A COMPACT DATA ACQUISITION AND CONTROL TERMINAL FOR PARTICLE ACCELERATORS*

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Summary

The present trend towards automation of information-processing in particle accelerators dictates the need for a thorough evaluation of the method used in collection and dissemination of this information. A compact, remote terminal for use in automatic data acquisition and control of particle accelerators will be described. The terminal may be controlled by either special-purpose digital logic or by a central control computer. Interfacing to the various accelerator equipment is provided through analog and on-off control and monitoring modules. The detailed design of the logical portion of the remote terminal, in regard to data format, instruction, and command decoding, will be discussed. The method of selection of the appropriate module interface for completion of the desired function will also be treated. In addition, the equipment-interfacing design criteria resulting from actual implementation on accelerator devices will be discussed.

Introduction

A simple survey of the control system philosophy specified and incorporated into the present-day medium or high energy particle accelerator indicates a definite trend towards automation of information processing, as contrasted to the "Big Machines" of a decade or so ago.

The automated control system, generally based upon a digital control computer, may encompass only a portion of the accelerator controls[1,3,9] or implement the entire control problem.[2,10] The partial or total automation of accelerator information processing, while extending the "control vistas" of machine physicists and engineers, introduces additional termination and interface problems at control points throughout the entire installation.

The intent of this paper is to describe the remote data acquisition and control terminals to be used in the Los Alamos Meson Physics Facility (LAMPF) 800-MeV proton linear accelerator. The basic design objective of the terminal is the effective collection and dissemination of control information at approximately 60 remote points along the accelerator. Each terminal, under control of a digital control computer located in the Central Control Room (CCR), receives serial-digital function requests, processes them, and, if required, passes serial-digital information back to CCR.

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Functions of the Remote Terminal

The remote terminal is able to perform the basic functions of (1) monitoring on-off and analog variables and transmission of this information back to CCR and (2) initiating on-off and analog set-point control in various accelerator equipment throughout the terminal's area of influence. In addition, relay switching of pulse analog signals over coaxial transmission lines to CCR is considered an important feature.

The monitoring functions performed by the terminal are termed Video Select (VDO), Binary Data-Take (DTKB), and Analog Data-Take (DTKA). The control functions performed are termed Binary Command (CMDB) and Analog Command (CMDA). These functions must be executed reliably and at speeds compatible with the degree of control sophistication desired in the overall operation of the accelerator. In addition, monitoring function requests may be executed during the execution of a control function. This feature allows the possibility of true dynamic sampled-data control.

Remote Terminal Components

The remote terminal, as shown in Fig. 1, consists of four distinct component groups. These are the terminal control or RICE (Remote Information and Control Equipment), the interface logic or RICE I/O (Input/Output), the analog data system (ADS), and the local controls. The operation of the terminal will be discussed from the point of view of the interaction of CCR with the terminal and various accelerator equipment.

Remote Terminal Operation

Each remote terminal is coupled to CCR by two high-grade, twisted pair, shielded cables. These cables serve to convey the serial digital information to and from the terminal. The decision to utilize serial rather than parallel data transmission was based on cost factors and the required data rate needed to effectively control LAMPF in a supervisory mode (<200,000 bits/sec, burst rate).

Function requests and transmissions to CCR are coded (phase lock, pulse-code modulation) with odd-parity included in each data burst. Ground isolation and security from noise-induced errors is provided by transformer coupling at each transmitter and receiver[5] and by signal-filtering and discrimination at each receiver. Other laboratories[6,7] have provided this ground isolation through the use of differential amplifier data receivers with equally good results. Figure 2 depicts the form of digital transmission to and from the remote terminals.

Data flow into the terminal is checked by RICE for validity of the operation code and correct odd-parity. Should either be in error, an Error Return transmission (Fig. 2) is sent to CCR. This transmission indicates that the last function request was not accepted by the terminal in question and further action is necessary.

Immediately following the operation code, a seven-bit channel address is received. In the case of monitoring function requests, a final parity bit will conclude the request. Control function requests will contain, in addition, a twelve-bit instruction, followed by the final parity bit. Figure 2 depicts the serial-data function request formats.

The receipt of correct parity on any of the five basic function requests will cause RICE to transfer the received channel address and steering terms to RICE I/O for completion of the request. Figure 3 depicts the interconnections between the terminal components.

Monitoring Function Requests

Video Select (VDO) - the channel address and steering terms transferred to RICE I/O actuate a relay switching matrix called the Video Control Unit. The matrix switches a pulse-analog signal onto a high grade coaxial cable running to CCR. The analog variable may then be viewed on an oscilloscope located in the console area of CCR.

