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ФИЗИКА И ТЕХНИКА УСКОРИТЕЛЕЙ

DeLiDAQ-2D — A NEW DATA ACQUISITION SYSTEM FOR POSITION-SENSITIVE NEUTRON DETECTORS WITH DELAY-LINE READOUT

F. V. Levchanovskiy, S. M. Murashkevich[1]

Joint Institute for Nuclear Research, Dubna

Software for a data acquisition system of modern one- and two-dimensional position-sensitive detectors with delay-line readout, which includes a software interface to a new electronic module DeLiDAQ-2D with a USB interface, is presented. The new system after successful tests on the stand and on several spectrometers of the IBR-2 reactor has been integrated into the software complex SONIX+ [1]. The DeLiDAQ-2D module [2] contains an 8-channel time-code converter (TDC-GPX) with a time resolution of 80 ps, field programmable gate array (FPGA), 1 GB histogram memory and high-speed interface with a fiber-optic communication line. A real count rate is no less than 10^6 events/s. The DeLiDAQ-2D module is implemented in the NIM standard. The DeLiDAQ-2D module can operate in two modes: histogram mode and list mode.

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INTRODUCTION

The development of data acquisition systems for neutron spectrometers is one of the main conditions for successful implementation of the program of condensed matter research at the IBR-2 reactor. The improvement of measurement techniques, creation of new more advanced neutron detectors along with the rise in demand for accuracy of data acquisition equipment and its operation speed, computers of new generation required the development of a new DAQ system for modern 1D and 2D position-sensitive detectors (PSD) with delay-line readout.

HARDWARE

For the advanced DAQ system a new data collection module DeLiDAQ-2D has been made and successfully tested. It includes an 8-channel time-code converter (TDC-GPX) with a resolution of 80 ps, and a field programmable gate array FPGA with the firmware performing logical operations, selection and filtering of data events. The module has a 1-GB histogram memory, which allows the collection of 3D-spectra X-Y-TOF of up to $512 \times 512 \times 1024$ 32-bit words. The DeLiDAQ-2D provides two basic options of data acquisition: histogramming with on-line sorting and collection of spectra in the module memory, and list mode. The actual

[1]E-mail: svetlana@nf.jinr.ru

count rate together with data transfer and writing to PC is no less than 10^6 events/s. The DAQ electronics has a build-in test generator which imitates the system operation without detector input. It allows a quick check-up of equipment operation efficiency before an experiment and its debugging. The DeLiDAQ-2D has a NIM standard architecture. Its photo and a diagram of data acquisition are shown in Figs. 1 and 2, respectively.

Data transfer between the acquisition electronics and USB computer interface is performed via a serial optical fiber line at a rate of 1.25 Gbit/s. For reliable data transfer, a check-up CRC-code follows each data package. It allows resending the package if an error has occurred. The maximum distance between DAQ electronics and computer is up to 100 m. Thus, DAQ electronics may be placed at the experimental site, while a host computer is in a distant room. Data transfer rate through USB 2.0 port is 32 MB/s.

