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A MULTI-PURPOSE DIGITAL CONTROLLER FOR THE LEP RF SYSTEM

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Summary

The RF system for the initial phase of LEP consists of eight identical units. Each RF unit contains a large amount and diverse range of equipment. The control configuration within an RF unit is described and the main categories of control parameters summarized. A description of the digital control units 'equipment controllers' used for the interface to and the control of the elements making up the RF unit is given. The design is such that as far as possible the same hardware (and software) can be used for the control of all the various pieces of equipment. The hardware is based on the G64 bus standard widely used at CERN and most of the software is written in Pascal. The equipment controllers are also used for various tests on RF equipment and 22 have been installed in a complete prototype RF unit (Test String). The 176 required for LEP are at present being manufactured in outside industry.

Introduction

The RF system for the first phase of LEP will consist of a total of 128 coupled cavity assemblies operating at 352 MHz producing up to 400 MV circumferal voltage. The system is arranged as eight identical RF units installed in pairs on either side of interaction points 2 and 6. Each RF unit is made up of 16 coupled accelerating cavity/storage cavity assemblies, two 1 MW klystrons with modulators, a 3.6 MW dc power supply and high voltage equipment, cavity vacuum equipment and a large amount of associated low power and control electronics.

RF Unit Parameters

In addition to the normal functions required for machine operation the relative complexity of the RF unit and its remoteness from the control centre require a maximum amount of monitoring to be carried out automatically and locally. Also the status of all parameters which can influence the behaviour of the RF unit must be known remotely via the computer system.

The main categories and the number of individual parameters per RF unit are listed below:

(a) Control of power supply and HV equipment, klystrons and related equipment. 58

(b) RF power measurements and calibration factors for klystrons, waveguides and cavities (via power meters). 148

(c) Cooling temperatures on HV equipment, klystrons, waveguides and cavities (via temperature scanners). 284

(d) Interlocks on HV equipment, klystrons and cavities. 282

(e) Cavity tuning loop control signals, detector signals, tuner controls and position readouts. 1136

(f) Low level system parameters, e.g. function generator values, RF voltage and phase, loop controls, timing, RF synchronization and fast timing. 54

(g) Cavity vacuum gauge/pump readings and status. 64

In addition, since a large fraction of the faults which can occur in low power and control electronics are due to power supply faults, the output levels of over 350 such supplies will be interfaced to the control system to allow automatic checking.

The total number of parameters to be controlled or read is of the order of 2400 per RF unit.

Control of the RF Unit

Each RF unit is identical and the control configuration is such that each unit may be run independently, either locally or remotely via the control system.

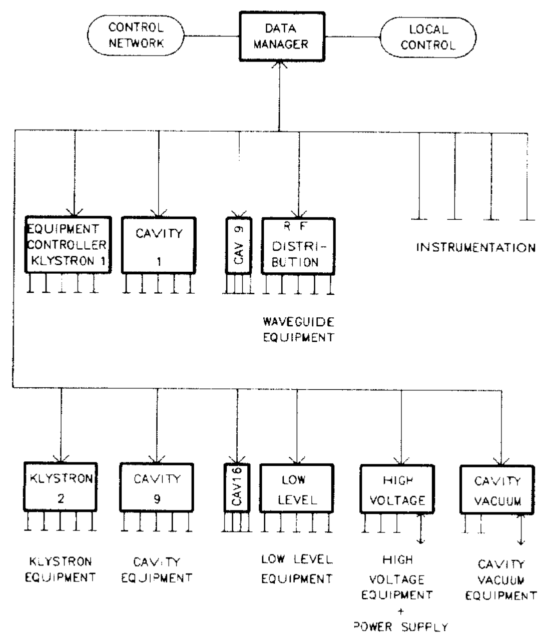

Fig. 1: Digital Control of one RF Unit.

A crate called an 'equipment controller' is assigned to every individual major piece of equipment in the RF unit. There is one equipment controller for each klystron, one for each cavity, one for high voltage equipment, one for the waveguide system, one for low level electronics and one to link to the separate cavity vacuum equipment. There are a total of 22 equipment controllers per RF unit.

A 'data manager' provides overall control of the RF unit. It provides the connection to the computer network and also allows local control.

The equipment controller contains interfaces to all the hardware associated with the piece of equipment. Information on the details of the interface, control procedures, calibration factors etc. is contained in the equipment controller permitting control and acquisition to be carried out by the transfer of simple messages to and from the data manager.

Since it has access to all the control functions and parameters of the equipment the equipment controller can independently provide surveillance of the equipment plus logging and local display of all equipment parameters. It also carries out calibrations and certain closed loop control functions.

