Test System for an Optical Readout Chain of a Silicon Microstrip Detector

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Abstract

A test system, for an optical readout chain of a double-sided silicon microstrip detector, is presented. The system can be used for a quick but complete test of the working performance of the optical readout chain, and for finding exactly the faulty part of the readout chain, in case that an error is detected. It was designed, developed, and built for a silicon microvertex detector used at the LEP collider. A description, of both the hardware and software of the system, is given. Finally, experimental results, of laboratory tests, are shown.

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1. INTRODUCTION

Silicon microstrip detectors are widely used in high energy physics experiments, due to their excellent spatial resolution. The use of double sided microstrip detectors is particularly advantageous, since it enables measurements of both the perpendicular and parallel directions to the beam, called $R_\phi$ and $z$ coordinates.

The output signals of the detector are at two different dc-voltage levels, corresponding to the bias required for the depletion of the silicon junctions. Therefore, their readout must use either optical or capacitive devices, in order to decouple its two sides. In our solution, the usage of optical devices was preferred, since it reduces noise and synchronization problems [1].

We designed, developed, and built a system for testing the readout chain, made of a double sided silicon microstrip detector, its front-end electronics, and optical readout [2]. The test-system is used for testing the readout of the silicon microvertex detector of the L3 experiment, presently installed in the LEP experimental area [3].

The system manages the command of the readout chain, via a microprocessor, receives the output data coming from optical fibers, and processes them.

A user-friendly program, displaying the data on a PC screen, was also implemented.

Both the hardware and software of the system are described and laboratory test results are given.

2. Optical Readout Chain for Double-Sided Microstrip Detectors

A readout chain consists of three main parts.

a) a silicon microstrip detector with its front-end electronics,
b) an optical readout, and
c) a data acquisition system, DAQ.

2(a) Silicon detectors

Silicon microstrip detectors are made of a large number of strips, implanted on both sides. Their front-end readout is usually made of VLSI (Very Large Scale Integration) chips like, for instance, SVX (Silicon Vertex) [4], where the charge preamplifiers are directly connected or integrated.
Output data, from silicon detectors, are in both analog and digital form. The analog data represent the charge, collected by each particular strip. To each analog value, digital data, giving both the corresponding channel number and front-end chip number, are associated.

2(b) Optical readout

The optical readout is used for the decoupling of the high and low voltage sides and for the analog signal digitization. To have the output data in digital form, enables the usage of an optical transmitter (for instance, a 10-bit Fiber Distributed Data Interface, FDDI). This device transforms the digital signals into light signals and sends them to the DAQ, through optical fiber, reducing noise problems.

2(c) Data acquisition system, DAQ

Our test system collects data coming from the detector, through the optical readout, thus, performing the DAQ functions. It consists of three electronic modules:

1) The dsp, based on a Texas Instrument TMS320C25 microprocessor [5],
2) an optical link, called linkott,
3) a module which interfaces the microprocessor with the serial port of the PC, called serint.

Output data arrive, through optical fibers, to two optical receivers, installed on the linkott module. They are used for the conversion of light signals into electrical signals. The data are then transferred to two FIFO (First In First Out) registers of 2 kbytes. Each FIFO register can store data of up to 768 channels. Both the digitized analog data and the digital data are presented on a PC screen. This enables to check the performance of the readout chain, with the help of a simple view test. In addition to performing the DAQ functions, the three electronic modules contain, on the EPROMs (Erasable Programmable Read Only Memory) of the dsp module, the routines which are used to send the command sequences to the readout chain.

The sequences of binary bits, are used for the control of the preamplifiers (e.g., they can set a threshold for the preamplifiers) and other devices. They are brought to the optical readout, 2(b), through a flat cable, connecting it to the linkott module.

The test system enables a complete remote check of the detector front-end electronics and of the optical readout, which can be completed in a few seconds, since the microprocessor is very fast (10 million instructions per second).
Moreover, the system is very flexible, and it can, by changing the microprocessor routines, be adapted to various requests.

