DeviceNet in SSRF control system

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Abstract In the process of making preliminary design for the Shanghai Synchrotron Radiation Facility (SSRF) control system, we designed and implemented the fieldbus DeviceNet for communication between IOCs (I/O Controller) and device controllers. DeviceNet, as an open network standard, provides application layer protocol (IOS/OSI layer 7) and thus can transparently connect devices and IOCs without any need for network programming. The application of the DeviceNet to the EPICS (Experimental Physics and Industrial Control System) based control system are described.

Keywords Control system, EPICS, DeviceNet

CLC numbers TL503.6, TP393.06

1 INTRODUCTION

The control system development toolkits EPICS (Experimental Physics and Industrial Control System), which was initially developed by the Los Alamos and Argonne National laboratories, has been used by worldwide scientific institutions. An EPICS-based control system usually consists of three layers, i.e., OPI (Operator Interface), IOC (Input/Output Controller) and LAN (Local Area Network). OPI is workstation, which provides a man-machine interactive interface. IOC, or front-end computer, provides actual control for equipments. LAN usually is Ethernet, which provides the communication between OPI and IOC[1].

Shanghai Synchrotron Radiation Facility (SSRF) is a medium-scale machine including a 300 MeV LINAC, a booster and a 3.5 GeV storage ring. The SSRF control system will be an EPICS-based system containing about 20,000 process variables. Most of the device controllers are distributed in several hundred meters around the machine[2]. To construct such a distributed system, a reasonable way for data transmission among IOCs and devices is to use an additional network called fieldbus. The advantages of a fieldbus-based architecture are as follows[3]:

A) Installation is simplified

(1) Short signal cable: The DAC and ADC can be placed as close as possible to the devices. Combined with properly specified components analog signals with 16 bit or more resolution become meaningful.

(2) Secure and cheap connection: The fieldbus protocol guarantees reliable data transmission via shielded twisted pair cable even in noisy environments.

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(3)Electrical independency: Cross talk via the common ground or bus backplane does not exist.

B) Intelligent actuators and sensors can be utilized.

(1) Data preprocessing: Raw measured values are converted to relevant physical quantities.

(2) Data sharing: Fieldbus multicast facility allows task synchronization and interlocks.

(3) Autonomous control applications: The embedded controller may generate ramp functions, perform regulation loops and monitor device status.

C) Process Security is improved.

(1) Separate CPU per device: Equipment specific software and configuration are very localized and simple.

(2) Stateful recovery: Service is not interrupted by higher level system crashes, actual IO status and setpoints are provided to the rebooting systems.

(3) Independent trouble shooting: Replacement of faulty or suspicious hardware does not affect other devices.

Because of the above reasons, the fieldbus are widely used in distributed control systems. DeviceNet protocol based on CAN was chosen in SSRF because of its reliability, ease of use and wide acceptance and support by industry, both on the device and the chip level.

2 DEVICENET INTRODUCTION

The DeviceNet is a low-cost communications link to connect industrial devices (sensors, actuators) to a network and eliminate expensive hardwiring. It is an open network standard. The specification and protocol are open for vendors and anyone may obtain the DeviceNet Specification from the Open DeviceNet Vendor Association (ODVA)[4].

The DeviceNet specification incorporates CAN (Control Area Network) specification. CAN specification from Bosch defines a serial communication protocol and covers basically the bottom two layers (i.e. Data Link Layer and Physical Layer) of the IOS Layer Model. DeviceNet specification defines a network communication system for moving data between elements of an industrial control system and covers the top layer (Application Layer) of the IOS Layer Model (Fig.1).

Instead of a traditional source-destination approach, DeviceNet uses a more efficient Producer-Consumer Model that requires packets to have identifier fields for the data. DeviceNet defines two different types of messaging. They are called I/O Messaging and Explicit Messaging. I/O messages are for time-critical, control-oriented data. They provide a dedicated, special-purpose communication path between a producing application and one or more consuming applications. Explicit messages provide multipurpose, point-to-point communication paths between two devices. They provide the typical request/response-oriented network communications used to perform node configuration and problem diagnosis. DeviceNet communication protocol features:

(1) Peer-to-Peer data exchange in which any DeviceNet product can produce and consume message, (2)Master/Slave operation defined as a proper subset of Peer-to-Peer, (3)A DeviceNet product may behave as a Client or as a Server or both, (4)A DeviceNet network may have up to 64 Media Access Control Identifiers or MAC Ids (node address). Each node can support an infinite number of I/O. Typical I/O counts for the pneumatic value actuators are 16 or 32.

