# BEAM MONITOR SYSTEM CONTROLLER FOR XFEL/SPRING-8

S.Inoue#, H.Maesaka, S.Matsubara, Y.Otake,
RIKEN/SPring-8, 1-1-1, Kouto, Sayo, Hyogo, 679-5148, Japan,
K.Yanagida, H.Ego, A.Yamashita,
JASRI/SPring-8, 1-1-1, Kouto, Sayo, Hyogo, 679-5198, Japan

*Abstract*

We have developed a controller for the beam monitor system of the X-ray free electron laser project at SPring-8. The control items are the electronics of an rf cavity beam position monitor and a current transformer, the actuators of a screen monitor (SCM) and a bunch length monitor, and the stepper motors of a SCM lens system and a beam collimator. To operate such complicated devices, we designed a control system based on a programmable logic controller (PLC). For the communication between the PLC and other equipments, we employed FL-net (a protocol to communicate with computers) and DeviceNet (a connection with peripheral devices). We newly developed a DeviceNet-based stepper motor controller to satisfy our complicated requirements of motion manipulation. The PLC enables us to implement complex commands easily.

## INTRODUCTION

The Japanese X-ray free electron laser project (XFEL/SPring-8) is under construction at the SPring-8 site. The beam monitor system of XFEL/SPring-8 consists of an rf cavity type beam position monitor (RF-BPM)[1], a current transformer (CT)[2] to measure a beam charge, a screen monitor (SCM)[3] to observe a transverse beam profile, a bunch length monitor using a coherent transition radiation[4], and a beam collimator. We have developed a controller to operate these monitors and to communicate with an upper-level computer.

To operate the complicated beam monitor system, we designed a control system based on a programmable logic controller (PLC). The PLC enables us to implement complex commands easily, and it is highly reliable. The PLC-based controller is also useful to debug the operation sequence before the installation. We use FL-net [6] as a standard protocol for the communication between a VME computer and the PLC, because FL-net is strongly supported by the XFEL/SPring-8 control framework, MADOCA [5], that was originally developed for SPring-8. For the communication between the PLC and peripheral devices, we employed the DeviceNet [7] protocol. DeviceNet is useful to reduce the amount of cables and has a good noise compatibility. We also use some multi-wire cables to control the devices that are not suitable for DeviceNet.

#inoues@spring8.or.jp

## BEAM MONITOR SYSTEM CONTROLLER

A schematic layout of the beam monitor system is shown in Fig. 1. The beam monitor controller is composed of PLC modules, an analogue circuit, and a DC power supply. We use following PLC modules: a D/O module to output contact signal, a D/I module to input contact signal, an A/D module to take analogue voltage, an FL-net module to communicate with upper-level VME computers and a DeviceNet module to communicate with peripheral devices.

The beam monitor controller is operated by a touch panel of a klystron controller [8] through an Ethernet for a local control and by a MADOCA framework through an FL-net for a remote control. In addition, a portable touch panel is prepared for maintenance of the controller. The detailed description of each device controlled by the beam monitor controller is given in the next section.

### *RF-BPM Electronics*

An RF-BPM electronics detects an rf signal with an IQ (in-phase and quadrature) demodulator that has an attenuator selector switch to change the measurement range. The attenuator switch is controlled by DeviceNet from the beam monitor controller.

### *CT Electronics*

The CT electronics amplifies and shapes a CT signal, and has an attenuator selector switch to adjust the measurement range. The attenuator switch is controlled by DeviceNet in the same way as the RF-BPM circuit.

### *Stepper Motor Controller*

A stepper motor controller is used to drive the motorized stage of an RF-BPM, the zoom mechanism of an SCM and the actuator of a collimator. The stepper motor controller communicates with the beam monitor controller by DeviceNet. The details of the stepper motor controller are given in the last section.

### *Collimator*

Our collimator is water-cooled, and equipped with a flow switch and a thermo switch. The signals from these switches are transmitted to the beam monitor controller with a multi-wire cable. When the beam monitor controller detects an abnormal signal of those switches, the controller automatically removes the collimator material from the beam path in order to prevent overheating.

