Nuclear Instruments and Methods in Physics Research A 695 (2012) 61–67

Contents lists available at SciVerse ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Using ultra fast analog memories for fast photodetector readout

Dominique Breton [a],*, Eric Delagnes [b], Jihane Maalmi [a]

[a] Laboratoire de l'Accélérateur Linéaire, Orsay, CNRS/IN2P3, France
[b] CEA/IRFU Saclay, France

ARTICLE INFO

Available online 9 December 2011

Keywords:
WaveCatcher
Waveform
Digitizer
ADC
TDC
USB

ABSTRACT

The recent progresses in the field of photodetection have pushed the performances of the detectors toward the picosecond scale. Necessary precise charge and time measurement are mainly based on high-end oscilloscopes or commercial modules, but these solutions are expensive and house very few channels.

The USB-WaveCatcher board provides high performances over a short time window. It houses two 12-bit 500-MHz-bandwidth digitizers sampling up to 3.2 GS/s. Its low consumption allows it to be USB-powered and it offers a lot of functionalities. The board has been used in different test benches dedicated to fast MCP-PMTs or SiPMs, and a reproducible time precision better than 10 ps rms has been demonstrated. Implementations with up to 16 channels have been designed and exhibit the same time precision.

The USB-WaveCatcher thus seems to be a wonderful tool for photodetector characterization. Our next step is to widely expand the number of channels while keeping the 10 ps time precision.

1. Introduction

Photodetectors are implied in all kinds of applications. Associated electronics can be used either for their characterization (test benches) or for their readout (physics experiments or medical apparatus).

In the case of test benches, ultimate performance of the electronics is requested. If the number of channels is small (≤ 4), then high-end oscilloscopes can be used. But if the number of channels increases, and if one wants to study all of them in parallel, difficulties occur.

In the case of physics experiments, dedicated ASICs are usually used. They shape the signal and then permit amplitude, charge and/or time measurement.

But, what happens if time measurement precision has to be better than 30 ps rms? Or if one wants to measure A, Q and/or T, but also see the waveforms on demand?

2. Introducing analog memories.

The recent progresses in the field of photodetection have pushed the performances of the detectors toward the picosecond scale. This is especially true for MCP-PMTs (Micro-Channel Plate PMTs). Currently existing electronics dedicated to precise charge and time measurement for test or characterization benches is mainly based on the use of high-end oscilloscopes. Their cost per channel is high and their number of channels very limited. Numerous test benches are also based on commercial modules, both Charge-to-Amplitude Converters and Constant Fraction Discriminators (CFD) associated with Time-to-Digital Converters (TDC). The time resolution obtained with some of these modules, like the ORTEC 9327CFD, TAC588, and 14 bit ADC114 electronics, is very good ($\sim$5 ps rms after amplitude correction), but they are expensive and house very few channels. Some TDC boards offer a higher number of channels, using multi-channel TDC ASICs based on a coarse measurement performed by a digital counter associated with a fine measurement (interpolation) using Delay Line Loops, but their overall resolution is only of the order of 30 ps rms. However, they currently are the only solution for high scale measurements like those needed on big physics experiments.

Recently, alternative methods for amplitude, charge and time measurements have been developed. They are based on digital treatment of the analog sampled then digitized detector signal. Such methods permit an easy calculation of the charge and amplitude, and achieve a timing resolution far better than the sampling frequency thanks to signal interpolation. Digitization systems have followed the progress of commercial ADCs, but the latter exhibit prohibitory drawbacks like their huge output data rate and power consumption. The former implies the use of very high-end FPGA to treat the data flux, thus introducing extra cost and complexity. Conversely, high speed analog memories now

* Corresponding author. Tel.: +33164468330; fax: +33164468934.
E-mail address: breton@lal.in2p3.fr (D. Breton).

0168-9002/$ - see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2011.12.007

offer sampling rates far above 1 GHz at low cost and with low power consumption. Moreover, their companion FPGA can be low-end, thus also low-power and low-cost.

3. Analog memories vs ADCs/TDCs

Analog memories actually look like perfect candidates for high precision measurements at high scale. Indeed:

- Like ADCs they catch the signal waveform (this can also be very useful for debug)
- TDC is built-in (position in the memory gives the time)
- Only the useful information is digitized (vs ADCs), thus ensuring a low power consumption
- Any type of digital processing can be used.

Main difficulty is less sampling frequency than signal bandwidth.

