A CONVENTIONAL READ-OUT ELECTRONICS FOR THE BUTTON-TYPE BPM IN THE ATF DAMPING RING

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Abstract

A conventional read-out electronics for button-type beam position monitor (BPM) has been developed for the KEK ATF (Accelerator Test Facility) damping ring[1]. This electronics system is used in early stage of beam commissioning in the damping ring. The system can measure the beam orbit by single pass processing of bunch train, have the resolution of about $10\ \mu$m, and is reliable. It is also desirable that it is low cost because of a requirement of several hundreds of circuit channels. The system consists of charge-sensitive ADCs and clipping modules. The clipping module employs a clipping technique, which clips the bipolar signal from a BPM to integrate the signal charge. It is also useful for strip-line type BPM because of the enrichment of low frequency component. The design and test results with a beam operation are reported.

1 INTRODUCTION

To achieve as small an emittance as possible is one of critical issues to obtain a high luminosity in the linear collider, as well as to achieve a high acceleration efficiency and a strong final focus. Future linear colliders, such as JLC, require a very small vertical emittance, typically $\varepsilon_{ny} = 30$ nm. A damping ring, the most feasible method for obtaining such a tiny emittance, is a fundamental part necessary to ensure the high performance of a linear collider. An ATF damping ring is one of those machines which is devoted to verifying and to demonstrating the tiny emittance of JLC. The damping ring has a race track shape and the lattice has a symmetry of a 180 degree rotation. There are four wiggler magnets and RF cavities or kicker magnets in an each straight section.

To achieve such a low-emittance beam we must correct the dispersion of the orbit, which is small ($\eta < 2$ mm) in the long wiggler section of the damping ring. A precise measurement of the dispersion is indispensable. Usually, the actual dispersion is obtained by comparing each closed-orbit distortion under the conditions of different RF frequency ($\Delta f_{RF} \sim 10$ kHz). For this reason, the requirement for the resolution of the BPM is less than $5 \mu m$. Furthermore, the impedance of the components, such as the vacuum chamber, can be the source of a single-bunch instability which could degrade the beam quality. To avoid such an instability, the total longitudinal impedance must be less than about 0.2Ω. The results of wake-field calculations indicate that the impedance is very small on the electrode of the button-type compared with the directional-coupler type. We therefore selected the button-type electrode for the BPM. The detail about BPM chamber is described in[2].

2 SYSTEM OVERVIEW

We developed a conventional read-out electronics system, which feature is a single-path monitor, enough position resolution, flexibility, simple and low cost. To measure the beam orbit with only one-passage of the beam is desirable for well understanding of the beam status; damping, stability, etc. To be a single-path monitor is also very important especially in the first stage of beam commissioning, because we have no screen monitor in the damping ring. In the ATF damping ring, the beam operation is performed with single or multi-bunch beam. In the case of the multi-bunch beam, the bunch spacing is 2.8 nsec and the number of bunches is about 20. Those bunches form a bunched train and the maximum number is five trains which can circulate in the damping ring. It is favorable to measure the position of each bunch in a bunched train, however, it is very hard to satisfy this requirement with the above many conditions in same time. Therefore we did not take into account of this point for the present system. We tried to construct the whole system to be quite simple taking into account of the flexibility and maintainability.

Figure 1 shows BPM system for the ATF damping ring.

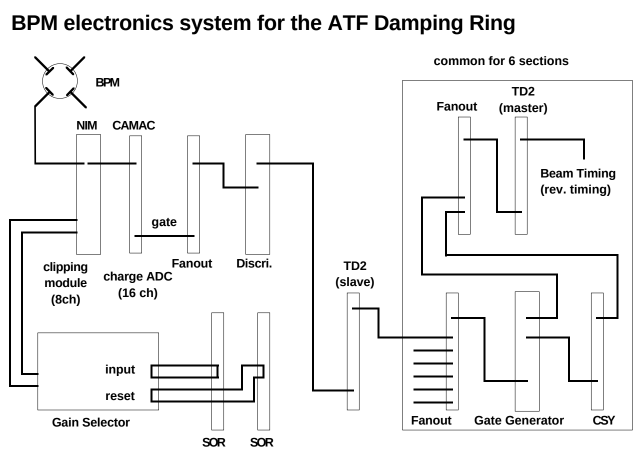

Figure 1: Schematic diagram of the BPM system.

There are 96 button-type BPMs in the damping ring totally, and which belong to three kinds of types. One type of button BPMs are mainly used in the two arc sections of the race track ring, which has a cylindrical shape of inner diameter of 24 mm. The second type is used in the two wiggler sections which has a race track shape, and the third one is in a septum section, which has a cylindrical shape of inner diameter of 14 mm. These 96 BPMs are divided into six sections with respect to the beam line, i.e. two straight sections and 4 quarters of 2 arc sections. These BPMs can measure the position in a same time. The same time means to measure the same turn signal of a circulating beam. The signal cable length in each section is adjusted taking into account of time of flight to detect the same turn beam by a common trigger signal.

