NSLS-II BEAM DIAGNOSTICS CONTROL SYSTEM*

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Abstract

A correct measurement of NSLS-II beam parameters (beam position, beam size, circulating current, beam emittance, etc.) depends on the effective combinations of beam monitors, control and data acquisition system and high level physics applications. This paper will present EPICS-based control system for NSLS-II diagnostics and give detailed descriptions of diagnostics controls interfaces including classifications of diagnostics, proposed electronics and EPICS IOC platforms, and interfaces to other subsystems. Device counts in diagnostics subsystems will also be briefly described.

INTRODUCTION

The NSLS-II beam diagnostics and control system is designed to monitor the electron beam of NSLS-II accelerator complex [1]. The beam quality is measured by a variety of parameters such as bunch charge, bunch structure (filling pattern), beam position/orbit, beam size/profile, energy & energy spread, circulating beam current, tunes, beam emittance, bunch length and beam losses. Figure 1 briefly shows the beam parameters to be measured from Linac to Storage Ring.

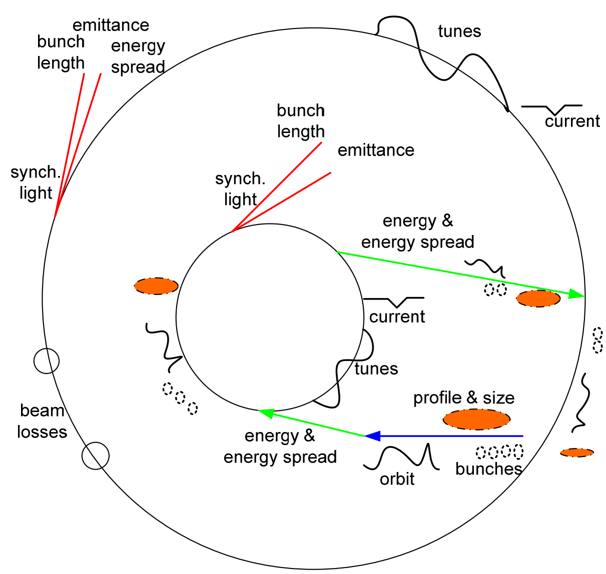

Figure 1: Beam Parameters to be measured at NSLS-II.

A correct measurement of beam parameters depends on the effective combinations of a variety of beam monitors, control and data acquisitions (DAQ) and high level physics applications. Thus, an effective collaboration between Diagnostics Group, Controls Group and Physics Group is essential. The NSLS-II Diagnostics & Instrumentation Group is in charge of the definition of beam diagnostics specifications and the design of beam monitor systems, including the layout of these monitors around the machine. The Physics Group is responsible for submitting the physics requirements for diagnostics and control, system modelling, algorithm, etc.

The scope of Controls Group on beam diagnostics system includes the following: requirement analysis and specifications for the beam diagnostics controls; Make vs. buy analysis and decision of electronics for various beam monitors; Development of EPICS [2] drivers for the diagnostic monitors and system tests on the software and hardware; Design of interfaces between diagnostics controls and other subsystems (timing, machine protection system, etc) and system integration of them.

DEVICE COUNTS IN DIAGNOSTICS

Table 1: Device Counts in NSLS-II Diagnostics

	Linac	Ltb	Booster	BtS	SR
WCM	5				
Screen/Flag	6	9	6	9	3
BPM	5	6	37	7	240
Bergoz FCT		2	1	2	
Bergoz ICT		2		2	
Energy Slit		1		1	
Faraday Cup	1	2		1	
Bergoz DCCT			1		1
Streak Camera					1
Visible Light Monitor			1		1
Pinhole system					2
Tune Monitor			1		1
Transverse Feedback System					1
Beam Loss Monitor					5
Beam Scrapers					5
Photon/x-ray BPM					2 per front-end

NSLS-II accelerators consist of one injector and one storage ring (SR). According to the functionality as well as geographical distribution, the injector is divided into 4 subsystems: Linac, Linac to Booster (LtB) transfer line (including 2 beam dumps), Booster, Booster to Storage ring (BtS) transfer line (including 1 beam dump). Table 1 gives a summary of the diagnostic monitors distributed over the whole machine. Although Linac and Booster are turnkey solutions provided by vendors, BNL will specify

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the requirements for diagnostics and controls and vendors implement them. For better standardization and maintenance, the same type of diagnostics (e.g. CCD cameras) used in different accelerator subsystems will be provided by the same manufacture (e.g. GE1290 by Prosilica) so that they almost have the same control interfaces and requirements.

