DATA ACQUISITION OF BEAM-POSITION MONITORS FOR THE KEKB INJECTOR-LINAC

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Abstract

About 90 stripline-type beam position monitors (BPM) have been installed for the KEKB e-/e+ injector-linac. A data acquisition system for the BPM has been developed. It is comprised of two Unix workstations and eighteen dedicated front-end systems (VME computers and digital oscilloscopes). The BPM waveforms, detected by a digital oscilloscope, are analyzed by a VME computer, then the calculated beam parameters (beam current, x-position, y-position) are transferred to workstations using the UDP protocol. The workstations are used as data servers for client applications. The present data acquisition system enables a real-time indication of the beam parameters over the whole linac.

1 INTRODUCTION

The KEKB (KEK B-factory) project, which aims to investigate CP violation in the decay of B mesons by an asymmetric electron-positron collider, is now undergoing accelerator commissioning. As a part of the KEKB project, the e-/e+ injector-linac [1, 2] has been upgraded to provide single bunch beams of 3.5 GeV positrons and 8 GeV electrons directly to the KEKB rings. The beam currents (design values) are 0.64 nC/bunch and 1.3 nC/bunch for positrons and electrons, respectively. In addition, high current electron beams (10 nC/bunch) are required to produce a sufficient amount of positrons. In order to suppress any beam blowup generated by a large transverse wakefield, a real-time monitor for beam orbits is indispensable.

We developed a data acquisition system for the beam position monitors in the KEKB e-/e+ injector-linac. It has been extensively used during the commissioning of the KEKB accelerators since December, 1997. In this article, detailed descriptions of the data acquisition system are given in Section 2, and discussion follows in Section 3. Some other subjects (i.e. design of the monitor, calibration coefficients determination, etc.) are given in [3, 5].

2 DATA-ACQUISITION SYSTEM

2.1 Overview

About 90 stripline-type beam position monitors (BPM) have been installed at the KEKB e-/e+ injector-linac [3, 4, 5]. The data acquisition system comprises two[1] Unix workstations and eighteen[2] dedicated front-end systems. An overview of the data acquisition system with important control processes and data flow is shown in Fig. 1.

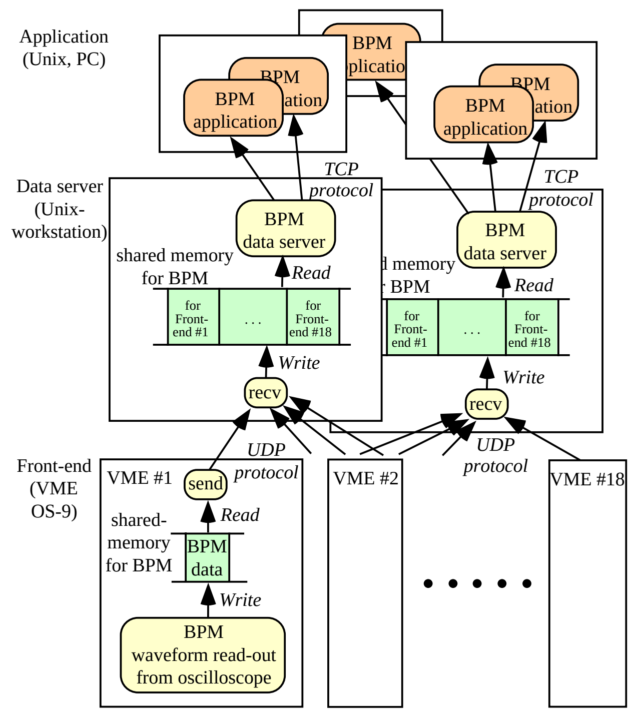

Figure 1: Overview of the data-acquisition system.

2.2 Front-end

The eighteen front-end systems are located in the linac klystron gallery at a nearly equal interval along the beam line. Each front-end system controls 3–12 BPMs (12 at maximum). Fig. 2 shows a schematic drawing of a front-end system. It is comprised of a VME computer (the OS-9 operating system with a 68060 microprocessor at 50 MHz), a digital oscilloscope (Tektronics TDS680B) as a signal digitizer, and two signal combiners in a box.