Each section has several units, which consist of clipping modules, charge-sensitive ADCs and a discriminator. Master timing signal from common timing system is adjusted to the beam injection by a master TD2 module and distributed to six sections. The timing adjustment for each section is done by a slave TD2 module. The another turn signal can be easily measured in same time by remote control of the delay timing of the master TD2. And also if we need, arbitrary turn orbit can be measured for each section independently by remote control of the delay timing of the slave TD2. The four signals from each BPM are processed by clipping module, which clips the bipolar signal in order to integrate the charge by charge-sensitive ADC. Figure 2 shows the circuit of clipping module.

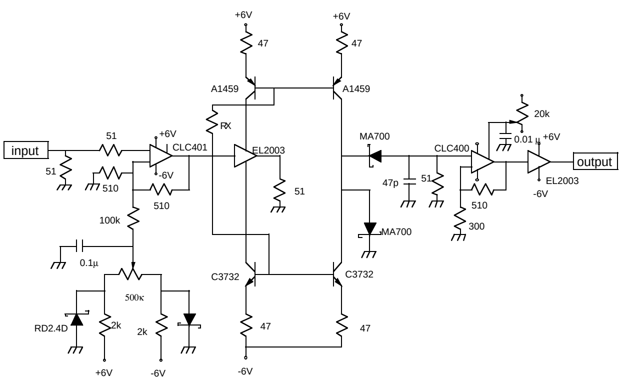

Figure 2: Circuit of CL mini-card in the clipping module.

The clipping module is a NIM type module and highly condensed to mount eight channels, so that one clipping module can process signals for two BPMs. One channel of the clipping module consists of a low-pass (100 MHz) and a band-pass filter (30 MHz), amplifiers and a clipping mini-card. For the first two amplifiers inside the clipping module, which gain can be changed corresponding to the signal level. Inside the clipping mini-card, bipolar signal is clipped by a shot-key barrier type diode, MA700/A (V_F=0.4 V, @I_F=1 mA). The output signal from clipping module is then digitized by the charge-sensitive ADC, which has 16 channels with 14 bit inside a CAMAC one width module.

3 PERFORMANCE OF THE ELECTRONICS

The preliminary electronics test was carried out at a test bench. Test signal was generated by differentiation of a short width rectangular pulse from a pulse generator (Hewlett Packard), and then fed into clipping module. Output linearity of the clipping module was checked with this test signal. Because of the diode feature in the clipping mini-card, the clipping module doesn't have good linearity. Fig. 3 shows the result of output linearity. The horizontal axis is an input signal level (arbitrary unit) changed by an attenuator. The solid line shows a linear fit for the central region.

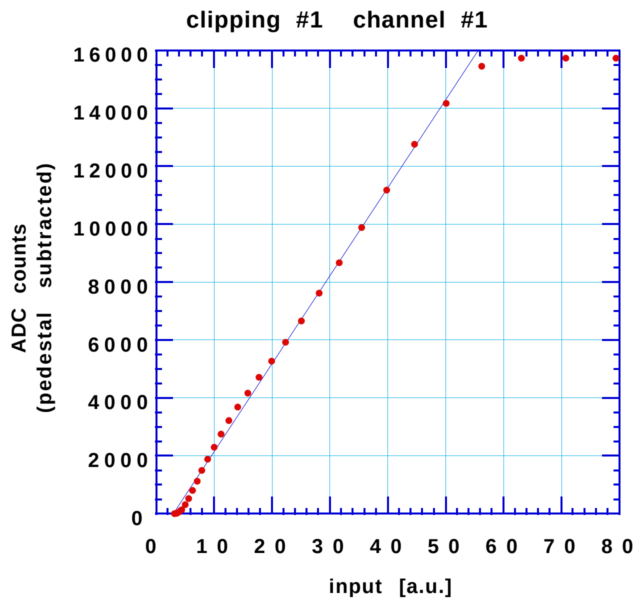

Figure 3: Output linearity of clipping module.

Although this linearity will be improved by a circuit modification, presently the nonlinearity is corrected by a software on the position calculation.

The performance of electronics was checked by using a HP pulser. The input signal which simulated a BPM signal was split into two channels of a clipping module as a centered beam. The position is calculated by $X = k * (Va - Vc)/(Va + Vc)$, where Va and Vc were ADC counts after pedestal subtracted and linearity corrected. Conversion coefficient $k = 6388$ μm was used. In order to estimate a resolution, 50 measurements were made during each signal amplitude and the standard deviation was taken as a resolution. Figure 4 shows the measured resolution of the electronics system. Equivalent beam charge was normalized by an actual beam signal. If beam charge of 2×10^{10} particle/bunch is achieved, the position resolution of about 10 μm will be realized. If more resolution is required, averaging will be taken over several turns.

The position resolution was also demonstrated by using a wire method at a test bench. Test pulse was fed into the 50 μm tungsten wire, and a BPM was moved by x-y mover with respect to the wire. Figure 5 shows the measured wire position as a function of the mover position with 50 μm step. Though the signal shape was not exactly same as the beam one because of miss-match into the thin wire, the measured position could be easily distinguishable with less than $100\mu m$ resolution.

