RHIC BEAM PERMIT AND QUENCH DETECTION COMMUNICATIONS SYSTEM[1]

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Abstract

A beam permit module has been developed to concentrate RHIC[2] subsystem sensor outputs, permit beam, and initiate emergency shutdowns. The modules accept inputs from the vacuum, cryogenic, power supply, beam loss, and superconducting magnet quench detection systems. Modules are located at equipment locations around the RHIC ring. The modules are connected by three fiberoptic communications links; a beam permit link, and two magnet power supply interlock links. During operation, carrier presence allows beam. If a RHIC subsystem detects a fault, the beam permit carrier terminates - initiating a beam dump. If the fault was a superconducting magnet quench, a power supply interlock carrier terminates - initiating an emergency magnet power dump. In addition, the master module triggers an event to cause remote sensors to log and hold data at the time-of-failure.

1. Work preformed under the auspices of the U.S. Department of Energy.
2. Relativistic Heavy Ion Collider

INTRODUCTION

Brookhaven National Laboratories Alternating Gradient Synchrotron, and Booster have room temperature magnets that are not effected by beam losses. RHIC has superconducting magnets, and there is sufficient beam energy to damage the magnets. The possible beam damage, and use of superconducting magnets, created the requirement for a beam permit and quench detection communications system. RHIC has two rings, therefore, the RHIC permit and quench communications system has three functions:

- Beam permit: single permit link to permit beam entry and presence in both rings.
- Yellow magnet interlock: yellow quench link protects yellow ring magnets.
- Blue magnet interlock: blue quench link protects blue ring magnets.

There were similar requirements in the design of the Fermilab Tevatron a decade earlier. The author wishes to acknowledge the work of Robert J. Ducar of the Fermilab, Accelerator Controls Section. Mr. Ducar developed two CAMAC modules to meet the requirement, the CAMAC 200 PERMIT CONCENTRATOR and CAMAC 201 PERMIT LINK GENERATOR. The RHIC permit system design is based upon these two Fermilab modules. The major differences between between the two systems are the inclusion of the quench protection system, modules based on VME specifications, and the use of complex programmable logic devices which were not available a decade ago.

The RHIC beam permit/quench detection communications system concentrates RHIC subsystem sensor outputs to allow beam entry, and its continued presence. RHIC subsystem inputs include vacuum, cryogenic, beam loss monitors, power supply status, safety, and superconducting magnet quench detection systems. These subsystems report their status to the permit/quench system. If any permit/quench input or interconnecting cable fails, all modules terminate their local permit level output, and if a quench input failed, the associated power supply interlock. In addition, the master module generates a beam dump command, and triggers an abort event transmission. While the beam permit system is considered an emergency system, the beam permit system will be normally be used to purge the accelerator at the end-of-cycle.

PERMIT/QUENCH COMMUNICATIONS SYSTEM MODULES

One beam permit/quench module becomes the master by its location, and printed wire board jumper patch. To initialize the beam permit/quench communications system, both yellow and blue magnet quench detector inputs must be active. On an event link command, the master module initiates two 10 MHz carriers; yellow and blue QUENCH_LINK. Slave modules receive the QUENCH_LINK carriers (input or upstream), test local magnet quench detector inputs, and retransmit the QUENCH_LINK carriers (output or downstream). The QUENCH_LINK carriers return to the master module in less than 0.5 sec (if all magnet quench detector outputs are asserted). If the master module detects the QUENCH_LINK carriers at its upstream inputs 0.5 seconds after start, the QUENCH_LINK carriers are maintained, and all modules enable their power supply interlock outputs.

Once the quench links have been established, the superconducting magnets can be energized, the permit link may be established. The PERMIT_LINK is similar to the QUENCH_LINK, an event link command initiates the carrier at the master module. The master and slave modules concentrate local beam permit inputs and pass the permit carrier if conditions permit. If the master module detects the PERMIT_LINK carrier at its upstream input, the PERMIT_LINK carrier is maintained, and all modules enable their local permit outputs.

