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Description of a4 –channel FPGA-controlled ADC-based DAQ system for general purpose PMT signals

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Abstract: We describe a general purpose data acquisition system for PMT signals. Hardware-wise it consists of a 4-channel ADC daughter board, an FPGA mother board, a GPS receiver and an atmospheric pressure sensor and a temperature sensor. The four ADC channels simultaneously sample PMT input signals with a sampling rate of 100MS/s. We have evaluated the noise of our system obtaining less than -48.6dB. This DAQ system includes a firmware suitable for pulse processing in cosmic rays applications. In particular, we describe in detail the way in which this system can be used during the commissioning and early operation phases of the High Altitude Water Cherenkov Observatory (HAWC) currently under construction at Sierra Negra in Mexico.

1. INTRODUCTION

The HAWC observatory is under construction by a collaboration of scientists from the US and México at the Sierra Negra site, in México, at an altitude of 4100 m.a.s.l. It will make use of a compact array of water Cherenkov detectors (WCDs) to survey the sky in search of steady and transient gamma ray sources in the 0.1-100TeV energy range. The HAWC Observatory will reuse PMTs and electronics from the Milagro gamma Ray Observatory [1]

A prototype array for HAWC consisting of 7 cylindrical water Cherenkov detectors, with a diameter of 7.3 m and filled with water up to a height of 5 m is under construction. Each detector will have 3 PMTs looking at the water volume from the bottom of the tanks. The general purpose data acquisition system that we describe in the following sections can digitize up to 4 PMT signals with a sampling rate of 100 MS/s; it represents a low-power, portable, fast and easy-to-operate readout system that can be used along with a more powerful VME-based system during the construction phase of HAWC to test individual detectors.

2. The DAQ Hardware

Our 4-channel ADC daughter board has two independent dual analog to digital converter working at 100MS/s, with local memory and FPGA in its mother board for real-time data processing. The purpose of the pulse processing is to perform online signal processing on the digitized signals directly to minimize the data transfer size, these algorithms are implemented in the FPGA and can be reprogrammed at any time.

Each event will be tagged with precise GPS time using an embedded GPS receiver with 1 PPS (one pulse per second) synchronized with UTC within an uncertainty of 50 ns (Motorola Oncore UT+ GPS receiver). A pressure and temperature sensor (HP03D) is also connected to the FPGA board (Nexys2 from Digilent Inc.). The FPGA that we use is the Spartan 3E-500 from Xilinx.

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Figure 1 shows the block diagram of the ADC daughter board. The PMTs convert the energies deposited in the detector by charged particles into negative pulses with typical widths of 5-10 ns. These pulses are conditioned and shaped inside the ADC board into positive pulses with widths of 20-40 ns. The use of dual ADCs simplifies the firmware program written in hardware description language (VHDL) of the whole DAQ system.

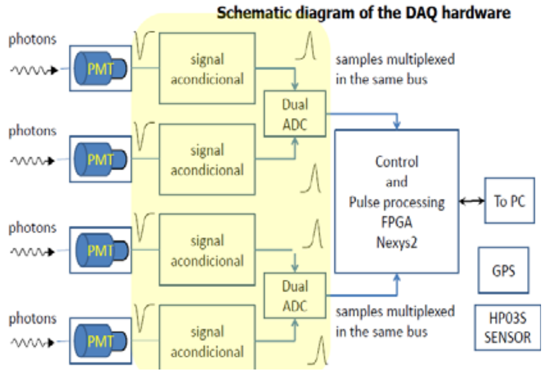

Figure 1 Block diagram of the ADC daughter board.

