cosylab

Beam Position Monitor

Requirements Specification

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Document History

Revision	Date	Changed/ reviewed	Section(s)	Modification
1.0	2008-07-18	iverstovsek, msekoranja/ gjansa, kzagar	All	Created.
1.1	2008-09-08	gjansa	All	Modified use cases based on [5] and on several discussions with the GSI-SD group, in particular with Piotr Kowina and Tobias Hoffmann.
1.2	2008-09-15	gjansa	1, 2.1, 2.1.2, 2.1.3, 2.1.4, 2.3, 2.4	Modifications after meeting on Friday 12.09.2008.
1.3	2008-09-24	gjansa	2.3	Updated.

Confidentiality

Scope

This document specifies detailed requirements for the software of the beam position monitoring (BPM) subsystem. Also, requirements and assumptions on other parts of the subsystem (e.g., Instrumentation Technologies Libera Hadron, network infrastructure, timing subsystem, etc.) are listed. Initially, the software will be installed on 13 Libera BPMs on the SIS-18 synchrotron, but a future installation on all FAIR's synchrotrons is expected.

Audience

The audience of this document are:

- All members of the GSI-SD group.

- All members of the GSI-BEL group.

- All members of development team at Cosylab.

The document can be disclosed to all GSI staff and staff of all entities participating in the FAIR project.

Table of Contents

Figures

Tables

1. OVERVIEW

The purpose of the system is beam position monitoring for SIS 18. This system will be an upgrade of the existing SIS 18 BPM system. The system will be developed in the context of the future control system for FAIR [1].

The architecture and the hardware used in the system are already defined by GSI-SD group (see [3], [4] and [5]), so they are listed in this section as a part of requirements. The system will use:

- 12 Libera Hadron BPMs and 2 clock splitters for Libera Hadron (BPM Liberas) [2].

- 1 Libera Hadron will be used to acquire additional machine signals (AUX Libera) [5].

- 20 Channel ProCurve Switch 10 GBit, specification is in [4].

- Two Concentrator servers (CCCP), specification is in [4].
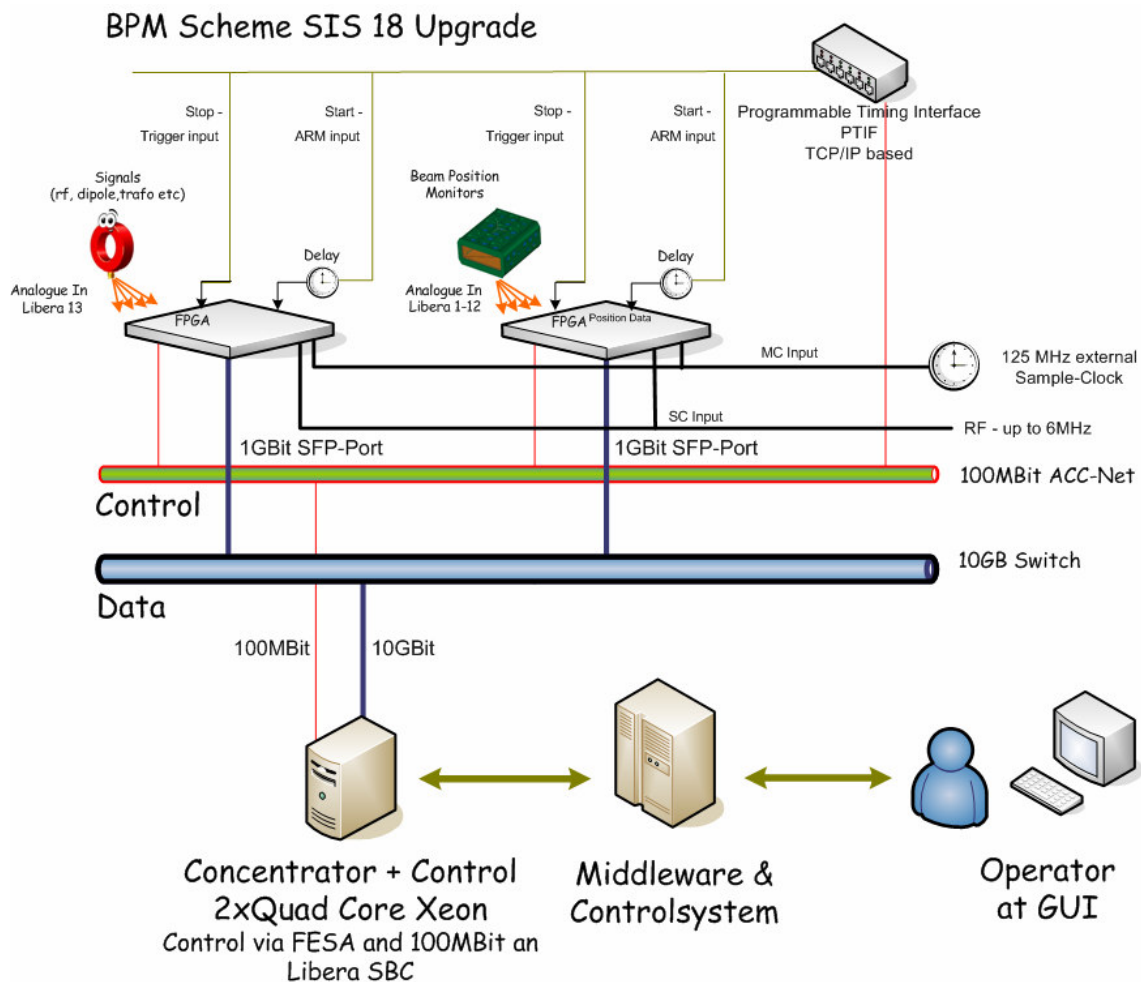
Figure 1: Layout of the system reprinted from [5].

