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DATA ACQUISITION AND CONTROL OF THE ZERO GRADIENT SYNCHROTRON 500 MeV BOOSTER SYNCHROTRON*

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Summary

A data acquisition and control philosophy for the Zero Gradient Synchrotron (ZGS) 500 MeV booster has involved a top down design incorporating all of the systems comprising the booster. Consideration of operational complexity was necessary because the booster is to be used simultaneously for ZGS injection, and solid state physics studies. Existing software and hardware capabilities of the ZGS computer were considered.[1] The resulting data acquisition and control system is based on a mix of sequential logic and a minicomputer. Hardware considerations were based on a ten year life expectancy of the booster. Due to time, budget, and manpower constraints, the incorporation of the total design has been divided into three phases of implementation. The first phase will be covered in this paper and the remaining phases will be outlined.

Introduction

Booster data acquistion and control are significantly different from the ZGS in operation because of the difference in time of an acceleration cycle. The ZGS injection-acceleration-extraction-rest cycle is nominally 4 s whereas the booster is 0.033 s. The 30 Hz rate of the booster is continuous since it provides beam for the ZGS and for neutron physics. The high rate of operation precludes using the ZGS data acquisition computer system. Fig. 1 shows a basic booster operational period based on the ring magnet operational profile.

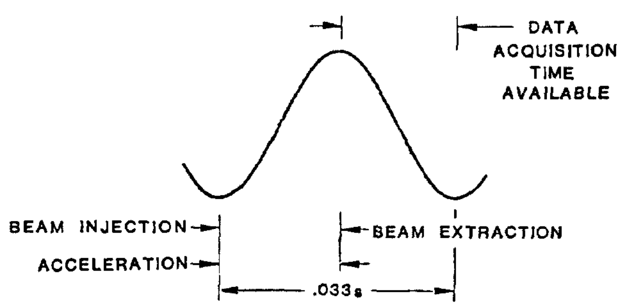

Figure 1.

The basic systems for booster operation are identified in Table 1, they are grouped by functional tasks and construction support requirements. After the booster systems were identified the support necessary for each in the form of data acquisition and control was defined. The basic classes of support are:

data acquisition: bistable signals
analog signals, and
pulsed signals,

control: bistable functions,
rotary functions, and
pulsed functions.

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Each basic class was further identified as to whether it was referenced to ground or floating. After the systems and their support were defined, Table 1 was used as a basis to define final system requirements based on existing time and manpower.

System Overview

The data acquistion and control system based on Table I is shown in the block diagram of Fig. 2. The block diagram is composed of three main subsystems:

1. analog data acquisition, display, and control,
2. bistable data acquistion, display and control and
3. stand alone control.

Although the subsystems are identified uniquely they may be used together in a relationship based on features that are desirable to incorporate in support of a particular booster system but not necessary for that system's operation.

TASK	ϕ1 - MINIMUM TURN-ON REQUIREMENTS	ϕ2 - MINIMUM TURN-ON REQUIREMENTS	ϕ3 - MINIMUM TURN-ON REQUIREMENTS	DATA			CONTROL			STAND ALONE
				BISTABLE	ANALOG	PULSED	BISTABLE	ROTARY	PULSED	
VACUUM: 50 MEV RING 500 MEV	VACUUM GAUGES VACUUM PUMPS BORE VALVES	UPGRADE RING VACUUM		•••	•		•			••
BEAM LINE: 50 MEV	MAGNET TRIPS MAGNET PARAMETER P.S. CONTROL	COMPUTER CONTROL	AUTOMATIC COMPUTER CONTROL	•	•			•		••
DIAGNOSTICS: 50 MEV 500 MEV	WIRE SCANNERS FARADAY CUPS TORROIDS	CRT DISPLAY			•••	•••				•
DIAGNOSTICS: RING	Q SYSTEM FARADAY CUPS POSITION MONITORS	CRT DISPLAY			•••	•••				•
BOOSTER RING:	BUMPER MAGNETS CORRECTION MAGNETS SEPTUM MAGNET BRMPS STRIPPER RF EXTRACTION KICKER	UNDEFINED		•••••••	••••••	•••••	•	•••••	•••	••
BEAM LINE: 500 MEV		MAGNET TRIPS MAGNET PARAMETER P.S. CONTROL INFLECTOR INJECTION KICKER	COMPUTER CONTROL	•••	•••	•		••		•
MCR:	INTERFACES CONSOLETTES TIMING	CTR DISPLAY DISC-ZGS COMPUTER INTERFACE	ZGS ALGORITHM MINICOMPUTER CLOSED LOOP	••						•
SAFETY:	MAGNET VOLTAGE RADIATION			•••			•••			•••

TABLE 1 - BOOSTER SYSTEMS & SUPPORT REQUIREMENTS

Analog Subsystem

The main component of the analog subsystem is the minicomputer, in this instance a Data General Nova 2/10. The minicomputer with its common bus input-output (I/O) architecture is desirable because of its ease in growth, thus supporting, phase 1 now and phases 2 and 3 later. The manufacturer was selected because of its present use in support of ZGS operations, thus taking advantages of familiarity, existing hardware/software support, and spare parts.

