RE-CONFIGURABLE DIGITAL PULSE PROCESSOR FOR HIGH-RATE HIGH-RESOLUTION X-RAY SPECTROSCOPY

R. Alberti[(1)], T. Frizzi[(1)], S. Moser[(1)], A. Abba[(2)], A. Geraci[(2)], L. Bombelli[(2)]
[(1)]XGLab SRL, via Moretto da Brescia 23, I-20133, Milano, Italy, ph. +390249660460, email info@xglab.it
[(2)]Politecnico di Milano, Dip. Elettronica e Informazione, Piazza L. da Vinci 32, I-20133, Milano, Italy

A Digital Pulse Processor (DPP) developed for high resolution and ultra-fast X-Ray Spectroscopy will be presented. The system is principally suitable for spectrometers based on last generation Silicon Drift Detector (SDD) used in application with high speed elemental mapping.

The analog input signal, typically from a preamplifier (in pulsed reset mode or RC feedback mode) cascaded with an analog conditioning stage, is digitized by a high performance 150 MHz 16-bit analog-to-digital converter (ADC). The bitstream is driven into the digital processing section of the module, which is based on a digital Field Programmable Gate Array (FPGA) device that plays the roles of main processor, control logic and digital communication interface. The choice of a FPGA instead of a DSP device, for instance, stems from spatial computing improvements in hardware resource availability and in operation frequency. The design of the digital processor has been carried out bearing in foreground linearity, noise immunity, i.e. active and passive electromagnetic (EMI) compatibility, and processing data rate that the specific application requires. This in addition to the (re)configurability of the processing hardware that the configurable FPGA device offers. A user friendly firmware and interface both for configuration and use of the instrument have been realized.
The FPGA operates slightly above 100 MHz of clock frequency and controls the whole process. The on-chip RAM stores the acquired spectrum. The spectra are sent to the host PC via USB2.0 interface. Custom made control software provides data visualization and analysis.

Following outstanding features makes the DPP superior with respect to competitor systems.

1. Fast processing: the fast filtering peaking time (less than 0.1 usec) allows processing of an Input Count Rate of 2Mcps with throughput of about 50%.
2. High performances pile up rejection recovery thanks to an Automatic Adaptive Filtering Mode: the processor in real time changes the filtering parameters in order to recovery the maximum number of piled up events maintaining best performance in resolution with constraints preset by the user.
3. Optimum filter synthesis is addressed by taking into account the specific characteristics of both signal and noise, plus any other desired filter constraint. The algorithm for optimum filter synthesis consists of three main steps. First, the variance of the filter output noise is expressed as a function of the input noise, characterized from the experimental acquisition of a proper set of noise sequences and as a function of the yet unknown digital filter. In this way every input noise or disturbance, a priori known or unknown is always taken into account, which allows synthesizing the optimum filter for the actual experimental condition. Second, the input signal is sampled by the ADC and this set of experimental acquisitions is averaged to obtain a noiseless reference input signal. All the desired constraints are then imposed on both the output signal and the digital filter and a corresponding set of functionals is calculated, which indicates how well each constraint is satisfied as a function of the yet unknown digital filter. Third, the calculated output noise variance and all the functionals calculated in the previous step are weighted and summed together and that final functional is minimized with respect to all the coefficients of the digital filter.

The characterization and some XRF application of the proposed DPP coupled with a complete X-ray spectrometers based on a Silicon Drift Detector will be presented showing high spectroscopic resolution, high peak stability and high data throughput in very high count-rates regime.