A 10 MBytes/sec Fibre Optic Link

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Abstract

This paper presents a fibre optic link (FOL) that has been developed for the NA48 experiment at CERN [1]. About fifteen FOLs will be used to transfer event data to the Data Merger (event builder) over a distance of 200 metres.

The FOL has a very simple interface and is capable of transmitting data at a rate of over 10 MBytes/sec while performing error detection.

The optical part of the FOL uses industry standard components. This, combined with its simplicity of use, makes the FOL suitable to be reused in a wide range of applications, which is shown by its use outside the NA48 experiment.

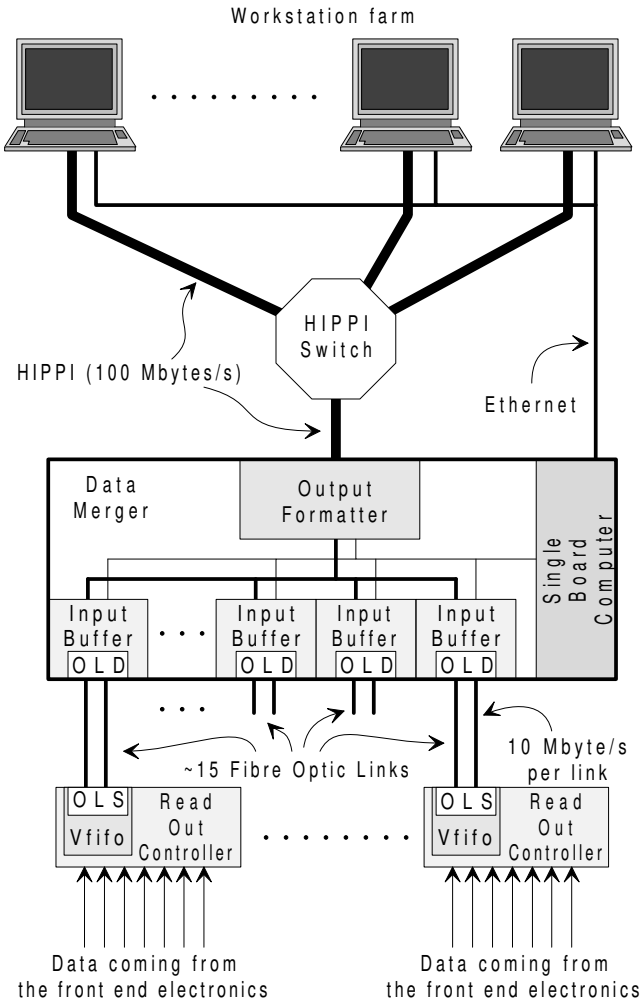

Figure 1. The NA48 data acquisition system.

I. Introduction

Many of the high energy physics experiments now being planned require the collection of large amounts of data coming from several detectors and at high instantaneous event rates. This is the case of the CP-violation experiment, NA48, at CERN.

In the NA48 experiment, the event rate is expected to be 10,000 events/s, with an average event size of 10 Kbyte. This gives a total data rate of 100 Mbyte/s.

Figure 1 shows an overview of the NA48 data flow system after the second level trigger.

Data coming from the subdetector is written into a FIFO memory module (Vfifo) via the Read Out Controller. The Vfifo receives the data and strobes it into the Source of the FOL which then transmits it serially over 200 metres of optical fibre. The Destination of the FOL deserialises the data and feeds it to the Input Buffer of the Data Merger. The Data Merger builds an event from the frames of data received in the Input Buffers and transfers the event information to the workstation farm using the HIPPI protocol [2,3].

The need for a fibre optic link

The fact that the Read Out Controllers are 200 metres away from the Data Merger prevents using HIPPI or another copper media based protocol.

Using fibre optics has the advantage of being cheap and taking little space. Fibre optic technology is also completely insensitive to electrical interference and guarantees galvanic isolation between the modules.

