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DATA ACQUISITION AND CONTROL SYSTEMS FOR THE IBR-2 SPECTROMETERS COMPLEX*

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Abstract. *Frank Laboratory of Neutron Physics (FLNP) of the Joint Institute for Nuclear Research (JINR) has the long-term program to develop new generation of the data acquisition systems for IBR-2 spectrometer complex. The goal of the program – to create such electronics and software for data acquisition, data accumulation and data treatment that would be adequate to the word level of the FLNP spectrometers. Such a goal can be reached only with the modern technical tools, software and information technologies, as well as the unified approach to the system design. In the report the requirements for the data acqusition and control systems for the neutron instruments are discussed together with the review of the status of such systems at the FLNP.*

Keywords: *data acquisition, position sensitive detectors, delay line detectors.*

1. INTRODUCTION

In general, neutron scattering instruments are designed so that the intensity of scattered neutrons can be measured as a function of the wave vectors of both the incident and scattered neutrons.

This scattered intensity is directly related to the differential scattering cross-section and proportional also to the time-averaged flux of neutrons with wave vector near incident wave vector on the sample, the number of scattering units in the sample, the solid angle range and energy range over which the scattered neutrons were sampled to produce the measured intensity, and the detection efficiency. The differential scattering cross-section contains the microscopic structural and/or dynamic information of interest. This microscopic information is usually expressed as a function of the momentum and the energy transferred to the sample by the neutron [1].

Any good physical experiment usually tests a hypothesis, test a question or test previous results. It is important that one knows all factors in an experiment. It is also important that the results are as accurate as possible. Carefully conducted experiment must be repeatable. An experiment must control the possible confounding factors - any factors that would mark the accuracy or repeatability of the experiment or the ability to interpret the results.

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By definition, data acquisition is the process of sampling signals that measure real world physical conditions and converting the resulting samples into digital numeric values that can be manipulated by a computer. Data acquisition systems (DAQ) typically convert analog waveforms into digital values for processing. The components of data acquisition systems include:

- Sensors that convert physical parameters to electrical signals.
- Signal conditioning circuitry to convert sensor signals into a form that can be converted to digital values.
- Analog-to-digital converters, which convert conditioned sensor signals to digital values.

Data acquisition applications are controlled by software programs developed using various general purpose programming languages. Specialized software tools used for building large-scale data acquisition systems include EPICS. Graphical programming environments include ladder logic (that represents a program by a graphical diagram), Visual C++, Visual Basic, MATLAB and LabVIEW.

The requirements for the design of the new data acquisition and control systems for neutron scattering instruments can be splitted to a few categories. Obvious general requirements to data acquisition systems include such features as reliability, non-interaction between instruments, flexibility, ease-of-operation, flexible grouping scheme of the measured data, live display (on-line visualization), and possibilities of on-line simple spectra manipulations.

Specific requirements to new data acquisition and control systems for neutron instruments can be sub-divided to ones dictated by the nature of the neutron scattering instruments and ones dictated by the operation of the facility in a user-oriented mode. The neutron scattering length varies from isotope to isotope rather than linearly with the atomic number. Diffractograms of neutrons can show well defined diffraction peaks even at high scattering angles, particularly if the experiment is done at low temperatures. Many neutron sources are equipped with liquid helium cooling systems that allow to collect data at temperatures down to 4.2 K. Although neutrons are uncharged, they carry a spin and interact with magnetic moments. Neutron diffraction can reveal the microscopic magnetic structure of a material; therefore, such devices as magnets and spin flippers are often used at the neutron instruments. When neutrons are scattered from hydrogen-containing materials, they produce diffraction patterns with high noise levels, accordingly, noise reducing techniques are necessary. All this lead to the requirement for the instrument control and monitoring systems to be able to automatically control a large set of different kind of the devices and store its working parameters and physical parameters together with the neutron spectra measured in current conditions.

In case of the use of time-of-flight techniques the data capture electronics (DCE) must record the neutron event by first registering the time of arrival [2]. Because the neutron detection rates reach tens of megahertz in some cases, it is important that the DCE should not introduce any excessive dead-time corrections (dtc). In any case, the highest dtc should not exceed 4% and in general should be well below 0.5%. The time of arrival is recorded as an n-bit time descriptor so that $2^n \geq n_t$ where n_t is the maximum number of time channels required for a particular instrument. The time descriptor specifies the time channel where the event occurred. The time channels may have a constant width $\Delta t = c$, but provisions should be made to allow the user to choose a regime where the width of the time channels increases at longer times. For example, $\Delta t_j = c + At_j$ where c and A may be set by the user.

The user interface of the new data acquisition systems must satisfy the data taking and the data analysis requirements. A run is the basic unit of data collection. It is a period of data acquisition with the detectors, sample position, and sample environment in a fixed state.

