NEW DATA-ACQUISITION SYSTEM OF BEAM-POSITION AND WALL-CURRENT MONITORS FOR THE KEKB INJECTOR LINAC

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Abstract

About 90 stripline-type beam-position monitors (BPMs) and 70 wall-current monitors (WCMs) have been newly installed in the KEKB injector linac. These monitors reinforce easily handling beam orbits and measuring the amount of beam charges for single-bunch electrons and positrons which are injected to the KEKB rings. A new data-acquisition (DAQ) system has been developed in order to control these monitors in real time. Hardware and software of 18 front-end computers were tuned for the linac commissioning. This report describes the DAQ system, the calibrations of the hardware system, and preliminary beam-test results.

1 INTRODUCTION

The KEK B-Factory (KEKB) project [1] is in progress in order to test CP violation in the decay of B mesons. The KEKB is an asymmetric electron-positron collider comprising 3.5-GeV positron and 8-GeV electron rings. The KEKB injector linac [2] is also being upgraded in order to inject single-bunch positron and electron beams directly into the KEKB rings. The beam currents are required to be 0.64nC/bunch and 1.3nC/bunch for the positron and electron beams, respectively. High-current primary electron beams (~10nC/bunch) are required in order to generate sufficient positrons. Therefore, it is important to easily handle the orbits of the beams, and especially, the beam positions and current of the primary high-current electron beams have to be controlled so as to suppress any beam blowup generated by large transverse wakefields. A BPM system has been developed to perform this function since 1992. The goal of the beam-position measurement is to detect the charge center of gravity within a resolution of 0.1mm. The WCMs have been also newly developed in order to reinforce the monitoring system of the beam currents. The amount of the beam current needs to be precisely measured in order to keep the positron production and the beam-injection rate to the KEKB rings higher, because a well-controlled operation of its injector is required so that we can reach an optimum operational condition with as a short tuning time as possible and also keep it during a long-term operation period. A new DAQ system based on VME/OS-9 computers, which are connected with the linac control system, has been also developed in order to control these monitors in real time. The performance of the new system has been tested using the electron beams at an extended beam line of the linac during its commissioning.

2 HARDWARE SYSTEM

2.1 Beam-Position and Wall-Current Monitors

A conventional stripline-type BPM was designed with a $\pi/2$ rotational symmetry. The total length (195mm) was chosen to make the stripline length (132.5mm) as long as possible so that it can be installed into limited spaces in the new beam line of the linac. The angular width of the electrode is 60 degrees in order to avoid a strong electromagnetic coupling between the neighboring electrodes. A 50Ω SMA-vacuum-feedthrough is connected to the upstream side of each electrode, while the downstream ends are short-circuited to a pipe. The WCM comprises a disk-shaped ceramic solid resistor, a Mn-Zn toroidal ferrite core inside an aluminum case, and four pickup BNC-type receptacles with $\pi/2$ rotational symmetry. The resistance was selected to be 2.5Ω so as to have a good frequency response for short-pulse beams. More detail descriptions are given elsewhere [3-7].

2.2 Monitor Station

All the BPMs and WCMs are connected with the monitor stations. Eighteen monitor stations, each of which comprises a front-end computer (VME/OS-9 with a 68060 microprocessor at 50MHz), a signal digitizing system (an oscilloscope), and a signal-combiner box, are located on the linac klystron gallery at a nearly equal interval along the beam line. Each monitor station can control twelve(six) BPMs(WCMs) at maximum. The schematic drawing of a monitor station is shown in Fig. 1. The 4 signals of one BPM are directly sent to a signal-combiner box. Two signal combiners combine the horizontal and vertical signals of the BPM with the signals from the other BPMs, and the WCM signal is also sent to the same combiner box. The two signals from the signal combiners are fed to two channels of a digital sampling oscilloscope (Tektronics TDS680B) with a sampling rate of 5GHz, and for the WCM the combined signal is also fed to another channel of the same digital oscilloscope. The Unix workstations and the front-end computers communicate with each other through the extended network system. As shown in Fig. 2, all the front-end computers are linked to a switching-hub with a star-topology. Fiber-optic cables are used for physical connections in order to avoid electromagnetic interference from high-power klystron modulators. The hub has a link to the linac control network, where Unix workstations and man-machine interfaces are connected.

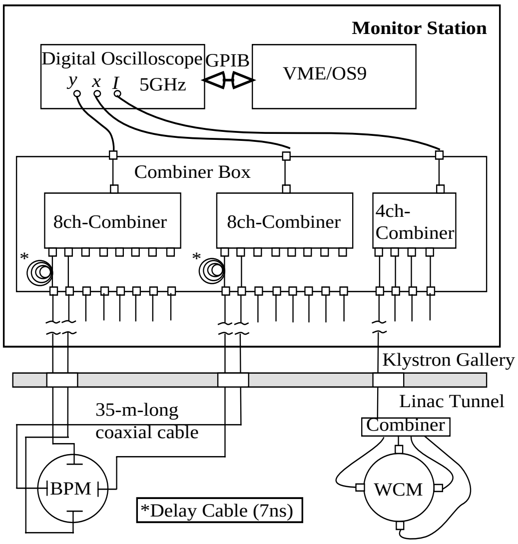

Figure: 1 Schematic drawing of a monitor station.