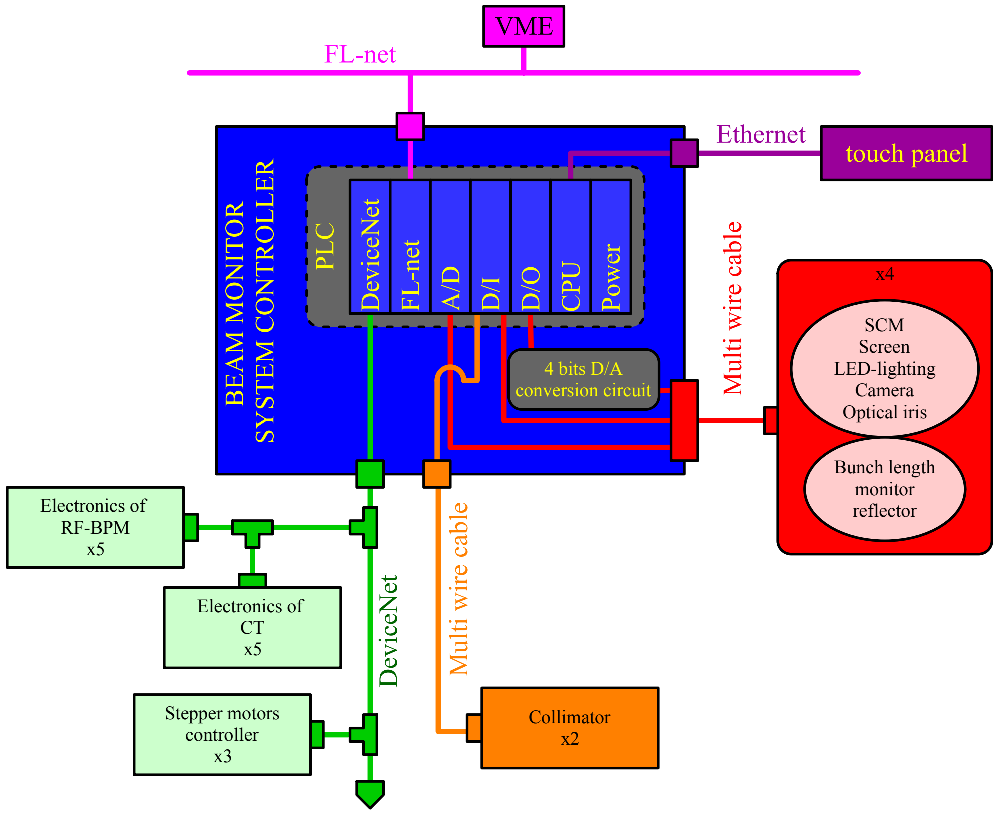


Figure 1: Schematic layout of the beam monitor system. The maximum number of devices for each monitor is also shown.

### *SCM and Bunch Length Monitor*

The SCM control items except for a stepper motor are a pneumatic actuator to insert the screen, a micro-switch to detect the screen position, brightness of an LED to illuminate the screen target, a camera power switch, and an optical iris aperture. The valve of the pneumatic actuator and the camera power switch is controlled by a PLC D/O module. The micro-switch is monitored by a PLC D/I module. The LED brightness and the iris control are described in the next subsections.

We use two types SCM, one has a one screen and the other has two screens. The single-screen SCM has two actuator states and has one valve and two micro-switches. The double-screen SCM has three actuator states and has two valves and three micro-switches.

The bunch length monitor has a retractable reflector driven by a pneumatic actuator in the same way as an SCM.

The above-mentioned control signals are transmitted to the beam monitor controller with a multi-wire cable.

### *Adjustment of LED Brightness*

The LED brightness is adjusted by changing the applied voltage. We use a 4-bit D/A conversion circuit of a resistor ladder network consisting of resistors and relays. The D/A conversion circuit is built in the beam monitor controller, and the relays of the D/A conversion circuit is operated by a PLC D/O module.

