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WIDGET: A DATA ACQUISITION SYSTEM FOR A BALLOON BORNE Si PARTICLE CALORIMETER

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ABSTRACT

We describe Widget; a complete data acquisition system (DAS) designed for a balloon-borne calorimeter using silicon strip detectors. The design includes a general purpose CPU as well as five to twenty Digital Signal Processors in order to control the acquisition of the data. This local intelligence also allows the instrument to re-calibrate itself, to perform calculations on the data and to control the functionality of the instrumentation. The DSPs filter the data to avoid overflowing the radio link to ground. In principle the system could control the instruments, without direct intervention from the ground, on flights with durations of several days .

1. INTRODUCTION

Widget (Wizard Data Getter) is the data acquisition system for the balloon phase of the Wizard collaboration [1]. The ultimate purpose of the collaboration is to launch a satellite borne instrument capable of extending our knowledge in cosmic ray physics and related disciplines. This includes the search for primordial antimatter, the determination of the energy spectra of antiprotons and positrons up to a few hundred Gev and the measurement of energy and spectra of protons, electrons and nuclei up to Carbon.

The Wizard payload includes, in its various possible configurations, several other instruments besides the silicon calorimeter. The main concern of this paper is the data acquisition system of the silicon calorimeter.

The calorimeter provides discrimination of electrons from protons by measuring the energy deposited by the particles while passing through plates of tungsten. Electrons produce bremstrahlung photons, which in turn produce electron positron pairs, hence generating a particle shower. The slabs of high-Z material are alternated with planes of detectors to sample the development of the shower. The ability of the calorimeter to discriminate between electrons and proton resides in recognizing the different spatial development of both types of showers and in its energy resolution.

The collaboration chose silicon strip detectors as the detecting medium[2]. Silicon detectors are widely used in High Energy Physics (HEP) experiments. But, unlike its ground counterpart, air borne and space applications present additional requirements for the data acquisition system such as: low weight, low power consumption and high reliability.

Widget will be used for the already programmed balloon flights; two during 1993 and the remaining flight during 1994. Widget was designed and built using off-the-shelf components. The prototype system was designed to check the concept of massive computing power for balloon flights as well as to obtain relevant physics results.

For the satellite phase much of the electronics will be monolithic although the architecture will be the same. In particular, we will publish separately the details of the monolithic implementation of the front end electronics, there are already prototypes in silicon and gallium arsenide, since it is an issue all by itself.

2. GENERAL ARCHITECTURE

In an accelerator environment, the usual role of a data acquisition system is to wait for a trigger signal to enter into action. Some fast electronics generates the trigger signal every time that it recognizes, in one event, some predetermined sought after characteristic. At that moment the data acquisition system reads all the signal channels, it converts the analog values into digital form, it builds the event and stores the data into some magnetic media in order to analyze it off-line. If the operator want to recalibrate the system or check its functionality the data taking is stopped and it resumes only after the procedure has been carried out. If a system failure is detected there is ample time and easy access to the electronics.

A balloon borne data acquisition instead has to perform all the aforementioned tasks and more. Since a typical flight lasts for some 25 hours, time is at a premium and no physical access to the electronics is available. Some of these extra tasks are: to control the functionality of the whole instrument, to filter and compress the data since it has to be downloaded to ground through a narrow bandwidth radio link, to recalibrate the systems because of temperature variations or aging, to locally store tha acquired data because the link is too slow or because the downloading is possible only at determined periods.

The fine details of the electronics and of the on-board software can be found in the technical literature written for the users of Widget [3][4].

Figure 1 shows the architecture of Widget. The main system architecture looks very much like a funnel, to have at all times and places, a data bandwidth and computing power coherent with the amount of data to be handled.

