ION-CHAMBER BEAM-LOSS-MONITOR SYSTEM FOR THE LOS ALAMOS MESON PHYSICS FACILITY

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A new loss monitor system has been designed and installed at the Los Alamos Meson Physics Facility (LAMPF). The detectors are ion chambers filled with N_2 gas. The electronics modules have a threshold range of 1:100, and they can resolve changes in beam loss of about 2% of the threshold settings. They can generate a trip signal in 2 µs if the beam loss is large enough, and if we include the response time of the Fast Protect System, the beam will be shut off in about 37 µs.

I. INTRODUCTION

We needed a new loss-monitor system because the old loss-monitor system was based on photo-multiplier tubes that saturate on the narrow, high-peak-amplitude pulses extracted from the Proton Storage Ring (PSR). Other drawbacks of the old system are 1) the gain of the photo-multiplier tubes change with time, 2) a separate power supply is needed for each detector, 3) it uses a hazardous material (scintillator fluid) that becomes a mixed waste when irradiated, and 4) if a detector must be replaced it must first be recalibrated, which involves spilling the beam. The new system does not suffer from any of these drawbacks. The detectors are ion chambers filled with 160 cm^3 of N_2 gas at 1 std. atm. They do not have the speed of the photo-multiplier tubes (the ion collection time is about 200 µs, compared to the several-nanosecond speed of a photo-multiplier tube), but for our application this is not a problem. The primary purpose of the new system is to protect beam line components from errant beams, but it can also be used as a companion system to a separate, fail-safe loss-monitor system [1], where it can limit the average beam current to prevent errant beams from tripping the fail-safe system used for personnel protection. In this paper we will discuss the design details of the new loss monitor system and describe its performance at our facility.

II. SYSTEM OVERVIEW

A block diagram is shown in Fig. 1. The ion chamber detector, located in the beam tunnel, is connected via long (up to 100 m) coaxial cables to the Current Monitor electronics module and the High Voltage Distribution Unit. The cables are surrounded by solid metal wiring troughs to help reduce noise pickup that could affect the weak signals. The Current Monitor electronics are packaged into single-width NIM modules that fit into a standard NIM bin, which supplies power to the modules. Each NIM bin can hold up to twelve modules, but we use only eleven positions for the Current Monitors, and reserve the twelfth position for the Fast Protect Interface Module. This latter module is the bridge between the Current Monitor Modules and the Fast Protect System, which quickly (in about 35 µs) shuts off the beam, using electrostatic deflectors at the beginning of the linac, when requested by any one of its many inputs. Some specifications of the system are shown in Table 1.

Other components of the system include a high voltage power supply, set for -2000 V; a High Voltage Distribution Unit; a 5-V floating power supply; and a custom-made Load and Clear Module that is a companion to the LeCroy 4434 scalar CAMAC module used for reading out the Current Monitor module.

The first twenty units have been operating successfully since 1989, and the number in service has been continually expanding since that time.

III. ION CHAMBER DETECTORS

Our ion chambers are custom made by Far West Technology (Model 1054). They are filled with 160 cm^3 of N_2 gas at one std. atm. pressure. We chose this gas type and pressure to minimize the effect of a leaky ion chamber: if the ion chamber leaks, the new gas composition will be 78% N_2 (the natural abundance of nitrogen in air), with a slight pressure decrease to the local pressure of about 3/4 std. atm. Because the gas is still mostly nitrogen, and because the pressure drops just 25%, the response of the system will not change drastically. However, the change is still large enough to detect with a radioactive source. These ion chambers are also the same ones used for the fail-safe ion-chamber system [1], except that we do not add the extra resistors between the high voltage and signal electrodes.

Unlike photo-multiplier tubes, ion chambers do not easily saturate on PSR pulses, and their gains are all practically identical and do not change with age. They are inherently slower devices, but this feature is not a significant drawback in our application.

IV. CURRENT MONITOR MODULES

The function of Current Monitor electronics is to monitor the currents from the ion chamber detectors, and, if the currents

Table 1. Some specifications of the system.

