Model for RHIC Ramp Controls *

J. Kewisch, V. Mane, T. Clifford, H. Hartmann, T. Kahn, B. Oerter, S. Peggs
RHIC Project
Brookhaven National Laboratory, P.O. Box 5000
Upton, New York 11973

Abstract

This paper introduces the hardware and software concepts for the implementation of the ramp controls. The hardware part of the ramp controls consists of a number of multi-purpose Wave Form Generators (WFGs) which control the settings of accelerator hardware directly or indirectly by controlling their WFG. A Real Time Data Link (RTDL) data transfer system connects the WFGs in a three layer architecture. To the usual two layers which generate an independent timing signal and dependent set points, respectively, an intermediate layer is added which produces accelerator parameters such as the magnet strength. The task of the bottom layer is therefore reduced to the function of implementing those parameters. This architecture de-couples two independent functions which are normally folded together. The function of the hardware becomes modular and easily maintainable.

The ramp control software is layered in the same way. Between the top layer (the ramp procedure application program) and the bottom layer (the hardware interface) an additional layer of "manager" programs allow operation of accelerator subsystems.

1 INTRODUCTION

The Relativistic Heavy Ion Collider (RHIC) is an accelerator consisting of two intersecting storage rings. The rings are concentric and cross over in six interaction points so that each ring is on the inside in three sextants and on the outside in the other three sextants. The circumference is 3833.845 meters and superconducting magnets allow a maximum particle energy of 100 GeV/u for gold ions or 250 GeV/u for protons.

The accelerator uses the tunnel built for the Isabelle project. The existing AGS accelerator complex will serve as the injector for RHIC. The transport lines from AGS to RHIC are being installed and the first superconductive magnets for the collider have been delivered.

A ramp is the transition of the accelerator from one state into another. In order not to lose beam during a ramp, various widely distributed pieces of equipment must follow a pre-calculated waveform of set points synchronously. For the successful acceleration of the RHIC ion beam several different ramps must be performed: the injection (persistent current correction), the energy ramp, the γ_t transition jump, the rf rebucketing, and the beta squeeze. Although done without beam, the set-up of the machine for injection is also considered to be a ramp.

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The ramp system for RHIC is a critical component of the control system. The accelerator places the following requirements [1] on the system:

1. Devices need to be ramped synchronously.
   (a) The magnet power supplies use 12 phase rectifiers. Therefore an update rate of more than 720 Hz would not be necessary.
   (b) Faster response is required for RF controls while rebucketing and in the transition jump.
2. Due to intra beam scattering the gold beam emittance doubles at injection energy in 6 minutes. A highly automated system is necessary to inject and accelerate the beam in minimum time.
3. In order to avoid quenching the loss of protons or ions has to be minimized. The ramp curves need to be smooth.
4. The speed of the ramps is limited by:
   (a) maximum dB/dt is 0.05 T/sec for main dipoles
   (b) time necessary for switching power supplies
   (c) slow start of ramp and stop of ramp to maintain power supply regulation
5. In order to minimize heat losses the interaction region quadrupoles are wired using common feedthroughs. Therefore a single power supply influences up to 5 different magnet quadrupoles, and vice versa. The wiring should be transparent to the operator. Fig. 1 shows the wiring of the interaction region quadrupoles.

Many of the required features can be found at other accelerators such as the AGS and Fermilab's Tevatron. The experience gained from these machines has influenced the design of RHICs control system. Major design criteria were to make the system modular and maintainable. An object oriented view was applied to the designs of the software and hardware.

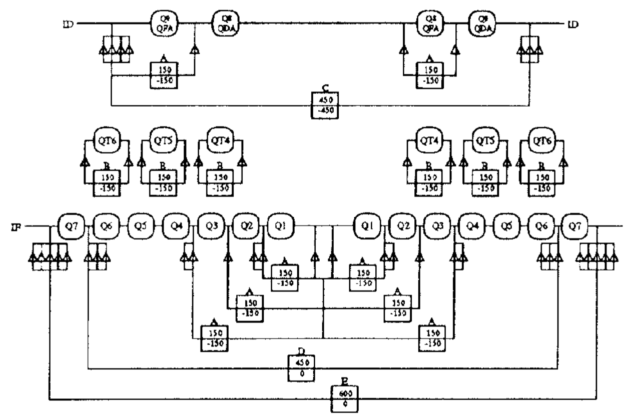

Fig. 1 Power supply configuration for IR quadrupoles.

2 HARDWARE ARCHITECTURE

In order to ramp the set points synchronously a real time data transmission system is necessary. As in the Tevatron control system, RHIC uses an event line and a data line. The data line, called Real Time Data Link (RTDL), transmits 255 variables with a update rate of 720 Hz [2].

The main element of the ramp controls is a waveform generator (WFG)[3]. Four of these generators occupy one VME card. The digital output of a WFG is generated from 3 tables according to the formula:

$$W = S_1 \cdot V_1 \cdot T_1(t) + S_2 \cdot V_2 \cdot T_2(V_4) + S_3 \cdot V_3 \cdot T_3(V_5)$$

where t is the time after receiving a start event on the event line, S_n are constant scale factors, V_n are variables on the RTDL line and T_n are constant tables. Since the WFG is controlled by the RTDL variables as well as by the time, its function is general. There will be about 1000 WFGs in the RHIC accelerator.