3. System Set-up

Figs. 1 and 2 present the system set-up. It consists of five separate parts, to be described in the following:

3(a) Silicon microstrip detector and its front-end electronics (with preamplifiers)

The silicon microstrip detector, used for the readout chain, is called semiladder [3]. The front-end readout is realized, using six SVX chips, on each side of the semiladder.

3(b) Optical readout

To drive signals, to and from the SVXs, we have used two converter boards (called converters) and two optical boards (called optoboards) [6].

The converter transforms the TTL (Transistor to Transistor Logic) signals (SVX side) into differential signals (DAW side) and also drive the voltage lines. The optoboards are used to decouple the ground lines of the two detector sides. In the optoboards there is an ADC/DAC (Analog to Digital/Digital to Analog Converter) board [6] used to digitize the analog output and to set calibration pulses. Moreover, the data are sent from an optical transmitter, which transforms the electrical signal into light signals, through optical fibers, from the optoboards to the DAQ.

3(c) Electronic modules

There are three electronic modules: (1) dsp, (2) linkott, and (3) serint.

(1) The dsp is a conventional digital signal processor module based on a Texas Instruments microprocessor (TMS320C25) [7]. The TMS microchip memory consists of four memory banks, of 1568 words each, with short access time.

Since the four memory banks are not sufficient for complex applications, there are two EPROMs with routines, in order to manage the data input and output of the serial RS232 PC port and to deal with debugging.
The program translation from the Assembler Language to the machine code and the communications with the dsp module, is done by a program on the PC. The PC program includes a debugger for the Assembler.

(2) The signals, which command the readout chain, arrive from the dsp to the linkott module, where they are converted into differential signals, in order to be sent to the optical readout. Two optical receivers, one for each detector side, are located in this module. They are used to convert light signals, coming from the optical fibers, into electrical signals. Data are then transferred to two registers (FIFOa and FIFOb).

The reading of FIFOa and FIFOb is done by a readout cycle of memory location 5800h and 6000h, respectively. A Programmable Array Logic (PAL), installed on the dsp module, addresses correctly FIFOa and FIFOb.

The same PAL provides the strobes for the resetting of the linkott optical receivers and its FIFOs (by a writing cycle of locations 5000h and 6000h).

(3) The interface module, which drives signals between the dsp and the PC serial port, is called serint. A PAL is installed on serint. By changing the PAL program it is possible to change the communication velocity (we used a 19600 baud rate).

4. Commands Form

The command bits are stored in the PC. The user can load the desired command in the dsp. The commands for the optical readout and the front-end chips are written in the dsp memory location 4800h, before being sent out.

The Assembler Commands for performing this operation, are:

- LRLK AR0, 4800h load the Auxiliary Register 0 (AR0) register with address 4800h.
- LARP AR0 register pointer on AR0,
- RPTK ENDSEQ-SEQ-1 repeat the next instruction (ENDSEQ-SEQ-1) times.
  Where (ENDSEQ-SEQ-1) represents the number of bit lines that constitute the command bit sequence to be sent,
- BLDK SEQ* move a word at a time, from the location to 4800h
where sequence SEQ is a label to flag the beginning and the end of the bit sequences. In the following example, the bit sequence, called SEQ, is made of two words. Each word is composed of 14 bits.

```
SEQ
 .word 1 0 0 0 0 0 0 1 0 0 0 0b
 .word 0 0 0 0 0 0 1 1 0 1 1 1b
```

ENDSEQ

5. Functions Available on the Test System

A different test is being performed by the test system for every part of the detector’s readout electronics, thus, allowing to detect with high precision, the broken part, in case of error detection.

1. The input stage of the ADC on the optical readout is a differential amplifier and is used to add a variable DC level to the ADC (ADC offset). The first check is done on the digital output (front-end chip number - CHIP ID -, and detector strip number - STRIP ADD -, together with a check of a fixed offset value.

