Automated, adaptive, fast reset circuit for wide-energy range detector front-end

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Introduction

While working with high-intensity wide-energy-range radiation, fast discharging of the feedback capacitor after pulse processing is especially important whenever high count-rate performance is expected. If a detector leakage current is an issue, using an appropriate feedback circuit is important.

The fast reset can be performed with a high bias current (low effective resistance) of Krummenacher feedback [1]. However, since this approach discharges the capacitor right after (or even during) the event, precise ADC-based energy measurement is extremely difficult or even impossible.

A possible solution is to apply Krummenacher feedback with a larger time constant, but equipped with additional circuitry responsible for baseline restoration whenever the amplitude measurement is done.

Here we present two common reset circuits and propose the new one. For simulation, 28 nm CMOS technology with a supply voltage of 0.9 V is used. We assume the energy range is 40-140 keV.

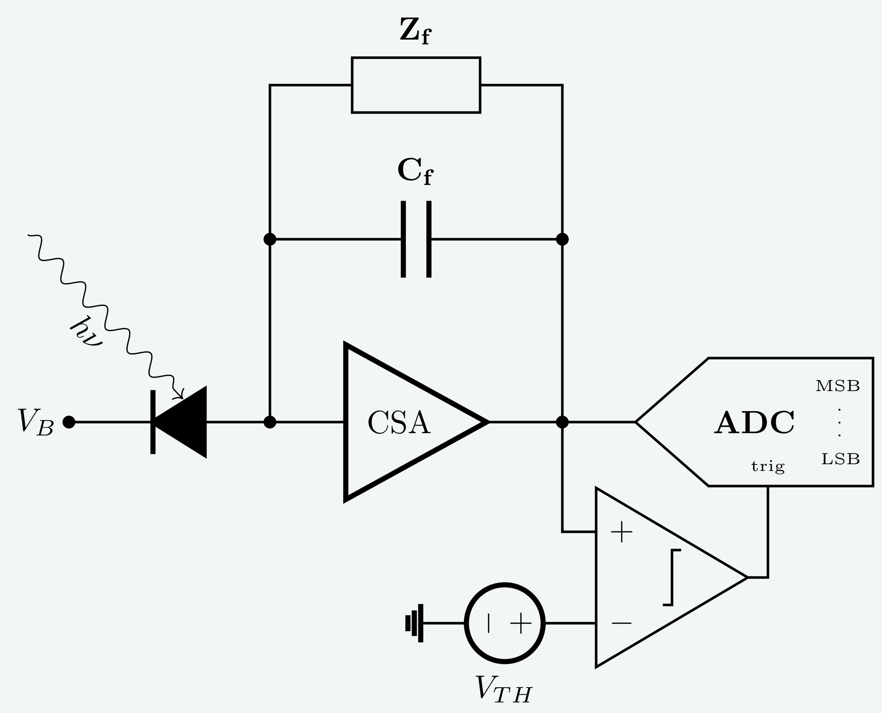

Figure 1: Simplified readout channel

Common reset methods

Switch

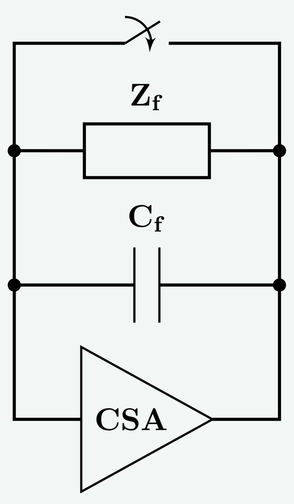

Figure 2: CSA with switch reset

The simplest approach consisting in shorting both capacitor plates using a switch [2]. Such a solution may result in either high overshoot or temporary oscillations, disenabling pulses amplitude measurement or even their detection.

Click-clack

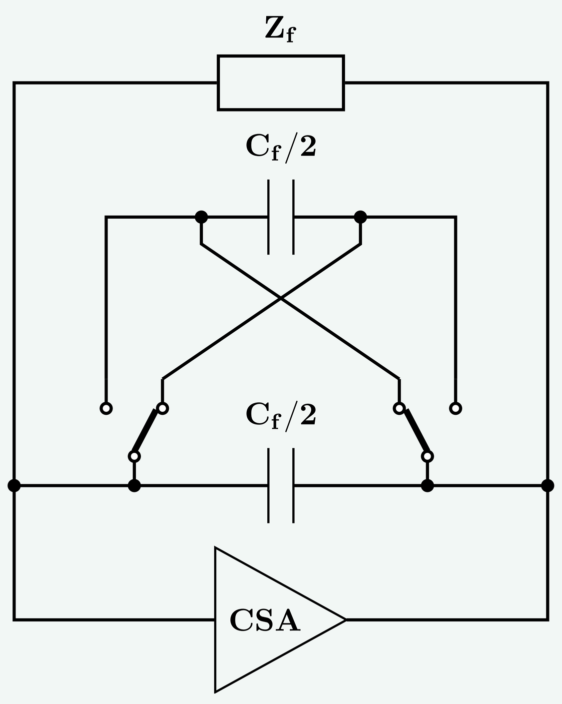

Figure 3: CSA with click-clack reset

This method is based on switching between parallel and antiparallel connections of the feedback capacitors [3]. Parasitic capacitances and precise timing circuits play an important role.

