Analysis and performance Evaluation of trapezoidal filter in pulse shaping

N. Nabavi[1], M.Asadi[2] , K.Kiani[3]

[1]*Amirkabir University of Technology, Tehran, Iran;* [2]*Kermanshaah University of Technology, Kermanshaah, Iran;* [3]*Amirkabir University of Technology, Tehran, Iran*

n.nabavi2009@gmail.com, asady1223@gmail.com, kourosh.kiani@aut.ac.ir

Paper Reference Number: 0129-855

Name of the Presenter: Neda Nabavi

Abstract

The Implementation and realization of a digital pulse processor depends on the complexity of its software algorithms. Therefore, it is better to have simpler algorithms so that the possibility of straightaway use of them is provided. Based on recursive algorithms for real-time digital pulse shaping, exponential pulse is amplified and then digitized. Digital data are deconvolved and this deconvolved pulse is processed by a time-invariant digital filter which allows trapezoidal/triangular output pulse to be synthesized. Pulse shaping techniques used in trapezoidal filter are analyzed through MATLAB program. The new experiment shows how changes in parameters of pulse shaping algorithms affects the output waveform.

Key words: data convolution, digital signal processing, pulse shaping , trapezoidal filter, Triangular /trapezoidal pulse

1. Introduction

In this discussion, it is assumed that an exponential pulse is digitized. This signal can be achieved by CR differentiation of the signal from a reset type charge sensitive preamplifier or by differentiation with a pole-zero cancellation network of the signal from a resistive feedback preamplifier. Our efforts have focused on the use of digital shaping algorithms [1], which allows symmetrical trapezoidal/triangular pulse shapes to be synthesized.

2. Research Methodology

Supposing that the input signal is exponential, Recursive algorithm [1] which converts this exponential pulse $s(n)$ to trapezoidal pulse can be obtained by this equations:

$$d^{k,l}(n) = v(n) - v(n-k) - v(n-l) + v(n-k-l) \quad (1)$$

$$p(n) = p(n-1) + d^{k,l}(n) \quad (2)$$

$$r(n) = p(n) + M \times d^{k,l}(n) \quad (3)$$

$$s(n) = s(n-1) + r(n) \quad (4)$$

Where $v(n), p(n)$, and $s(n)$ are zero for $n < 0$
The M parameter only depends on decay time constant τ of the pulse and the sampling period T_{clk} of ADC converter, value of M can be obtained by this equation:

$$M = \frac{1}{e^{\left(T_{clk}/\tau\right)} - 1} \qquad (5)$$

For values of T/T_{clk} > 5, Eq. (5) can be rewritten as $M - T/T_{clk}$- 0.5

Equation (1) as a consequence of two identical procedures can be rewritten by these two equations:

$$d^k(n) = v(n) - v(n-k) \qquad (6)$$

$$d^{k,l}(n) = d^k(n) - d^k(n-k) \qquad (7)$$

The unit that implements the algorithm of Eq. (6) is shown in Fig. 1 .

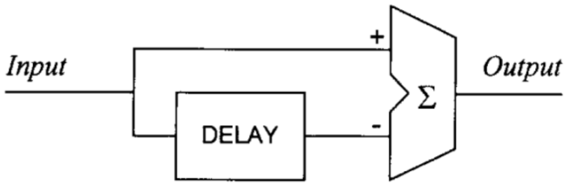

Fig 1: Block diagram of the delay-subtract unit

This building is called block delay-subtract unit (DS), and it include***s*** two functional elements: the first element is a programmable delay pipeline and the second one is a subtracter. Algorithm given by Eq. (1) can be realized by connecting two DS units in series. K is the depth of the delay pipeline of one of the units, while L is the depth of the pipeline of the other unit. As both units represent a linear time-invariant system, the order of connection of the units is not important .So, the rising (falling) edge duration of the trapezoidal shape can be obtained by the smaller value of k and l ; (min (k , l)) and the flat part duration of the trapezoid can be obtained by the absolute value of the difference between k and l (abs ($l - k$)). One of the most important components of the digital trapezoidal shaper is the unit which implements the operations of Eqs. (2) and (3). The algorithm determined by these equations lead to deconvolution of the response of CR highpass filter.
Fig. 2 shows a [2] block diagram of the high-pass filter deconvolver (HPD).

