A New Autonomous Microcontroller-Based Mössbauer Spectroscopy Data Acquisition System

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Introduction

Modern Mössbauer spectrometers base their data recording and storage procedures to Personal Computer (PC) systems, combining separate hardware acquisition System(s) (AS) in the form of expansion card(s) inside (or connected to) the PC. On the other side, for conventional Mössbauer spectroscopy, the nature of the acquisition procedure has not changed much in the past decades. Discrimination of the Pulse Height Analysis (PHA) spectrum of the γ-photon source and source movement synchronization with data acquisition through the Multi Channel Scaling (MCS) logic are still standard modes operated by data ASs [1].

Here we present the development of a new AS which can be used in Mössbauer spectrometers. The system is based on the Propeller^{TM} [2] MicroController Unit (MCU). We have developed the necessary firmware to operate this AS in order to perform, at the same time, data acquisition of: a) the γ-ray source's PHA spectrum (total and user-defined discriminated), and b) the MCS Mössbauer spectrum in synchronization with the source movement.

Results and Discussion

Schematics of the Acquisition System's Main Components

The implementation of the prototype AS is made on a test board (Propeller Proto Board) supplied by Parallax [2]. The γ-ray pulse detection and acceptance/rejection decision is done through the use of four units. The MCU accepts signals from and controls a typical precision Peak Detector circuit (**Unit1**), an analog Comparator (**Unit2**), a Set-Reset Measurement analog switch (**Unit3**), and an Analog to Digital Converter (**Unit4**), which are interconnected following the form given in Figure 1 [3].

In the present form, the γ-ray counter's pulses, after being processed and shaped accordingly by the preamplifier and the main analog amplifier, are fed directly to the appropriate pin of the AS (Figure 2).

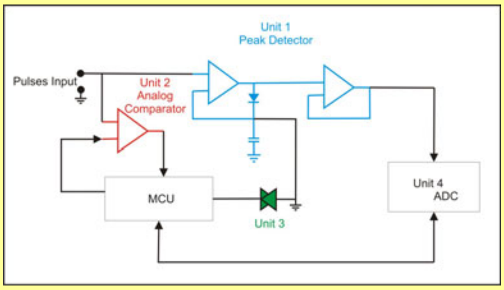


Fig. 1. Schematic of the acquisition system's main units used for pulse detection.

The source movement synchronization (Start) and Channel Advance signals are also fed directly to the AS. The prototype assembly indicating its main components is shown in Figure 2.

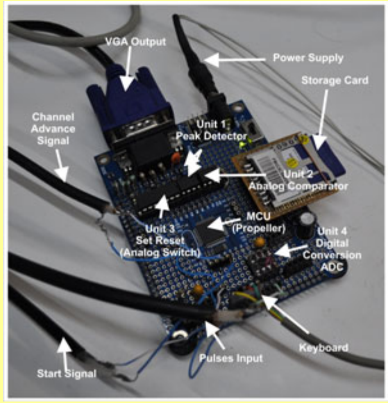


Fig. 2. The prototype Mössbauer spectra Acquisition System assembly. The main units and components are indicated.

Firmware Principles and Method of Operation

The amplified and shaped pulses are fed simultaneously to Unit1 and Unit2. Each pulse is being processed in parallel by both Units. Unit1 extracts a digital signal only if the pulse's magnitude and shape meets the following criteria: 1) is above a threshold level (electronic noise) and 2) has rise time (determined by the firmware) in accordance to the amplifier's shaping. At the same time Unit2 detects and holds the maximum magnitude of the pulse's voltage (Figure 3). The MCU processes the information from both Units (1 and 2) and decides if the pulse is assumed valid or non-valid (noise). If the pulse is assumed non-valid, the MCU forces Unit3 to reset (discharge) the peak detector's sampling capacitor and the pulse is being ignored. If the pulse is assumed valid, then the output of Unit2 is fed to Unit4 for digital measurement. After the end of the digital conversion process, if the pulse height drops between the lower and upper discrimination levels set by the firmware, the pulse is being stored in the appropriate memory position (channel) according to its magnitude.

