Fast Time Front End with CSPA's made with discrete elements

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Basic error of a Time Measurement

"JITTER"

if \( \sigma_n \sim \sqrt{Nd \cdot BW} \)

\[ \frac{dV}{dt} \sim \frac{As}{t_r} \]

then

\[ t_r = 0.35 / BW \]

\[ \sigma_t \sim \sqrt{Nd / (As \cdot \sqrt{BW})} \]

IEEE Nuclear Science Symposium 1999
Radiation Detection and Measurement
Pulse Processing and Analysis, Helmuth Spieler,
Lawrance Berkeley National Laboratory

if \( t_r^2 = t_{ra}^2 + t_c^2 \)

\[ \sigma_t \approx \frac{\sqrt{t_c}}{V_0} \sqrt{\frac{t_c}{t_{ra}} + \frac{t_{ra}}{t_c}} \]

has a minimum for \( t_c = t_{ra} \)
"Walk" and Sigma versus: UINP, Amplifier BW, Detector Rise Time

Detector signal is Step with variable Rise Time, Noise=3uV, THR=100mV
Motivation: Fast CSPA for MIP's

We used FEE1 also to measure timing with single- and polycrystalline diamond detectors. For minimum ionizing particles the signal amplitude fairly small (16000 e). For protons, we used due to that a CSPA in front of FEE1, to increase the overall sensitivity.

FEE1 for diamond detectors, $\sigma_t^{\text{START}}$ versus $\Delta E$
Measurements

CSPA – circuit diagram

CS stage
- BF908, DG-MOS
- \( C_F = 1\, \text{pF} \) (S=1mV/fC)
- \( \tau_D = 10\, \mu\text{s} \)

Diff+PZC
- \( \tau_{\text{diff}} = 5\, \text{ns} \)
- pasive

BB stage
- GALI 66, RF block
- Gain \( \approx 10 \)
Measurements

CSPA – Noise

► Output noise

\[ Q_{N}^{IN} (e_{RMS}) = \frac{U_{N}^{OUT} (RMS)}{G} \cdot C_{F} \cdot \frac{1}{q_{e}} \]

where:
- \( C_{F} = 1pF \)
- \( G = 10 \)
- \( U_{N}^{OUT} \approx 1000\mu V_{RMS} \)
- \( q_{e} = 1.6 \cdot 10^{-19} C \)

\[ Q_{N}^{IN} = 625e_{RMS} \]

(1fC=6250e)

<table>
<thead>
<tr>
<th>Preamp</th>
<th>Output noise ((U_{N}^{OUT}))</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>860 994 970 946 928</td>
<td>(\mu V_{RMS})</td>
</tr>
<tr>
<td>No. 2</td>
<td>875 979 994 970 947</td>
<td>(\mu V_{RMS})</td>
</tr>
<tr>
<td>Amplit. scale</td>
<td>2 5 10 20 50</td>
<td>(mV) (\text{div})</td>
</tr>
</tbody>
</table>

20mV/div
50ns/div
20GS/s

Oscilloscope noise subtracted

► Comment: S/N ratio for MIPS in SC-DD

<table>
<thead>
<tr>
<th>(W_{DD})</th>
<th>100</th>
<th>200</th>
<th>300</th>
<th>400</th>
<th>500</th>
<th>(\mu m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Q_{MIP})</td>
<td>3k6</td>
<td>7k2</td>
<td>11k8</td>
<td>14k4</td>
<td>18k</td>
<td>(e)</td>
</tr>
<tr>
<td>(Q_{MIP}/Q_{N})</td>
<td>5.8</td>
<td>11.5</td>
<td>17.3</td>
<td>23.0</td>
<td>28.8</td>
<td></td>
</tr>
</tbody>
</table>
**Measurements**

**CSPA – Rise time**

- **Output signal level**: \( \approx 60 \text{mV} \)
  - 10mV/div
  - 1ns/div
  - 20GS/s
  - Generator+osc. rise time subtracted

<table>
<thead>
<tr>
<th>Preamp.</th>
<th>Input transition</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>neg.</td>
<td>pos.</td>
</tr>
<tr>
<td>No. 1</td>
<td>753</td>
<td>719</td>
</tr>
<tr>
<td>No. 2</td>
<td>666</td>
<td>619</td>
</tr>
</tbody>
</table>

- **Output signal level**: \( \approx 200 \text{mV} \)
  - 50mV/div
  - 1ns/div
  - 20GS/s
  - Generator+osc. rise time subtracted

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<td>neg.</td>
<td>pos.</td>
</tr>
<tr>
<td>No. 1</td>
<td>775</td>
<td>670</td>
</tr>
<tr>
<td>No. 2</td>
<td>688</td>
<td>570</td>
</tr>
</tbody>
</table>

**Comment:**

- \( T_R \approx 700 \text{ps} \)
- \( B \approx 500 \text{MHz} \)

\( T_W \approx 1\text{ns}/100\mu\text{m} \)

(transit. time in SC-DD)

CSPA is fast enough to handle signals from SC-DD having \( W > 100\mu\text{m} \)
Time CSPA use a modified architecture with a Time Branch
Measurements: Pulse with short and long rise time

Input signal: step with ~1ns and ~25ns rise time
Measurements: Pulse and scope with 380ps rise time

Time Output

negative outputs: $t_F=558\text{ps}$

positive outputs: $t_R=517\text{ps}$
Linearity

Time and Energy Outputs: Linearity for CF=0, CD=0

Tout
Q<0, y=0.3-4.22x
Q>0, y=0.8-4.86x

Eout, y= -1.6-7.75x
TCSPA1, Noise versus detector capacitance, for Cf 0 and 1.6pF
For the pulser line, the Gauss fit give:
$X_c = 544.9$
$w = 1.2$
$ER = 1.2 / 544.9 = 0.22\%$