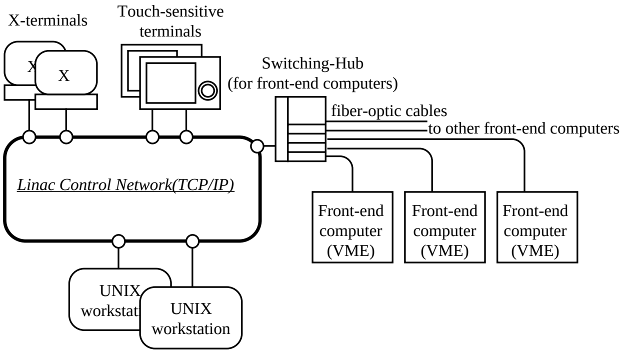

Figure: 2 Block diagram of the linac control network and the extended network (right side) system.

2.3 Calibration of the monitors

All the monitors have been installed into the beam line after the bench calibration. The bench calibration system for the BPMs and WCMs are described in detail elsewhere [5,8]. Here, only the bench calibration for the BPMs and how to calculate the beam positions are briefly given. All the BPMs have been calibrated by “mapping” by use of the test bench with a thin current-carrying wire (500 μmϕ) stretched through the center of the monitor to simulate the beam. Calibration coefficients of the map function, which relates the pulse-height information obtained from the four pickups with the wire positions, is measured by the bench calibration. The map function using third-order polynomials can be given as the following:

$$x = \sum_{i,j=0}^{3} a_{ij} (\Delta_x / \Sigma_x)^i (\Delta_y / \Sigma_y)^j , y = \sum_{i,j=0}^{3} b_{ij} (\Delta_x / \Sigma_x)^i (\Delta_y / \Sigma_y)^j ,$$

$$Q = G \sum_{k=1}^{4} g_k V_k ,$$

and here,

$$\Delta_x = g_1 V_1 - g_3 V_3 ,\ \Sigma_x = g_1 V_1 + g_3 V_3 ,$$
$$\Delta_y = g_2 V_2 - g_4 V_4 ,\ \Sigma_y = g_2 V_2 + g_4 V_4 ,$$

where x and y show the horizontal and vertical beam position, a_{ij} and b_{ij} are derived by fitting the map data to the map function by using the least-squared procedure, and V_1 and V_3 (V_2 and V_4) are the horizontal (vertical)-pickup voltages, and g_k (k=1-4) the gain correction factors, and G the conversion factor for the summation of the four-pickup voltages in order to calculate the beam charge Q. The gain correction factors g_k, which correct signal-gain unbalance caused by attenuation losses of the cables and difference of the coupling strength of the combiner, are measured by using fast test pulse with a width of 500 ps. These parameters (a_{ij}, b_{ij} and g_k) are stored in the Unix workstations as the calibration table and are loaded into each front-end computer at every startup.

3 SOFTWARE SYSTEM

3.1 Control Software

Several DAQ processes are running concurrently at front-end computers and at Unix workstations. The processes with data flow are shown in Fig. 3. The read-out process resides on each front-end computer. It reads waveforms of BPM/WCM signals from a digital oscilloscope, then calculates beam positions and currents taking into account the calibration coefficients (see Section 2.3). The trigger-pluses synchronized with the linac beam are provided to all of the oscilloscopes at the 0.67 Hz cycle. This rate is limited from the communication throughput between a front-end computer and a oscilloscope through a GPIB line. Simultaneous measurements of both BPMs and WCMs are not possible at present, since there is only one oscilloscope for each monitor station. In addition, it takes five seconds to change the DAQ mode from the BPM/WCM mode to another. Calculated beam positions and currents are transferred to two Unix workstations over the linac control network with the UDP-protocol. In order to reduce the network traffic, data transfer is done only when the beam-current data at front-end is renewed. As a result, the total traffic between front-end computers and Unix workstations is always constant (24 packets per second; 0.67 Hz x 18 VMEs x 2 WSs x 1). Unix workstations receive beam currents from eighteen front-end computers and store recent ten data for each front-end on the shared-memory regions. The data servers for BPM/WCM use the data on the shared-memory. It is worth noting that the data requests from applications do not increase network traffic to front-end computers.

