THE DESIGN AND PACKAGING OF THE INSTRUMENTATION ELECTRONICS FOR THE AGS BOOSTER, A GENERIC APPROACH*

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Abstract

Instrumenting the new AGS Booster required the construction of a great deal of support electronics for many beam monitoring devices. Early in the project it was realized that it would be necessary to use a building block approach to the problem of providing the necessary equipment. Modules providing generic functions such as amplification, integration, sample and hold, etc., were designed and packaged so as to provide maximum flexibility in the implementation of typical instrumentation tasks. This paper describes these modules and includes some specific examples of how they have been combined to perform certain functions. Several unique features of the packaging will be described.

I. INTRODUCTION

The AGS Booster and its associated injection and extraction lines required, for the proper monitoring and control of the beam, a sizable collection of beam detectors to give accurate measurements of beam position, beam profile, beam intensity and beam loss during every phase of the acceleration cycle and for every species of particle (i.e. protons, polarized protons and heavy ions up to Au^{+33}).

Beam Instrumentation electronics is frequently designed to be detector specific. This is very often unavoidable given the requirements of sensitivity, timing and bandwidth imposed by special detection requirements and techniques.[1] However, while it is often the case that instrumentation must be tailored specifically to the special requirements found in accelerator environments, it is as well advantageous if it can be designed from a functionally modular point of view. The clear advantage of this is that a small group of identical building blocks can provide a wide variety of analog signal processing functions.

In order to provide the necessary support electronics for the Booster within rather severe constraints of time, money and manpower, several things were done. First as many common functions as possible were identified. Next, an appropriate packaging scheme was sought. Third, every attempt was made to exploit what was already part of our beam instrumentation design repertoire to reduce development time. Fourth, commercial vendors were sought at every stage, from the manufacture of small pieces to the construction of whole units.

II. PACKAGING

Except for one smaller project, almost all modular instrumentation electronics that was built by the accelerator instrumentation groups at BNL had been packaged in NIM[2] modules. NIM is an old established standard, the most vexing problem with the NIM packaging is the low density of pins in the standard rear connector and the necessity of coping with this by going to front panel connectors. Even with moderately dense input or output signal requirements front panel connections can cause an unwieldy mess. An alternative was needed.

It was decided to change to Eurocard packaging.[3] Since Eurocard is a mechanical standard for which hardware is becoming readily available, and since this standard has high density, mass terminated rear connector options, it seemed to offer many advantages that were needed.[4] Two standard modules, both 6U high by 220 mm deep, 7HP and 14HP wide have been adopted. This provides nearly the same physical board real estate and internal volume as the single and double width NIM modules.

One problem was finding a shielded enclosure for the modules similar to what NIM provides. In accelerator environments some electrical shielding is considered essential. No available options for enclosed Eurocard modules were completely suitable. A compromise was to use rails, side covers and front panel hardware from one manufacturer and to design our own back panels to fit these.

One important packaging issue is the crate design in this modular environment. For the particular module chosen many commercial choices for crates, or subracks as they are called, exist. These subracks usually include a selection of backplane construction techniques from simply mounting connectors on a rear frame to the use of a printed circuit backplane. To handle the interconnections, an aluminum enclosure (called a doghouse) was designed to fit over the rear of the crates. This metal enclosure provides additional shielding and a mounting point for connectors from external devices. It also serves as a protective enclosure for wires from these connectors to the module connectors.

III. THE MODULES

The modules developed for use in the Booster complex are described below in summary form. The descriptions are intended to point to their generic uses. All of the modules described here are packaged in 7HP by 6U by 220mm deep shielded Eurocard cassettes unless otherwise noted in the text.

Baseline Restorer

This module contains three channels, each is used to restore the proper baseline level to pulses that originate from capacitively or inductively coupled pickups or are AC coupled at some point in the front end of the system. It can also eliminate the effect of low frequency pickup on high speed pulses. A TTL input, at least 25 usec wide and at a rate commensurate with the expected baseline variations must be provided to sample the baseline at the appropriate time. The output then is the baseline at the sample time subtracted from the input. Bandwidth of each channel for inputs of a few volts is 1.5 MHz.

Beam Transformer Amplifier

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This module provides one channel with three current to voltage transfer ratios, 10mA/V with a 70 nsec rise time and 100uA/V or 10uA/V with a 1 usec rise time. It has a differential front end that is tuned to cancel common mode noise. A current boosted output stage provides cable drive capability. Selection of the gain can be done locally on the front panel and remotely on two rear connector pins.