Following this procedure with minimum and maximum sets of the lower and upper discrimination levels respectively, the PHA spectrum is recorded constantly in real time. In order to operate the AS in the MCS mode, the MCU detects the Start and Channel Advance signals and feeds the valid measured pulses dropping inside the discriminated PHA window to the appropriate memory (channel) positions, according to the information determined by Unit1 in combination with the current channel value indicated by the channel advance signal. The number of channels is user defined and are limited only by the number of Channel Advance signals produced by the frequency generator of the spectrometer, if the AS is operated in this mode. If a Dwell-Time operation mode is chosen, the number of channels is exclusively user defined.

In addition to the PHA and MCS data acquisition modes the MCU is capable of driving an independent video screen display and keyboard, as well as saving the acquired data to an electronic storage system like a Secure Digital (SD) card. An important feature of this unit is that all its operations can be carried out as "stand-alone", that is without the use and support of a PC, making this device an autonomous AS. However we have developed also a relative software to acquire, display and save the recorded data from the AS to a PC. In Figure 4 the AS in operation during PHA and MCS modes is shown.

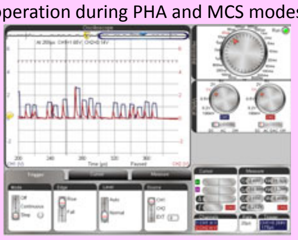
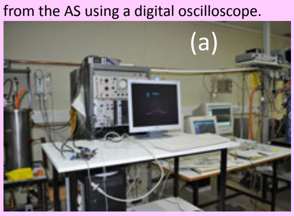
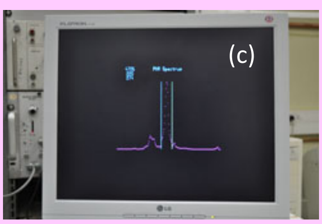
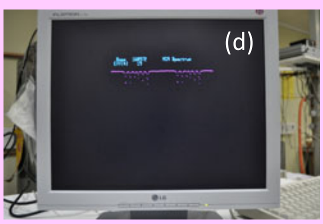
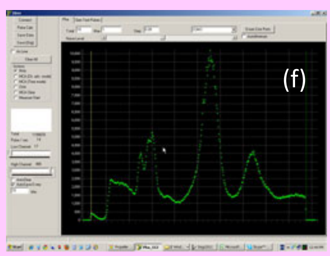


Fig. 3. Snapshot of the original pulses (red line) and measured pulses (blue line) taken from the AS using a digital oscilloscope.









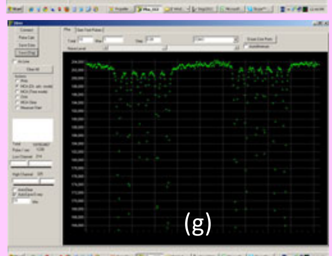
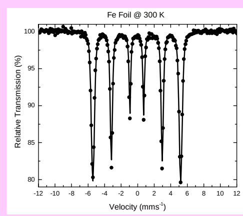


Fig. 4. Pictures and snapshots of the acquisition system in operation during PHA (using a ^{57}Co source, α-Fe foil and Kr/CO_2 proportional counter) and MCS (recording a Mössbauer spectrum of an α-Fe foil @ 300 K) modes. (a) general view, (b) & (c) PHA Mode (autonomous operation), (d) & (e) MCS Mode (autonomous operation), (f) PHA Mode (PC operation), (g) MCS Mode (PC operation).



δ (α-Fe@RT) mm/s	HWHM mm/s	2ε mm/s	Bhf kG
0.000	0.109	-0.005	330.1

Fig. 5. The fitted Mössbauer spectrum of Fig. 4(e) with its resulting Mössbauer parameters.

Conclusions/Development

We have successfully materialized a new AS for Mössbauer spectroscopy based on the Propeller^{TM} MCU. All commercial data AS implement the PHA and MCS modes by exploiting the Complex Programmable Logic Device (CPLD) or Field Programming Gate Arrays (FPGA) capabilities. This technologies are used in large scale production and require an analogous high cost investment. The main reason for choosing the Propeller^{TM} MCU to materialize the PHA and MCS acquisition modes in this AS is that this specific unit combines the advantages of FPGA technology (raw speed, plenty of internal ram, parallel processing, etc) with flexible and versatile firmware programming environment and relatively low cost.

The firmware of this prototype device is under development to include even more additional features, as multiple spectra acquisition from different Mössbauer resonances produced by the same source, and spectral statistics improvement through multiple spectra acquisition.

References

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