A Flexible Control System for the SRS RF Cavity Test Facility

S.F.Hill and M.J.Pugh
DRAL Daresbury Laboratory, Daresbury, Warrington WA4 4AD, UK

Abstract

In order to improve the data taking capabilities of the RF cavity test facility at Daresbury a modular control system has been installed. It uses a Motorola single board computer on VME running under the OS-9 real-time operating system. The input and output systems are based on IndustryPack (IP) modules, offering economy and flexibility of configuration. Software has been written and commissioned, with a standardised console interface program and I/O routines all interconnecting by way of a C structure database, the generator for which was developed at Daresbury for use on the new SRS Beam Steering System.

1. INTRODUCTION

The RF cavity test facility at Daresbury consists of a 50 kW 500 Mhz transmitter and a spare SRS single-cell cavity. The power is transmitted in 6 " coaxial line from the transmitter, then fed to WR1800 waveguide for coupling to the cavity through a planar ceramic window. The system was run from the mid 1970's to the mid 1980's, during the construction and early commissioning and operating of the SRS. Operation of the system was almost totally manual, with no computer control or monitoring.

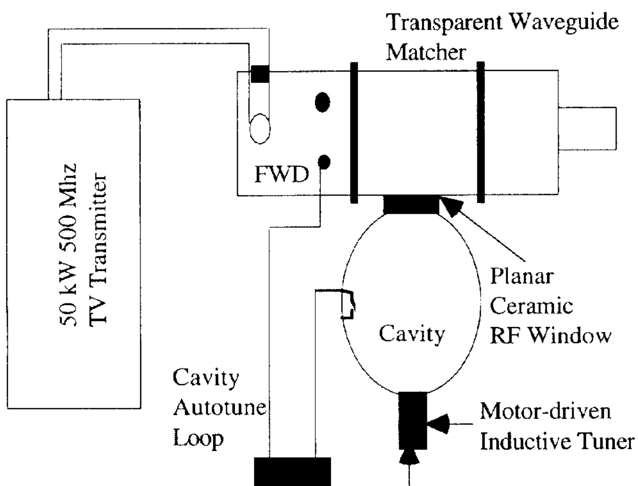

Figure 1. SRS RF Test System Layout

With a planned refurbishment of the test facility, it was decided to bring in a large amount of machine control, the details of which are described.

The projects anticipated for the upgraded test facility include: testing a large number of rf ceramic windows for use as SRS spares; identifying and characterising cavity and window multipactor behaviour and investigating the best methods for cavity conditioning. It would also be used to provide a test bed for new low-level rf systems design, including high performance amplitude and phase control loops for cavity auto-tune control, for both the SRS and future accelerators.

2. CHOICE OF HARDWARE

The basic computer platform was chosen as a Motorola MVME-147 single-board computer[1], residing in a VME crate. This would allow flexibility in the configuration of system interfacing, with space available for expansion. The VME system is also engineered for remote/continuous operation, with a sophisticated power supply monitor/trip circuit, and is supplied with continuous-duty rated cooling fans. Hard disk and floppy disk drives were integrated into the crate to provide local storage facilities. The 147 board is a high specification computer on a single 6U VME board, comprising a 68030 processor running at 20 Mhz, a floating point co-processor, 4 MByte RAM and all the control hardware for the VMEBus. It also has SCSI, ethernet, serial and parallel input/output ports on board.

When providing analog and digital interface cards for a large-scale project, such as the control of a storage ring, it would be desirable that a single card was used for a particular purpose, e.g. DAC (digital-to-analog converter) so that wiring to plant would be simplified and so that a stock of easily swappable spares could be maintained. These cards tend to be expensive, especially when only one of each item would be required. The solution adopted for the RF control system is the IndustryPack™ (IP) modular I/O system[2]. IP's are small (credit-card sized), self-contained boards, each one providing a specific function. A 6U VME card provides a "motherboard" for up to four of these IP "daughterboards", and the functions of the four IP's can be mixed. The particular arrangement used is for two IP-carrier boards; one carrying a 6-channel 12-bit DAC and a 20-channel 12-bit ADC; and one carrying 80 lines of bit-programmable digital I/O, 2 programmable counter-timers and a IEEE-488 interface. This system gives a very flexible arrangement (IP's can be swapped in and out, or between boards in minutes) which is also economic: the total cost of the control system interfacing is similar to one dedicated multi-channel 6U VME DAC card. There is a comprehensive range of modules already available in the IP format, from a variety of manufacturers, and new modules are currently being developed.