Beam Current Integrator

This is a fast integrator that provides an output voltage proportional to the input charge of signals as narrow as 50 nsec occurring in a time window .5 to 1 μsec. Charge injection and offset voltage adjustments are provided and a peak hold circuit following the integrator stage allows the resultant integral to be retained for 10 msec with an accuracy of within 0.1%. The circuit provides a range of 10^3 in four gain ranges selected under external control.

Device Actuator

This module is a 14HP wide, two channel unit that is intended to provide drive to a detector positioner. Each channel accepts TTL commands and provides for 2 TTL status bits derived from limit switches. Thus the unit can be used to command the device to insert or retract and can provide bits to tell if the command suc-ceeded. All of the lines into or out to the device are optically isolated. Each channel can drive up to 24 VDC at 0.5 A. The unit may, in local mode, be used to drive the device from front panel switches. LED status indicators on the front panel show the status of the device and can indicate an "in process" or "hung" device. A bit is also provided to indicate to a remote computer if the module is in the local mode.

Digital Input/Output

The digital I/O module contains eight optically isolated, differential input and eight optically isolated output channels. Each input channel contains a TTL line receiver and each output a TTL line driver. High speed optical isolators separate the cable from the TTL receive and drive sections. In its standard application the module is used to transmit digital signals at one MHz over distances of 250 meters, and receive a corresponding "loopback" signal with high fidelity. However, the unit has also seen use as a sixteen channel, general purpose isolator.

Faraday Cup Amplifier

This module contains a single current to voltage amplifier channel which has four ranges selected from either the front panel (local mode) or by TTL inputs at the rear connector. Transfer ratios can be 1 or 10 nA/V (internal jumper selected) and 100 nA/volt with a 350 Hz bandwidth and 1 or 10 uA/V (again jumper selected) and 100 uA/volt with a 300 kHz bandwidth.

Faraday Cup Bias Supply

This high voltage bias supply generates -600 VDC using a DC to DC converter with a maximum output current of 3 mA. A comparator circuit monitors the output voltage and sets a bit (TTL level) at one of the rear connector pins if the output voltage varies from a window of -570V to -630V.

8-Channel Analog Receiver

This module has 8 individual, differential input receivers for signals transmitted from remote sources. The front end provides a resistor for cable termination and is tuned to cancel broadband common mode noise. A gain of two is provided to compensate for the attenuation due to the cable termination. The gain is variable by ± 10% to make up for cable losses. A final, back terminated, driving stage provides output cable drive capability.

8-Channel Individual Sample/Hold

The fast Sample and Hold module is an eight channel unit with a 1 μsec acquisition time to .1% and hold times of greater than 500 μsec. The circuit captures a sample of the input with a fast acquisition sample/hold, and transfers it to a second sample/hold which has very low droop. A TTL input pulse of at least 1 usec is required for sampling. Optional fast outputs from the first sample/hold appear on the upper (P1) Eurocard connector.

8-Channel Integrator

This module contains 8 independent charge integrators gated and reset by common TTL inputs. Any channel will provide a voltage proportional to the integral of the input current present during the gate interval. Outside the gate interval the resulting level is held to within a few percent for up to one second. Sensitivity is selected in two ranges and may be set from a maximum of 10^{10} Volts/Coulomb to 10^7 Volts/Coulomb. Input currents may go as high as 3 uA. Output dynamic range is ± 10 volts. Drift is less than 10pA equivalent input current. Output offset is less than 1 mvolt. Gating time must be greater than 10 μsec. Response time to input signals is 1 μsec. This module is now available commercially.

Low Level Multiplexer

This module contains one 32 pole double pole electronic switch that can be used to select either of two groups of 32 inputs. It is intended to be used to route signal arrays from multiple wire, low level analog devices to preamplifiers or other signal processing electronics. Group selection is accomplished either by front panel control or TTL level at the rear connector.

This unit features less than 100pa of leakage at any input, an input signal range of ± 10 volts, ± 2 mA, and 50 db of crosstalk and channel off isolation over a 1 Mhz bandwidth. The series resistance of any pole in the on state is less than 100 ohms.