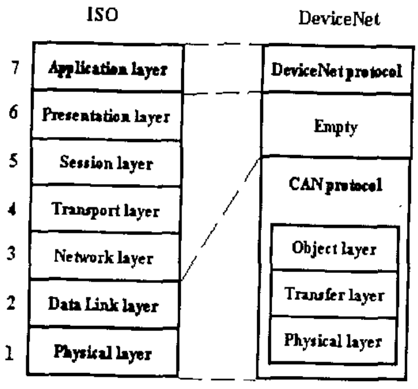

Fig.1 ISO/DeviceNet layer model

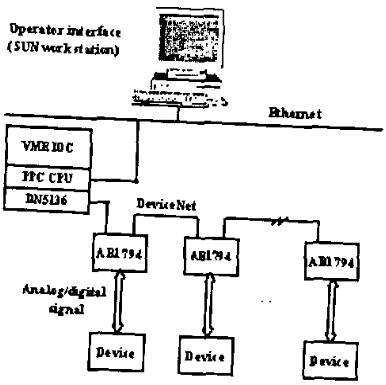

Fig.2 Typical application of the DeviceNet layer in SSRF

3 DEVICENET IN THE SSRF CONTROL SYSTEM

3.1 Hardware structure

Fig.2 shows a typical application of the DeviceNet in SSRF control system. On VME (i.e. IOC) side there is a DeviceNet Scanner (master) that communicates with the device controller through a DeviceNet adapter (slave).

SST 5136-DN-VME card is used as a DeviceNet Scanner, which includes an optically isolated CAN interface and a 16 MHz V40 microprocessor with 128 K shared RAM. The shared memory can be divided into three functional blocks, i.e., 64 K Card Code Segment, 48 K Card Data Segment and 16 K Host Interface Block. All interaction between the host application and scanner application takes place in the Host Interface Block. There is an interrupt signal from the card to the host application and an interrupt from the host application to the card. These interrupts request action based on changes in the Host Interface Block[5].

Consisting of LINAC, BOOSTER and RING, the SSRF has a wide variety of needs for control, monitoring, and data acquisition I/O systems that collect information from distributed devices and present it to I/O controllers in a comprehensive form. It is generally hoped that a single type of device controller with the DeviceNet interface can accommodate all requirements that the different applications might have. A prime candidate among several products on the market is Allen-Bradley 1794 FLEX I/O system, which is a flexible, low-cost, modular I/O system for distributed applications that offers all the functions of larger, rack-based I/O[6].

The FLEX I/O based device controller consists of a DeviceNet adapter, a power supply module and several I/O modules (Fig.3). All these modules are connected with FLEXbus interface. The I/O modules contain circuitry needed to perform special functions related to users application and the DeviceNet adapter powers the internal logic for as many as eight I/O modules and transfer the I/O data to/from the DeviceNet Scanner.

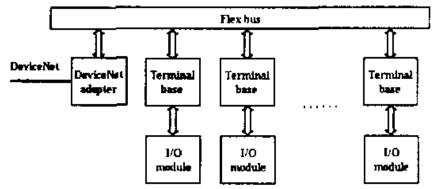

Fig.3 Structure of FLEX I/O based device controller

A variety of FLEX I/O modules enable us to construct different kinds of device controller to meet the requirements of the SSRF control system.

3.2 Software structure

DeviceNet application software consists of VME host application, host interface, DeviceNet master application and slave application. The software structure is shown in Fig.4.

