DESTRUCTIVE BEAM PROFILE MONITOR ELECTRONICS USING GATED CURRENT INTEGRATORS

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Abstract

Strip detectors are used to determine the profile and position of the pulsed ion beams from the EBIS ion source CRYSIS. Electronics for amplification, multiplexing, analogue-to-digital conversion and read-out will be described, as well as network client/server software.

The use of integrating amplifiers gives a current range of 1 pA to 100 μA and a charge range of 0.1 pC to 1 nC for each strip. The integration time can be varied down to 1 μs and the shortest time between beam pulses that can be handled is 10 ms. The electronics also produce a pulse output for the total beam current.

1 INTRODUCTION

1.1 Ion source

CRYSIS [1] is a cryogenic electron beam ion source for heavy highly charged ions at the CRYRING [2] facility. The pulsed ion beam that is produced by the source is transported in different beam lines for use in the storage ring, in the ion trap or in different low energy experiments. Usually the pulse length varies between 50 μs and a few hundred milliseconds. Slowly extracted pulses can give strip currents down to the picoampere region.

1.2 Beam profile monitor

As beam profile monitors in the transport lines about 10 strip detectors are used. A strip detector consists of 16 horizontal and 16 vertical aluminium strips mounted on a frame. The strips cover 94 % of a 50 x 50 mm^2 area. Close to the ion source there is a harp-like detector covering 10 % of the total area. This detector is used for monitoring of both injected and extracted beam.

1.3 Electronics

For several years a system with pulse amplifiers at the detector, sample-and-hold circuits and multiplexer in a CIM crate and ADC and CPU in a VME crate has been used for the strip detectors. When a new beam line was constructed, it was decided to design new improved electronics (see figure 1) instead of adding more pieces to the existing system. The improvements comprise:

- Better current sensitivity, especially for long pulses, can be obtained by the use of gated current integrators. The timing is also less critical than with a pulse height measuring amplifier.
- ADC and CPU as front ends eliminate long cables for analogue multiplexed signals.
- The whole system is integrated in one box connected directly to the detector and it is isolated; it can be elevated to a bias voltage of about 30 V for secondary electron suppression.

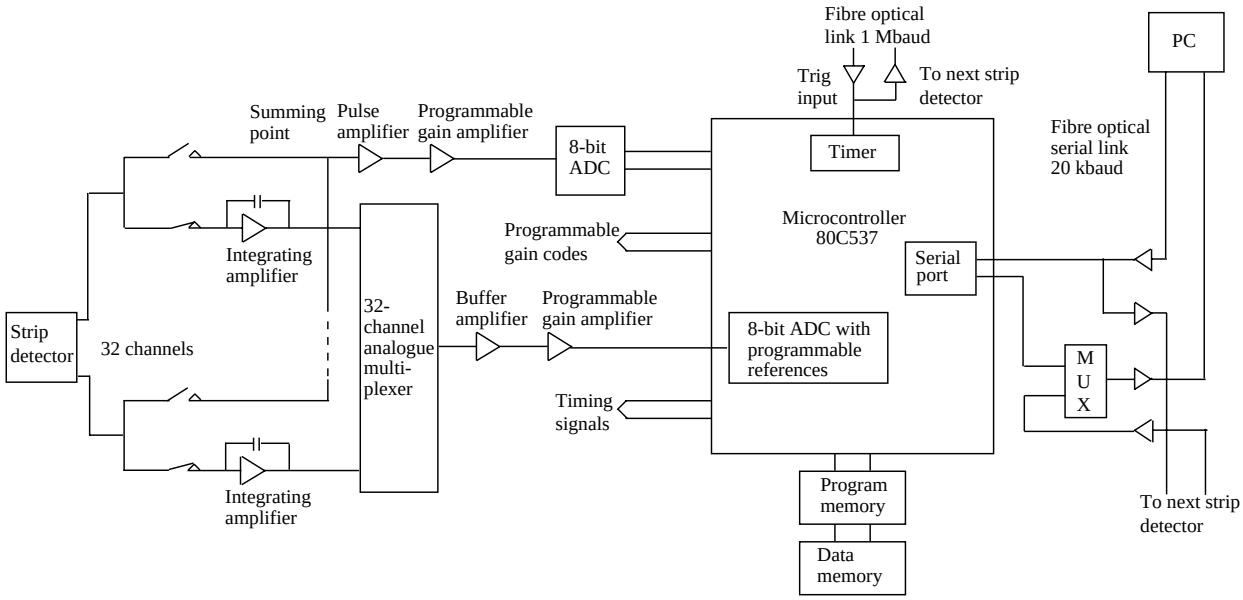

Figure 1: Block diagram of the new strip detector electronics.

- The total beam current as a function of time can be obtained as a complement to integrated individual strip currents; the switching between these two modes can be done from pulse to pulse.
- The system is able to handle several beam pulses after one trig pulse, e.g. injected and extracted beam.

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2 HARDWARE

2.1 Profile mode

The transversal profile of the beam is obtained by parallel integration of the currents on the 32 strips during the beam pulse. The Burr-Brown IC ACF2101 is used as a reset-integrate-hold integrator. The outputs from the 32 integrators are multiplexed and fed through a programmable gain amplifier, that together with an 8-bit ADC with programmable references acts as a "logarithmic" ADC; the total range is divided into 9 sub-ranges with a resolution varying from 0.03 pC to 2.16 pC. The ADC is included in the Siemens microcontroller 80C537, which also includes the serial port for communication with a PC, the 16-bit timer used for gating, digital I/O and 256 bytes data memory. External 8 kb data memory and 8 kb program memory are added.