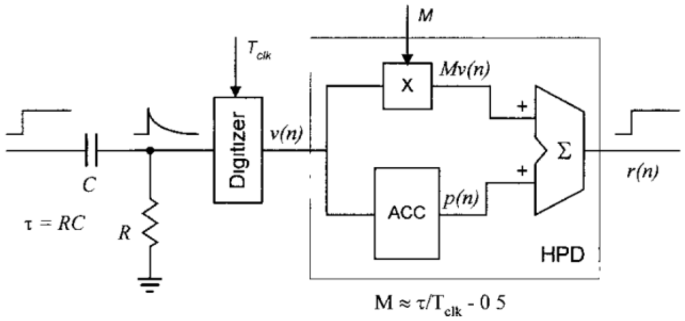

Fig 2: Block diagram of the high-pass network digital deconvolver

The HPD unit can also be used as a digital pole-zero cancellation circuit [2] as it is shown in figure 3.

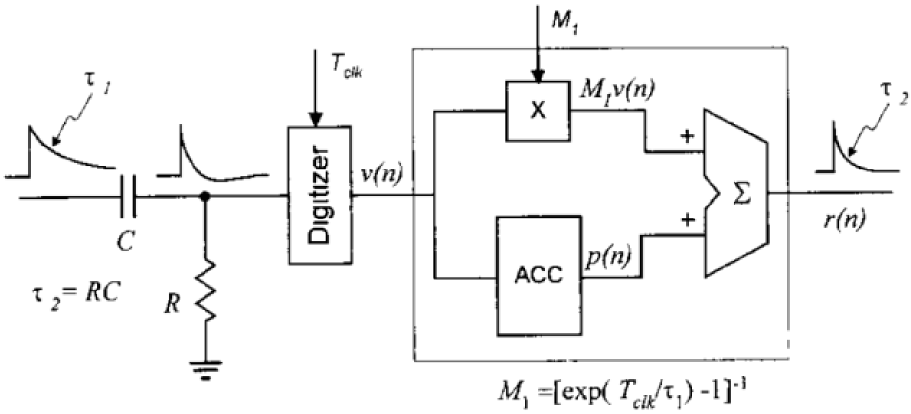

Fig 3: Digital pole - zero cancellation configuration

As both the HPD and CR differentiation networks are systems which are linear time-invariant, so when they are connected in series, combined response of both units does not depend on the order of connection. Therefore, the effect of the input exponential pulse is eliminated by setting the parameter M as a function of the decay time constant of the input signal Eq. (5).

3. Results and Analysis

For analyzing the algorithm which is represented by Jordanov [1], first we should have exponential pulses. So we use $\boldsymbol{Cs^{137}}$ source and NaI detector which have a pre-amplifier. Since these analyses need digitized data, it is better to convert analog exponential signals to digital data by a digital oscilloscope.

The detector output pulse which is drown by a digital oscilloscope is shown in figure 4.

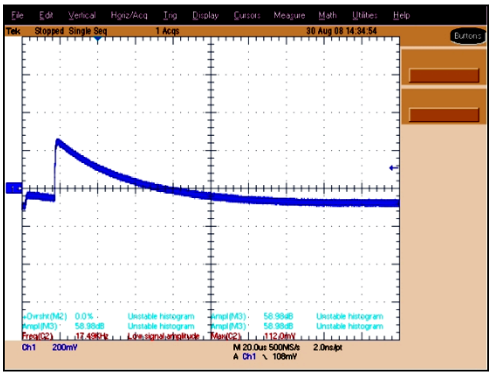

Fig 4: the detector output pulse drown by a digital scope

Digital data of this figure are saved in oscilloscope for further analysis. For analysis of 1 to 4 equations, MATLAB program is used, which indicates how K,L and M parameters affects the trapezoidal pulse.
In running this program, we change one parameter each time and other parameters are constant. The result of running this program is shown in figures 5 to 7 and changed parameters are highlighted.

As it is shown in figures 5, increment in value of parameter M from M1 to M2 and then M3 causes tiltness of upper part of trapezoid. So parameter M is effective in tilt of the waveform.

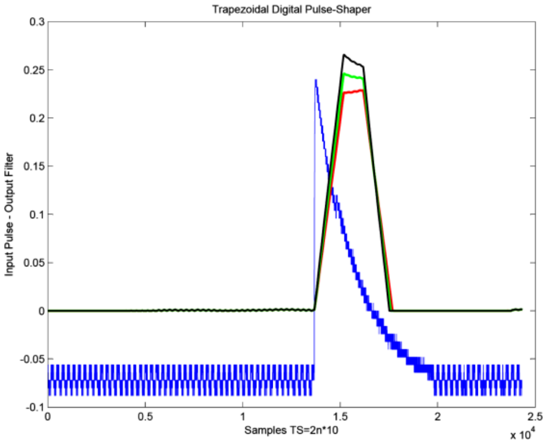

Fig 5: Blue waveform ; input exponential pulse – red waveform; output trapezoidal pulse