Simulation results

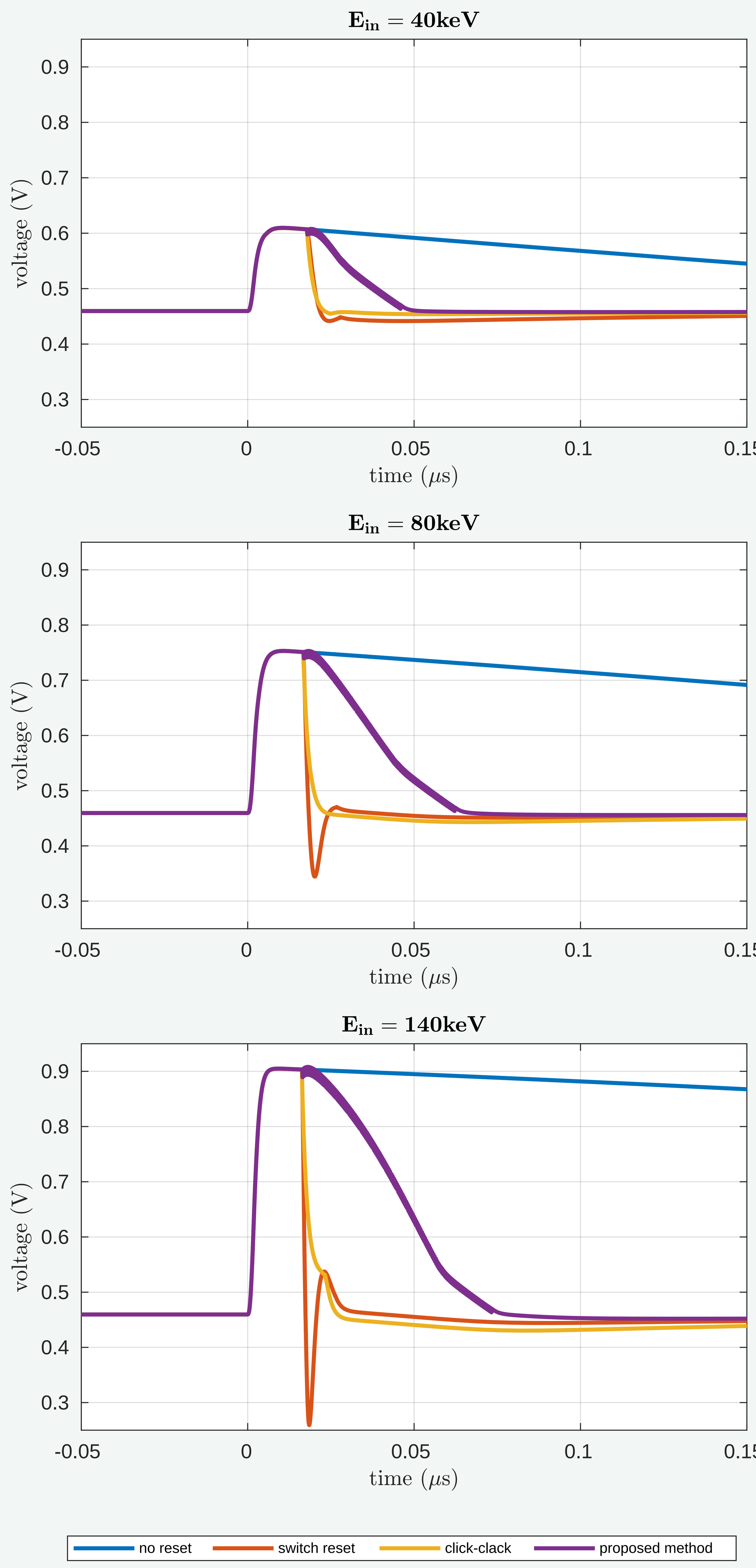

Figure 4: Reset methods comparison

Proposed circuit

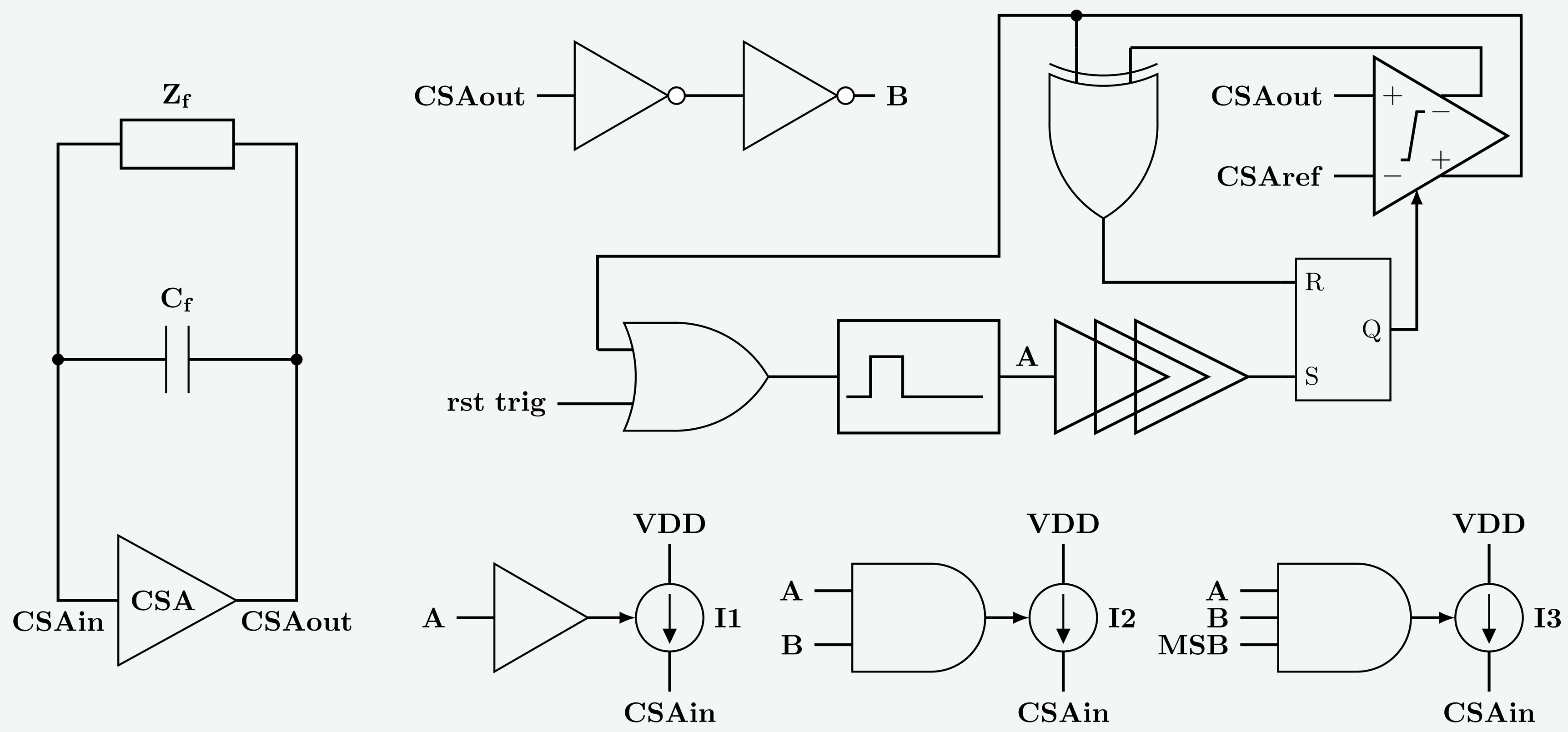

Figure 5: Proposed reset circuit

We propose a self-clocking and automated reset circuit based on additional and simple circuitry to perform feedback for restoring the CSA baseline. This is realized by current sources that inject current pulses into the CSA input node, compensating the capacitor charge. Each step is followed by a comparison of the CSA output voltage and the reference voltage level, and a decision is made if further discharge is needed.

The discharge process is divided into two phases – coarse and fine. During the latter, only I1 feeds current to the capacitor, making it quite slow, but reducing the overshoot. The coarse phase checks the MSB of the ADC conversion result. If it is set, all sources I1-I3 work, if not, only I1-I2. The transition from coarse to fine phase is controlled by the inverter-based comparator that monitors the CSA output.

Conclusion

The proposed solution allows for working with both high count-rate and wide-energy pulses, keeping the Krummenacher feedback equivalent resistance very high, thus enabling fast and precise photon energy measurement. Due to the adaptation of the discharge speed to the pulse amplitude, a fast reset without significant overshoot can be achieved for a wide energy range. The solution is implemented in 28 nm CMOS technology and will be manufactured soon.

References

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[2] H.-S. Kim et al., IEEE J. Solid-State Circuits vol. 48 no. 2 (2013), 541-558

[3] R. Kleczek et al., IEEE 45th Eur. Solid State Circuits Conf. (ESSCIRC) (2019), 85-88

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