Front-end electronics integration for the Angra Project central detector

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Abstract

We present a proposal for the integration of the Angra Neutrino Project central detector front-end electronics system. The modules composing the analog sector of the data acquisition chain are considered, including low and high voltage supply units, and digital data transmission lines for control and monitoring purposes. The general concept and the architecture are introduced, with particular emphasis on the main devices foreseen to provide physical support to this concept. The general guidelines for the development of particular circuits involved in the system are given, so that development and production tasks may be assigned to different groups committed to match their products to the specified standard.

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1 Introduction

The Angra Neutrino detector [1] includes two basic instrumentation assemblies: the central detector and the veto system. The former is expected to be made with three liquid volumes inside a cylindrical vessel, surrounded by $\approx$ 128 Photomultiplier Tubes (PMT). In the present note we consider one possibility to integrate the front-end electronics plus the low and High Voltage (HV) units required to operate the central detector. To every one of the PMTs are assigned two circuit paths: one for signal conditioning and shaping, one for power supply. These define, in the whole detector, two main branches of the front-end electronics which are considered in the following sections. A fast signal (width $\approx$ 10 ns) is expected as input to the shaping branch. From this, two signals have to be provided as output: an analog signal slower than the input, so that it may be sampled by an analog to digital (ADC) converter; a digital signal obtained from leading-edge discrimination of the analog one. Both are driven to the digital data acquisition system, which is not covered in this note. The power branch supplies high and low voltage, respectively to the PMT and to the signal shaping circuits. The two branches require precise control and monitoring facilities, with remote access to and from a microcomputer. A schematic view of these basic blocks is shown in Figure 1.

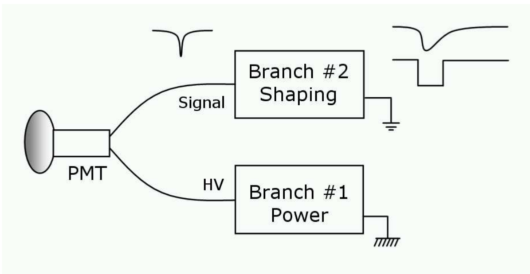

Figure 1: The two electronics branches assigned to each PMT.

2 Overview of the Instrumentation Setup

A 50 Ω characteristic impedance $\approx$ 3 m long cable takes the PMT signal to the front-end amplifier and shaping circuit. This cable length is not excessive, since the PMT signal amplitude is expected to be above 1 mV. Anyway, low capacity co-axial cables shall be used. The connection is done with BNC standard connectors. High voltage is supplied to the PMTs via SHV standard connectors. The used connector standards is presently dictated by the chosen PMT (Hamamatsu model R5912). A general view of the proposed arrangement is shown in Figure 2. It should be readily noticed that two ground levels are present in the different circuits. Although these should be both at the zero volts level, they serve as reference to different circuit tasks. They are therefore treated separately, in order to avoid undesirable interferences. They connect to each other at the PMT base only.

Once the circuit blocks sketched in Figure 2 are developed and tested, they should all be implemented in the same printed circuit board. We propose each board to be associated to one PMT channel and mounted in a NIM standard metallic box. All the boards are mechanically fixed to NIM crates, with external low voltage power supplies. This solution takes benefit on the well established mechanical standard for nuclear instrumentation, but it relies on external power supplies, so that the cost is reduced.