Personality Module

This module can provide timing to the 8-Channel Integrator and the 64-Channel Analog Multiplexer. When operated remotely, it converts the computer timing signals to a form compatible with the Integrator and Multiplexer. In local mode, it provides adjustable timing from its built in clock. Locally, it can select a single channel of the Multiplexer instead of scanning. It is also designed for future expansion of the Multiplexer to as many as 256 channels.

16-Channel Comparator

This module provides 16 independent channels of adjustable threshold, analog voltage comparison for signals of ± 10 Volts at frequencies up to 100 kHz. Input impedance is 10 kohm. The threshold of each channel is set by internal potentiometers and is accurate to ± 20 mV with a hysteresis of 75 mV. The outputs are open collector TTL compatible. Each channel has an LED indicator on the front panel which is on when the trip point has been exceeded, and a test jack that can be used to measure the trip point setting.

16-Channel Sample and Hold

The sixteen channel sample/hold is a general purpose sampler. It has an acquisition time of 20 μsec to .1% and a droop rate of 20 mV/sec. There are two blocks of eight channels, which allows some segmentation of input channels. Each block of channels requires its own sample signal, which can be either low or high true.

64-Channel Multiplexer

This module consists of two 32 to 1 analog multiplexers. Each multiplexer has an output current buffer with cable driving capability. Bandwidth is 70 kHz. Inverted outputs from either channel is an option. In addition the outputs of the two groups may be jumpered together to make a full 64-channel multiplexer. Channel selection is accomplished by TTL inputs that contain the binary channel number. Scanning is accomplished by combining this module with a Personality module.

32-Channel Amplifier

This module is a 32-channel general purpose preamplifier and signal buffer for low level currents. Two user determined gain ranges are allowed and are selected by changing the input resistance with TTL inputs on the rear connector or, in local mode, by a front panel switch. Circuit board pads are provided for the installation of feedback capacitors and output DC blocking capacitors or series resistors. The arrangement of the inputs and outputs allows the use of mass termination connectors in the Eurocard rack.

IV. A SAMPLE SYSTEM

A example of how the above module set might be used to assemble a system to perform an integrated task is typified by the HARP Crate shown in Fig. 1. This system is used to integrate the charge from a multiwire beam profile monitor and to produce a single output containing a time multiplexed version of the output of each integrator. Thus one can see on an oscilloscope an image of the beam profile.

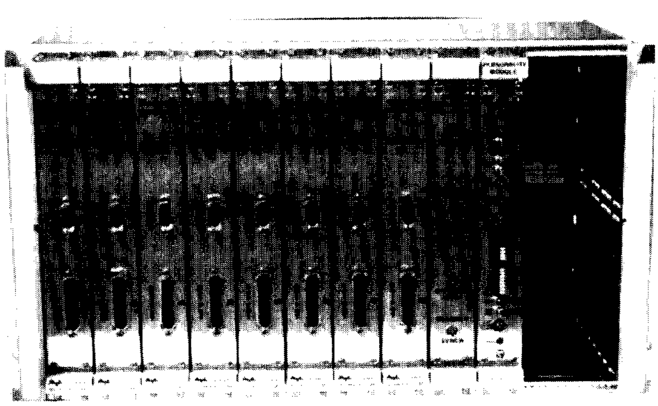

Figure 1 The HARP Crate

The HARP Crate is one of the more numerous that have been built at BNL. It contains eight, 8 Channel Integrator modules, one 64 channel Multiplexer module and one Personality module. Two 7HP slots are left open at the end of the crate with connectors installed and appropriately wired for power. These may be used for other modules as desired.

V. CONCLUSIONS

All in all the instrumentation effort has resulted in the construction of approximately 300 modules for 42 crates located in 20 racks around the Booster Complex. This large a construction project is beyond the normal manpower resources of the Beam Instrumentation group. To handle this, much of the work had to be done piecemeal through outside vendors. One of the most important aspects of this effort has been the struggle to involve commercial vendors in the design and construction of these modules and systems. Attempts to identify common building blocks is a key to the success of this.

It is hoped that future projects will see much more industry involvement, from the design stage through the production testing. Reports such as this are just a beginning attempt to disseminate information that might begin to attract some commercial interest. Beam instrumentation people from all the DOE laboratories have, at regular meetings, been discussing the prospects for establishing some commonalty in instrumentation on an intralaboratory scale.[5] In Addition, the new emphasis in USDOE on Technology Transfer is opening up some new possibilities for cooperation between DOE laboratories and industry.

VI. REFERENCES

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