EVALUATION OF A LAN-DIO (DIGITAL-IO TO LAN) CONVERTER

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Abstract

In J-PARC, digital-IO signals are often handled by PLC D-IO modules. Even when number of signals is less than 8, a PLC CPU module is necessary. This fact results in slightly high cost. A commercial digital-IO to LAN (LAN-DIO) converter, FutureNet XIO-100, has been tested as an alternate low-cost solution. The converter has 8 digital inputs and 8 digital outputs, which can be monitored/controlled through Ethernet or a serial line. The remote communication is based on Modbus protocol. An EPICS support for the converter was developed using Stream Device. In March 2023, a converter was demonstrated at KAGRA. The remote monitoring of KAGRA vacuum devices (two gate valves, a roots pump and an ion pump) was realized successfully. The details of the converter, development of EPICS support, and the evaluation at KAGRA will be described.

INTRODUCTION

J-PARC (Japan Proton Accelerator Research Complex) is a high-intensity proton accelerator complex. It consists of three accelerators: a 400-MeV Linac (LI), a 3-GeV Rapid Cycling Synchrotron (RCS), and a 30-GeV slow cycling Main Ring Synchrotron (MR) [1, 2]. Since the initial beam in 2006, J-PARC has been improving beam power. Concerning MR, new power-supply system for the main magnet started operation since Jan. 2023. A high-power trail of MR achieved 753-kw in Apr. 2023 [3].

In J-PARC, PLC is a standard form factor for control system [4, 5]. The PLC digital-in and digital-out (D-IO) modules are widely used for controlling and monitoring accelerator components. However, to use a PLC D-IO module, a PLC CPU module must be accompanied, even there are fewer than 8 signals. This fact leads to a high cost. Therefore, we want a cheaper solution when number of signals is fewer than 8.

In FY2022, we surveyed commercial digital-IO to LAN (LAN-DIO) modules. Among candidates, we finally selected FutureNet XIO-100.

At first, this paper shows LAN-DIO candidates in the market, and reasons why we chose XIO-100. Then, the paper describes the initial configuration of the module, development of EPICS support using StreamDevice, demonstration with vacuum devices in the KAGRA tunnel in March 2023.

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LAN-DIO CONVERTER

There are many possible products of LAN-DIO converter in the market, here we showed four of them.

(1) ioLogik E1212 module [6]: it is produced by MOXA company (Taiwan), which has 8 digital input (DI) channels and 8 configurable digital input output (DIO) channels. Many protocols are supported, such as Modbus and Ethernet/IP. It is widely used in control system field, e.g., RIBF/RIKEN uses the module to control and read “Open”, “Close”, and “Status” of the electromagnetic valve [7]. The module costs around 50,000 yen.

(2) ADAM-4055 [8]: It is produced by Advantech company (Taiwan), which has 8 isolated DI channels and 8 isolated DO channels. It costs around 32,000 yen.

(3) LA-485R-P [9]: It is produced by a Japanese company, Line Eye. The module has 2 DI channels and 2 DO channels. The channels can be controlled or monitored by Ethernet. It costs about 43,000 yen.

(4) FutureNet XIO-100 [10]: It is also made by a Japanese company, Century Systems. It has 8 DI channels and 8 DO channels, which can be controlled or monitored through Ethernet or a serial line. The module costs about 50,000 yen.

In FY2022, we found that the ioLogik E1212 module was out of stock in Japan, and the ADAM-4055 module was also difficult to be delivered to Japan because of COVID-19. Therefore, we prefer to buy a domestic product. Between LA-485R-P and FutureNet XIO-100, we tried to contact company’s salespersons. Finally, we decided to use FutureNet XIO-100 because of its better technical support. In addition, Century Systems company guaranteed that the product could be delivered before the end of FY2022.

FUTURENET XIO-100 AND EPICS

FutureNet XIO-100

Fig. 1 shows the picture of the FutureNet XIO-100 module. There are 8 channels for DI and 8 channels for DO signals, respectively. We can choose two different signal types on demand: DC 24V type or Relay type. The module can be configured by an Ethernet port or a RS232 serial line at the bottom side. For remote monitoring or control, the same Ethernet port or a RS485 line is used.