Their drawbacks:

- The limited recording depth.
- The readout dead-time.

But only a few samples/hit can be read and this may limit the dead time. Moreover, simultaneous write/read operation is feasible, which may further reduce it if necessary.

4. ASIC and board developments

4.1. The SAM family

The SAM family ASICs are based on an analog matrix structure patented in 2001 [1]. The two current versions (SAM: 256 cells per channel [2], and SAMLONG: 1024 cells per channel) used on the WaveCatcher boards are shown on Fig. 1.

They have been designed in a cheap pure CMOS 0.35 μm technology and consume only ~150 mW per channel. Their high dynamic range ($\geqslant$12 bits) and high bandwidth (500 MHz) allows them to finely sample high speed signals like very short pulses, and makes them very well suited for photodetector readout. Moreover, thanks to the servo-controlled matrix structure, the time parameters are very well mastered thus offering an impressive sampling time precision.

4.2. The WaveCatcher board

The USB-WaveCatcher board [3] (see Fig. 2) has been designed to provide high performances over a short time window. It houses on a small surface two 12-bit 500-MHz-bandwidth digitizers sampling between 400 MS/s and 3.2 GS/s. It is based on the SAM chip family described hereabove. The board is DC-coupled with a unity gain, but can also be AC-coupled with a gain up to 15 (still offering 350 MHz of bandwidth). A DC offset can be added at input in order to get a full benefit of the 2.5 V dynamic range, and a individual trigger

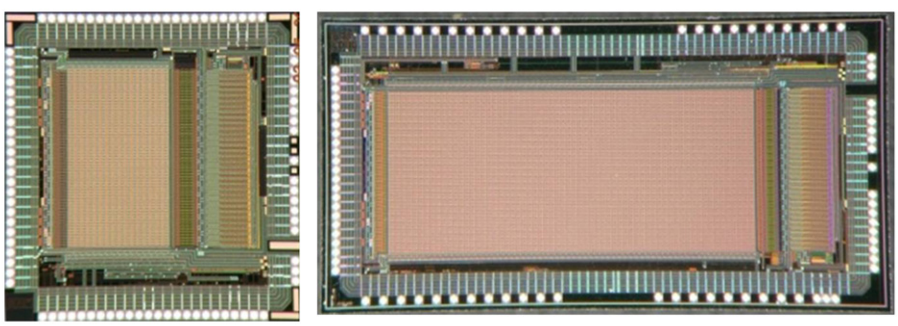

Fig. 1. SAM and SAMLONG chips, 0.35 μm technology, 2 ch – 256/1024 cells/ch – 12 bits – 3.2 GS/s.

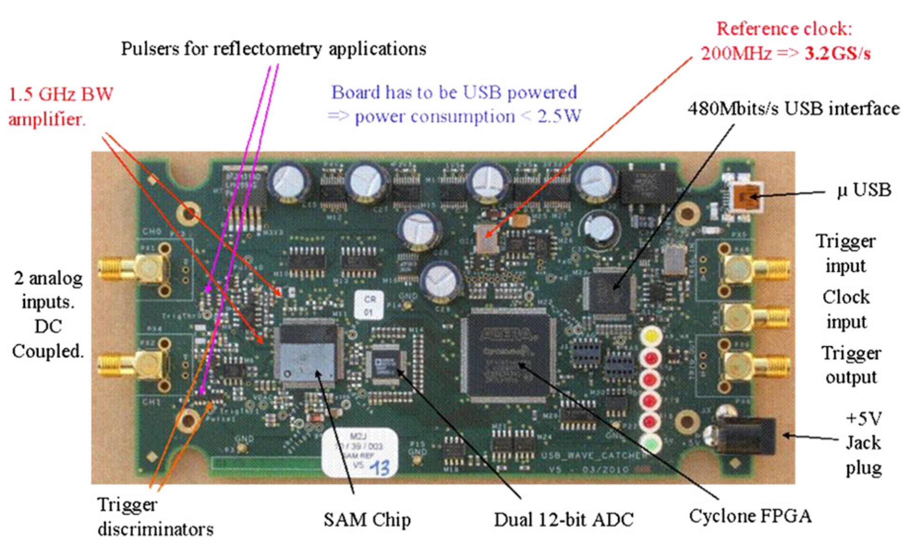

Fig. 2. The USB-powered USB_WaveCatcher board (3.2 GS/s, 12 bits, time resolution < 10 ps rms).