Hardware wise this system possess the following characteristics:

- Uses the Nexys2 board with a Spartan 3E-500 FPGA from digilent inc. [2]. The Nexys2 is a powerful digital system design platform built around a Xilinx Spartan 3E FPGA. With 16Mbytes of fast SDRAM and 16Mbytes of Flash ROM, the Nexys2 is ideally suited to embedded processors like Xilinx's 32-bit RISC Microblaze™.
- Uses a 4-channels ADC daughter board with two dual 10-bit ADC chips AD9216 [3]. The AD9216 is a dual, 3 V, 10-bit, 105 MSPS analog-to-digital converter. It features dual high performance sample and hold amplifiers and an integrated voltage reference. The AD9216 uses a multistage differential pipelined architecture with output error correction logic to provide 10-bit accuracy and guarantee no missing codes over the full operating temperature range at 105 MSPS.
- Uses one quad, 10-bit, low-power, buffered voltage-output, digital-to-analog converter (DAC), MAX5741 [4], to control the baselines of the four input channels of the ADC daughter board.
- Uses a Motorola Oncore UT+ GPS receiver [5].
- Uses an HP03S pressure and temperature sensor. It provides 16 bit word data for pressure and temperature related voltage [6].
- Uses the RS-232 port for slow communications.

Figure 2 shows a photograph of the ADC daughter board connected to the Nexys2 board. This system will be used on the first stage of the construction of the HAWC Observatory, called the VAMOS Array, to test individual detectors.

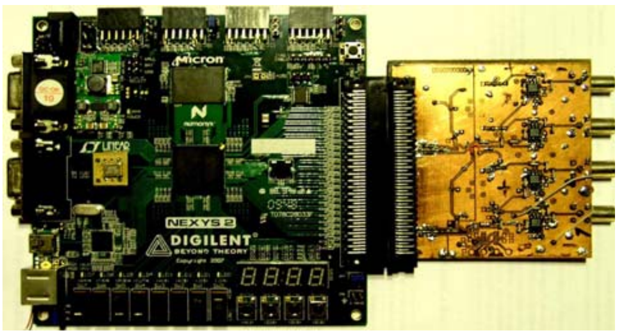

Figure 2 Photograph of a prototype of the ADC daughter board connected to the Nexyx2 board.

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3. RESULTS

We first studied the baselines of typical input pulses and measured the width of their distributions. Figure 3 shows examples of digitized baselines and their respective distributions.

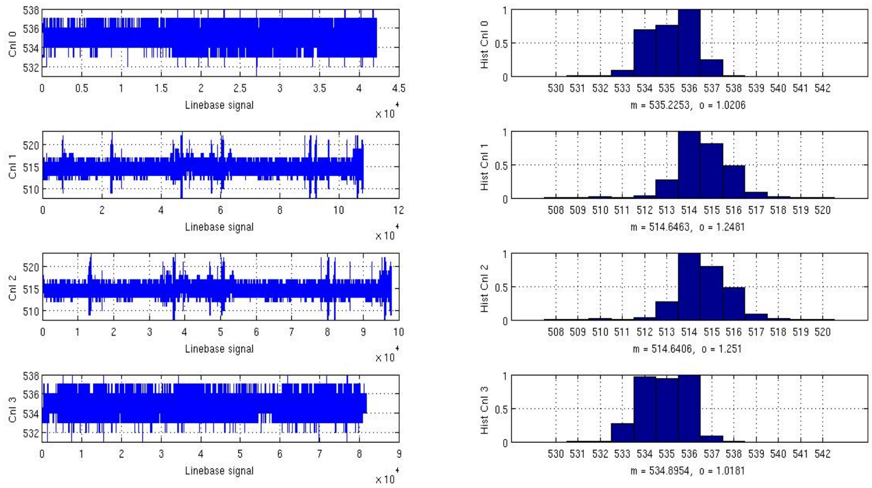

Figure 3 Examples of digitized baselines (left plots) and their respective distribution (right plots) for signals from a pulse generator.

Figure 4 shows the FFT (Fast Fourier Transform) computed for four sine signals using 4096 samples. The frequencies of these sine signals were 500 Khz, 750 Khz, 1 MHz and 2 Mhz, respectively. These four signals were sampled simultaneously at 100 MS/s by using the 4 channels of the ADC board. We used the same trigger threshold on all the four channels.

Figure 5 shows a trace firmware for a signal sampled at 100MS/s. Each trace has 16 samples, and the same threshold for all channels. Each signal corresponds to one channel with different frequency, and different pulse width.