The connection between the equipment controllers and the data manager is by IEEE488 (GPIB) bus. Use of the GPIB bus allows easy connection of commercial instrumentation into the system. It also allows the possibility of checking equipment controller functions and carrying out tests on the individual pieces of equipment using practically any computer.

Equipment Controller Hardware

The equipment controller is contained in a split 6U eurochassis as shown below.

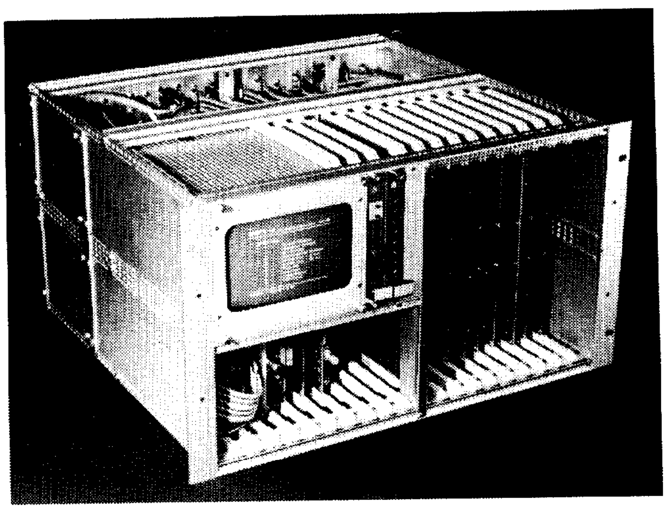

Fig. 2: Equipment Controller (Cavity version).

The equipment controller chassis contains a 20-slot G64 bus driven by a Z80 microprocessor. System G64 modules such as processor, memory, GPIB etc.which contain few I/O connections are plugged into the 3U section on the lower left. There is also an EEPROM card which holds calibration constants and nominal values. A CRT monitor for local display is situated above.

Equipment interface modules are contained in the 6U section. These modules have the G64 interface on the lower connector and I/O connections on the top connector. The I/O is brought to the rear of the crate. The connections are brought out to individual rear panels and are arranged such that the maximum use can be made of flat cables. Where flat cables cannot be connected directly to the external connector small adapter boards are mounted on the rear panel. Interlocks are however wired directly.

Standardization of connections early in the design of the equipment has allowed maximum use of a small set of 6U I/O modules. The standard modules are: 16-bit parallel input-output with optocouplers, 16-channel 12-bit ADC with input protection and

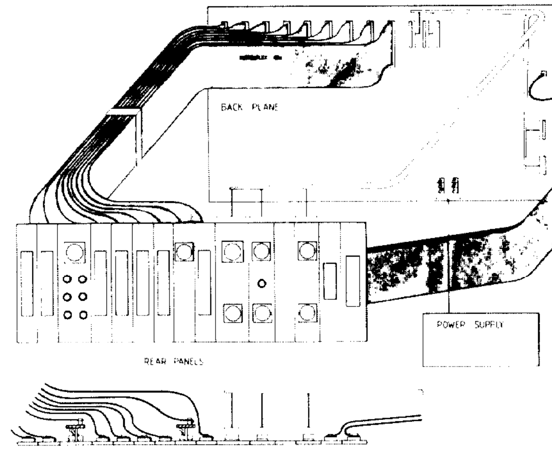

Fig. 3: Connections to Rear of Crate

eight-channel 12-bit DAC. In a small number of cases special interface modules are used e.g. HV measurements via optical fibres and klystron heater and focus control.

Connection to the remote power supply control electronics is by a current loop link in the high voltage equipment controller. Connection to cavity vacuum equipment is by an RS422 based network with a drop to each cavity equipment controller. Temperature scanners and RF power meters are interfaced using parallel I/O modules. The interlock system is modular and is contained in the equipment controllers. The interlock modules are situated in the top part of the crate just to the left of the 6U/3U separation. The interlocks themselves are hard wired. The status of the interlock modules passes by a small backplane bus to an interlock interface module situated in the first 6U slot. Information on the first fault when a series of faults occurs is latched in the interlock module and can be read by the processor.

All equipment controller types are made up of the same basic elements, the main differences being the actual interface modules used and the I/O connections, the number of interlocks and the use of special modules where required.

Software

Most of the software is written in Pascal. The compiler used is Turbo Pascal™ running under CP/M 80™. This compiler has the feature of having rapid compilation time, particularly when compiling to memory. The individual driver routines making up the equipment library for each piece of equipment can be developed and debugged rapidly. Debugging can be done in situ if necessary by connecting a terminal and floppy disc drive to the crate concerned.

