NEW BUNCH-BY-BUNCH FEEDBACK SYSTEM FOR THE TLS

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Abstract

FPGA based bunch-by-bunch feedback systems were deployed in 2005-2006 by using SPring-8 designed feedback processors for the Taiwan Light Source. To provide spare units and explore integrate with the control system in the EPICS toolkit environment, feedback processors from the Dimtel were setup. The new system can be swap with the existed system by simple cable re-connection and integrated with the EPICS system in seamless way. Rich functionality except the basic feedback function includes excitation of individual bunch or specifies bunches, averaged spectrum, tune measurement by the feedback dip in the averaged spectrum, fill pattern measurement, …etc. are explorer. Current stage implementation and features of the system will summary in this report.

INTRODUCTION

Digital bunch-by-bunch feedback systems for the TLS were deployed during 2005 ~ 2006 to combat transverse and longitudinal coupled-bunched instability highly successful. In the TLS, these feedback loops are indispensable to deliver high quality photon beam. To explore functionality of the new generation bunch-by-bunch feedback solutions, provide a better diagnostics and evaluate functionality for TPS usage, a general feedback signal processor solution, called iGp (Integrated Gigasample Processor) was selected for the upgrade. The iGp provides real-time baseband signal processing at an RF frequency of 500 MHz for 200 bunches at the TLS. The major reason is that the system supports EPICS control environment and provides good control system integration for future machine upgrade. Rich functionalities are supported, such as feedback, bunch train excitation; selective bunches excitation, tune measurement, bunch cleaning, precision timing adjustment and etc. This new system accompany with the existed system as hot spare purpose. Explore the bunch-by-bunch feedback functionality for the future 3 GeV Taiwan Photon Source (TPS) which being under construction is another driven force of this test.

FEEDBACK PROCESSORS

Two versions of iGp processors were used for the bunch-by-bunch feedback system upgrade due to historical reason. The iGp processor is implemented with a high-speed (500+ MHz) processing channel with 8 bits ADC and 12 bits DAC. The iGp12 is the new version of iGp with 12 bits ADC and DAC. Functionalities of both models are the same. The processor unit is primarily designed for bunch-by-bunch applications in storage rings. However, wideband low-noise ADC input and integrated diagnostic features make the feedback processor to be a valuable bunch-by-bunch diagnostic tool, and applied in the electron storage rings. The feedback processor is configured to individually process for all bunches in the ring. Signal for each bunch passes through a 16-taps and 32-taps FIR filter for transverse feedback and longitudinal feedback respectectly before being sent to the one-turn delay from there, to the high-speed DAC. The main signal processing chain consists of a high-speed ADC, an FPGA, and a high-speed DAC and is driven by the RF clock. In addition to performing real-time control computations, the FPGA interfaces to the on-board devices, such as high-speed data acquisition memory (SRAM), low-speed analog and digital I/O, as well as temperature and supply voltage monitors. The FPGA uses an internal USB interface to communicate to an embedded EPICS IOC computer and is housed in the same chassis. The IOC runs the Linux operating system and is connected to the overall control system via the Ethernet. System control and diagnostics are performed via EPICS. All control and diagnostic features are accessible through the supplied EDM panels. Acquired diagnostic data can be exported for off-line analysis.

TRANSVERSE BUNCH-BY-BUNCH FEEDBACK

Transverse bunch-by-bunch feedback system adopt iGp as shown in Fig. 1. It accompany with the existing SPring-8 processor. Both unit can switch easily.

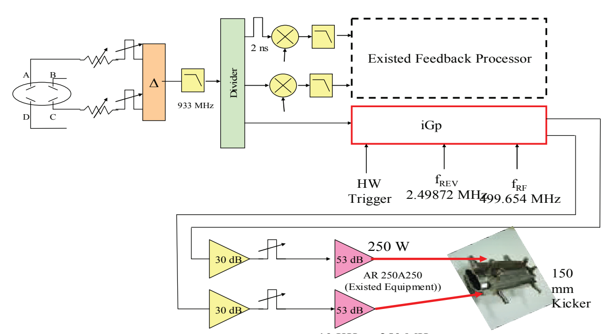

Figure 1: Functional block diagram of the new transverse feedback configuration.

The transverse feedback used diagonal striplines in skew position as feedback kicker. Two peaks of 16-tap filter was designed as shown in Fig. 2. The iGP waveform interface is shown as in Fig. 3. The lower right corner of Fig. 3 shows two notches in averaged spectrum corresponding to vertical and horizontal rejected betatron sideband. It can be used as betatron tune monitor with high resolution without extra excitation to the beam except the feedback functionality.

