Universal LabVIEW-powered Mössbauer spectrometer based on USB, PCI or PXI devices

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Abstract. A new design of the universal Mössbauer spectrometer is presented. Hardware solution is based on commercial-available data acquisition devices working on the USB, PCI or PXI platform controlled by the main application running on the personal computer. Final application allows, in addition to Mössbauer spectra accumulation, the detailed analysis of the acquired detector signal in energy and time domains, and also to tune the velocity driving system separately. The experimental results show a high flexibility in various detectors and velocity transducers usage. It is easy to change the way of operation according to the different experimental requirements. This concept can be used with all common spectrometric benches with different velocity transducers, radioactive sources and gamma-ray detectors. This is a new approach in the Mössbauer spectrometer construction.

1. Introduction
Different programming techniques and instrument solutions were used in the development of Mössbauer spectrometers [1-3]. The development of the original measurement electronic devices can be much demanding and expensive. The better approach can utilize verified and fully serviced commercial devices and develop only the software to its control. With this design, the end-user can alter the whole application fulfilling the user’s requirements.

A new design of Mössbauer spectrometer which uses the virtual instrumentation techniques [4] is presented. This design is based on National Instruments (NI) commercially available USB, PCI or PXI devices. The NI LabVIEW software flexibility allows a wide number of hardware combinations to make which can provide the required function when used for building the application. The developed spectrometer application is nearly “hardware platform independent” [3,5,6].

2. LabVIEW powered Mössbauer spectrometer
The most classical electronic parts of the standard Mössbauer spectrometer are now replaced by the digital signal processing (DSP) algorithms. Here, virtual instrumentation technique is implemented in the first Mössbauer spectrometer powered by LabVIEW. The LabVIEW programming environment allows to realize such a system with minimum single purpose electronic devices, and final product can be used with all the common spectrometric benches.
2.1. \(\gamma\)-ray detection unit

The \(\gamma\)-ray detection unit consists of the detector and the multichannel amplitude analyzer based on a high-speed digital oscilloscope (digitizer). The unprocessed or amplified detector signal is recorded by the digitizer for consecutive processing. The acquired signal is sampled with a limited sampling rate given by the used digitizer. This device is selected with respect to its maximum sampling rate which is chosen by the time-length of the detector impulses for correct acquisition. The most common NaI:Tl scintillator impulses are sampled by 5 MS/s sampling rate. The much shorter impulses from the faster detectors are suitable for sampling with higher rates, i.e. 100 MS/s. Consequently, the sampling rate of the detector output signal differs with the detector type used. In figure 1, the detector signal analysis in the multichannel analysis (MCA) application is shown.

![Figure 1. The MCA front panel.](image)

In this window, the user can set proper sampling rate, vertical range of the analog input, detected events with positive or negative impulses, and detector channel while the digitizer device has two input channels. This sub-application allows detailed analysis of the acquired signal in energy and time domains. After this process, the MCA could be performed. In this step, the user can perform the MCA analysis of the sampled detector signal acquired with parameters applied in the previous step. After MCA, the user can set new discrimination window for selecting the events to be accumulated in the Mössbauer spectrum. In figure 2, the MCA-window is shown.

![Figure 2. The detector signal processing setup and impulses analysis in the MCA application.](image)

2.2. Velocity driving system

A common velocity-driving system for the Mössbauer spectrometer consists of the velocity signal generator, feedback control system (proportional-integral-derivative - PID) with power input/output buffers, and electromechanical linear transducer coupled with a Mössbauer source.
Velocity signal generator is based on the function generator which allows to generate user-defined waveforms with all standard ones. In figure 3, the set-up window for a velocity generation is shown.

![Figure 3. Spectrometer configuration-window.](image)

During the further improvement, the commonly used analog PID controller was here replaced by the digital one [7,8]. This controller is implemented on Field Programmable Gate Array (FPGA) in the NI CompactRIO system [9]. The control algorithm is based on a Discrete PID LabVIEW function and operates in real-time conditions. The reference velocity signal can be also generated in the CompactRIO system or the external one (above mentioned) can be used.

The proposed velocity driving system is flexible enough to cover the wide range of disturbances (including vibrations coming from vacuum and cryogenic equipment, external magnetic forces, etc.) and increases system reliability. In addition, the CompactRIO system works as a remote system controlled via Ethernet, i.e. the PID controller parameters can be changed in the safe distance from a radioactive source and a high magnetic field.

2.3. Hardware solutions

The main unit provides spectra accumulation with the amplitude analysis of the data acquired by the detection unit, and reference velocity signal generation. All the tasks use DSP abilities of LabVIEW system running in the main computer. Several hardware implementations for each unit were tested. The detection unit with NI PXI 5102 (8-bit, 20 MS/s) digitizer [3,5], NI PCI-5124 (12-bit, 200 MS/s) [6] and NI USB-5133 (8-bit, 100 MS/s) were used. Higher sampling rates open the possibility to use the faster detectors and the high-activity radiation sources.

At the place of velocity driving unit, different analog input/output devices were used. Early presented spectrometer used NI PXI 5401 (12-bit, 40 MS/s update rate) function generator [3,5,6] coupled to the analog PID circuit. This generator can be replaced by other multifunction card with a proper analog and digital output on the USB, PCI or PXI platform. Limiting parameters are 12-bit resolution and the 150 kS/s update rate at the analog output as the minimum. Two USB devices, NI USB-6221 (16-bit, 833 kS/s) and NI USB-6215 (16-bit, 250 kS/s), with analog outputs were used. The trigger signal has to be produced by those devices to synchronize the spectra accumulation process.

The second available generation of the velocity unit takes advantage of CompactRIO system building a digital PID controller and the reference velocity generator on the joint device. The analog and digital input/output cRIO modules are used in this driving system where the FPGA provides the digital PID algorithm [7,8].
3. Conclusion
The accumulation unit has a major influence on the performance of the whole system. Not the accumulation process itself but rather the detector data DSP analysis can lead to the overloading of the main computer and data acquisition parameters have to be optimized. The performance tests showed a significant dependence of the measurement time on the actual computer configuration.

Several Mössbauer spectrometers are daily used in the Centre for Nanomaterial Research at the Palacky University in Olomouc. The part of these spectrometers use the principles described above. The advantages of the digital PID control come into effect for the high magnetic field system used in in-field Mössbauer spectroscopy. In figure 4, the main application window of the spectrometer is shown, where the presented spectrum for the standard $\alpha$-Fe sample has a background level of 115 000 counts and a resonance effect of 28%.

![Figure 4](image)

The measurement system described in this article represents a new way of Mössbauer spectrometers construction. The former single-purpose spectrometer units were replaced by universal data acquisition modules. LabVIEW software flexibility allows a wide number of hardware combinations to make which can thus provide the required function. The spectrometer is becoming to be nearly “hardware platform independent” and is prepared to be a commercial product.

Moreover, the commercial devices can be used independently in other measurement processes besides Mössbauer spectroscopy.

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