The analog data is gathered via two analog-to-digital converters (ADC) having a conversion time of 25×10^{-6} s and a full scale accuracy of 1 part in 10,000. Each ADC is supported by a 256 channel multiplexer. The two computers are software controlled in an interlace manner such that as one is told to convert the other is ready to output its conversion thus giving an effective conversion time of 12.5×10^{-6} s or a total conversion period of 6.4 ms for all 512 analog inputs. Data is gathered for all systems at a 30 Hz rate.

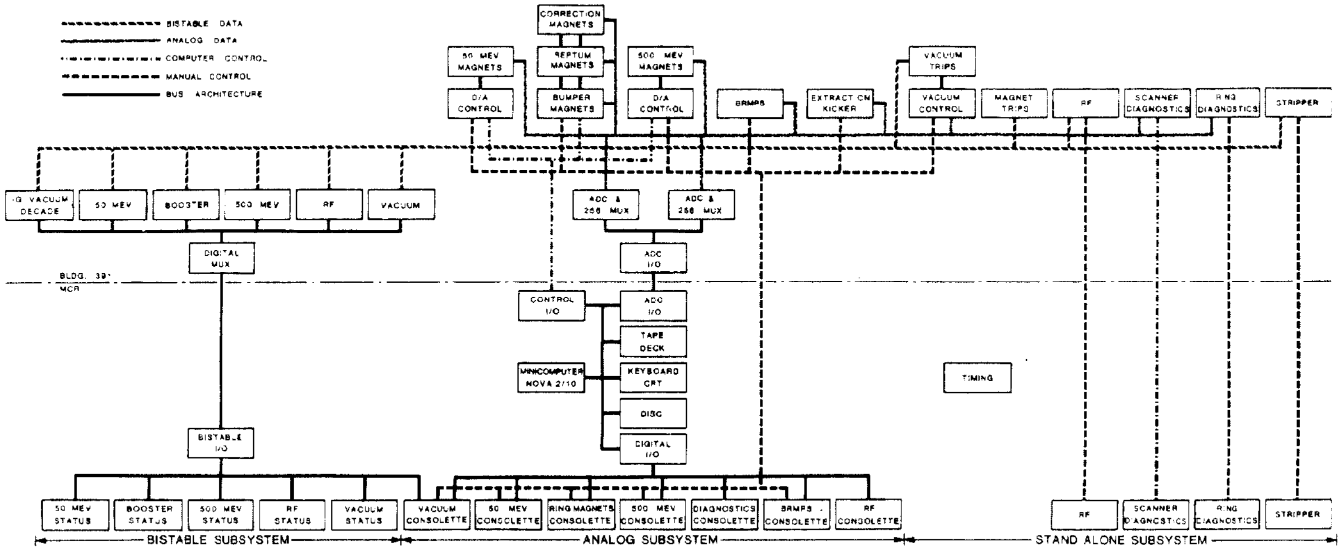

FIGURE 2 - BOOSTER DATA ACQUISITION & CONTROL SYSTEM BLOCK DIAGRAM

The digitized information is displayed via the data I/O (DIO) assembly and bus architecture on individual booster system consolettes. The main control room (MCR) consolettes are shown in Fig. 3. Each booster system has the capability of a digital readout (DRO), a selection switch matrix, manual control, and computer control. Data is updated at a 4 Hz rate improved for operator comprehension. Control of each system is via buffered digital-to-analog converter with resolution of one part in 4096.

The additional support of the minicomputer consists of: an I/O cassette tape deck, an I/O disc unit, and an I/O keyboard-CRT display. The keyboard-CRT will be used to support implementation of diagnostic algorithms and other simple data manipulation.

Bistable Subsystem

The bistable data acquisition and control require a less complex form of data manipulation. The digital I/O is comprised of sequential clocked logic that addresses and stores bistable information for 160 inputs. All data inputs are updated at 1 s intervals. The inputs generally consist of contact closures or buffered logic levels. The displays in the MCR are divided into five status panels generally along the task form of Table I. The actual warning indication is displayed "by exception",[2] this display mode does not illuminate normal status, thus if all systems are normal all five panels will be blank. The display by exception is used throughout the booster.

The bistable sequential logic is also used to monitor the ion gauges decade range in a 1-2-8 code. The MCR display uses the vacuum system consolette for selection on ion gauge, the analog subsystem for the intradecade portion of the display, and the bistable subsystem for the decade portion.

Stand Alone Subsystems

The stand alone subsystems are so classified because of a unique requirement based on application, control, data acquistion, etc. The stand alone systems are:

the vacuum system,
50 MeV wire scanner diagnostics,
ring diagnostics,
power supply protection,
the RF, and
magnet trips.

However, even though the systems are classified "stand alone" all of them use to some extent the analog and/or bistable subsystems but only in a secondary support role. Thus, as in the case of the vacuum system, automatic trips, pump control, and valve control are supported by its own sequential logic, the MCR uses the other two subsystems data acquisition and control to provide monitoring capabilities and limited beam line bore valve control. In all instances this philosophy was used so that these system do not require general support for emergency action.