Although IP's do exist to support serial data links, for the Test Facility these were not purchased, since the MVME147 supports up to three uncommitted RS-232 serial ports, which are used for the intelligent vacuum devices: an ion pump controller; an ion gauge controller and a residual gas analyser.

3. SOFTWARE

3.1 *Operating System*

The OS-9™ Real-Time Operating System [3] was chosen for this application; the combination of OS-9 and MVME147 is now a site standard platform. OS-9 allows multi-tasking of processes in real-time, giving a control system application the power to make a change to a parameter with known system timing. All input/output is handled by file managers, which allow user programs to write directly to interfaces as though they were read/write files. The detailed information relating to a specific device, e.g. the location address in the memory map, are held in a special file called the descriptor, so that installing new devices, or changing the locations of existing ones, is a small task affecting one part of the system.

The environment is very similar to UNIX and coding is done mainly in 'C'.

3.2 *Interface Drivers*

The IP's were purchased with device driver and file manager code modules, allowing a readily accessible route from a 'C' coded program down to the hardware. No driver was available for the counter/timer elements, and work is ongoing to adapt/develop a suitable driver for this. Serial links (RS-232) are managed from within the OS-9 system.

3.3 *Applications Software*

Figure 2 shows the software modules that comprise the test system.

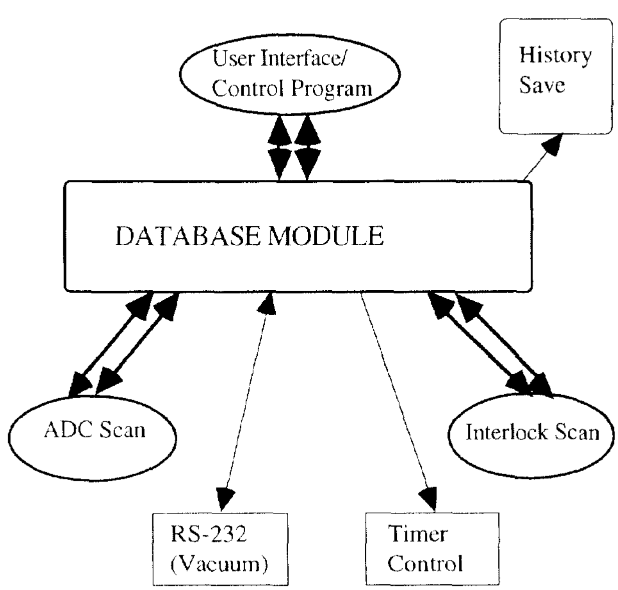

Figure 2. Layout of the RF Control System programs

The heart of the system is the database module. This is an OS-9 data module incorporating a binary 'C' structure. The data module facility provides a method for the sharing of data between several processes, but with built-in security and error checking so that simultaneous calls to the same information are correctly handled.

The database module is easily created because a database generator program has already been implemented on the SRS, for the upgraded beam steering system which is VME based [4]. The generator allows all the detailed information relating to a parameter to be input as a plain text file, which is then converted and compiled into the final module. The text below shows an extract from the RF system database source :-

```
NEWITEM
Name                  CAV.TUNER.01
Description           Cavity Tuner Position
Address_PICid         16
Units                 mm
Decimal_places        2
Analog_in_device      /ip1a
Analog_in_channel     16
Analog_in_calfactor   1.0
Analog_in_caltype     1
Analog_out_device     /ip1c
Analog_out_channel    3
Analog_out_calfactor  1.0
Analog_out_caltype    1
Analog_out_FSHI       70.0
Analog_out_FSLO       0.0
Status_device         /ip0c
Status_channel        2
Interlock             1 AUTOTUNE ENABLED
ENDITEM
```

This is then compiled using the SRS-written DBgen program to produce the OS-9 data module. To use this, all that is required is a read or write to the appropriate section. An example of its usage is shown below :-

```
Database[i].analog_in.digital_value=GETADC(device,channel)

where   device=Database[i].analog_in.device
and     channel=Database[i].analog_in.channel
```

This code is all that is required to read the adc for parameter number i and store the result in the database. All the information specific to the parameter, such as analog hardware location, is kept in an easily modifiable module, not in the source code for the program.

The software modules comprising the control system are:-

ADC_scan : This cycles round all the parameters in the database and, for all items which have ADC inputs, reads the ADC and stores the result.

Interlock_scan : This scans the digital input lines looking for trip or fault status readback changes from the RF system. If a line does change, a 16-bit word is assembled and written into the interlock section of the database for the appropriate parameter, which is then interpreted and displayed in the user interface program.