The four signals of one BPM are fed to two signal-combiners (vertical and horizontal) together with the sig-

[1] To be three after September 1999. See 3.2.
[2] Since June 1999, there are nineteen.

nals from other BPMs. Delay cables (7ns) are used to avoid waveform overlaps at the signal combiners. The two combined signals are digitalized by an oscilloscope at a sampling rate of 5 GHz. The digitalized signals are analyzed by a VME computer in order to deduce the beam parameters (beam-current, x-position, y-position), taking into account the calibration coefficients.[3]

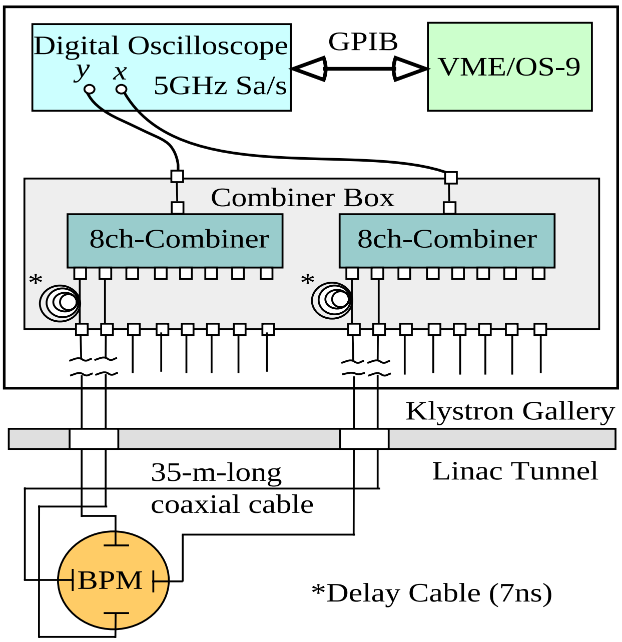

Figure 2: Schematic drawing of a front-end system.

Trigger pulse signals, which are synchronized with the linac beam, are provided to all front-end systems at 0.7 Hz cycle. These signals are used to start the data taking cycle of each front-end system. The trigger rate is limited by the GPIB communication throughput between the VME computer and the oscilloscope.

2.3 Data Servers

Calculated beam parameters at a front-end are transferred to the Unix workstations with the UDP protocol, where data servers are available (see Fig. 1). The workstations are the same ones for the injector-linac control system [6, 7].

Two data servers have been prepared to realize higher redundancy, as well as to distribute the CPU loads over the existing workstations. In order to reduce the network traffic, data transfer is done when the beam positions and currents are renewed at a front-end. As a result, the traffic rate between the front-end systems and the Unix workstations is always constant (25 frames per second, 0.7 Hz x 18 x 2).

Unix workstations store the most recent ten data sets for each front-end in shared memory. The data server returns averaged values by using this cached data. The use of cached data greatly decreases the total amount of the network traffic and the workstation CPU load.

[3]Detail description on the calibration coefficients is given in [3, 5].

2.4 BPM Applications

All of the BPM applications receive the latest beam parameters by sending requests to one of the data servers. This communication is made with the TCP-protocol using the standard format of the injector-linac control system. Typical response times are 1–10 ms, depending on the CPU power of the application side computer.

Some applications with real-time graphical presentation have been developed. An example, which runs with the X-window environment, is shown in Fig. 3. This application can show the positions (x and y) and beam-currents of the entire linac with a refresh interval of 2–5 seconds. It is interesting that the graphic part of the application is generated by using the resources of the SAD computers[4] at the KEKB-ring control system. Thus, this is an example of successful communication between two different control systems.

More important applications of the BPM are feedbacks of the energies and the orbits. The feedback applications have been developed in order to suppress beam instabilities over long-term operation. As of July 1999, there are roughly 20 feedback applications, and among them 10 are always running during normal operation [10, 11].

