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Digital acquisition systems for the EDELWEISS experiment

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Abstract

We describe the digital acquisition systems used in the EDELWEISS experiment. In the EDELWEISS-I experiment, both charge and phonon signals are continuously digitized after preamplification and transferred to a computer using a high-speed DMA channel via a 1.5 Gbit/s optical fibre link, decoupling the detectors from the acquisition computer. Both phonon and charge triggers are defined numerically, without any analog triggering module, allowing a flexible filtering and trigger definition. The performances reached in this system are described, together with the improvements presently realized for the second phase of the experiment, EDELWEISS-II, involving up to 120 detectors.

Keywords : digital electronics, acquisition systems, filtering.

1. Introduction

Digital acquisition systems present several advantages when compared to their traditional analog counterparts. First, with the increase in performances of modern computers, they now represent extremely cost effective solutions.

Second, high speed optical fibre links allow the decoupling of the sensitive cryogenic experiments from the computer and, more generally, external sources of electronic noise. Third, relatively elaborate and nearly optimal triggering strategies can be implemented rapidly. Last but not least, for cryogenic experiments where charge and phonon signals are relatively slow, multiplexed electronics can be used to further reduce the cost per detector of the acquisition and readout system.

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2. The EDELWEISS-I acquisition system

A first version of a numerical acquisition system has been realized in the EDELWEISS-I experiment [1]. In this version, a commercial solution was chosen, based on a PXI system controlled through an optical fibre MXI-3 interface [2] at a transfer rate of 1.5 Gb/s. Analog signals issued by the cold-FET preamplifiers, filtered to avoid aliasing, are digitized on two PXI cards. A multiplexed 16-channel PXI-6070E card with a 12-bit digitizing precision is used to record the charge channels. For three 320 g bolometers with two charge channels each — a guard ring and a fiducial volume electrode —, the maximum digitizing speed for each channel using a single PXI-6070E card is 200 ksamples/s. For the slower phonon channels, a multiplexed PXI-6052E card with a 16-bit digitizing precision was used. Using the synchronisation possibilities of the PXI backplane, the two cards are synchronized by feeding the 200 ksamples/s digitization clock of the charge channels to a time counter on the PXI-6070E card used as a divider (usually by a factor 100 to 200) to create a synchronized clock signal at a reduced rate for the phonon channels.

In addition, a PXI-8420 serial card is used to drive a TRMC2 regulation and low temperature resistance bridge through an RS-232 interface [3]. Using this system, the operating temperature of the dilution refrigerator is measured and regulated using a PID algorithm with a precision better than 10 microkelvin. The instantaneous value of the temperature is stored with each event.

3. Digital filtering and trigger definition

An anti-aliasing analog filtering is first realized on the preamplifiers of the charge (4^{th} order Bessel lowpass) and phonon (RC lowpass filter) channels. Once this analog filtering is done, noise and signal power spectra are measured and used to build band-pass IIR (Infinite Impulse Response) filters. These filters are numerically efficient and can be easily tailored to the main features of the noise spectrum. The trigger on both phonon and charge channels is then defined by requiring that the absolute value of each channel exceeds a fixed threshold. During the first two data taking periods of EDELWEISS-I [1,4], only the charge trigger was used. In the last run, a phonon trigger, with better sensitivity, is initially required and a convolution between charge data and a template is used to look for the best charge signal associated with the phonon trigger. A buffer of 8 Msamples per channel (40 s of continuous charge acquisition at 200 ksamples/s) is used to allow the remote connection to the acquisition system through internet. The computer presently used in EDELWEISS-I is a commercial PC with a Xeon bi-processor. This high-end PC allows continuous data transfer and filtering at a total transfer rate exceeding 4 Msamples/s, allowing e.g. 10 bolometers with two charge channels at 200 ksamples/s. Power spectra, using FFT transformations, have been realized at acquisition rates up to ≈ 3Msamples/s.

4. Square wave lock-in: reducing phonon noise

An extension of this system has been built for development purpose. The same PXI hardware has been complemented by a commutation system synchronous with the charge digitizing clock, allowing a square wave modulation lock-in for the phonon channels. This lock-in scheme, with constant power dissipated in the sensor, was first used successfully in the Diabolo and ARCHEOPS experiments [5,6] and adapted to the EDELWEISS experiment to accommodate the acquisition of the faster charge channels. The use of the lock-in modulation allows choosing the frequency window best adapted to the noise spectrum of the preamplifier FETs. The commutation on the phonon sensor polarization voltage is associated with a limited induced signal on the charge channel. Integrating the charge signal by charging a capacitance leads to a FWHM charge resolution of 400 eV at an energy of 10 keV electron equivalent.

