KEK Preprint 95-29
May 1995
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SW 9500

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*Contributed paper at 1995 Particle Accelerator Conference and
International Conference on High-Energy Accelerators,
May 1 - 5, 1995, Dallas, Texas, U.S.A.*

National Laboratory for High Energy Physics, 1995

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BEAM POSITION FEEDBACK SYSTEMS FOR THE PF STORAGE RING

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Two types of fast beam position feedback systems, global and local feedback systems, are proposed for a low-emittance configuration of the 2.5-GeV PF storage ring, which will be started in 1997. The global feedback system corrects the closed orbit around the ring, and the local feedback system stabilizes the beam positions and angles at insertion devices. Both systems are expected to suppress vibrations up to 50 Hz. For these systems the beam position monitors will be improved so as to achieve fast data-taking and high position resolution; also, the fast steering magnets and their power supplies will be reinforced. In the feedback control, VMEbus-compatible DSP (digital signal processor) boards will be used for fast computation and a reflective memory network will be used for fast data transfer. In a preliminary test, the global feedback DSP board was confirmed to have a sufficient computation performance for its purpose.

I. INTRODUCTION

At the Photon Factory (PF), a new configuration of the 2.5-GeV storage ring will start in 1997 to provide more brilliant photon beams for SR users[1,2]. In the high-brilliance (low-emittance) configuration, the horizontal and vertical beam sizes are reduced by a factor of about two, and the beam sensitivity to external disturbances is enhanced, because the number and the field strength of the quadrupole magnets are increased. It is easily foreseen that beam stability will be more important for taking full advantage of the high brilliance.

A global feedback system has been operated since 1987 to mainly suppress a slow orbit drift caused by building distortion[3,4,5]. However, the effective position resolution of the electron (or positron) beam position monitors (BPMs) limiting the system performance is often deteriorated by contact faults of mechanical switches used for multiplexing BPM position signals. Furthermore, the present system cannot correct relatively fast orbit fluctuations caused by floor vibrations due to air-conditioners, temperature variations of cooling water, etc. Therefore, the construction of an improved global feedback system is planned; it must be carried out in coincidence with the upgrade of the PF storage ring for the high-brilliance configuration. In addition, a local feedback system dedicated to beamlines is proposed for further beam stabilization at insertion devices. It will be constructed in stages after operation in the high-brilliance configuration starts. This paper presents an overview of the feedback

systems, and reports on a performance test of a DSP board used for the global feedback control.

II. SYSTEM DESCRIPTION

The global feedback system corrects the vertical closed orbit using many steering magnets, while taking position data from all of the BPMs. The eigenvector method used in the present system will be adopted again as an orbit-correction scheme. The local feedback system stabilizes the beam positions and angles for both the horizontal and vertical directions at insertion devices, using a local bump generated by four steering magnets. Two BPMs on the sides of an insertion device will be used until a photon beam position monitor which is applicable to undulator beamlines is developed. Both systems are desired to cover a wide frequency range (0 – 50 Hz), because the orbit fluctuations spread up to 50 Hz[6]. The position-measurement error of the systems should be less than 10 μm , 10 – 20% of the vertical beam sizes at the photon source points in the high-brilliance configuration. Each system component is described below.

A. Beam Position Monitors (BPMs)

Figure 1 shows the planned locations of the BPMs in the high-brilliance configuration. The BPMs will be increased from 46 to 65, because quadrupole magnets in the normal-cell

Figure 1: Planned locations of the BPMs and steering magnets in the high-brilliance configuration of the PF storage ring

section (B05–B12 and B19–B26) are doubled. Forty-one of the BPMs will be reconstructed to match the new vacuum-chamber structure of the normal-cell section; the others will be used without any modification. The BPM signal-processing electronics will be newly designed so as to totally satisfy both high position resolution ($< 10 \mu\text{m}$) and a fast data-acquisition time ($< 1 \text{ ms}$). Electrical switches will be used as BPM signal multiplexers in place of mechanical switches in order to improve the switching speed and to avoid deterioration of the effective position resolution due to contact faults. The details of the improved BPM system will be described elsewhere.

B. Steering Magnets and Power Supplies

As shown in Figure 1, twenty-eight vertical steering magnets will be used for the new global feedback system. Twenty of them have already been used for the present global feedback system. The core of the steering magnet is made of 0.35mm-thick silicon steel laminations in order to obtain a good frequency response by reducing the effect of the eddy currents. The power supply is manufactured so that there will be no significant deterioration of the frequency response in both gain and phase, at least below 100 Hz. For the local feedback system, twenty-eight steering magnets for both the horizontal and vertical directions will be additionally installed in seven long straight sections.

