

FAST ORBIT FEEDBACK FOR DELTA AND FAIR*

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Abstract

A stable beam orbit is essential for safe operation of particle accelerators. This applies to electron machines and even more to ion accelerators running high beam currents. Based on developments at DELTA, basic designs of fast orbit feedbacks systems for the FAIR rings SIS-18 and HESR (planned) and COSY at the Forschungszentrum Jülich are presented.

INTRODUCTION

While fast orbit feedback systems are rather common among electron storage rings and especially light sources, hadron rings, except those running very high beam currents did not have the need for orbit feedbacks up to now. In using the expertise gained at DELTA, the FAIR project opts for fast orbit feedback systems for its future rings SIS-100, SIS-300 and HESR. Studies will be undertaken installing a fast local orbit feedback in the proton ring COSY at Jülich and a fast global orbit feedback in SIS-18 at the GSI in Darmstadt.

DELTA

At the 1.5 GeV light source DELTA[1], the storage ring as well as the booster synchrotron were originally equipped with Bergoz MX - Beam Position Monitors (BPM)[2]. They provide the measured beam position as an analog voltage that is digitized by 12-bit analog-to-digital converters (ADCs) and fed over the CAN-bus into the EPICS control system of the accelerator. Even though the measurement precision of the MX-BPM itself is better, the precision of the beam position measurement is approx. 5 μm at a bandwidth of 10 Hz, limited by the resolution of the ADC.

In recent years, some of the MX-BPMs in the storage ring have been replaced by I-Tech Libera Electron/Brilliance BPM electronics which are capable of measuring the beam position turn-by-turn (tbt). Other accelerators [3] [4] have set up global fast orbit feedbacks based on Libera Electron. They use a part of the Virtex-II-Pro FPGA contained in the Libera BPMs to implement a data distribution software (DCC) [5] to spread position measurements derived from tbt-data at a reduced data rate of 10 kHz around the ring. Different solutions have been found to receive these data and to calculate and apply orbit corrections to the beam. Correction bandwidths of several hundred Hz have been obtained.

The MX-BPM electronics may be clocked up to 40 kHz to obtain a data rate of 10 kHz in the vertical and the horizontal plane [2]. Its analog bandwidth should allow a correction bandwidth in excess of 100 Hz [6] (see fig. 1).

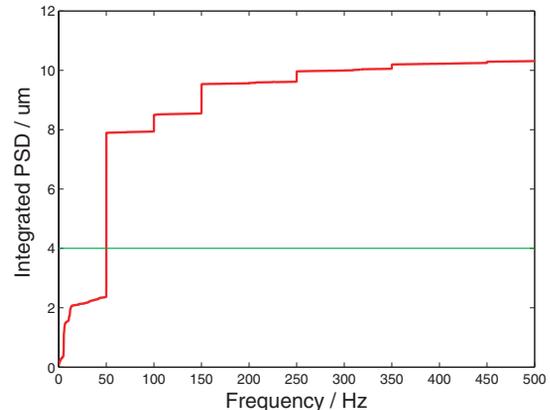


Figure 1: Integrated Power Spectral Density (PSD) measured in the vertical plane using a Bergoz MX-BPM (BPM42). The green line represents the $\sigma/10$ limit [4].

In order to improve the precision of the beam position measurement and to implement a fast global orbit feedback at DELTA, we have developed a digital frontend for the Bergoz MX-BPMs which provides precision beam position data at 10 Hz to the control system and integrates the MX-BPM seamlessly into the DCC network at 10 kHz data rate [7, 8]. We call this device the 'BPM-Extender' even though it is rather a multi-purpose FPGA device.

The BPM-Extender is based on the Xilinx University Program Virtex-II-Pro Development Board (XUPV2P) [9]. Attached to one of the GPIO ports of the XUPV2P we developed an ADC board carrying two Analog Devices AD974 ADCs. Their sampling rate of 200 kSamples/s allows to read the horizontal and vertical beam position data of four MX-BPMs. The ADC board also has inputs for several triggers like the machine clock of the accelerator from which the sampling rates are derived.

In order to integrate the board into the EPICS control system of the DELTA rings we have installed GNU/Linux on the XUPV2P board. It is executed by one of the two hardwired PowerPC cores of the Virtex-II-Pro FPGA and uses a 256 MB DDR SDRAM plugged into the board's DIMM slot. Symmetrical multiprocessing of the two available PowerPC cores was not an option because the PowerPC 405 cores do not implement cache coherence [10]. After the Linux system is booted up, an EPICS softIOC is started. Communication between the Linux kernel driver

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talking to the FPGA cores and the EPICS record was programmed using the asyn-driver [11] framework. Its device support reads BPM data in slow access mode and distributes it over the slow EPICS control system network.

