A New Dynamic Time over Threshold Method

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Abstract—**A Time Over Threshold (TOT) system has advantage over pulse height measurements on its high integrity and low power dissipation because of its binary readout and circuit simplicity. However the relation between TOT and input charge is strongly nonlinear and dynamic range is limited. We propose a new dynamic TOT system which converts the pulse height to pulse width with a dynamically changing threshold. This kind of TOT system can enable wider dynamic range and improves linearity since the threshold follows the input signal and even shorten the width of TOT pulse. We show the concept of dynamic TOT system and results with discrete circuits. It can improve the dynamic range and theoretically it is possible to desired relation between TOT and input charge by using dedicated threshold function. We also designed and fabricated 48channel dynamic TOT ASIC with 0.25um TSMC CMOS technology.**

I. INTRODUCTION

TOT (Time Over Threshold) system has advantages over conventional pulse height measurement system with analog to digital converter (ADC) on high integrity and low power dissipation because of its binary output and circuit simplicity. However, since the relation of TOT versus deposited charge is strongly nonlinear, reconstruction with lookup-table is required and this nonlinearity degrades the energy resolution and distorts the spectrum. There are some researches which utilize multi-level TOT system with 3 to 4 level thresholds. Multi-level TOT improves the dynamic range, but it complicates the circuits and post processing again. We propose a new dynamic TOT system which converts the pulse height to pulse width with a dynamically changing threshold. This dynamic TOT system improves linearity, enables the wide dynamic range and also shortens the TOT. In this paper we report the concept and experimental result of dynamic TOT method with discrete circuit. We also designed and fabricated an ASIC with dynamic TOT method.

II. DYNAMIC TOT SYSTEM

A. Concept of Dynamic TOT

Figure 1 shows the concept of dynamic TOT system. Dynamic TOT system dynamically changes the threshold level after the first trigger pulse. This is realized by feedbacking the digital signal to the threshold level itself after the signal comes over the threshold. Since threshold level follows the input signal for crossing, Dynamic TOT system shortens the TOT pulse width, improve the dynamic range and linearity. By choosing and generating the optimal threshold function for the form of input signal, we can acquire the desired relation of TOT and input charge. In the dynamic TOT method, the rising edge can be used for timing information, and the pulse width (TOT) with good linearity can be used for energy information and the timing information can also corrected by the energy information.

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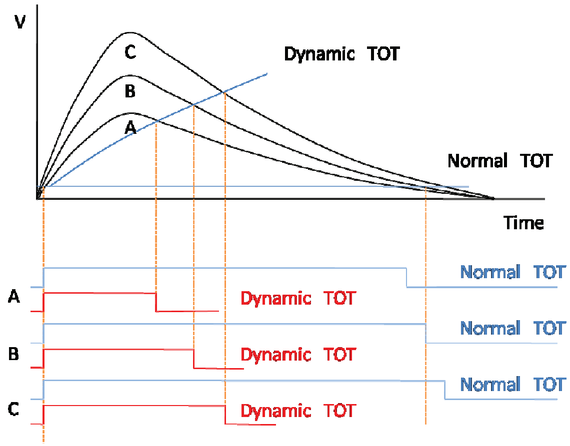

Fig.1 concept of dynamic TOT system

B. Experiment of dynamic TOT

We setup a circuit shown in Fig.2 for the experiment of dynamic TOT method. After the comparator's output is widen by the monostable circuit, it is feed-backed to the threshold of comparator through the RC network and changes the threshold level itself. The whole circuit was setup by the discrete circuits.

