A novel feedback circuit for analogue time walk compensation

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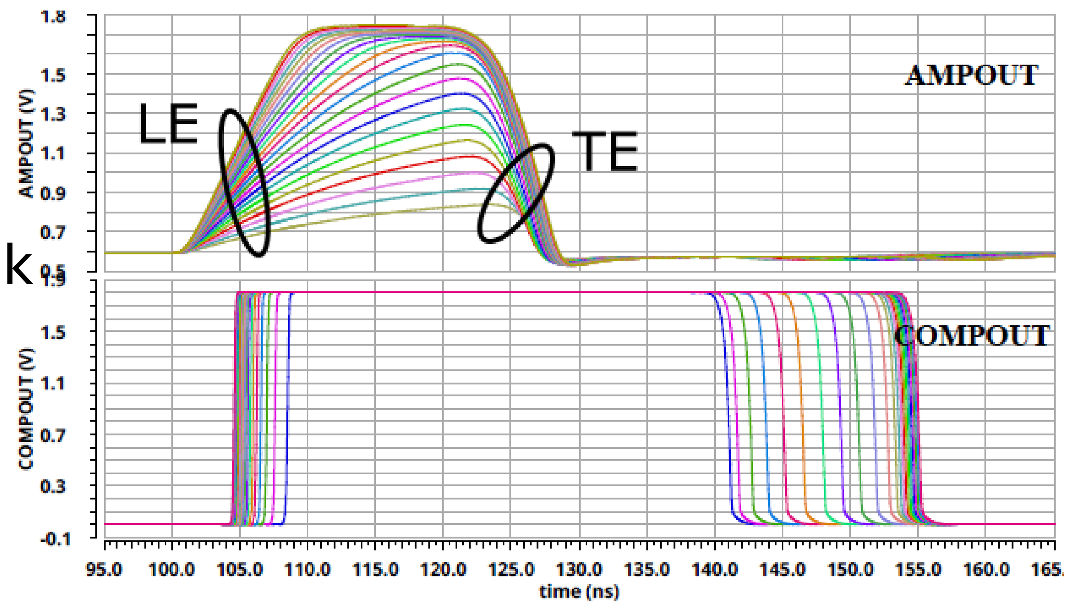
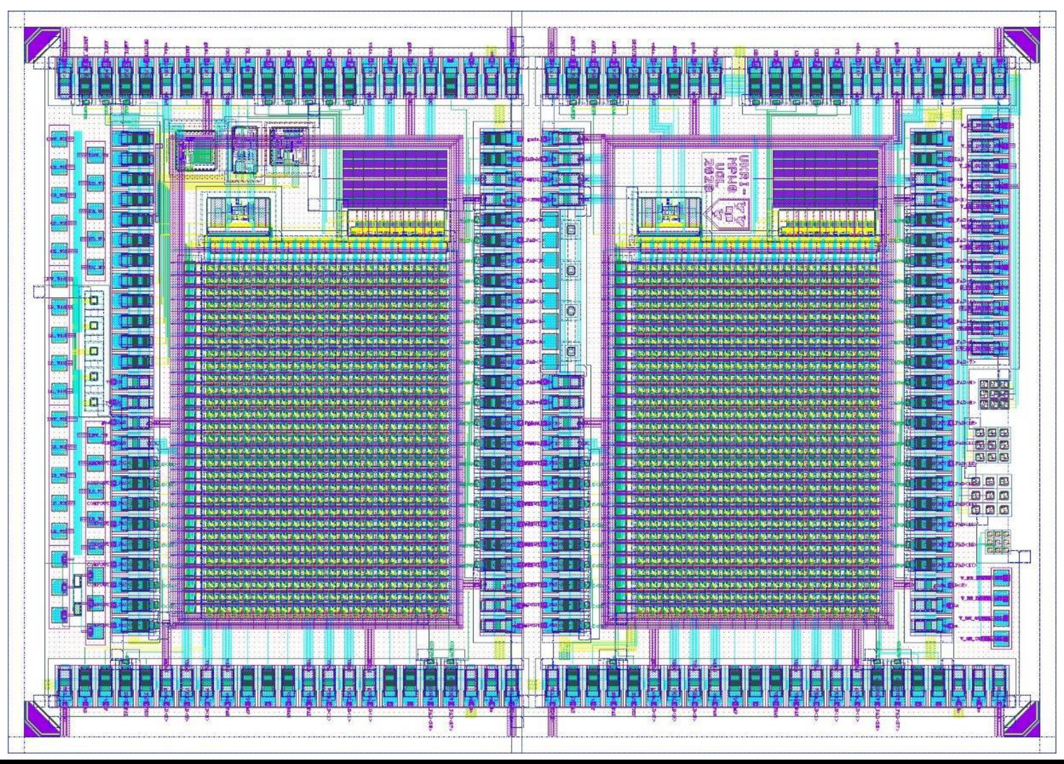
Motivation:

Particle physics experiments require increasingly precise time information to resolve pile-up and reduce combinatorial backgrounds. Better time resolution usually comes at the price of more power consumption and circuit area which are scarce in pixel detectors.

Idea:

DMAPS prototype RD50-MPW2 implements a switched-feedback to reduce the shaping time [1]. The comparator triggers a feedback current source to return the amplifier to its nominal working point. As side effect the time walk on the Trailing Edge (TE) is suppressed compared to the Leading Edge (LE). Can the TE be exploited to compensate time walk?

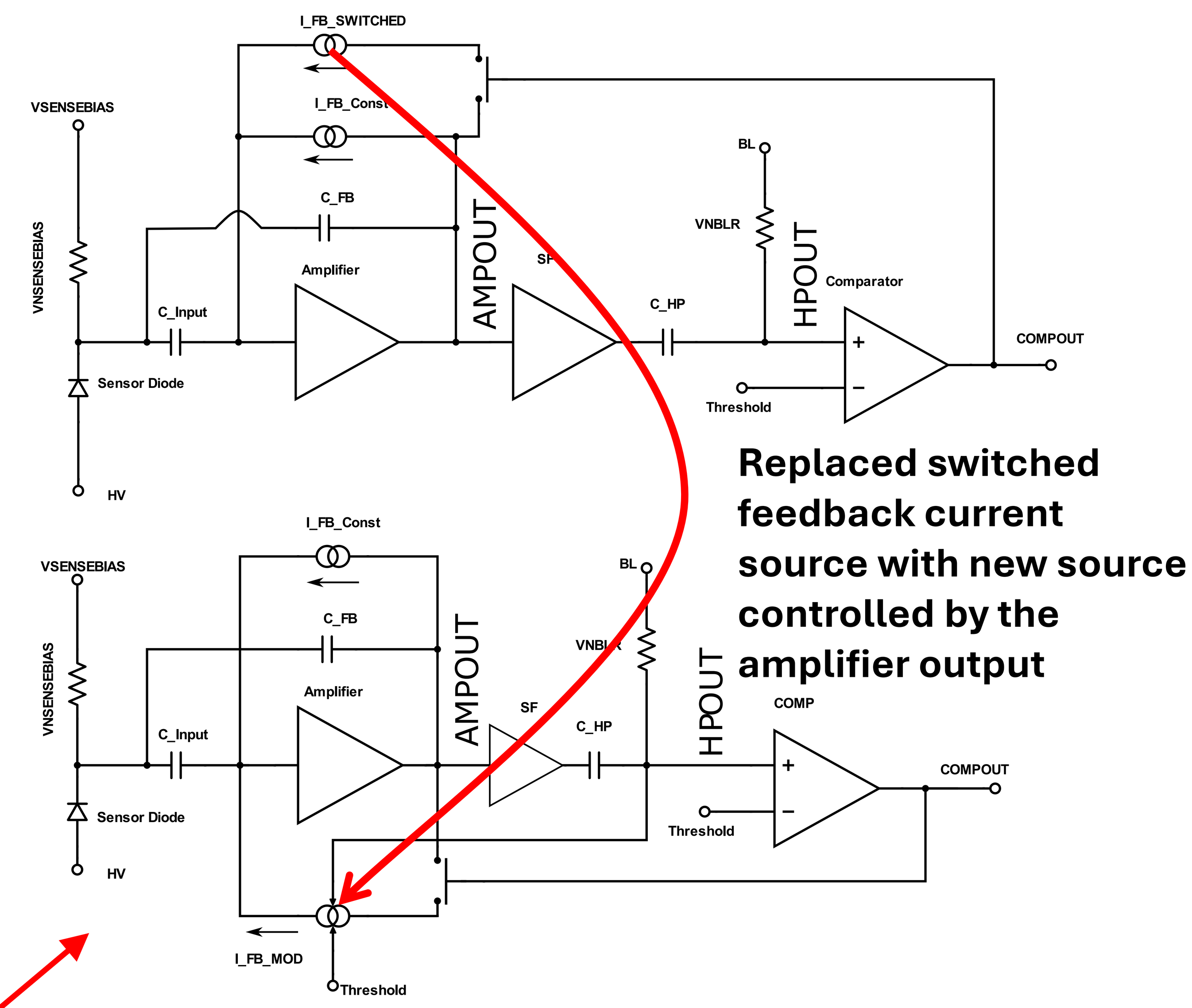




Implementation:

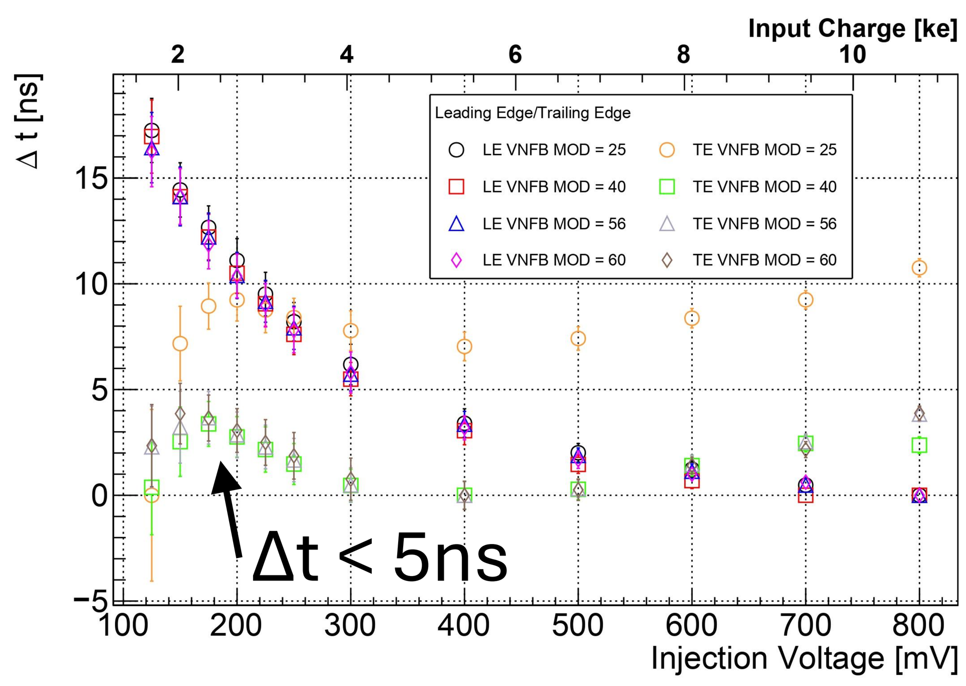
New type of feedback implemented in UKRI-MPW0 [2], a DMAPS demonstrator in the LFoundry 150nm node. Compensation is achieved by making the feedback current dependent on the amplifier output. Compensating feedback pixels are implemented in column 20-28 in both matrices.