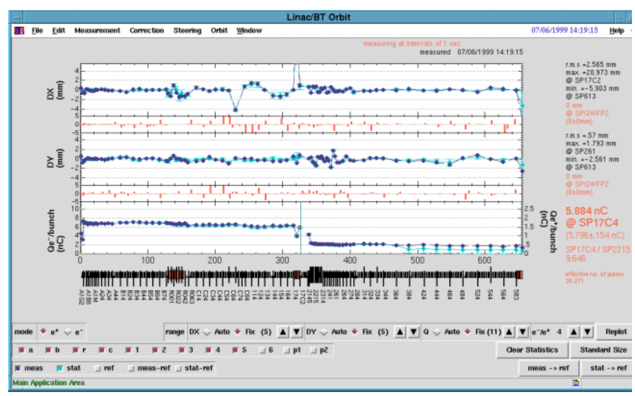

Figure 3: Example of a graphic application of the BPM.

3 DISCUSSION

3.1 Performance

Though the injector-linac can be operated at 50 pps (pulses per second) at maximum, the data-acquisition rate of the present system is 0.7 Hz (see 2.2).

The position resolutions have been measured using single bunch electron beams [3, 5]. The measured values are 0.12 mm for a beam of 1 nC/bunch, and 0.098 mm for 7 nC/bunch, respectively. These values agree well with the design value (0.1 mm).

[4]SAD, Strategic Accelerator Design, is a computer program complex for accelerator design. It has been developed in KEK since 1986. See [8] for more detail.

3.2 Operational Experiences

The present data acquisition system has been sufficiently stable since December, 1997. During the KEKB commissioning in 1998-1999, many BPM applications (see 2.4) were developed. They are now indispensible for both the operators and the commissioning staff to achieve highly stable beam supplies for the KEKB rings.

During operation in the first half of 1999, we have experienced very high CPU consumption rates on the Unix workstations, because too many BPM applications (especially feedback applications) were invoked at the same time. We have rearranged the feedback applications so as not to consume so much CPU power (i.e. set the iteration intervals longer). In addition, a new Unix workstation was introduced in August, 1999, in order to increase the total CPU power. This third workstation will be used for operation very soon [9, 10].

Occasionally (typically once a month), due to long-term jitter of the trigger signals for the oscilloscopes, the system becomes unable to analyze BPM waveforms. In such a case, we control the main source of the trigger signals to cancel the jitter.

3.3 Transactions

An analysis of the log files produced by the BPM data servers enables us to determine how many transactions per second (data requests) arrived at the data servers. Table 1 gives the expansion of BPM transactions during the recent KEKB commissioning period.

In June, 1999, the BPM servers accepted 158 transactions per second, while the total transactions for all the accelerator devices (including klystron modulators, magnet power-supplies, vacuum pumps, and so on) was 230. This amount (230) corresponds to 700 network frames per second, and 90 kB/s data transfer over the control network [9]. We consider that such a high transaction rate has been possible with the use of cached data at the data servers.

Table 1: Expansion of the BPM transactions.

time	Transactions
Dec.1997	0 trans./s
Jun.1998	35 trans./s
Dec.1998	62 trans./s
Jun.1999	158 trans./s

4 CONCLUSION

We developed a data acquisition system for the beam position monitors at the KEKB injector-linac. The system has been extensively used since December, 1997. The data acquisition rate is 0.7 Hz, which is limited by the GPIB communication throughput of a digital oscilloscope.

The applications of the BPM have been acknowledged to be fundamental tools for the commissioning of the KEKB accelerators. The real-time monitors are essential for successful beam handling, and the feedback loops are inevitable to suppress beam instabilities over long-term operation.

The number of BPM transactions is increasing year by year. The amount reached as high as 158 transactions per second in June, 1999. The use of cached data is efficient to decrease the network traffic and the CPU loads in total. In addition, we introduced a new workstation to increase the total CPU power.

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