The first version of the calorimeter will fly with only five silicon detector planes, the second with seven and the last with thirteen planes. Hence, we designed a modular hardware architecture admitting up to 32 detector planes and capable of servicing 50-100 events per second regardless of the number of planes. This flexible data acquisition system required the following boards:a) the GMX a general purpose single board CPU5 capable of running OS-9, a Real-Time operating system;b) the PiggyBoard ,a module provider of general services;c) the RomeModule, a board capable of generating test signals for the maintenance and in-flight calibration of the system;d) the FlashDisk, an ultra low power consumption solid state disk using a bank of FlashCards; e) the VoodooCards- one for each plane- they embody a digital signal processor (DSP), 16 A/D converters and a 4 kword double port memory (DPM). For the main processor we used a commercial single board computer while all the other boards were custom designed. We will refrain from describing here the FlashDisk since it is only needed when flying with more than five planes.

Figure 2 shows the data path for the signal coming from one of the Si strips. In what follows we will outline the acquisition of the data after the S/H circuit.

We assigned to each Voodoo one TMS320E256 DSP, running at 40 Mhz, to service all the functions of a plane. Each DSP acts sometimes as a CPU and at other times as a sequencer7, controlling the activity of the A/Ds and selecting those channel values that are above the electronic noise.

The analog signals are converted in parallel in all 16 A/D of a plane and in each plane. This high degree of parallelism provides a large throughput. Each highly integrated LM14458 A/D converter is capable of outputting a 12-bit+sign number at a rate of 87 ksamples/s. Also, the LM14458 can recalibrate itself, it goes into an standby mode if requested, it has 8 S/H inputs and a multiplexer that selects the channel to be converted and an internal 32 conversion deep FIFO. This IC is one of the first available data acquisition systems in a chip.

The DSPs filter the large amount of data generated for each event. Each plane has 256 data channels, and since the signal from each is passed through a x1 or x16 amplifier, the DSP has to compare 512 numbers against 512 different thresholds. The DSP writes into the DPM only the converted signals with values that are above the thresholds. The GMX reads out these values from the other side of the DPM, labeling and writing them, together with the data coming from the other planes, into the CamacCard. The onboard MicroVax reads the data from the Camac and it transmits these relevant data to ground through the radio link.

The GMX is the master of the system. After Reset it delivers to the DSPs the initial values for the thresholds, S/H times, and programs for the A/D. These programs instruct the A/D to acquire the data from any of the 8 channels of the multiplexer, either versus ground or differentially. A reference voltage is connected to one of the input channels. This voltage is used to control the functionality of the A/Ds. The GMX can also instruct the DSPs individually: to test the functionality of each Voodoo, to wait for a trigger and to acquire data; to load a new program into its memory and to execute it.

The PiggyBoard provides services such a nonvolatile memory used to store tables and programs, a watchdog reset system that - if not itself resetted by the GMX every second- generates a reset pulse for the whole system.

The RomeModule conditions the trigger into a TTL level. But its main function is to generate internally 10 Hz trigger pulses in order to calibrate the system. Under the command of the GMX it provides the preamplifiers with test-in levels, coming from a programmable D/A, to check the functionality and linearity of the pre-amplifiers. If the test-in voltage level is zero, Widget measures the noise of the system. The mean of the noise and the width of the its histogram determines the threshold. The determination of new thresholds can be achieved while flying, hence compensating for changes of the electronics, either intrinsic or produced by changes of environmental variables such as power supply noise or payload temperature.

The CamacBoard also allows the system to receive instructions from the ground. Consequently recalibrations and other tasks can be requested on demand, when some anomaly is noticed through the monitoring of the data arriving to the ground.

3. CONCLUSIONS

The flexibility and modularity of the system allows to accommodate from 1 to 20 planes with almost degradation of the acquisition data rate. The high programability permits, that with a simple change of software, novel tasks can be executed. Also, the presence of a general purpose computer allows the system to control the hardware faults minimizing their influence in the overall performance.

