A bipolar shaping amplifier for low background alpha/beta counters with silicon detectors.

Sam Thys[1,2](sthys@mirion.com), Olivier Evrard[1], Sofie Put[1], Paul Leroux[2]
[1]Mirion Technologies – Canberra
[2]KU Leuven

ABSTRACT

This work focuses on the design of a 4 complex pole, bipolar shaping amplifier for use with Si (PIPS®) detectors in alpha/beta counters and presents calculations and measurement results.
Earlier bipolar shapers based on the bridged-T feedback topology have been developed but only with 2 complex poles [1]. This design allows for the compensation of the preamplifier pole.

INTRODUCTION

- Current existing alpha/beta counters use gas-flow detectors because of their low energy detection threshold compared to Si (PIPS®).
- The latest evolutions of the characteristics of PIPS® detectors allow to reach a lower energy threshold, that is comparable to gas-flow detectors. For these systems, optimized processing electronics like shaping amplifiers are needed.
- Bipolar shapers have no baseline shift , require no baseline restorer and have no background artefacts from the baseline restorer

MEASUREMENTS

Measurement setup

- Source with PU-239 ,AM-241 and Cm-244 is used for calibration of the spectrum
- A pulse generator is connected to a 2003BT charge sensitive amplifier and generates the pulse for the determination of the resolution,
- The signal is filtered by the bipolar shaper and acquired by a Multiport II MCA
- The sectrum is analysed with GENIE 2000

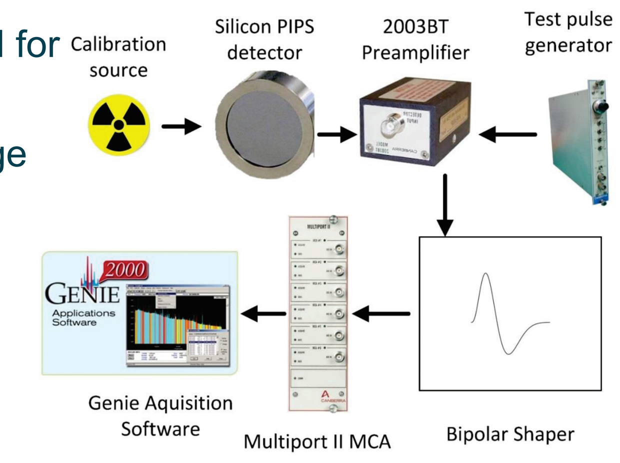

Figure 1 – Measurement setup used for validation

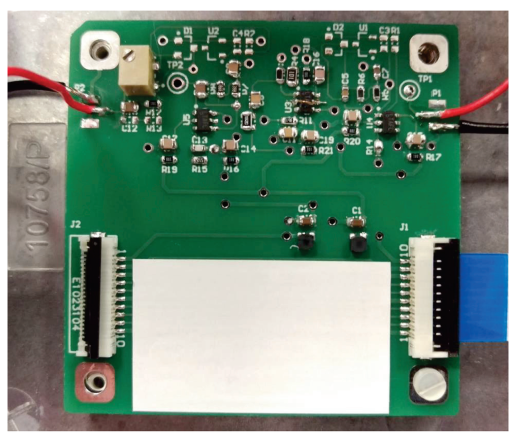

Figure 2 – Bipolar shaper PCB

Table 1 – Measurement results of the bipolar shaper with three different detectors

Detector Area [mm²]	Detector capacitance [pF]	Serial resistance [Ω]	Leakage Current [nA]	Resolution FWHM [KeV]
300	155	30	1,0	6,93
600	270	31	1,5	11,57
900	415	22	3,5	20,64

METHODOLOGY and CALCULATIONS

Requirements and theory

Pulse Shape Requirements

- Derivative of unipolar pulse with time constant of 2 µs
- Shaping time Constant = 2 µs
- Peaking Time = 2,61 µs
- Cross-over time = 4,76 µs

Time domain response

- Pulse shape of a unipolar pulse has a response according to [2]

$$f(t) = e^{-3t}\, sin^n(t)$$

- The bipolar pulse shape is the derivative of the unipolar pulse shape

$$\frac{df(t)}{dt} = e^{-3t}\, sin^{n-1}(t) \cdot [n\, cos(t) - 3\, sin(t)]$$

Normalized transfer function of bipolar shaping amplifier

- Laplacian transform for a bipolar shaping amplifier
- All poles have a real value of -3 Hz or rad/s and a complex value of a multiple of +/-2j Hz or rad/s
- Taken N=4 (number of complex poles)
- Poles need to be scaled with shaping time constant
- Derivative of unipolar pulse shape

$$\mathcal{L}\{\frac{df(t)}{dt}\} = \frac{n! \cdot s^2}{(s+3)} \prod_{k=1}^{\frac{n}{2}} \frac{1}{(s+3-2kj) * (s+3+2kj)}$$

