DEVELOPMENT OF SPILL CONTROL SYSTEM FOR THE J-PARC SLOW EXTRACTION

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Abstract

J-PARC (Japan Proton Accelerator Research Complex) is a new accelerator facility to produce MW-class high power proton beams. From the main ring (MR), high energy protons are slowly extracted and delivered to Hadron Experimental Facility. The slow extraction beam is required a flat structure and low ripple noise. We have developed a new signal processing board for the spill feedback control to realize the requirement. Using two DSPs contained in this board, digital filtering, phase-shift processing, servo feedback control, real-time calculation of power spectrum density and adoptive control are examined.

INTRODUCTION

The slow extraction of proton beams from the J-PARC MR utilizes the third integer resonance using sextupole magnets, and delivers to Hadron Experimental Facility to be used in nuclear and particle physics experiments. The extracted beam is required small ripple to prevent pileup events in particle detectors or data acquisition systems. In slow extraction of KEK-PS, the analog circuit which was used as a feedback device had been changed to a digital feedback device using a DSP and we could get a big improvement about the operation of spill control. Based on this experience and preliminary experiments at HIMAC (Heavy Ion Medical Accelerator in Chiba) we designed a signal processing board for digital spill feedback in slow extraction of J-PARC.

SPILL CONTROL

In the J-PARC MR the slow beam extraction is mainly carried out by electrostatic septa (ESS) and magnetic septa. The extraction Q magnets (EQ) and ripple Q magnet (RQ) are additionally used to obtain better spill characteristics. As shown in Fig. 1 the shape of extracted beam is adjusted to rectangular beam intensity by the EQ magnets. At the same time, the ripple component is suppressed by the RQ magnet.

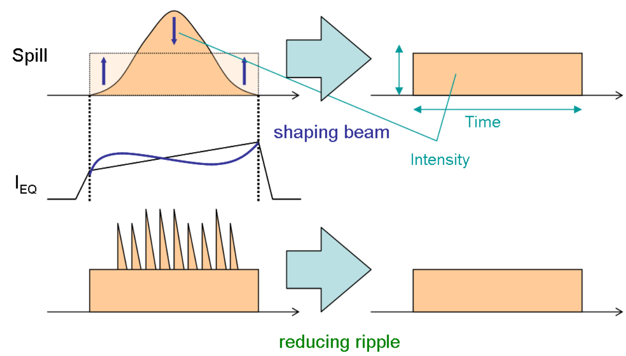

Figure 1: Constitution of spill feedback control.

Figure 2 shows the block diagram of the new spill residual control unit which is used for slow extraction of J-PARC. Three input signals are a gate signal to enable feedback operation, a beam intensity signal to know the remaining protons in the MR and the extracted spill signal. The output signals of spill feedback unit are the exciting current patterns for the EQ and the RQ magnets.

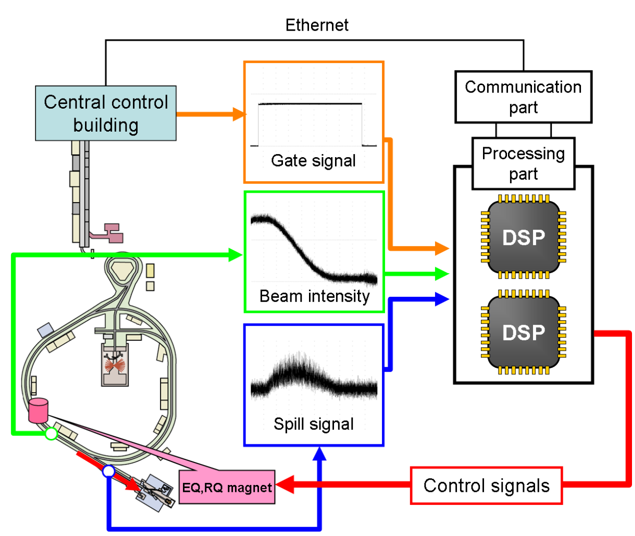

Figure 2: Block diagram of the spill feedback system.

DIGITAL FEEDBACK

Hardware

Figure 3 shows the block diagram of the spill feedback unit. It consists of three digital signal input ports for the gate signal, the beam intensity signal, and the spill signal, two DSPs (TMS320C6713) to analyze power spectrum density and to carry out spill feedback control, dual port memories, FPGAs, a LAN interface for remote control to change feedback parameters from a central control room and three digital signal output ports for the EQ and the RQ magnets. The sampling clock is variable from 1 kHz to 200 kHz.

