NEW X-RAY BPM DATA ACQUISITION SYSTEM FOR THE APS*

F. Lenkszus,† R. Laird, G. Decker, O. Singh, M. Hahne, and L. Erwin
Advanced Photon Source, Argonne National Laboratory, Argonne, IL

Abstract

A new digital signal processor (DSP)-based data acquisition system has been designed and installed at the Advanced Photon Source. This system uses a commercial VME-based DSP card to acquire and process x-ray blade signals to determine x-ray beam position for both bending magnet and insertion device beamlines. The system also acquires and processes position data from the narrow-band rf BPMs that straddle each insertion device. It is integrated within the storage-ring fast-feedback system and provides filtered data to both the feedback system and the EPICS control system. Features of the system, including analog and digital signal processing, are discussed.

1 INTRODUCTION

Previously at the Advanced Photon Source, x-ray BPM blade signals were processed by a system consisting of a high-performance preamplifier, a digitizer, an intelligent controller chassis, and a stand-alone digital signal processor (DSP) [1]. The system had many valuable features and provided x-ray BPM data for several years. However, as experience with the x-ray BPMs accumulated, it became evident that a more flexible system that allowed code and algorithms to be easily changed and tested was needed. To this end, a new system was developed based on commercial VME DSP and digitizer boards. The remainder of this paper describes the new system.

2 OVERVIEW

The new DSP-based data acquisition system (DAS) collects and processes data for beamline x-ray BPMs and narrow-band rf BPMs straddling each insertion device. Each APS insertion-device (ID) beamline has two four-bladed x-ray BPMs, while each bending-magnet (BM) beamline has two two-bladed x-ray BPMs. The narrow-band rf BPMs are four button devices mounted directly on the ID vacuum chamber.

This new DAS system (shown in Fig. 1) consists of commercial DSPs [2]; 16-bit analog-to-digital converters (ADCs); 12-bit ADCs; 8-channel, 7-pole anti-aliasing filters; and preamp control chassis. The blade preamps, narrow-band BPM electronics, and associated filters were in use prior to this project.

With one exception, the DAS DSPs and ADCs are located in the APS storage-ring fast-feedback [3] input-output controllers (IOCs). The 16-bit ADC digitizes x-ray blade signals and narrow-band BPM (NBBPM) position signals, and the 12-bit ADC digitizes narrow-band BPM sum and automatic gain control (AGC) signals. The DAS DSP is synchronized to the fast-feedback system clock (1534 Hz). It reads digitized values from the ADCs and passes values to the vertical-axis feedback DSP via a high-speed byte-serial communications port. It also low-pass-filters the values and deposits them in dual-ported DRAM for access by the feedback IOC processor, which runs the EPICS control system software.

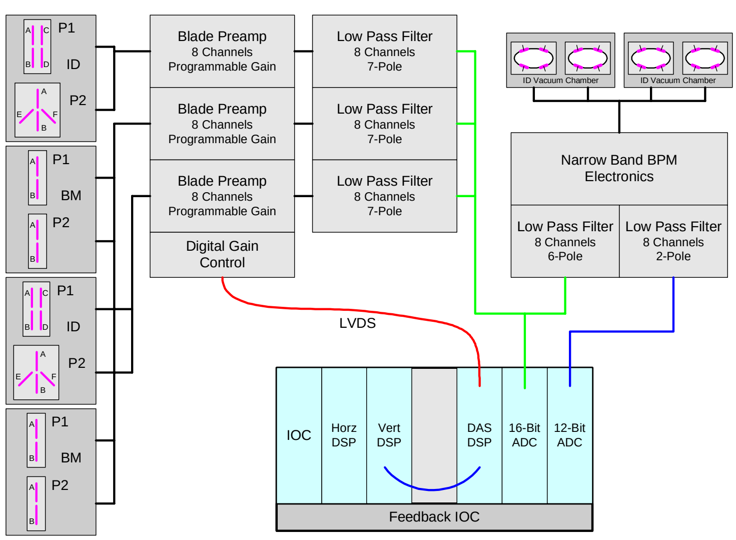

Figure 1: Block diagram of data acquisition system.

