# Development of a Network Interface Card for a Digital Safety I&C

Kwang-Il Jeong, Seok-Boong Hong, Heui-Youn Park, In-Soo Koo
*I&C HFE Department, Korea Atomic Energy Research Institute, 1045, Daedeokdaero, Yuseong, Daejeon 305-353, Republic of Korea.*
**Corresponding author: hisunny@kaeri.re.kr*

## 1. Introduction

Communication technology may have the most significant impact on digital safety I&C systems of any technology since the introduction of a microprocessor and digitalization [1]. Thus a data communication network (DCN) has become an important system for transmitting the data generated by an I&C system.

To apply a DCN to the safety systems in a NPP I&C system, the DCN should be designed to meet the applicable requirements such as a high safety, high reliability, independence, isolation, deterministic data communication and a status-based communication which are included in IEEE Std. 603, IEEE Std. 7-4.3.2 and NUREG/CR-6082[2-5]. A network interface card (NIC), one of the most important components in a DCN, provides the safety systems with a connection point to a DCN. Therefore a NIC should meet the requirements for a DCN and a digital safety I&C system.

In this paper, a NIC with a VME bus interface, an fiber optic interface, a deterministic data communication, an unidirectional communication for each input and output port, and buffering circuits, as well as a non-interruptible communication for the safety functions of the safety systems are proposed.

## 2. NIC Implementation

Usually commercial off-the-shelf(COTS) NIC is typically connected to one interrupt-request (IRQ) line, that is used to notify the CPU of events that are needed to service an operating system(OS). If this COTS NIC is used for safety systems, its operation or failure affects impairs the safety functions of the safety systems. Therefore our motivation for designing a NIC was to support the communication methods without COTS components in a NPP. Figure 1 and 2 shows the block diagram and the programmable logic device(PLD)-based prototype of proposed NIC.

The NIC is designed to be non-interruptible for a DSP in which safety functions run, even if a NIC has failed or has frames received from other safety systems. Namely there is no interrupt mechanism for a DSP. Only the application programming interface (API) instructions of the applications which run on a DSP can exchange data with a NIC. When the applications are unable to fetch data from a NIC three times, consecutively, the applications use the redundant NICs.

To satisfy the independence/isolation requirements, the NIC is designed to be non-interruptible for a DSP and to use an fiber optic cable for an electrical isolation.

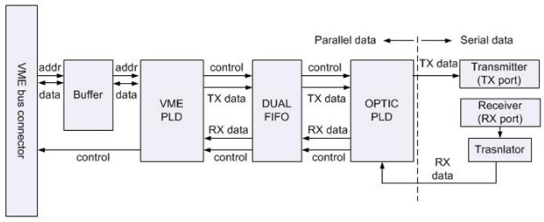


Fig. 1. The block diagram of NIC

Fig. 2. The PLD-based prototype of NIC

The separations between the TX(transmit data) and RX(receive data) ports and between the cables for an unidirectional communication respectively satisfy the communication isolation requirements. Also buffering circuits which consist of a PLD and the buffers in the NIC satisfy the communication independence requirements [4].

Periodic TX/RX operations and point-to-point connections satisfy the deterministic data communication and status-based communication requirements. Periodic TX/RX operations executed by API instructions are initiated by a scheduler. This scheduler is a part of the application programs. It has an execution sequence of a system functions, API instructions, etc. The communication network has a fixed operating cycle time and it is so designed that the data flow rate is essentially constant and independent of a plant status or change in a plant status.

Point-to-point connections are commonly used to establish a direct connection between two nodes. Because the point-to-point connection of each cable for an unidirectional communication has no collision, the transmission delay between two nodes is within a finite and predictable time delay which is the function of a system's communication load.

