The BOSC Project

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Abstract

In the monitor group of the SPS a data acquisition system BOSC has been built. The intensity and the position of up to 8 particle bunches can be measured each turn. A measurement of up to 1 million subsequent turns is possible. The first use of the system is for machine studies, in which we need to measure tunes to a high precision, reconstruct phase space plots by using the information of 2 pick-ups (90 degrees apart in phase), find intensity losses and record the lifetime of a coasting beam. Soon, however, it will replace different systems used in operation, which measure the beam intensity, the injection oscillations, the tunes and the bunch lifetime. In this report we describe the main features of BOSC and discuss first applications done for the SPS Dynamic Aperture Experiments[1].

Introduction

The SPS works in many different modes: as an injector of lepton bunches for LEP, as a proton - antiproton collider and as a proton/ion synchrotron. For LEP injection and for p - pbar collisions the machine operates with a few bunches, in synchrotron mode with many (some thousand) bunches, and unbunched beams can also be stored. To keep up with the ever more complex operation of this machine a new control system is being designed. It is clear that an appropriate instrument capable to measure the beam parameters in the various operational modes is needed as well.

Our new turn by turn data acquisition system BOSC (Beam OSCillations) has been constructed for the SPS as a very flexible system to replace a number of single purpose instruments for operation as well as to serve as a tool for specific machine experiments.

The hardware has now reached a final stage. It basically consists of a VME crate equipped with a powerful CPU board and 24 ADC units with a large memory of 2 Megabytes each. This allows for 23 seconds of continuous data acquisition. One of the strengths of this system is that it can be fed by signals from any source: position and intensity from directional coupler pick-ups (bunches) or electrostatic pick-ups (many bunches) with their 20MHz and 200MHz receivers respectively, signals like the intensity signal of the beam current transformer (BCT) for unbunched beams and various signals monitoring the hardware.

We will soon have three crates, two for bunches with particles of positive and negative charge respectively and one for special purposes like lifetime measurements, which allows us to make use of the full potential of our instrument in all possible machine configurations.

The actual measurement with BOSC is started from an Apollo workstation in the SPS control room. The communication to the crate is based on the TCP/IP protocol on an Ethernet or Token ring.

The measurement request, for which we have developed a control code, that is sent to the crate and the acquired data which are sent back to the Apollo are held in special data structures called MOPS[2].

A large effort is currently undertaken to prepare the application software for doing the operational measurements including the possibility to talk to the crate from different Apollos at the same time. We have also added a DSP board[3] to the crate, so that the calculation of FFTs can now be done in the crate itself when preprocessing of the data is requested.

Hardware Description[4]

As a basis for our system a VME chassis has been chosen. This chassis has 6 VME modules, which are the CPU board, a timing card (TG3), a bunch selector card, a sequencer board, a digital signal processing card (DSP), and a VME bridge which allows the connection to an isolated bus on which there are 12 slots for the ADC boards.

As a CPU card the MVME 147 (68030) with 8MB of inboard RAM from Motorola was selected as the most powerful processor available at that time, where the manufacturer offered a real time operating system (OS9), TCP/IP and an Ethernet port for communication with the outside world, up to 4MB of inboard EPROM (automatic recovery from power cuts) and allowing through special ports the temporary connection of a computer terminal and a hard disk for developing and debugging purposes.

The TG3 card is a receiver for the SPS timing system, which provides timing events from the accelerator for example at the start of the cycle. These events are then used to interrupt the CPU, to start the sequencer or act as a start reference for the circular buffer on the ADC boards.

The bunch selector has an internal phase locked loop which locks onto the SPS revolution frequency of 43.38KHz. The voltage control oscillator (VCO) runs at 461 times the revolution frequency (output every 50ns). By programming the internal RAM we can create gate pulses to select the same bunch in each turn of the SPS. During this time gate the ADC cards are activated to acquire data.

The sequencer module allows to program a fast kicker at specific times in the cycle. The beam is kicked horizontally and/or vertically with a small kick amplitude, so that the subsequent oscillations of the beam are just strong enough to derive the tunes using a FFT routine.

As FFTs are very time consuming (typically 1s for a sample of 1024 values with the 68030 CPU) a speedup is necessary for operational tune measurements for every cycle (14,4s in the SPS). This has been achieved by using a special board[3] equipped with an AT&T DSP32C chip, that can execute a 1024 point FFT in 4ms. When data transmission to and fro the board via the VME is included, the time rises to 28ms.

The last VME module is a VME bridge which separates the VME bus from an isolated bus reserved for the ADC cards only. This was necessary to keep bus noise out of the 16 bit ADCs.

The main effort went into designing the ADC cards, which have two independent analog signal processing channels. Each channel has an input buffer, a programmable gain amplifier, a peak hold detector, a 16 bit 10μs conversion time ADC and 2MB of buffer memory. The buffer memory is organized as a hardware circular buffer with the ADC having direct memory access. Each ADC's memory is directly mapped into the CPU's memory map. Programs running on the CPU card can therefore read data from the ADC memory without going through drivers or managers. All the logic for the two DMA channels, the hardware circular buffers, the dynamic memory refresh and the VME access is implemented in a single Xylinx 3042 chip. The ADC board also has a read/write gain and mode control register for the external pick-up receivers.