II. The Fibre Optic Link

The FOL is composed of the Optical Link Source (OLS), the Optical Link Destination (OLD) and the fibres connecting the two (figure 2). The modules are based on a Fibre Channel [4] optical link card (OLC) from IBM [5] and a Xilinx FPGA.

The link is designed to transfer information in one direction over a distance of up to 250 metres at a rate of at least 10 Mbyte/sec with a bit error rate of less than 10^{-14} and to perform error detection. The data is sent in 32-bit words plus a control bit, using 8B/10B encoding [6].

The data flow is controlled with the XON/XOFF protocol.

The Fibre Optic Link uses two fibres: one fibre is used to transfer the data and one fibre is used for the data flow control (figure 2).

The link is equipped with a test mode, which enables the user to check easily if the link operates properly.

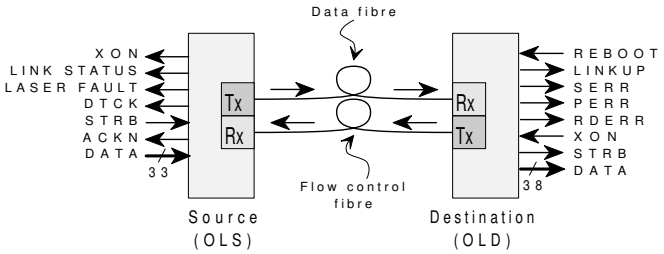

Figure 2. The NA48 Fibre Optic Link

Data transfer

The transfer of user data is from the OLS to the OLD.

A data word is sent through the link with a handshake procedure: after the word and the control bit are stable STRB is raised until the OLS acknowledges with ACKN (figure 3).

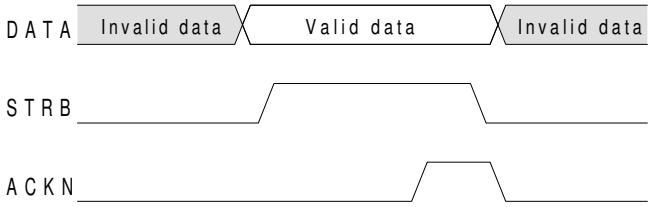

Figure 3. The data word to be sent is given to the fibre optic link source with a handshake protocol.

At the OLD, the presence of the word and the control bit is signalled by the strobe STRB. The data remains stable more than 30 ns before and after the strobe (figure 4).

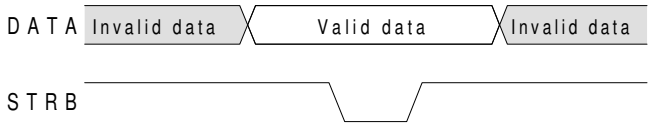

Figure 4. The reception of a data word is indicated by a strobe.

The Optical Link Source (OLS)

When a data word is strobed into the Source, the Source first sends a synchronisation character and then the four bytes of the word, one by one. Finally, a control byte is sent. This control byte contains the control bit provided by the user, a sequence bit (a toggling bit), the parity bits of the four data bytes, and the parity of the control byte itself.

While sending the control byte, the Source raises ACKN and the user can release the STRB, control bit and data lines.

When a byte is sent it is encoded to a 10-bit character before it is fed to the OLC, which serialises and launches the bit stream into the optical fibre.

Figure 5 shows the physical implementation of the OLS. Most of the logic is inside the FPGA. The 8B/10B encoding is external to the FPGA and is implemented with two EPROMs. These are connected to the IBM OLC, which launches the 10-bit characters into the fibre.

The OLS receives flow control information from the OLD but since only a very small set of characters are used for the flow control, the decoding of the 10-bit characters is implemented directly in the FPGA.