During a run all parameters should stay constant. The end-product of a successful run is a file containing a list of all the parameters that may be set to define a run, together with the time-of-flight spectra (the run histogram) recorded in the DCE memory. Data analysis must provide an immediate display of physically meaningful spectra (S(Q) vs. Q, etc.) to the user while a run is in progress, and reducing the entire run histogram to a form suitable for comparison with theory or for the least-squares refinement of structural models.

2. LONG-TERM PROGRAM AT THE FLNP

Development of data acquisition systems, computing and information infrastructure is a key to a successful program of research of condensed matter at the IBR-2. Improvement of measurement techniques, the growing number of managed and controlled parameters, increasing the number and complexity of the detectors used in the experiment, increasing demands on accuracy and speed of the data acquisition equipment, the need for a remote (from anywhere in the local area network) management of the spectrometer and the experiment subsystems have put forward new requirements to the automation system experiments, which can not be satisfied in full without the modernization of the existing hardware and software environment, computing and information infrastructure. Selected technical solutions must take into account the development trends of microelectronics and computer technology, i.e. it should be a system “of tomorrow”.

FLNP has the long-term program to develop new generation of the data acquisition systems for IBR-2 spectrometer complex. The goal of the program – to create such electronics and software for data acquisition, data accumulation and data treatment that would be adequate to the word level of the FLNP spectrometers. Such a goal can be reached only with the modern technical tools, software and information technologies, as well as the unified approach to the system design.

At present, JINR Topical Plan includes the theme “Novel Development and Creation of Equipment for the IBR-2M Spectrometer Complex” lead by S.A. Kulikov and V.I. Prikhodko. Among its sub-topics we should mention the following long-term directions:

- Research, development, manufacturing of prototypes and working models of perspective neutron detectors.
- Development and creation of new generation of data acquisition and experiment control systems for the IBR-2 spectrometer complex.
- Development of new sample environment systems including cryostats and cryomagnetic systems and beam forming systems for the IBR-2 spectrometer complex.

User mode spectrometer of IBR-2 puts additional demands on the systems of data acquisition: the simplicity of development and user-friendly graphical interface, access to measurement results on the Internet, etc.

The main problems in creating new data acquisition systems for neutron spectrometers are reliability, cost, development time, and commissioning, as well as the ability to quickly adapt systems to changing requirements of the experiment. Adaptability is essential, because provides the necessary flexibility to meet the requirements (sometimes unknown) future experiments.

The modernization project for the control systems of the IBR-2 spectrometers includes projects of the unified control system of stepper motors, actuating mechanisms, the sample-changing systems, motor-based beam choppers.

The sample environment of modern neutron spectrometers can include the following types of equipment:

- stepper motors: goniometers, slits, valves, platforms, collimators,
- temperature controllers: refrigerators, stoves,
- magnets,
- the loading machines, the pressure chambers,
- other devices.

The last modernizations of control and monitoring systems of neutron instruments at reactor IBR-2M [3,4] were directed mainly to providing direct control of all aquipment from PC and to the unification. After recent modernizations of the control systems the corresponding neutron instruments have got the following new features:

- New control systems of neutron instruments based on an industrial 4-8-channel relay input-output block with interface RS485 and CAN controllers/drivers with USB interface to PC connection (spin-flippers, high-voltage sources, current power supplies, temperature regulators, etc.)
- Newly created control systems for shutters, choppers and other equipment with concrete features of an instrument. Position sensors are now incorporated into the new control systems.

New developments of the software for the experiment control on the IBR-2 spectrometers at FLNP are concentrated on the instrument control software package Sonix+ (http://sonix.jinr.ru/). It is the long-term project, which includes interfaces to the detectors, motors (goniometers, slits, platforms, and collimators), temperatures controllers (refrigerators, stoves), etc. and is used already on several neutron instruments at the FLNP JINR. Sonix+ [5,6] has modular structure, provides a large set of different modules, has unified protocol of module-to-module communications, provides tuning by configuration, uses the scripting language python (http://www.python.org/) to implement specific instruments requirements, has unified own data format and possibility to switch to any other format with the use of a script, and unified graphical user interface.

After recent modernizations Sonix+ has got the following new features:

- Windows XP environment is now supported.
- New graphycal user interface (previoulsy each controller has own window, and now every main user need has its own window).
- Python script library and preliminary online data treatment is now available. Using the Python as a script language opens wide door for the user to program experiments and to include online preliminary data processing components without obliging assistance of authors of the instrument software.
- Remote supervision and control via Web [6].

The software for data acquisition from the modern position-sensitive detectors with delay line readout includes the software interface to the DeLiDAQ-1 PCI board (http://wwwinfo.jinr.ru/~elitvin/DeLiDAQ/) and will include in the nearest future the software interface to the next generation of the DeLiDAQ electronics with USB interface.