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† frl@aps.anl.gov

3 HARDWARE

The hardware design involved two distinctly different components: (1) an anti-aliasing filter sufficient to maintain 16-bit overall system resolution and (2) high-speed digital signal communications to the feedback system DSPs and blade preamp gain controls.

The primary specification for the anti-aliasing filter is to provide 16-bit performance at the feedback system Nyquist frequency, which at the time was 833 Hz. An extremely conservative specification would be 98 dB of attenuation at the Nyquist frequency; however, 96 dB at 800 Hz was specified as adequate for this filter. The next consideration was to select filter type, order, and cutoff frequency. The filter was designed as a 7-pole Butterworth low-pass filter with a 3 dB cutoff of 165 Hz.

Eight channels are implemented on a single printed circuit board. Table 1 lists measured performance.

Table 1: Measured Filter Performance

Bandwidth (3 dB)	165 Hz
Attenuation (at 800 Hz)	98 dB
Spurious Free Dynamic Range (45 Hz Full-Scale Input)	90 dB
Noise and Pickup	-115 dB
Adjacent Channel Crosstalk (at 105 Hz)	-116 dB

Achieving the performance listed in Table 1 required considerable attention to component selection and circuit layout.

The original concept was to locate all the DAS DSPs in storage-ring BPM IOCs. This necessitated a high-speed communications link to transfer data from the DAS DSP to the feedback system DSPs located in the feedback IOCs in different racks. The commercial VME DSP boards used are based on the Texas Instruments C40 floating point DSP. These DSPs have six byte-serial communication ports with a specified peak transfer rate of 20 Mbytes/s. Since these six ports are readily available on the front panel of the DSP VME cards, they were a natural choice for DSP-to-DSP communication and x-ray BPM preamp gain control. The native communication ports are limited to cable lengths on the order of 12 to 14 inches. Low-voltage differential signaling (LVDS) transceivers are used as buffers to permit cable lengths of up to 10 m. Ultimately, all but one of the DAS DSPs were installed in the feedback IOCs to minimize BPM signal cable lengths. The DAS DSP for sector 35 was installed in a separate VME crate to facilitate testing in the production system with minimum impact on storage-ring operations. Thus, except for sector 35, the front panel communication ports are used without the aid of buffers to transfer BPM data from the DAS DSP to the feedback vertical DSP.

The LVDS buffers are used on the C40 communication ports used to digitally control the gain of the x-ray BPM blade preamps, because the preamps are located several meters from the DAS DSPs.

4 DIGITAL SIGNAL PROCESSING

Figure 2 illustrates the signal processing flow for the x-ray BPM blade signals and the NBBPM position signals. NBBPM sum and AGC signal processing are omitted for clarity.

Both the NBBPM and x-ray BPM blade signals are passed through anti-aliasing filters before digitization. The 16-bit ADC is a commercial VME card [4] of the

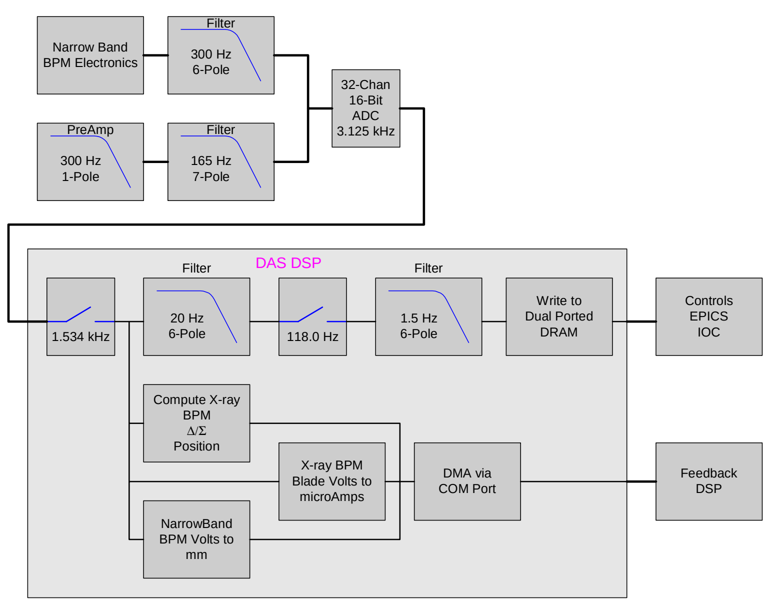

Figure 2: X-ray BPM blade and narrow band BPM position processing.

