A Generation of Readout ASICs for CZT Detectors

Gianluigi De Geronimo - Paul O'Connor
Brookhaven National Laboratory, Instrumentation Division
Upton, NY, USA

Joe Grosholz
eV Products, Division of II-VI Incorporated
Saxonburg, PA, USA
The BNL-eV Cooperation

CZT readout: discrete or ASIC?

Cost
- multi-chip project $\approx$ $35/ch$ (compare $\approx$ $75/ch$)
- large numbers $\approx$ $1/ch$
- R&D: C.R.A.D.A.

Manufacture
- time savings
- board simplification
- reduced number of process steps

Reliability
- reduced external interconnects
- lower exposure

Size
- $\approx$ 1 mm$^2$/ch (compare $\approx$ 700 mm$^2$/ch)
- opening to new applications

Power
- $\approx$ 10 mW/ch (compare $\approx$ 300 mW/ch)
- reduced detector temperature
- opening to battery operation

Performance
- reduced parasitics
- high order shaping
- additional processing
The BNL-eV Cooperation
CZT readout: discrete or ASIC?

ASIC's key **requirements**

- low noise
- high linearity
- programmability
- low power
- low noise dc coupling
- high order shaping
- high driving capability
- high baseline stability

A generation of ASICs
Channel Simplified Schematic

RESET

CHARGE PREAMP

COMP.

1st POLE

FLF POLES

OUTPUT STAGE

Continuous Reset System

High Order Shaper

Class AB Rail-to-Rail

BLH

Baseline Holder
Reset System

\[ V_g \]

\[ M1 \]

\[ M1 \times N \]

\[ Cf \]

\[ Cf \times N \]

\[ -A \]

\[ Z \]

\[ Q_{det} \times N \]

\[ I_{det} \times N \]

\[ Q_{det} \]

\[ I_{det} \]

\[ Cin \]

\[ N_1 = 24 \]

\[ N_2 = 6 \]
Reset System: Experimental Results

- Preamplifier Normalized Output
- System Normalized Output
- Preamplifier Output Voltage [V]
- Parallel Noise [A/√Hz]
- Detector Leakage Current $I_{det}$ [A]
- Measured vs. Simulated

Graphs showing the response of the system for different conditions:

- Q = 1fC
- Q = 1fC, 10fC
- $I_{n}^2 / \sqrt{I_{D}}$
- Threshold $I_L$ + Sh M1
- 3nA full shot
- 1nA
- 600pA
- 100pA
- 100pA full shot
Shaper Amplifier: 5\textsuperscript{th} order complex semigaussian

\textit{FLF 4 complex conjugate poles}

\textit{Real pole}
Output Stage

Loaded Stage

Error Amplifier

Unloaded Stage

\[ \text{input} \xrightarrow{R} 2 \times R \xrightarrow{\text{output}} ZL \xrightarrow{R} V_{dd} \xrightarrow{V_{g}} \text{output} \]

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BLH (Baseline Holder)

Low Pass

Slew Rate Limited

Differential

from channel output

Vdd

MN

VL

Vg1

C1 MP

Vg2

VE

Gd

VBL

VOUT

to FLF input

IF

C2

1n 10n 100n

1µ 10µ 100µ

5m 8m 12m

0 5µ 10µ 15µ 20µ

0 5µ 10µ 15µ 20µ

0 5µ 10µ 15µ 20µ

Differential Slew Rate Limited

IF      VL      VE     VOUT
SHAPER / BLH (Baseline Holder): Experimental Results

- **Normalized Amplitude**
  - Time [s]: 0, 1x10^-6, 2x10^-6, 3x10^-6, 4x10^-6
  - Graph shows normalized amplitude over time for different order semigaussian shapes.
  - Equal 0.1% width indicated.

- **Channel Gain [Ω]**
  - Frequency [Hz]: -0.5, 0.0, 0.5, 1.0
  - Channel gain and frequency response graph.

- **Channel Output [V]**
  - Time [relative scale]: sample #1, sample #512
  - Graph showing channel output with BLH and AC coupling.

- **Channel response [V]**
  - Time [s]: 0, 5.0x10^-4, 1.0x10^-3, 1.5x10^-3, 2.0x10^-3, 2.5x10^-3
  - Graph showing channel response with specified parameters.

- **Graphs**
  - Gain = 200mV/fC
  - τₚ = 400ns
  - Q = 10fC, G = 2
  - Rate = 500kHz

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### Prototypes

<table>
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<tr>
<th></th>
<th>application</th>
<th>channels</th>
<th>shaping</th>
<th>gain [mV/fC]</th>
<th>pk time [µs]</th>
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<tbody>
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<td>B,D,E</td>
<td>2</td>
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<td>26-180</td>
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<tr>
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<tr>
<td>IC60</td>
<td>A</td>
<td>16</td>
<td>UNI</td>
<td>30-200</td>
<td>0.6 - 4.0</td>
</tr>
</tbody>
</table>

A  general purpose  
B  bone densitometry  
C  intra-operative probe  
D  baggage scanning  
E  down-hole logging
Typical

Size  5.1mm × 3.7mm
Ch.s  16

Gain  30mV/fC, 50mV/fC, 100mV/fC, 200mV/fC
Pk Time  0.6µs, 1.2µs, 2.4µs, 4.0µs
ENC$^2$ (@ 1.2µs, 200mV/fC)  $35^2 + 35^2/pF^2 + 55^2/\sqrt{nA} + 0.2Q/q$
Integral Linearity Error  < 0.3%
Cross Talk  < 0.4% (< 0.1% non adj.)
Power  ≈ 4mW + 18mW/ch.
Baseline Adjustment  -100mV ÷ +400mV
Test With CdZnTe Detector
Conclusions and Future Work