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Simulations of several time picking methods using Matlab.

1- Simulation package under Matlab

The simulation package (Simtime) implements five different time picking strategies:

- Fixed threshold on leading edge
- Ideal constant fraction threshold
- Actual constant fraction as zero-cross of (delayed – attenuated) input
- Multiple fixed thresholds on leading edge
- Full pulse sampling and reconstruction

Input is a triangular waveform to which noise is added as a sum of parallel, serial, 1/f contributions. It is processed through a charge integrator and a CR-(RC2) shaper. Two Landau amplitude distributions (1 and 2) are used

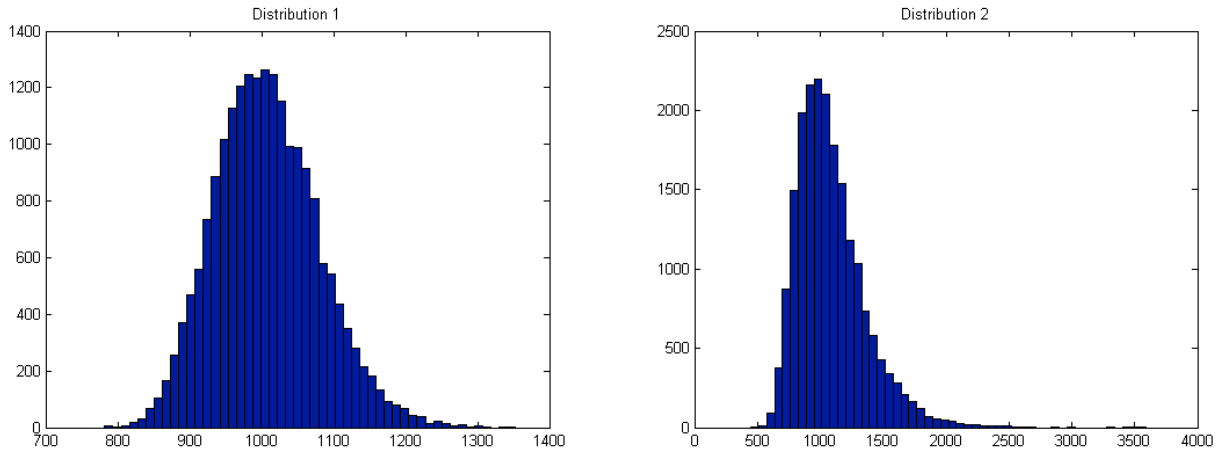

Figure 1 Amplitude spectra 1 and 2 (1000 is one MIP).

In the following simulations, leading edge, actual constant fraction and multiple thresholds have been used and are compared, in the same detector and electronics conditions.

Time resolution is mainly sensitive to:

- signals rise time
- shapers peaking time
- signal to noise ratio
- noises spectral distributions
- pulses amplitudes distribution

and obviously time picking method parameters such as thresholds, sampling frequencies.

2- Simulations

The following parameters have been used in the simulations:

Detector parameters:

```
telec=5e-9;                             Rise time
thole=25e-9;                            Fall time
C=10e-12;                               Detector capacitance
Ileak=1e-8;                             Leakage current
Rbias=2e6;                              Biaising resistor
T=300;                                  Absolute temperature
```

Electronics parameters

```
A=1e4;                                  Charge Amplifier Open loop gain
gbw=1e12;                               Amplifier Gain/bandwidth product
Cf=133e-15;                             Feedback capacitor
Id=50e-6;                               Input stage current
gm=.7e-3;                               Transconductance of input FET
nadc=16;                                ADC number of bits
% Strong inversion
Samp=8*(1.38e-23)*300/(3*gm);           Spectral serial noise density  (SI)
% Weak inversion
Samp=(2/3)*Samp;                        Spectral serial noise density  (WI)
kf=1e-24;                               Flicker noise coefficient (current)
af=1;                                   Flicker noise exponent
ef=1;                                   Flicker noise exponent
L=250e-9;                               Length of channel input FET
tox=5e-9;                               Width
Cox=3.45*1e-11/tox;                     Oxide capacitor (unit area)
kf=kf/gm^2;                             Flicker noise (voltage)
taumin=30e-9; taumax=30e-9; taustep=30e-9;
                                        Shaper's peaking time range
```

Single threshold

```
th=0.4;                          Threshold (Fraction of a MIP)
Gq=-1/(Cf*(1+1/A)+C/A);          Charge gain
thresh=-Gq*th*25000*1.6e-19;     Absolute threshold
```

CFD

```
frac=0.5;                        Threshold for CFD trigger
thresh=0.4;
delay=10e-9;                     Delay for CFD differentiation
```

Edge

```
th=[0.1 0.2 0.3 0.4];            Thresholds (Fraction of a MIP)
thresh=-Gq*th*25000*1.6e-19;     Absolute thresholds
```

Sampling

```
nmin=12;                         Minimum number of points
nmax=12;                         Maximum number of points
```

Figure 1 illustrates Multiple Threshold and Sampling methods.

