

## Digital Control of the LEP RF System

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**Abstract** The RF system for the initial phase of LEP consists of eight identical units of 16 cavity assemblies with associated high power and control equipment. These units are installed underground, distant from the control centre, and each one has around 2,500 parameters and status indications, all of which must be remotely accessible. Digital control is achieved by assigning a G64 based 'equipment controller' crate to each major element of the unit linked by a bus to a VME based 'data manager' with overall control and connection to the control network. It executes locally or remotely initiated complex control and surveillance procedures to simplify operation. The different classes of parameter and data are summarized. Interfacing with the data manager are outlined. The form of equipment access functions and the development of complex control procedures are discussed. The implementation of corresponding functions at control console level is discussed. Finally experience with the six RF units presently installed is described.

### Introduction

The LEP accelerating structure, consisting of 128 cavity assemblies, is physically split into units of 16 such assemblies. Each assembly is made up of a five-cell accelerating cavity side-coupled to a low-loss storage cavity. The output of two 1 MW CW klystrons with slightly different frequencies[1] are combined in a magic-tee hybrid junction. Each output of the junction then feeds a group of eight cavity assemblies via three stages of magic-tee dividers.

It was decided at an early stage in the project to treat a unit of 16 cavity assemblies together with the two klystrons and all the associated drive and controls electronics as a 'stand-alone' element from a controls point of view. This is also reflected in the choice of one HT power converter for supplying d.c. power to two klystrons. The control of this power converter forms part of the global control system for one RF unit. Furthermore a modular approach inside the RF unit itself was adopted. Each major element inside the units — cavities, klystrons, HT power supply etc. — is controlled and interfaced via an 'equipment controller' using as much as possible the same hardware and software for the various elements[2].

All the major elements of an RF unit are housed underground. A klystron tunnel parallel to the main tunnel at a distance of 8 m contains the klystrons and associated HV equipment, part of the waveguides and all the low power and drive electronics. These klystron tunnels are located on both sides of intersection points 2 and 6, far away from the LEP control centre.

In line with the modular approach, each RF unit can be run independently of the others and also independently of the general LEP control system for test of all major functions. A dedicated multiprocess controller - the RF data manager - installed in each RF unit[3] is linked to the equipment controllers by a bus system. This data manager executes control and surveillance procedures locally. The same processes can be initiated remotely via the

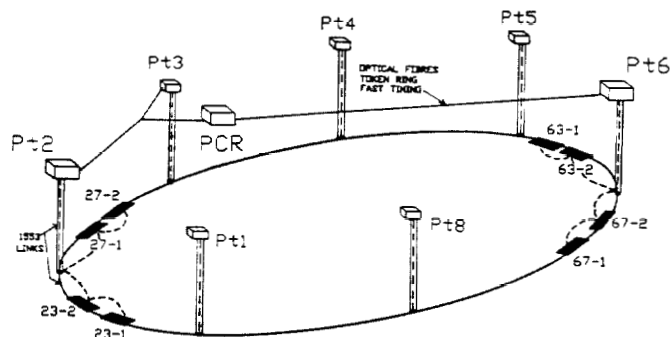


Figure 1: Control Layout of the LEP RF System

general control system. All the equipment for the generation of RF frequency and phase reference signals for LEP, together with equipment for producing beam-related synchronizing signals for injection, is located in the LEP control centre (PCR). This equipment is controlled using the same approach as for the different RF units, with the same type of hardware and software.

### RF Parameters and Data

The classes of parameters, data and status indications to be accessed in the RF units can be categorised broadly as follows :

- Direct control of power converter and klystrons — e.g. Main circuit breaker, power converter output, klystron filaments, focus, drivers, klystron current etc.
- Low level system parameters — e.g. RF voltage and phases, loop status, fast/slow timing, function generator data.
- RF power measurements — klystrons, cavities and waveguides.
- Air and water cooling temperature measurements.
- Cavity tuning loop control, status signals and drive motor controls.
- Cavity vacuum gauges/pumps status and readings.
- Protection interlocks on HV equipment, klystrons and cavities.
- Low voltage power supplies.
- The total is around 2500 per RF unit.

For the surface buildings and PCR :

- RF frequency synthesis and distribution.
- Fibre optic transmission.
- Beam synchronised timing.

### Controls Configuration for the RF System

The control layout of the RF system for LEP Phase 1 is shown in Fig. 1. The eight accelerating units are grouped in pairs around intersection points 2 and 6. The four units at each point are connected by a MIL-1553 multidrop to the surface building where a process control assembly (PCA) provides the connection to the

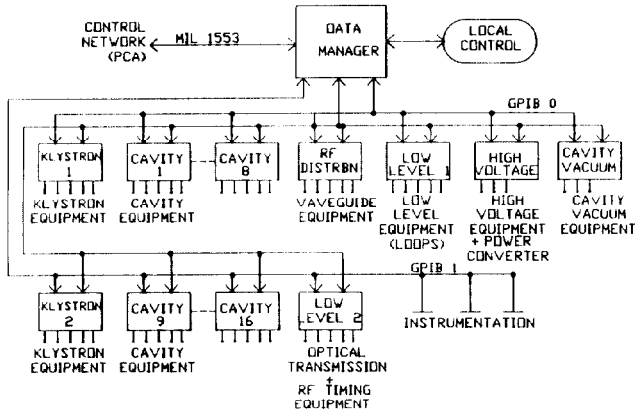


Figure 2: Control Layout of an Accelerating Unit

token ring network of the control system. Optical transmission equipment for synchronization and fast timing situated in the surface buildings and in the Preessin control room (PCR) is connected in a similar manner.