2.2 Pulse mode

The longitudinal profile or the total beam current as a function of time is obtained by connecting all 32 strips to the summing point of a pulse amplifier via ultra-low leakage CMOS analogue switches. Programmable gain amplifiers and a fast sampling ADC give 16 current ranges from 8 nA to 100 μA, each with 8-bit resolution and 4 μs time resolution. Otherwise the same hardware is used as in the profile mode.

3 SOFTWARE

The communication with the PC uses the Modbus protocol [3] with RTU mode binary coding. The PC acts as the master and up to 255 slaves (e.g. microcontrollers) can be connected in a daisy-chain. The PC writes set up information to an addressed slave, requests a measurement of either profile or pulse and reads the data. The Modbus master PC acts as the server in a network client/server environment.

3.1 Microcontroller software

The microcontroller software is written in 8051 assembler. It essentially performs the Modbus interface, the gate timing, the profile mode "logarithmic" ADC and the sampling of the pulse mode ADC. Up to 16 gates can be set with delay from 100 μs to 16 s and length from 1 μs to 16 s. In the profile mode the delay between consecutive gates has to be minimum 10 ms. This time is needed to convert and store the data in memory. The gates define the time window for the integration in the profile mode and for the sampling in the pulse mode.

3.2 PC software

The PC software is a network client/server system based on COM technique [4].

The server is basically a queuing device receiving jobs from remote clients. When a scheduler executes a particular job, it calls a specific protocol driver. In this environment the protocol driver is called StripMod and is implemented as an inproc COM server. The StripDetector protocol (as implemented by the StripMod driver) is a collection of convenient access functions for the strip detector system. The StripMod driver in turn calls the ModBus protocol driver which implements some Modbus functions. Finally the ComPort driver communicates with the hardware. The ModBus and ComPort drivers are also implemented as inproc COM servers. The system is written in C++, but the COM infrastructure is language independent, so other languages are possible to use, although more generic data types would have to be used to achieve maximum independence. The same system structure is being used in the new CRYRING control system.

Client programs communicate with a detector via the server in a multi-user configuration or directly through the StripMod driver in a single user configuration. They could be batch or interactive programs. A program with a graphical user interface has been used for testing (see figure 2). The display shows 3 gates with pulse and profile pictures created by a pulse generator. The total pulse charge calculated as the sum over 32 channels in the profile mode and as the integral of the total current in the pulse mode will be implemented.

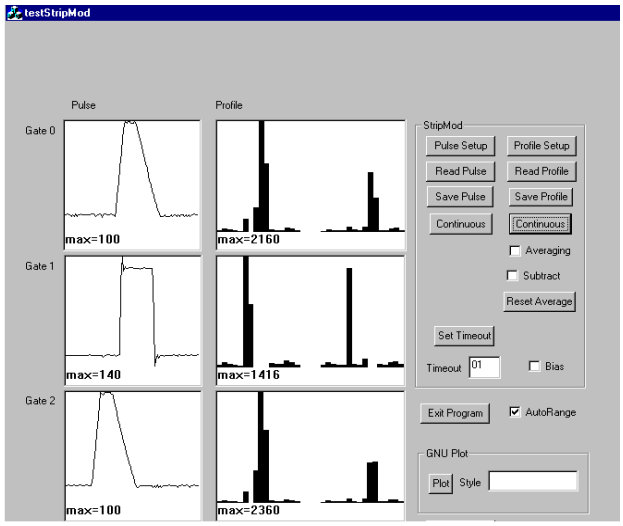

Figure 2: Screen print of the test program display.

4 RESULTS

A prototype has been built consisting of two 16-channel integrator boards and a microcontroller board. The integrator boards were tested with an Ar^{13+} beam on the harp-like detector with a temporary analogue read-out board before the microcontroller board was finished. After the prototype was completed, only bench tests have been performed so far with the following results:

4.1 Profile mode

- Total input leakage current from op-amp, analogue switches, integration capacitor, protection diodes and protection glow lamp: < 1 pA. It can be subtracted by software for a given integration time.
- Op-amp offset and analogue switches charge transfer offset: < 4 pC. It can be subtracted by software.
- Noise: 0.4 pC peak-to-peak at integration time 400 μs. The dominating noise is the 50 Hz interference. For long integration times this noise can be minimised by choosing the integration time to an integer multiple of 20 ms. It could also be decreased by synchronisation or averaging.

4.2 Pulse mode

- Offset is adjustable by hardware.
- Noise: 1 nA peak-to-peak.

5 LIMITATIONS

5.1 Charge

The full scale value of 1 nC for each strip is given by the integration capacitor of 100 pF internal to the ACF2101. The possibility of connecting an external capacitor in parallel via an analogue switch was not utilised due to lack of board space. Up to now the maximum total extracted pulse charge from CRYSIS has reached a few nanocoulomb. If the integrators become saturated, the solution will be to integrate only a suitable part of the beam pulse.

5.2 Current

- In the profile mode the maximum strip current is limited by the slew rate of the integrator to 100 μA.
- In the pulse mode the maximum total current is set by a resistor value to 100 μA.
- At currents below the noise level of the pulse mode, the profile mode will still give a signal for pulses that are long enough to have a charge above the noise level of the profile mode.
- The pulse mode can handle positive and negative currents, while the profile mode only can handle positive currents.

REFERENCES

[1] E. Beebe et al., Rev. Sci. Instr. 65, p 1718 (1994)
[2] A. Källberg et al., “Progress Report for the CRYRING Facility”, EPAC’98
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[4] Brockschmidt (Kraig), “Inside OLE 2 (2nd edition)”, Microsoft Press, ISBN: 1-55615-843-2