THE LEP RF TRIP AND BEAM LOSS DIAGNOSTICS SYSTEM

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Abstract

During the last years of operation the number of operationally independent RF stations distributed around LEP reached a total of 40. A serious difficulty when running at high energy and high beam intensities was to establish cause and effect in beam loss situations, where the trip of any single RF station would result in beam loss, rapidly producing further multiple RF station trips. For the last year of operation a fast post-mortem diagnostics system was developed to allow precise time-stamping of RF unit trips and beam intensity changes. The system was based on eight local DSP controlled fast acquisition and event recording units, one in each RF sector, connected to critical RF control signals and fast beam intensity monitors and synchronised by GPS. The acquisition units were armed and synchronised at the start of each fill. At the end of the fill the local time-stamped RF trip and beam intensity change history tables were recovered, events ordered and the results stored in a database for subsequent analysis and display. The system was made operational quickly and it proved invaluable for high energy running.

1 INTRODUCTION

During 1999 LEP at was run at high energy and minimum RF voltage margin. Under these conditions the trip of one or two RF units would quickly result in beam loss. Since the SC RF units were operating at high power, the loss of the beam itself would cause them to trip. These events could occur within milliseconds of each other, making it difficult to determine whether or not RF unit trips were the cause of the beam loss and if so which particular unit or units.

The problem became increasingly serious towards the end of the running period as maximum energies were being attempted, and a fast and precise system for global logging of RF unit trips and beam loss history was clearly necessary.

A fast diagnostics system [1], based on the existing GPS timing system [2] at the even points of LEP, was successfully implemented for the last year of LEP running.

The GPS system was extended into the klystron galleries of the RF sectors on either side of each IP by IRIG-B transmission over coaxial lines. A local acquisition unit in each sector monitored the RF unit HV and RF system control signals from all the units in its sector. Its timing was synchronised to the GPS system. Any changes in state were logged and precisely time-stamped. The acquisition unit contained a fast detector which took its signal from an existing Beam Position Monitor. A central UNIX application armed each local system at the start of each fill and recovered data from all the sectors at the end. It then calculated and displayed overall RF unit trip and beam loss event data in sequence. The results were stored in a database on a fill by fill basis. The results were regularly retrieved and compared with alarm system data and machine data to track systematic faults and to optimise the maximum operating levels of the individual RF units.

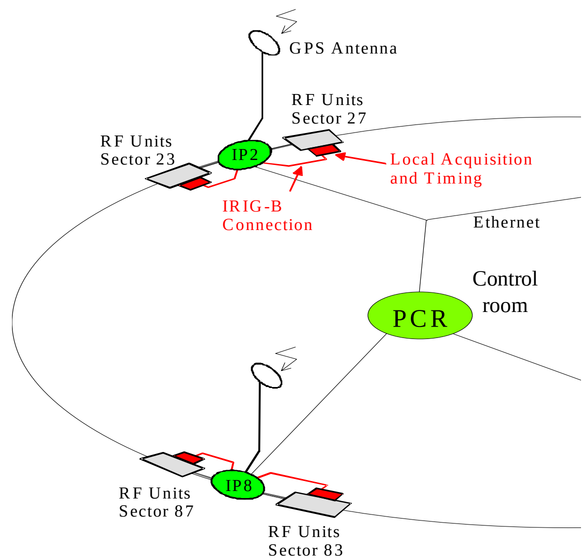

Figure 1. GPS connection to the LEP RF system

2 GPS TIMING SYSTEM

GPS receivers were first installed in LEP in 1995 in order to monitor the beam dump trigger system. The GPS systems have since been extended throughout CERN and now there are over 20 installations [2].

A GPS receiver consists of two parts: a high-frequency (1575 MHz) radio receiver and a Time Code Processor (TCP). Additional remote TCP units can be connected to an existing receiver using IRIG-B transmission over coaxial cable. These units generally provide a fixed rate 1 pulse per second output and an external event capture input in addition to the time of day information. The TCP chosen was the Datum bc336VME module. From measurements performed at CERN [3], we know that the Datum TCP can provide the 1 pulse per second output with a jitter of less than two microseconds with respect to Universal Co-ordinated Time (UTC).

3 DSP SYSTEM FOR LOCAL DATA ACQUISITION

A large number of status signals had to be monitored for the whole RF system. The solution adopted was to have a fast DSP based local acquisition unit in each klystron gallery, which monitored monitored RF switch states and HV Power Converter thyristor states for all three RF units installed in its sector, and recorded unit trip and beam loss events. A single TCP provided precise synchronisation of its local clock. This single TCP was contained in the RF unit controller crate (Data Manager) of the RF unit in the middle of the sector. The layout for one sector is shown in Figure 2. The beam intensity and beam loss detector (see below) provided analog and digital signals.

