*UPGRADE OF THE CONTROLS FOR THE BROOKHAVEN LINAC**

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Abstract

The control of the magnets, rf system, and other components at the Brookhaven Linac uses a system that was developed at Brookhaven in the late 1960's. This system will be retired in the summer of 1995.

The Linac controls are being upgraded using modern VME-based hardware compatible with RHIC generation controls, and an existing serial field bus. The timing for the Linac will also be upgraded and will use components developed for RHIC. The controls in general, the timing for the Linac, and the modules developed will be described.

I. INTRODUCTION

The control for most of the Brookhaven 200 MeV Linac is a system developed at Brookhaven over 25 years ago. This system derives reference voltages from motor-driven potentiometers which can be set via computers. This system is robust but is inflexible in that seconds are required to reconfigure the Linac control parameters. Also, the computers to control the potentiometers and acquire readbacks are obsolete and no longer supported [1]. Because of this, the PDP10 and PDP8 computers used to control the Linac are scheduled to be retired this summer. It was decided that since a new generation of VME based distributed controls for RHIC are being developed, the Linac controls should also be VME based to take advantage, as much as possible, of the RHIC development work.

II. LINAC CONTROL SYSTEM

The new controls for the Linac consist of RHIC style VME control chassis located in the Linac control room with local control and readback devices distributed along the Linac at the rf stations. The VME chassis is in turn connected to the accelerator control network (Ethernet). Workstations on the network provide the user interface. The VME controls are centralized and the distributed local controls for the more than 400 Linac devices are interfaced to the VME controller via a field bus called Datacon. Datacon is a bit serial bi-phase communication system developed at BNL in the 1970s. Although an old system, Datacon is extremely robust and noise immune. Datacon is a multidrop, transformer isolated serial bus that can operate over 2000 ft. of coaxial cable. It uses a simple protocol that is easily implemented in gate arrays and is, therefore, relatively inexpensive. Because of its simplicity, the need for embedded microprocessors in remote Datacon devices is eliminated. This makes Datacon ideal for use in electrically hostile environments.

At the heart of the Datacon field bus system is the VME Datacon master [2]. This device was developed using field programmable gate Array (FPGA) and risk processor technology. The Datacon master supports multiple Datacon channels, each capable of addressing the full Datacon address space. The Datacon master has an on board direct interface to the accelerator serial timing link and local memory so that all Datacon transactions can be preloaded into tables, executed on selected timing events, and data returned and stored without intervention by the VME processor. This has resulted in a many fold increase in data throughput compared to older Datacon implementations.

As mentioned above, Datacon is a simple, inexpensive, and noise immune protocol. Due primarily to operation of high power rf devices, the electrical environment at the control points along the Linac is noisy. Because of this the decision was made to use the Datacon field bus and custom modules there and centralize the computing and storage functions in a quieter environment. Therefore, the VME chassis is located in the Linac control room. Residing in the chassis is a Datacon master module that communicates to fifteen remote Datacon chassis on four field busses. The Datacon chassis are installed at the quadrupole/rf stations and at other areas in which power supplies and other Linac devices have to be controlled. The Datacon chassis contain modules that control the state of, provides voltage references for, and returns digitized analog signals and statuses from the various Linac devices.

At each quadrupole/rf station there will be one or, in some cases, two Datacon chassis containing dual channel Datacon power supply control modules. Each Datacon field bus will service a number of quadrupole/rf stations such that all readbacks can be returned and all new setpoints updated within 100 ms. Thus, the Linac control parameters can be reconfigured between Linac beam pulses allowing full pulse-to-pulse modulation (PPM) of the Linac.

Each Datacon control chassis has several quadrupole magnet power supplies whose state is controlled in common. For example, the 30 tank 1 quadrupole magnet power supplies are turned on or off by a single Datacon command sequence. Each RF station has a separate command sequence to control the state of the high voltage power supply and a separate command sequence to turn the rf pulsing on or off. State

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control of the quadrupole power supplies and the rf control is done on a non-PPM basis.

Returned with the various analog readbacks is the status of the state of the quadrupoles and the rf systems and the state of various interlocks and system faults. Distributed along the Linac are nine sector vacuum valves. Each Datacon chassis located at the quadrupole/rf stations will have a Datacon power supply control module dedicated to providing a command line and a status line for the valve control and status. The valve statuses and the valve state commands will also be non-PPM devices. There are also vacuum gauges that are distributed along the Linac. Each gauge has an analog output that represents the vacuum read by that gauge. A Datacon power supply control module will provide control and status for the sector valves and will read the vacuum gauges on a non PPM basis. Finally, two Datacon chassis will be located at the Linac vacuum-ion pump panel to control and monitor the vacuum pumps and vacuum pump power supplies. These will also be non-PPM devices.