The three permit/quench links are constructed from standard AGS/RHIC event link communications components. The module carrier input and output buffers are EIA RS-422, differential TTL components. All module

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RS-422 inputs are transformer coupled for galvanic isolation. The RS-422 links are converted to fiberoptic if the link exceeds 25 meters. Multi-mode fiberoptic links are used for long distance transmissions. During the first loop around the RHIC ring, the fiberoptic link receivers require approximately 8 msec to detect carrier, and unblank. As there may be 40-50 fiber optic links around the RHIC ring, there is an initial permit/quench link loop delay of 300-400 msec. After the fiber optic receiver's have unblanked, the fiber optic, copper wire, and integrated circuit propagation delays will not exceed 2 beam revolutions.

After the PERMIT_LINK is established, any module detecting a permit input, or upstream PERMIT_LINK carrier failure terminates its local permit level and PERMIT_LINK carrier output. The PERMIT_LINK carrier failure propagates around the RHIC ring, terminating local permit level and PERMIT_LINK carrier outputs. When the master module detects an upstream PERMIT_LINK carrier failure, its local permit level, and PERMIT_LINK carrier outputs are terminated. Blue and yellow beam dump commands are initiated, and an event link abort event code is triggered. The PERMIT_LINK carrier failure continues to propagate from the master module to the module that initiated the failure, terminating local permit levels and PERMIT_LINK carrier outputs. Within 2 beam revolutions, all modules have detected the failure, the beam dump initiated, and local permit levels terminated.

If the module input failure was a quench input, the associated local power supply interlock level and QUENCH_LINK carrier are terminated in addition to the PERMIT_LINK. However, the yellow and blue quench links are not coupled, a quench detection in one magnet ring doesn't propagate to the other ring. The ring that contains a quenching magnet is "crowbared," a stressful process, the other ring will be slowly "ramped" down.

A permit/quench module contains:

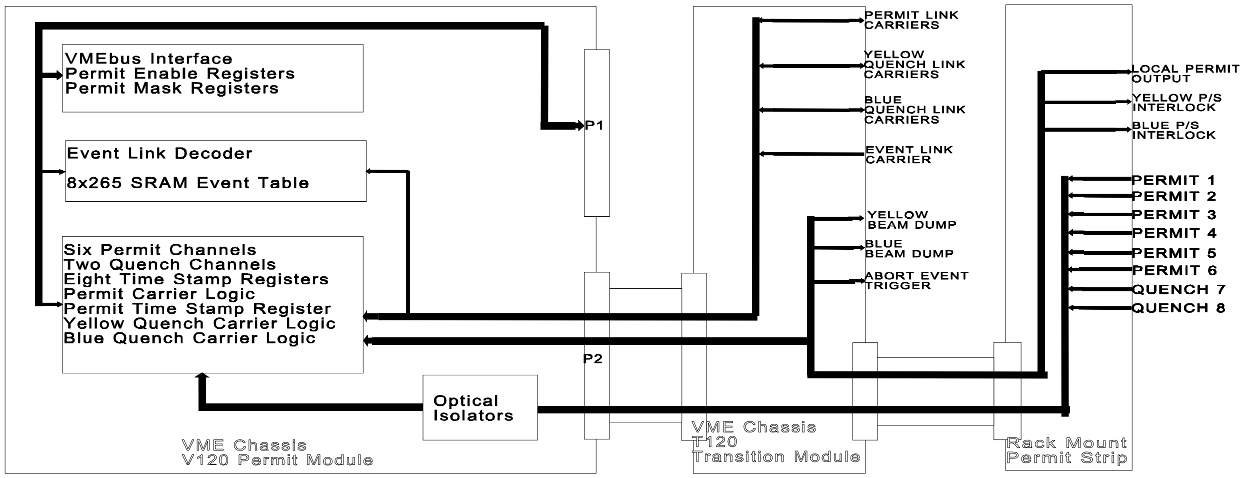
- VMEbus interface; D8(OE), D16, A16 data transfers
- Six, fail-safe, optically isolated, permit inputs; subsystems must drive a 50 ohm line termination. Permit inputs may be disabled by VMEbus command, and masked during operation. Masks are controlled by event link event codes.
- Two, fail-safe, optically isolated, quench inputs; subsystems must drive a 50 ohm line termination. Quench inputs can be permanently deactivated by module jumper patch, however there is no VMEbus control of quench inputs.
- Four, RS-422, 10 MHz carrier inputs; permit, yellow quench, blue quench, and event links. Inputs are is transformer coupled for galvanic isolation, and terminated in 100 ohms. The permit/quench modulation is on-off, while the event link modulation is bi-phase-mark.
- A 32-bit time stamp is register is provided for each permit, quench, and permit upstream carrier input. The module time stamp counter is driven by a 1 MHz clock derived from the event link, and the counters are synchronized by an event link event code.
- Three, RS-422, 10 MHz carrier outputs; permit, blue quench, and yellow quench links.
- Pulse output; trigger event link abort event code. Output will drive a 50 ohms termination to a TTL level.
- Five, fail-safe, level outputs; blue and yellow beam dump, local permit level, and blue and yellow power supply interlock. Outputs will drive a 50 ohms termination to a TTL level. These outputs are negated on initialization, or link failure, and are asserted approximately 0.5 seconds after link initialization. The transition from assertion to negation initiates, power supply emergency shut-down, beam dump, and local shutdowns.
- Interface to RHIC event link [1]; event link event codes control permit and quench initialization, time stamp counter synchronization, and permit input masks. Eight masks are available to disable permit inputs. During various machine operating phases, permit inputs may be masked. For example, a loss monitor near the injection kicker may be masked during injection, when losses may exceed the normal operating threshold.

