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 to achieve fast data-taking and high position resolution, and 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 for fast data transfer. In a preliminary test, the global feedback DSP board was confirmed to have a computation performance enough 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 the 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 the 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 construction of an improved global feedback system is planned and has to be done 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 by stages after the operation in the high-brilliance configuration starts. This paper will present an overview of the feedback systems and also report a performance test on a DSP board used for the global feedback control.

II. SYSTEM DESCRIPTION

The global feedback system corrects a vertical closed orbit with a lot of steering magnets, taking position data from all the BPMs. The eigen vector 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 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 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 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 section

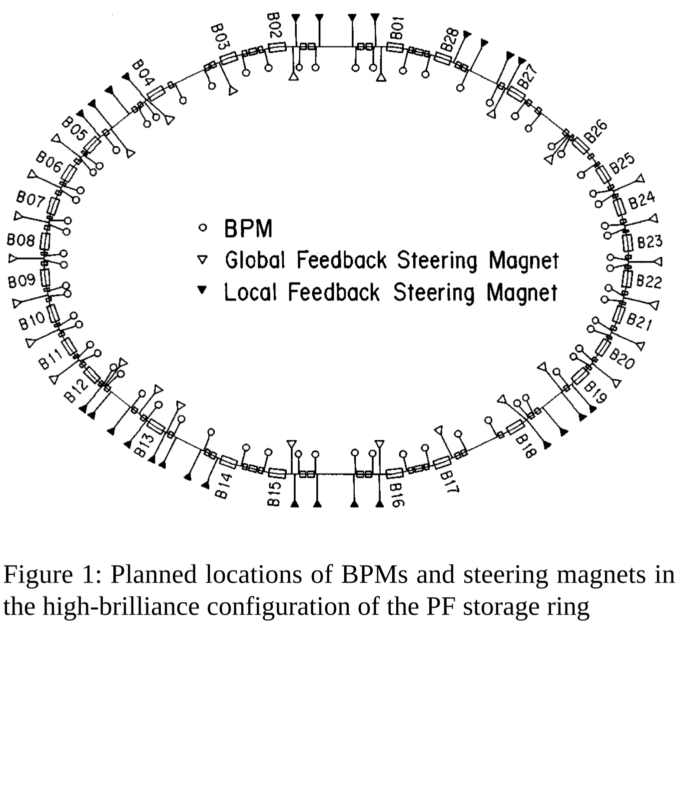

Figure 1: Planned locations of BPMs and steering magnets in the high-brilliance configuration of the PF storage ring

(B05–B12 and B19–B26) are doubled. Forty-one of the BPMs will be reconstructed to match with new vacuum chamber structure of the normal-cell section and the others will be used without any modification. The BPM signal processing electronics will be newly designed so that it can totally satisfy both high position resolution (< 10 μm) and fast data-acquisition time (< 1 ms). Electrical switches will be used as BPM signal multiplexers in place of mechanical switches for improving the switching speed and avoiding 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 been already used for the present global feedback system. The core of the steering magnet is made of 0.35mm-thick silicon steel laminations to obtain good frequency response by reducing the effect of the eddy currents. The power supply is manufactured so that there is 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 horizontal and vertical directions will be additionally installed in seven long straight sections.

C. Control System

Figure 2 shows a 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 (the Texas Instruments TMS320C40s) calculates the beam positions from the electrode-voltage data of all the BPMs, writes them to 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 to control the BPMs and the power supplies of the vertical steering magnets and also connected with a CPU board and a reflective memory board through a VME bus. In a local feedback VME crate, two DSP boards are contained. Each of them has a DSP (the 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 the test of a local feedback system[7]. Since one local feedback VME crate is dedicated to two insertion device beamlines, four crates will be 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 by use of a program simulating the global feedback computation (not including the control of the BPMs and the steering magnets). This program consists of the following parts:

(1) Calculation of Horizontal and vertical positions from electrode-voltage data of the BPMs and quality check of the position data
(2) Calculation of steering magnet currents from the vertical position data
(3) Calculation for PID (proportional, integral and derivative) control improving the feedback performance
(4) Communication of the electrode-voltage data and the horizontal position data between the main and sub DSPs