CONTROLS INTERFACES FOR DIAGNOSTICS

Diagnostics controls are actually more about data acquisition (DAQ) than device control. Diagnostics control subsystem will conform to NSLS-II control system standards. It will be EPICS-based and the preferable operating systems for IOCs are RTEMS (Real-Time Executive for Multiprocessor Systems) and Linux/Debian. For VME-based controls, the CPU board will be standardized as Motorola MVME3100.

Whenever possible, diagnostics controls pursue the utilization of commercial off-the-shelf hardware to reduce cost as well to achieve better reliability. Although NSLS-II Linac and Booter are turn-key solutions provided by vendors, it's better to standardize the diagnostics controls for the whole machine. The following section describes the classified method for controls standardization.

Classifications of Control Interfaces

From point view of controls, the beam monitors output signals/interfaces can be classified into the following several groups.

1) Analog output with high-bandwidth (>500MHz): WCM, FCT, etc. [3];
2) Analog output with low-bandwidth (<10KHz): DCCT, ICT&BCM;
3) Simultaneous 4-channle RF signals: BPM;
4) Gigabit-Ethernet camera interface: pinhole camera, flag/CCD, streak camera etc.
5) Stepper motor driven: linear stage in pinhole system, energy slit, beam scraper, etc.
6) Ethernet-based instrument: Windows XP-based network/spectrum analyzer for tune monitor and beam stability monitor;

There are other miscellaneous I/Os for diagnostics: binary input/output including TTL I/O for DCCT range settings, pneumatic actuator with limit switch in flag, limit switch in stepper-based stage, 24 V binary outputs for XIA filter inserter in pinhole system, 12-bit DAC for illuminator control in pinhole and flag system, temperature sensors for diagnostics beamline mirror, etc.

Here are some considerations and principles about the selection of electronics for the above groups of beam monitors:

1) WCM and FCT are used to measure individual bunch charge. The time interval between adjacent bunches is 2 ns so that the digitizer for WCM & FCT should have at least 500MHz bandwidth and 1GS/s sampling rate. Since NSLS-II physics requirement for filling pattern accuracy is 1% of maximal bunch charge, 8-bit resolution digitizer should be fine;
2) The output of DCCT and BCM/ICT is nearly DC voltage so that the requirement of sampling rate for digitizer is not demanding. For Booster DCCT and transfer-lines ICT, the digitizer with 16-bit resolution and 20KS/s would be suitable. For Storage Ring DCCT digitizing, the resolution requirement is determined by beam lifetime calculation considered 20mA in 60 hours with 1% accuracy. This translates to 18-bit ADC resolution;
3) For 4-button-pickup RF BPM, in-house BPM receiver will be utilized;
4) For camera controls, NSLS-II diagnostics will be standardized as Gigabit-Ethernet interface (Prosilica Gig-E CCD camera) for high bandwidth, easy cabling, good anti-EMI, etc.;
5) For stepper-motor based diagnostics, the controls will be integrated into NSLS-II motion control subsystem;
6) For Windows-based network/spectrum analyzer, it's possible to make an EPICS IOC run inside the instrument.

Controls and Data Acquisitions for Diagnostics

Each type of beam monitor requires electronics (device controller) to process its output signal. The electronics for the above groups and associated EPICS IOC platform are listed in Table 2. Figure 2 shows the controls interfaces for these various beam monitors.

Table 2: Diagnostics Electronics and IOC Platform

Beam Monitor	**Diagnostics Electronics**	**IOC platform**
WCM & FCT & FC	Acqiris DC252 (2GHz bw, 10-bit, 4~8GS/s)	cPCI/Linux
DCCT & ICT	1)GE ICS-710-A (24-bit, 200KS/s, 8-ch) 2)Allen-Bradley PLC (DAC, Digital I/O)	cPCI/Linux
BPM	In-house BPM receiver [4]	PC/Linux
Prosilica GigE Camera	PC/Linux	PC/Linux
Stepper-motor-based	Delta Tau GeoBrick LV PC	PC/Linux
Instrument controls	Windows-based network/spectrum analyzer	PC/Linux
Misc: digital I/O, DAC, temperature sensor	Allen-Bradley PLC	PC/Linux

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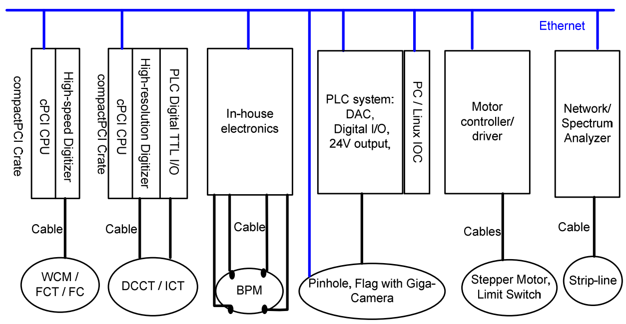

Figure 2: Diagnostics Controls Interfaces.