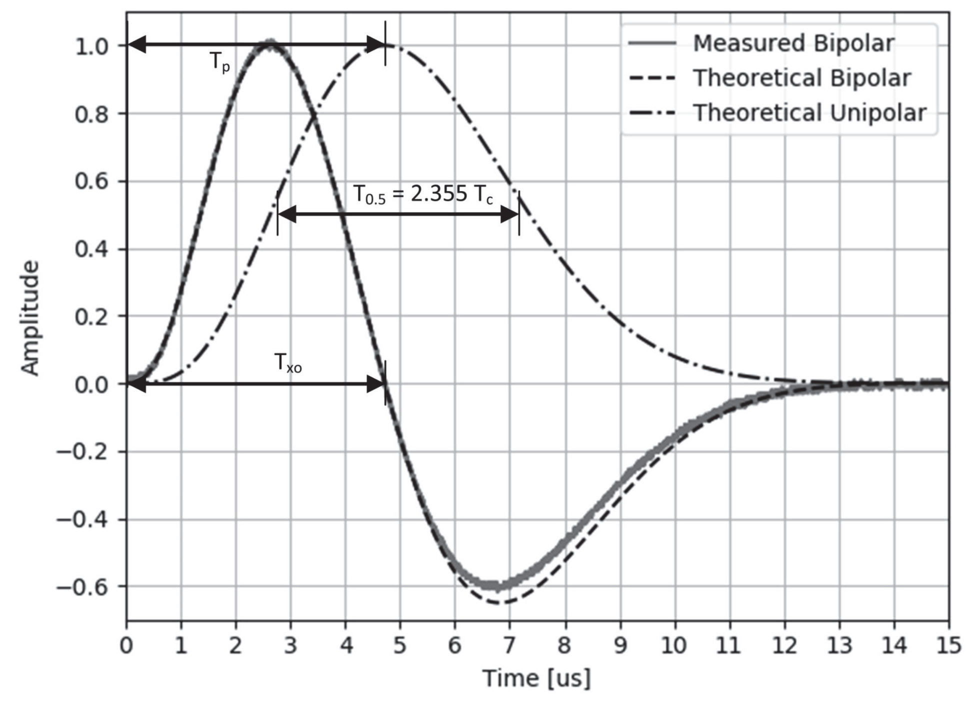

Figure 3 – Normalized theoretical and measured waveforms

Circuit and Calculations

Circuit Description

- 2x bridged-T feedback = 2x (2 complex poles and 1 zero)
- 2x CR differentiators = 2x (1 real pole, 1 zero in origin)
- 1x RC integrator = 1 real pole
- Zeros of bridged-T feedback compensated with poles of RC differentiators.
- Pole-zero compensation with R_{pz} for preamplifier time constant and can be checked after the amplifying stage, where the pulse is still unipolar.

$$F(s) = \frac{s + \frac{1}{(R_{pz}+R_1)C_1}}{s + \frac{1}{R_1C_1}} \; \frac{s + \frac{1}{(R_2||R_3)C_3}}{s^2 + \frac{1}{(R_2||R_3)C_3}s + \frac{1}{R_2R_3C_2C_3}} \; \frac{\frac{R_7}{R_8}}{s + \frac{1}{R_0C_0}} \; \frac{s}{s + \frac{1}{R_4C_4}} \; \frac{s + \frac{1}{(R_5||R_6)C_6}}{s^2 + \frac{1}{(R_5||R_6)C_6}s + \frac{1}{R_5R_6C_5C_6}}$$