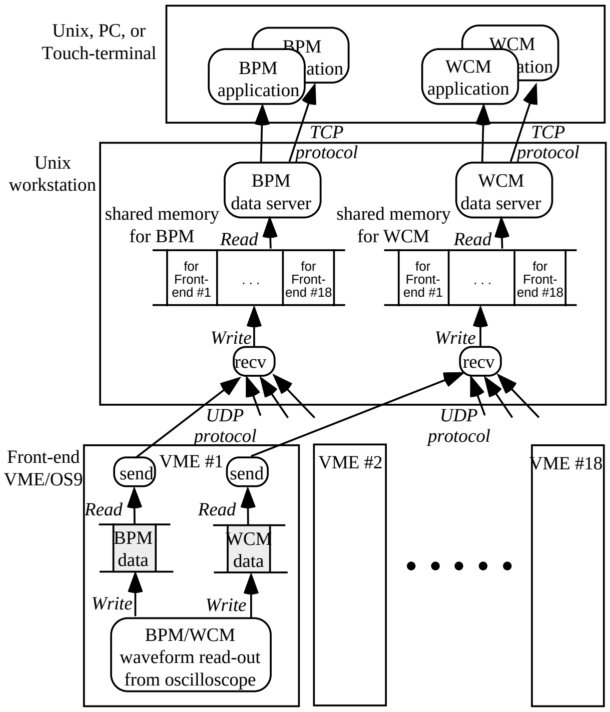

Figure: 3 Block diagram of the control software and data flow.

3.2 Man-Machine Interface

Applications for the BPMs/WCMs send requests to a data server at Unix, then receive the latest beam-current data. The communications are made with the TCP-protocol using the standard format of the KEK-linac control system [9]. Typical response times are 1-10 ms, depending on the CPU power of the client computer. So far some applications for the BPMs/WCMs have been developed. A graphical presentation for the BPMs, which was developed with the X-window environment, is shown in Fig. 4.

4 BEAM TESTS

The DAQ system tuning and the beam tests have been performed by using single-bunch electron beams at the extended linac section (sectors A and B) [2]. The single-bunch electron beams can be generated by the new pre-injector [10] which comprises two subharmonic bunchers, a prebuncher and a buncher. The electron gun can generate a beam charge of about 18nC/pulse with a beam repetition rate of 50Hz. The single-bunch electron beams greater than 10nC/bunch were stably accelerated from the outlet of the buncher until to the end of the sector B without any observational beam loss. The beam energy was about 1.5 GeV at this end. The beam tests have been performed under the condition of 5Hz repetition rate. Figure 4 shows an example of the beam tests. It shows the horizontal displacements of the beam from the center (the top drawing), the vertical displacements (middle), and beam charge (bottom), simultaneously with the refresh rate at around 1 Hz after the elaborated software tuning. The DAQ system has operated stably during the beam tests.

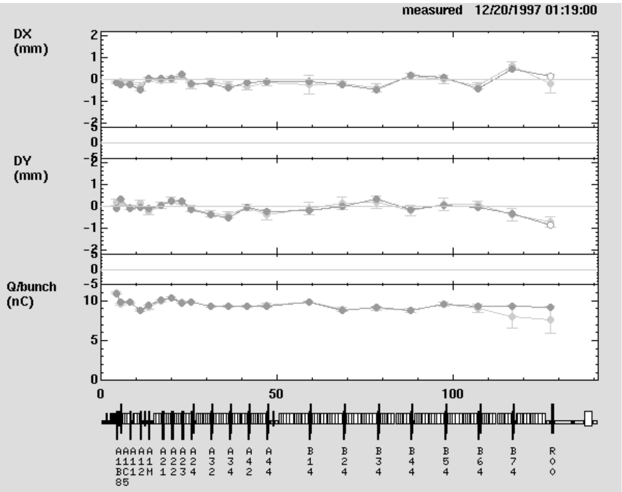

Figure: 4 Variation of the beam orbits and charge intensity along the linac. The single-bunch electrons of the beam current is 10nC/bunch.

5 CONCLUSIONS

The new DAQ system has been developed in order to reinforce the beam monitoring for the beam positions and beam currents. The present system was inspected with electron beams at the extended beam line of the injector linac. The data-taking speed is 0.67 Hz, mainly limited by the data transfer rate of the oscilloscope through a GPIB line. The present DAQ system is found fast and stable enough.

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7 REFERENCES

[1] S. Kurokawa, et al., KEK Report 90-24 (1991).
[2] I. Sato, et al., KEK Report 95-18 (1996).
[3] T. Suwada, et al., in AIP Conf. Proc. 319, (1993) p.334.
[4] T. Suwada, et al., in AIP Conf. Proc. 390, (1996) p.324.
[5] T. Suwada, et al., to be presented in this conference.
[6] T. Suwada, et al., Nucl. Instr. and Meth. A396 (1997) 1.
[7] T. Suwada, Proc. the 10th Symp. on Accel. Sci. and Tech., Hitachinaka, 1995, p.269.
[8] T. Suwada, to be in preparation.
[9] N. Kamikubota, et al., Proc. the 1994 Intern. Linac Conf., KEK, Tsukuba, 1994, p.822.
[10] S. Ohsawa, et al., Proc. the XVIII Intern. LINAC Conf., CERN, Geneva, Switzerland, 1996, p.815.