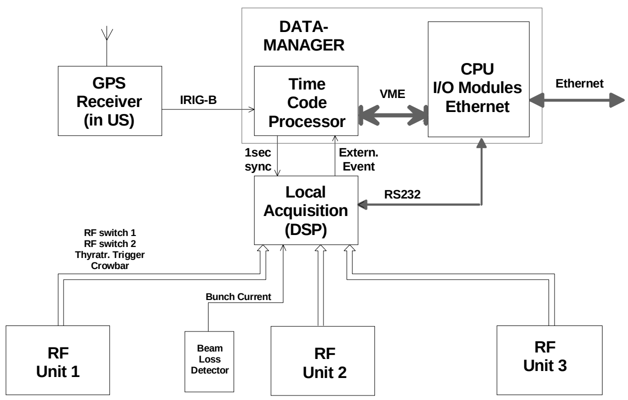

Figure 2. Local acquisition and timing in a klystron gallery

The acquisition unit is based on an Analog Devices AD21065L 60 MHz Digital Signal Processor (DSP). A commercial 'mini-kit'- containing the DSP, memory, I/O, flash EPROM and timer - is mounted on a standard 3U board with additional I/O buffering, A/D and D/A converters. This same board has been successfully used in the test of digital filters to damp SC cavity ponderomotive oscillations [4].

The embedded program in the DSP ran continuously in a loop, checking all inputs every 10 µs, incrementing an interval counter. When a change of any input was detected, all states were stored, along with the interval count, as a record in the DSP board's memory. The initial states of all input signals were also stored at startup. A command interpreter allowed the DSP program to receive and respond to commands sent over the RS232 link from the Unit Controller. The 1 pulse-per-second output of the TCP was sent to the local unit, allowing it to readjust its interval counter if necessary.

4 BEAM INTENSITY AND BEAM LOSS DETECTOR

The detector is a simple diode and filter (Figure 3). The resulting analog signal is an approximate but fast measurement of the total beam intensity. Two comparators on the raw detector signal, Level a (high) and Level b (low), trigger monostables with output times of 300 µs and 100 µs respectively. A fast beam loss signal was generated when the detector signal dropped from the high to the low levels in less than 200 µs. This signal was monitored by the local data acquisition system. It could also be connected to the RF beam dump system in order to switch off RF units and protect them from the potential damage that could result from RF power transients on beam loss.

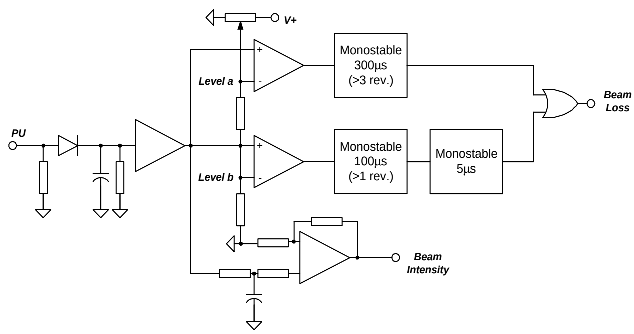

Figure 3. Beam intensity monitor and beam loss detector

5 INTERFACE TO THE CONTROL SYSTEM AND SYNCHRONISATION WITH GPS

The operating sequence was as follows:

- At the start of a LEP physics coast, upon request from a UNIX application running in the control room, a "start" command was sent from the Unit Controller via the RS232 link. The DSP waited for the next 1 PPS and replied with a start pulse which was captured by the TCP module, providing a precise time-of-day timestamp corresponding to zero time on the DSP's internal clock.
- The DSP software resynchronised its internal clock once per second using the 1 PPS signal from the TCP module.
- After a beam loss, the Unit Controller sent a "stop" command via RS232 and the DSP replied with a stop pulse to the TCP, giving a second timestamp which was used to check that the DSP had remained in synchronisation throughout the coast.
- The history table was then read out of the DSP memory via RS232 and stored in the Unit Controller as a disk file, pending transfer via the same UNIX application to an ORACLE database.

At the end of the fill a control room application program would read all eight tables. It determined the overall RF unit trip sequence using the individual local timer readings together with the starting time of each from the GPS. The main events, including beam intensity history from the detector in RF unit 872, were stored in the database with the calculated time of occurrence. The data for the current fill or any previous fill could then be read and displayed as shown below in Table 1. Relative time is that with respect to the moment when the beam lifetime dropped below 1 second. The origin of the beam loss is diagnosed as the trip of unit 232_1 followed by the loss of a second unit, 472_2. Beam loss occurs over a period of about 0.2 seconds and is followed by further units tripping, some within a few hundred milliseconds of the beam loss and some a few seconds after.