Schematic:

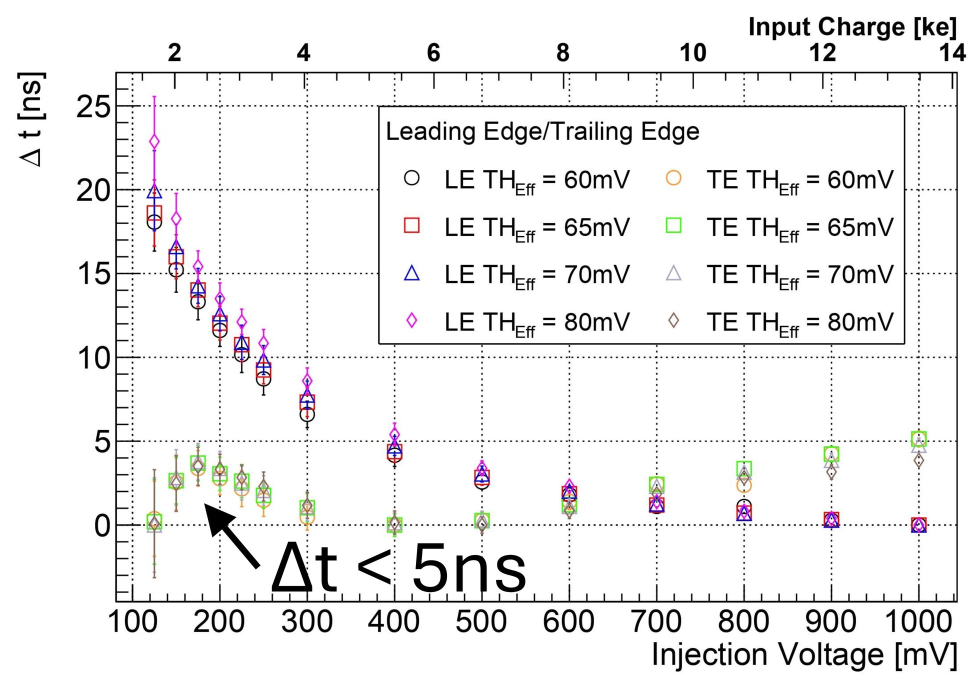


Measurements:

Much higher bias DAC setting (6 in simulation) required to prevent oscillations and achieve optimum performance. Shape of measurement results replicates simulation.



Wide operational DAC range

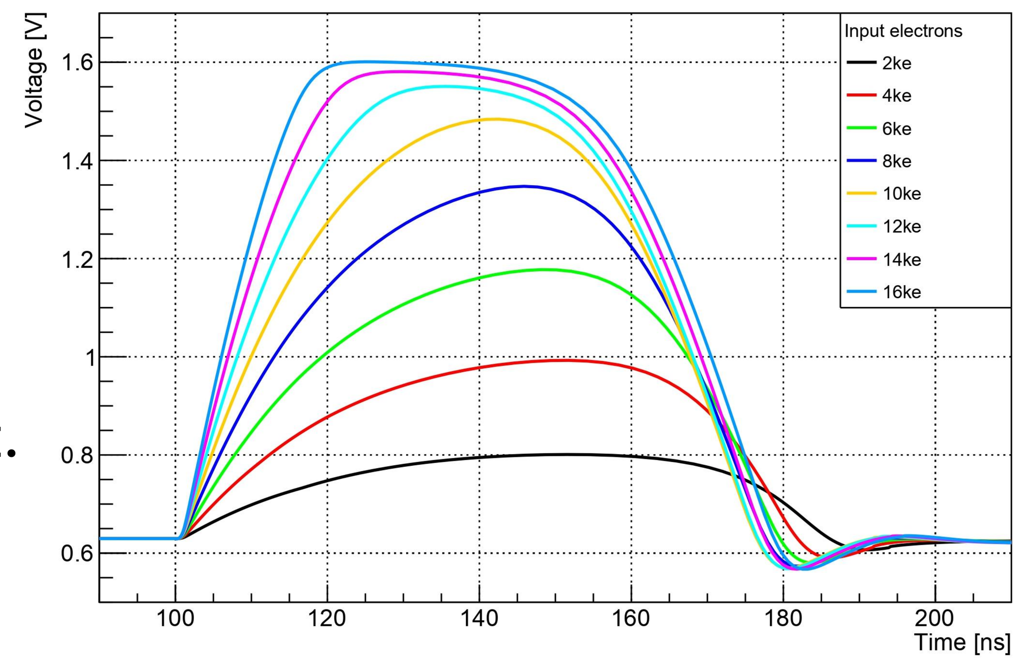


Little impact of threshold

Simulation:

Post-layout simulations demonstrate working principle of the circuit for a wide range of input charge. Measure delay ($d_x(Q)$) of each comparator edge (LE/TE) w.r.t. injection and define the corrected delay Δt as figure of merit:

$\Delta t = d_x(Q) - \min(d_x)$.