Binary Data-Take (DTKB) - the interface logic located in RICE I/O is enabled and receives the on-off status in groups of twelve binary-data bits. Local control modules provide the interface to the accelerator equipment. These modules also provide a local indication of device status. RICE I/O then transfers the twelve-bit status word to RICE for transmission to CCR.

Analog Data-Take (DTKA) - the interface logic located in RICE I/O and in the ADS is enabled and the low level, differential multiplexer in the ADS switches the selected analog variable to a twelve-bit analog-to-digital (ADC) converter. The twelve-bit word resulting from the ADC conversion is transferred through RICE I/O to RICE for transmission to CCR. A schematic of the ADS is shown in Fig. 4.

Control Functions Requests

Binary Command (CMDB) - a group of twelve relays located in RICE I/O, corresponding to the channel address, is actuated by the twelve-bit command instruction. A binary "1" will close a relay. The twelve isolated RICE I/O relay contacts (for the selected channel) are wired to binary-command local control modules. Relays within these local control modules are actuated by the RICE I/O relays and, in turn, control various accelerator equipment. The local binary-command modules also provide local indication of status and a means of operating the equipment locally. A latch circuit within RICE I/O logic allows one to switch between CCR and local operation without affecting the equipment status.

Analog Command (CMDA) - the twelve-bit instruction held by RICE contains the sense and number of pulses sent to RICE I/O. These pulses are transformer coupled to analog-command local control modules located throughout the terminal area. Pulse motors located in or near these modules serve to turn potentiometers or actuate valves, etc., thus providing a means of set-point control.

It should be noted that the described method used for analog commands was selected on the basis of the required degree of control sophistication throughout the accelerator. The time required to rotate a set-point potentiometer ten complete turns (a count of 2000 decimal with the pulse motors used) is approximately 6 seconds. This would then be the time interval required to implement a full-scale change in set-point to some device.

The requirement of dynamic control of various analog systems, dictating the need for parallel transfer of the control word to a digital-to-analog (DAC) converter, was not included in the basic control philosophy.[4] Computer control systems at other laboratories[3,7] have incorporated parallel transfer of control words to DAC units; however, the nature of the control problem handled by these systems is somewhat different. An analog-command and a binary-command local control module is shown in Fig. 5.

Remote Terminal Construction

RICE and RICE I/O are implemented, with a few exceptions, with diode-transistor micrologic (DTL) elements placed on printed circuit cards. Commercially available card files contain the cards.

A small panel, mounted on one RICE card, contains the necessary controls for manual operation. This feature allows one to manually send RICE a function request for setup or maintenance operations.

Both the ADS and the various local control modules are packaged in Nuclear Instrument Modules (NIM) for their shielding and flexibility.

Conclusion

The LAMPF Remote Data Acquisition and Control Terminal, as described in this paper, will provide an efficient and economic means for collection and dissemination of accelerator control information under the guidance of a central control computer. All forms of information needed for supervisory control of the accelerator are available to the computer at compatible data rates. The accelerator equipment may be operated locally through local control modules designed for easy connection to the terminal.

In addition to the fixed area usage throughout LAMPF, terminals may also be housed in mobile enclosures for use in accelerator development or particle physics experimentation.

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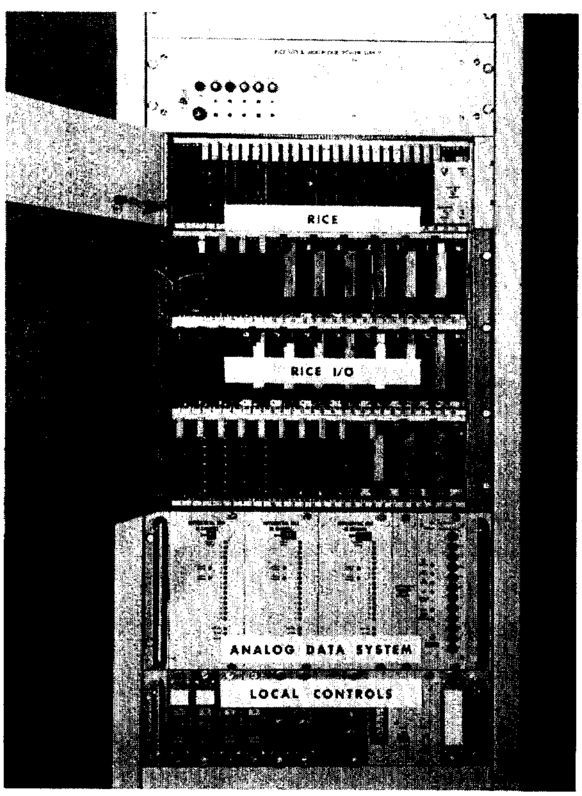

Fig. 1. LAMPF Data Acquisition and Control Terminal.