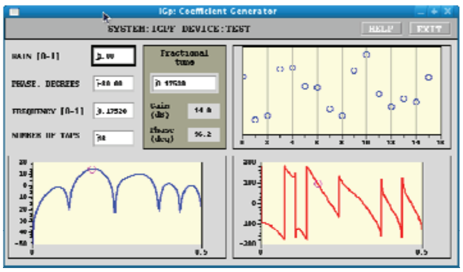

Figure 2: Two peaks 16-taps filter to suppressed instabilities in vertical and horizontal planes using striplines installed at skew position.

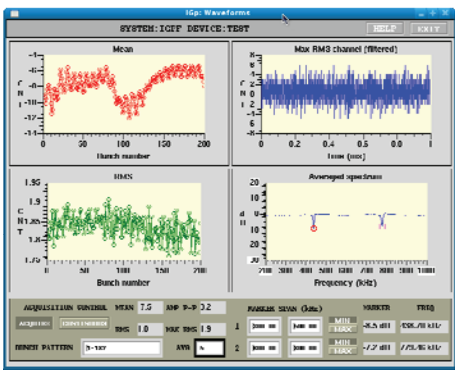

Figure 3: iGp for transverse feedback.

Bunch Cleaning

To explore the bunch cleaning functionality, the multi-bunch stored beam was killed and left one bunch as shown in Fig. 4. However, due to low kick efficiency of the transverse excitation system, a vertical orbit bump was intentionally produced to ensure excited betatron motion of the unwanted bunches that can be scraped by the ID cambers.

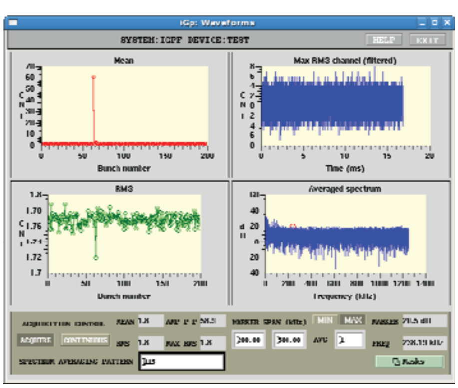

Figure 4: Bunch cleaning test, all bunches were killed form original multi-bunch fill except the selected bunch is still survived.

Arbitrary Pattern Excitation

The bunch excitation pattern can be in arbitrary way with feedback system. For example we can excite the beam according the Morse code of TLS as shown in Fig. 5.

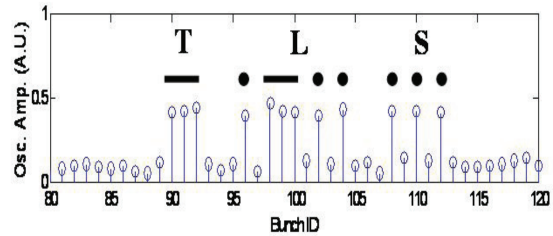

Figure 5: Bunch excitation, a selective bunch were excited as pattern of TLS encoded in Morse code.

Tune Measurement Functionality

There are two possibilities to measure tune supported by the feedback system. The first one uses the notches in the turn-by-turn averaged bunch spectrum as shown in the lower-right corner of Fig. 3, these notched spectrum are derivate from the noise suppression due to negative feedback. The second is performed peak identification of Fourier analysis of the single excited bunch data. Figure 6 shows the rms value of bunch without excitation and excite the bunch ID 20. Fourier analysis of the turn-by-turn data for the bunch ID 20 shows a clear betatron oscillation peak.

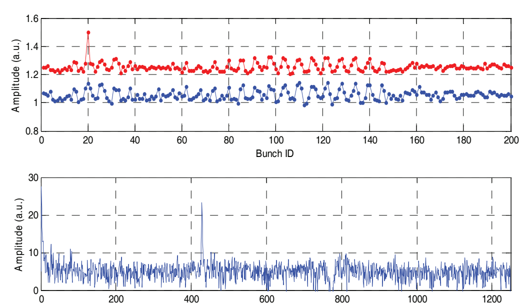

Figure 6: Single bunch excitation and single bunch spectrum for tune identification.

Growth-Damp Experiment

The iGp/iGp12 can capture bunch data by software or hardware trigger. There are two feedback filters can be switched upon trigger. It is easy to do grow-damp experiments and capture data for further analysis for model predictions, and the achieved system performance with timing to switch filters.

