ETHERCAT SOLUTION FOR THE TPS CONTROL SYSTEM

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Abstract

The EtherCAT real-time Ethernet technology is now widely used in the field of industrial automation. This paper is to evaluate and establish the EtherCAT (Ethernet for Control Automation Technology) solution for digital and analogue I/O and motion control in accelerator applications. Thanks to developments at the Diamond Light Source, EtherCAT is integrated into EPICS with support for most devices of a general data type. Preliminary tests and plans are summarized in this report.

INTRODUCTION

The Taiwan Photon Source (TPS) is a low emittance, high brightness synchrotron light source, located in Hsinchu, Taiwan. New control technologies have begun to emerge in the past few years and we pay specific attention to the EtherCAT technology [1], which is a fieldbus system based on Ethernet and was developed by Beckhoff Automation [2] in 2003. It has become one of the mainstream communications interfaces for connecting to PLCs, sensors, servo motors, I/O and other automation equipment. The goal of EtherCAT development is to enable Ethernet applications to reduce data update time, lower communications jitter and reduce hardware costs for application to automation. The EtherCAT protocol is standardized in IEC 61158. The EtherCAT master sends a telegram through to each slaves and each EtherCAT device reads the data and inserts its data into the frame as it moves downstream. EtherCAT supports almost any topology, such as line, tree or star.

Several support programs were developed for communication between EPICS IOC and the EtherCAT master. At the Diamond Light Source (DLS) support is being developed based on a scanner process through the IgH EtherCAT which can transfer data between EPICS IOC and EtherCAT master [3] through the UNIX socket. Based on IgH EtherCAT, the PSI [4] also develops an EtherCAT driver, ecat2, for the same purposes. The HE Youngcheng [5] uses the OPC (Object Linking and Embedding for Process Control) gateway driver, which can operate in a Windows OS system. In this study, the DLS-EtherCAT driver is used. It can support most EtherCAT devices of a general data type. A system architecture, plans and implementation will be presented in this report.

ETHERCAT EPICS ARCHITECTURE

Platform

The platform for EtherCAT application is based on the Linux OS, the real-time patch is optional. Two Ethernet ports are basic configuration, one for control system internet and one to connect to EtherCAT devices. In our applications, CompactPCI (Advantech) [6], MXC industrial PC (Adlinktech) [7], UP Squared (Up-board) [8], Raspberry pi [9], all are acceptable. Some existing control systems for ID control are based on the cPCI platform. As a new platform, we select the MXC platform. UP2 and Raspberry are used for special standalone applications. The x86 or x64 works as the EtherCAT master platform.

IgH EtherCAT Master

The IgH EtherCAT Master is an open-source EtherCAT communication software tool [10] for the Linux platform. The devices in the EtherCAT network can be divided into master and slaves. The master acts as the controller of the entire network and is responsible for sending instant packets to each slave to read data or control its behaviour. The Linux OS kernel version must be 2.6 or 3.x. Currently the version of IgH EtherCAT modules is 1.5.2 which was released on 2013-02-12. The performance was studied by Soyeon Kim [11], which shows that the real-time performance is similar to or better than Beckhoff's TwinCAT. The Ethernet driver is divided into the native EtherCAT-Capable Ethernet drivers and the Linux standard Ethernet driver. Users must use the first driver to support real-time communication. After installation of the IgH EtherCAT master, execution of the command "ethercat version" can check if the machine has the EtherCAT driver module loaded, the command "/etc/init.d/ethercat status" checks the status of the IgH EtherCAT master, and the command "/etc/init.d/ethercat stop(start or restart)" controls the behaviour of the IgH EtherCAT master.