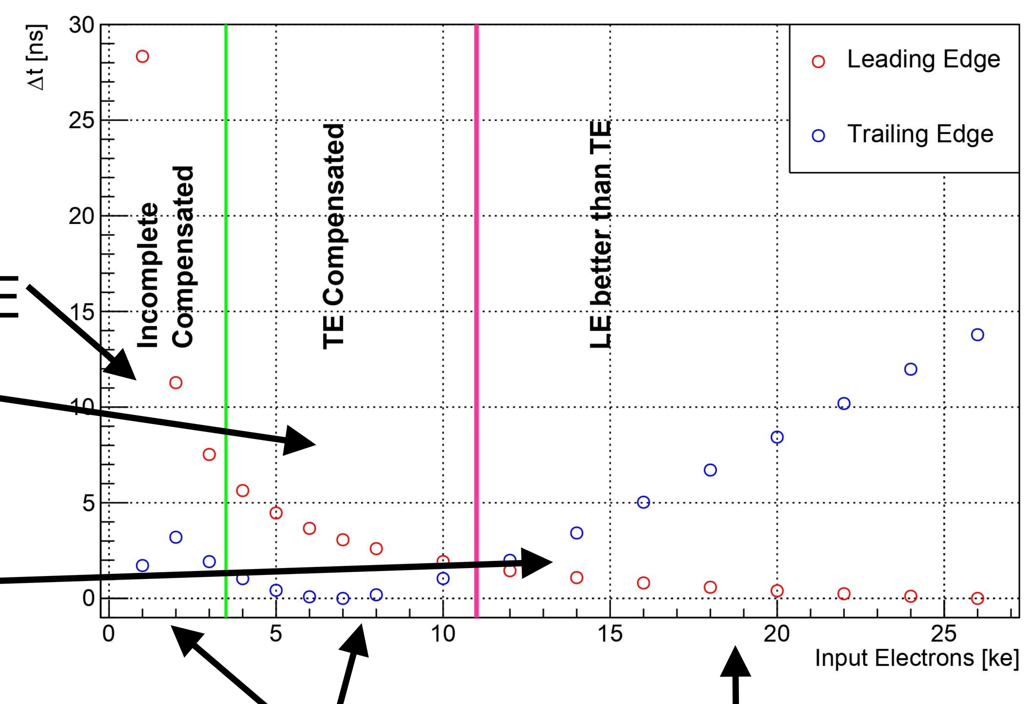


Simulation Results:

Three regions of performance:

1. Incomplete compensation with TE still performing better than LE
2. TE fully compensated
3. Amplifier saturates and TE can't be compensated. In this region LE performs better.

→ Simple ToT cut to decide between TE and LE timestamp for ToA improves timing significantly



$ToA = TS_{TE}$ $ToA = TS_{LE}$

$\Delta t < 5ns$ for $Q \in [1ke, >20ke]$

Notes:

Area of the compensating feedback is ~25% (66μm²) larger than the switched-reset current source (52.5μm²) .

To achieve optimum performance in simulation the analogue pixel frontend consumes 20% less power (20μW vs 25μW).

Outside of the feedback both pixel flavours are identical.

Outlook:

- Circuit works in principle
- Ideas how to improve performance and stability
- Looking for possible applications
- Filed Patent: Application Number GB2404472.9

Acknowledgements:

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References:

[1] C. Zhang, (2021) "Development of Depleted Monolithic Active Pixel Sensors for High Energy Physics Experiments". PhD thesis, University of Liverpool.

[2] C. Zhang et al., "Design and evaluation of UKRI-MPW0: An HV-CMOS prototype for high radiation tolerance", Nucl. Instrum. Meth. A 1040 (2022) 167214

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