2. USE CASES

In the FAIR CS study [1], the relevant use cases are: Monitor a beam ([1], 3.5.5), Monitor a process variable ([1], 3.5.10), Examine post mortem data ([1], 3.6.1) and Drill down to device level ([1], 3.6.2). Note that none of these is specific to BPMs, however the general requirements specified there-in must be reflected in the use cases below. In effect, all of the following use cases extend the use cases in the study.

From user point of view use cases can be divided into the following categories (BPM mode)

- Use cases based on bunch to bunch data mode

- Position offset calibration

- Zero line calibration

- Use cases based on raw data

General requirements and assumptions:

ID	Description
1	The highest sampling rate supported by Libera is 125 MSa / s.
2	Trigger rate for SIS18 ring is from 850 kHz to 5 MHz. Highest trigger rate for SIS100 ring will be 6 MHz. Taking into account later upgrade of the system to ring SIS100 the supported trigger rate will be up to 6MHz.
3	Each Libera supports up to 4 channels.
4	Sampling resolution at ADC is 14 bit; digital signal has 16 bit precision.
5	Size of the "BPM package" is 96 bits [5]. This follows from 92 bits of data plus 4 bits of overhead.
6	Libera provides two means of communication with the outside world: • 100 Mbit Ethernet for control and data acquisition. This connection is based on TCP/IP protocol. • 1 Gbit Ethernet via SFP port for data acquisition. This is a one-way connection, based on UDP protocol.
7	It should be possible to export the BPM package to the 1 Gbit Ethernet in real-time. Maximum expected data rate from one Libera is approximately 576 Mbit / s. This follows from 6 MSa / s * 96 bit = 576 Mbit / s + UDP overhead. This means that this requirement can be realized using 1 Gbit Ethernet. Data rate from all 12 Liberas will be approximately 7000 Mbit/s (875MB/s). If maximum sampling rate of Libera is taken into account (125 MHz), the maximum rate from one Libera sending raw data could be as high as 8 Gbit / s (125MSa/s * 4 channels * 16 bit / channel = 8 Gbit/s). This is higher than the rate of the 1 Gbit Ethernet, so in this case, this requirement could not be realized, i.e. it is not possible to export raw data over the 1 Gbit SFP port in real time.
8	The acquisition rate of Libera 13 will be slower or equal to the rate of other Liberas, used in this project.
9	Amount of data provided to the GUI for each use case is no more than 5 MB at a time. However, by user actions in the GUI, the user will be able to select which subset of available data stored on the CCCP data to display (dynamic zoom).
10	Amplifiers are controlled using UFC client library.

