BUNCH-BY-BUNCH FEEDBACK SYSTEMS FOR KEKB RINGS

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Abstract

The bunch-by-bunch feedback systems to cure coupled bunch instabilities in KEKB are now under development. The minimum bunch space of only 2 ns requires the bandwidth of the feedback systems wider than 255 MHz. The huge number of stored bunches which amounts to 5000 per ring demands the high speed and large memory digital signal processing for both signal delay and phase shift. The pickup electrodes and position detection systems are designed to satisfy the requirements of time response. The signal process part consists of high speed two tap FIR filters enables us the functions of DC rejection, phase shifts and simple delay. The waveguide overloaded cavities will be used as the longitudinal kickers. All the components are now under fabrication and will be installed until the commissioning of the rings.

1 INTRODUCTION

The KEKB rings are designed to accumulate huge beam current with many bunches. Even with the great care on the reduction of the possible impedance sources around a beam, unexpected impedance may remain high and it can cause strong coupled bunch instabilities. The method to analyze and suppress the instabilities has the key to achieve the expected quality of the rings. A straightforward and the only realistic method is to apply bunch by bunch feedbacks based on very fast digital technology with the wide bandwidth up to 255 MHz and large power to supply enough negative impedance. The target of the KEKB bunch feedback systems has been set to achieve the damping time of about 1 ms both on the transverse and the longitudinal planes for the minimum bunch spacing of 2 ns.

The feedback system consists of three major parts: a front-end circuit to detect the bunch positions, a signal processing system, and kickers and wideband amplifiers with large power. The front-end circuit need to detect the individual bunch positions without disturbed by the signals from the preceding bunches with enough resolution. The signal processing system is a simple digital filter with the function of signal delay which corresponds to phase rotation thorough 90°, and the noise elimination, if necessary. The kickers should have enough shunt impedance over the necessary bandwidth without HOM's.

The prototype systems have been tested during the high-beam-current experiment of TRISTAN-AR[1]. We show the final design of the feedback systems for KEKB rings which has decided based on the many experience of the high-beam current study. Related parameters of the KEKB rings are shown in Table 1.

Ring	LER / HER	
Energy	3.5 / 8.0	GeV
Circumference	3016.26	m
Luminosity	1×10^{34}	$\mathrm{cm}^{-2}\mathrm{s}^{-1}$
Beam current	2.6 / 1.1	A
Bunch current	0.5 /0.2	mA
Bunch length	4	mm
Synchrotron tune	$0.01 \sim 0.02$	
Betatron tune	45.52/45.08 (LER)	
	47.52/43.08 (HER)	
RF voltage	$5 \sim 10$ / $10 \sim 20$	MV
RF Frequency	508.887	MHz
Harmonic number	5120	
Damping time (L)	43 / 23	ms

Table 1: Main parameters of KEKB.

2 BUNCH OSCILLATION DETECTION SYSTEMS

All the feedback instruments will be installed around the Fuji crossing area, which is just opposite side of the Tsukuba collision point. Figure 1 shows the plan of the location of the systems. We use two sections of monitor-electrodes for both rings, each has 20 pickup electrodes with SMA connectors. The simulated output and its Fourier transform of the electrode for 4 mm bunch of 1 C are shown in Fig. 2. Figure 3 shows the block diagram of the frond-

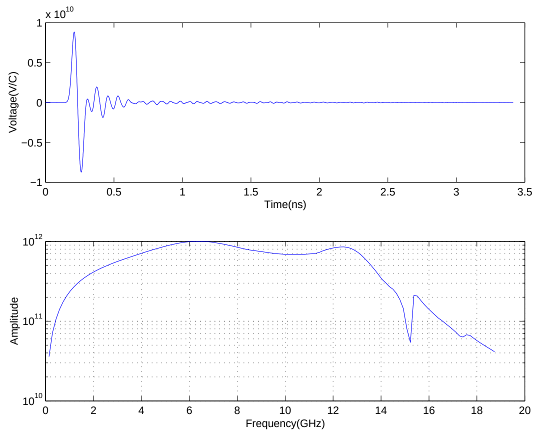

Figure 2: Simulated output of a BPM for 4 mm bunch using MAFIA T3 (upper) and its Fourier transform (lower).

end circuit for the transverse and the longitudinal detection systems. Signal from the electrode is divided into three branches by a power combiner and summed up again by another power combiner. As the differences of the length of the cables are chosen to be the multiple of the effec-