DLS EtherCAT EPICS Support

The Diamond Light Source (DLS) EtherCAT is an EPICS support module to interface an EtherCAT bus to EPICS. It uses a scanner process that serves as a server to communicate with EPICS IOC. The PDO (Process Data Objects) and SDO (Service Data Objects) access are supported. The module along with Diamond's Remote I/O was presented in [3]. An EtherCAT device with "REAL" data type of PDO is not supported. We hope to be able to support it in the future. The DLS EtherCAT support consists of four components:

1. Real-time Linux kernel (Optional)
2. IgH EtherCAT device driver
3. Scanner
4. IOCs.

The EPICS environment with asynDriver (asynchronous driver support) and Sequencer (snc/seq) modules are needed for running the DLS EPICS IOC.

Start-up

After the slaves (EtherCAT devices) are connected to the setup, the EtherCAT command line tool can help to visualize it. First, the platform must find the EtherCAT devices

via the command "ethercat slaves". For example, the TPS IU22 insertion device has EtherCAT devices and this command will list all its devices as shown in Fig. 1. Then, using this information, the DLS-EtherCAT chain.xml file is created to configure the sequence and device names. Compiling (Make) the chain.xml file generates the scanner.xml file and operation of the scanner process with the scanner.xml. The scanner process will open up a UNIX socket waiting for communication with the EPICS IOC, thus starting the IOC process to create the PVs.

```
172.20.3.17:~ # ethercat slaves
 0  0:0   OP  +  EK1100 EtherCAT Coupler (2A E-Bus)
 1  0:1   OP  +  EL1819 16K. Dig. Eingang 24V, 10µs
 2  0:2   OP  +  EL2819 16K. Dig. Ausgang 24V, 0,5A, Diagnose
 3  0:3   OP  +  EL3104 4K. Ana. Eingang +/-10V. Diff.
 4  0:4   OP  +  EK1100 EtherCAT Coupler (2A E-Bus)
 5  0:5   OP  +  EL3104 4K. Ana. Eingang +/-10V Diff.
 6  0:6   OP  +  EL3104 4K. Ana. Eingang +/-10V Diff.
 7  0:7   OP  +  EL4134 4K. Ana. Ausgang -10/+10V. 16bit
 8  0:8   OP  +  EL9505 Netzteilklemme 5V
 9  0:9   OP  +  EL1124 4K. Dig. Eingang 5V, 10µs, Sensorversorgung
10  0:10  OP  +  EL2124 4K. Dig. Ausgang 5V, 20mA
11  0:11  OP  +  EK1100 EtherCAT Coupler (2A E-Bus)
12  0:12  OP  +  EL3318 8K. Ana. Eingang Thermoelement (TC)
13  0:13  OP  +  EL3318 8K. Ana. Eingang Thermoelement (TC)
14  0:14  OP  +  EL3318 8K. Ana. Eingang Thermoelement (TC)
172.20.3.17:~ #
```

Figure 1: List of EtherCAT devices installed for the IU22 insertion device.

APPLICATIONS

The DLS-EtherCAT EPICS supports several EtherCAT devices with the general data type. Some of the devices are testing, such as Beckhoff, ADLINK, MOONS, and Taiwan Pulse Motion EtherCAT devices. A wide range of applications can be considered for the accelerator, such as insertion device control, power supply, interlock system, feedback control et al and many devices, including DIO and AIO control, temperature monitor, SSI encoder monitor, and et al are employed.

Insertion Device Control System

For insertion devices, EtherCAT modules are used such as digital and analogue I/O for correction power supply control, gauge pressure reading and temperature monitoring. Figure 2 shows the IU22 insertion device control system layout. EtherCAT devices used are shown in Table 1. The MXC-6300 is used as a control platform with Linux kernel 3.10.0 (rt56) CentOS 7, EPICS base 3.14.12.7, and IgH EtherCAT master 1.5.2.
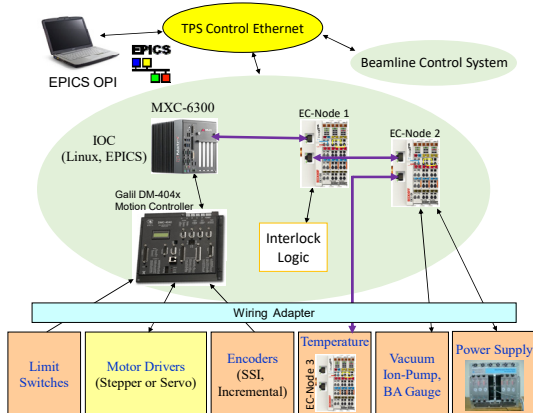
Table 1: List of EtherCAT Devices used for the IU22 Insertion Device Control System