The T_1 table has 128 rows, the T_2 and T_3 table have 64 rows. A WFG can store 16 different sets of tables, scale factors and RTDL variable indices. For each set, 8 different events can be defined to start the ramp. Waveform parameters are all down-loadable from the Front End Computer (FEC) that controls the VME crate in which the WFG resides. The waveform output is calculated at a selectable rate of 720 Hz, 1 kHz, 5 kHz, or 10 kHz. For the fast control of RF components during transition jump and rebucketing, special single purpose devices will be developed.

The vast majority of WFGs provide their output values as set points to various accelerator equipment. Because of this common usage, a WFG also includes 2 digitizing channels of analog input, connected to circular buffers supporting circular, pre-trigger and post-trigger recording. The maximum recording time in these buffers is 10 seconds, at a rate of 720 Hz. In addition to the 2 analog channels, digital set point loop-back data can be recorded in the same manner.

While the output of a WFG usually goes to a piece of equipment as a setting, such as the current set point for a power supply, the output may also be used to generate a variable that is reinserted onto the RTDL line via an RTDL input module. This arrangement allows the use of a 3 layer ramp system [4]. The principle is shown in Fig. 2, using the example of the energy ramp.

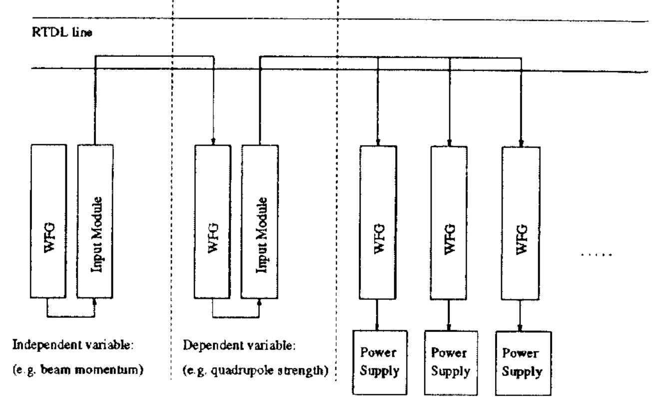

Fig. 2 Layout of the ramp control hardware.

The first layer contains a single WFG producing the independent variable, in this case the beam momentum, and sends it out on the RTDL line. This makes the beam momentum also available for purposes other than the ramp. This WFG in this layer is the only one using the time dependent table T_1.

Using the beam momentum as V_2 and V_4, the WFGs driving the equipment could calculate the necessary waveform given the proper table T_2. T_2 would be computed by folding the function of the equipment set point (e.g. the magnet strength) with the set point conversion function (e.g. the saturation curve). For the RHIC controls the two functions are unfolded. An additional layer of WFGs converts the beam momentum into an accelerator parameter and reinserts this value via an input module into the RTDL line. One additional WFG per magnet family is necessary.

The third layer (WFGs driving the equipment) adds the hardware specific set point conversion. Since this information is independent of the set point of the magnet, these tables remain unchanged after being down-loaded.

The three-layered structure makes the ramp procedure simple and modular. Intermediate parameters are available on the RTDL line for debugging.

3 SOFTWARE ARCHITECTURE

The software is also implemented in an object oriented manner. A layout of the software involved in the ramp control is shown in Fig. 3. The top layer is the ramp procedure. This program produces the waveform of the independent and dependent accelerator parameters and starts the ramp sequence. Instead of dealing with the accelerator equipment directly the program uses several servers which build the second layer.

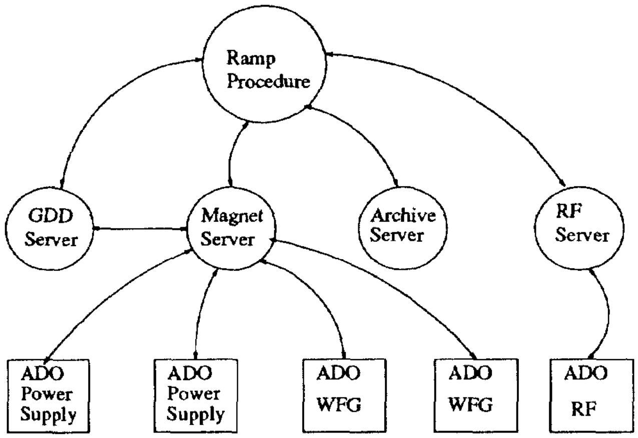

Fig. 3 Layout of the ramp control software.

A data base server using the Generic Device Description (GDD) format [5] supplies the information regarding which devices need to be set. An archive server allows access to stored machine data. A magnet server allows operating magnets and hides the complicated wiring of RHICs magnets from the high level program. The magnet server receives the wiring data also from the data base server.

Below the server layer is the equipment interface, called Accelerator Device Object (ADO). An ADO controls a piece of accelerator equipment such as a power supply. The equipment may interface to the control system through various VME cards. The ADO combines these into a single object.

4 REFERENCES

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