# A BEAM DIAGNOSTIC AND CONTROL MODULE

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*Abstract*

A Beam Diagnostic and Control Module based on MSC1210 mixed-signal processor was developed in IMP. It used OPA128, an ultra-low bias current monolithic operational amplifier, as preamplifier, a high accuracy 24-bit ADC on MSC1210 for weak beam current read out. It also has digital I/O function and relays for beam diagnostic components control. It is a stand-alone meter, can communicate with computer through RS-232 or RS-485 communication ports. The display panel is an 8-digit LCD. The modules are now used in HIRFL-CSR beam diagnostic and control system. It plays an important role in whole HIRFL-CSR control system.

## INTRUDUCTION

The Beam Intensity is an important parameter that presents the ion beam size of the Accelerator. The beam can be considered as the weak current source, generally varying in range of $10^{-5}$~$10^{-15}$A. The main task of the Beam Diagnostic is to measure the beam, which means to measure the weak current of detectors, or moving strings and Faraday Cups. It is not only to measure, but also need to control the detectors of the measurement elements. In order to finish this task, to figure out the beam situation during the operation of the Accelerator, we have designed a Beam Diagnostic and Control Module based on MSC1210 mixed-signal processor. The modules are now used in HIRFL-CSR beam diagnostic and control system. It plays an important role in whole HIRFL-CSR control system.

## PRINCILPLE OF THE METER

The Principle of the Beam Diagnostic and Control Meter is shown in Fig. 1.

It consists of the front measurement BUS and a MSC1210 mixed-signal processor that is used as BUS controller. There are four sockets on the BUS. Every socket can supply two single terminal or one differential analog input, which can be converted into 24-bit digital data, and 8-bit digital I/O used to convert range and other measurement control functions. The BUS also supplied the high accuracy analog and digital power supply. Thus it has up to four measurement channels. Every channel can measure one or two weak current signals.

For different measurement requirements, we designed different measurement card to plug on the BUS sockets, for example, the Faraday cup measurement card.

The BUS controller can not only support the measurement control and read out, but also support the ADC DMA function. It can read out up to 256 measurement samples in one time, and then make digital filtering or averaging operation to lower the noise influence. It also includes other support to measurement, external digital I/O, programmable high voltage supply, keyboard support, display support, communication support, etc.

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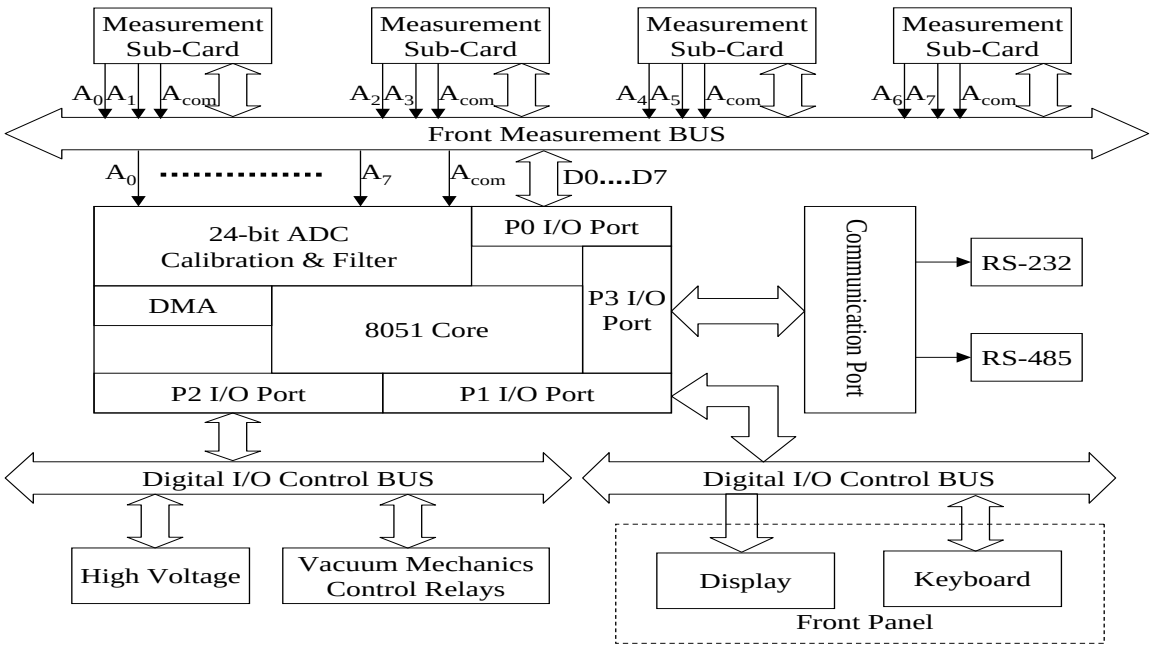