Table 1: General requirements and assumptions

Below is a figure showing possible implementation of the BPM GUI. GUI consists of three major sections:

- General settings panel. In this panel all settings which are not depended on the selected BPM mode are displayed.

- BPM mode settings panel. In this panel all settings which are specific for the selected BPM mode are displayed.

- BPM sub modes panel. In this panel all selected sub modes are displayed (e.g. closed orbit).
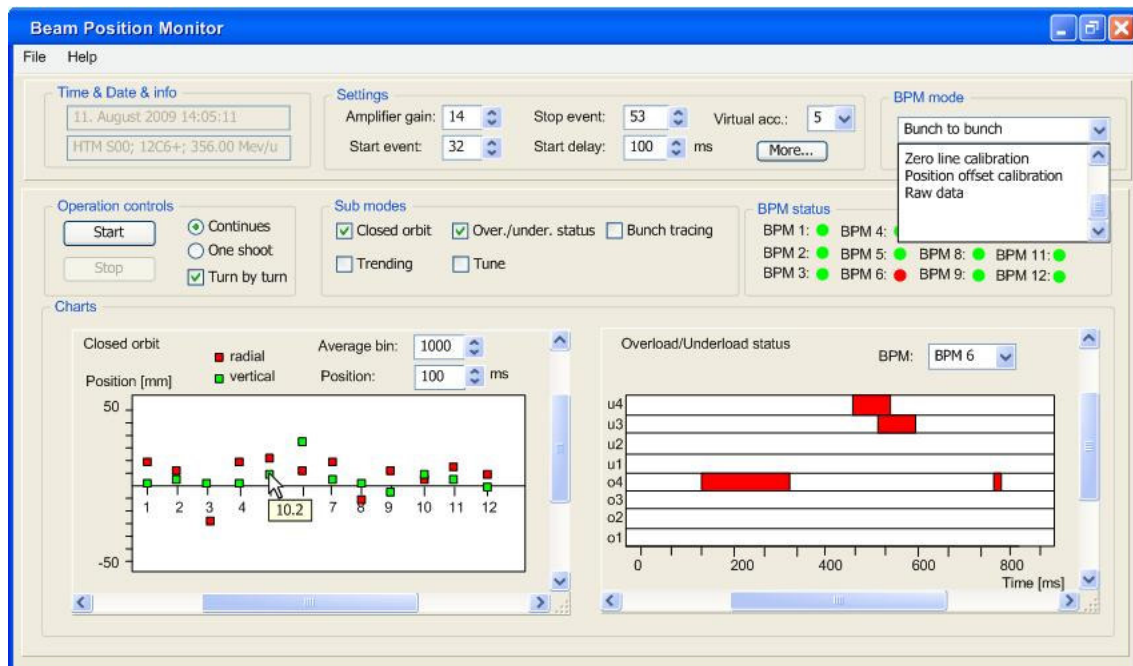
Figure 2: BPM user interface

2.1. USE CASES BASED ON BUNCH TO BUNCH DATA MODE

All use cases listed in this section are based on bunch to bunch data mode (BPM package is acquired from each BPM Libera) hence they can all be run concurrently. This means that user is able to observe closed orbit from all Liberas and concurrently watch overload/underload status from one of 12 Liberas and for example perform position trending from another Libera. In addition to that also data from the AUX Libera can be observed at the same time.

All use cases in this section are intended to be used in two ways (user selectable)

- Continually (e.g. cycle by cycle).

- One shot (one cycle then stop).

Depending on the use case data is displayed in one of the two ways:

- Online – meaning that data is displayed cycle by cycle.

- Offline – meaning that more time is needed to display data due to calculations (e.g. FFT calculations). For each use case displaying data offline an estimated latency before data is displayed is given in requirements table of each use case.

The following accounts for all use cases in this section:

- User selects bunch to bunch data mode out of given list of global modes.

- The user selects virtual accelerator out of list of available virtual accelerators (this information will be obtained from database).

- The user selects start/stop trigger and start delay (using PTIF). It should be possible for expert to set a delay for each Libera.

- The user selects amplifier gain.

