GTA BEAMLOSS-MONITOR SYSTEM*

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Abstract

The GTA Beamloss-Monitor System at Los Alamos National Laboratory has been designed to detect high-energy particle loss in the accelerator beamline and shut down the accelerator before any damage can occur. To do this, the Beamloss-Monitor System measures the induced gamma radiation, from (p, γ) reactions, at 15 selected points along the beamline, converts this measured radiation to electrical signals, integrates and compares them to preset limits, and, in the event of an over-limit condition causes the Fast-Protect System to shut down the entire accelerator. The system dynamic range exceeds 70 dB which will enable experimenters to use the Beamloss-Monitor System to help steer the beam as well as provide signals for a Fast-Protect System. The system response time is less than 7 μs assuming a step-function, worst-case beam spill of 50 mA. The system resolution, based on the noise floor of the electronics is about 1.3 mRads/s. Production units have been built and meet the above specifications. The remainder of the system will be installed and tested later in 1992/93 with the GTA accelerator. The ionization chamber sensitivity and response time are described in the paper.

Introduction

This paper describes the GTA-24, Beamloss-Monitor System which will be used to detect high-energy particle loss in the accelerator beamline wall and shut down the accelerator before any damage can occur. To do this, the Beamloss-Monitor System detects and measures the beamloss-induced, gamma radiation at 15 selected points along the beamline, converts this information to electrical signals, compares them to preset limits, and in the event of an over-limit condition, causes the Fast Protect System to be activated which shuts down the entire accelerator. Figure 1 shows the general placement of the monitors along the accelerator.
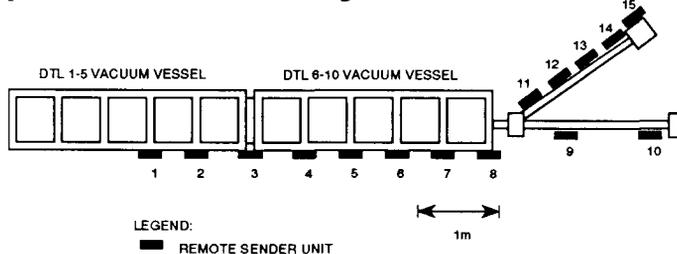

Fig. 1 Remote Sender Unit placement along the accelerator.

The beam spill is assumed to be anywhere from a line spill to a worst-case, point spill which will cause the most damage. Calculations show that for a 24 MeV, 50 mA point spill, significant melting of the accelerator hardware will occur in about 30 μs [1]. Damage caused by a line spill is significantly less. In order to safely respond to a worst-case beamspill, the response time of the Beamloss-Monitor System has been set at a lesser value of ≤7 μs which includes detection of the gamma radiation, processing of the signals, and activation of the Fast Protect System if necessary. In addition, integrated measurements of the gamma radiation macropulse-to-macropulse at each location are available through the computer control system for diagnostic and monitoring purposes.

System Description

The Beamloss-Monitor System consists of the following subsystems: Remote Sender Unit; Differential Receiver Module; Receiver Chassis; DC Control Power Chassis; and Control System Interconnects. A simplified block diagram is shown in Fig. 2.
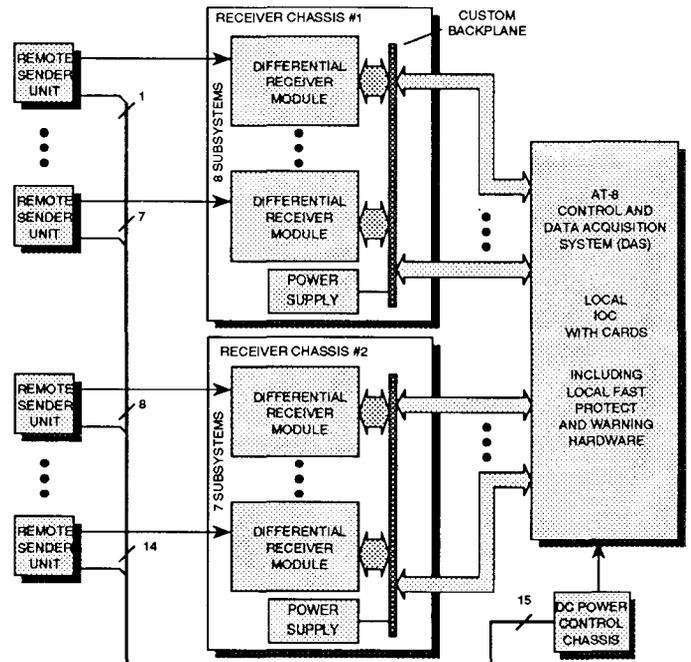

Fig. 2 Block diagram of the Beamloss-Monitor System.