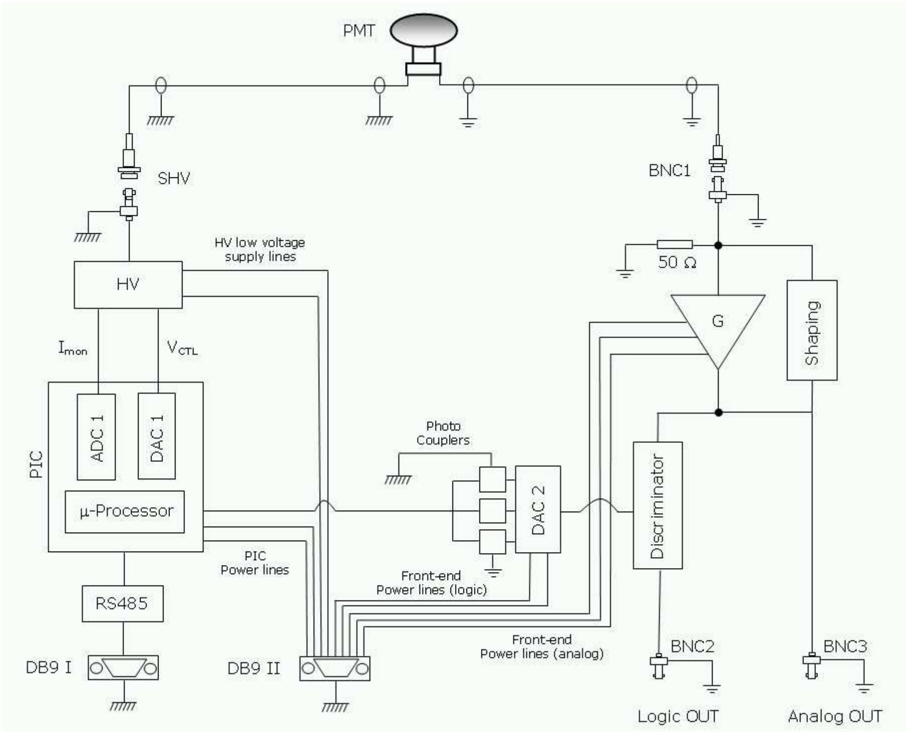

Figure 2: General view of the circuit blocks composing the front-end electronics system.

2.1 The Signal Conditioning Branch

The strategy for neutrinos detection in the Angra Project includes the digitalization of pulses from all the PMTs hit in a valid event. This supposes an external triggering circuit, for which a discriminated logic pulse from each PMT is required, as well as shaping of the analog signal, so that it can be properly sampled by an ADC. Two outputs must therefore be available per PMT channel. These requirements are dealt with in the signal conditioning branch.

The first stage in this branch, given the relatively low amplitude of the input pulses, is amplification and shaping. These two functions are usually implemented in a single circuit. The output of this stage is an analyzable signal which can easily provide a logic pulse after treatment by a discriminator circuit. A preliminary simulation study of the front-end amplifying and shaping circuit has already been undertaken and is reported in [2].

The discriminator circuit may use any kind of leading-edge sensing technique. Constant fraction discrimination is not necessary, unless tight requirements on timing precision are specified. This is presently not the case. Whichever particular circuits are adopted for the amplifier and the discriminator blocks, they should both be remotely controlled. In particular, the discriminator threshold level is set by sending a digital word to a Digital-to-Analog (DAC) converter. A variable resistor is typically used in shaping circuits to establish the gain or to set a time shaping constant. Thus, a digital resistor might eventually be used as part of the shaping amplifier. The digital control words are programmed in a PIC block shared by both the conditioning and the power branches (see Section 2.3). The process of sending a digital word to the DAC is done through photo-couplers, so that noise and interference are avoided. As shown in Figure 2, a DB9 connector is supposed to convey the low voltage power lines to all circuits.

It should be remarked that the output of the amplifying stage is split in two ways: one is driven to the input of the discriminator, another one is the analog signal output. This imposes the requirement of low output impedance. The length and the characteristic impedance of the circuit paths have to be taken into account, so that distortions due to attenuation and to reflections are minimized.

2.2 The power branch

The specification of implementing the high voltage circuit in the same board as the conditioning circuit leaves us with two possibilities: developing a high voltage power circuit, or using small size commercial units. In either case, a low voltage control signal should be used to tune the high voltage adjustment, and the output high voltage should be available in a SHV connector. It is also required that the effective applied voltage and the supplied current are remotely monitored. The low voltage power lines are available via the same DB9 connector previously referred to; the same PIC block reads the monitored current and voltage, and programs the nominal voltage to be applied to the PMT.

2.3 The control unit

At least three main tasks have to be done remotely: setting the threshold level to the discriminator circuit, programming the high voltage to the PMT, monitoring the supplied power (current and effective high voltage). It seems to us that a PIC micro-controller is an adequate and cost-effective solution to perform these tasks. The PIC is then, in the board, the block responsible for controlling its operation. It is addressed via the RS485 communications standard. Another DB9 connector is foreseen in the board to provide the physical connection to a microcomputer.

The adjustment of the high voltage level to operate the PMT is done by setting a digital control word in a second DAC. The latter is incorporated inside the PIC circuit. Conversely, the high voltage circuit block may provide a DC level proportional to the output high voltage, so that it could be read by the PIC and used in a feedback loop to stabilize the nominal PMT voltage. The current supplied to the PMT must be read from the high voltage circuit and used in the power monitoring algorithm. The ADC channels required to readout voltage and current are also implemented in the PIC module.

Since the discriminator threshold level is set by the PIC, which shares a separate grounding network, the signals sent to the second (external) DAC are photo-coupled.

3 Integration

Up to 12 modules may be installed in each NIM crate. Supposing that the central detector is equipped with 128 PMTs, 11 crates are required. In order to minimize the cable lengths, three racks are placed symmetrically around the detector, each of them housing 4 crates. Under this configuration, 16 slots are left free in the crates and may be filled with spare modules. Figure 3 is a sketch of the modules mounted on crates which are fixed to a rack on wheels.