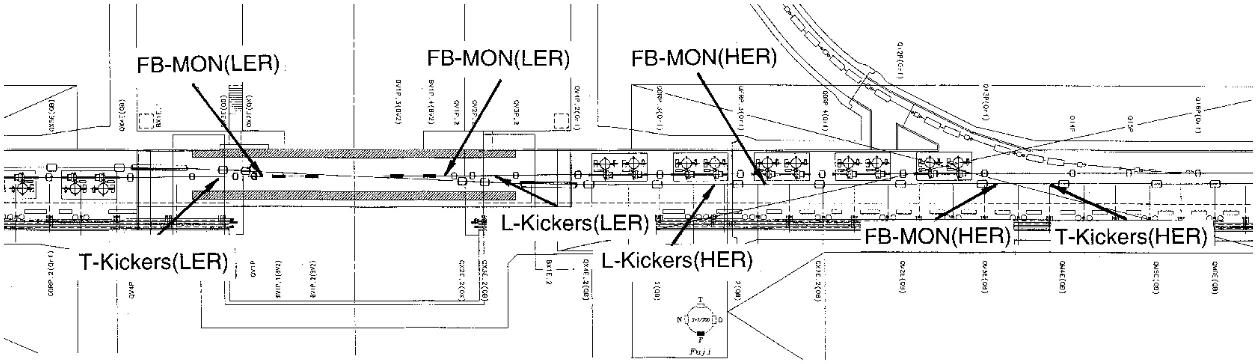

Figure 1: Location of the feedback instruments at Fuji crossing area. Positrons comes from left side and electrons comes from the right side. The local control room for the feedback system is located under the accelerator tunnel (B4 level). Feedback amplifiers will be installed under the crossing bridge.

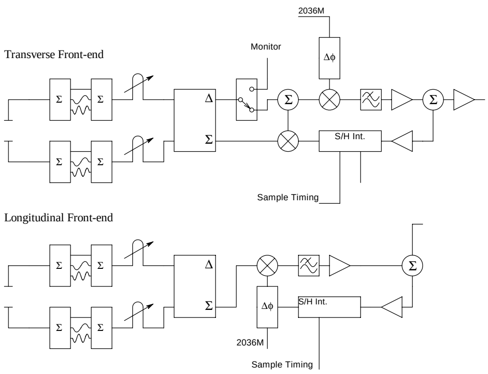

Figure 3: Block diagram of the frond-end circuit of the transverse and the longitudinal detection system.

tive wavelength of the detection frequency in the cables, this system works as an FIR bandpass filter with the first center frequency of the detection frequency, in our case 2 GHz($= 4 \times f_{RF}$). For the transverse detection, the differential of the two sine-like burst signal by a 180°-hybrid is multiplied by the reference signal which is quadruple of the RF signal with a double balanced mixer (DBM). Higher-frequency components are rejected by a low pass filter (LPF) of which cutoff frequency is 750 MHz. As the distance between the two monitor-electrodes is chosen to be roughly 90° in the betatron phase for both horizontal and vertical planes, we will be able to tune the phase difference between the monitor and the kickers by combining the two positions vectorially.

The longitudinal position is detected simply by multiplying the sine-like burst with the reference signal around the phase difference of $90°$ and rejecting the higher-frequency components with the LPF.

To make sure the necessary dynamic range without saturation before the ADC, we cancel the DC component, such as COD at the detector, from the detection circuit automatically by employing a local feedback system made of a fast sample-and-hold and active low pass filters. The synchronized sampling timing pulse will be controlled with the change of the filling pattern from single bunch mode (100 KHz) to a few MHz. The cutoff frequency of the LPF will be chosen very low ($\sim$ 10 Hz) not to disturb the frequency response for the lowest synchrotron frequency.

3 DIGITAL FILTER COMPLEXES

The signal process is performed with a two-tap FIR filter realized by a simple hardware system. It consists of a 509 MSPS 8-bit ADC daughter card, four fast data demultiplexers (FDMUXs) of GaAs LSI, 16 memory and ALU daughter cards, four fast data multiplexers (FMUXs) and a 508 MSPS DAC. For the transverse systems, we use the filter with the simple one-turn delay mode by outputting the previous position data just one turn before synchronized to the same bunch. For the longitudinal signal processing, we use two-tap FIR filter mode that enables us the function of phase shift of $90°$, DC-suppression and also the signal delay. As it has 1 Mb of memory totally, more than 100 turns of position data for all bunches are usable for the filtering process. This means the synchrotron tune less than 0.01 is well covered by this board. These functions are controlled through the VME system without any modification on the circuit. We have also developed the large memory system using the same mother board, ADC and FDMUXs that is capable to accumulate 4096 turns per all the bunches in the KEKB ring. This enables us to analyze the growing or damping modes of the instability by turning-on or off the feedback systems. Figure 4 shows an example of the growing modes of vertical instability measured during the high-beam-current study of TRISTAN-AR with the two-tap FIR filter board. The detailed description of the filter system is written in the reference[2].