Figure 1 shows the front view of the VME chassis with the 6 VME boards and the 12 ADC cards. It is also shown how the data of the 8 bunches (a-h) are acquired: 3 ADC cards (6 channels) are shared between two bunches which need 3 channels each for the sum signal and the horizontal and vertical positions.

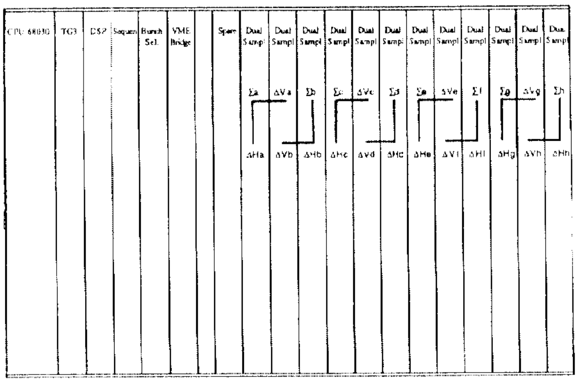

Figure 1 BOSC VME-Chassis (front view)

BOSC control software[5]

The control software for BOSC has to take care of the following tasks: setting up the communication between the crate and the Apollo workstation, changing the hardware parameters, organizing and sending measurement requests to the crate, starting the data acquisition on the crate and receiving the data on the Apollo after an acquisition has been finished.

For the communication the TCP/IP protocol with a BSD4.2 socket library interface has been used for both the Apollo and the crate hiding the differences of low level networking (Ethernet/Token ring). To facilitate the software development throughout the system it was decided to use for any data transfer in both directions MOPS data structures. The MOPS package has therefore been ported to the OS9 environment on the crate. With TCP as a basis providing a very reliable data transport service, we have achieved a fast connection time (300ms) and for transfers of MOPS data structure a throughput of more than 50 Kilobytes per second.

The setup program to start the system can also be used to change a few basic parameters controlling the hardware, that are base addresses, gains and bunch selector settings. The use of base addresses allows the translation from the physical to logical channel addresses, so as to freely choose channels without the need of swapping cables. Each sum ADC can have an independent gate delay and width. Position ADCs are controlled by the sum ADC. The receiver gain can be changed from 14db to 70db in 14db steps. Each ADC channel can be changed from 0db to 24db in 6db steps.

The MOPS data structure which is sent to start the measurement on the crate holds in one of its objects a coded request. This code consists of 12 integer numbers 6 of which are used presently, they specify the start time (ms from the start of the SPS cycle), the time between blocks of acquisitions in a cycle, the number of blocks of acquisitions, the number of SPS cycles during which this measurement should be repeated, the selection of which of the 24 channels shall acquire data and a processing flag, which allows a preprocessing of the data in the CPU of the crate.

A server program is running on both ends to receive MOPS data structures with measurement requests or acquired data respectively. The BOSC has a unique TCP port number known to the Apollos, while the port numbers of the Apollos are sent with the measurement request. The program on the crate side is prepared to handle up to 5 requests, which it treats one by one. The data taken from the ADC memory as requested and the hardware settings like gain registers and timing information are added to the MOPS data structure that has been received from the Apollo. Besides sending the acquired raw data an averaging of intensities for a lifetime calculation can be performed and the DSP card can be activated when a on-line FFT has been requested with the use of the preprocessing flag.

Once the measurement has been completed the MOPS data structure is sent back to the requesting Apollo, where processing of the data can be started after the server program has received the data structure.

BOSC application software

After shortly describing how the data is processed a couple of examples are shown that illustrate how such a system can help to understand particle motion in an accelerator with nonlinear fields.

The processing is done under the control of the run time coordinator (RTC[6]), which allows starting of each task on the Apollo via mouse control. These tasks are processing the data, displaying them with the use of the DATAVIEWER[7], saving MOPS data structures in files with the help of the CATALOGUE[8] package and recalling old data sets for further analysis.

Figure 2 shows a schematic overview of how a measurement is done with the BOSC system from the pick-ups to the actual plotting of the data.

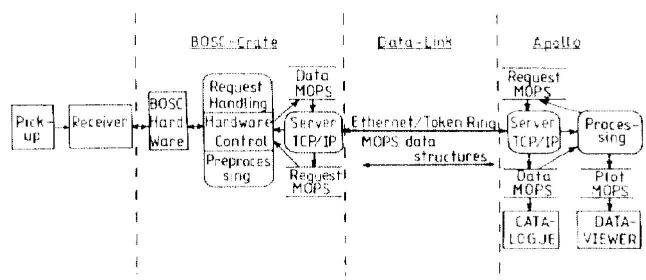

Figure 2 Schematic Overview of BOSC

The programs for processing are written in Fortran and 'C', where programs of the second type have the advantage that they can be ported and used in the crate.