The Datacon control chassis located at each of the Linac quadrupole/rf stations are commercially manufactured chassis that are similar to standard commercial VME chassis. The Datacon card cage uses the standard P1 and P2 connector configuration in the 21 available card slots as the VME chassis. Although not a VME implementation, it uses the P1 VME bus structure to control the Datacon power supply control modules in the chassis via a Datacon crate controller module. The chassis has a 6u x 220 mm card cage in the front for the control modules and crate controller and a 6u x 100 mm card cage in the rear for transition modules. P2 of the 220 mm card cage and P2 of the 100 mm card cage are connected via ribbon cables supplied and installed by the chassis manufacturer. Transition modules are used to adapt the Datacon power supply control module's generic outputs to the particular needs of the Linac control. Therefore, there is no hand wiring or configuration of the chassis needed. The modules plug in and the chassis is ready for service. Each of the control chassis has the following complement of modules.

1. Datacon crate controller - The Datacon crate controller accepts the Datacon bi-phase encoded serial transmission and decodes several data fields that are used by Datacon modules in general and the power supply control module in particular. For example, the power supply control module uses the following standard Datacon fields . The magnitude field that represents the required analog setpoint. The command field that represents the required state of the device controlled or the state of the Datacon power supply control module's analog I/O. Finally the address field to select the correct Datacon power supply control module to respond to the Datacon transmission. These fields along with a clock are sent to the control modules in the chassis via the VME bus structure. When a Datacon power supply control module in the chassis recognizes its address and finishes its task it then sends a reply back to the crate controller where it is encoded and returned to the source. The reply consists of (for the Linac) a digitized voltage readback and several status bits.

   Older asynchronous implementations of the Datacon crate controller required that several one-shots be adjusted to establish proper pulse widths, clock trains, and delays. This required periodic adjustments as the module aged. The redesigned crate controller incorporates synchronous FPGA technology and requires no adjustments.

2. Datacon Power Supply Control module - A general purpose power supply control module was designed for digital control, digital status readbacks, analog output, and analog input. The Datacon power supply control module was also designed using FPGA technology. The module has two channels per module with each channel having the following features.
   a. Eight status inputs.
   b. Four command lines. Each command line can be active low , active high, pulsed high, or pulsed low. The commands are encoded in the Datacon command field as described above.
   c. An analog input that can be configured to be either - +/- 10 V or 0-10 V. The input is differential. The A/D converter can be triggered either by a Datacon transmission or by external timing pulses. Each channel is independently triggered.
   d. An analog output that can be configured to be either- +/- 10v or 0-10v. The output is single ended. The analog output powers up at 0 volts and remains at 0 volts until a Datacon command packet is sent to that channel. The power up condition is reported in the Datacon status field. The output of the D/A can be looped back to the A/D or a 1/2 scale reference can be read into the A/D via a command encoded into the Datacon command field.

3. Timing input module. This is a simple module that interfaces the read time trigger pulses which are AGS standard pulses (20 volts at 1 µs) and converts them to TTL level. The read pulses are then fanned out to the power supply control modules via P1b bus lines to trigger the A/D conversion. Eventually this module will be replaced by a timeline interface module in which events to trigger the A/D conversion will be directly decoded from the Fiber Optic Linac timeline. This module will be capable of placing events on any of the eight P1b bus lines that are reserved for timing signals. The Power supply control module can then be set up to select one of eight possible sources to trigger the A/D conversion. The timeline interface module will also route the selected timing pulses on the front panel connectors for use as triggers or inputs to Linac devices.

III. LINAC TIMING

As in all modern accelerators, equipment operation at the Linac must be synchronized. In the past this synchronization was accomplished by individual timing pulses on coaxial cables distributed throughout the Linac. Adding signals to this system was difficult since new cable distributions were required for each signal added. The next generation Linac timing system was designed and installed during the Booster Project and is based on the AGS and Booster timing systems. A fiber optic serial link is used, which has encoded timing events and clocks that are generated and transmitted on the cable from a central location. Timing events are then decoded at the place they are needed, converted to electrical pulses, and fanned out as required. Changes and additions to the timeline are not as difficult as in the original system but require programmable logic device changes to add and change events encoded onto the timeline.

The new Linac timing system will be an encoded timeline as before but will use the RHIC generation VME timing system modules [3,4]. The V100 event encoder module will be used to encode and transmit event codes on the Linac timeline. The V100 is interfaced via a bus structure to V101 event input modules that each input 16 event triggers and determines their relative priority. Event triggers can originate from two sources, either external triggers or the event input can have a trigger written to it via the VME processor. The timing system will also use the V104,V102 decoder/delay modules. These modules connect directly to the timeline and provide decoded pulses from events or can provide delayed outputs from an event. The events to decode and the delay from these events are fully programmable through the VME processor. These signals can then be used to trigger other devices such as scopes or can be conditioned by external circuitry and the results put onto the timeline via a V101 event input module channel.

Using the RHIC timing system modules, a Linac timeline can be built without hard wiring or hard coding. The timeline can be changed by command from computers on the accelerator control network and/or by cable changes between modules at the generator. The timeline generator will be located in the Linac control room and the encoded timeline will be distributed along the linac via fiber optic cables. .

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