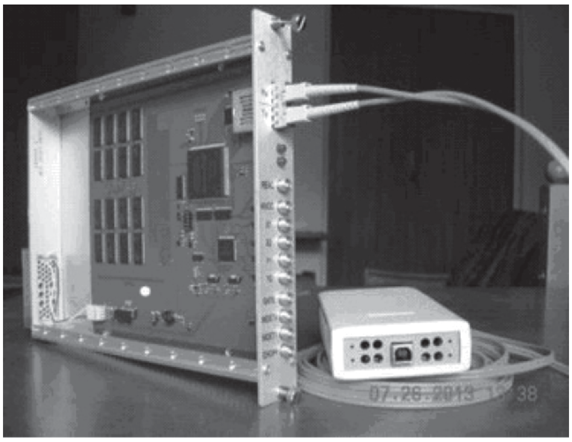

Fig. 1. DeLiDAQ-2D module for data acquisition from PSD

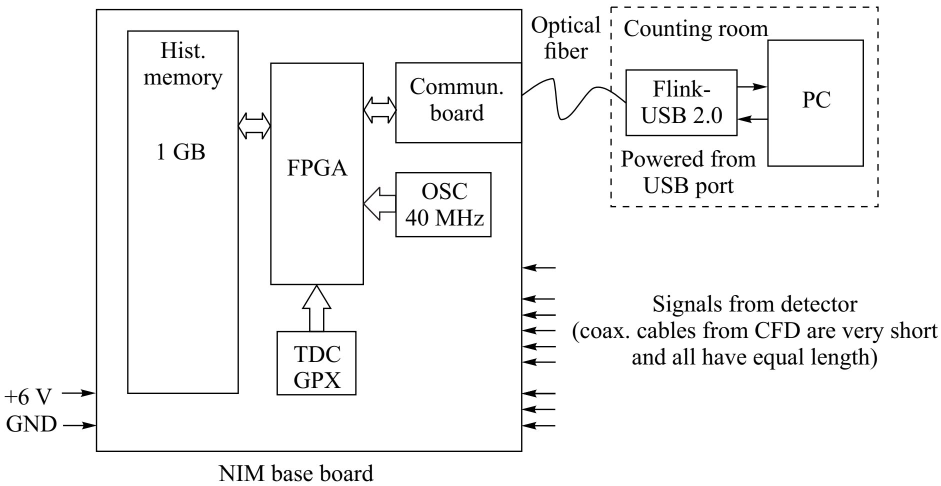

Fig. 2. Architecture of a new system with DeLiDAQ-2D for data acquisition

For matching communication protocols between the fiber-optic line and USB-port a special adapter based on a Cypress CY7C68001 USB SX2 controller and aimed at converting the rate and format of transferred data is installed near a computer. The hardware sequence of data transfer between the computer and DAQ circuit board is as follows:

$$\text{Computer} \leftrightarrow \text{CY7C68001 (chip USB 2.0)} \leftrightarrow \text{FPGA1} \leftrightarrow \text{TLK1501} \leftrightarrow \text{duplex optical fiber} \leftrightarrow \text{TLK1501} \leftrightarrow \text{FPGA2} \leftrightarrow \text{DAQ Board.}$$

Here, FPGA1 is a host for USB chip and initiates its internal registers. In addition it realizes the data interchange protocol via optical fiber and TLK1501 chip (converter of parallel data stream into a serial one and vice versa) with DAQ circuit board.

The USB controller has 4 end points (pipes). The EP2 point is configured for data writing to a histogram memory. The command block defines the type of data interchange through the EP4 point: "read"/"write" to a histogram memory, "write a constant"/"memory erase", "read"/"write" of the registers, "read" of the status register. The EP6 point is for reading data from a histogram memory and contents of the registers. The EP8 point is for reading "raw data". The end points of the USB controller are configured for the standard interchange mode "BULK". All of them, except for 14-byte EP4 are double buffered (512 bytes $\times$ 2).

SOFTWARE

The driver CyUSB.SYS (Generic USB Device Driver) has been chosen as an interface with SX2 controller. It is adapted for Windows XP/7 and works well with other DAQ systems with a similar interface. The library CyAPI.lib from "Cypress" company is used to control data interchange with the module. This library is a program interface for USB driver and contains classes with all necessary functions for the operation with the end points. For reading and writing data from/to the module a synchronous method XferData() of class CCyUSBEndPoint from the library is used.

Several test programs for the module were made, as well as a program d_DeLiDAQ2.exe for data collection and control. This program is a part of apparatus software package for experiment control Sonix+ [1]. All programs were written in C++ and Python. Data visualization was realized using the Matplotlib library. For the work with data arrays the NumPy package was used.

All functions and parameters of the DeLiDAQ-2D module are programmed. The parameters and commands for the module are listed below.

The parameters for data selection and filtering from the time-code converter (TDC–GPX):

— hardware delay between detector start and stop signals;

— time window width with all signals from the same event (largest value of X/Y delay line);

— dynamic range of TDC operation time (5 μs is recommended by the manufacturer to provide a minimal nonlinearity of conversion);

— time quantity of delay line for X-coordinate;

— time quantity of delay line acceptable spread for X-coordinate;

— time quantity of delay line for Y-coordinate;

— time quantity of delay line acceptable for Y-coordinate.

Parameters for controlling TOF neutron counters:

— delay of time window after reactor start pulse (to reject fast neutrons);

— time channel width;

— number of time channels.

Parameters for controlling histogram dimension (bit number code in an address field of histogram memory):

— most significant bit number of detector X-coordinate;

— code of bit array number of X-coordinate for the histogram build-up;

— most significant bit number of detector Y-coordinate;

— code of bit array number of Y-coordinate for the histogram build-up.