A disadvantage of the module: as shown in Fig. 1, the DI/DO signal-cable connection ports are too small to plug

in. Careful treatment of signal cables is required to avoid cable loosening.

Configuration

At first, we need to configure the IP address. With a cross network cable, we can configure the module by various setting commands after "telnet" connection (default IP address: 192.168.254.252). For example, the IP address can be changed using "ip lan address IP/MASK" command. The commands and examples are given in the manual [11].

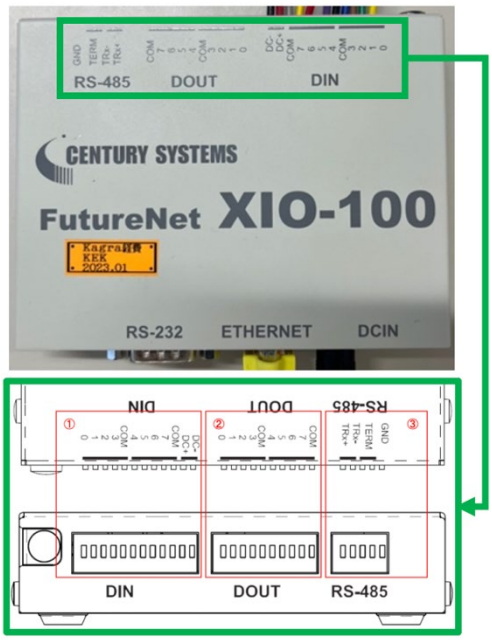

Figure 1: Picture of FutureNet XIO-100 module.

Modbus Protocol and EPICS StreamDevice

To realize remote monitoring and control of the module, we selected the Ethernet port and Modbus/TCP protocol.

The communication commands based on Modbus/TCP protocol follow the format: transaction identifier (2 bytes), protocol identifier (2 bytes), length field (2 bytes), unit identifier (1 byte), Modbus function code (1 byte), followed by data as needed [12].

To get the status of 8 DI channels, the command is as following. The transaction identifier is 0. The protocol identifier is 0. The length field means the number of bytes following, 6 in this case. The unit identifier is used when there are many XIO-100 modules, thus, 0 in our case. The Modbus function 2 is used, which means "Read input discrete". Finally, the command for monitoring 8 DI channels is: "00 00 00 00 00 06 00 02 00 00 00 08".

The request and response of the command is shown in Fig. 2. The response "c2" is "1100 0010" in binary, which means ch1, ch6, and ch7 are in "on" status, other channels are in "off" status. The observed communication throughput is about 0.1 second.

Experimental Physics and Industrial Control System (EPICS)-based systems are widely used in accelerator control field [13]. We developed EPICS support of XIO-100 module based on StreamDevice [14]. The protocol file and part of EPICS db file are shown in Fig. 3. We use "mbbiDirect" record to get a combined value of the status of 8 channels, then, the received data is separated into 8 Process Variables (PVs) according to the bit order, which indicate the status of 8 channels.

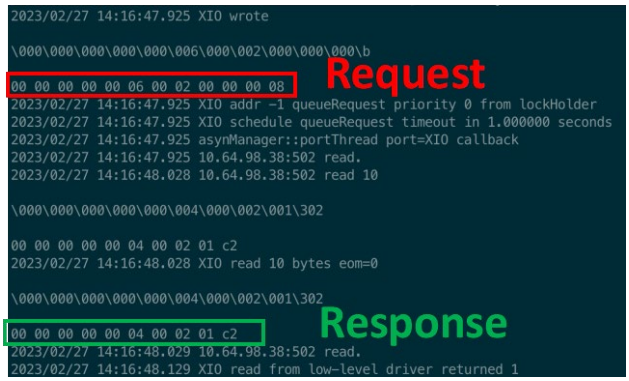

Figure 2: Request and response of the communication command to get 8 DI status.