It may be noticed in Figure 3 that four power supplies are planned per rack. This has the aim of providing independent DC supplies to different sectors of the front-end system, so that they don't interfere with each other. The PIC circuit is powered with one +5 V unit. Two other units supply ± 12 V to the high voltage circuit and to the analog front end modules. Finally, another +5 V unit powers the logic part of the front-end circuitry. Power line cables are connected from the power supply units to the respective pins of the DB9 connectors in the backplane of each rack, composing a DC patch panel. The other set of DB9 connectors (related to the PIC control unit) connect to RS485 plugs, also

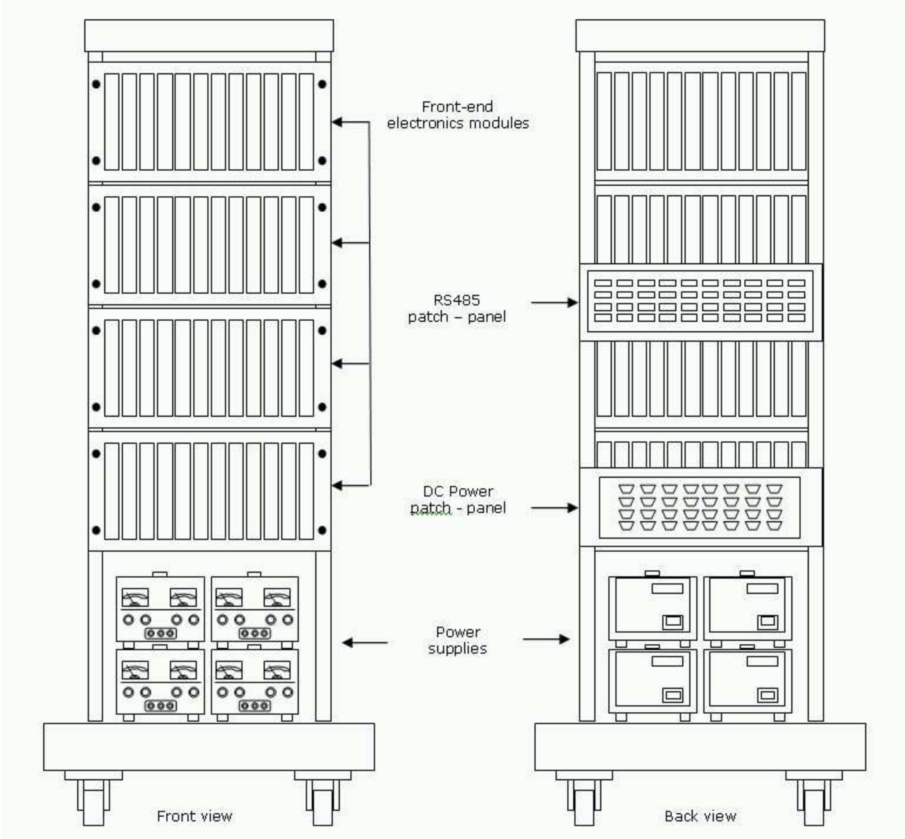

Figure 3: Sketch of the setup of racks with front-end modules, power supplies, and patch panels for DC power output and RS485 connections.

implemented in the backplane of the rack, composing another patch panel. From this panel follows the connection to the computing facility in the general data acquisition system.

In the front side of the racks, three BNC and one SHV connectors are installed in each of the front-end modules. The BNCs are associated to the PMT signal (input), the shaped analog signal (output), and the logic PMT signal (output). The SHV connects to the PMT high voltage power supply. From this side of the rack, a bunch of high voltage cables is driven to individual PMTs in the central detector. Another bunch of cables brings signals from the PMTs to the front-end modules. Shorter cables will connect the analog and the logic pulses to the digital sector of the data acquisition system.

4 Conclusions

The instrumentation setup here presented may be considered as very simple and practical, although efficiently adapted to its application. It does not represent a challenging development, in the sense that it may not be qualified as a large scale experimental environment. It incorporates well known and tested technologies, and concentrates most of the development tasks in the circuits inside NIM mechanical standard front-end modules. Details related to robustness and reliability are thought of, and introduced as guidelines to circuit developers. These are expected to identify their tasks in the general frame and interact with each other, converging to either one of the main directions: production of front-end modules, communication with the modules via RS485, software packages implementation.

References

[1] J. Anjos et al. Brazilian Journal of Physics. Vol. 36, nro. 4A, 2006.

[2] A. F. Barbosa, *Preliminary simulation study of the front-end electronics for the central detector PMTs*, AngraNote **001-2007**, 2007.