The presence of beam signal detectors in all RF sectors enabled cross-checking of the operation of the GPS system and the local DSP acquisition units using the beam itself. This proved to be an extremely useful feature. An example, showing agreement of the separate measurements of the beam loss in the four IPs, is shown in Figure 4.

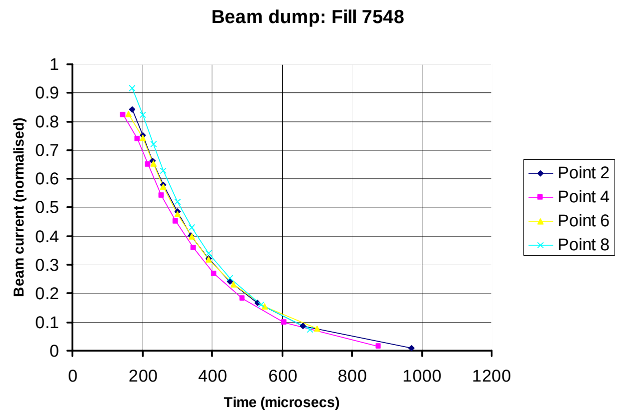

Figure 4. Beam loss measured independently in the four IPs

6 CONCLUSIONS

The existing GPS timing system was very successfully extended into to the RF system to provide timing for RF unit trip and beam loss diagnostics. Use of existing DSP hardware, with experience already gained, made the development of the local diagnostics system feasible in the short time available. Software facilities were quickly implemented and the use of the ORACLE database from the outset simplified the debugging process. The system proved invaluable in the operation of LEP at the highest possible energies in 2000. The experience gained is expected to be very useful for similar post-mortem diagnostics applications in LHC.

7 REFERENCES

[1] L. Arnaudon et al., RF trip and Beam Loss Diagnostics in LEP Using GPS Timing, CERN SL-Note-2000-055 2000.

[2] C. G. Beetham, J.B. Ribes, "GPS Precision Timing at CERN", PAC 1999, SL-Note-98-050 CO 1998.

[3] C. Antfolk et al., "Long Term Precision Measurements on GPS and IRIG-B Equipment" CERN SL-Note-2000-037 (CO) 2000.

[4] E. Ciapala, "RF System Hardware Improvements and New Procedures", Proc. of the 10th Workshop on LEP Performance, ed. J. Poole, CERN SL-2000-007 DI.

Date	Time	Relative ms	Unit	Event type	Current	
10/31	**04:59:32.424**	**-626.4**	**232_1**	**RF OFF**		<----
10/31	04:59:32.780	-269.9		Current	4048	
10/31	**04:59:33.049**	**-1.7**	**472_2**	**RF OFF**		<----
10/31	04:59:33.050	0.0		Losing beam...		
10/31	04:59:33.065	14.8	833_2	RF OFF		
10/31	04:59:33.072	21.2		Current	3232	
10/31	04:59:33.101	50.7		Current	2824	
10/31	04:59:33.149	98.9		Current	2420	
10/31	04:59:33.202	151.4		Current	2016	
10/31	04:59:33.234	183.2		Current	1612	
10/31	04:59:33.249	198.4		Current	1208	
10/31	04:59:33.264	213.6		Current	800	
10/31	04:59:33.276	225.3	632_1	RF OFF		
10/31	04:59:33.279	228.9		Current	392	
10/31	04:59:33.294	243.2	872_2	RF OFF		
10/31	04:59:33.294	243.2		Current	0	
10/31	04:59:33.295	244.2	673_2	RF OFF		
10/31	04:59:33.382	331.2	873_1	RF OFF		
10/31	04:59:33.497	446.4	832_2	RF OFF		
10/31	04:59:33.507	456.5	433_2	RF OFF		
10/31	04:59:33.507	457.1	471_1	RF OFF		
10/31	04:59:33.583	532.5	873_2	RF OFF		
10/31	04:59:33.637	586.5	472_1	RF OFF		
10/31	04:59:33.686	636.0	633_1	RF OFF		
10/31	04:59:33.796	745.6	632_2	RF OFF		
10/31	04:59:36.859	3808.8	832_1	RF OFF		
10/31	04:59:37.828	4778.0	432_2	RF OFF		
10/31	04:59:40.290	7240.1	431_2	RF OFF		

Table 1. Global diagnostics information on beam loss and trip history – Fill 8959