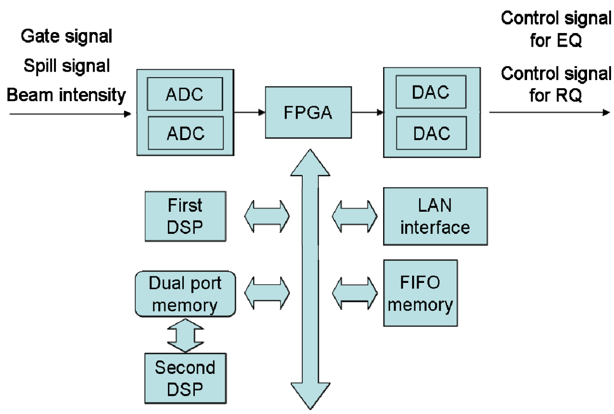

Figure 3: Block diagram of the spill feedback unit.

Software

Figure 4 shows feedback algorism of the slow extraction. At first the difference between the spill signal and the target value is derived. The target value should be calculated by dividing the initial beam intensity by an expected extraction time.

In case of the EQ magnet the deference signal is multiplied by the coefficient which varies depending on the beam intensity. The following low pass digital filter was used in the digital feedback control system in KEK-PS. In case of the RQ magnets the deference signal is fed into a high pass digital filter to obtain the ripple components. The following phase shifter is prepared to adjust a delay time to the optimum value for effective ripple suppression. These processing is carried out in the DSP-1.

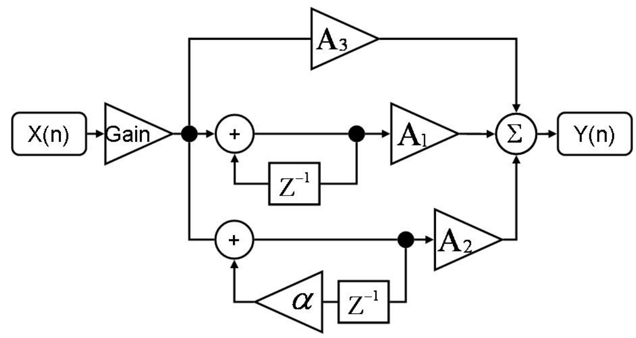

Figure 5: Structure of the digital low pass filter for the EQ magnet.

The DSP-2 calculates power spectrum density of the spill signal to examine a special digital feedback technique of frequency dependent algorism. In the result of preliminary experiments in KEK-PS and HIMAC we observed anomalous increase of some frequency components in the power spectrum of the spill signal. Therefore, we prepared additional function to detect increase of the power of specific frequencies.

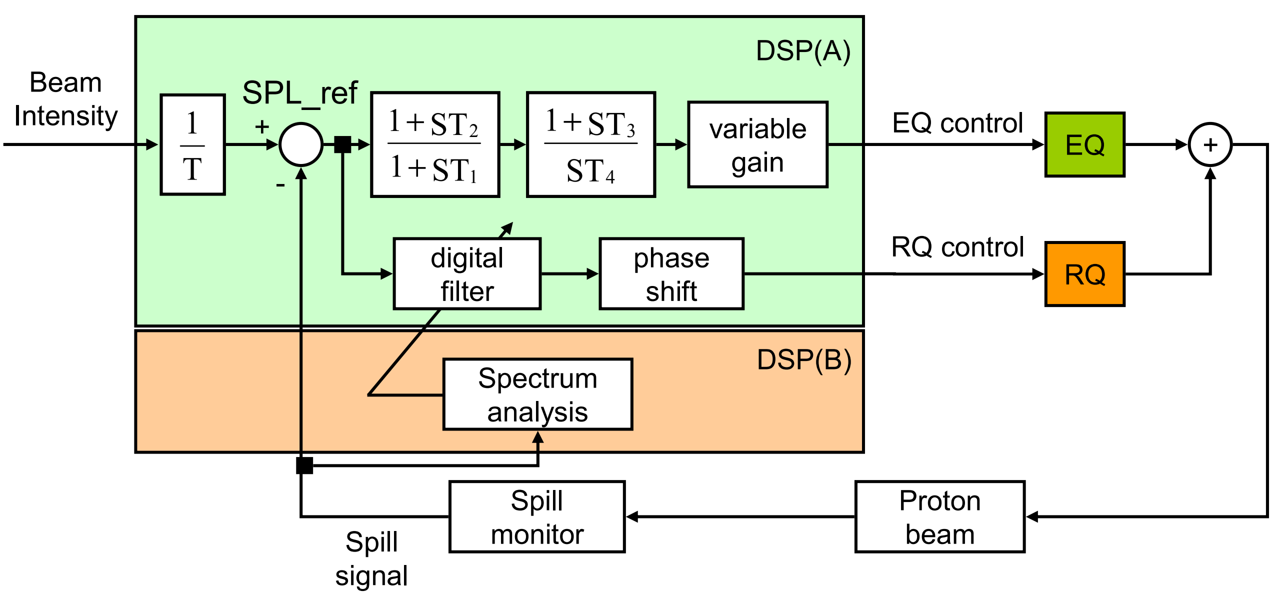

Figure 4: Block diagram of the digital spill feedback processing.