Figure 1: Beam Diagnostic and Control Meter Function Block

### *ADC System and Controller Kernel* [1]

The ADC system with 8-channel multiplexer, burn-out current sources, selectable buffered input, offset DAC (Digital-to-Analog Converter), Programmable Gain Amplifier (PGA), temperature sensor, voltage reference, accepts low-level differential or single-ended signals directly from transducers. The ADC provides 24 bits of resolution and 24 bits of no-missing-code performance using a sinc3 filter with a programmable sample rate. The ADC also has a selectable filter that allows for high-resolution single-cycle conversion. The Digital Filter can use the Fast Settling, Sinc2, or Sinc3 filter. ADC has self-calibration function, before every measurement, it executes self-calibration if configured. The offset and gain errors in the MSC1210, or the complete system, can be reduced with calibration.

In addition, the Auto mode changes the Sinc filter after the input channel or PGA is changed.

The voltage reference used for the MSC1210 ADC can either be internal or external. We designed a high accuracy voltage reference with excellent performance. The differential voltage reference provides easy means of performing ratio-metric measurement.

The Controller is based on MSC1210 mixed-signal processor, a completely integrated of mixedsignal device incorporating, 8-bit 8051 compatible microcontroller, Flash Program Memory, Flash Data Memory, Data SRAM.

On-chip peripherals include an additional 32-bit accumulator, an SPI compatible serial port with FIFO, dual UARTs, multiple digital input/output ports, watchdog timer, low-voltage detect, on-chip power-on reset, 16-bit PWM, breakpoints, brownout reset, and three timer/counters.

The microcontroller core is 8051 instruction set compatible. The microcontroller core is an optimized 8051 core, which executes up to three times faster than the standard 8051 core, given the same clock source. That makes it possible to run the device at a lower external clock frequency and achieve the same performance at lower power than the standard 8051 core. The power dissipation for the part is typically less than 4mW.

### *Weak Current Measurement* [2]

Analog input sub-card is designed according to dedicated applications. The flexible architecture makes the meter more versatile in real applications. We just need to change the sub-card for different detectors. The sub-card can accept two single-end signals or one differential signal.

An IVC Circuit and a pre-amplifier on sub-card for weak current measurement are based on BURR_BROWN OPA128 Difet Electrometer-Grade Operational Amplifier. It has following features:

| | |
|---|---|
| Ultra-low Bias Current: | 75fA max. |
| Low OFFSET: | 500uV max. |
| Low Drift: | 5uV/$^{o}$C max. |
| High Open-Loop Gain: | 110dB min. |
| High Common-Mode Rejection: | 90dB min. |

The IVC circuit with low-pass-filter converts the weak current signal to voltage signal; it also acts as an impedance converter. It has very high input impedance and very low output impedance. The low-pass-filter rejects the 50Hz AC interference.

A range controllable amplifier is designed for weak current amplification. Together with digital filter in ADC system, accumulator for averaging, the weak current measurement meter presents very good performance.

The noise interference rejection is a challenge in weak signal measurement. The design has been proved in HIRFL-CSR control system. Take Faraday Cup as an example. Its main technical specification is as following:

| | |
|---|---|
| Measurement Range: | $10^{-2}$~$10^{-13}$A |
| | (Divided into 9 ranges) |
| Accuracy: | 0.1% |
| Zero Drift: | <$10^{-12}$A/8H |
| CMRR: | >80dB |

### *Digital I/O and Control*

The meter can input 8-bit digital status signal and output 8-bit digital control signal for beam diagnostic elements through a 25-pin D-type connector on rear panel. Optical couples isolate the inputs and an 8-channel Darlington Driver drives the outputs for Relay control.

### *Display and Operation Button*

Front panel has a 8-digit decimal LCD display and 7 LED to indicate the meter status. 8 buttons are used for manual range conversion.

### *Communication with Computer*

The meter has a RS-232 interface (9-pin D-type connector) and a RS-485 interface (general phone connector) for communication with computer.

## CONCLUSION

The Beam Diagnostic and Control Meters have been used in HIRFL-CSR control system. It has been proved satisfied to requirement of the HIRFL-CSR control system. More than 40 meters have been installed in HIRFL site. And more refined meters will be installed in CSRm and CSRe site. The electronics design and system design are successful.

## REFERENCES


[1] Burr-Brown Products from Texas Instruments, “Precision Analog-to-Digital Converter (ADC) with 8051 Microcontroller and Flash Memory”, SBA203A -MARCH 2002

[2] Song Haihong, Ma Weinian, Chu Zhensheng, “Application of Fast Low-Pass-Filter in Weak Signal Measurement”, Journal of Data Acquisition & Processing, Vol.16, Suppl. Oct. 2001, p. 4.