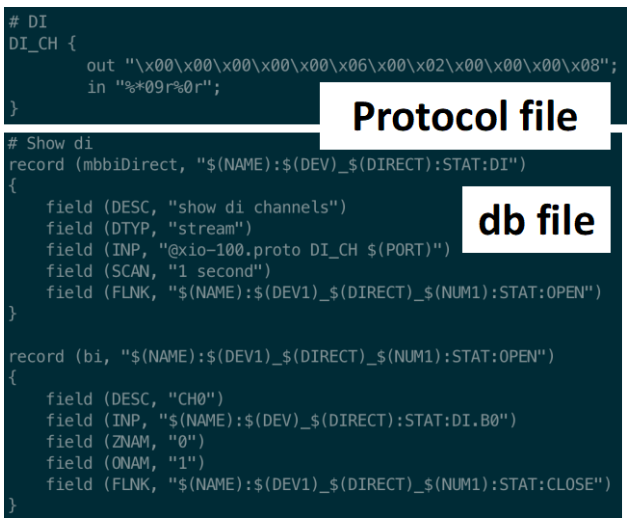

Figure 3: EPICS protocol file and part of database file.

IMPLIMENTATION AT KAGRA

KAGRA is a gravitational wave detector, which is a 3-km x 3-km laser interferometer located at Kamioka, Gifu, Japan [15]. In March 2023, the XIO-100 module was introduced at KAGRA. It was used for remote monitoring of vacuum devices in the KAGRA tunnel [16].

The Fig. 4 shows a signal interface box with an XIO-100 module. The DI channels of XIO-100 are connected to two Gate Valves (GV), a Roots Pump, and an Agilent Ion Pump. Former four DI channels are configured to DC 24V type to monitor the Open/Close status of two GVs. Latter four DI channels are set to use Relay type to monitor pump status.

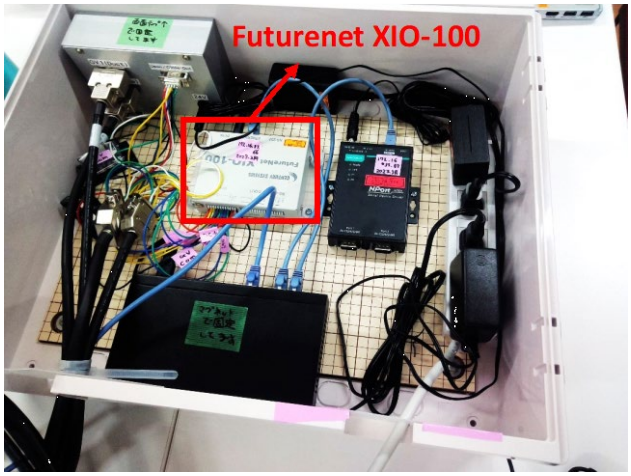

Figure 4: A signal interface box with an XIO-100 module.

The remote monitoring GUI of KAGRA vacuum devices is shown as Fig. 5. The status of two GVs, one Roots Pump and one Ion Pump was monitored successfully.

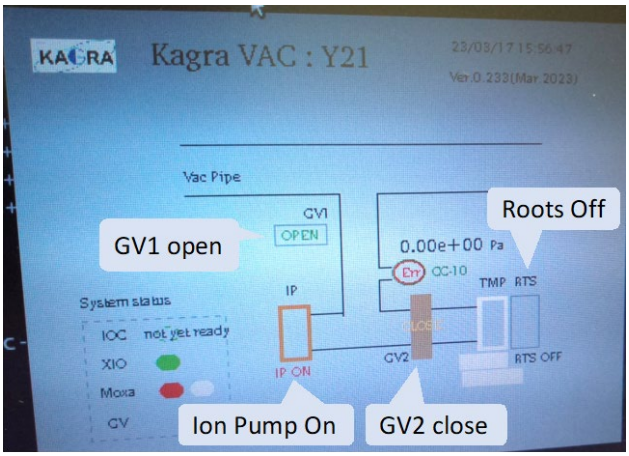

Figure 5: Picture of the GUI of KAGRA vacuum monitoring system.

DISCUSSION

The implementation of XIO-100 at KAGRA demonstrated the good enough performance of the module. Table 1 shows the comparison between the PLC D-IO and the LAN-DIO.