- Between start event (plus delay) and stop event a BPM package from all 12 BPM Liberas are send to CCCPs at the trigger rate from the available interval.

- Data/bunch consistency check is performed on the CCCPs. This will eventually be an algorithm. For now only graph of time window vs. time is displayed in GUI.

- The user selects if data is to be saved on the disk together with meta information (time, date, virtual accelerator, gain). If saving is enabled the acquisition will not perform cycle by cycle but next acquisition will start only after the current data is saved, which can last for several seconds. The user selects the format (binary/ACSII) and name of the file.

- Graph can be saved as an image.

Requirements and assumptions:

ID	Description
11	All 12 BPM Liberas are used in these use cases
12	AUX Libera is used in these use cases.
13	BPM package is acquired on each of BPM Liberas at the trigger rate from the available interval and all data from 12 BPM Liberas is delivered to the CCCPs.
14	All the data is time stamped.
15	Absolute time stamp is added to the data on the CCCPs.
16	Perform data/bunch consistency check.
17	AUX package is acquired from Libera 13.
18	The data from Libera 13 is displayed online.
19	Graph of time window vs. turn number or time is displayed.
20	Signals from AUX Libera are shown on separate graph.

Table 2: Common requirements and assumptions

2.1.1. Closed Orbit – All BPMs

This use case is based on closed orbit sub mode of bunch to bunch data from [5].

Use case description:

- User selects closed orbit mode.

- The user selects bin size for averaging of position (default 1000).

- Data is displayed in graph of position (in mm) vs. BPM Libera number.

- The user is able to change currently displayed positions (e.g. point in time) (similar to POSI 15).

Requirements and assumptions:

ID	Description
21	Set the bin size for averaging (default 1000).
22	The result of the averaging of the data is displayed online in graph of positions vs. BPM Libera number.

Table 3: Use case Closed Orbit – All BPMs requirements and assumptions

2.1.2. Trending – One BPM

This use case is based on trending without averaging and trending with averaging of bunch to bunch data from [5].

Use case description:

- User selects trending mode.

- The user selects one of the 12 BPM Liberas.

- The user selects averaging.

- If averaging is selected the user is able to set bin size for averaging (default 1000).

- Data is displayed online in graph of position (in mm) vs. turn number or vs. time (user selectable). It is possible to display data of up to 6 Liberas.

Requirements and assumptions:

ID	Description
23	Activate/deactivate averaging.
24	Set the bin size for averaging (default 1000).
25	The data is displayed online in graph of position (in mm) vs. turn number or vs. time.
26	Data from up to 6 Liberas is displayed in graph.

Table 4: Use case Trending – One BPM requirements and assumptions

2.1.3. Overload and Underload Status – One BPM

This use case is based on overload graph like trending of bunch to bunch data from [5].

Use case description:

- User selects overload and underload status mode.

- The user selects one of the 12 BPM Liberas.

- Data is displayed online in graph of status vs. turn number or vs. time (user selectable).

- Warning is displayed in GUI if overload or underload status is set.

Requirements and assumptions:

ID	Description
27	Warning is displayed in GUI if overload or underload status is set
28	Data is displayed online in graph of status vs. turn number or vs. time.

Table 5: Use case Overload and Underload Status – One BPM requirements and assumptions

2.1.4. Tune – One BPM

This use case is based on FFT analysis of bunch to bunch data from [5].

Use case description:

- User selects tune mode.

- The user selects one of the 12 BPM Liberas.

- The user selects turn by turn mode (i.e. FFT is calculated for one bunch only – the number of bunches in SIS18 ring is obtained from harmonic value)

- The user selects bin size for the FFT calculation (e.g. 1024)

- FFT is calculated after enough samples are obtained from Libera.

- Data is displayed offline in graph of amplitude vs. frequency.

- Data is displayed offline in a 2D graph of Qy vs. Qx.