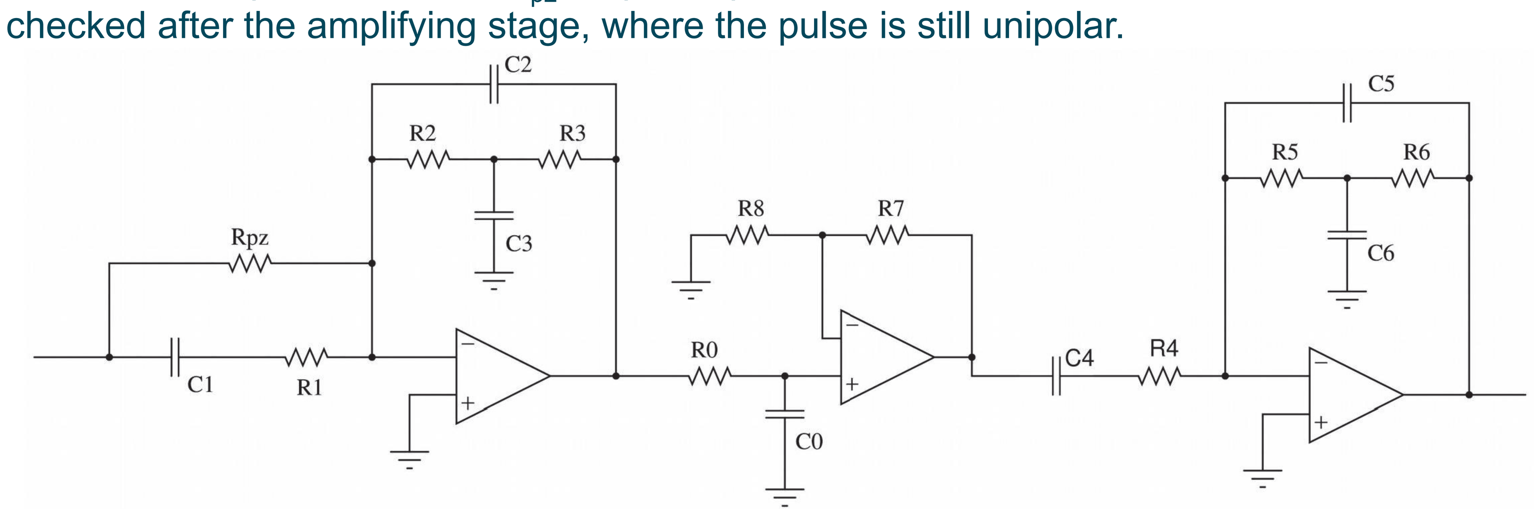

Figure 4 – Bridged-T based bipolar shaper circuit

Poles and zeros calculations

- Shaping time constant (T_c) is equal to σ of a gaussian unipolar pulse
- $T_{0,5}$=2,355 T_c
- Poles must be multiplied by 0,3927 and $1/T_c$

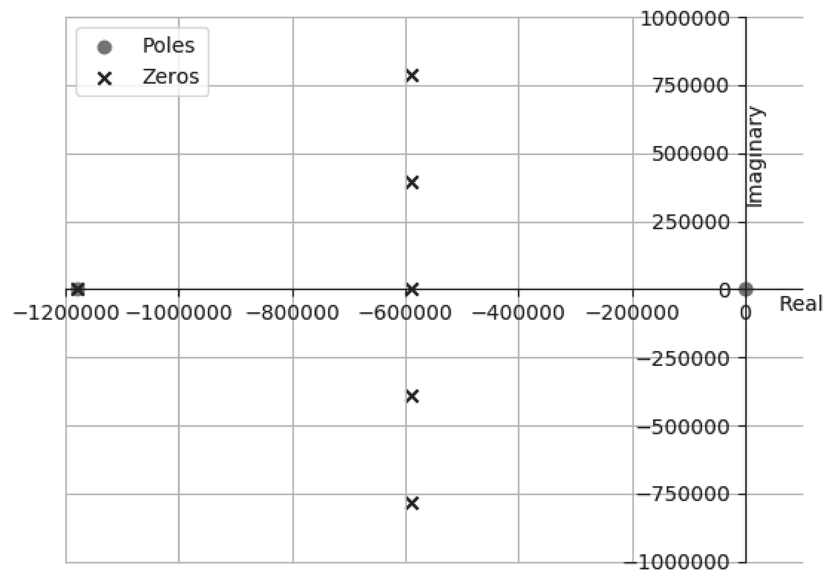

Figure 5 – Calculated pole-zero plot

CONCLUSIONS

Bridged-T feedback based bipolar shaping amplifier

- Developed and tested a bridged-T feedback bipolar shaper
- There is a very good match between the calculated and measured pulse shapes
- Although bipolar shapers are less prone to misadjustment to pole-zero compensation, the preamplifier pole can easily be compensated

REFERENCES

[1] E. Fairstein, "Bipolar pulse shaping revisited," in *IEEE Transactions on Nuclear Science*, vol. 44, no. 3, pp. 424-428, June 1997.

[2] C. H. Mosher, "Pseudo-Gaussian Transfer Functions with Superlative Baseline Recovery," in *IEEE Transactions on Nuclear Science*, vol. 23, no. 1, pp. 226-228, Feb. 1976.

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KU LEUVEN
KU Leuven
Dept. of Electrical Engineering (ESAT), ADVISE Lab,
Geel Campus, Kleinhoefstraat 4 - 2240 Geel - Belgium