E-berm

Electronic Berm Interlock Module
Functional Description

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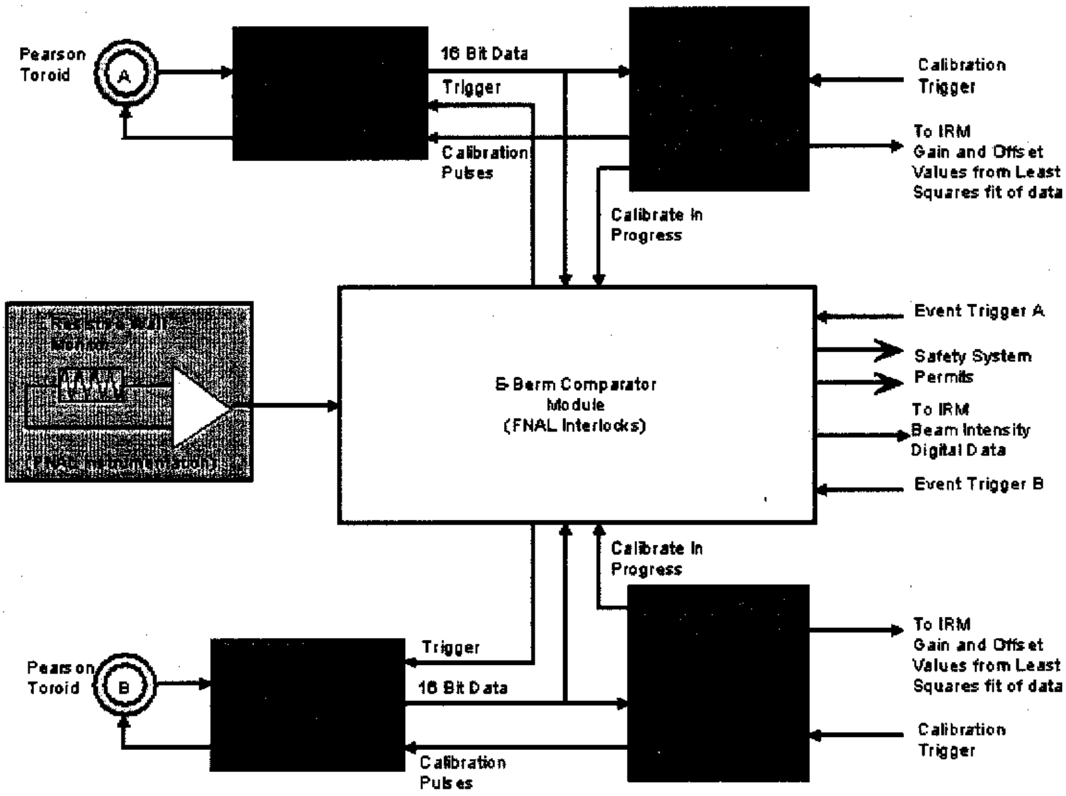
Introduction

The 8 GeV Fixed Target Facility, being built at Fermilab, is used to transport beam from the Booster accelerator to a new area dedicated to external beam physics. MiniBooNE, the first experiment to use the new facility, has requested 5E20 protons per year. This equates to more beam per year than has been accelerated in the history of Fermilab. To minimize radioactivation of beamline components, groundwater, and areas outside the overburden; the project has specified a total beam loss monitoring system termed an Electronic Berm or E-Berm. This system is intended to monitor the amount of beam lost between two toroids and disable the beamline if losses exceed a predefined level.

The system described here will use two toroids and the associated integrating electronics. One toroid will be located at the upstream end of the 8 GeV beam line and the other will be located slightly in front of the target focusing horn. The comparator module will measure the absolute value of the difference of the two toroids on a pulse-to-pulse basis. Using the pulse-to-pulse difference along with summing the error of the last 10 pulses, both an instantaneous and integrated loss can be measured.

