**Multi-Point Methods for the Time Walk Reduction of Discriminators**

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## 1. Introduction

Three methods for the improvement of the accuracy of time measurement in the nuclear physics experiments are proposed in this report. These methods are based on the assumption that the leading edge of a signal can be described by the following function:

$$\begin{aligned} V(t) :=& \quad a(A,tr)\cdot(t-t0-Ds)^n \\ for& \quad 0 < V(t) \le Vu < A, \quad a(A,tr) > 0, \\ & \quad t \ge t0 + Ds, \quad n \ge 1 \end{aligned} \tag{1}$$

where:

$$\begin{aligned} t &\;-\; time, \\ V(t) &\;-\; pulse\ height\ at\ a\ given\ time, \\ a(A,tr) &\;-\; constant\ value\ for\ a\ given\ pulse, \\ A &\;-\; pulse\ height\ (amplitude), \\ tr &\;-\; rise\ time, \\ t0 &\;-\; time\ at\ the\ beginning\ of\ the\ pulse,\ V(t^0) := 0, \\ Ds &\;-\; auxiliary\ delay, \\ n &\;-\; real\ number, \\ Vu &\;-\; voltage\ value\ characterizing\ the\ upper\ limit\ for\ a\ good\ adjustment\ of\ all\ examined\ pulses \end{aligned}$$

For convenience further considerations will be carried out for positive pulses.

## 2. Constant-Level Two-Point Method

If one compares the leading edge of a signal at two voltage levels V1 and V2, one obtains according to formula 1 the following set of equations:

$$\begin{aligned} V1 &:= a(A,tr)\cdot(t1-t0)^n \\ V2 &:= a(A,tr)\cdot(t2-t0)^n \\ for& \quad 0 < V1 < V2 < Vu, \quad Ds := 0 \end{aligned} \tag{2}$$

which lead to:

$$t0 := t1 - \frac{t2-t1}{(\frac{V2}{V1})^{\frac{1}{n}} - 1} \tag{3}$$

Choosing the values V1, V2 and n in the region where function 1 can be fitted to the shape of the leading edge for all examined pulses, and measuring times t1 and t2 for V1 and V2, one can determine time t0. It is worth noting that the knowledge of the pulse height and the rise time is not necessery.

## 3. Constant-Level Three-Point Method

The invariability of the parameter n for all pulses in the constant-level two-point method may lead to inadmissible deviations of function 1 from the shape of the leading edge of a pulse. This could be improved by the three-point method which adds one equation to the set of equations 2:

$$\begin{aligned} V3 :=& \quad a(A,tr)\cdot(t3-t0)^n \\ for& \quad V2 < V3 < Vu \;\; and\ Ds := 0 \end{aligned} \tag{4}$$

Equations 2 and 4 lead when assuming that $\frac{V3}{V2} := \frac{V2}{V1}$ to the following expression for t0:

$$t0 := t1 - \frac{t2-t1}{\frac{t3-t2}{t2-t1} - 1} \tag{5}$$

Equation 5 implies that by measuring the times t1, t2 and t3 for three different voltage levels V1, V2 and V3 one can determine the beginning of the pulse t0, even if the pulse height, the rise time and the exponent n are unknown. Of course, voltages V1, V2 and V3 should be properly matched.

## 4. Constant-Fraction Two-Point Method

Splitting the examined pulse into two branches (each having certain auxiliary delays Ds1 and Ds2) and comparing the fraction of the origin pulse with both splitted ones, one obtains a set-up which can be described as follows:

$$\begin{aligned} F\cdot a(A,tr)\cdot(t1-t0)^n &:= a(A,tr)\cdot(t1-t0-Ds1)^n \\ F\cdot a(A,tr)\cdot(t2-t0)^n &:= a(A,tr)\cdot(t2-t0-Ds2)^n \end{aligned} \tag{6}$$

where:
$0 < F < 1,\ Ds1 < Ds2\ and\ \ V(t2, Ds := 0) < Vu$

The solution of the above set of equations gives:

$$t0 := t1 - \frac{t2-t1}{\frac{Ds2}{Ds1} - 1} \tag{7}$$

Taking fraction F and auxiliary delays Ds1 and Ds2 such that the function 1 fits well to the shape of the leading edge of all examined pulses, and measuring the times t1 and t2 for the corresponding branches, one can determine, the time t0 using equation 7. Note that the values of A, tr, n and F are not used.

## 5. Three Threshold Discriminator

An example of the three threshold discriminator, based on the constant-level two-point method, is shown on figure 1. The drawn scheme corresponds to the following set of equations:

$$\begin{aligned} T1 &:= t1 + tpc1 + tcq1 \\ T2 &:= t2 + tpc2 + tpd + tcq2 \\ \# \quad Tc4 &:= T1 - \frac{ai22}{ai11}\cdot(T2-T1) + \end{aligned}$$

$$+\frac{Vi2s2}{ai11}+tpi1+tpc4$$

$$\begin{aligned}
\$ \quad Tc4 &:= T1-\frac{ai21}{ai11-ai21}\cdot(T2-T1)+ \\
&+\frac{Vi2s1}{ai11-ai21}+ai11\cdot tpi1-ai21\cdot tpi2+tpc4 \\
Tout &:= Tc4+trq1+tp1 \qquad (8)
\end{aligned}$$

where:
tpc1, tpc2, tpc4, tpd, tcq1, tcq2, tpi1, tpi2, trq1, tp1 denote propagation times of the blocks of the discriminator (constant values), ai11, ai21, ai22, Vi2s1, Vi2s2 denote parameters of integrators (constant value) and symbols # and $ indicate indices of the characteristic of the integrator 2.
Solving equation 8 one obtains the expression defining Tout for both characteristics of the integrator 2:

$$\begin{aligned}
\# \quad Tout &:= t1-\frac{ai22}{ai11}\cdot(t2-t1)+Td2 \\
\$ \quad Tout &:= t1-\frac{ai21}{ai11-ai21}\cdot(t2-t1)+Td1
\end{aligned} \qquad (9)$$

where: Td1 and Td2 stand for resultant delays (constant values).