C. Control System

Figure 2 shows the design of the feedback control system. Two types of VME crates will be used for the global and local feedback systems. In a global feedback VME crate, a DSP board with two DSPs (Texas Instruments TMS320C40s) calculates the beam positions based on the electrode-voltage data of all the BPMs, writes them into the reflective memory, and computes the coil currents of all the vertical steering magnets. The DSP board is linked with some kinds of I/O boards via a local I/O bus in order to control the BPMs and the power supplies of the vertical steering magnets; it is also

connected to a CPU board and a reflective memory board through a VME bus. Two DSP boards are contained in a local feedback VME crate. Each of them has a DSP (Texas Instruments TMS320C31) to read the beam positions from the reflective memory and to calculate a local bump. A similar DSP board already gave good results in a test of the local feedback system[7]. Since one local feedback VME crate is dedicated to two insertion device beamlines, four crates are needed in total for seven insertion devices. The CPU board in each VME crate is interfaced with a common UNIX workstation by Ethernet. A DSP program coded on the workstation is downloaded to the DSP board through it.

III. PERFORMANCE TEST OF THE GLOBAL FEEDBACK DSP BOARD

The computation performance of the DSP board with two TMS320C40s[8] for the global feedback was tested using a program which simulates the global feedback computation (not including the control of the BPMs and the steering magnets). This program contains the following parts:

- (1) Calculation of the horizontal and vertical positions based on electrode-voltage data of the BPMs and a quality check of the position data,
- (2) Calculation of the steering-magnet currents based on the vertical-position data,
- (3) Calculation for the PID (proportional, integral and derivative) control in order to improve the feedback performance,
- (4) Communication of the electrode-voltage data and horizontal-position data between the main and sub DSPs.

Figure 3 shows a flow chart of the program. Parts (1), (3) and (4) were coded in C-language and Part (2) in assembly language. Parallel C[9] was used as an optimizing C compiler, assembler and linker to reduce the consumed time

Figure 2: Design of the feedback control system

for Part (1) by parallel programming of the two DSPs. Part (4) means that the sub DSP has to take the electrode-voltage data from the main DSP directly connected with the outside of the DSP board and return the calculated horizontal position data to it. The communication speed between the two DSPs is 20 MBytes/s, except for the software overhead. The program forced the main DSP to change the output voltage of a DAC board before and after one computation cycle. Therefore, the total computation time was easily obtained by observing the DAC output level with an oscilloscope. The consumed time for each part was also measured in the same manner. The results are summarized in Table 1. Since the data-acquisition time of the BPMs is less than 1 ms, the total computation time (555 μ s) is sufficiently short for the global feedback with a planned sampling time of 2 ms. It was also confirmed that the total computation time is almost unchanged in parallel programming when the horizontal global feedback computation is added to Parts (2) to (4). This suggests that

we can join the horizontal global feedback to the vertical one without changing the sampling time, if necessary.

IV. SUMMARY AND FUTURE WORK

For the high-brilliance configuration, the global and local feedback systems will be constructed so as to suppress the beam motion below 50 Hz with a position resolution of better than 10 μ m. In order to achieve the system performance, the BPM system will be improved and the fast steering magnets will be increased along with their power supplies. A VME system with DSP and reflective memory boards will be used for fast feedback control. The computation speed of the DSP board is adequate for the global feedback.

Frequency response measurements will be made for the newly designed vacuum chambers of the normal-cell section, though the frequency-response curves of the steering magnet, the power supply and the aluminum vacuum chamber of the straight section have already been obtained. Thereafter, digital filters will be designed to compensate for a considerable phase rotation caused by the time delay of 2 ms sampling and the eddy currents of the vacuum chambers, and to equalize the frequency responses of the vacuum chambers. The power supply load and DSP computation time increased by these digital filters should be experimentally evaluated at the same time. In addition, the data communication with the reflective memory network will be tested.

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Figure 3: Flow chart of a DSP program simulating the global feedback computation

Table 1. Measured DSP computation time

(1) Position calculation (x&y)	305 μ s
(2) Magnet current calculation (y)	100 μ s
(3) PID control (y)	25 μ s
(4) Data communication	125 μ s
Total	555 μ s