System Implementation

E-Berm Block Diagram



The diagram above shows a block diagram of the E-berm system. There are four major components to the system; the toroid and integrator electronics, the calibration module, the beam presence detector (resistive wall monitor), and the comparator module. The focus of this document is on the comparator module with a brief description of the other three components.

Input Devices

Toroid Integrator

The Toroid Integrator receives an event trigger to open a 10us integrate window. Upon completion of the integration window, the integrator sends the E-berm comparator module a 16 bit 2 s compliment binary data word and a valid data pulse. There are 4 possible gain settings on the integrator electronics card; they are ±1.875E14, ±5.625E13, ±1.875E13, and ±5.625E12 protons at full scale. Using the lowest gain setting and taking into consideration that the signal is bipolar, the output resolution achieved is 1.717E8 protons per count.

The integrating electronics card buffers the output data word and the valid data pulse before being sent to the E-berm comparator module.

Beam Presence Detector

The beam presence detector utilizes a resistive wall monitor (beam sensing device) connected to a 53Mhz-tuned detector to provide a TTL level output pulse for each beam pulse. This signal is used as a coincidence check within the E-berm comparator module to verify the toroid integrator electronics is looking for beam at the correct time. The beam presence detector will detect beam signals of approximately 5E10 or higher.

Toroid Integrator Calibration Module

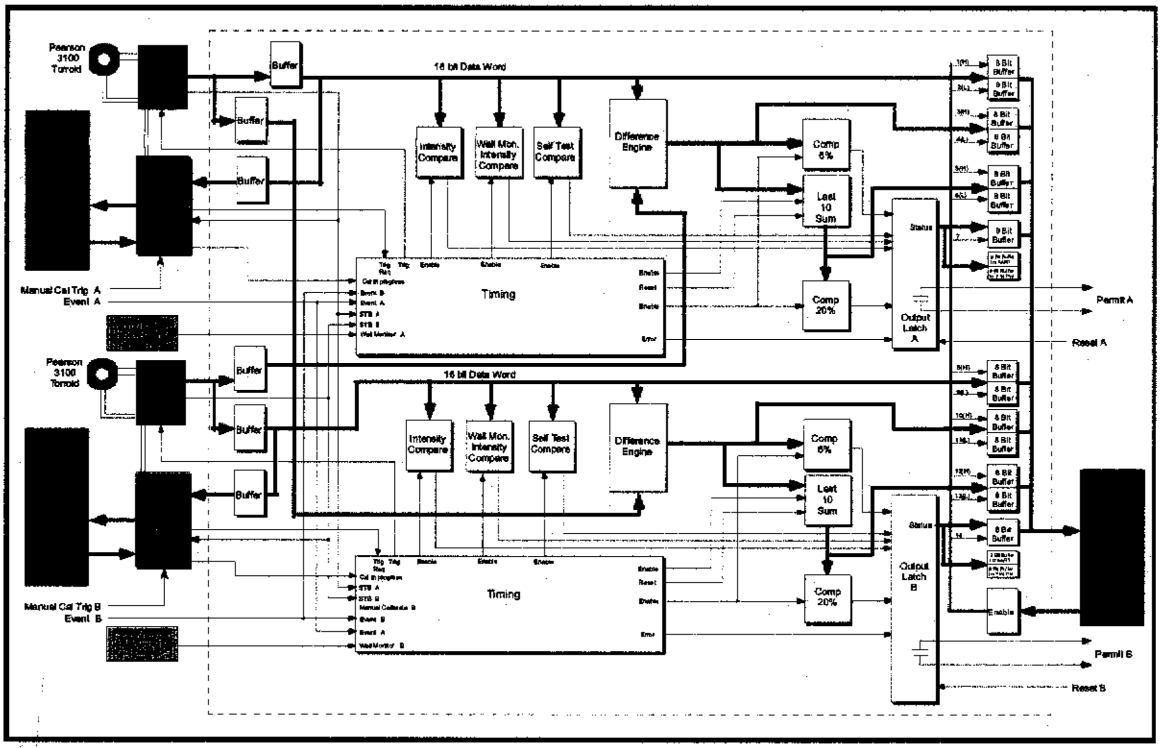
The Toroid Integrator Calibration Module is a part of the E-Berm total beam loss monitoring system. The module provides the ability to monitor the performance of the toroid and the integrator electronics, thus greatly improving the reliability of the beam to the experiment. The module is not part of the Fermilab Safety Systems, but rather a tool to improve the systematic performance of the E-Berm system.