Figure 3 shows the 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

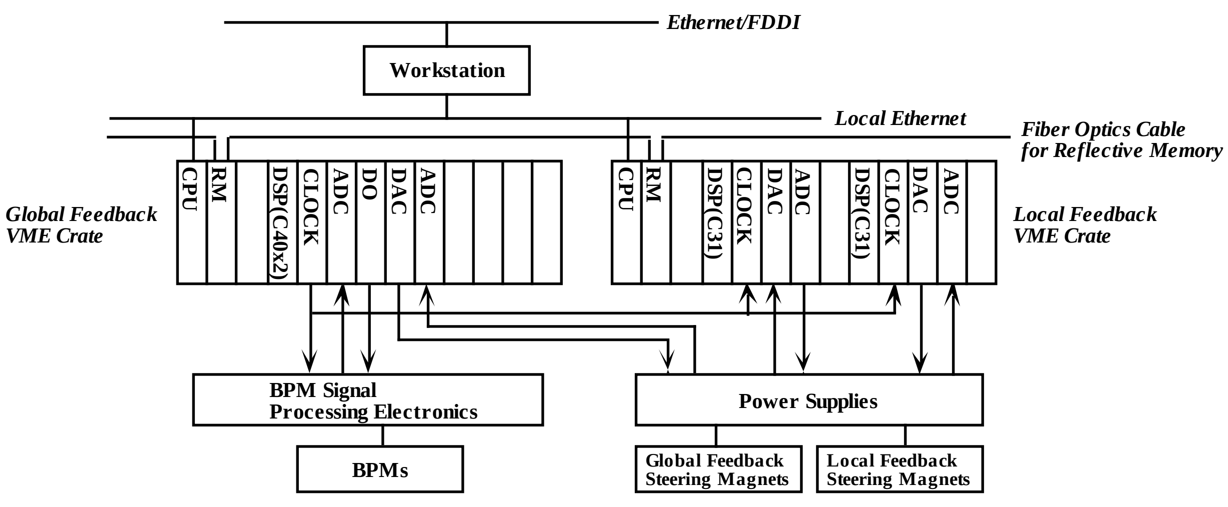

Figure 2: Design of the feedback control system

compiler, assembler and linker to reduce the consumed time 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 result is summarized in Table 1. Since the data-acquisition time of the BPMs is less than 1 ms, the total computation time (555 μs) 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 the 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 a change of the sampling time if necessary.

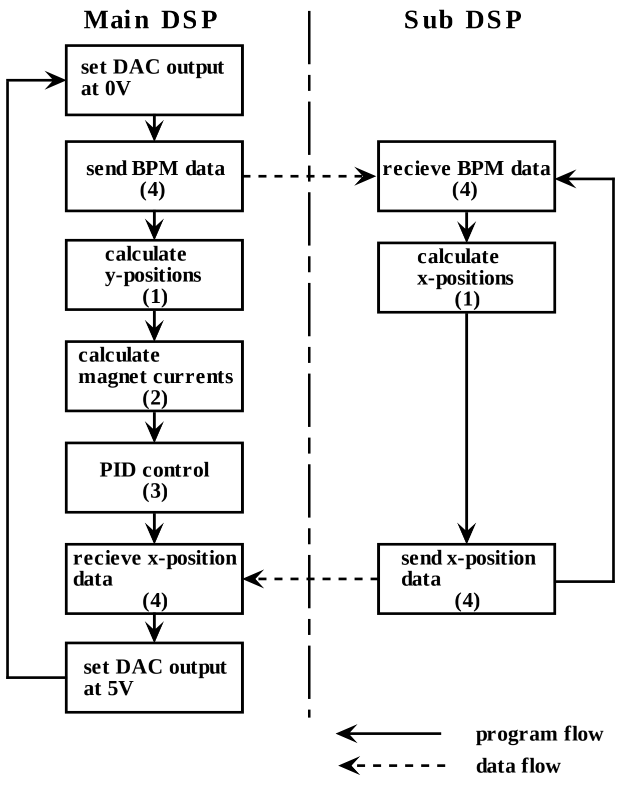

Figure 3: Flow chart of a DSP program simulating the global feedback computation

Table 1. Measured DSP computation time

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

IV. SUMMARY AND FUTURE WORK

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

Frequency response measurements will be done 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 were already obtained. Thereafter digital filters will be designed to compensate 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 the 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.

V. REFERENCES

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