5. The EDELWEISS-II acquisition system

The increasing number of detectors induces a more complex scheme, and a new acquisition system is currently being developed for EDELWEISS-II. The electronics is now fully home-made. The cold-FET preamplifiers are connected to boxes called BB (for Bolometer Box). Each BB, directly fixed on the cryostat to limit unwanted electromagnetic coupling with the outside, contains the amplifiers and 14-bit ADCs for all channels of each bolometer. Also, it delivers the square wave modulation as in the previous system, and all the various DACs to control the bolometer parameters (charge and NTD polarization, temperature setpoints, etc.). Each amplifier, as well as the digitization-and-transmission daughtercard, is isolated into separate compartments connected by feedthrough EMI filters. The commands and the common clock are received on two separated optical fibres, while data is transmitted on a third one (Fig.1).

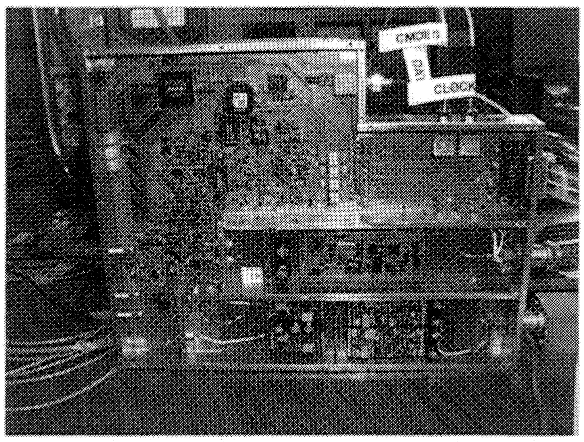

Fig. 1: An EDELWEISS-II BB box. Lower two compartments contain charge (bottom) and phonon preamplifiers. EMI filters, thick metal walls and direct coupling to the cryostat maintain signal integrity from external and digital electronics noise.

After digitization, the signal is continuously transferred to an Apple computer through an optical link system. The basic component of this system is a "dispatcher". This is a 6U VME-form crate receiving data from up to 32 optical fibres, collecting them and delivering the whole data on one or more high-bandwidth optical fibres. A tree-like, two-stage set of dispatchers allows collecting data from 120 detectors. The last dispatcher broadcasts the whole data to one or more acquisition computers (Fig.2).

Each computer houses a PCI interface card performing a programmable sorting operation within the data packets, allowing it to select data of an arbitrary set of detectors. These computers are currently PowerMacintosh running MacOS 9.2, realizing numerical demodulation, filtering and event detection.

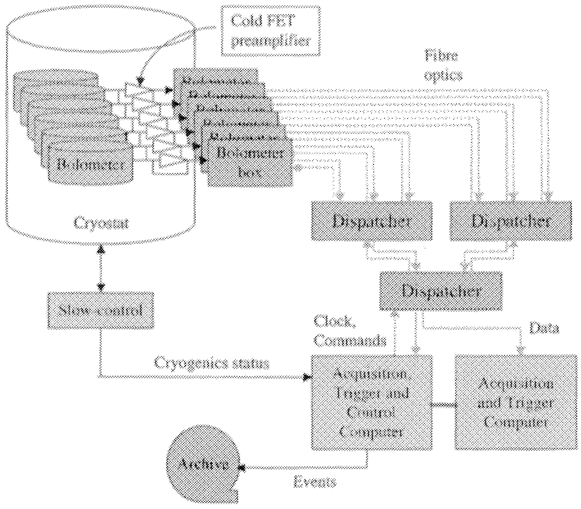

Fig. 2: Schematic architecture of the EDELWEISS-II digital acquisition system, expandable to > 100 bolometers (see text).

The events are stored on disk with typically 1 ksamples per recorded channel per event. With the increasing computational power, it is expected to achieve the acquisition of the 120 bolometers with a few high-end microcomputers. The software is written in C and designed to be architecture-independent; only the real-time part will be distributed. Finally, a dedicated program monitors the informations from the slow control.

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