Digital Pulse Processing Simulations in MATLAB® & OCTAVE for Nuclear Spectroscopy

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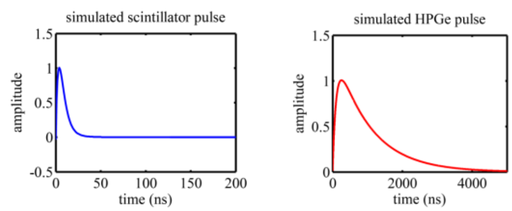
Introduction

Conventionally the pulse processing and the data acquisition systems in nuclear spectroscopy have been based on the front-end NIM based analog shaping & timing amplifiers followed by ADC and subsequent interfacing & storage protocols / systems. Recently novel systems based on the Digital Signal Processing concepts are been extensively used in in-beam experiments. These systems provide a compact and self-contained pulse-processing and histograming components. In a DSP based systems, the pre-amplifier signal from the detector is directly digitized by a fast flash ADC and is then processed completely in the digital domain. Thus allowing for a compete numerical analysis of the detector pulse signals. Hence, the numerical algorithms replace conventional pulse circuitry. The current work investigates the different recursive algorithms used for pulse shaping in DSP systems. A digital pulse processor computes the pulse height out from the data sampled by a fast & high-resolution ADC. The post-processing setup involves streaming of the sampled ADC data into real-time processors usually implemented in FPGAs. They continuously perform pileup inspection and pre-compute arrival times and pulse heights using filters such as trapezoidal, triangular to name a few.

Recursive Algorithms

The recursive algorithms have been developed using the MATLAB® and OCTAVE as the numerical computing environment under the Windows and LINUX operating systems and have been tested on simulated pre-amplifier pulses. The preamplifier (gamma) pulses both from scintillator and HPGe detectors were simulated following the prescription provided by Marrone *et al.* [1] & V.T Jordanov *et al.* [2] and are depicted below :



The filters that could be employed for shaping the pulse are Trapezoidal, Triangular, Cups, and the familiar CR-RC. The recursive algorithms shape the digitized pulse $x(n)$,

Trapezoidal	$y(n) = y(n-1) + x(n) - x(n-k) - x(n-l-k)$
Triangular	$y(n) = y(n-1) + x(n) - 2x(n-k) + x(n-2k)$
Flat top Cusp	$y(n) = y(n-1) + p(n) - [x(n-k) + x(n-l)]k - x(n-l) + x(n-l-k) \ldots$ $p(n) = p(n-1) + x(n) - x(n-l) - x(n-l-k)$
CR-RC	$y(n) = 2\alpha y(n-1) - \alpha^2 y(n-2) + x(n) - \alpha(1 + at)x(n-1)$ $a = \frac{1}{\tau}, \alpha = e^{-t/\tau}$

Table 1: Digital recursive algorithms

These digital recursive algorithms allow a variety of different shapes to be synthesized in real time. These were initially tested for an idealistic “step-pulse”, which has a very fast rise time and an infinite tail and the results are summarized in the table below.

Trapezoidal

Triangular

Flat top Cusp

CR-RC

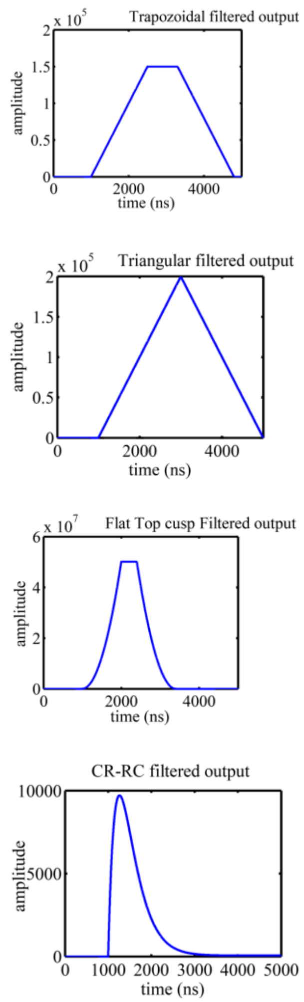
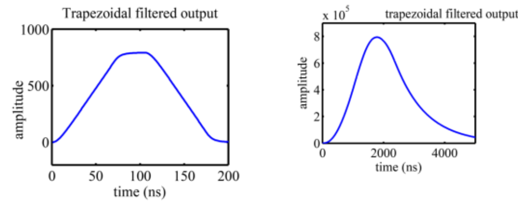


Fig II: Output responses of the digital recursive algorithms to a step input signal

Simulations

Having successfully demonstrated the applications of the digital filters to for a pulse which has extremely short rise time, which is an ideal case. In reality, the rise time of the signals is finite and depends on variety of factors. Trapezoidal shaping is the preferred choice for shaping detector pulses. The results of the application of the Trapezoidal shaping to both the scintillator and HPGe pulse is illustrated in Fig.II.



For Scinti. i/p pulse For HPGe i/p pulse

Fig. III Corresponding trapezoidal shape for the pulses depicted in Fig.I

It has been shown that the Trapezoidal shaping has an advantage that it circumvents the loss in resolution due to ballistic deficits, provided the time duration of the flat top must be long enough to accommodate the rise time variations.

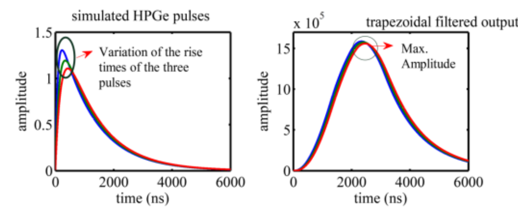


Fig. IV Trapezoidal shaping for removal of ballistic deficit.

The simulations were then extended to the detector pulses after incorporating white noise. The corresponding spectra were also generated.

Efforts are in progress to extend the simulations for obtaining the time information from these pulses *i.e* development of digital CFD. In addition these algorithms are been tested on live detector pulses which would be sampled using the conventional storage oscilloscopes. These efforts will aid in understanding the impact of various parameters in the digital pulse shaping procedures. This is eventually expected to contribute in optimization of the digitizer based pulse processing and data acquisition systems, being used as well as being contemplated for the contemporary detector arrays.

References

[1] S. Marrone *et al*, Nucl. Instr. and Meth. in Phys. Res A 490 (2002) 299.
[2] V.T Jordanov, G.F Knoll, Nucl. Instr. and Meth. in Phys. Res A345 (1994) 337.