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CLARO-CMOS, an ASIC for single photon counting with PMTs, MCPs and SiPMs

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An ASIC named CLARO-CMOS was designed for fast photon counting with MaPMTs, MCPs and SiPMs. The ASIC was realized in a .35 um CMOS technology, and has 4 channels, each with a fast amplifier and a discriminator. The main features of the design are the high speed of operation, aiming to completely eliminate the dead time at a 40 MHz event rate, and low power dissipation, around 1 mW/ch and below. The high speed of operation combines with low noise to give a very low jitter, down to 10 ps rms, enough for most TOF applications.

Summary

Several applications in the field of particle physics require detectors capable of counting pulses of single or a few photons at high rates. These include RICH detectors, TOF detectors, scintillating trackers and calorimeters.
Multi-anode photomultiplier tubes (Ma-PMTs), thanks to the negligible dark count rate, are most often the baseline for RICH detectors. New TOF detector designs often employ light detectors with superior time resolution, such as microchannel plates (MCPs). Scintillator-based detectors usually generate a larger number of photons per event, and can thus take advantage of light detectors with a higher dark count rate, but lower cost, such as silicon photomultipliers (SiPMs).
The first prototype of an ASIC named CLARO-CMOS was designed to deal with such applications. The ASIC was realized in a .35 um CMOS technology, and has 4 channels, each made of a fast amplifier with settable gain (3 bits), and a discriminator with settable threshold (5 bits).
The main features of the design, compared to similar ASICs already available, are a higher speed of operation, aiming to completely eliminate the dead time at 40 MHz event rate, and a low power dissipation, below 1 mW/channel. The speed requirement calls for transition edges of the order of a few nanoseconds, both from the preamplifier and from the discriminator. When the discriminator triggers, the output is high for less than 25 ns within a dynamic range of a factor of 10 above threshold (the typical amplitude spread for a single photon pulse from a Ma-PMT).
Noise is 6 kiloelectrons (1 fC) rms at the input, with a total input capacitance of 3.3 pF.
The speed of response and very low noise are obtained with a low power dissipation, of 0.71 mW/channel in idle (1.90 mW/channel if the discriminator triggers with a 10 MHz rate, and its output is loaded with 8 pF).
The high speed of operation combines with low noise to give good time resolution: a jitter of 79 ps was measured for pulses of 330 kiloelectrons (53 fC), just above threshold, going down to 11 ps for pulses of 4.5 million electrons (720 fC). The time walk is about 2.5 ns over the whole dynamic range, and can be compensated with a time over threshold technique.
The power dissipated by the circuit can be set with an external bias resistor. If the power consumption is increased to 1.52 mW/channel in idle, the optimal timing performance can be achieved: a jitter of 52 ps was measured for pulses of 330 kiloelectrons (53 fC) in these conditions, going down to 9 ps for pulses of 4.5 million electrons (720 fC) likely limited by the measurement setup. This should allow a time resolution good enough for most TOF applications.
The ASIC was also tested coupled to a R11265 MaPMT from Hamamatsu, the baseline for the upgrade of the LHCb RICH detector, and with a MicroSL-10050-X18 SiPM from SensL, giving good results.

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