FIRST RESULTS WITH A NONLINEAR DIGITAL ORBIT FEEDBACK SYSTEM AT THE NSLS *

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Abstract

We report on the first experimental results with a nonlinear digital orbit feedback system for the NSLS X-ray ring. The system uses the existing RF receivers and orbit corrector magnets (trims) as well as parts of the NSLS control components. The orbit measurement micro was upgraded to a Motorola 68040 CPU in order to achieve the necessary data rate. Filtering and orbit correction calculations are done in a dedicated HP 742 rt micro. The system operates at a 555 Hz data rate, and achieves a bandwidth of 15 – 20 Hz.

I. INTRODUCTION

Orbit stability is an important issue for storage rings, like the ones at the NSLS. Brightness of the photon source and beam lifetime can deteriorate due to even small motions in the beam orbit. The orbit can be stabilized with feedback systems. Digital feedback systems Ref. [1] are very flexible, since the filter and orbit correction algorithms are programmed and any change does not require changes in the hardware. This is a clear advantage over the presently used analog hardware based feedback systems.

II. ORBIT CORRECTION ALGORITHM

In implementing the digital feedback system, we are using the eigenvector decomposition based orbit correction method described in Refs. [2], [3]. This method yields the 'minimum' kick vector required for a desired accuracy of orbit correction.

III. FILTERING

The feedback system and its elements are illustrated in Fig. 1.

G represents the effect of the vacuum chamber. It behaves like a single pole low pass filter, with the pole at ≈25 Hz: [1]

$$G(s) = \frac{2\pi 25}{s + 2\pi 25} \quad (1)$$

H_{AA} is an "anti aliasing" filter which limits the bandwidth of the signal in order to prevent aliasing (folding) of the signal spectrum after the D/A conversion. It is a low pass filter with a single pole at ≈80 Hz:

$$H_{aa}(z) = \frac{2\pi 80}{s + 2\pi 80} \quad (2)$$

$H_d(z) = z^{-3}$ represents the phase delay due to sampling time, computation time and conversion time.

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[1] In this section G(s) is the Laplace-transform of an g(t) continuous signal ($s = j2\pi f$), and H(z) is the Z-transform of an h(n) discrete signal ($z = \exp(j2\pi f t_s)$), where t_s is the sampling time.

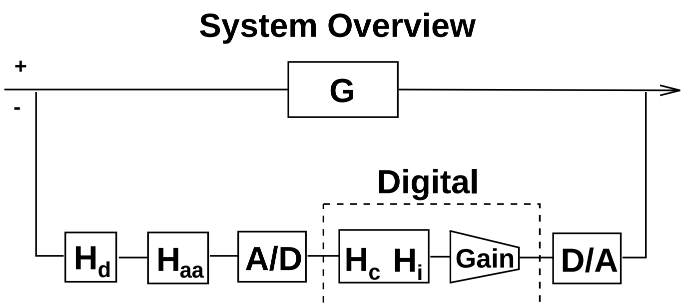

Figure. 1. Block diagram of the ring and feedback loop showing the elements of the feedback system.

The H_c filter is designed to compensate for elements in the system G that may be limiting the bandwidth and adding phase retardation to the system. This filter is a high pass filter:

$$H_c(z) = \frac{1}{G(z)} = 8.026\frac{1 - 0.751z^{-1}}{1 + z^{-1}} \quad (3)$$

H_I is an integrator, which together with the gain is used to limit the bandwidth of the system and to stabilize it.

$$H_i(z) = 1.69 \times 10^{-3}\frac{1 + z^{-1}}{1 - z^{-1}} \quad (4)$$

Note that a pure integrator generates infinite gain at DC. Hence, the correction at DC is absolute.

The closed loop response of this system is

$$T = \frac{G}{1 + g_o G H_{tot}}, \qquad where \quad H_{tot} = H_{aa} H_d H_c H_i, \quad (5)$$

T is plotted as a function of the f frequency on Fig. 2

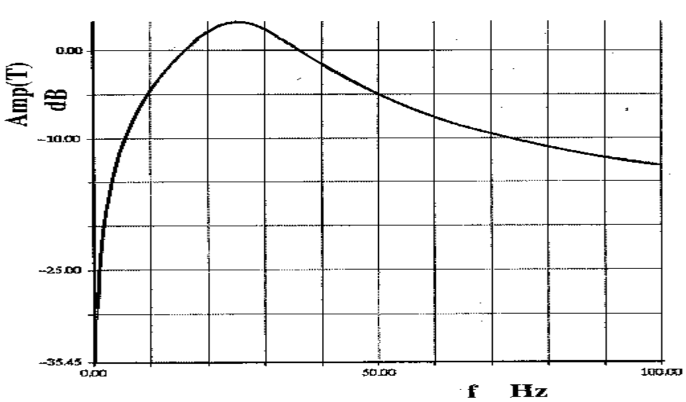

Figure. 2. Calculated amplitude response.

IV. HARDWARE

The feedback system consists of three micros; the HP-742rt CPU based feedback micro, the Motorola-167 CPU based orbit micro and the Motorola-133 CPU based trim micro. The communication between the micros is done by the Bit-3 bus adapter boards through shared memory in the trim and in the orbit micro. The basic layout is shown in Fig. 3.

