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DEVELOPMENTS OF 4GSR BPM ELECTRONICS

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Abstract

The emittance of the 4th-generation storage ring (4GSR) to be constructed in Cheongju-Ochang, Korea, is expected to be approximately 100 times smaller than the existing 3rd-generation storage ring. With the decrease in emittance, more precise beam stabilization is required. To meet this requirement, the resolution of the beam position monitor (BPM) system also needs to be further improved. We have conducted research and development on the electronics of the BPM system for the 4GSR storage ring. In order to perform fast orbit feedback in the 4GSR storage ring, we need to acquire turn-by-turn beam position data, with a desired beam position resolution of 1 µm. Additionally, prototypes of the bunch-by-bunch monitoring system are being developed for the transverse feedback system and longitudinal feedback system. The internally developed electronics are intended to be modified for future use as monitors for multi-bunch beam energy measurements at the end of the linear accelerator, by adjusting the logic accordingly. In this presentation, we will describe more details of the current status of the development of the beam position monitor electronics for the 4GSR in Korea.

INTRODUCTION

To achieve precise beam orbit stability in the 4th-generation storage ring with an emittance about 100 times smaller than the existing 3rd-generation storage ring [1], a more precise beam position monitor system with higher resolution is required. Figure 1 shows the construction view map of Korea 4GSR. In addition, the design of the 4GSR BPM electronics should be measure and provides Turn by Turn beam position data for Fast Orbit Feedback (FOFB) system with 375 kHz rate, which is a revolution frequency of 4GSR storage ring.

Figure 1: Construction view map of Korea 4GSR.

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DEVELOPMENT STRATEGY OF 4GSR BPM ELECTRONICS

The strategy for developing 4GSR BPM electronics is as follows: First, we aim to develop BBB (Bunch by Bunch) BPM electronics capable of providing the highest performance for bunch-by-bunch beam position measurements. Subsequently, using this technology as a foundation, we will proceed to develop TbT (Turn by Turn) BPM electronics specifically tailored for the 4GSR storage ring. By integrating the front-end and back-end electronics, we will create Transverse & Longitudinal feedback systems (TFS & LFS), referred to as TFS & LFS BPM electronics.

Following this, we plan to adapt the data processing logic of the BBB electronics into a single-pass logic. This adaptation will enable us to install these electronics along the LTB (Linac. to Booster) beamline in the linear accelerator backend. They will serve as multi-bunch beam energy measurement monitors. The diagram below illustrates the development strategy for 4GSR BPM electronics. Figure 2 shows that the development strategy of 4GSR BPM electronics systems.

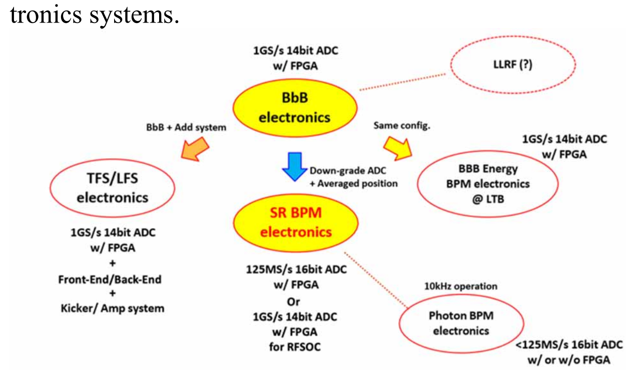

Figure 2: Development strategy of 4GSR BPM electronics.

Development Status of BBB BPM Electronics

The BBB electronics are currently in the prototype development phase [2], and we are undergoing several beam tests to ensure the system's stability. By configuring the desired storage ring parameters and turn counts, we have confirmed the capability of measuring the beam position for all bunches.

Figure 3 shows signal processing logic of BBB electronics. The signal processing procedure of BBB electronics as follows: To obtain a sufficient amount of bunch information, data is collected over several turns. Subsequently, the ADC data from every bunch is rearranged to calculate the beam position information for all bunches in the time domain. However, as previously mentioned, BBB Electronics is also adaptable for use with TbT BPM Electronics.

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In the case of TbT data, the design ensures that the average beam positions of the bunches are calculated in the time domain for each turn with 375 kHz rate.

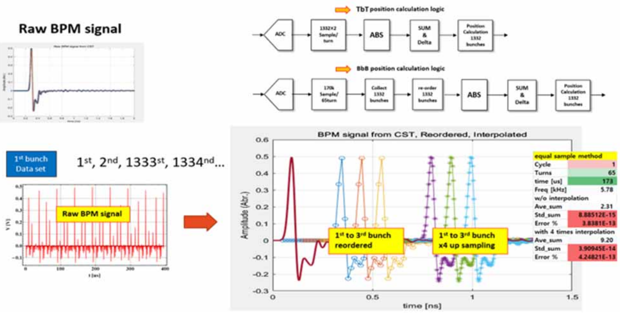

Figure 3: Design and simulation of 4GSR BBB BPM electronics logic.