Control : This is the main user interface program. It displays the parameters with their analog monitored value and status, in a text-based format which can be displayed on any vt-100 terminal emulator. A sample of a typical user display is shown below:

LOAD.RETURN_T.01	45.0	DegC		
CAV.FLOW_T.01	46.0	DegC		
CAV.RETURN_T.01	50.0	DegC		
CAV.WINDOW_T.01	56.0	DegC		
CAV.TUNER_T.01	52.0	DegC		
CAV.BODYTEMP.01	50.6	DegC		
WAVG.WINDOW_T.01	57.2	DegC		
WAVG.FORWARD_P.01	40.4	kW		
WAVG.REVERSE_P.01	2.5	kW		
WAVG.MATCHER.01	35.0	cm	OFF	READY
TX.DRIVE_P.01	11.2	W		
TX.FORWARD_P.01	42.1	kW		
TX.REVERSE_P.01	2.3	kW		
CAV.TUNER.01	45	mm	OFF	AUTOTUNE ON
CAV.RAD_MON.01	2.0	mr/H		
CAV.GAPVOLTS.01	**100**	**kV**	**ON**	
CAV.BRIDGE.01	-2.2	V		
CAV.DETUNE.01	-3	Deg		
CAV.ION_GAUGE.01	4.2e-9	Torr		
CAV.PIRANI.01	1.0e-3	Torr		
CAV.ION_PUMP.01	5.0e-8	Torr		
TX.KLYSTRON_HT.01			ON	
RF.PULSE.01			OFF	READY
CONTROL>				

This is very similar to the layout of the SRS control system user interface, and was chosen because the users of the system would be already familiar with its usage. A standard output format of vt-100 was chosen so that a variety of terminal emulator based console systems could be used, both locally and remotely, using the OS-9 TCP/IP Telnet package.

The control program reads a list of parameters from a page file, and for each parameter the analog and/or digital status is obtained from the database and displayed. A user input prompt is provided, and the program loops back to refresh the display. Control of parameters is provided for using an active-parameter bar (in colour usually, but shown in **bold** above) which can be moved up and down to the wanted control by the user. Once selected, a control parameter can have a digital status changed (On/Off/Reset) and/or the DAC corresponding to this parameter can be set. All specific detail is referenced from the database, just as for ADC reading shown above.

History_Save: This program scans the entire database at regular intervals (presently 1 minute) and saves all analog and status information to a disk file, using the database to allow the information to be saved in a very compact way. A companion program, Get_History, allows the user to ask for tabulated information to be extracted from the disk file, ready for plotting or exporting to another system for analysis.

RS-232 Vacuum control: This will handle the serial control of the intelligent ion pump supply and the combined ion gauge/pirani gauge controller, providing information to the database which will be used by the main control program. There will also be a user-callable program from within Control which will be specifically aimed at exploiting the residual gas analyser system, with the goal of characterising the ion species associated with the process of cavity conditioning.

Timer Control: Two 24-bit timers are implemented on the digital I/O IP, giving programmable timers from 4 µS to 64S. A sub-program will be callable from the Control input prompt, which will allow the user to set up a variable mark-space ratio square wave, which will be used as an auxiliary input to the master low-level RF enable/trip detect circuit, to allow flexible pulse modulation of the cavity RF. This will be the subject of a series of experiments aimed at the characterisation and understanding of the optimum method of conditioning accelerator RF cavities, that is, overcoming the secondary electron emission/avalanche process known as multipactoring.

4. STATUS AND FUTURE WORK

The basic control system software has been written and bench commissioned. The VME crate has now been installed in the RF Test Room and signal interfacing is to be designed and commissioned. This will consist of signal conditioning modules (isolation, level-shifting and amplification) together with the installation of a new low-level RF system, for both amplitude and phase system control, and an upgraded autotune cavity phase control loop.

Together with the High Power testing phase, a programme of work will also commence, dealing with cavity coupling and matching techniques, both waveguide planar window based and loop coupling based. This will involve both new 500 Mhz cavity designs and new transmitter/cavity combinations at 125 Mhz. The VME RF control system will provide a flexible platform to allow data to be obtained easily for the anticipated configurations.

5. REFERENCES

[1] Motorola MVME147 Single Board Computer: Motorola Computer Systems Ltd., 27 Market Street, Maidenhead, Berkshire, SL6 8AE, England.

[2] IndustryPack™: GreenSpring Computers, Inc., 1204 O'Brien Drive, Menlo Park, CA 94025.

[3] OS-9™: Microware Systems Corporation, 1900 N.W. 114th Street, Des Moines, Iowa 50325-7077.

[4] Development of a VME-Based Control System for the SRS Orbit Feedback Project, W R Rawlinson *et al.*, these proceedings.