The intent of the calibration module is to perform a toroid calibration sequence in approximately 100ms. To do this, the module generates a family of calibration pulses sent through the toroid calibration winding, performs a least squares fit to the data measured by the toroid integrator module, and outputs the gain and offset values to the Fermilab control system in the form of five 8 bit digital data words.

In the normal operating mode, (not performing a calibration sequence), the module sits idle.

To initiate the calibrate mode, the module receives a 1 microsecond calibrate trigger from the Fermilab control system. A calibrate in progress bit is sent to the E-berm comparator module to trip the output permits to inhibit beam during a calibrate sequence.

Comparator Module



The above figure shows the interconnecting logic functions performed by the comparator module. The logic functions are implemented in Altera™ large scale EPLD logic to eliminate the need for microprocessors. The diagram above shows both the A and B side comparison circuits. A description of each internal logic function is described below.

Intensity Compare:

The 16-bit signal from the A integrator is compared to switch settings in the A side EPLD s of the module and if the signal from the integrator is higher, a trip occurs. The same function occurs for the B side with the B integrator. This allows setting of a maximum intensity limit for the beamline. This is not expected to be used in the MiniBooNE beamline but is included for future applications.

Difference Engine:

This block takes the 16-bit 2 s complement data values from Toroid Integrator A and Toroid Integrator B , subtracts them and returns the absolute value of the result. The A side EPLD s perform an | A-B | function and the B side EPLD s perform an | B-A | function. The inversion of the two functions between the A and B sides is done to assist in preventing common mode errors.

Last 10 Sum:

This block adds the current value of the difference engine to a running total and stores the value in a 10 deep by 16-bit shift register. The value that gets shifted out of the memory is then subtracted from the total. Thus generating a sum of the last 10 beam samples to be used for subsequent comparisons.

Pulse to Pulse Comparison:

The absolute value of the difference between integrator A and integrator B is compared to a set of switches located on the comparator board. The value of the switches for MiniBooNE is set at approximately (~3E11). This equates to 6% of the total pulse-to-pulse beam of (~5E12) per pulse. If the difference value is higher than the switch setting a trip occurs.

Integrated Loss Comparison:

The value of the sum of the last 10 beam pulse differences is compared to a set of switches again located on the comparator board. The value of the switches for MiniBooNE is set at approximately (~1E12). This equates to approximately a 20% loss of beam for the last 10 beam pulses. Looking at this from a pulse-to-pulse basis yields an average loss of less than 2%. Again, if the value is higher than the switch setting, a trip occurs.

18000 pulses / hr

Self Test Compare:

Between beam pulses, the integrator is triggered to take a sample with no beam present. The absolute value is then compared to a small positive value to check if the integrator has drifted away from zero. If the value gets too high, the module is tripped. This value is defined inside the EPLD s. At present, the value is set to (2.7E9) and will be defined during the commissioning process after the noise floor for the toroid integrators has been established.

Beam Presence Detector Compare:

The Beam Presence Detector compare logic is used as a beam coincidence check with the toroid integrator electronics. If either toroid integrator reads more than 1E11 beam, then a pulse indicating beam has passed is required from the beam presence detector. The absence of this pulse, when more than 1E11 beam is detected by either of the integrator electronics, will initiate a system trip.