	Device	Function
EC-Node 1	EK1100	EtherCAT Coupler
	EL1819	DI for limit switch and subsystem status input
	EL2819	DO for alarm reset and brake open
	EL3104	AI for driver signals monitor
EC-Node 2	EK1100	EtherCAT Coupler
	EL3104	AI for coil power supply monitor
	EL3104	AI for gauge pressure monitor
	EL4134	AO for coil power supply control
	EL9505	Power Supply terminal 5V
	EL1124	DI 5V for coil power supply fault
	EL2124	DO 5V for coil power supply reset
EC-Node 3	EK1100	EtherCAT Coupler
	EL3318	Thermocouple, Ch01-08
	EL3318	Thermocouple, Ch09-16
	EL3318	Thermocouple, Ch17-24

ID Encoder Malfunction Protection

Insertion devices (ID) are essential components in third-generation synchrotron light sources. Reliable operation of insertion devices is important to users of the beamlines. The most unpredictable fault is due to a soft error of absolute optical encoders due to irradiation. There are several solutions to avoid this kind of fault, one is to increase the distance of the encoder from the beam level, the other is a lead cover shielding and the final method is to adopt auxiliary position sensing devices to help recovery from a fault.

The Beckhoff EL3255 (potentiometer reader) module and potentiometer (GEFRAN, PZ-12-S-200 for Gap, PZ-12-S-075 for Phase) are installed in the ID as shown in Fig. 3. After calibration of the potentiometer reading with SSI encoders, the auxiliary absolute position information can be used to cross check the absolute SSI encoder health for malfunction protection purpose. A protection process is developed to compare the position from two sensors, if the difference is too large, the abort motion command will be sent to the controller to stop the motor driver.
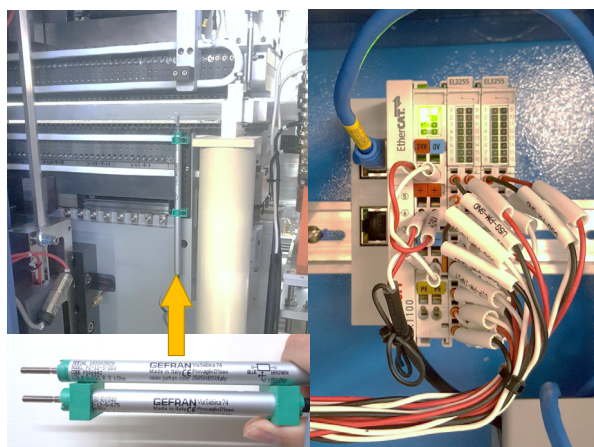

Figure 2: IU22 insertion device control system layout.

Figure 3: Potentiometer and EtherCAT devices for ID.

SUMMARY

The EtherCAT real-time Ethernet technology is now widely used in the field of industrial automation control. The EtherCAT hardware is introduced into the TPS acceleration control system due to its simple configuration and easy extension. The Diamond Light Source EtherCAT EPICS support is selected for communication with the EPICS environment. It's easy to use and works well with most EtherCAT devices for digital and analog I/O, temperature monitoring, encoder monitoring, and et al. Currently, the new TPS insertion device control system uses EtherCAT devices. Another application in the TPS is to develop a protection process for the insertion device when the optical encoder fails. Thanks to the short cycle time of the EtherCAT protocol, the protection cycle can reach 1 kHz. The features of the EtherCAT in the TPS use the EtherCAT motion controller for motor control applications and adoption of the EtherCAT based data acquisition (DAQ) modules for signal acquisitions are in planning.

ACKNOWLEDGMENTS

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