The control layout of the RF unit is shown in Fig. 2. The data manager allows remote control via the MIL-1553 and local control via a touch screen and colour display. It can independently execute remotely or locally initiated tasks e.g. switch-on procedures or conditioning processes. A local surveillance background process provides global data and alarms. The access to the equipment inside the RF unit is via 23 G64 based equipment controllers. Connection between data manager and equipment controllers is by means of two separate GPIB buses and an RS422 based LAN, the latter being primarily for the distribution of cavity vacuum data.

The equipment in the PCR is interfaced by four equipment controllers as shown in Fig. 3. A data manager provides similar facilities as in the accelerating units. Connection to a the main control system is via MIL-1553 and a PCA. The surface building equipment for each point is interfaced via a single equipment controller which has a direct MIL-1553 connection to the PCA.

### Communications

Equipment controller communication is based on the command response transfer of simple messages in the form of ASCII strings. Any parameters required are included in brackets after the command. Any command other than a simple read is prefixed by a character denoting the action and an underline character, the aim being to permit a simple protection mechanism.

The same command/response principle is used for communication between the PCA and the data manager over the MIL-1553. Commands are in the standard family, member, action, mode, useroption format[4]. Family and member are used by the PCA to route the message to the appropriate MIL-1553 drop. The action field is used by the data manager to determine the equipment to be acted on. This can be the data manager itself, an individual equipment controller or a group of them. The useroption field contains the command string.

A single remote procedure call (RPC) over the network permits the transfer of these strings from the control room console to the

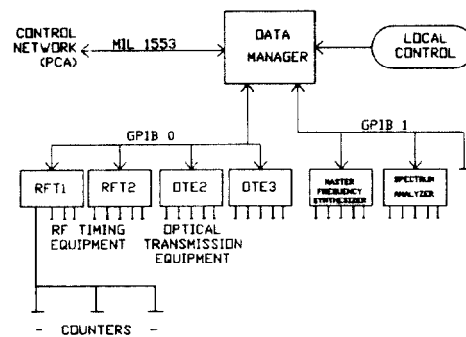


Figure 3: Control Layout of PCR Equipment

appropriate PCA. This allows straightforward equipment access from the control system and also allows the application software for the control room consoles to be built up in a similar way to the data manager software.

### Software

The low level software of the equipment controllers was developed in Pascal and is fixed in EPROM. Both data manager and control console software are written in 'C'.

Data manager software is built up on a library of around 500 equipment access functions. These are implemented as macro definitions which use a basic set of bus transfer and data conversion routines to send the appropriate command to the equipment required and convert the reply to the required data type.

Equivalent macro definitions and function calls exist for the control consoles. In this case an error status is returned for all functions, a pointer to the result variable being passed in the function call.

For example, to obtain the sum of all 16 detected cavity RF levels in RF unit LRF.631 the 'C' program statement is:

```
com_stat = LRF_dsum(LRF_631,&result)
```

Where LRF\_631 is an integer representing the unit and result is a float. The return value of the call is an unsigned long giving the error status. The call is a macro and the expansion is:

```
com_stat = lrf_eq_float(LRF_631,LL1,"dsum",&result)
```

The parameter 'LL1' indicates that the low level 1 equipment controller is the destination. The function lrf\_eq\_float() calls the RPC and forms a floating point value from the reply.. The RPC transmits the parameters to the PCA which forms the MIL-1553 message string:

```
"LRF_631,LL1_RS,0000.0000!dsum"
```

When the data manager receives the MIL-1553 message it directs the command to the device over the local bus by executing the following statement:

```
reply_string = rbtomil(mbusr(LL1,"dsum"))
```

The local bus transaction is made by mbusr() and the resulting reply is converted by the function rbtomil() to MIL-1583 format of the form:

```
"R!98.350"
```

To acquire the same information locally, the data manager software would use the statement:

```
result = dsum()
```

The call is again a macro and the expansion is:

```
result = rbtof(mbusr(LL1, "dsum"))
```

In this case the result string from the equipment controller is converted to floating point type by rbtof().

At the present time data manager and equipment controller software is complete. Essential software for equipment access, accelerating unit switch on, voltage ramping and surveillance has been written for the control room. The interface to the interactive graphics package used for LEP controls comparable to that already running on the data managers is under development. Work has started on more elaborate software which will be required for routine control room operation.

### Present Status

Six of the eight RF units are presently installed and have run up to full nominal RF power. Although the application software is not in its final stage, all the units can run simultaneously with full remote control from the PCR over the general LEP controls network. Two of the units have been used successfully for simultaneous ramping of the magnetic field and the RF volts using a simulation program for keeping a constant synchrotron tune from the injection energy to the present maximum collision energy for LEP. The last two RF units are presently being installed and are scheduled to become operational in April.

### Future Operation with Superconducting Cavities

The superconducting cavities will also be installed in units of 16 cavities. Generally, as far as possible the same equipment as for the copper cavities will be used. For the controls, the approach will be the same and to a large extent exactly the same hardware and software will be used. The controls for the cryogenic system are kept separate and do not form part of the general LEP control system.

### Conclusions

The modular approach for the controls of the LEP RF system, together with an interactive local control facility, has been vital in commissioning and testing of the RF system. It also allows the addition of units with superconducting cavities to be integrated gradually into the controls system with minimal disturbance to the operation of the accelerator.

### Acknowledgements

We highly appreciate the collaboration of R. Keyser and his colleagues in the software section of the LEP Controls Group for their help with the integration of the RF controls into the general LEP controls system.

### References

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