By suitable adjustment of the discriminator thresholds one can obtain such values for V1 and V2 that the equations will be fulfiled which correspond to the characteristics of the integrator 2, namely:

$$\begin{aligned}
\# \quad \frac{V2}{V1}^{\frac{1}{n}}-1 &:= \frac{ai11}{ai22} \qquad \mathit{or} \\
\$ \quad \frac{V2}{V1}^{\frac{1}{n}}-1 &:= \frac{ai11-ai21}{ai21}
\end{aligned}$$

Thus substituting equation 3 in equation 9 one obtains:

$$\begin{aligned}
\# \quad Tout &:= t0+Td2 \qquad \mathit{or} \\
\$ \quad Tout &:= t0+Td1
\end{aligned}$$

This proves that the described discriminator reduces the time walk effect. A first module has been built and presently the discriminator is tested. Preliminary results confirm the good expectation of the used method.

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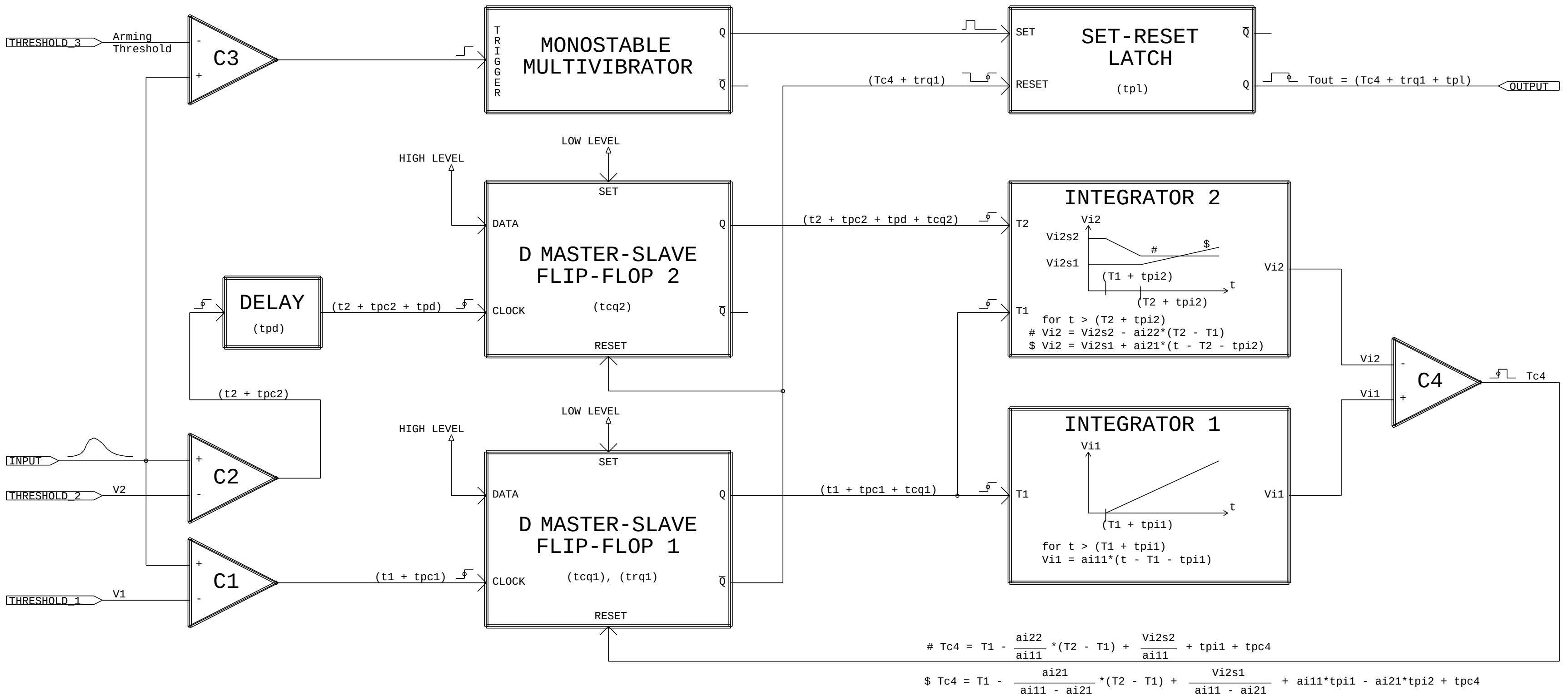


Fig.1: Three-Threshold Discriminator Block Diagram

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|---|---|---|
| Title | 3-THRESHOLD DISCRIMINATOR | |
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