Power Spectrum Density (PSD)

Usually, the Fast Fourier Transform algorism (FFT) is used to calculate the power spectrum density. However the FFT has the problem which is not able to obtain power spectrum density before all multiply-accumulates are completed. According to this problem the FFT is not suitable for real time control. As a result the PSD analytical method presented by Murata was adopted to calculate power spectrum density. As shown in fig. 6 after every data sampling the multiply-accumulate operation is carried out between the sampling data and special weight coefficient to obtain the power of specific frequency.

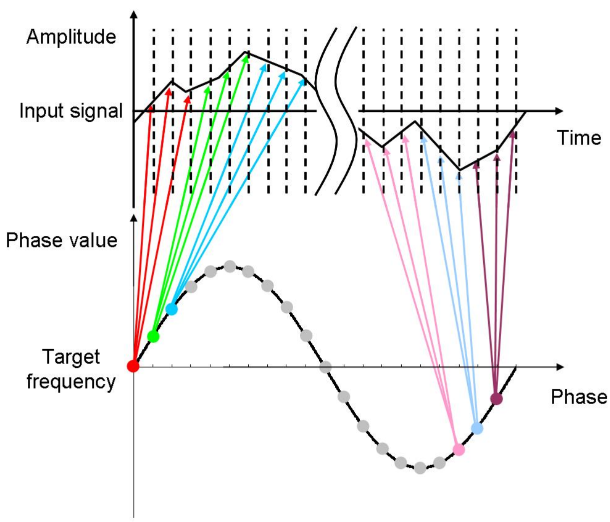

Figure 6: Principle of the real-time PSD analysis.

BEAM TEST

We had the beam test to verify the spill feedback in HIMAC of National institute of Radiological Sciences in Chiba. In HIMAC, the beam extraction is carried out by employing same J-PARC as third resonance extraction. The QDS magnet that corresponds to EQ of J-PARC is prepared, and it is useful as the test facility of spill feedback. In beam test, the input pattern for QDS magnet is given by spill feedback device. Figure 7 shows non feedback and feedback spill signal.

CONCLUSION

After time, we need to change parameter by remote control for long time operation. It is necessary that develop the communication part using SUZAKU-V SZ-410.

Now, J-PARC has been constructed and carried out beam test. HIMAC equips only QDS magnet that corresponds to EQ of J-PARC. In the present experiment, we verified mainly feedback using EQ magnet. In J-PARC, we need to verify feedback using RQ magnet, and test the changing parameter by using PSD because it have not test yet.

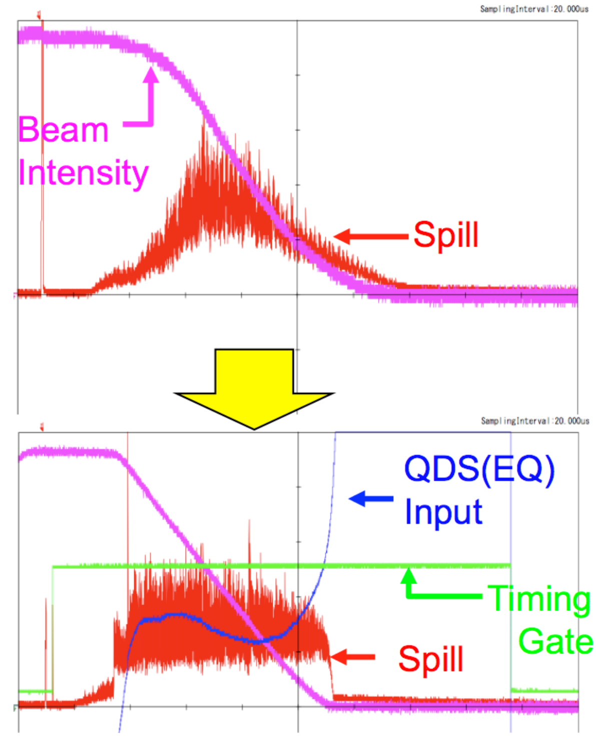

Figure 7: Constitution of spill feedback device.

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