Requirements and assumptions:

ID	Description
29	FFT is calculated after enough samples are obtained from Libera.
30	Set the bin size for FFT calculation.
31	Data is displayed offline. Maximum latency from when data is acquired to when it is presented is 5s. This time must be long enough so that time of calculation on the concentrator, FESA overhead and 100Mbps controls network can handle it. Calculation for the lower limit: • Time for calculation on the concentrator is hard to estimate, 2s is assumed • Data transfer: 5 MB over 100 MBit Ethernet = 0.4s • FESA and CMW overhead: 1s

Table 6: Use case Tune – One BPM requirements and assumptions

2.1.5. Bunch Tracing – All BPMs

This use case is based on bunch tracing sub mode of bunch to bunch data from [5].

Use case description:

- User selects bunch tracing mode

- Betatron phase advance is calculated on the fly (i.e. calculation is performed in parallel with data acquisition)

- Data is displayed in GUI in graph of Betatron phase advance vs. turn number or vs. time.

Requirements and assumptions:

ID	Description
32	The result of the calculation need not be available in GUI in real-time. Maximum latency from when data is acquired to when it is presented is 20 s. This time must be long enough so that time of data acquisition, time of calculation on the concentrator, FESA overhead and 100Mbps controls network can handle it. Calculation for the lower limit: • Time for calculation on the concentrator is hard to estimate, 5s is assumed • Data transfer from CCCP to GUI: 5 MB over 100 Mbit Ethernet = 0.4s • FESA and CMW overhead: 1s

Table 7: Use case Bunch Tracing – All BPMs requirements and assumptions

2.2. POSITION OFFSET CALIBRATION – ALL BPMS

This use case is based on calibration of bunch to bunch data from [5].

> Position offset calibration will not be performed using signals from bunches but rather test signals connected to amplifiers.

Use case description:

- User selects position offset calibration mode (since this mode will affect all BPM Liberas any previous ongoing acquisition has to be stopped).

- Test generators are switched on and signals connected to amplifiers.

- The user selects amplifier gain.

- Warning message in GUI is showing that position offset calibration is in progress.

- The user selects bin size (default 1000) which is used for averaging of position.

- The user initiates start. This is achieved by programming PTIF in a way that is sends start trigger to Liberas immediately (i.e. not waiting for start trigger from the GSI timing system).

- When enough samples are acquired (i.e. more than bin size) stop trigger is send to Liberas to stop acquire data.

- Position offset is calculated (i.e. averaged), showed on the GUI in similar chart as for closed orbit position.

- Calculated values are stored on the disk together with date and time.

Requirements and assumptions:

ID	Description
33	All 12 BPM Liberas are used in this use case.
34	AUX Libera is not used in this use case.
35	RF trigger input is not used on BPM Liberas.
36	Start of the calibration is manual.
37	BPM package is acquired from each of 12 Liberas at maximum trigger rate (6Mhz) and all data is delivered to the concentrator. Data rate from one Libera is 576 Mbit /s, total rate for 12 Liberas simultaneously feeding the concentrator is approximately 576 Mbit / s * 12 = 6912 Mbit/s plus UDP overhead
38	Calculate position offset.
39	Stored values are used for all acquisition thereafter.

Table 8: Use case Position Offset Calibration – All BPMs requirements and assumptions

2.3. ZERO LINE CALIBRATION – ALL BPMS

This use case is based on zero line identification of bunch to bunch data from [5].

> Zero line calibration must be performed during beam brake (i.e. no beam must be present).

Use case description:

- User selects zero line calibration mode (since this mode will affect all BPM Liberas any previous ongoing acquisition has to be stopped). Since this mode is a special mode also on Libera this selection will put Liberas into the appropriate mode using Fast Application (FA).

- Warning message in GUI is showing that zero line calibration is in progress.

- Warning message in GUI is showing if the beam is present.

- The user selects bin size (default 1000) which is used for averaging of acquired values. The bin size is set on Libera via Fast Application (FA).

- User selects between manual and automatic start of calibration. Automatic start uses PTIF to start the measurement. When manual is selected user has to initiate start manually (via PTIF).

- The user selects start/stop trigger (using PTIF). The start and stop trigger must make sure that no beam is present.

- The user initiates start (if manual mode is used). This is achieved by programming PTIF in a way that it sends start trigger to Liberas immediately (i.e. not waiting for start trigger from the GSI timing system).

- Each of 12 BPM Liberas performs zero line calibration, meaning it samples inputs and averages acquired values.

