

# EPICS CONTROL SYSTEM FOR RAON DIAGNOSTICS

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## Abstract

RAON has a variety of diagnostic devices for measuring beam characteristics, such as FC, WS, and BV, etc. Each device is driven through a PLC and acquires data with a DAQ. The whole system is controlled through EPICS and is displayed OPI of CSS. PV created in PLC, DAQ are aliased according to the naming convention. EPICS SEQUENCER are written in FSM code to step through the operation of each device sequentially. Below we show the working principle of the device and its algorithm and measurement results.

## INTRODUCTION

RAON is a heavy ion accelerator facility to accelerate both stable and rare isotope (RI) beams up to the power of 400 kW with an energy higher than 200 MeV/u [1]. For this purpose, RAON has a variety of diagnostic devices such as Faraday Cup(FC), Wire Scanner(WS), and Beam Viewer(BV). Experimental Physics and Industrial Control System(EPICS) is adopted to efficiently control many devices. Device is managed through EPICS PV and sequential operation is performed through SEQUENCER. microTCA has two Single Board Computer(SBC), Data Acquisition(DAQ) that acquires data, and a Control board that controls DAQ. SBC and Control board are connected to the main system through Ethernet and the EPICS IOC is running. One SBC is used as Programmable Logic Controller(PLC) IOC and PLC is used to controlled Servo Motor of WS and Air Cylinder of FC and BV and E-relay. In DAQ, current of WS and FC is obtained, and it is connected to the main system through Control board. Another SBC IOC has a SEQUENCER module, which is used to operate devices in sequence. CS-Studio(CSS) Operator Interface(OPI) provides a display of control system. A schematic diagram of this is shown in Fig. 1.

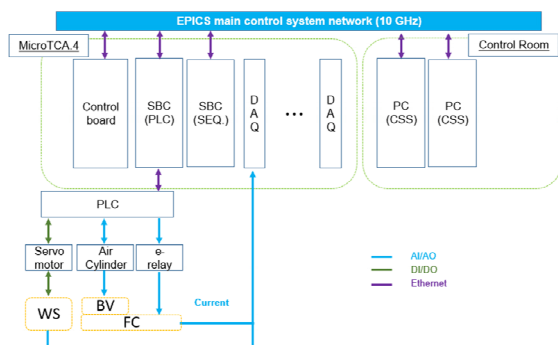


Figure 1: Schematic diagram of diagnostics control system.

## EPICS

EPICS is used to implement distributed control systems for large-scale experiments [2]. It uses a server/client based SCADA architecture. EPICS consists of IOC that transmits and receives data of device, OPI to display data and control experiments, Protocol Channel Access (CA) used for data distribution and PV to which data is transferred item. The structure for this is shown in the Fig. 2.

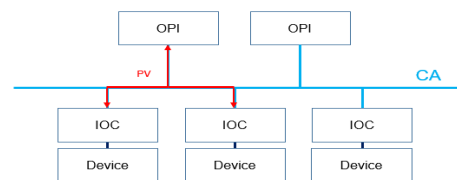


Figure 2: EPICS system.

PV is the name given when creating a record in Database and represents a single value within the EPICS host. PV are shared between IOCs through CA. Therefore, the same PV must not exist. Record can be written directly in the EPICS database or using Visual Database Configuration Tool(VDCT). Record sets types such as analog input(ai) or analog output(ao) and has a PV name. Fields represent the action of the record, and we can set initial values, calculations, scan rates, and so on. It can easily create many records by using the macro function of PV.

Typically, each record value is initialized when the IOC is rebooted. This can be problematic for experiments if all PV values are reset every time a reboot for an IOC change or shuts down due to some issue. To avoid this, we use the autosave module. Autosave module assign the PV and time interval to save, and it's make a saving file during IOC running. Then, when the IOC is run, the PV value is loaded from the saved file.

The SEQUENCER module is used for sequential operation of each device. SEQUENCER is a Finite State Machine (FSM) and has a structure and syntax similar to that of C language. FSM have multiple states and drives the program to states based on events. When an event occurs in one state, it performs action and transitions to the next state. PV can be assigned to a variable in a Sequencer. Therefore, it can operate sequentially according to the change of PV.