The DAQ systems for delay line detectors at FLNP [7] consist (Fig. 1) of an NIM crate, a discriminator, high-voltage power supply, a personal computer with PCI board for the detector data collection and accumulation, and high speed preamplifiers, developed at FLNP. The DeLiDAQ-1 board with PCI interface [8] for delay line detectors was developed at the Frank Laboratory of Neutron Physics of the Joint Institute for Nuclear Research in collaboration with the Hahn-Meitner Institute of Berlin (HMI in 2008 was transformed into the division of the Helmholtz Zentrum Berlin, HZB). The available set of versions (executed by the logic array and the digital signal processor of the DeLiDAQ-1 board) makes it possible to use the data accumulation system for both linear and area position sensitive detectors without changes in the hardware.

The software of the DeLiDAQ-1 system [9] runs under the Microsoft Windows XP operating system and makes it possible to use the detector either independently or as a part of the packages for controlling experiments. The FLNP has an experience in integrating the DeLiDAQ-1 software with the SONIX+ software package. At the Helmholtz¬ Zentrum Berlin DeLiDAQ-1 software works in the user mode at several spectrometers of the BER-II reactor (integrated with the HZB standard experiment control software package CARESS) and at the SAXS facility of the BESSY synchrotron radiation source.

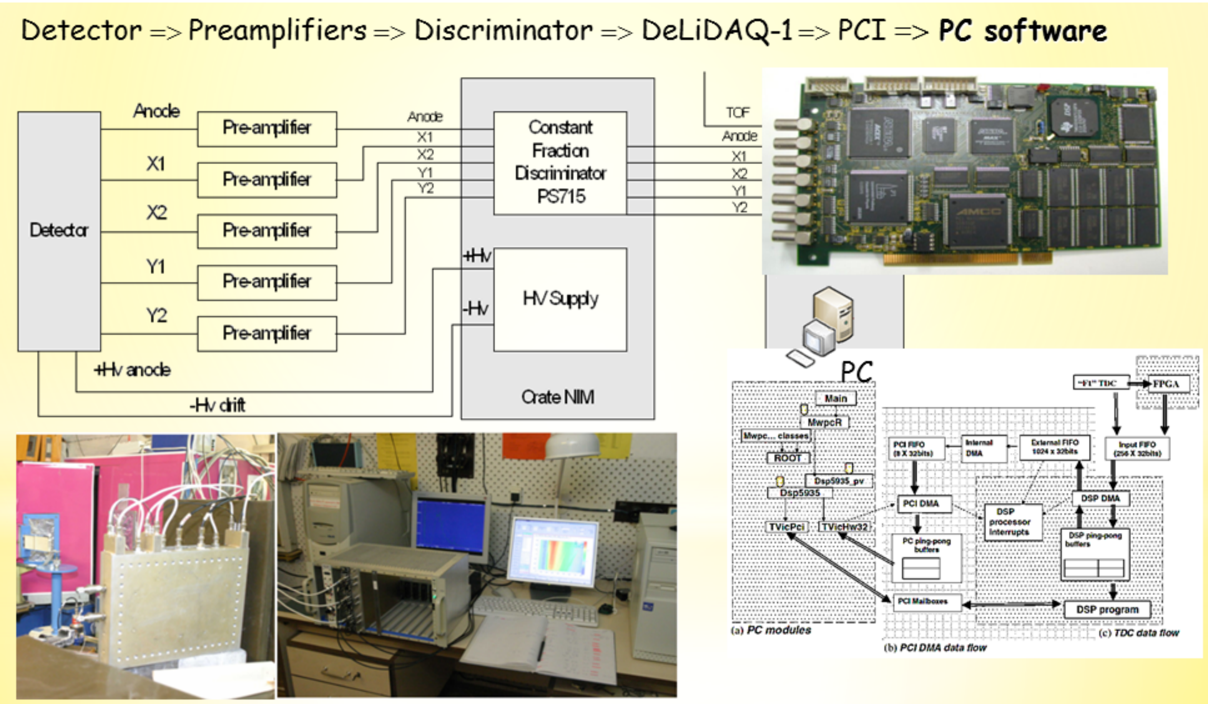

Fig. 1. The components of the DeLiDAQ-1 data acquisition system.

3. CONCLUSIONS

Data acquisition systems are one of the key components for a success of research of condensed matter. Modernization of the existing hardware and software environment, computing and information infrastructure is a must in order to reach several goals:

- Improvement of measurement techniques,
- Growing number of managed and controlled parameters,
- Increasing the number and complexity of the detectors used in the experiment,
- Increasing demands on accuracy and speed of the data acquisition equipment,
- Need for a remote management of the spectrometer and the experiment subsystems,
- Simplicity of development,
- User-friendly graphical interface,
- Access to measurement results on the Internet.

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