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Electronics for SPring-8 X-ray beam monitors

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A sensitive current-measuring system is required to construct a highly sensitive X-ray beam-position monitor (XBPM). A current–voltage converter (I/V) which can measure currents between 0.1 nA and 10 mA was designed, and the signal processing system of the XBPM was constucted using this I/V. This system was used in beamline commissioning. Beam-position data standard deviations of $\sigma \simeq 3$ µm for the bending-magnet beamline, and $\sigma_x \simeq 3$ µm and $\sigma_y \simeq 1$ µm for the insertion-device beamline were obtained during the beamline commissioning.

Keywords: X-ray beam-position monitors; beamline commissioning.

1. Design of the XBPM data-acquisition system

1.1. *Current to voltage converter (I/V)*

Current signal ranges from XBPMs (Shiwaku *et al.*, 1994) have previously been estimated as shown in Table 1. The estimated currents vary according to the driving mode of the SPring-8 storage ring and the insertion devices. Thus, the I/V converting ratio needs to accommodate gains of 1 nA V^{-1} to 1 mA V^{-1}. An ultralow-drift and low-offset OP amp (AD549, Analog Devices) is used in the I/V for detecting small nanoamp currents (Fig. 1). This module was manufactured by Clear Pulse CO.

As the signal from the XBPM is a micropulse-shaped current, the time constant of the I/V conversion electronics is designed to be longer than the pulse period (5 µs) in single-bunch mode, so that the signal current is properly averaged. (In the case of SPring-8, the signals are sent through 40 m of cable. Therefore, the current signals may be also averaged by the inductance of the cable.)

1.2. *Signal processing and position calculation*

The monitor has four blades for the insertion-device beamline for obtaining information about the two-dimensional beam position. The beam position can be calculated using the following equations,

$$X = A_x \frac{(I_{U\text{-}R} + I_{D\text{-}R}) - (I_{U\text{-}L} + I_{D\text{-}L})}{I_{U\text{-}R} + I_{D\text{-}R} + I_{U\text{-}L} + I_{D\text{-}L}} \quad (1)$$

$$Y = A_y \frac{(I_{U\text{-}R} + I_{U\text{-}L}) - (I_{D\text{-}R} + I_{D\text{-}L})}{I_{U\text{-}R} + I_{D\text{-}R} + I_{U\text{-}L} + I_{D\text{-}L}}, \quad (2)$$

where $I_{U\text{-}R}$, $I_{U\text{-}L}$, $I_{D\text{-}R}$ and $I_{D\text{-}L}$ (*U-R*, upper-right; *U-L*, upper-left; *D-R*, lower-right; *D-L*, lower-left) are the currents from each blade, and A_x and A_y are coefficients to be calibrated. For the bending-magnet beamline, the monitor has two blades for obtaining information about the one-dimensional beam position. The beam position is then calculated from

$$Y = A_y (I_U - I_D)/(I_U + I_D), \quad (3)$$

where I_U and I_D are currents from the upper and lower blades, respectively.

The analog data of the I/V are sent to the 16-bit AD board in the VME workstation system of each beamline, and processed. Users can then utilize the information about the photon beam position. A block diagram of this system is shown in Fig. 2.

Table 1
Signal currents from Spring-8 XBPMs.

Light source	Monitor type	Signal current
Insertion device	Diamond area	1 pA–10 mA
	Diamond blade	1 pA–(1 A)
Bending magnet	Metal blade	1 pA–10 mA

2. Evaluation of the electronics and the system

The system characteristics of the I/V are: input current range, 10 pA–10 mA; I/V conversion ranges, 10 nA/10 V, 1 µA/10 V, 100 µA/10 V, 10 mA/10 V; temperature drift, <100 p.p.m. K^{-1}; output noise, each channel <2 mV (peak-to-peak); linearity, <0.1% full scale; output voltage, −10 V to +10 V.

The signal-to-noise ratio is limited by the output noise (<2 mV peak-to-peak, white noise), which is generated from the OP amp itself and is difficult to remove by filtering. The output voltage should be kept greater than 1 V, in which case the signal-to-noise ratio is approximately 1000. In fact, in the commissioning of the SPring-8 beamline, it was found that the XBPM in the insertion-device beamline can easily demonstrate micrometre resolution when the output voltage from the I/V is greater than 1 V. If the output signal is smaller than 0.1 V, then the I/V range of all blades should be manually changed to improve the signal-to-noise ratio.

The voltage data from the I/V are acquired by the AD board in the VME system every few seconds, and the data are then processed to give the position data. Therefore, the position data are rewritten every few seconds. The data-sampling time is limited by the workstation software, which must also control many other beamline components. However, in beamline commissioning, the systematic data-acquisition speed was sufficient for our purposes.