Table 1: Comparison Between LAN-DIO and PLC D-IO

	PLC D-IO (SP71, XD08, YC08, etc.)	LAN-DIO (XIO-100)
Experience	Wealth	Inexperienced
Price	~150,000 yen/set	~50,000/module
Extension	Yes (max. 15 IO modules/ unit)	No (DI channel x8, DO channel x8)

The PLC D-IO has advantages: much experience in J-PARC and KEK, scalable for maximum 15 I/O modules at one base unit (a base with 16 slots is available for Yokogawa FAM3 series [17]). But it costs about 150,000 yen for our case, including a CPU module, power supply module, a base and two I/O modules.

Compared with the PLC D-IO, the LAN-DIO module is a cheaper substitute. But there is one disadvantage: if number of signals is more than 8, another XIO-100 module should be prepared, which will cost another 50,000 yen.

CONCLUSION

A LAN-DIO converter, FutureNet XIO-100, is evaluated as a cheaper substitute of PLC D-IO modules. The module was implemented at KAGRA in March 2023, and demonstrated to monitor KAGRA's vacuum devices. Compared with the PLC D-IO modules, it worked with a cheaper price.

The result shows that a LAN-DIO converter can be a possible cheaper solution for monitoring DI/DO signals of any accelerator or experimental facility, when the number of digital signals is less than 8.

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REFERENCES

[1] J-PARC website: http://j-parc.jp/index-e.html

[2] S. Nagamiya, "Introduction to J-PARC", Prog. Theor. Exp. Phys., vol. 2012, p. 02B001, 2012. doi: 10.1093/ptep/pts025

[3] Y. Sato *et al.*, "The beam operation of J-PARC main ring after the first step of the high repetition upgrade", The 20th Annual Meeting of Particle Accelerator Society of Japan (PASJ2023), Funabashi, Japan, Aug.29-Sept.1, 2023, WEOB4, this meeting.

[4] J.Odagiri *et al.*, "Application of EPICS F3RP61 to Accelerator Control", Proc. ICALEPCS 2009, Kobe, Japan, Oct. 2009, pp.916-918.

[5] N. Kamikubota *et al.*, "J-PARC control toward future reliable operation", in Proc. ICALEPCS 2011, Grenoble, France, Oct. 2011, pp.378-381.

[6] MOXA ioLogik E1212: https://www.moxa.com/jp/products/industrial-edge-connectivity/controllers-and-ios/universal-controllers-and-i-os/iologik-e1200-series/iologik-e1212

[7] Application of MOXA ioLogik E1212 at RIKEN: https://ribf.riken.jp/sisetu-kyoyo/Tips/AyLV/MoxaCTRL.html

[8] ADAM-4055: https://www.advantech.com/ja-jp/products/gf-5vwk/adam-4055/mod_fd19e628-4ea5-4c16-915c-5ceeef2fb65c

[9] LA-485R-P: https://www.lineeye.co.jp/html/product_LA-485R-P.html

[10] FutureNet XIO-100: https://www.centurysys.co.jp/products/protocol/xio100.html

[11] FutureNet XIO-100 users' manual.
https://www.centurysys.co.jp/downloads/archive/xio100/xio100_manual_v2.1.0.pdf

[12] OPEN MODBUS/TCP SPECIFICATION.
https://wingpath.co.uk/docs/modbus_tcp_specification.pdf

[13] EPICS introduction:
https://epics-controls.org

[14] StreamDevice introduction:
http://epics.web.psi.ch/software/streamdevice/

[15] KAGRA website: https://gwcenter.icrr.u-tokyo.ac.jp

[16] N. Kamikubota *et al*., "Introduction of accelerator know-hows to KAGRA's vacuum system II", The 20th Annual Meeting of Particle Accelerator Society of Japan (PASJ2023), Funabashi, Japan, Aug.29-Sept.1, 2023, THP13, this meeting.

[17] Yokogwa PLC:
https://www.yokogawa.co.jp/solutions/products-and-services/control/control-devices/programmable-logic-controller/