Threshold range	0.1 to 10.0 volts
Ion chamber sensitivity	50 nC/rad
Number in service	68
Speed	About 2 μs for the electronics, plus another 35 μs for the Fast Protect System to actually shut off the beam.
Reduced gain mode	Reduces gain by a factor of 10

surpass the threshold settings, to send a trip signal to the Fast Protect Interface electronics. A block diagram is shown in Fig. 2. Current from the ion chamber enters U19, where it is integrated on the 8-nF capacitor, thus generating a voltage on the output of U19. As soon as the output of U19 deviates from zero, U16 turns on the FET Q2, which allows U14 to feed back a current equal to the ion chamber current. The maximum feedback current, I_{MAX}, is proportional to the threshold voltage V_{THR}. As long as the average ion chamber current is less than I_{MAX}, the output of U19 will be maintained close to zero. However, when the ion chamber current exceeds I_{MAX}, U19's output begins to rise, until the comparator U12 fires the one shot U9, which sends a TRIP signal to the Fast Protect System, which shuts off the beam. A signal proportional to the feedback current is used to drive the voltage-to-frequency converter (VFC) U7. A scalar CAMAC module (see Fig. 1) counts the number of pulses from the VFC for one second. The number of counts is therefore proportional to the average current from the ion chamber, which is proportional to the average beam loss. To prevent electrical noise from entering the Current Monitor, the following signals are brought in or out of the module with optically coupled chips powered by an external floating 5-V power supply: the gain control, the trip status to the control system (FPID), the trip signal to the Interface Module, and the VFC output. For the threshold readback signal we use high-impedance differential inputs on the CAMAC module to reduce ground-loop noise.

A threshold dial on the front panel allows the sensitivity to be varied over a rainge of 100:1. Front panel LED's indicate the status of the power to the unit and the status of the trip circuitry. A disable button prevents the unit from tripping the interface module, and a gain-reduction button lowers the sensitivity of the unit by a factor of 10 and turns on the gain-reduction LED. The gain-reduction mode can also be set by remote control. A test button injects 60 nA into the front-end circuit to test the module. The output of a buffer amplifier, capable of driving a 50-Ω load, is available on the front and rear panels to monitor the signals from the ion chamber. This buffer circuitry first integrates the ion-chamber signal with a 16-μs time constant, then amplifies it by a factor of -100. This amplification is important because of the inherently weak signals from the ion chamber. Several other signals are also available on the front panel for diagnostic purposes.

Reaction times of the Current Monitor Module can be as fast as 2 μs if the beam spills are large enough. If we include the reaction times of the interface module and the fast protect hardware, the total time to shut off the beam is about 37 μs.