The Remote Sender Units are connected to their respective Differential Receiver Modules by about 200 feet of

cable. The Differential Receiver Modules are connected via ribbon cable to the computer system.

Remote Sender Unit

The Remote Sender Unit detects gamma radiation, converts it to an electrical signal, and then transmits that signal to the Differential Receiver Module via a twisted, shielded pair. The Remote Sender Unit has subparts consisting of an ionization chamber, preamplifier, -1500 VDC high-voltage power supply, bipolar ±15 VDC power supply, and enclosure. Figure 3 is a side view of the unit.
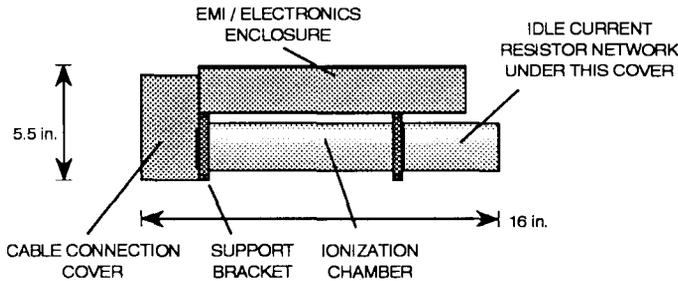

Fig. 3 Side view of the Remote Sender Unit.

The ionization chamber is a Health Physics Instruments, Model 1054, which has been characterized [1] to have a response time of less than 1 μs and gamma radiation to output current transfer function of -59 nA/Rads/s when operated with a -1500 VDC power supply. The ionization chamber acts as a current source when exposed to radiation. The minus sign indicates that current flow is negative with respect to the ionization chamber.

As part of a system functionality test procedure, a small, negative bias or "idle" current is set with a resistor network connected to the ionization chamber. This current is set to -40 nA which is DC coupled to the Remote Sender Unit's preamplifier. The preamplifier housed in the electronics enclosure uses a transimpedance amplifier to convert the input current to a voltage. This signal is then sent via a differential driver circuit to the Differential Receiver Module. The total preamplifier gain is 2×10^6 V/A.

Given that each Remote Sender Unit is to be installed in a radiation environment, the life expectancy of each unit is at least one year even under the worst-case radiation levels. End-of-life is determined by noticeable degradation of the electronics. The worst-case radiation levels are calculated from a continuously repeating, line-source spill of 30 μA/m at 24 MeV which is expected to produce gamma radiation at 60 mRads/s at each Remote Sender Unit. Once the duty factor, repetition rate, and worst-case, run-time per year of the accelerator are taken into account, the total absorbed dose per Remote Sender Unit is estimated to be about 25,000 Rads which according to manufacturers' data is a lower threshold on

incipient, electronic failure. In the event of a failure, the electronics can be easily replaced due to the modular nature of the Remote Sender Unit.

Differential Receiver Module

The Differential Receiver Module takes the signal from the Remote Sender Unit, conditions and integrates it, and compares the integrated value to two preset threshold settings. The lower setting is called the Warning Fault, and the higher one is called Fast Protect Fault. Figure 4 is a block diagram of the Differential Receiver Module.
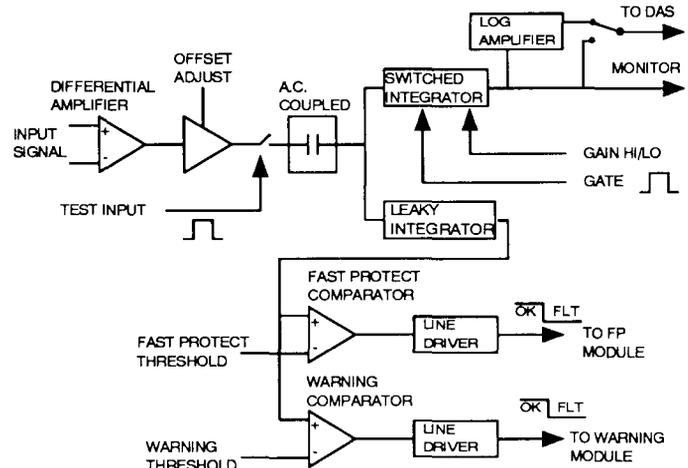

Fig. 4 Block diagram of the Differential Receiver Module.