The final program consists of a main loop, a command interpreter and a library of equipment routines. As far as possible the same basic elements are shared between the various equipment controller versions. The relevant set of source files are put together, compiled directly and the code put into EPROM. No intermediate assembler or link files are involved which simplifies software maintenance. A small amount of code - drivers for GPIB and local display - has been written in assembler.

™ Turbo Pascal and CP/M 80 are trade marks of Borland International and Digital Research.

The main program loop carries out surveillance and local display if selected. The overall status (e.g. OK, fault, warning) of groups of parameters (in some cases all parameters) are collected and made available to the data manager in order to simplify its task of surveillance of the RF unit.

Cavity equipment controllers keep records of RF and vacuum history over 20 hours with a resolution of 3 min and over 3 h with a resolution of 30 s. This information can be sent over the GPIB interface to the data manager or displayed locally.

In general parameters can be displayed in groups, the selection being by a front panel digit switch. Up to nine pages can be selected.

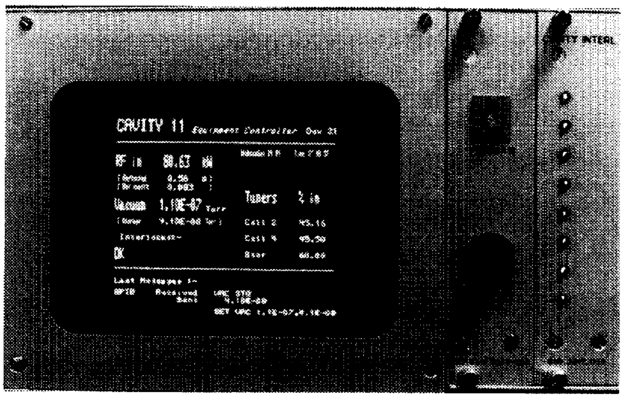

Fig. 4: Example of local display

Communication between the data manager and the equipment controller is based on the transfer of ASCII strings on a simple command/response basis. Commands are initiated only by the data manager. Reception of a command by the equipment controller ('My Address' on the GPIB interface) produces a hardware interrupt which causes the processor to jump to a command sorting routine. This then calls the appropriate equipment routine to carry out the required action and prepares a reply to be sent on a subsequent interrupt.

Since the equipment controllers handle a diverse range of equipment a command format is required which allows a large number of possible commands which at the same time can be easily processed by the command sorter. The command format used allows up to four words. These are delimited by spaces and except for the last only the first three characters of each word are significant.

FUNCTION
e.g. REAd,SET,INCrement,DECrement,CLEar,TESt.

NAME of individual piece of hardware
e.g. TUNer,DRIver,DETector.
or general parameter type
INTerlock,TEMperature,RFPower.

ATTRIBUTE or property (if required)
e.g. VOLtage,OUTput,FORward

VALUE
e.g. Numerical value, ON, LOCal

Examples: SET DET SP3 0.95
sets cavity detector set point 3 to 0.95.

CUR
reads klystron dc current from a klystron equipment controller.

SET DRI LOC
sets a driver amplifier to local control.

The default for Function is REAd. Value where appropriate is simply taken as the last word of the command.

The command sorter first breaks down the command then uses 'NAME' to jump to a block where 'ATTRIBUTE' and 'FUNCTION' are used to identify the action required.

The total amount of Pascal in the overall program is between 2000 and 2500 lines depending on the equipment controller version. This occupies around 30k EPROM and 8 k RAM. The run time library for the compiled code occupies another 8 k EPROM. Assembler for GPIB and local display drivers occupies 3 k.

Applications in RF Equipment Testing

1) **Klystron Acceptance**
Each klystron goes through a series of acceptance tests when received from the manufacturer. RF power, load power, dc power and efficiency are measured automatically using a single crate similar to a klystron equipment controller. The various test programs required are loaded from floppy disc.

2) **Cavity Conditioning**
Before installation each cavity assembly must be conditioned to full RF power. Two automatic conditioning stands have been made [2]. Each test stand has a cavity equipment controller and a klystron equipment controller connected by GPIB to an intelligent touch terminal which controls the conditioning process. To date 100 cavities have been conditioned.

3) **Test String**
A complete RF unit has been constructed to check all aspects of generation and distribution of RF power. All equipment, including the 22 equipment controllers, is as far as possible the same as that which will used in LEP. The test string has been running for short periods over nearly two years and has permitted the development of final software in the equipment controllers.

Series Production

The 176 equipment controllers for the LEP RF system are at present being manufactured in industry. An automatic system is used to test the complete crate on reception. At present 80 have been received and are ready for installation. Installation in the klystron tunnels is due to start towards the end of 1987.

Acknowledgements

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