V. THE INTERFACE MODULE

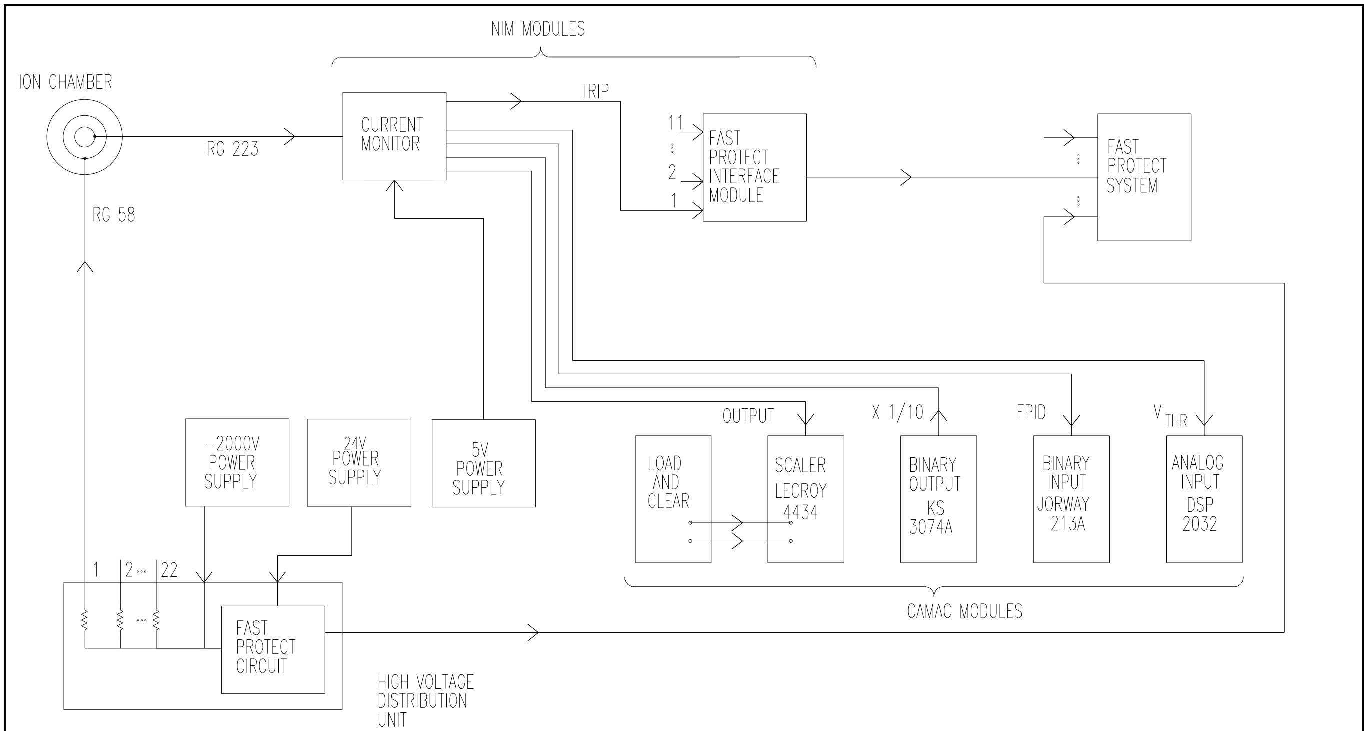

Fig. 1. A simplified block diagram of the system.

The Fast Protect Interface module occupies the twelfth slot of the same NIM bin as the Current Monitors. Each Interface Module receives trip signals from up to eleven Current Monitors. Upon receiving a TRIP signal, it breaks a current loop flowing through the Fast Protect System, which in turn quickly shuts off the beam. DIP switches inside the module allow individual Current Monitor TRIP signals to be disabled. Indicator LEDs on the front panel allow monitoring of the status of each input (disabled or tripped), and the status of the current loop to the Fast Protect System. A push button switch also allows a lamp test.

VI. INTERFACE TO CONTROL SYSTEM

Four different CAMAC modules are used to control and read out the Current Monitor: a binary input module to monitor the status of the Current Monitors, a binary output module to reduce the sensitivity of the Current Monitors by a factor of 10, an analog input module to monitor the thresholds of the current monitors, and a LeCroy 4434 scalar to measure the signal levels from the Current Monitors. Signal-level information is sent to the scalar from VFCs in the Current Monitors, and the scalar is loaded and cleared asynchronously once per second by a custom-made Load and Clear module also located in the CAMAC crate. An update rate of once per second was chosen for convenience, but this is not a limitation of the system. With some hardware changes, it can be as made as fast as the rep rate of the accelerator.

VII. LOAD AND CLEAR MODULE

These modules are located in the same CAMAC crates as the LeCroy 4434 scalars. Their function is to issue 70-ns-wide load and clear pulses, once each second, to the scalars. Since the scalars are driven by VFCs, the number of counts in one second is proportional to the average voltage, and thereby the average current from the ion chamber.

VIII. HV POWER DISTRIBUTION UNIT

Located in same rack as the current monitor electronics, the function of these units is to distribute -2000 V from the Power Designs model 2K20A high-voltage power supply to the ion chambers. An internal relay circuit will trip the Fast Protect System if the voltage drops below about 1350 V. A green front panel LED indicates current in the loop to the fast protect chassis. This LED will turn off if the high voltage is too low, if there is a problem with the connections to the fast protect chassis, or if there is a problem with the 24 V supplied to the unit.