This system was used in the beamline commissioning. Standard deviations of $\sigma \simeq 3$ µm for the bending-magnet beamline and σ_x

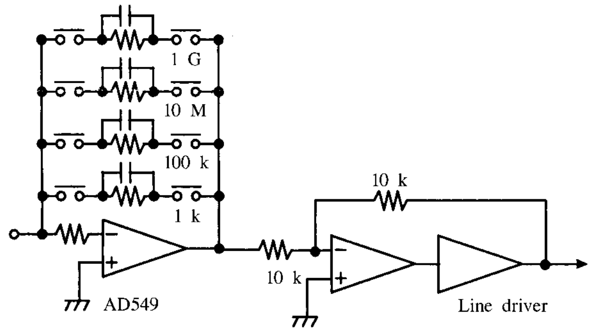

Figure 1
Current–voltage converter (I/V).

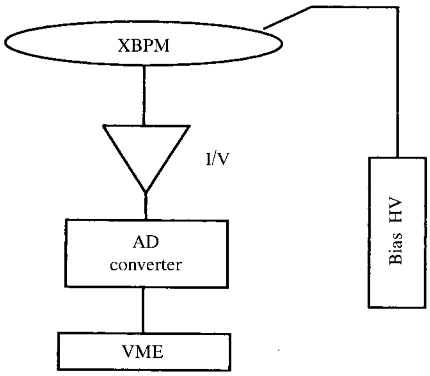

Figure 2
SPring-8 XBPM system.

$\simeq$ 3 μm and $\sigma_y \simeq 1$ μm for the insertiondevice beamline were observed.

3. Future plans for the XBPM data-acquisition system

The XBPM data-acquisition and electronics systems worked well in the commissioning of SPring-8 beamlines. There were, however, some points that could be improved, especially in the control of the I/V conversion ratio.

In the present system, the I/V conversion ratio is manually optimized. This manual operation is a troublesome task for users. Thus we are considering ways of automatically optimizing the I/V ratio. A simple way to resolve the problem is to adjust the I/V ratio remotely through the DIO interface board of the VME. The hardware for this change is simple, and a linearity of 0.1% can be easily attained, although the continuity of the analog data is lost when the I/V ratio is remotely changed. However, this problem is not too severe in the present case. We have already tested a prototype of this system, and confirmed that the system works well.

We are considering alternative routes for current–voltage conversion involving a logarithmic amp (ex. 755N, Analog Devices). By use of the logarithmic IC, I/V ratio control might be omitted, since the IC has a large dynamic range. The voltage data from the module with a logarithmic circuit are taken by the AD and processed after anti-log conversion by software. For example, if a circuit with a 755N is used, 1 nA to 1 mA of current can be logarithmically converted into voltage with 1% accuracy in the logarithm (Analogue Devices, 1995/1996). However, the necessary accuracy is 0.1% for XBPM data acquisition. Alternatively, the I/V conversion ratio might be controlled electrically using an analog-feedback system (Fig. 3).

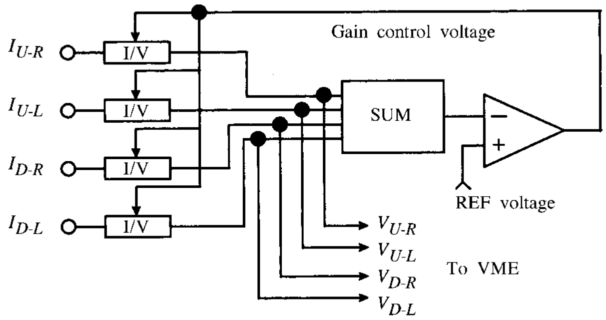

Figure 3
Feedback control for XBPM signal processing.

In the XBPM, only the ratio of the current signals from each blade is required to calculate the beam position, and the absolute value is not necessarily needed. Therefore, it is required that all four (or two) current signals are converted by the same I/V ratio in order to keep the output voltages within the optimum range for the AD converter. For future computer control the I/V conversion circuit could be accurately set by controlling the amount of negative feedback.

An I/V circuit can be constructed with an OP amp and resistor with the I/V ratio dependent on the resistor value. If the resistor value can be accurately controlled by a control voltage, this system might be feasible.

References

Shiwaku, H., Sakae, H. & Kitamura, H. (1994). *SPring-8 Annual Report 1*, p. 162. SPring-8, Hyogo 678–12, Japan.
Analog Devices (1995/1996). *Linear Data Book*, 755N, 755P.