Parameters and commands which define the mode of system operation during data acquisition:

— command with data bits, which defines the mode of data collection (1D, 2D, presence of TOF, histogramming, or "raw" data with/without filtering, test or work operation, permission/denial of the superimposed event check — unimportant for the low count rate);

— start/stop of data taking;

— time period of frame sequence in a test mode, which imitates the reactor start;

— reset of the registers of lost events.

Program d_DeLiDAQ2.exe, as well as other parts of the Sonix+ system, keeps the initialization parameters in the common configuration file, and the parameters during operation in the Varman database. When downloading the program provides the initialization of the mod-

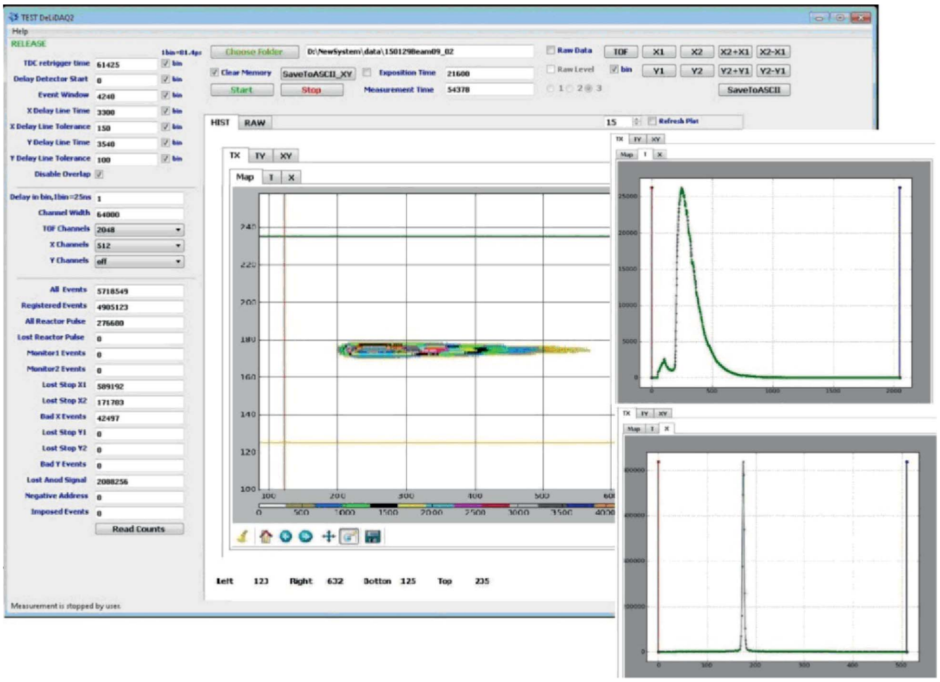

Fig. 3. Main window of the program "TEST DeLiDAQ2"

ule and sets operation to test or real detector mode. The parameters and operation modes can be changed during the experiment by means of commands. Users may choose the operation mode 1D, 2D, with or without TOF. They can change the values of X- and Y-coordinates, number and width of time channels, delay of time window after the reactor start. Users may also set histogramming mode or one of the three list modes: raw data from TDC (Raw1), data from TDC with ordering of events (Raw2), or data after selection and filtering (Raw3). The program starts and stops data taking, reads data from the histogram memory and stores them to a disk. It also reads the counters, which register the number of detected or lost (for some reason) events.

The program "TEST DeLiDAQ2" was designed to test the DeLiDAQ-2D module as well as for adjustment of delay lines and their tolerance before the experiment. Figure 3 shows a window of this program.

This program is a graphical interface for d_DeLiDAQ2.exe. In the main window the user can choose a data histogramming mode, or one of three "raw" data options: Raw1, Raw2, Raw3. If the histogramming mode is selected, the periodical on-line visualization of spectra is provided during data acquisition. Spectra are displayed as the density plots TX, TY, XY after summation over the third coordinate. The 1D-spectra along X, Y and T coordinates after summation over the other two can be displayed as well. In the list mode after finishing the data taking, the data from the histogram memory are stored in a file and by request may be displayed as histograms: T, X1, X2, X1 + X2, X1–X2, Y1, Y2, Y1 + Y2, Y1–Y2. These data are important for the adjustment of the circuit board and determination of actual values of the delay lines and their valid deviations. After finishing data taking, the readings of counters of detected and lost events are displayed in the bottom left corner fields.

CONCLUSIONS

The DAQ system DeLiDAQ-2D has been successfully tested at the stand. It is planned to continue testing the system on the GRAINS spectrometer of the IBR-2 reactor in real experimental conditions.

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