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[1] M. Plum et. al., "Fail-Safe Ion-Chamber Errant Beam Detector Tailored for Personnel Protection", Proceedings of the 1989 IEEE Particle Accelerator Conference, March 20-23, 1989.

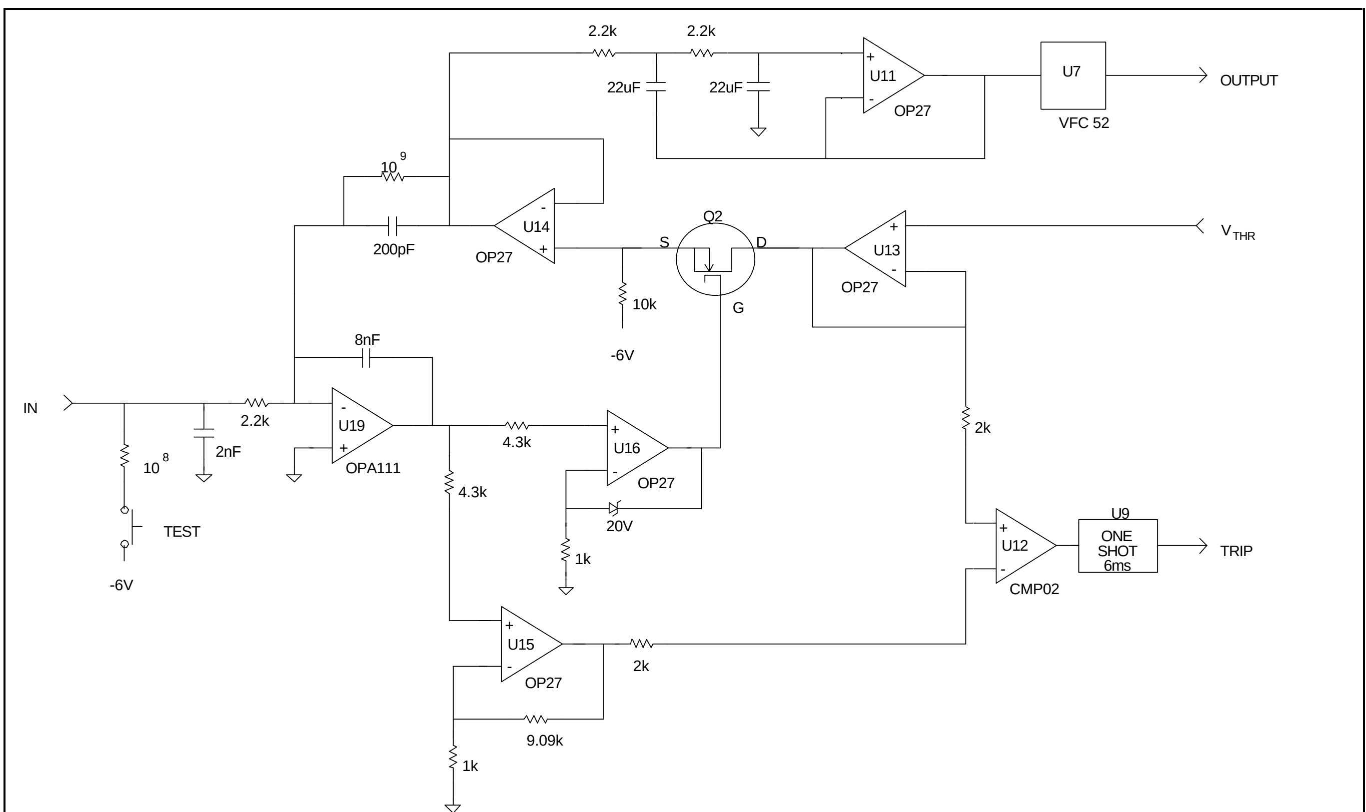

Fig. 2. A simplified schematic of the Current Monitor.