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 um. 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.

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, 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.

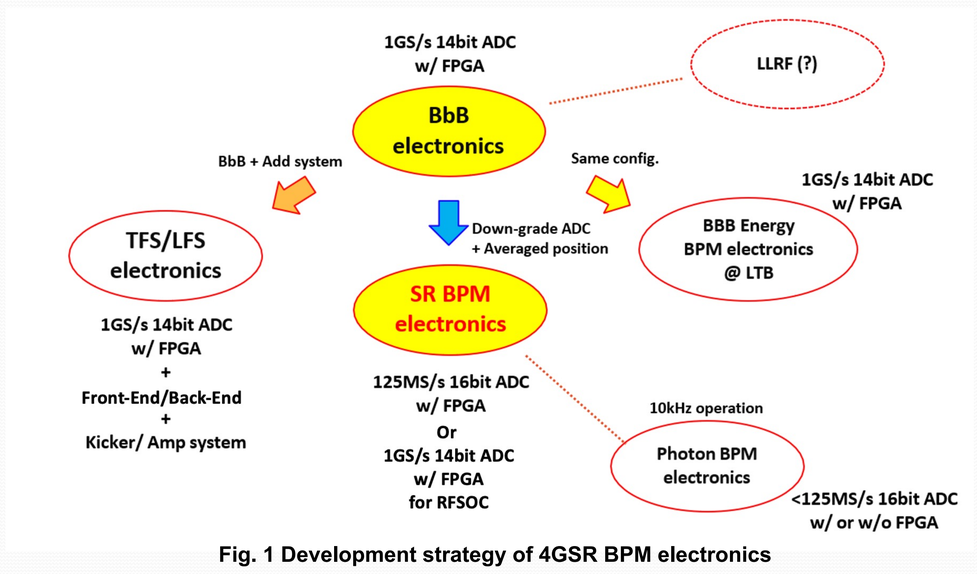

Fig. 1 Development strategy of 4GSR BPM electronics

Development status of BBB BPM electronics

The BBB electronics are currently in the prototype development phase, 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. Figures 2 and 3 below illustrate the circuit configuration of the developed prototype and provide the Bunch-by-Bunch beam position measurement results.