Figure	Ts	J	K	L	M	AVE(j) Gain
Black	2n×10	4005	1500	2500	2500	(474.68e-9 * 0.5)
Green	2n×10	4005	1500	2000	2250	(474.68e-9 * 0.5)
Red	2n×10	3005	1000	2000	2000	(474.68e-9 * 0.5)

Table 1- Values of parameters used in trapezoidal pulse shaping algorithm

As it is shown in figure 6, in case of changing parameter k and increment of it from K1 value to K2 and then to K3, it is noticeable that not only pulse height is changing but also a little

Figure	Ts	J	K	L	M	AVE(j) Gain
black	2n×10	5505	2500	2500	2100	(474.68e-9 * 0.5)
green	2n×10	4505	2000	2500	2100	(474.68e-9 * 0.5)
red	2n×10	4005	1500	2500	2100	(474.68e-9 * 0.5)

change is occurring in pulse width and upper flat part duration**.** It can be implied that k parameter has effect on pulse height. It is noticeable that when $K = L$ trapezoidal pulse will change to triangle pulse which is shown in figure 6**.**

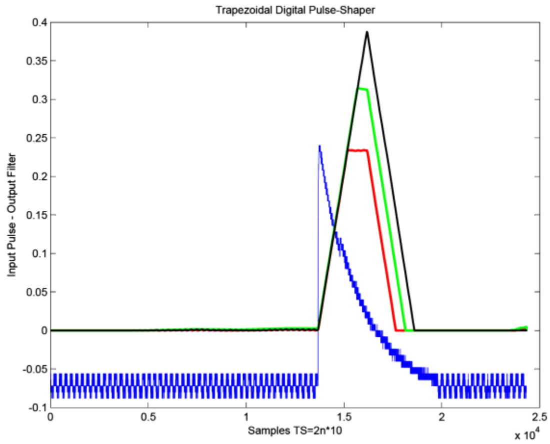

Fig 6: Blue waveform ; input exponential pulse – red waveform; output trapezoidal pulse

Table 2- Values of used parameters in trapezoidal pulse shaping algorithm

As it is shown in figures 7, changing of L parameter and its increment from L1 to L2 and then L3 lead to change in pulse width of $\boldsymbol{T_p}$ and also change in upper flat part duration $\boldsymbol{T_{Top}}$.

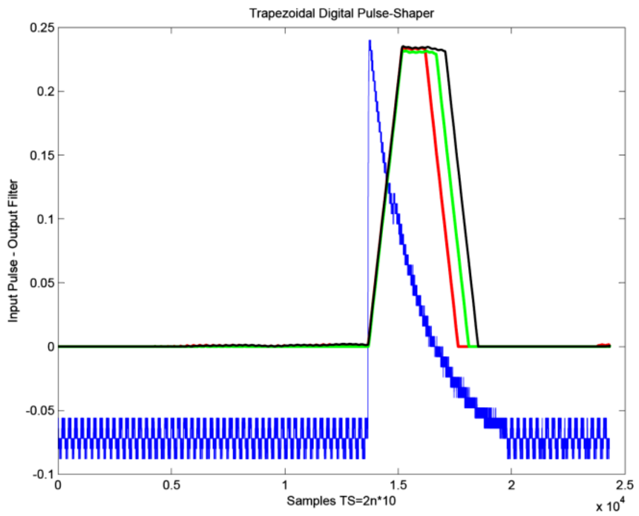

Fig 7: Blue waveform ; input exponential pulse – red waveform; output trapezoidal pulse

Figure	Ts	J	K	L	M	AVE(j) Gain
black	2n×10	4905	1500	3400	2100	(474.68e-9 * 0.5)
green	2n×10	4505	1500	3000	2100	(474.68e-9 * 0.5)
red	2n×10	4005	1500	2500	2100	(474.68e-9 * 0.5)

Table 3- Values of used parameters in trapezoidal pulse shaping algorithm

4. Conclusion

Trapezoidal filter which is based on algorithms for real-time digital pulse-shaping is analyzed and with changing of the parameters of the algorithms, it is shown that triangular pulse shape can be obtained.

References

V.T. Jordanov and G.F. Knoll, NucI. Instr. and Meth. A 345 (1994) 337.

Valentin T. Jordanov a,*, Glenn F. Knoll, Nucl. Instr and Meth. A 353 (1994) 261-264