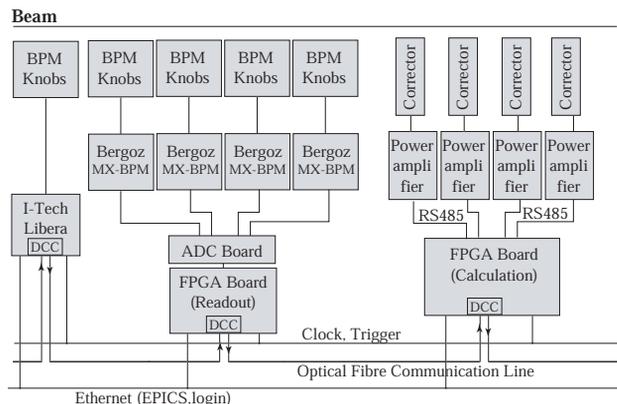


Figure 2: Conception of the fast global orbit feedback system for DELTA: Bergoz MX-BPMs, equipped with BPM-Extenders, deliver fast orbit data in parallel to Libera BPMs. The data are picked up by modified BPM-Extenders that calculate and apply orbit corrections to the electron beam.

COSY AND SIS-18

Based on the experience made at DELTA, the orbit feedbacks for the ion accelerators COSY and SIS-18 are developed in a collaboration between DELTA, the Forschungszentrum Jülich and the GSI at Darmstadt. Its goal is to install a fast local orbit feedback for the proton storage ring COSY at Jülich and a fast global orbit feedback for the ramped ion synchrotron SIS-18 at the GSI. These implementations will serve as prototype studies for the fast orbit feedbacks for the planned hadron rings SIS-100, SIS-300 and for the HESR of the FAIR project.

As the hardware basis for the ion accelerator feedbacks, I-Tech Libera Hadron beam position processors were chosen. They use shoebox-type [12] pickups as the frontends. Based on the turn-by-turn position measurement software developed at the GSI [13, 14] we have implemented a data path running at a reduced data rate of 10 kHz. At this frequency the position data is then again distributed in a fibre network using the Diamond Communication Controller (DCC). By using four of the available seven Rocket I/O ports (one is used for the turn-by-turn data communication) for the DCC, the feedback network latency can be kept low by choosing an appropriate network topology. Having the Libera Hadron distribute data over the DCC, we can re-use the hardware applied at electron rings for fast orbit correction on ion machines. We expect to handle the integration of the fast orbit feedback into the GSI control system based on FESA [15] the same way we have integrated the DELTA orbit feedback into EPICS. Further studies in this direction are under way.

06 Beam Instrumentation and Feedback

T05 Beam Feedback Systems

Currently, we are setting up a feedback testbed at DELTA, consisting of four Libera Hadron. The feedback software will be tested using a 2-channel fast signal generator to simulate input signals of ion bunches in the revolution frequency range of SIS-18 (850 kHz to 5MHz). After the test phase, two of the Libera Hadron will go to COSY for the local orbit feedback. The feedback software will also be installed on all 12 Libera Hadron at SIS-18, providing that it will not interfere with the existing turn-by-turn measurements. The BPM-Extender mentioned above will, after minor modifications, serve as a 'sniffer board' for feedback diagnostics and as a fast calculator for the orbit correction.

PROJECT STATUS

We have developed a digital frontend for Bergoz MX-BPMs, based on a Xilinx FPGA board. This board integrates four MX-BPMs seamlessly into the fast orbit feedback network based on the Diamond communication controller. This digital frontend will also be used a calculator device for orbit corrections based on the SVD-method [16]. In parallel, we have set up a fast local orbit feedback at DELTA [16] as a proof of concept for the methods used. A fast global orbit feedback system for DELTA is under construction.

In order to transfer this knowledge to ion accelerators we have implemented a 10 kHz data path based on the turn-by-turn measurement software developed at the GSI for the Libera Hadron beam position processors. The position data is fed at a data rate of 10 kHz into the Diamond communication controller and is distributed over the fibre feedback network. Currently, we are setting up a testbed for a fast orbit feedback for COSY and SIS-18.

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