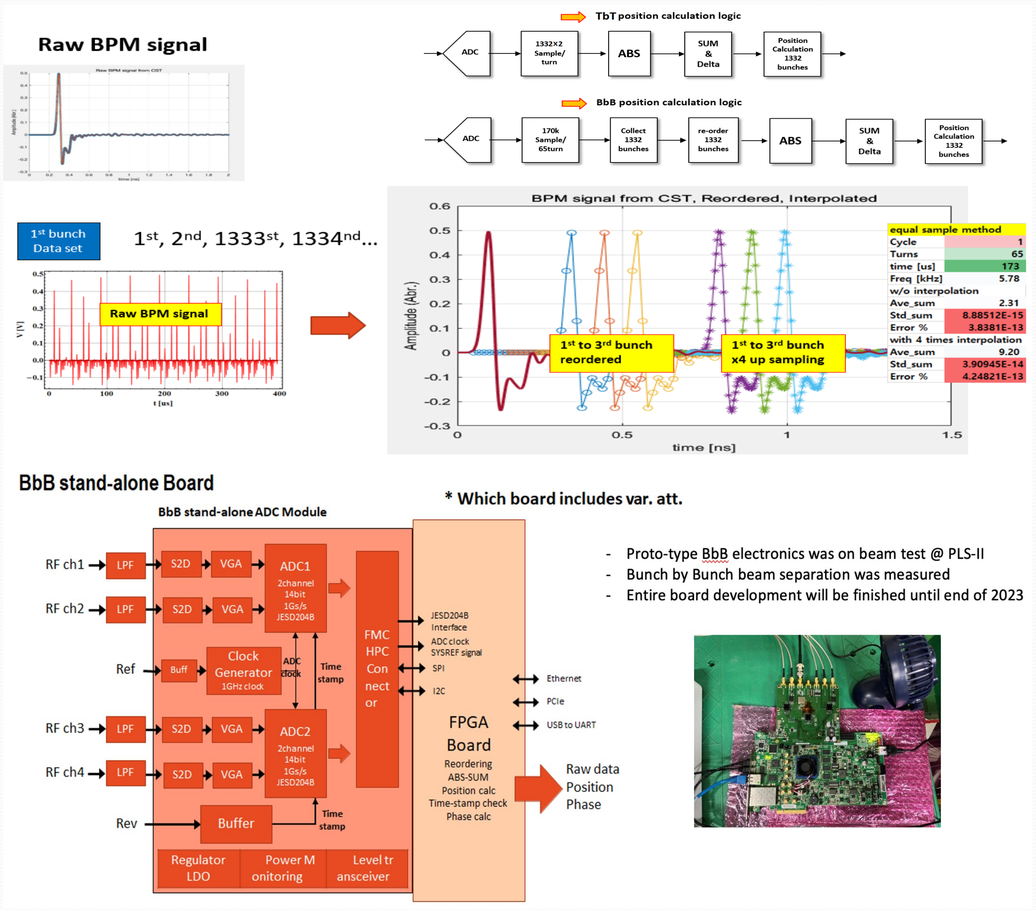

Fig. 2 Proto-type of 4GSR BBB BPM electronics

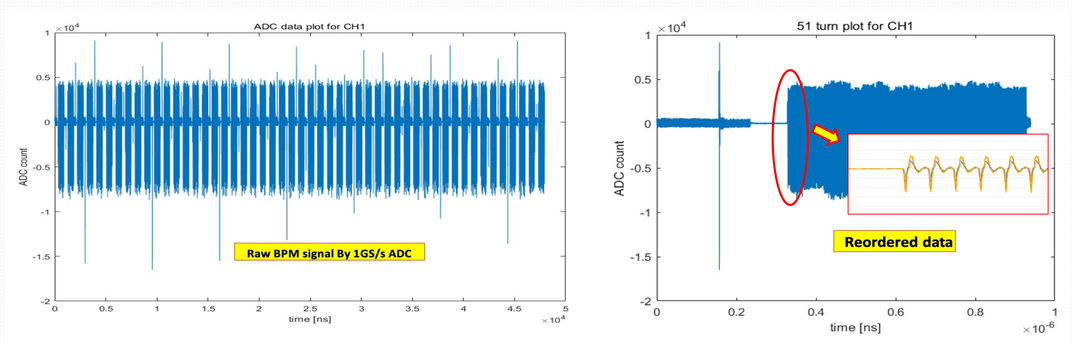

Fig. 3 Beam test results of 4GSR BBB BPM electronics @ PLS-II

4GSR SR BPM electronics & system configuration

For the 4GSR Storage Ring (SR), TbT (Turn by Turn) 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 375kHz for the Fast Orbit FeedBack (FOFB) controller, Fast Orbit Interlock 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.

Figures 4 depict the I/O port and data flow configuration for SR BPM electronics, while Figure 5 illustrates the configuration of BPM cable connections for the storage ring.

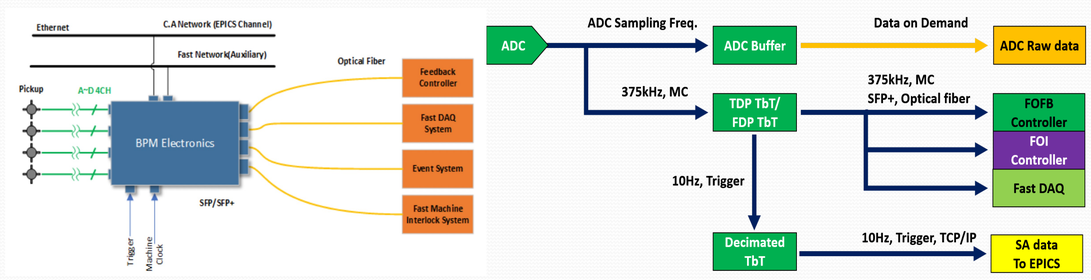

Fig. 4 4GSR SR BPM electronics I/O and data flow configuration

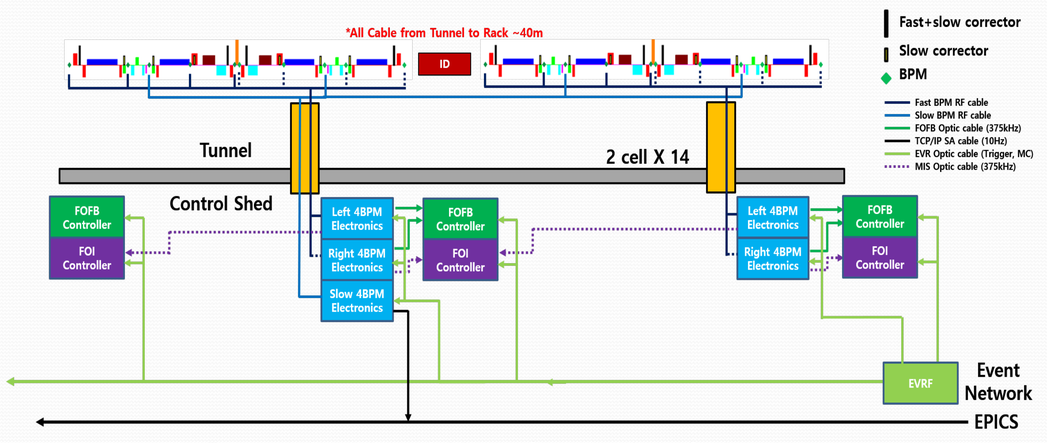

Fig. 5 The configuration of BPM cable connections for the storage ring

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 2Hz using a total of 288 All BPMs and Correctors across the entire storage ring. The corrected closed orbit becomes the new Reference Orbit (Ref. Orbit). Subsequently, the Fast Orbit Feedback (FOFB) system operates at each cell, receiving TbT data from BPM electronics at 375kHz intervals and providing new set point information to the Kicker MPS every 15.6kHz. 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 illustrates the target parameters of the 4GSR feedback system.

Type	Data	Spec.	Conditions
Position resolution [RMS]	Turn by Turn (375kHz)	1um rms	400mA, 1065 bunch
	SA (10Hz)	30nm rms	
	Turn by Turn (375kHz)	100um rms	0.1~1mA (Commissioning)
	SA (10Hz)	1um rms	
Beam Current Dependence	-	~ 1um	From 0.1mA to 400mA
Absolute accuracy	-	< 500um	Before BBA
		< 5um	After BBA
Long-term Stability	-	±0.2um	Daydrift
		1um rms	Weekdrift

Table 1. Specification goal of 4GSR Beam stability.

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 based on the development of the 1st stage BBB BPM electronics prototype. Based on this, BPM electronics for the storage ring and feedback systems for both TFS (Transverse Feedback System) and LFS (Longitudinal Feedback System) 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 Pohang Light Source-II (PLS-II) storage ring in collaboration with the ongoing development of the FOFB (Fast Orbit Feedback) controller.

REFERENCES

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