Since the first beam commissioning in January 1997, the ATF damping ring is successfully operated with single bunch beam of about 3×10^9 particles per bunch. Although this beam intensity is much smaller than the designed one, which is mainly limited by the efficiency of the beam trans-

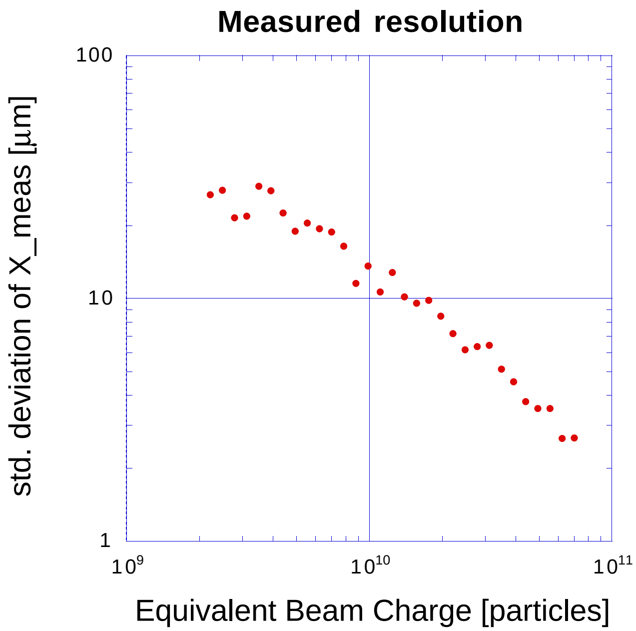

Figure 4: Measured resolution of the electronics. 50 times position measurements. (electronics only)

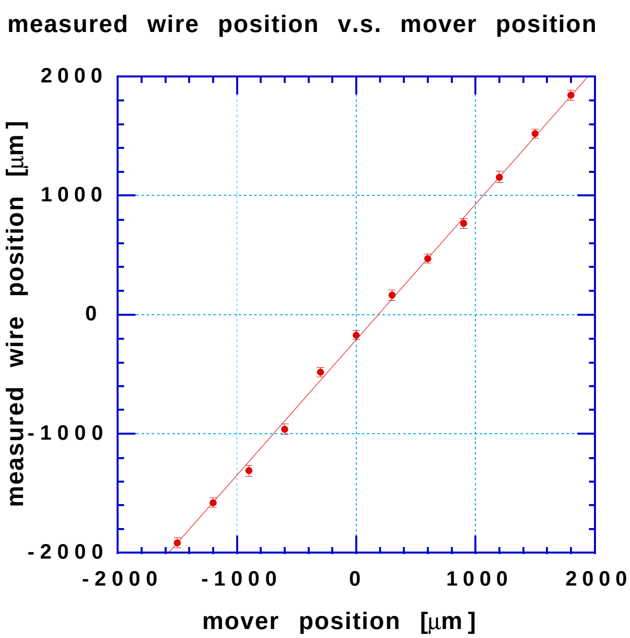

Figure 5: Measured wire position by the BPM pickup. 50 times position measurements.

port, the BPM signal is clearly observed except for some BPMs. Faults of these BPMs are caused by an insufficient signal level and a large noise from a kicker magnet. Figure 6 shows the measured position response to the position calculated from steering magnet currents. The result shows large standard deviation due to the beam jitters, however, the mean position is quite consistent with the position calculated from steering magnet current.

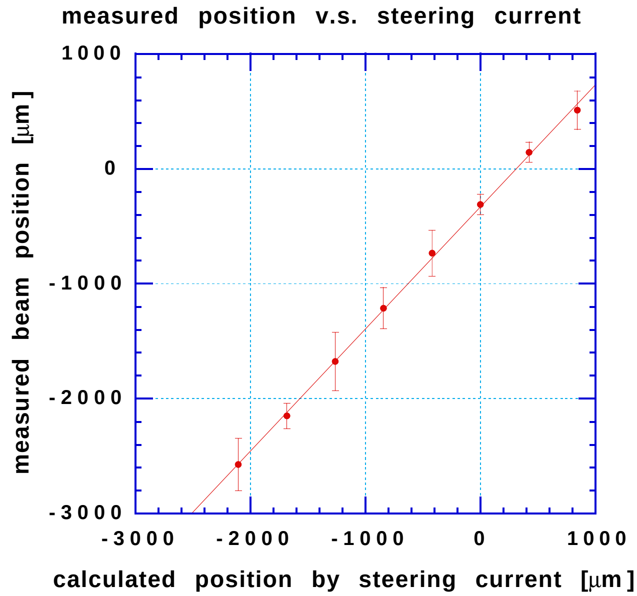

Figure 6: Measured position response to the steering magnet. 100 times position measurements.

4 SUMMARY

A conventional read-out electronics for button-type BPM has been developed. Nevertheless the quite low beam intensity, the damping ring was successfully commissioned with this BPM system. This system has still some points to be improved, however, preliminary result shows the resolution of 90 μm with the beam intensity of 3×10^9 particles as a one-path monitor. As increase the beam intensity, the performance will be improved.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

[1] "ATF Design and Study Report", KEK Internal 95-4 (1995).

[2] F. Hinode et al., KEK Preprint 95-55 (1995).