4 FEEDBACK KICKERS

We will use two types of stripline kickers: a 40 cm wide-band kicker for 50 kHz to 255 MHz and a 1.2 m lowest band kicker (the long kicker) for 5 kHz to 400 kHz. Expected shunt impedance is about 8 kΩ at 100 MHz for the wide-band kicker, and about 120 kΩ for the long kicker.

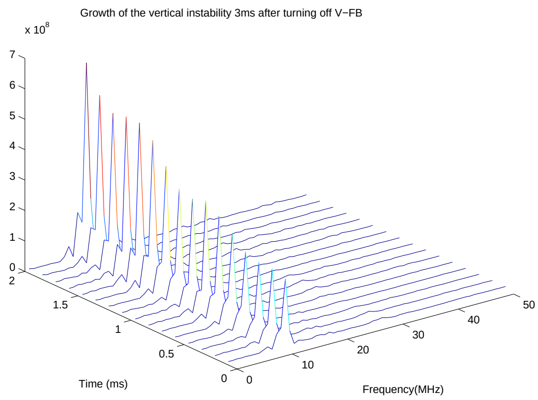

Figure 4: Growth of the vertical coupled bunch oscillation recorded in the two-tap FIR filter.

Ring	40 cm kicker	1.2 m kicker
LER	0.2 mm	0.7 mm
HER	0.09 mm	0.3 mm

Table 2: Maximum amplitude for exponential damping region of the feedback system.

The maximum power of the feedback amplifier for the wide-band kicker is 250 W per each stripline, and 200 W for the long kicker. The maximum amplitudes at the saturation of the amplifier with the damping time of 0.5 ms are listed in Table 2. Above the value, the feedback system works in the bang-bang damping mode.

For the longitudinal kicker, we will install the waveguide-overloaded cavity (DAΦNE type kicker[3]) with totally 8-input / output ports. By using the codes HFSS and MAFIA, we optimized the geometry of the kicker to get reasonable shunt impedance and the quality factor. Figure 5 shows the photo of the cavity under fabrication. The shunt impedance of about 600 Ω with the quality factor of about 5 has been obtained. The calculation using MAFIA shows the longitudinal loss factor of about 0.3 V/pc, and the peak output voltage of about 280 V_{p-0} with the bunch current of 0.5 mA. As we will use the circulators with the power capacity of 6 kW, the operation with the bunch current larger than 2 mA will be dangerous.

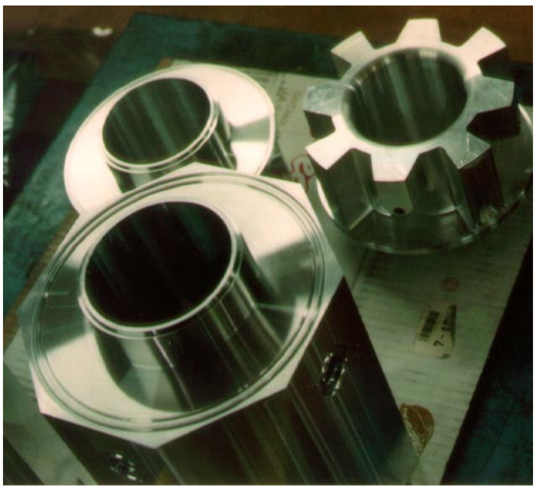

Figure 5: Photo of the DAΦNE type cavity under fabrication.

The transverse impedance of the cavity has also calculated with MAFIA. The result shows the transverse impedance of about 5 kΩ at the frequency around 1.6 GHz. This value is comparable of residual HOM of the ARES cavity.

We plan to install two kickers only in LER at the commissioning stage. With two 500 W amplifiers, that is 8×125 W amplifiers, we will have the effective damping time of about 10 ms with the bang-band damping scheme for the phase amplitude about 2 °.

5 SUMMARY

The both rings of KEKB are scheduled to start commissioning on middle October, 1998. All the vacuum components, such as the monitor chambers or the kickers, are now under final fabrication process and will be ready by the end of March, 1998. The installation will be, however, postponed until the middle of August because of the delay of the vacuum chambers around our systems. The power amplifiers will also be prepared by the start of the commissioning. All the cables will be laid by the middle of September. The temperature of the vacuum components and the high-power components will be monitored by using Pt-RDT.

We will install 6 two-tap FIR filter boards and 6 memory boards at the commissioning stage. Also two special memory boards, which have less memory than the normal ones, will be used to measure the bunch current in each RF bucket within the injection period. The low level electronics system will be assembled soon.

We use many special VME boards that are not supported by the EPICS system now. Therefore, we must prepare the device supports by ourselves. The huge size of the memory of the filter/memory board needs a special structure outside the EPICS system to analyze the data.

Together with the progress of the operation of the rings and the feedback systems, we will improve the systems to have sufficient performance.

6 ACKNOWLEDGMENTS

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7 REFERENCES

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