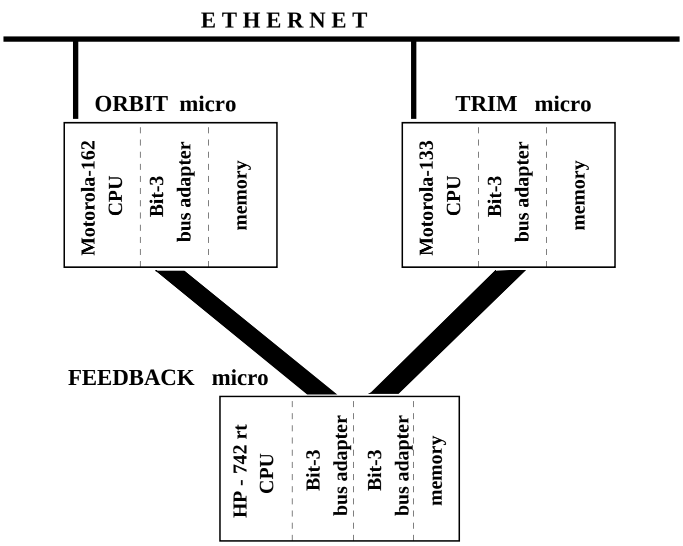

Figure. 3. Layout of the feedback system.

The orbit micro samples the PUE data at 555 Hz rate and the data is stored in memory. This memory is mapped by the adapter board to the address space of the feedback micro which calculates the orbit correction and optimizes it. The data communication between the feedback and trim micros is again through memory mapping. The trim micro then controls the power supplies of the orbit corrector magnets. The most computational intensive task is that of the feedback micro. Hence, we chose an HP 742rt, which we estimate to run six times faster than a Motorola 167/162 for this kind of application.

Though the orbit is sampled at 555 Hz rate for the feedback, the data at 32 Hz rate is available for the workstations for existing control programs [4] such as Real Time Orbit, Fast Orbit History, *etc*. Thus the PUE and feedback micros are isolated from the general control network.

To prevent aliasing problem the PUEs are set up with an analog low pass filter.

If it becomes necessary, we will include a control micro in the design to isolate the feedback system from the general control network. The need may arises, since the micros are expected to operate at close to full load and any requests addressed to them on the network may slow them down, reducing the feedback rate.

V. SOFTWARE

The orbit and trim micros use the existing NSLS real time monitor [5]. The programming of the monitor, as well as of the orbit and trim micros were modified such that the feedback micro can place the read points and set point into the shared memory, and that the data collection is synchronized with the feedback micro. The PUE readpoints are sampled with 555 Hz for the feedback micro but updated with 32 Hz for general use. A new monitor was written for the feedback micro, based on the HP-RT operating system. The orbit correction code is a modification of the code that was used for orbit correction in Refs. [2], [3]. This is an object oriented code written in C++.

VI. FIRST RESULTS

The feedback system was run successfully on the vertical plane of the NSLS X-ray ring, using all 40 orbit correctors and 48 PUEs. The frequency response of the closed system was measured and compared with the frequency response without feedback. One of the orbit correctors was driven by the output of an HP Dynamic Signal Analyzer in the .1 – 100 Hz frequency region and the amplitude and phase response of one of the PUE's was recorded. The results are shown on Fig. 4.

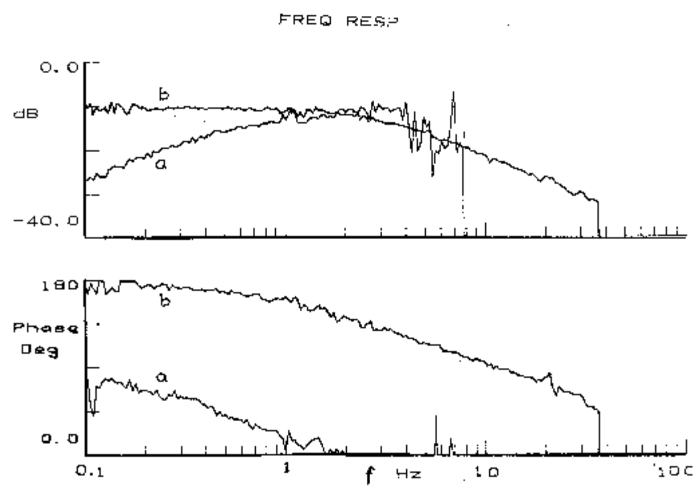

Figure. 4. Measured amplitude and phase response.

The DC noise reduction is ≈40 db and the effective bandwidth is 15 – 20 Hz with a small noise amplification between 20 – 30 Hz. These results are in good agreement with the calculated closed loop response shown in Fig. 2.

VII. FUTURE PLANS

In order to achieve a higher (1.5 – 2.0 kHz) orbit sampling rate, we will replace the present orbit reading system with Analogic 16-bit, 400 kHz data acquisition boards and 32 channel multiplexers.

We are planning to add a notch filter at 60 Hz in order to effectively suppress a sometimes strong noise at that frequency. In this case the H_{tot} in Eq. (5) is replaced by

$$H_{tot} = H_{aa} H_d H_c (H_i + g_n H_n). \quad (6)$$

The calculated amplitude response of the total closed system with the wide band low pass filter and the notch filter is shown in Fig. 5.

VIII. ACKNOWLEDGEMENT

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Figure. 5. Calculated amplitude response with notch filter.

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