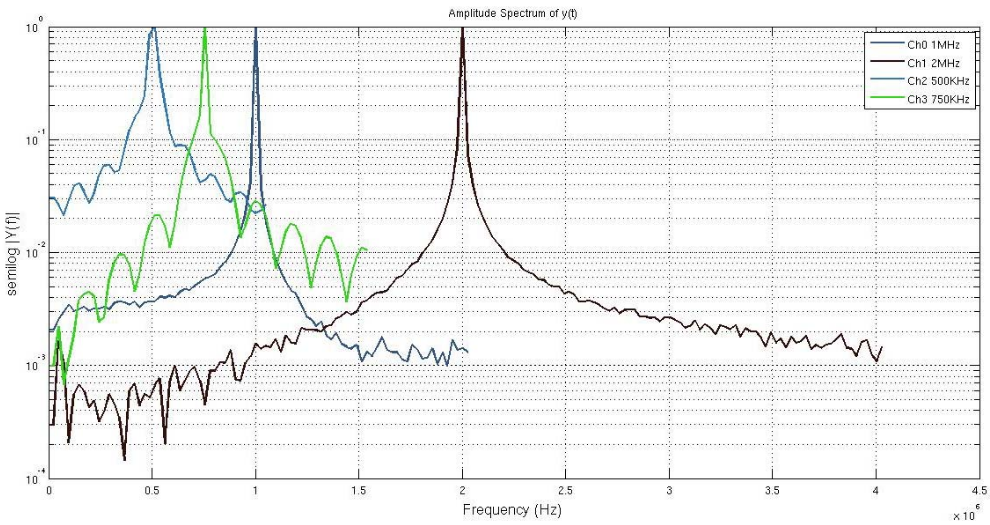

Figure 4 Fast Fourier Transforms (FFTs) computed for four sine signals 4,096 microsecond long using 4096 samples. The frequencies of these sine signals were 500KHz, 750KHz, 1MHz and 2MHz, respectively. These four signals were sampled simultaneously by using the 4 channels of the ADC board

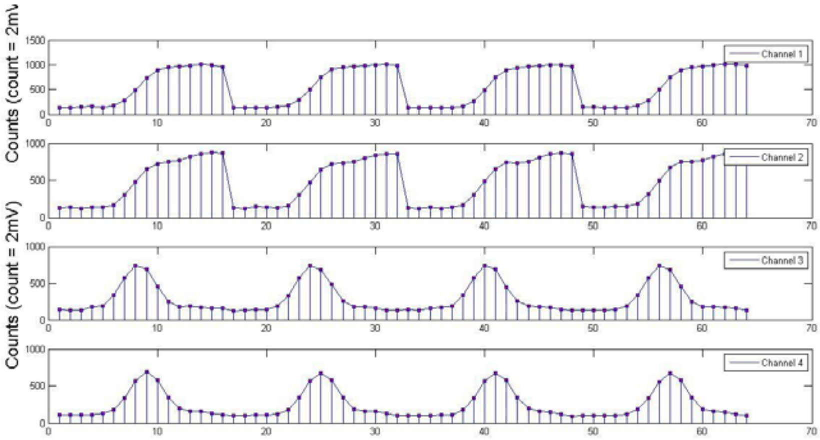

Figure 5 Examples of traces digitized at 100 MS/s with the DAQ system described in this paper. The first 16 points of each plot correspond to synchronous pulses fed into the system by using a pulse generator..

The firmware of the DAQ system described was written in hardware description language by using VHDL. On the PC side we used Perl and MATLAB under Linux to process, store and display the data acquired.

4. CONCLUSION

We have evaluated the performance of the data acquisition system to sample the PMT signals from water Cherenkov detectors at 100 MS/s and we have built a custom-made data acquisition (DAQ) too. This DAQ system includes a firmware suitable for pulse processing in cosmic rays applications.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

[1] http://hawc.umd.edu/detector.php
[2] http://www.digilentinc.com/Products/Detail.cfm?NavPath=2,400,789&Prod=NEXYS2
[3] http://www.analog.com/en/analog-to-digital-converters/ad-converters/ad9216/products/product.html
[4] http://www.maxim-ic.com/datasheet/index.mvp/id/3107/t/al
[5] http://www.tapr.org/gps_oncoreut.html
[6] http://www.hoperf.com/upfile/HP03S.pdf