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DEVELOPMENT OF BUTTON BPM ELECTRONICS FOR THE BUNCH BY BUNCH FEEDBACK SYSTEM OF 4GSR

S.W. Jang†, Department of Accelerator Science, Korea University, Sejong, South Korea

Abstract

With the advent of the fourth-generation storage ring, the size of the vertical emittance of the electron beam is expected to be about 100 times smaller than that of the existing generation. By advanced of synchrotron light source performance, the resolution of the beam position monitor (BPM) should also be further improved, and it can be providing a more stable and uniform beam to end station users through improved bunch by bunch (BbB) feedback system compared to a system called turn by turn or fast feed-back [1-4]. A developed BPM electronics for BbB feedback will be installed in Bessy II booster ring at HZB (Helmholtz-Zentrum Berlin) Research Institute in Germany [5]. BbB feedback BPM electronics with an improved three button BPMs will be used to measure beam position resolution and calculate an information for BbB feedback, and then it will apply to the BbB feedback system. In this proceeding, we will describe the development of button BPM electronics for BbB feedback.

INTRODUCTION

Brightness and stability are key specifications of the light source accelerator storage ring. Continuous efforts are made to achieve high current, high brightness and beam stability. The limitation of the performance of storage ring due to coupling impedance is one of issue for the next generation light source accelerator storage ring.

What made the coupled beam instability and how to treat it is a key question that accelerator researcher for light source storage ring around the world must face. Observing and measuring the bunch by bunch beam in real time helps researchers analyze the stored beam status of storage ring. As much as more precise beam bunch measurements for beam position and charge helps to quantitatively study beam impedance, coupling instability, and nonlinear dynamics, and can provide. In particular, bunch by bunch feedback is widely used as a method to solve the transverse coupled beam instability that occurs in many of light source accelerator storage ring.

With the rapid advances of DAQ devices by relate industry companies, the performance of ADC and FPGA systems has improved incredibly. High sampling rates with large memory capacities, multi-channel broadband ADC can be providing an ideal tool for obtaining raw data information of beam signal from BPMs. Bunch-by-Bunch beam position and relative charge can be obtained through the FPGA online algorithm process.

Using the high-performance uTCA board with ADC and FPGA as above, it is intended to implement the BBB feedback system by using the time domain processing (TDP) logic using raw signals without a separate FIR filter and down converting. The most important key element of this system is to obtain the same time resolution and high vertical resolution as the raw signal of the beam from BPM by interpolating the data between insufficient sampling through up-sampling technique using FPGA.

MAIN IDEA OF BBB FEEDBACK ELECTRONICS

The parameters of the BESSY II storage ring and booster ring were used to design the BbB feedback algorithm. HZB also developing their own BbB feedback system based on frequency domain processing (FDP) logic for the storage ring [1]. To compare with frequency domain processing logic, BbB electronics using time domain processing logic and also newly upgraded three beam position monitors are will be installed to booster ring. We will measure beam position resolution by using BbB electronics and three button BPM, after changing the operation mode of the booster to storage ring mode. The main parameters of BESSY II accelerator, which are used for BbB feedback signal processing logic, are summarized in Table 1.

Table 1: Main Parameters of BESSY II ofBooster Ring & Storage Ring

Parameters [unit]	Booster	Storage
Energy [GeV]	0.05 to 1.7	1.7
Circumference [m]	96	240
RF frequency [MHz]	499.622801	499.622801
Beam current [mA]	3	300
Harmonic number	160	400
T_rf [ns]	2.0015	2.0015
Sampling ratio	2048/1020	2048/1025
Sampling freq. [MHz]	1003.16421	988.270728
Sampling time [ns]	0.99684577	1.0017
Rev. frequency [MHz]	3.12264251	1.249057
T_rev [ns]	320.24159	800.603974
Integer sample turns	51	41
Samples/51 or 41 turns	16384	32768

Beam position measurement using TDP has the advantage of analyzing the beam position by using the whole information of the signal output from the beam position monitor as it is without distorting it. However, the RF frequency of a light source accelerator storage ring, such as BESSY II, usually used around 500 MHz, so the length of one bunch signal is about 2 ns. In order to measure a signal

