware are made for T0 fanout and time synchronization.

THE STRUCTURE OF INSTRUMENT CONTROL

Figure 2 shows the structure of instrument control. An instrument control is divided device control layer and global control layer. Device control layer mainly focus on local control of the device, providing standard EPICS CA interface and expert HMI. As a special case, detector, electronics and DAQ software can be viewed as one devices. DAQ software provide a standard interface to online analysis and also provide an online monitor interface to detector and electronics experts.

Global control layer mainly focus on integrating all device, providing global information and execute the procedure of experiment.

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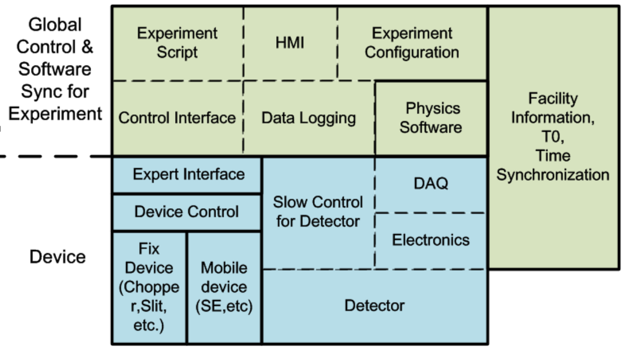

Figure 2: The Structure of CSNS Instrument.

DEVICE CONTROL OF INSTRUMENT

To maximum reduce the cost, commercial hardware and software are widely used in device control layer. Siemens PLC, Yokogawa PLC, Beckhoff PLC, PXI and NI CRIO now can be used to device control in CNS. IOC is used to communicate with field hardware, providing standard PV interface to global control [4][5].

In CSNS, some devices like sample environment will be transfer from one instrument to another instrument. To get maximum neutron beam usage, the process of device transfer must be simplify. So, all devices in CSNS can be grouped as fix devices and mobile devices. When the device transfer between instruments, the front controller and IOC will be transferred alone with device. After transferring, the prefix of PV and other parameter can be modified on expert HMI. When the instrument begins to operate, the transferred device can be selected on instrument experiment HMI. Then, the control system will check all the valid and status of device, and write the information to log file.

Low-cost Environment Monitor

In CSNS, there are much needs for environment monitor in detector, electronics and other systems. A low cost but more flexible system is designed as Fig. 3.

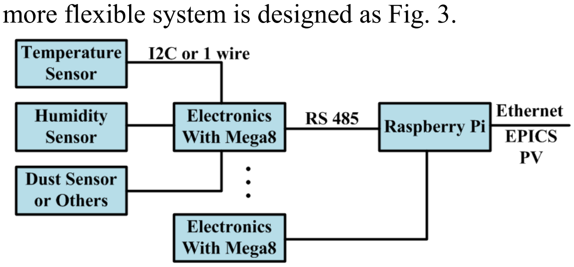

Figure 3: the low cost environment monitor

Temperature sensor, humidity sensor, dust sensor and others are integrated with Mega8 SOC by local bus. Many front electronics in different place are integrated by RS485, and a raspberry Pi is used to providing EPICS PV.

T0 TRIGGER AND TIME SYNCHRONIZATION SYSTEM

In instrument of CSNS, time of flight (TOF) of every neutron will be recorded. So the exactly time of proton brunch hit the target (T0) needs to know to trigger electronics as the begin point of TOF. And neutron chopper also needs this T0 trigger signal to synchronize chopper phase, cutting the useless gama ray and fast neutron.

The trigger signal is generated by time system of accelerator. Experiment control system will fanout this signal to every neutron instrument. And this signal will be monitored everywhere, to correct the propagation delay of T0. Some proton beam monitor is also marked a timestamp by WR node to exactly correct time jitter of T0 for some high energy neutron experiment. Electronics of neutron instrument are also synchronized by WR node.

T0

The neutron chopper belongs to the mechanical rotating part and has a great moment of inertia. The control strategy of chopper phase is detected in this beam cycle, and will be synchronized in next beam cycle. Using beam signal as its trigger will not do better to phase control. Since beam signal will be synchronized to a standard 25Hz signal of timing system with error less than 1us. So neutron chopper will use this standard 25Hz signal as its trigger.

More precise trigger signal will be needed by instrument electronics and DAQ. The beam extraction signal of RTBT and RTBT beam self-trigger signal will be used by electronics as trigger.

Time Synchronization System

To synchronization time of all device, the White Rabbit technology originate from CERN is used in CSNS instrument control [6][7]. WR grandmaster switch is synchronized to GPS time by pulse per second (PPS). A rubidium clock is used to reduce the time jitter of GPS. Several WR nodes are developed in CSNS to monitor T0, to synchronize electronics, to timestamp neutron signal in neutron measurement experiment and to timestamp proton beam measurement.