Timing:

The timing block takes the ACNET event strobe signals and passes the appropriate signal on to each integrator starting a beam event timing sequence. The event timing sequence requires that the beam pulse from the Beam Presence Detector occur between 2.5us and 8us after the event strobe occurs. Knowing that the Booster extraction pulse is 1.6us guarantees that both integrators were looking for the beam pulse at the correct time. This timing window is defined inside the EPLD's. Additionally a signal from the Beam Presence Detector at anytime outside the beam event will initiate a system trip.

Each Integrator Electronics module must provide a strobe signal indicating valid data is ready within 15us of an event strobe signal.

Event strobe signals may not occur at intervals of less than 40ms. This insures the previous event has been fully processes and the internal self test has completed before beginning the next event timing sequence.

Outputs:

The three digital output words connected to an IRM consist of the buffered 16-bit 2 s complement integrator values, the 16-bit absolute value of the difference between toroid A and B, and the 16-bit sum of the last 10-beam pulse losses.

Individual trip indicators are provided to the front panel for the self test compare trip, intensity compare trip, sum of last 10 beam pulse losses trip, single beam pulse loss trip, strobe error, beam presence detector error, event error, and clock error.

Two 24vdc active high A and B output permits are provided for connection to the safety interlock system.

Two RS-485 connections for the Safety System Data Acquisition System are also provided.

Reset:

There are three separate reset inputs for the comparator module. Each reset signal clears the data shift registers and resets the A & B output trip circuits. First, there is an internal power up reset for the board initialization. Second, there is a manual reset button located internal to the comparator module on the main board. Third, there is a reset in signal from the safety interlock system. To prevent undesired clearing of the shift registers; the reset-in signal from the safety interlock system is masked unless the system is in a tripped state.

Clock monitor:

The comparator module uses two 10Mhz clocks for internal timing. There are two independent clock watchdog circuits. A failure of either clock will remove the output permit signals.

Proposed Use:

The E-berm system is intended to be used in place of chipmunk radiation monitor arrays. The system is not intended to be used beyond allowing the same reduction in shielding as would be allowed by the use of chipmunks. The system does not and cannot prevent the initial beam loss. The major advantages of the E-berm over the standard chipmunk radiation monitors are that losses are detected from any direction. This will help to minimize ground water activation, component activation, and allow for a reduction in the required overburden.

Design Methodology:

The design methodology used in the proposed design is consistent with the guidance provided in the Fermilab Radiological Control Manual (FRCM) Chapter 10. Two independent monitoring channels are provided inside the comparator module both capable of interrupting the output permit loops.

Failure Modes:

During the design process, failure mode reduction principles utilizing redundant circuits were employed. Additionally, all signals to and from the comparator board are buffered. Monitoring two independent toroid integrators and comparing to a beam presence detector signal verifies event timing. The "A" side channel performs an Integrator |A-B| function while the "B" side channel performs an Integrator |B-A| function. The output permit signals are active high signals. All data is echoed to the ACNET control system via an IRM for further analysis.

Testing:

The calibration module built by Columbia University will be used to monitor the calibration drift of each toroid integrator between physical calibrations. A physical calibration of each toroid integrator will be performed at a minimum of every six months utilizing a pulse generator and oscilloscope. The gain and offset values for each integrator electronics module will be adjusted at that time to null out any errors since the last calibration.

The comparator module trip functions will be tested by inputting known data signals via an in-house built test unit. The test unit will verify the pulse-to-pulse difference trip settings, the sum of the last 10-event difference setting, the event timing functions, and the internal self-test functions.