†siwony@korea.ac.kr

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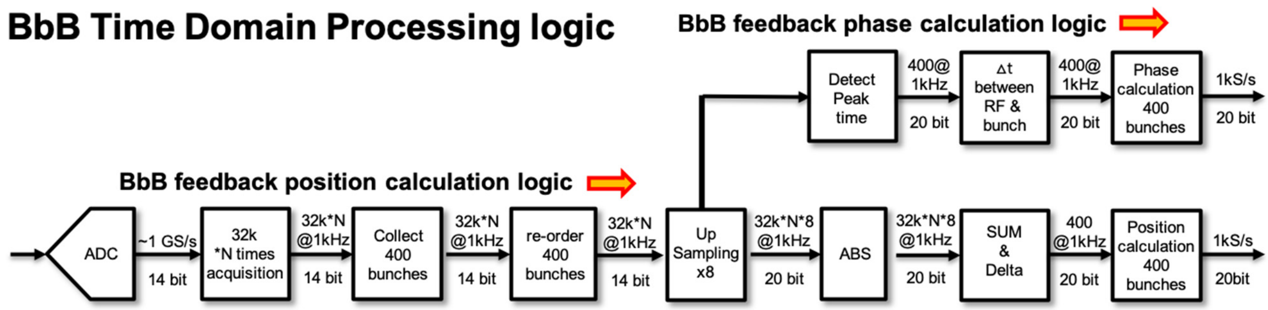

Figure 3: The time domain signal processing logic of Bunch by bunch feedback BPM.

of 2 ns, at least 5 to 10 samples must be obtained and then reconstructed. Moreover, in the case of BESSY II, the multi-bunch pulse width is about 45 ps of FWHM, so a sampling speed of tens of GS/s is required to measure these signals without losses of information.

The available sampling rate of the high-speed ADC is about 2 to 4 GS/s, and still has leak of sample numbers to reconstruct a single bunch within 2ns. Therefore, to overcome this problem, the asynchronous sampling frequency rather than integer multiple for RF frequency and technique of up-sampling by using FPGA are used.

HARDWARE OF ELECTORNICS

The hardware of BbB feedback electronics is mainly consists of two parts, analog front-end (AFE) and digital signal processing circuit. Figure 1 shows the schematic of BbB BPM electronics. The AFE electronics will be installed as much as reduce deformation of BPM signals. The output signals from the AFE are connects to the half-inch cables and connects to the digital signal processing circuit which installed in the gallery outside the tunnel.

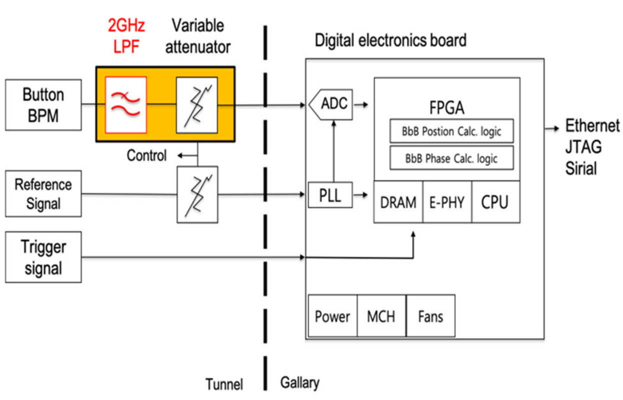

Figure 1: Schematic of BbB feedback electronics.

Analog Front End Electronics

The AFE part of electronics consists of 70dB variable attenuator used to a full scale of ADC dynamic range which modules can be controlled remotely and low pass filter with 2 GHz band width to limit the harmonics in the spectrum. Figure 2 shows the details of AFE part of BbB electronics.

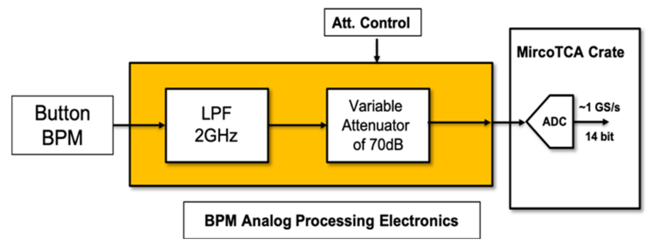

Figure 2: Schematic of Analog Front-end electronics.

Digital Signal Processing Circuit

As mentioned before, there are three of main key points of BbB feedback electronics by using TDP. The purpose of TDP is not only measurement of BbB beam positions, it's reconstruction of raw signals of every 400 bunches of BESSY II storage ring. Which can be helps to analysis of beam dynamics as like coupled beam instability. Figure 3 shows the TDP logic for BbB feedback BPM signals.

To measure all of stored bunches of raw signals by using electronics we should locked sampling frequency refer to RF frequency. For example, the sampling frequency of storage ring was locked by multiplying factor of 2048/1025 then we can acquire 32768 samples per every 41turns. This sampling ratio is depending on the harmonic number of storage ring, therefore 2048/1025 ratio for storage ring and 2048/1020 ratio for booster ring are used to getting integer sample points after 41 turns and 51 turns, respectively.

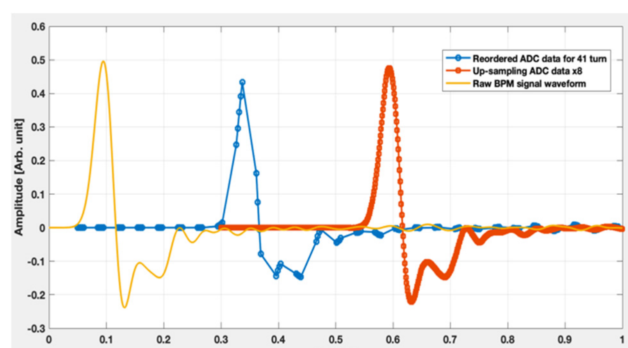

Figure 4: A signal reconstruction by using up-smapling method. Raw BPM signal(left), re-orderd ADC data(middle), and up-sample data(right).