Figure 4 shows the circuit configuration of the developed prototype BBB electronics. The prototype of BBB Electronics has been designed to synchronize two FMC ADC boards (2 Channel) on a Xilinx evaluation board. It utilizes 1 GS/s ADCs for data acquisition and has successfully measured bunch-by-bunch beam positions with stability during beam tests at the Pohang Accelerator Laboratory's PLS-II (Pohang Light Source-II) storage ring. In the future, to provide even more reliable performance, the entire board is undergoing upgrades. It will also utilize embedded EVR to receive the 500 MHz Master Oscillator RF signal, Machine Clock (MC), and 10 Hz Trigger signal, enabling the utilization of the 4GSR event system.

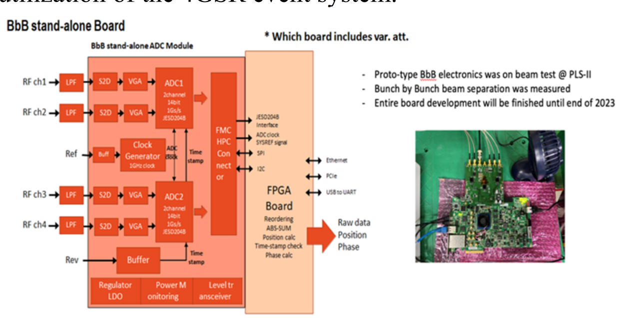

Figure 4: The configuration of BBB BPM electronics.

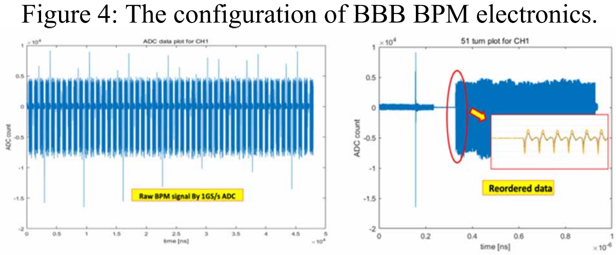

Figure 5: The beam test results of BBB BPM electronics. A signal reconstruction by using BBB signal with 51turn data at PLS-II storage ring.

Figure 5 shows the beam test results of BBB Electronics. After acquiring ADC data for 51 turns at a speed of 1 GS/s, the data was rearranged according to the bunch order, resulting in the acquisition of beam position information for all bunches. While additional data was obtained for sufficient data acquisition and precise signal waveform reconstruction, it is our aim to acquire beam position information for all bunches in a shorter time frame through the design of additional Analog Front-End Electronics, for future application in TFS & LFS.

4GSR SR BPM ELECTRONICS & SYSTEM CONFIGURATION

For the 4GSR Storage Ring (SR), TbT BPM electronics are currently in the process of being developed based on the prototype of the BBB electronics. The timing system for the storage ring utilizes the Event Network to provide Trigger signals and the Machine Clock to the BPM electronics. Additionally, SR BPM electronics employ SFP (Small Form-factor Pluggable) modules to provide X, Y, and Sum information at a speed of 375 kHz for the FOFB controller, Fast Orbit Interlock (FOI) controller, and Fast DAQ server. However, for Slow Acquisition (SA) data required to calculate the closed orbit of the storage ring, it is synchronized with a 10Hz Trigger and transmitted to the EPICS system for beam position information as shown in Fig. 6. Figure 6 shows the I/O port configuration of SR BPM electronics.

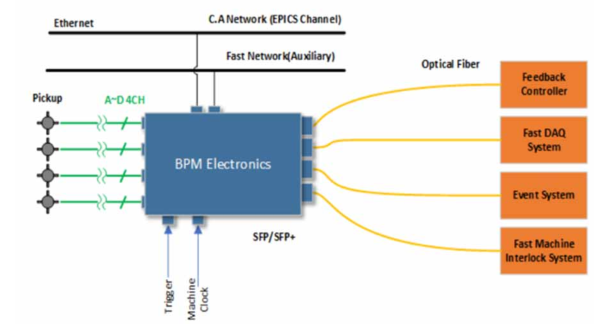

Figure 6: I/O configuration of 4GSR SR BPM electronics.

Figure 7 depict the data flow of SR BPM electronics for TbT data and SA data case, while Fig. 8 illustrates the configuration of BPM cable connections for the storage ring.

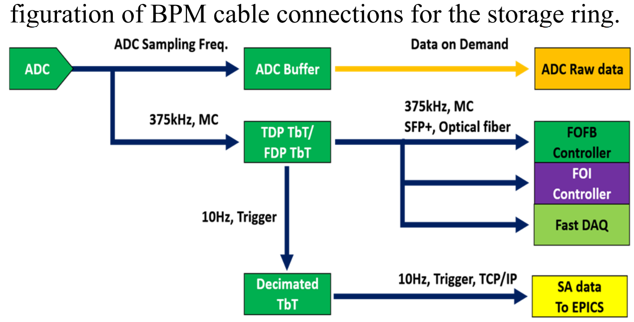

Figure 7: The data flow of 4GSR SR BPM electronics.