## RAON DIAGNOSIC CONTROL SYSTEM

PV is managed according to the RAON Naming Convention so that it does not overlap with other groups. Figure 3. shows the rules for naming conventions. Naming Convention is largely divided into elements such as system

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elements, device elements and signal element. System elements indicates section such as LEBT/MEBT and SUBSYS such as ECRIS/DIAG. Device elements indicates the devices and number such as FC001, WS001. Signal elements indicates such as current/position.

$$\underbrace{\text{SEC/SYS - SUBSYS}}_{\text{a system element}} : \underbrace{\text{DEVXXX(-SUBDEVXXX)}}_{\text{a device element}} : \underbrace{\text{SignalName.Field}}_{\text{a signal element}}$$

Figure 3: Naming convention.

Autosave module was introduced to maintain PV values such as FC calibration values, WS center position. Autosave module saves the value every 5 seconds and the stored value is entered when the IOC is turned on.

Control board has PV for local use. Such PVs are inconvenient to use in the main system. Perform alias according with Naming Convention to merge into main system. Figure 4 shows an example of Alias. It was written in python using a separate diagnostic device management list.

```
alias("LEBT:TS:ZQ9R001:MP0_SET_RANGE_4","LEBT-DIAG:WS002:YSET_RNG")
alias("LEBT:TS:ZQ9R001:MP0_BUF_1MHZ_CH_4","LEBT-DIAG:WS002:YBUF_1M")
alias("LEBT:TS:ZQ9R001:MP0_BUF_1KHZ_CH_4","LEBT-DIAG:WS002:YBUF_1K")
```

Figure 4: PV alias.

Sequential operation and interlock system of devices were configured using SEQUENCER. SEQUENCER is effectively used when performing sequential operations of FC or repetitive operations of WS.

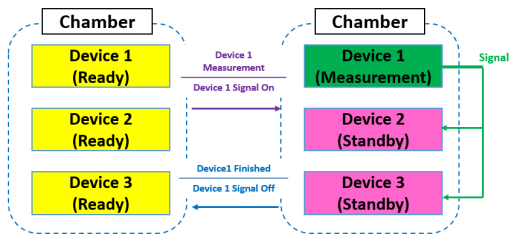


Figure 5: Interlock system for diagnostic chamber.

Several diagnostic devices are installed in single chamber. Interlock system was prepared to prevent a possibility of failure such as broken wire in WS, Conflicts between devices. The procedure of the interlock system is shown in Fig. 5. If there are no problems, all devices are Ready state. When Device 1 starts measuring, it sends a signal and other devices transitions to a Standby state. Measurement cannot be started in the Standby state. When the measurement of Device 1 is completely finished, the status of all devices is transitioned to Ready state.

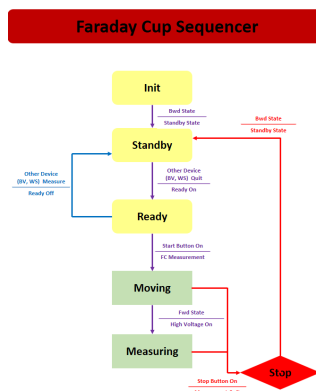


Figure 6: Faraday cup sequence.

Figure 6 shows the action sequence of the Faraday Cup. Initial state is the step to check the device state when IOC operation. When the device is in the backward position, it transitions from the initial state to the standby state. Standby/Ready status is determined by the interlock. In Ready state, pressing the start button on the OPI moves the Faraday Cup to the inside of the chamber. When FC moving inside, it can also exit by pressing the stop button. When the Faraday Cup goes to the measurement position, the high voltage turns on and starts the measurement. The measured value is the value obtained by calibrating the current read from DAQ. Measurements are displayed in the monitoring OPI. when the end button is pressed, the high voltage is turned off, the cylinder is pulled back, and it enters the standby state.

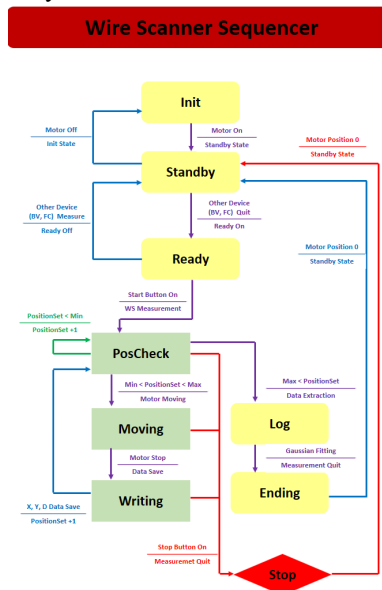


Figure 7: Wire scanner sequence.