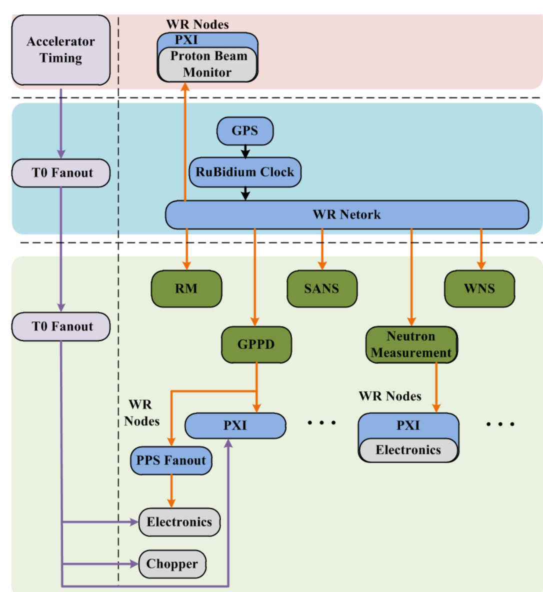

Figure 4: Time synchronization and realtime measurement system..

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The PPS fanout chassis will generate the pps signal with a series pulse standing for TAI time. So different electronics with different crystal oscillator can track this PPS signal to be synchronized. The timestamp over second is come from WR synchronization. The timestamp under second is come from crystal oscillator of electronics itself, and it will be formatted into nanosecond.

The PXI card with TDC and DIO is used to timestamp the signal. Also the NI hardware and Beckhoff PLC can be synchronized to WR by using standard IEEE 1588.

So every event in the experiment can be marked timestamp and serialized by time sequence.

Realtime Proton Current Service

In CSNS, for neutron flux normalization, proton beam current is wanted to be measured bunch by bunch as Fig. 5. This value needs to be broadcast for online use. A special WR PXI board was developed to complete the measurement with other NI PXI AD card. When the beam current signal over threshold, the FPGA on WR PXI card is triggered. This FPGA will relay this trigger to other board through PXI backplane bus. At the same time, this FPGA will mark timestamp on this signal, and broadcast a trigger message in WR network. After the AD complete the sampling and beam current calculation, the beam current will be written to the register of FPGA. Then, the Measurement package will be broadcasted. All this will be done in a bunch cycle, which is 40 ms.

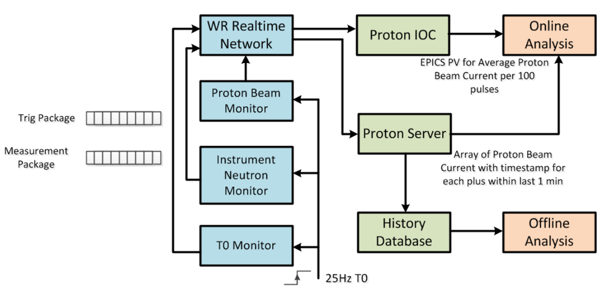

Figure 5: Proton current measure and service.

The proton Server and Proton IOC will received this message, providing proton service to online analysis. An PV based on epics V3 is created to provide average proton beam current per 100 Pulse. The proton server based on EPICS V4 will provide the each proton beam current within last 1 minute. These beam current will be provided with timestamp and sequence No. in an array. Also, all these data will be stored in history database based on MySQL, for offline use.

Realtime Trigger Message

A realtime message derived from LXI protocol as showed in Table 1, is designed to deliver all trigger and measurement message. This message was modified to use the realtime package forward ability of WR switch.

Table 1: Realtime trigger message type

Field	**Length**
Index to device	4 Bytes
Message type	16 Bytes
Sequence No.	4 Bytes
Trigger time (over second)	4 Bytes
Trigger time (under second)	4 Bytes
Reserved data1 (proton current)	4 Bytes
Reserved data1	4 Bytes
Data area	52 Byte
End (0x00)	4Byetes

CONTROL SOFTWARE OF INSTRUMENT

The control software of CSNS includes state machine of instrument, IOC based on EPICS, control interface, SCAN server, history database, and DAQ software for neutron monitor.

Boy is used as high level operator interface in CSNS. And SCAN is also used to experiment task automation. Python and Jython with epics CA support are used as control script. CA gateway is used to isolate the PV between instrument with outside net. A DAQ software based on EPICS V4 was developed to neutron monitor.

The Process of Neutron Experiment.

Figure 6 shows the procedure of neutron experiment of CSNS neutron instruments. Every instrument has a configuration file derived Nexus file format. Before experiment, device experts should prepare all the subsystem belongs to the instrument. These will be done through local control interface. When all these subsystem can accept remote control, the user can begin neutron experiment. First he must configure the experiment in experiment HMI, selecting the sample environment device, providing user id, proposal id and other parameter. Control system will start all service for the experiment, checking device status. Then user can submit a experiment to SCAN server to begin a neutron experiment. Control system will set the parameter according to configuration and then start a neutron run. Control, DAQ and physical software are synchronized through state machine. When the experiment is running, all status of device and neutron data will be recorded. After collecting enough neutron, the experiment will be end by control server. Summary file like Nexus XML file will be generated and submitted into run information system for offline use.