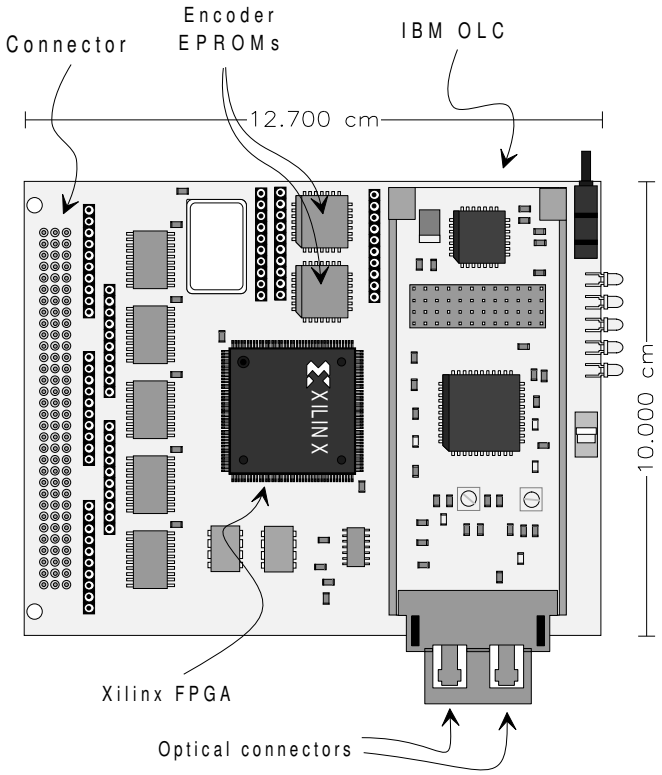

Figure 5. Physical aspect of the Optical Link Source.

The Optical Link Destination (OLD)

The OLC receives the serial bit stream from the fibre and regenerates the 10-bit characters. These are passed to the OLD and are decoded to 8-bit bytes.

The data bytes are stored in their corresponding place in a 32-bit register as they are received. When the control byte is received, the parity bits contained therein are compared to the parity of the data bytes. In addition, the sequence bit is controlled (if the sequence bits of two successive words are equal, a word may have been lost). Finally, the STRB is generated and the contents of the register is available to the user.

If an error is detected during the parity and sequence bit checking or a code violation occurs, the appropriate error signals are generated (PERR, SERR, RDERR).

The physical implementation of the OLD is very similar to the OLS.

Flow control

The XON/XOFF protocol is used for the flow control.

A high to low transition on the Xon line of the OLD causes the OLD to send an XOFF signal to the OLS, while a low to high transition causes the OLD to send an XON signal.

At reception of an XOFF signal the OLS inhibits the generation of the ACKN pulses. The OLS will resume its normal function at reception of an XON signal.

The test mode

When the link is set into test mode, the OLD generates and sends continuously a specific test word to the OLS. If the test word received by the OLD is not what is expected, an error LED is turned on.

III. TECHNICAL SPECIFICATIONS

Power requirement: 0.8A @+5V per module
Bandwidth: 10 MBytes/sec
Size:
-OLS: 127 x 100 [mm]
-OLD: 140 x 100 [mm]
Word size: 32 data bits + 1 control bit (user defined)
Flow control: XON/XOFF
Equipped with:
-Test mode
-Error detection

IV. APPLICATIONS

Although it was originally designed to be used only in the NA48 LKr calorimeter, the FOL is now also being used generally in NA48.

Outside the NA48 experiment, the link is used in the WA89 experiment and at Hermes, DESY [7].

V. CONCLUSION

The FOL has been developed to cover the need for high-speed and long distance data transmission in the NA48 experiment.

The control bit makes it possible to differentiate control information from the data stream without having to impose any particular format or length to the data. This feature makes the FOL a link of general use, which saves development costs. It also eases the task of designing an application using the FOL.

The test mode has proved to be more useful than expected, since not only is it used to test the OLS and OLD but also it can be used to test the physical fibre link and the input buffer.

The FOL has been shown to be easy to install and use because of its modularity and simple user interface. The result is that the FOL is now used in various environments in high-energy physics experiments.

VI. REFERENCES

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