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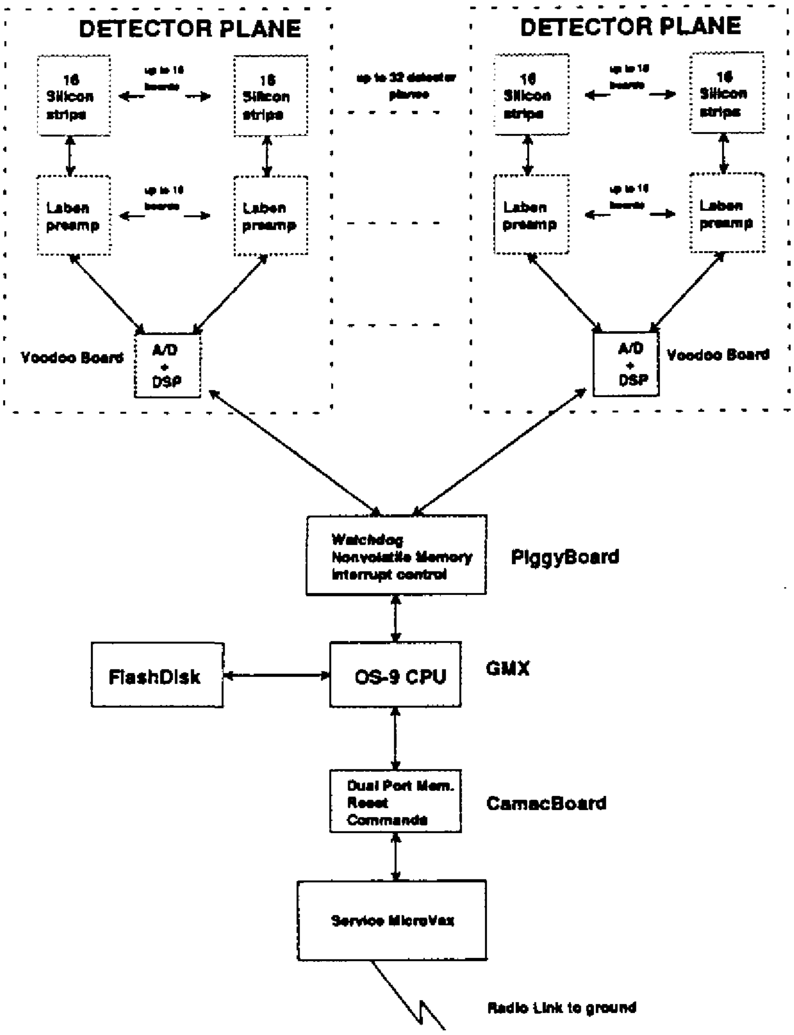

Fig. 1: General Architecture of the Si Calorimeter Data Acquisition System.

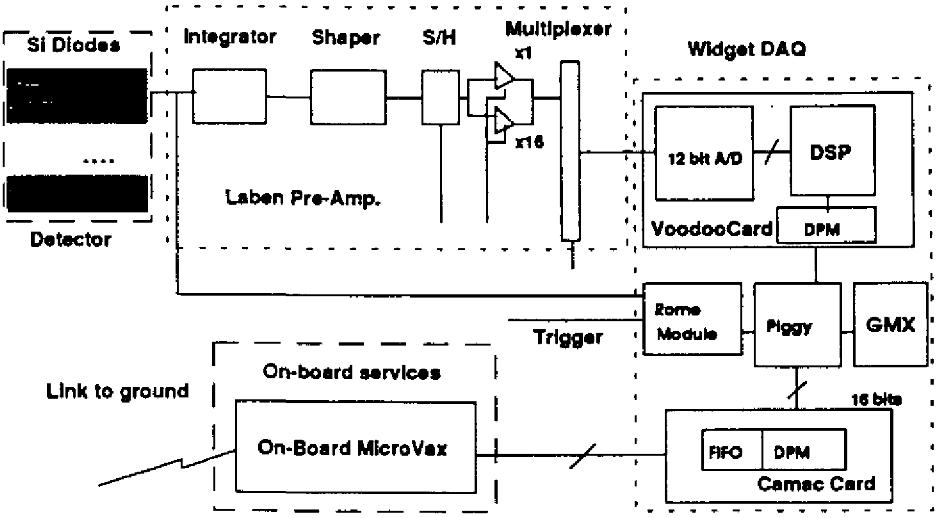

Fig. 2: The path followed by the signal for one data channel.