### *Optical Iris Circuit*

To adjust the numerical aperture (NA) of the lens system, we use a commercially-supplied iris for a photographic camera. This iris consists of a driving coil, a damping coil and a hall element. The iris is manipulated by a current applied to the driving coil. The speed of the iris movement is regulated by the damping coil. The currents of these coils are supplied from a servo circuit. The iris opening is detected by the hall element and fed back to the servo circuit. The reference voltage of the circuit is generated by a 6-bit D/A converter, which is operated by the PLC D/O module. In addition, the hall element signal is recorded by a PLC A/D converter module in order to monitor the iris opening.

### *PLC Programming*

The PLC program of the beam monitor controller was designed to be common to all controllers. Since the quantities of the devices for each beam monitor controller is different, the controller need to detect the quantities during the startup process. For the pneumatic actuator of the SCM, we use single-screen type and double-screen type. The beam monitor controller automatically distinguishes these types according to the bit pattern of the micro-switches to monitor the screen position. The existence of the bunch length monitor is also identified in the same way. The primary settings of the DeviceNet-based equipments are also detected automatically by means of the node numbers assigned to the equipments. Thus, the PLC recognizes how many devices to control.

## DEVICENET-BASED STEPPER MOTOR CONTROLLER

To achieve the complicated motion control of the beam monitor system, we developed a new stepper motor controller having following functions: (1) an absolute position management with a rotor position detector in order to prevent a misstepping, (2) high repeatability of initialization sequence to detect the mechanical origin, (3) programming limit, (4) capability to drive two motors, (5) two motor drivers in the controller for a synchronous operation.

The rotor position detector, called resolver, measures the mechanical angle within 360 degrees by means of an electromagnetic induction. This resolver has a good tolerance toward radiation. Since the number of rotations is managed by the motor controller, we can recognize a rotation angle more than 360 degrees. When the motor controller detects a misstepping, the controller stops the motor and raises a warning to DeviceNet.

A schematic sequence of the initialization to detect the mechanical origin is shown in Fig. 2. The mechanical origin is defined as the resolver origin position closest to the mechanical sensor. The initialization is triggered by one command from DeviceNet.

DeviceNet (500kbps) enables to connect far motor drivers up to about hundred meters. Since the motor controller has a sufficient intelligence, the programming of the PLC is simple. The amount of cables is also reduced. Thus, the combination of this motor controller and the PLC simplifies the control system even if the motor controller has complicated functions. It considerably helps a smooth startup of the beam monitor system.

## SUMMARY

We designed a PLC-based controller to manipulate a complex beam monitor system consisting of RF-BPMs, CT circuits, screen monitors and collimators. We also developed a DeviceNet-based stepper motor controller with intelligent functions. We tested the beam monitor controller at the SCSS test accelerator and confirmed that it worked well.

## REFERENCES


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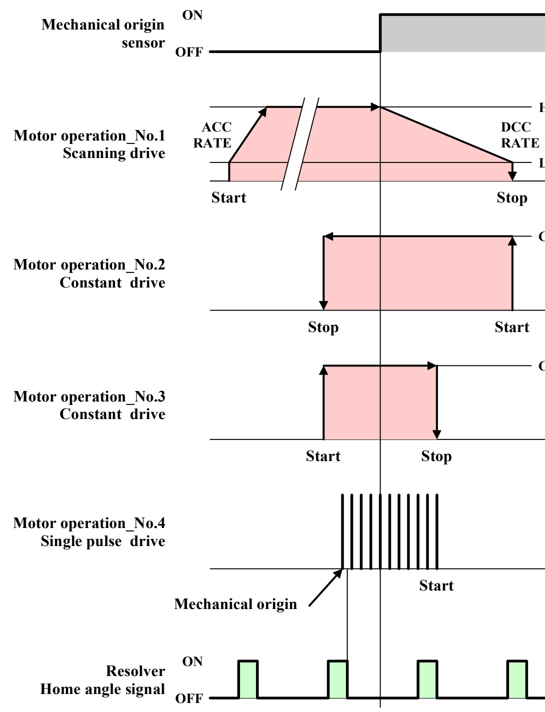


Figure 2: Schematic sequences of the initialization to detect the mechanical origin.


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