The feedback system for 4GSR is structured in two stages, with the first stage being the Slow Orbit Feedback System (SOFB). This system calculates and corrects the closed orbit at a rate of 2 Hz using a total of 288 BPMs and Correctors across the entire storage ring. The corrected closed orbit becomes the new Reference Orbit (Ref. Orbit). Subsequently, the FOFB system operates at each cell, receiving TbT data from BPM electronics at 375 kHz intervals and providing new set point information to the kicker MPS (Magnet Power Supply) every 15.6 khz.

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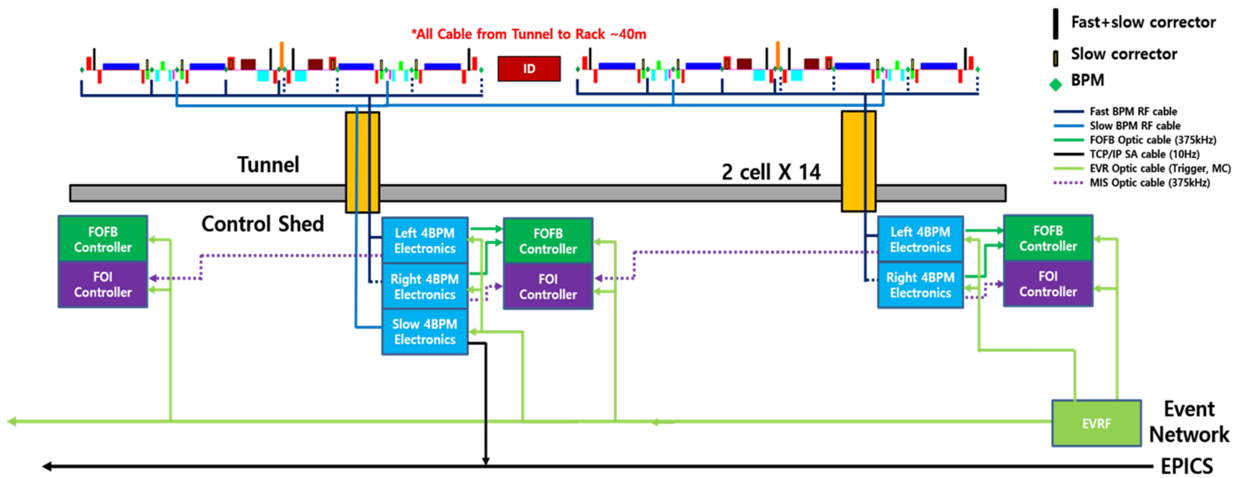

Figure 8: The configuration of BPM RF & timing cable connections for the storage ring.

Ultimately, the FOFB system aims to perform fast orbit feedback at a 10 kHz interval using fast BPMs and fast correctors to achieve a wide suppression bandwidth. While there isn't a master feedback controller for the entire storage ring, the FOFB controller exchanges information between adjacent cells at every turn. As a result, this system swiftly corrects distorted beam orbits in each cell and calculates kick angles for orbit correction based on the overall storage ring's orbit changes. Table 1 describes that the target parameters of the 4GSR feedback system.

Table 1: Specification Goal of 4GSR Beam Stability

Type	Data	Spec.	Conditions
Position Resolution [RMS]	TbT [375 kHz]	1 µm	400 mA 1065 Bunches
	SA [10 Hz]	30 nm	
	TbT [375 kHz]	100 µm	0.1 ~ 1 mA (Commissioning)
	SA [10 Hz]	1 µm	
Beam Current Dependence	-	~1 µm	0.1 mA ~ 400 mA
Absolute Accuracy	-	< 500 µm	Before BBA
		< 5 µm Max.	After BBA
Long-term Stability [RMS]	-	±0.2 µm	Day drift
		1 µm	Week drift

CONCLUSION

The Korean 4GSR project in Ochang is currently under construction with the goal of completion by 2027. The beam position monitor electronics system for 4GSR is in the process of development, and initial beam tests have been conducted by using developed prototype of BBB BPM electronics. Based on this, BPM electronics for the storage ring and feedback systems for both TFS and LFS are also under development. Additionally, preparations are underway for BBB energy measurement BPM electronics, which will be used for multi-batch beam energy measurements at the end of the linear accelerator. The aim is to complete the development of storage ring BPM electronics by the end of 2024. Simultaneously, tests will be conducted at the PLS-II storage ring in collaboration with the ongoing development of the FOFB controller.

ACKNOWLEDGEMENTS

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