The module can be configured to have the thresholds set by computer or by potentiometers accessible through the front panel. In either case, the computer monitors both thresholds. Normal operation calls for computer setting of the Warning Threshold and potentiometer setting of the Fast Protect Threshold for safety reasons.

The AC coupling capacitor removes any DC drift including the "idle" current signal from each system yet allows pulses from the Remote Sender Unit to pass uninhibited to the switched and leaky integrators. The switched integrator uses two gain settings, 2 and 20 pC/V, to measure induced-gamma radiation. The gate pulse coincides with the beam time and resets the switched integrator after each beam pulse. The system is designed for a beam macropulse of 2 ms and a repetition rate of 10 pulses per second. The leaky integrator has a conversion gain of 25 pC/V and a time constant of 1 ms which allows for low-level beam spill. A beam spill significant enough to cause damage will be quickly integrated by the leaky integrator and applied to the two comparators which determine the severity of the spill. If it is dangerous, the Fast Protect comparator will change. If it is less severe, only the Warning Fault will be generated. The leaky integrator time constant was determined by heat capacity and

conduction properties of the beamline hardware allowing for incidental beam spill.

The offset adjust is used to set the voltage at the output of the second amplifier to -40 mV which is 10^6 times the idle current of 40 nA. With the "idle" signal present, a Test Input gate is used to simulate a beam spill for the system. To do this, the Test switch is left open long enough for the A.C. coupling capacitor to completely discharge. When the switch is closed, the -40 mV appears to be a beam spill signal which is passed through to the switched and leaky integrators. If the Gate signal is also present, an integrated output signal will be available. In either case, the leaky integrator will respond to the input signal. By using this test procedure after proper calibration and adjustment of the Remote Sender Unit with its Differential Receiver Module, the system integrity will be verified all the way from the connections at the ionization chamber to the computerized Fast Protect Fault system.

To increase the dynamic range and boost the signal to noise ratio of the system, a logarithmic amplifier is used after the switched integrator. The output of the log amplifier is +10 V for +10 V input and -10 V for 10 mV input which corresponds to 60 dB of dynamic range. This coupled with a selectable gain factor of ten in the switched integrator gives a total system dynamic range of at least 70 dB when accounting for noise. The noise floor expected at $\leq$ 20 mV yields a system resolution of $\leq$ 1.3 mRads/s. Calculations show, at 24 MeV, this corresponds to a point beamloss of 0.9 μA and a line loss of 0.65 μA/m.

DC Control Power Chassis

The DC Control Power Chassis as shown in Fig. 2 provides power to each of the Remote Sender Units. It is essentially a power distribution chassis with sense circuits to trip a Fast Protect Fault in the event one of the Remote Sender Units loses power. It provides power at 17 VDC at up to 1.2 A to each Remote Sender Unit.

Receiver Chassis

The Differential Receiver Modules are housed in two, 9U high Euro chassis designated Receiver Chassis #1 and #2. Each chassis is designed to house up to eight modules including electrical interconnects and power. Each Differential Receiver Module plugs into a custom backplane that routes signals to and from the computer control system.

Each Differential Receiver Module has a dedicated slot which is known by the computer control system so that each output signal is module specific. Ribbon cables connect the backplane of the Receiver Chassis to the computer control system.

Control System Interconnections

The computer control system interconnections consist of various VME based I/O modules such as a Timing Module, Binary Output Module, Analog Output Module, two Analog Input modules, a 16 channel T/H module with A-D converter, two Fast Protect Fault modules, and two Warning Fault modules. These modules control the set points, read back the threshold values, digitize the switched integrator outputs, and monitor the Fast Protect and Warning Fault lines.

To control the system, computer screens have been designed and written that allow the operators to set the Warning thresholds, monitor both the Warning and Fast Protect thresholds, and set or adjust the timing of the Gate and Test pulses. Icons on the main control screen indicate the status of each Remote Sender Unit whether it be Okay, in Warning Fault, or Fast Protect Fault condition. In addition, each Remote Sender Unit/Differential Receiver Module system has a bargraph display which shows the integrated gamma dosage for each beam pulse.

Summary

A beamloss-monitor system has been designed for GTA-24 which will detect damaging beam spill using induced-gamma radiation and shut down the accelerator through the Fast Protect system. The response time of the entire system has been measured at less than 7μs. One complete system of Remote Sender Unit, Differential Receiver Module and support electronics and enclosures has been assembled and tested and is to be installed for the next accelerator experiment, experiment 2A. The remainder of the systems will be installed for subsequent experiments.

References

[1] Personal communication with C. M. Fortgang, Los Alamos National Laboratory, August 1991.