The machine experiments demand a constant development of the application software. For the time being the system is used to calculate lifetime and to study nonlinear parameters.

For the recent diffusion experiments at the SPS a precise measurement of beam intensity and from that a calculation of the beam lifetime is needed. For this purpose the BCT signal of the SPS intensity is fed into one channel of our system and on the Apollo the corresponding lifetime is calculated repetitively every SPS cycle (14,4s). The results of this experiment are reported in this conference[1].

To study the effect, nonlinearities have on the behavior of particle motion, the beam is kicked horizontally to various amplitudes, as we expect the basic parameters (tune,smear) of the accelerator to be amplitude dependent. We are interested in resonance phenomena, which lead to particle instability and can directly be observed in phase space.

For this application the data of two pick-ups separated by 90° phase advance are recorded in both the horizontal and vertical plane. This allows the reconstruction of phase space plots. Figure 3 is an example of the horizontal phase space, where the nonlinearities lead to the appearance of a 5th order resonance, which is reflected in the 5-fold symmetry in the figure.

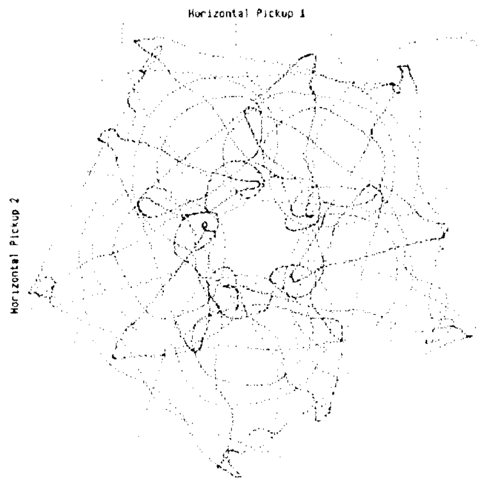

Figure 3 5th order resonance in the horizontal phase space

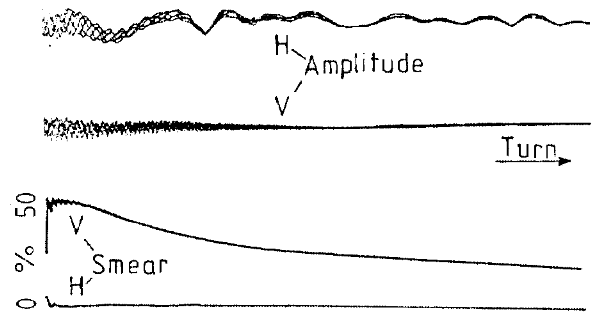

Figure 5 Amplitudes and smear

The measurement of the tune and smear allows a quantitative understanding of the nonlinear effect. A precision measurement of the tune for this case has been done using 8192 turns (7s on a Apollo 3500). Figure 4 shows the corresponding Fourier spectra for the horizontal and vertical oscillation planes. As the kick is applied horizontally this plane is not affected much by the coupling with the other plane (there is only one peak at a tune of Q_H = 26,600). In the vertical plane however one finds that due to nonlinear coupling the horizontal peak is even larger than the vertical tune of Q_V = 26,538.

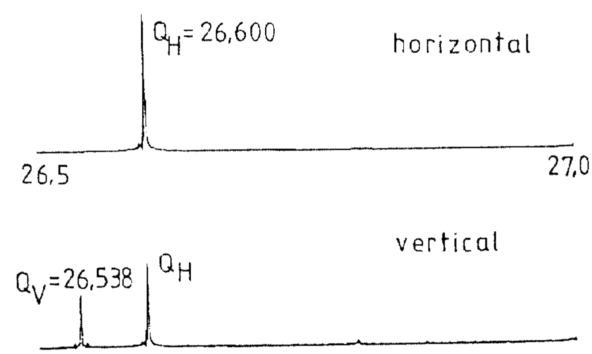

Figure 4 Tune analysis

A new feature of our application software is the calculation of the smear[9], which is the relative rms variation of the amplitude due to the nonlinearities. Figure 5 shows the horizontal and vertical amplitudes (the artificial decoherence effect which can not be avoided in the measurement is compensated for) from which the smear is derived. Note that the vertical smear is by far larger than the horizontal one. This is again caused by the fact that the vertical motion is more strongly affected by coupling.

Conclusions

The BOSC system has been proven to be fully operational reaching the level of performance that was initially specified. All operations from sending a measurement request, communicating with the crate, acquiring data in the different accelerator modes to the subsequent data processing work reliably and fast.

This instrument now being ready is more than adequate to provide the necessary status information about our machine as an input for the new SPS control system. Thanks to its flexibility and enormous storage capability it has the potential to cater for a wide range of possible future applications. Moreover this system is not restricted being useful for the SPS, it will possibly be installed in the near future for the PS and LEP.

BOSC has and will play an essential role in the machine experiments to study the effects that will dominate future accelerators. In this field an endless list of measurements can be performed, where the system can run up to its full capability.

References

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