Implementation Techniques

The entire booster data acquisition and control system was implemented and constructed in a modular form. By modularizing in a general manner all of the systems appear similar, thus a power supply has common functions whether it powers a magnet or an ion pump. By modularizing greater flexibility was provided in the construction and testing of systems as they became operational. This flexibility helped to focus attention on abnormal system requirements and provide the support attendant with them.

All bistable inputs are either contacts or buffered logic levels and were referenced only to the sequential logic; all analog transducers were scaled to +10 V full scale deflection; all controls were +10 V D/A values referenced to the unit. These general practices, in addition to hardware flexibility, provide the technicians with a universal first order skill in trouble shooting and maintenance of all of the systems.

The modular approach is in fact a form of human engineering along with the DRO update period. Other examples of human engineering used are: 1) uniformity of MCR consolette layout and operational function, 2) display by exception, 3) uniformity of transducer implementation, and 4) centralization of system location. The use of consolettes in the MCR was chosen over a keyboard-CTR in an effort to be compatible with existing ZGS equipment and to ease operator training.

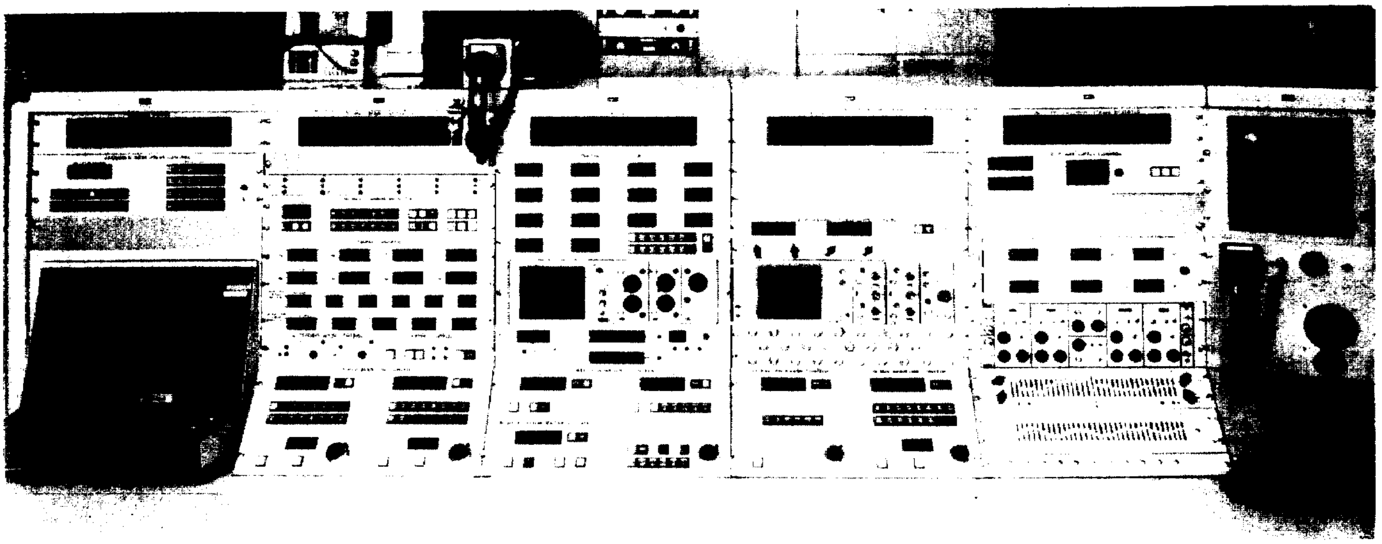

Fig. 3. Booster Displays and Controls

Implementation of Phases 2 and 3

As shown in Table 1 the future to the booster data acquisition and control system involves automation. The software support for this effort is expected to equal or exceed the present efforts on hardware. The newer phases will link themselves via the disc unit to the main ZGS control computer, this is principally because of the time constraint of basic minicomputer bookkeeping and the short accelerator period.

The software will benefit from the process of the learning curve of phase 1, thus phases 2 and 3 are only iterative growths and should gain ready acceptance by the operating personnel.

An example of phase 1, 2 and 3 being iterative dependent is the 50 MeV beam line data acquisition and control, and the wire scanner diagnostics. The beam line was initially configured with the aid of a program called MAYPO.[3] Power supplies, magnets and diagnostic were specified based on its calculations. In the initial tune up of the line the physicists and operators manually implemented the algorithmic values and modified them. Phase 2 is seen as entering values to the minicomputer and it automatically adjusts and maintains the currents at their designated values. Phase 2 can display the diagnostics beam profiles on the CRT for manual iterations. Phase 3 would take the MAYPO program as an on line program of the ZGS central computer, interface via the disc unit to the minicomputer, and close the loop of automatic adjustment and readout for an iterative best fit of the beam line transport.

References

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