Figure 7 shows the action sequence of the Wire Scanner. When the motor is powered on, it transitions from initial state to the standby state. Similar to FC, Standby/Ready status is determined by interlock. We can set the measurement condition such as range, interval of WS in Ready state. When the start button is pressed, the position to be measured is checked first. When the measurement range is confirmed, servo motor moves to that position. Then stops and

records current and position. Since the WS is inserted at a 45 degree angle, the X and Y axes have a compensation between the motor position and the recording position. Execute these corrections in the writing state. Diagonal (D) is recorded as the motor position. Measures are displayed in OPI in real time. Repeat positioning and measurement until all set ranges have been measured. After the measurement, the center position and sigma value are calculated through Gaussian fitting in the python EPICS module and the Gaussian graph is displayed in the OPI. After all measurements are completed, it returns to the position and enters the standby state.

## INSTALLATION AND REMOTE TESTING

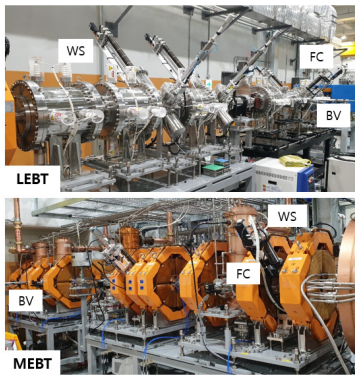


Figure 8: LEBT/MEBT section.

The injector section consists of ECR-IS and LEBT, RFQ, MEBT. The LEBT section has 4 WS, 2 BV and 3 FC. MEBT section has 4 WS, 1 BV and 2 FC. All installed as shown in Fig. 8.



Figure 9: Control room.

Figure 9 shows the RAON Control Room. The operation and measurement of the diagnostic device were performed in the control room.

Control System Studio is a collection of tools and applications to monitor and operate large scale control systems [3].

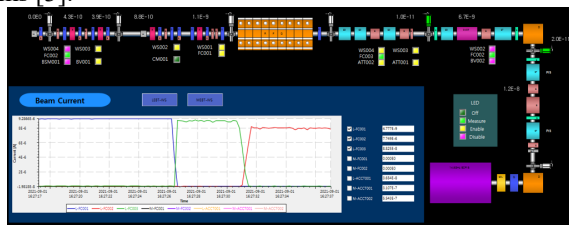


Figure 10: Monitoring OPI.

Figure 10 shows the monitoring OPI of the injector. We can check the vacuum level of the beam line and whether

the gate valve is open or closed. Real-time display of current from FC and ACCT so we can see only what we need. In addition, the current status of each diagnostic device can be checked through the LED. The LED state depends on the state of the sequencer. Dark green is OFF, green is measuring, yellow is Ready, and pink is standby.

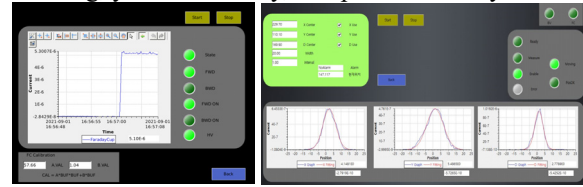


Figure 11: Control OPI, (a)left : Faraday cup OPI, (b)right : Wire scanner OPI.

Figure 11 shows each device Control OPI. The Faraday Cup OPI displays the measured current and the status of the pneumatic cylinder. It can input a calibration value to compensate for the current loss in the cable. Since the operation sequence is written in the SEQUENCER, it can use by pressing just the Start/Stop button. In the Fig. 11(a), FC is in the forward position and the current is measured after HV is turned on.

The Wire scanner OPI displays the measured current and position. And it can set the measurement options for WS. Options include whether the axis is measured or not, the center position, the measurement range and interval. When pressing the start button, it follows the sequencer to measure. It can stop at any time during the measurement. In Fig. 11(b), after the X, Y, D measurements of the WS are completed, Gaussian fitting is performed.

## CONCLUSION

Beam diagnostic device was installed in the injector section, and control and measurement were performed using EPICS/CSS. Sequential operation and interlock system based on SEQUENCER also confirmed no problem. Whenever an error occurs in SEQUENCER, it is being fixed. Research is underway to measure the beam of the injector and make an optimized beam for the acceleration part. The installation and control of diagnostic devices in the SCL3 and P2DT sections are also being prepared.

## ACKNOWLEDGMENT

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## REFERENCES

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- [3] CS-Studio, <https://controlsystemstudio.org/>.