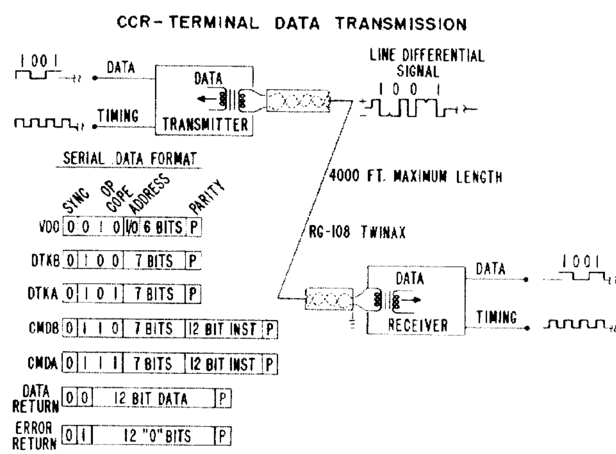

Fig. 2. CCR to Terminal Data Transmission and Formats.

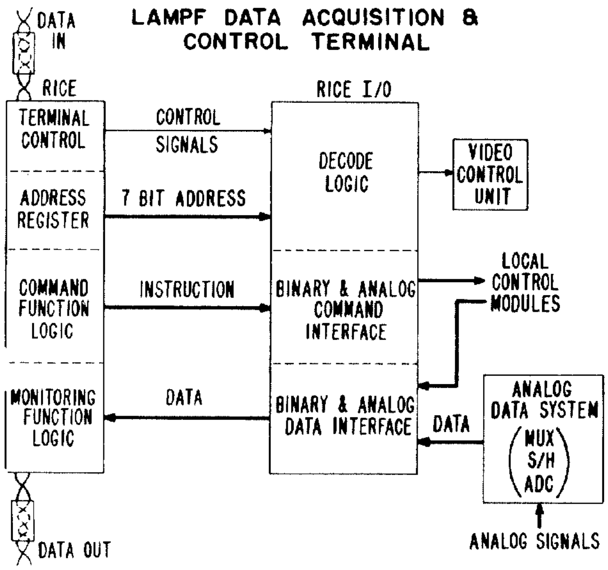

Fig. 3. Data Acquisition and Control Terminal Block Diagram.

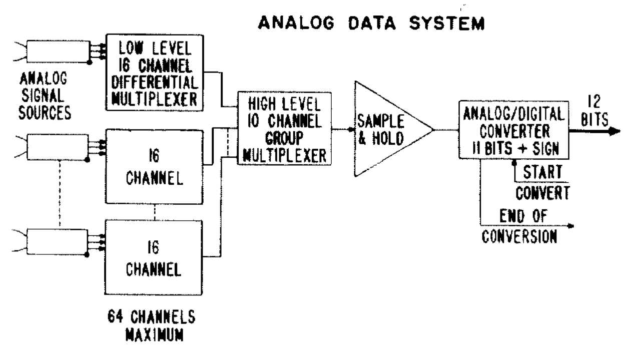

Fig. 4. Analog Data System.

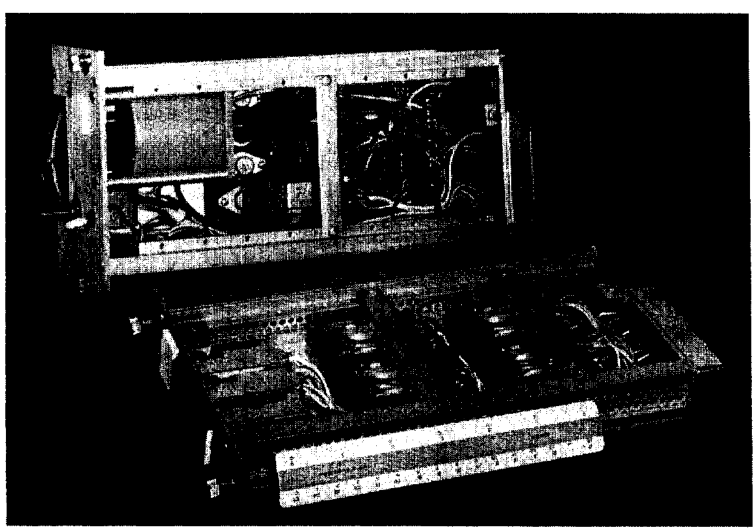

Fig. 5. Analog and Binary Command Local Control Modules.