scanning variety. Presently the ADC scans inputs using its internal 100 kHz scanning clock. Thus each of the 32 inputs is digitized at 3.125 kHz. An external clock derived from the same source as the DSP sample clock is planned to synchronize digitizations with DSP sampling.

The digitized values are processed and sent to two destinations: the controls IOCs and the fast-feedback DSPs. The IOC processor samples data deposited in the DAS DSP card's dual-ported DRAM at 2 to 10 Hz rates. To minimize aliasing, the digitized values are passed through digital low-pass filters. A single-stage decimator is used to improve overall system performance. As shown in the figure, the digitized values are first low-pass filtered by a 6-pole, 20-Hz filter, then sampled at 118 Hz (decimate by 13), and finally passed through a 1.5-Hz low-pass filter. The final filter's cutoff frequency is an EPICS process variable and thus readily changeable. The filter coefficients are computed by code in the IOC and written to the DAS DSP card's dual-ported DRAM. This permits the final filter cutoff to be dynamically changed.

The IOC processor further processes the BPM data. NBBPM position data are passed through bivariate linearization polynomials, while the x-ray blade values are normalized to beam current and used to compute delta/sigma positions. The resulting BPM position data are then used by workstation-based feedback processes to control the storage-ring orbit.

The DAS DSP also provides the x-ray and NBBPM data to the feedback system DSPs. The NBBPM data are linearly converted to millimeters and the x-ray blade data are converted to micro-amps. In addition, delta/sigma position computations are performed for all x-ray BPMs at the sample rate.

The blade micro-amps and BPM position data are sent to the fast-feedback system's vertical DSP via one of the 20 Mbytes/s communication ports using direct memory access. This has two advantages over depositing the data in dual-ported DRAM. First, it allows the DAS DSP to be located in a different VME crate from the feedback DSP. (This is done for sector 35.) Second, it avoids additional VME bus operations and contention. This is a serious consideration, because as shown in Fig. 1, the feedback IOCs have three processor boards in addition to the BPM DAS DSP board.

5 EXPERIENCE

The first x-ray DAS systems were installed in two feedback IOCs covering sectors 32 through 35. These systems were run from September 2000 until the December 2000 shutdown. During the December 2000 shutdown three additional systems were installed covering sectors 1 through 4 and 13 and 14. Within a few days of startup, unexplained beam losses occurred every few days. Investigation indicated that the feedback IOCs containing the DAS DSPs were the culprits.

Extensive study of the VME bus in the IOC covering sectors 1 and 2 revealed two separate problems. The first problem was related to early bus release by the bus master. It appeared that the DAS DSP card would occasionally malfunction, short cycling VME reads during VME early bus release. A work-around for this problem is to disable early VME bus release on the VME bus arbiter.

The second problem was more intractable and occurred less frequently. Investigation revealed that multiple masters were simultaneously active on the VME bus. This effect was traced to a glitch infrequently emitted by the vertical-axis DSP on its VME bus grant-out line that was sufficient to grant simultaneous mastership to the downstream master (DAS DSP). It was verified that this problem was characteristic of the board type and not specific to a single specimen. Moving the DAS DSPs to a different VME bus request level alleviated this problem, which had not manifested itself until the DAS DSP was added as a downstream master.

A board was returned to the vendor, modified, and returned to us. This board was installed and has been running without incident.

6 CONCLUSION

The system described here was first installed and tested in sector 35 in July 2000. Presently the system is installed and running without incident in nine of the 20 feedback IOCs covering sectors 1 through 14 and 32 through 35. The anti-aliasing filters have improved the noise performance of both the x-ray and the narrow-band BPM data reported to the control system.

7 REFERENCES

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