LONGITUDINAL BUNCH-BY-BUNCH FEEDBACK

Commissioning of the iGp12 for the longitudinal enable the feedback into operation based upon existed bunch-by-bunch feedback infrastructure. The functionality block diagram of longitudinal feedback loop is shown in Fig. 7. It accompany with the existing SPring-8 processor also. Both units can switch easily.

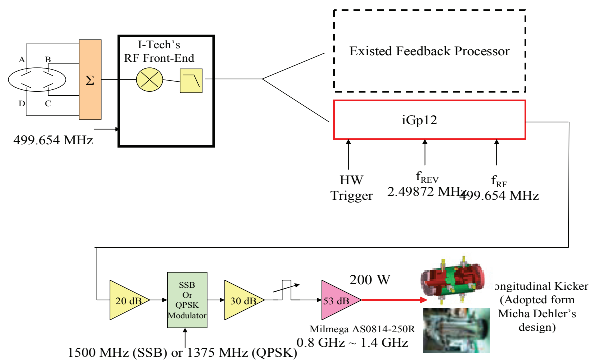

Figure 7: System configuration of the longitudinal bunch-by-bunch feedback system.

The rms value of bunch oscillation of each individual bunch provides a reliable way for filling pattern measurement as Fig. 8.

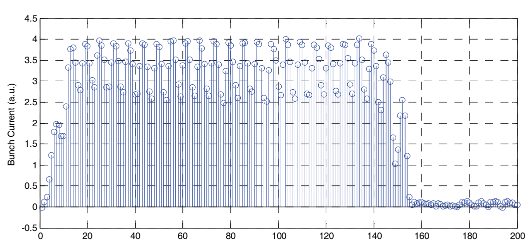

Figure 8: Averaged longitudinal bunch phase filling pattern.

All other functionalities of the longitudinal feedback system are identical as the transverse plane, is expected and applied on the longitudinal plane only.

OPERATION SUPPORTS

A simple GUI was deployed for the control room operator usage as shown in Fig. 9. Several waveforms accompany this interface to ensure the operator wheatear the bunch-by-bunch system working properly or not.

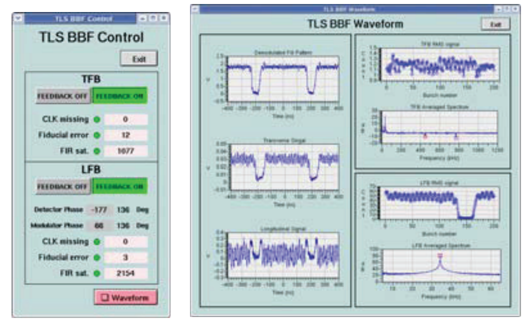

Figure 9: Operator interface to operate the bunch-by-bunch feedback system include transverse as well as longitudinal feedback system. Various waveforms include filling pattern, beam oscillation amplitude in rms and bunch phase oscillation in rms, are shown on the integrated with front-end and iGp control page. Corresponding spectrum are shown also, it is easily used as a tune monitor.

SUMMARY

Adopt iGp/iGP12 for the complementary units for the bunch-by-bunch feedback system at TLS, are successfully deployed in 2010. Functionality was explored. Separate horizontal and vertical feedback loops will provide flexibility for machine physics study and to test various issues for the operation, it will be next step when spare units available in future. Enhancement functionalities include: tune measurement, fill pattern measurement, abort trigger, injection study, etc are in process. Another useful thing is the abort trigger, during last several years experiences, the transverse feedback system can't sometime suppress instability occasionally in high current operation when machine condition is bad. The reason is mainly due to low kick efficiency of the l/4 slotted striplines. It is hard to find space to install a longer kicker at this moment. Implement another feedback loop is under plan to adopt another diagonal plane to increase feedback efficiency. Specifying the requirements of bunch-by-bunch feedback and bunch-by-bunch diagnostic for future 3 GeV TPS synchrotron light source is also on going.

ACKNOWLEDGEMENT

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REFERENCES

[1] K. H. Hu, et al., "Commissioning of FPGA-based Transverse and Longitudinal Bunch–by-Bunch Feedback System for the TLS", AIP Conference Proceedings 868, Beam Instrumentation Workshop 2006, Batavia, Illinois, USA, 1-4 May 2006.
[2] http://dimtel.com/.
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