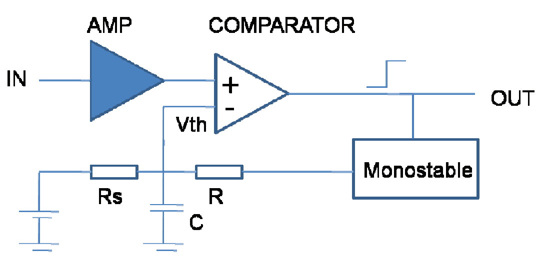

Fig.2 Experimental setup of dynamic TOT

The setup circuit can successfully create the TOT output pulse with a dynamically changing threshold level. (Fig.3)

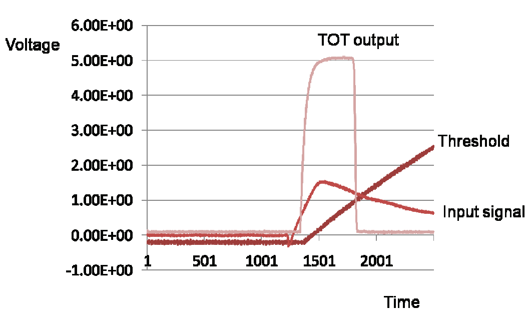

Fig.3 Measured input, output and threshold signal

Fig.4 shows the relation of pulse height (input charge) and TOT pulse width and shows rather good linearity and wide dynamic range. Dynamic range will be greatly improved with this method since the threshold follows and crossed with the input signal.

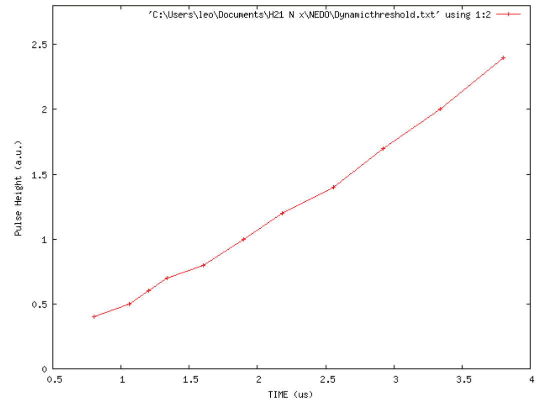

Fig.4 Pulse height versus TOT

C. Theory of dynamic TOT

Assuming the input signal as Vo*Exp(-t/T), where Vo is peak voltage (=pulse height) and T is the time constant of RC, we can get the linear relation t=Vo/A of TOT and pulse height by using the threshold function At*Exp(-t/T), where A is a constant (Fig.5). There are actually many other factors, however, dedicated threshold functions will deliver the desired relation of TOT and input charge.

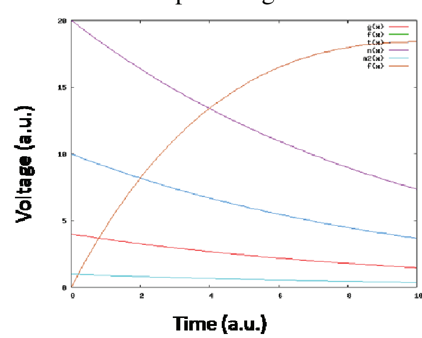

Fig.5 the theoretical input and threshold

D. Implementation of dynamic TOT in ASIC

We have designed a 3.4mm x 5.2mm ASIC chip with TSMC 0.25um CMOS technology (Fig.6.). This chip includes 48channel dynamic TOT system. One channel of ASIC consists of a charge-sensitive preamplifier, a comparator, a monostable multivibrator, capacitors and several transistors in place of resistors. 48threshold adjust pins are externally changeable.

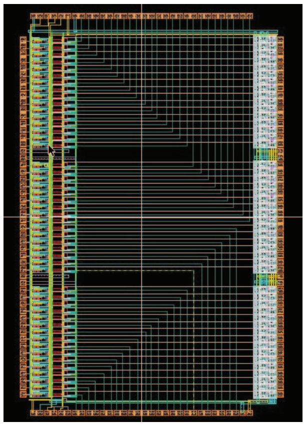

Fig.6 shows the layout of dynamic TOT ASIC

IV. DISCUSSION AND CONCLUSION

We have proposed and tested a new dynamic TOT method for nuclear signal pulse processing. The dynamic TOT greatly improves the dynamic range by changing the threshold level. We also designed an CMOS ASIC with TSMC 0.35umm technology. We plan to test the fabricated ASIC with novel dynamic TOT readout. The further relation between input signal and threshold function can be investigated.