Figure 4 shows the reconstructed signal by using up-sampling method on FPGA. The blue line (middle of Fig.4)

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is reconstructed 1st BbB BPM signal after 41 turn data acquisition and orange line (right of Fig.4) shows the reconstructed signal by using up-sampling method.

For more convenient visual comparison, Figure 4 drew the time axes of the ordered data and the up-sampled data with 50 ps and 300 ps delay, respectively.

Acquired ADC data after 41 turns are separate to 400 bunch data arrays then all the bunch data are reordered used to up-sampling method. Even we acquired ADC data of 41 turns, reconstructed BbB beam signals by using up-sampled data are not equal to actual raw BPM signals because we only have 81.92 sample numbers per each bunch after 41 turns. To solve this problem, we take more large data during 41*N turns and then the data was up-sampled by factor 8. Finally, we can get 81.92/41turn*N*8 samples for the raw signal reconstruction. If we acquire much longer time, we can clearly reconstruct raw signal of each bunch but it can't exceed more longer than feedback frequency what we designed for BbB feedback with fast kicker system. Figure 5 shows the reconstructed signals to compare between 41turn and 164 (= 4 times of 41turn) turn cases.

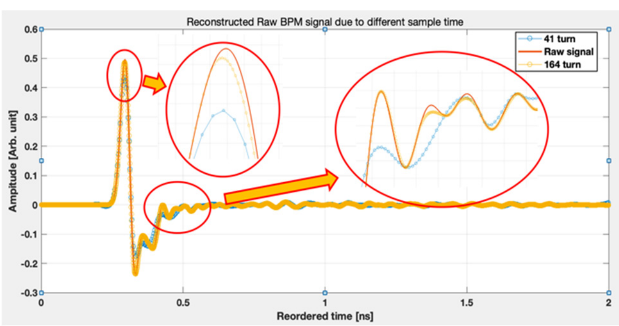

Figure 5: A signal reconstruction comparison results of 41 and 164 turns case by using up-sampling method.

As like results of Fig. 5, If sample number per bunch is not enough as 41 turn data acquisition case, then the produced up-sampled data still shows quite different waveform compare with actual raw BPM signal waveform. However, 164 turn data acquisition case shows almost close to actual BPM signal that means if we improve our ADC spec from 1GS/s to 4GS/s then even if we take data acquisition during 41turn, it will show almost close to actual beam signal waveform.

Figure 6 shows the results of accuracy of reconstruction signal versus ADC data sample acquisition time. The accuracy of reconstruction signal is calculated by standard deviation over integrated absolute SUM signal of BbB BPM data. The accuracy of reconstruction signal is proportional to inverse of data acquisition time. If we acquire BbB data during 328 turns, which corresponds to 262 us, the accuracy of up-sampled data compare with actual BPM signal is below 0.1%. This digital signal processing time allows for 1 kHz BbB feedback frequency operation. In order to operate the feedback system as much faster frequency, if the ADC sample speed will be upgraded to 4GS/s as mentioned before, a BbB feedback operation of about 10 kHz can be possible.

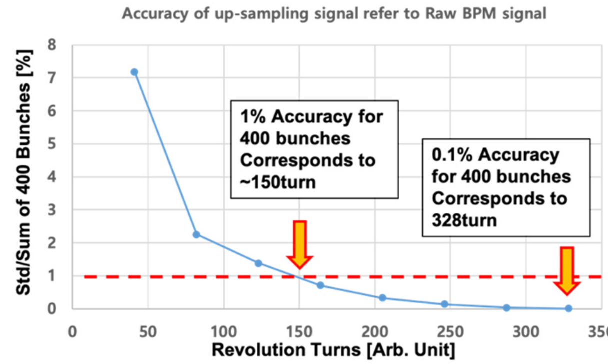

Figure 6: Accuracy of reconstruction signal versus ADC data sample acquisition time(turns).

CONCLUSION

In this proceeding, we discussed about new idea for BbB feedback BPM signal processing by using TDP. Using the technological advances of various beam diagnostics devices, we devised a new method of measuring BbB beam position monitoring. It is expected that TDP signal processing by using up-sampling method, including all possible raw BPM signal information, will be used for more light source accelerator beam diagnostics and beam dynamics research. The prototype BbB feedback BPM electronics of TDP method will be installed in the BESSY II booster to perform beam tests, compare the results with the existing FDP BbB feedback system, and then we will upgrade the current BbB electronics system.

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