Fiber optic cable satisfies the media requirements such as a noise immunity, enough bandwidth and low bit error rate and it also provides an electrical isolation. A NIC should adopt and use a simpler protocol, because simpler protocol stacks generally improve the reliability and performance of the communication nodes. The current prototype of a protocol has three open system inter-connection(OSI) layer designs; a physical layer, a data link layer and a application layer.

## 3. Experimental results

In this paper, we focus on the NIC's operability, ignoring all the issues related to the management functions and the control functions. Therefore, the algorithms related to a routing, congestion control, retransmission mechanism and resources management have not been implemented.

The PLD-based prototype of NIC is embedded as a module into standard 3U and 19 inch rack-mount enclosures. Through the transmission test between two nodes, the transmission delay and the frame loss rate are measured to ensure the operability of the implemented NIC. To measure the transmission delay, two nodes are connected via a single fiber optic cable as shown in Figure 3 and the details of the test environments are shown in Table I.

Table I. The test environments

| Component | Specification |
|---|---|
| **Host PC** | **- Intel Pentium III processor, 256 memory<br>- OS : Windows XP Pro<br>- TI(Texas Instrument) Code composer<br>- TMS320C40 Assembler, Linker & Debugger** |
| **Source & Destination node** | **- VME bus backplane<br>- Standard 3U & 19 inch rack-mount<br>- TMS320C40 DSP<br>- Network Interface Card<br>- Power supply** |
| **Fiber optic cable** | **- 1350nm Single mode<br>- ST type connector** |

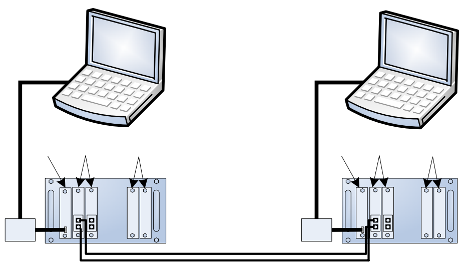

Fig. 3. Development & test environments

Code composer is the DSP industry's first fully integrated development environment (IDE) with DSP-specific functionality. The DSP programs are written in Assembler in order to achieve high speed real-time processing. The application program, programmed as a test program at the Host PC, is written in Assembler and is downloaded to the DSP via a JTAG emulator. The JTAG emulator transmits data between the host PC and the DSP board and accesses the state of the DSP's memory in a real time.

### *3.1 Transmission delay*

The source node transmits a frame to the destination node periodically by a scheduler for 24 hour. In most NPP I&C systems, the data length is about 1 ~ 128 bytes at regular intervals. Therefore we designed the frame structure so that it has 128 byte data in the data field.

The transmission delay includes the processing delay of the NIC and the propagation delay of an fiber optic cable. The propagation delay between two nodes measured by an oscilloscope is a minimum of 183 ㎲ and a maximum of 185 ㎲. The overall delay between two nodes, including the API processing delays, is a minimum of 1,472 ㎲ and a maximum of 1,476 ㎲, namely it is within a finite, predictable time delay, a timely arrival of a transmitted frame from the source node to the destination node can be acquired at all times.

### *3.2 Frame loss rate*

The frame loss rate, an important characteristic of the NIC's performance, is measured between two nodes for 24 hours. The source node transmits frames and the destination node receives them for 24 hours and counts the total number of transmitted frames and received frames respectively. Because the scheduler calls on the NIC API periodically at 25ms, about 3,456,000 frames are transmitted and received in 24 hours. The frame loss rate of this test is 0%, namely, all the transmitted frames at the source node are received at the destination node.

## 4. Conclusions

The PLD-based prototype of our NIC for the safety functions of safety systems has been implemented and tested. Through the transmission tests, the measured transmission delay of the NIC was within a finite, predictable time delay. Also during 24 hours' transmission tests, the frame loss rate was 0%, namely, the intended functions of the NIC were achieved. Through these activities, the operability and the intended functions of the NIC were tested and confirmed. Further demonstration of the performance and functions of the NIC under various test environments remain as future works.

## REFERENCES

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