V120 MODULE

The permit/quench module was named V120 by the BNL AGS/RHIC Accelerator Controls Section. The module is a standard 4U x 6HP VME module. The module is a VMEbus slave, responding to D8(OE), and D16 short address transfers. The front panel contains 16 LED status indicators. All input/output connections are made through the user pins in the VME P2 connector. The logic was implemented in three Altera EPM9320, complex programmable logic devices (CPLD). The three CPLD's contain a total of 960 logic cells. The EPM9320 is in-system programmable. Each CPLD has an individual programming connector, and is programmmed after the module is assembled. The EPM9320 was selected after the logic failed to partition in smaller CPLD's. The remainder of the module integrated circuits are primarily VMEbus, and module input/output buffers.

T120 TRANSITION MODULE

All RHIC/AGS VME chassis have a rear transition module mounting panel. The transition module mounting panel accepts 21 4U x 6HP modules, with 80 mm deep printed wiring boards. The V120 input/output connections are through the VME chassis backplane P2 connector. A ribbon cable connects the T120 transition module to the rear side of P2. The T120 module is an 8U x 6HP module. All permit/quench module system input/output connectors are contained on the T120 transition module. These include the permit/quench link, event link, beam dump, and event trigger connectors. The transition module contains the RS-422 differential input isolation transformers and terminators, and single ended input/output termination's, but



Single Module of Permit Communications System

no active circuitry. The link connectors are twin-BNC, and single ended connectors are Lemo NIM/CAMAC connectors.

The T120 contains connectors that are thought of as system connectors - controlled by the controls group. The RHIC subsystem input/outputs are contained on a rack mounted chassis. The transition module contains a 25-pin subminiature connector to connect the chassis.

RACK MOUNTED PERMIT INPUT CHASSIS

All subsystem permit and quench input/outputs are made on a 1RU rack mounted chassis. The chassis is normally mounted on the rack cabinet rear rack rails, with assess to the chassis is through the rack cabinet rear door. The chassis contains 11 Lemo NIM/CAMAC connectors; 8 permit and quench inputs, and 3 outputs. The outputs are permit level, and yellow and blue power supply interlocks. A 25-pin subminiature connector connects to the transition module cable. The chassis contains no active circuits, just single ended cable terminations.

1996-1997 RHIC SEXTANT TEST

Nine V120 modules were operating during the RHIC Sextant Test. A limited number of inputs were provided by quench detection systems, main power supply, and vacuum. Both yellow and blue quench links were operating. The yellow line contain test beam, while the blue line was used to complete the magnet power circuit for this test. Vacuum was the only permit input during the test. The power supply interlocks were active, and the permit output was used to control the switching magnet at the end of the AGS to RHIC transfer line. Beam couldn’t be switched into the RHIC sextant unless the local permit output near the switching magnet was asserted.

REFERENCES

[1] B. R. Oerter , C. R. Conkling, *Accelerator Timing at Brookhaven National Laboratory*, Proceedings of the 1995 Particle Accelerator Conference