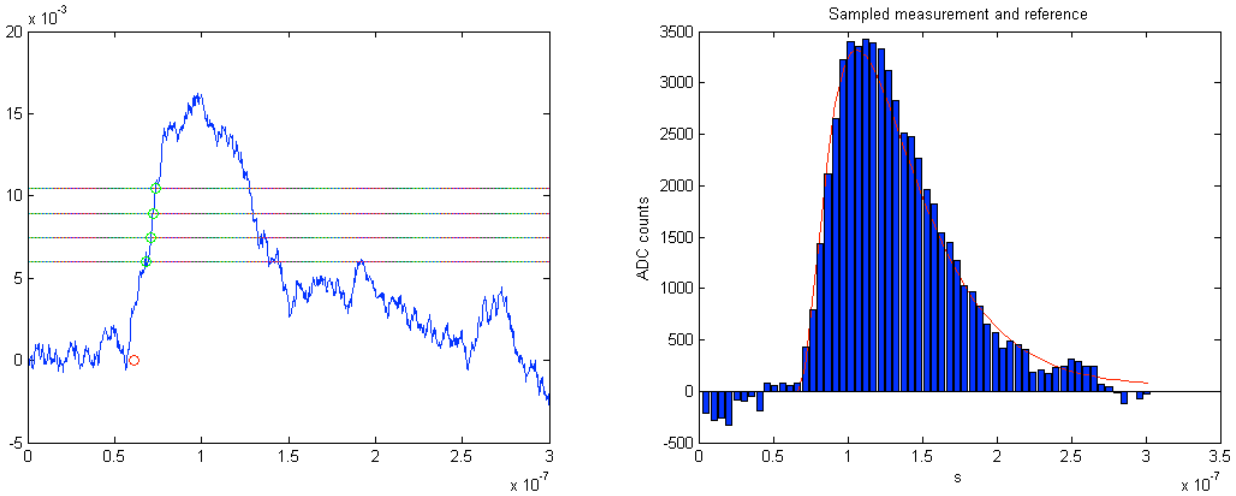

Figure 2 Multiple Thresholds and Sampling

3- Results

Simulations were run with 100 samples for a given method, signal to noise, and associated parameters.