- After calibration is done the values are stored in Liberas and used for all acquisitions thereafter.

- Stop frame is sent to CCCP indicating the calibration is over.

- Stored values in Liberas are acquired via FA, displayed in the GUI and stored on the disc along with time and date.

- The user has a possibility to retrieve previously stored values. This is needed if the calibration was done when the beam was present and hence the calculated values are incorrect.

Requirements and assumptions:

ID	Description
40	All 12 Liberas are used in this use case.
41	AUX Libera is not used in this use case.
42	RF trigger input is not used on Liberas.
43	No beam is present.
44	Start of the calibration is manual.

Table 9: Use case Zero Line Calibration – All BPMs requirements and assumptions

2.4. USE CASES BASED ON RAW DATA

2.4.1. Raw Data - One BPM

This use case is based on raw data [5].

It will be used for offline investigations and debugging.

Use case description:

- User selects raw data mode out of given list of global modes.

- The user selects virtual accelerator out of list of available virtual accelerators (this information will be obtained from database).

- The user selects start trigger and start delay (using PTIF).

- The user selects length of the measurement (set on the Libera via FA)

- The user selects amplifier gain.

- After start event (plus delay) a raw data from all 4 BPM channels on one Libera at the maximum sampling frequency will be stored whiting the Libera for a limited amount of time.

- After acquisition the data stored in the Libera is delivered to CCCP.

- The data is stored on the disk using binary or ASCII file format.

- The data is displayed in graph of ADC values vs. time.

Requirements and assumptions:

ID	Description
45	Only one BPM Libera is used in this use case.
46	Maximum sampling period is 0.256 second, and all 4 channels can be sampled simultaneously. The number of samples in this case is 125 MSa / s * 4 channels * 0.256 s = 128 M samples (or 256 MB of data), which is the buffer size of Libera [2]. Note that this requirement is different than it was suggested initially by GSI-SD [3], which did not take into account the limitations of the Libera.
47	The data need not be available in GUI in real-time. Maximum latency from when data is acquired to when it is presented is 5s. This time must be long enough so that FESA overhead and 100Mbps controls network can handle it. Calculation for the lower limit: • FESA and CMW overhead: 1s • Data transfer from Libera to CCCP : 256 MB over 1 Gbit Ethernet ~ 2s • Data transfer from CCCP to GUI: 5 MB over 100 Mbit Ethernet = 0.4s

Table 10: Use case Raw Data - One BPM requirements and assumptions.

3. DOCUMENT PROPERTIES

3.1. GLOSSARY OF TERMS

BPM .... Beam position monitor

BPM package .... Package containing data from one bunch

AUX package.. Package containing data from AUX (auxiliary) Libera

BPM Libera.. Libera sending BPM package

AUX Libera .... Libera sending AUX package

DAQ .... Data acquisition

FA... Fast Application (parameters on Libera FPGA)

FPGA.. Field-Programmable Gate Array

CCCP .... Concentrator and control computer

CSL.. Cosylab

CSPI .... Control System Programming Interface

GUI.. Graphical User Interface

HW... Hardware

SW .... Software

3.2. REFERENCES

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[2]   Instrumentation Technologies: *Libera Hadron, Specification*, revision 1.41.

[3]   T. Hoffmann: *SIS 18 BPM-System*, **TH-Notiz-2008-007**.

[4]   T. Hoffmann: *BPM DAQ System Study by Cosylab*, **TH-Notiz-008-2008.**

[5]   T. Hoffmann, P.Forck, P. Kowina, K. Lang: *Collection of BPM specifications*, **TH-Notiz-012-2008**

[6]   I. Verstovšek: SIS 18 BPM Upgrade, Minutes of Kick-off Meeting, revision 1.0, July 23 2008

[7]   G. Janša: Minutes of bi-weekly meeting, revision 1.0, August 08 2008

[8]   G. Janša: Minutes of bi-weekly meeting, revision 1.0, August 19 2008

[9]   G. Janša: Minutes of bi-weekly meeting, revision 1.0, September 03 2008

[10]   G. Fröhlich: Das Positionssonden – Messprogramm **U-POS-01-1.5**, August 12 1998