INTERFACES TO OTHER SUBSYSTEMS

Interfaces to Timing System

To capture the electron beam signal at the right time, the beam monitors should be sampled and synchronized to the passage of the beam. This function can be achieved by using Event Timing System to deliver delayed-trigger or clock signal to the diagnostics electronics.

The interfaces between diagnostics controls and timing system are shown in Figure 3. Some diagnostics controls, such as stepper motor, limit switch and DAC, don't need timing while other diagnostics electronics require trigger signals from Event Timing System [5] (EVR). Additionally, the reference for BPM receiver Machine Clock should be provided at the Booster/Storage Ring revolution frequency. For transverse bunch-by-bunch feedback system and streak camera system, trigger/clock signals are the only control signals.

For diagnostics timing requirements, 8ns resolution and 100ps jitter should be sufficient. Diagnostics controls require precisely time delayed trigger at injection rate (10Hz for Linac, 1Hz for Booster) to capture the beam at the right time. The delayed time for each diagnostics depends on the location of beam monitor, the cable length from monitor to its electronics and the distribution of event timing.

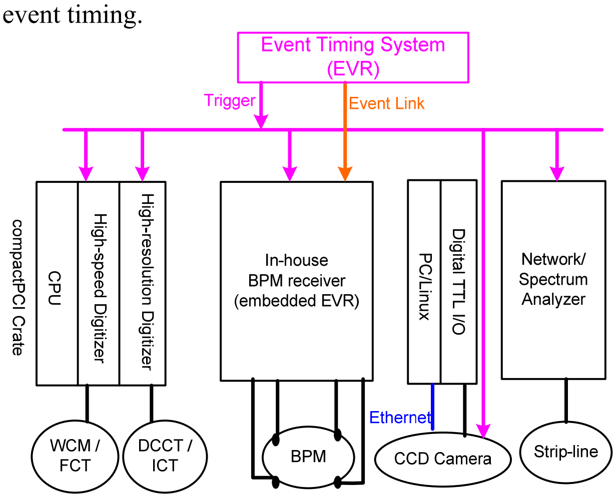

Figure 3: Diagnostics Interface to Timing System.

Interfaces to Machine Protection System

The diagnostics controls should send hardwired interlock signals, to machine protection system (MPS) if any specific parameter, such as beam positions, beam loss rate, beam current, is out of range.

The design of the interfaces between diagnostics controls and MPS are still in progress. Fig. 4 shows the draft diagram of the system.

The followings are some cases that diagnostics interlock protection should take action:

1) BPM position data are out of pre-defined position range;
2) For top off operation, the stored beam current must exceed 50mA;
3) Excessive beam loss is detected by LCM system;

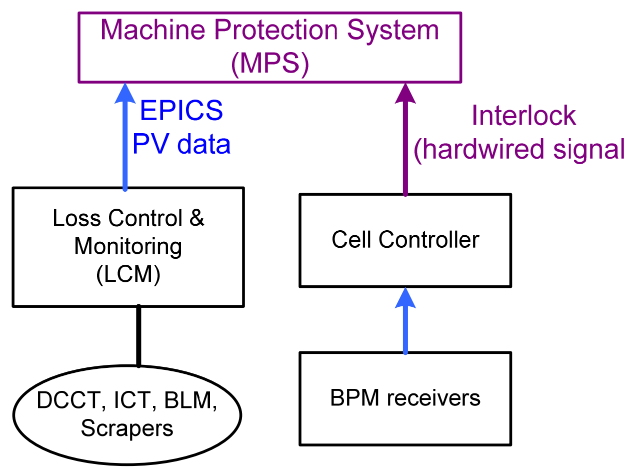

Figure 4: Interface to Machine Protection System.

CONCLUSIONS

NSLS-II beam diagnostics control system is completely EPICS-based. Utilization of commercial off-the-shelf hardware as well as in-house BPM electronics development is deployed to meet NSLS-II project requirements and schedule. All diagnostics controls hardware and software are well tested and ready for NSLS-II Injector installation and commissioning.

REFERENCES

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[4] Yong Hu, et al., "BPM Inputs to Physics Applications at NSLS-II", Proceedings of PAC 2011, New York, NY, US.
[5] http://www.mrf.fi/.

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