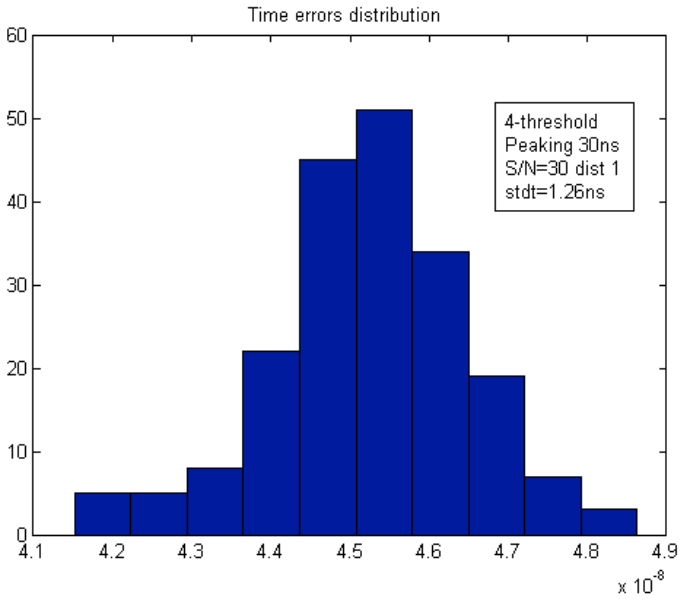

Figure 3 Typical time errors histogram using 4- thresholds

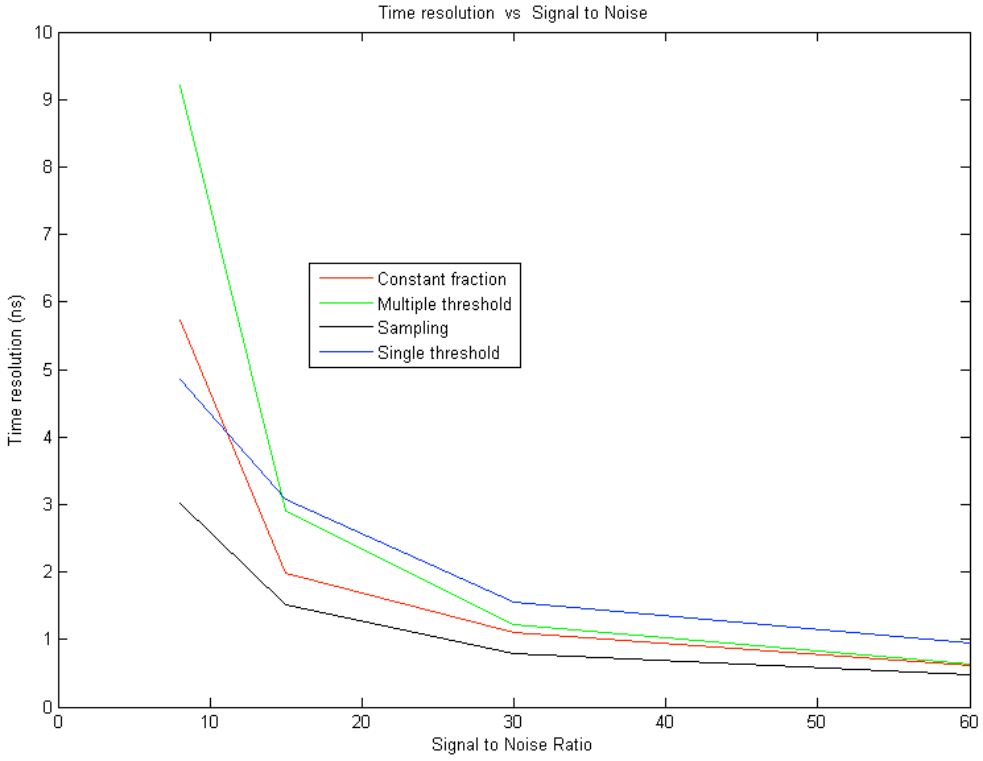

Figure 4 Time resolution as a function of Signal to Noise ratio (distribution 1)

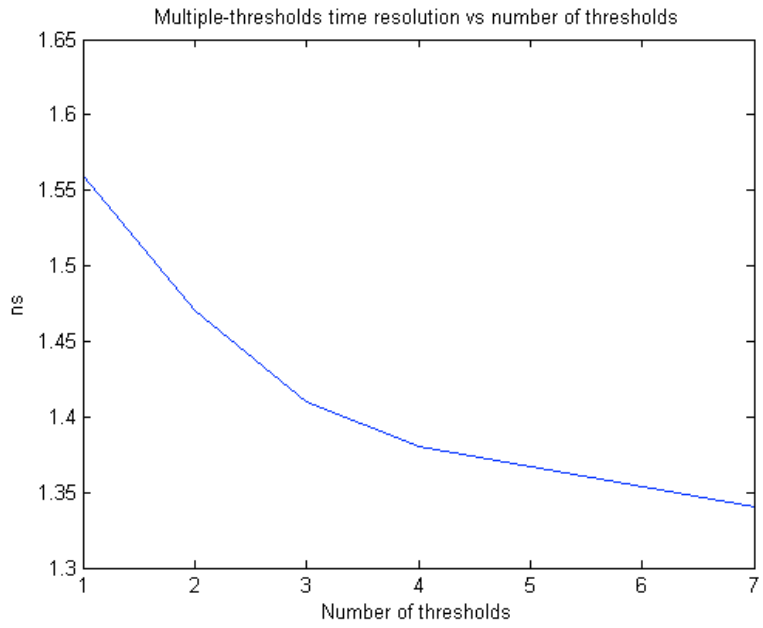

Figure 5 Multiple-thresholds resolution vs number of thresholds (S/N=30)

4- Conclusions

Under the assumptions above, the best method (also the most heavy in terms of practical implementation) is clearly sampling. Just after, constant fraction, then 4-thresholds, (surprisingly sensitive to high noise levels), and last, single threshold. With multiple-thresholds, increasing the number of thresholds above 4 does not improve significantly.

Table 1 show results for a typical signal to noise 30 and 30ns peaking time using amplitudes distribution 1 and 2.

Method	Time resolution (ps) dist 1	dist2
Single threshold	1559	
Constant fraction	1095	
Multiple thresholds	1223	
Sampling	791	

Table 1