2. A check can also be done on the digital output of each channel and on the ADC input stage, by fixing different offset values and checking whether they are equally spaced.

3. It is also possible to control the digital output, together with the DAC of the optical readout, which sets the calibration values.

6. Data Presentation

Every command bit sequence, prepared for the test system, checks the data from every detector strip, reading them out sequentially.

The data quality, collected by the readout chain, can be visualized on the PC screen, by employing a user-friendly interface, developed with the Visual Basic Language.

The data presentation window, shown in Fig. 3, can be used as the working environment, either for the normal test or for the development of the system. Data, coming from each side of the detector, are shown in this window. The output data from the detector side, perpendicular and parallel to the beam (measuring the \( R_\phi \) and \( z \) coordinate, respectively), are shown in the three
upper and lower small windows. On the small windows, called Analog Out R(Z), the digitized analog data are displayed. On the small Chip R(Z) windows, the results of the SVXs front-end chips counting, are shown. On the small Channel R(Z) windows the results of the detector strip counting are shown.

With these command bits sequences, the user can choose the right test:

1) analog (Fig. 4)

A check of the working conditions of the readout chain parts, involved with analog signal digitization, is done, by setting six different offset values, on the ADC input stage, so that the analog output, varies. It is possible to control the appearance of the six values and their equal spacing. Moreover, it is possible to perform a digital check of the number of a front-end SVX chip (CHIP ID) and of the number of detector strips (STRIP ADD), associated to a digitized analog value. No digital data are shown on the PC screen, but a software check, of their output order, is performed. In case of error, the analog output is set to zero.

2) calib (Fig. 5)

An important feature of the readout chain is the possibility of changing the DC voltage (calibration value) used as a threshold by the preamplifiers. With this test it is possible to set six different calibration values, thus, checking all the parts of the system involved with calibration changing. The six different calibration values are set, through the DAC module, into the SVX calibration line, changing the analog value. It is possible to check the appearance of the six values on the PC screen and whether they are evenly spaced. Moreover, it is possible to perform a digital check. Also, in this sequence, no digital data are shown, but a software test is done.

3) ladder (Fig. 6)

It is possible to perform a check of the CHIP ID and of the STRIP ADD, associated to a fixed digitized analog value (offset). No check is done on the digital output, so that any error is visible on the PC screen. This test enables to understand, by a simple view test, if the counting of the strips, performed by the SVX, is done correctly, thus, performing a quick test on the digital SVX parts.

4) scope

An infinite cycle, between the writing on the SVX chips and their readout cycles, is performed, thus, enabling to see the shape of the signals, with an oscilloscope. This is a powerful test, since the study of the signals, passing through the optical readout stage, enables to follow
since the study of the signals, passing through the optical readout stage, enables to follow completely the chain behavior. Moreover, with this test, it is possible to check the working conditions of the signal lines, to and from the detector.

7. Data Analysis

The data, collected by the DAQ, can be examined on the PC screen for an on line test.

In Figs. 3, 4, and 5, the output is shown for performed tests, with the ladder, analog and calibration sequences, respectively. It is also possible to save the data on files. The saved data, as described before, concern the SVX chip number, the detector strip number, and the corresponding digitized analog value. They are saved in blocks of four hexadecimal bits. In one block, there is the chip number (the two higher bits) and the channel number (the two lower bits). The two lower bits, of the next block, show the corresponding digitized analog value. The two higher bits are not being used.

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References


Figure Captions

Fig. 1: System set-up.
Fig. 2: System set-up for the test of the silicon microvertex readout chain.
Fig. 3: Data presentation window.
Fig. 4: Data presentation window with the analog sequence.
Fig. 5: Data presentation window with the calib sequence.
Fig. 6: Data presentation window with the ladder sequence.
Fig. 1

- Readout chain
- Test system
- Display
- Data acquisition (DAQ)
- Optical readout
- Front end elect.
- Silicon detector

PC
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