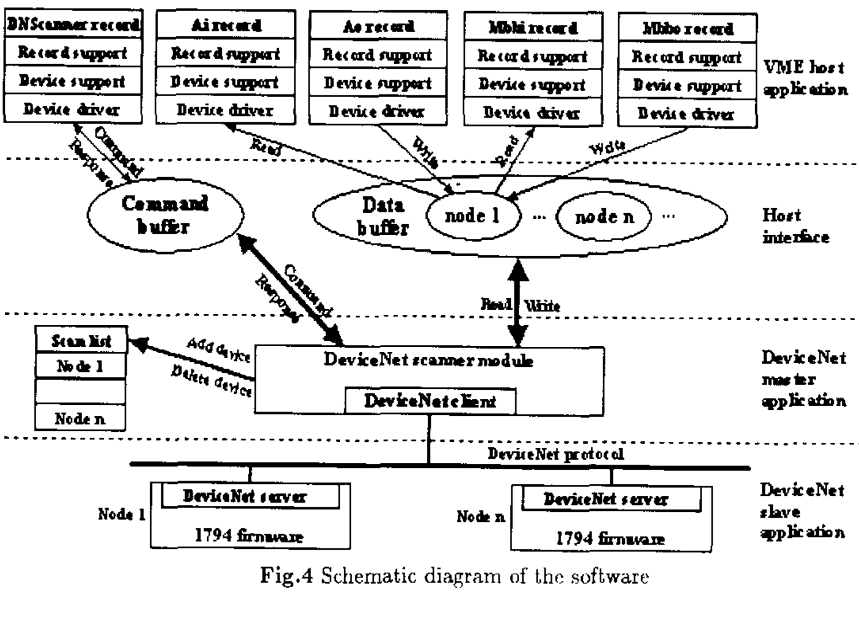

Fig.4 Schematic diagram of the software

EPICS records

Many EPICS records are used in the VME host, or IOC, application. Besides conventional EPICS records, a new type of EPICS record "DNScanner" and its support modules are specially defined and implemented in the application for DeviceNet communication. This record is also used for initialization and configuration of the DeviceNet subnet parameters at IOC boot time. The conventional EPICS records, Ai, Ao, Bi, and Bo, are used to map the I/O channels of the device controller, which acts as a DeviceNet salve. Thus the IOC control to the device controllers can be simply implemented by accessing these records[7].

DeviceNet Scanner Module

The DeviceNet Scanner Module (DSM) is the master node on the DeviceNet. It manages all DeviceNet communication without intervention by the host system and provides a high-speed memory-mapped interface for I/O data exchange between the host system and devices on the DeviceNet network[8].

Command Buffer

The Command Buffer is a section of the Host Interface Block. It is used to configure the DSM and provides a command-response interface to the scanner. Commands are written to the Command Buffer and an interrupt to the 5136-DN-VME triggers execution of the command. Also command results are returned in the Command Buffer.

Data Buffer

The Data Buffer consisting of the input data queue, the output data queue and the explicit message queue is allocated from the memory pool section of the Host Interface Block at the boot time. It provides a shared memory interface for I/O data exchange between the host application and the DSM. Output data is written to the Data Buffer and then put on the DeviceNet network, by DSM, as a polling I/O request message. The input data are also received as a polling I/O response message from the DeviceNet network and passed to the Data Buffer.

Scan List

The Scan List contains MAC IDs and Expected Packet Rate for all the DeviceNet nodes on the network. The DSM creates the scan list during system initialization and establishes Polling I/O connections between the DeviceNet master (i.e. scanner) and salves after receiving "start scan" command.

1794 Firmware

As a DeviceNet slave, the function of firmware on 1794-ADN module is to response all network request messages from the DeviceNet master and provides a high-speed memory-mapped interface for I/O data exchange between the DeviceNet master and the local I/O modules connected with FLEX bus.

DeviceNet Protocol

Base protocol for data exchange between the Master (5136-DN-VME) and the Salve 1794-ADN) is a minimal and efficient subset of DeviceNet called "predefined Master/Slave connection set". Protocol support and communication handler run symmetric both on the processor of 5136-DN-VME card and AB1794-ADN module. After system initializing the 5136-DN-VME reflects an image of the connected AB1794s over the DeviceNet bus.

3.3 Prototype control system built with DeviceNet

In order to evaluate the DeviceNet for device-level control, a prototype was developed for the magnet power supply of the storage ring in the process of SSRF preliminary research. The prototype consists of a SUN workstation, a VMEbus system including 5136-DN-VME DeviceNet interface module and a 1794FLEX I/O based device controller. We designed two types of device controllers to meet the different requirements. One is high resolution (with 16-bit DAC/ADC) controller for the ring dipole and quadrupole magnet power supplies. The other is a low resolution (with 12-bit DAC/ADC) controller for corrector magnet power supply.

Our measurements of the prototype control system for the dipole magnet power supply, which starts with EPICS MEDM application at the operator console, show a precision of 3×10^{-5} and an update rate of 50~100Hz, depending on how many DeviceNet nodes connected with the system.

4 CONCLUSION

The use of commercial products in the accelerator control system will significantly reduce cost and save system development time. DeviceNet, as an advanced fieldbus with application layer protocol (IOS/OSI layer 7), puts all of its essentials in form of firmware into the hardware chips and thus simplifies the tedious work of programming the I/O and the network communication. In the process of the SSRF preliminary research the DeviceNet has been applied to the power supply prototype control system and proven to be highly feasible. The performance of the DeviceNet-based controller together with its low programming cost will allow it to be widely used in the SSRF control system.

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