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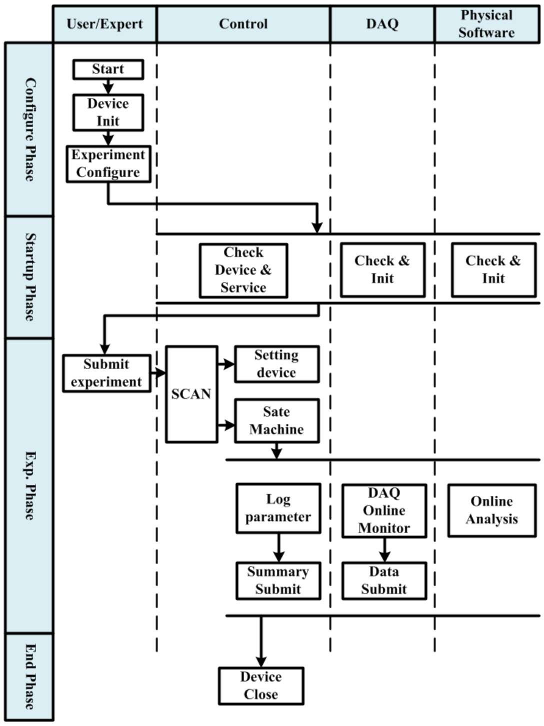

Figure 6: The flow of neutron experiment in CSNS.

The Data Flow of CSNS Neutron Instrument

The data flow of CSNS neutron instrument can be divided into neutron event data flow and control data flow as showed in Fig. 7. Control data flow consists of instrument configure flow and realtime data flow of devices.

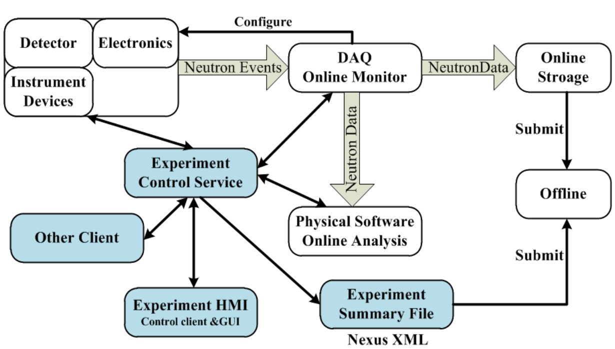

Figure 7: The data flow of CSNS neutron instrument

Neutron event data are produced by neutron detector and electronics and sent to DAQ through Ethernet. In DAQ software, raw data will be translated to neutron data. After neutron event assembled, neutron data are processed to detector data monitor, mainly in histogram figure. And then these data will be stored in online storage.

DAQ for Neutron Monitor

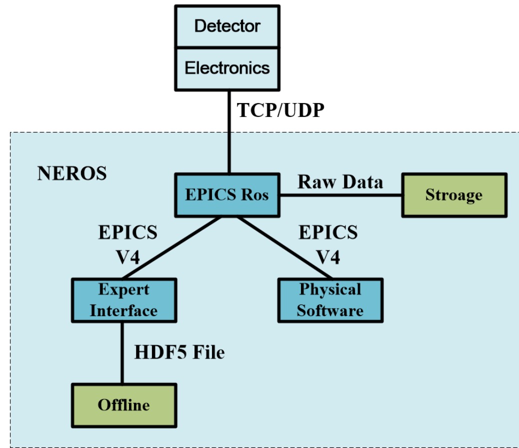

Figure 8: The structure of DAQ.

For instrument tuning and normalize neutron flux, several neutron monitor is used in every neutron instrument. The neutron monitor will be long-term running. A DAQ software, named NEROS, has been developed. NEROS is based on EPICS V4 and aeraDetector. NEROS can control electronics and setting parameters by UDP command. NEROS can receive neutron data from FPGA through Ethernet, or running on VME controller. It can also provide simulating test mode by using data file as source.

NEROS can provide histogram on whole detector or region of interest and two dimensional profile. NEROS store the neutron data as HDF5 file format, which can be directly used by Nexus software. As a software based on EPICS V4, it can be access by V4 client interface. Online physical software in CSNS use python interface access the monitor data realtime. Fig. 9 shows online test result of NEROS. The left is CSNS mask under x ray, and right is E mask under ^{252}Cf neutron source.

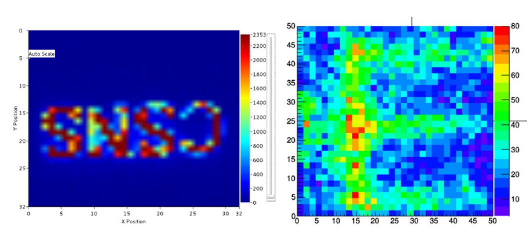

Figure 9: Left: the image of CSNS mask under X ray, right: the image of E mask under ^{252}Cf neutron source

CONCLUSION

The control system based on EPICS, White rabbit and other components has been developed for CSNS instrument. All hardware and most software has been deployed. The first neutron has been produced in Aug. 28, 2017. Some hardware and software has been verified in the first neutron beam measurement.

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