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SAMPIC-based systems for precise timing detectors: implementation and performance.

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The SAMPIC chip is based on the concept of Waveform Time to Digital Converter introduced in 2013. It permits performing timing measurements with a precision of a few ps directly on detector signals. The waveforms are digitized between 1.6 and 8.2 GS/s rate over 64 samples and Time Over Threshold measurement is integrated. A set of boards and DAQ system has been developed to record data with detectors in a real environment over 16 to 256 channels. The talk will focus on the new possibilities offered by the systems equipped with the latest chip version and report the performance measured.

Summary

SAMPIC is a Waveform Time to Digital Converter (WTDC) 16-channel chip designed in 0.18-µm CMOS technology which directly measures the arrival time of fast analog signals without the need of any external discriminator. Each channel associates a traditional DLL-based TDC providing a raw time measurement based on a counter and a DLL with an ultra-fast 64-cell deep analog memory (bandwidth ˜ 1.5 GHz, sampling rate between 1.6 and 8.2 GS/s) allowing fine extraction of the time after interpolation. Each channel also integrates a discriminator that can self-trigger independently or participate into a more complex central trigger embedded on-chip (multiplicity up to 3 channels over a programmable gate) and permits performing an individual Time Over Threshold (TOT) measurement. TOT can also be used for rejecting signal shorter than a programmable value.

After triggering, analog data is digitized on-chip by a massively parallel low-power 7 to 11-bit Wilkinson ADC running above 1 GHz. Dead-time is about 1.6 µs for an 11-bit conversion, and as low as 200 ns for an 8-bit conversion yet already providing excellent time precision.

The time resolution of the chip is of a few ps rms after a simple correction, itself based on a simple calibration (very stable with time). The raw time resolution before calibration is already very good (< 15 ps rms @ 6.4 GS/s). The last version of the chip permits its autonomous time calibration.

A set of boards and DAQ systems has been developed to record data with detectors in a real environment. A two-level trigger has also been implemented in order to perform coincidences between multiple chips or with an external trigger.

Control and readout can be performed via 3 different interfaces: USB, secured Gbit-UDP over optical fiber or copper (RJ45).

The current range of SAMPIC modules offer compact solutions with a number of channels ranging between 16 and 256. For systems up to 64 channels, a powerful software with an original interactive graphical interface has been developed. For systems above 64 channels, a C-library will soon be available.

The SAMPIC boards and modules are being used with different types of detectors for test benches or test beams: PMTs, MCPPMTs, APDs, SiPMs, fast Silicon Detectors, Diamonds,... The performances measured are equivalent to those performed with high-end oscilloscopes. For instance, TOTEM (CMS) has developed a motherboard housing 192 channels of SAMPIC (twelve 16-channel mezzanines) for the readout of the diamonds and ultra-fast silicon detectors of its Precision Proton Spectrometer on LHC. Another example: SAMPIC modules will be deployed in test beams at CERN in association with the MUSIC front end chip (Barcelona) for the characterization of a prototype of the Timing Detector of the SHiP project.

A specific version of the chip with differential digital input (SAMPET) has also been developed in collaboration with CERN for the readout of the NINO and SuperNINO chips for ToF-PET applications.
The talk will focus on the new possibilities offered by the systems equipped with the latest chip version and report the performance measured.

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