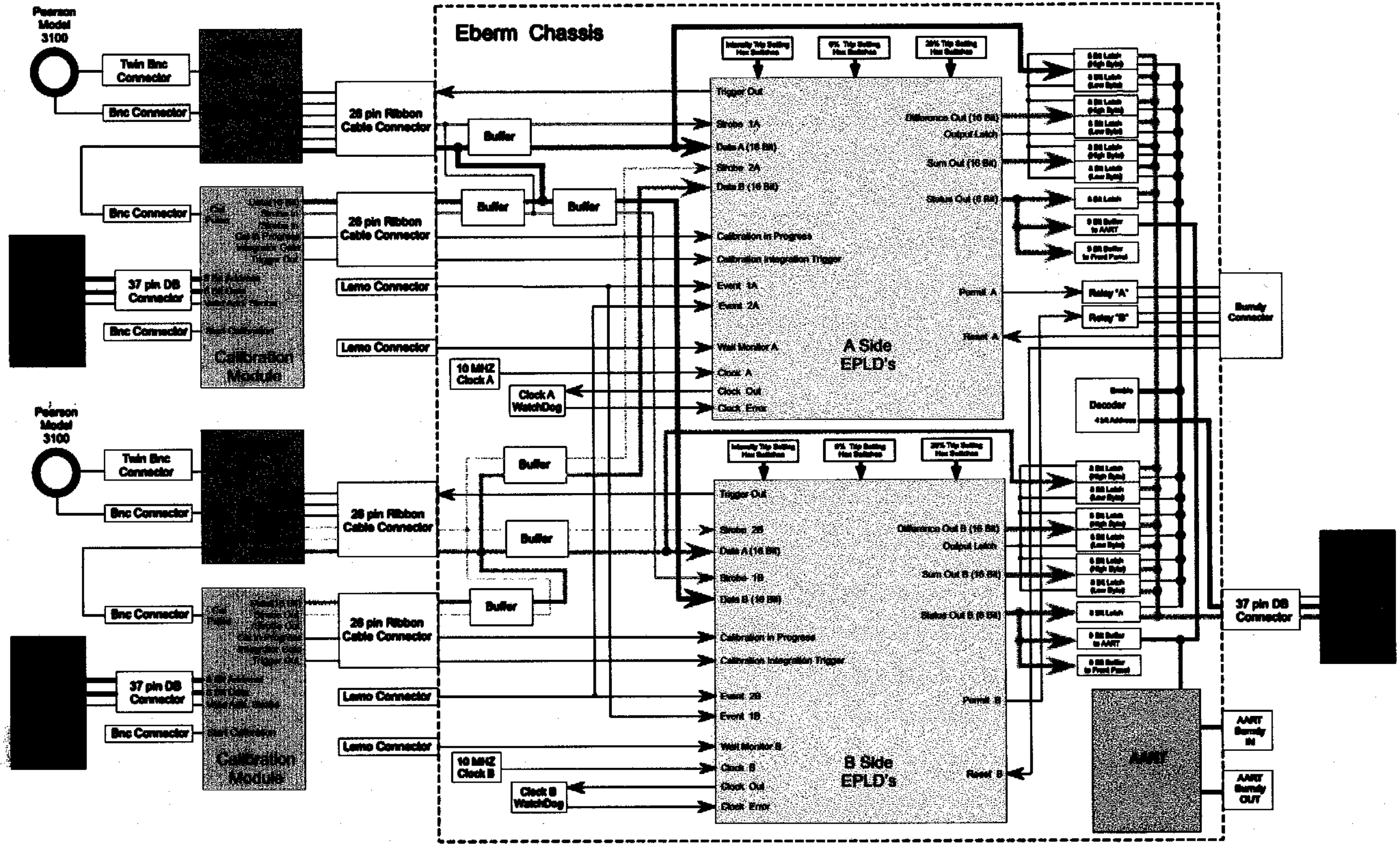
Review Process:

The review process established by the Beams Division Head is to produce a design with the joint inputs of the Fermilab ES&H Section, the RF&I Instrumentation Engineering Group, the MiniBooNE beamline Physicists, and the BD ES&H Interlock and Radiation Protection Groups. Upon completion of an approved design, the standard Request for Interlock Modification form, (Radiation Physics Form #42), will be submitted to the ES&H Section for a preliminary design approval. Final approval will be requested from the ES&H Section upon submission of completed test results.

Review Standards:

The review process established for the proposed design is consistent with the Fermilab Work Smart Standards set and the FRCM.

Eberm Connection Diagram



Electronic Berm Monitor Block Diagram