

INJECTION AND EXTRACTION TIMING CONTROLS AT SuperKEKB DAMPING RING

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Abstract

SuperKEKB project aims at the world highest luminosity to $8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$. To achieve the luminosity, a lot of equipment was newly constructed or upgraded. Especially, a Damping Ring (DR) was newly constructed at the middle of the injector linac for making lower positron emittance. The DR timing control system was also fabricated as a branch of the main SuperKEKB timing system. The synchronized timing is generated at the main timing system. It is received at DR sub-timing station and is distributed to the end of some equipment, Kicker, Septum, and monitoring devices.

We succeeded to generate not only synchronized timing but also beam control information such as beam gate for trigger inhibit signal and injection and extraction timing "value" via data buffer delivery. By using this method, accelerator operation became more convenient system.

INTRODUCTION

SuperKEKB accelerator is electron-positron collider for high-energy physics experiment [1]. Electron and positron are stored in High Energy Ring (HER) and Low Energy Ring (LER) at the energy of 7 GeV and 4 GeV, respectively. To overcome the luminosity of previous KEKB project, a Damping Ring (DR) has constructed to provide low emittance positron to LER. The specification of DR is listed in the Table 1.

Table 1: Key Parameters of Damping Ring

Parameters	Value	Unit
Energy	1.1	GeV
Repetition frequency	50	Hz
Circumference	135.5	m
RF frequency	508.9	MHz
Harmonic Number	230	
No. of bunch trains	2	
No. of bunches / train	2	

The positron beam is accelerated to 1.1 GeV in the injector linac, and delivered to the DR through beam transport line. The DR stores the positron beam during 40 ms which is an essential damping time to make low-emittance. On the other hand, since the maximum injection repetition is 50 Hz, it is necessary to simultaneously control three kinds of states of injection, extraction, and storage. However, since each

state is needed to occupy different bucket, different timing information is needed. Therefore, damping ring timing system has two timing receiver for injection control and extraction control.

TIMING CONTROL AT THE DAMPING RING

Overview

The timing signal is generated and controlled at SuperKEKB main timing station at injector linac [2, 3]. The timing is distributed to all over the SuperKEKB accelerator timing receiver with the fiber-optic cables. The DR timing system is its branch of the main timing system. Figure 1 is the picture of DR timing system. It is fabricated in one

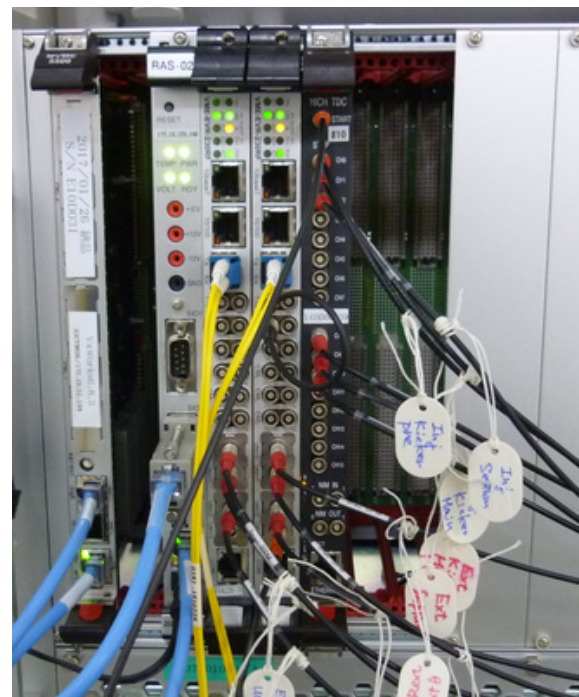


Figure 1: The picture of Damping Ring Timing System.

VME crate, and consists of a controller, a device monitor (RAS), two timing receivers and a time to digital converter (TDC). We use MVME5500 on-board CPU controller and VxWorks-6.8.3 is working on the board. The RAS monitors power voltage and temperature, and is controlled by serial port connection. As the timing receiver, we use Event Receiver (VME-EVR-230RF) developed by Micro Research Finland [4]. The TDC is originally developed to monitor the timing whether it is generating at an appropriate timing [5].

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All the generated timings are distributed to TDC and each device.

The timing system receives timing as a digitized 8-bit "event code" with fiber-optic cable, then generate the trigger when suitable event code is received. So, we call the system "event timing system". Application software is developed as EPICS device support [6].

Beam Gate Control

We integrated Beam Gate control system to event timing system by using "distributed bus bit" [7]. The distributed bus bit is one of the function of MRF event timing module and it can be transferred 8 types of bit information simultaneously. By using this function, we can change beam gate status faster than EPICS process and control each device independently. When the beam gate status is changed, the signal is input to Event Generator (EVG). The EVG sends it to EVRs at different timing for each device. EVR change trigger enable or disable status according to distributed bus bit status. This method made it possible to control injection only or extraction only mode. The greatest benefit was that the hardware can be done with no changes.

Pre-Trigger Generation

The kicker magnet of DR is needed to supply not only discharged trigger but also charged trigger, and charging time must be kept at 12 ms. In the operation of 2017, charged trigger for kicker magnet (we call it "pre-trigger") was not able to generate at EVG. Therefore, DR timing system is uniquely set delay timing by receiving appropriate pre-trigger timing as a "delay value" via data buffer. The data buffer function is already equipped in the MRF timing system. It is also used to send bucket number and shot number information and so on. The delay value for pre-trigger is sent before two shot of discharged trigger then set the value. This method could be kept fixed charged time in spite of fluctuated timing of bucket selection. The detail algorithm is described in [8].

Manual Extraction System

In the normal operation mode controlled by bucket selection algorithm, the extraction timing at DR is already calculated before its positron's injection timing. However, after unforeseen abort in the Main Ring happen, extraction cannot be controlled by the bucket selection algorithm. Same situation also happens after dispersion measurement there. To solve this situation, we developed manual extraction system.

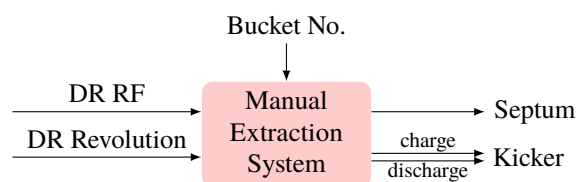


Figure 2: Schematic view of the manual extraction system.

Figure 2 shows schematic view of the manual extraction system. The system counts RF clock of the DR. The fre-

quency is 508.89 MHz which is the same frequency of the Main Ring. Furthermore, the system has input of revolution of the DR. It is the starting point of the bucket number-0. If the charging time is set, the pre-trigger is first issued. Then, after waiting charging time, the main trigger is generated. Since the main trigger timing has to depend on the stored positron bucket number, the system gives delay according to the number. When the extraction bucket number-N is set via epics process, the system counts N clocks from revolution timing, then generate trigger.

SYSTEM OPERATION IN SuperKEKB PHASE-2

SuperKEKB Phase-2 project was started operation from March 2018 and finished July 2018. Before the project, DR standalone operation has been done for a month. We tried to operate beam handling with this timing system. There was no major problem throughout. But to say a little bit, at the beginning of the operation, the charged trigger duration for kicker magnet was fluctuated and sometimes the magnet generates alarm information. This was because the timing calculation is initialized when the operation setting changed. At that time, wrong value of the delay timing was set at EVRs. To solve this problem, we changed output generation to disable mode during operation setting change.

SUMMARY AND OUTLOOK

We developed timing control system at Damping Ring. There are three characteristic control components, the first is we integrated beam gate control to event timing system with distributed bus bit. It became useful function by separating injection and extraction control. Since it became unnecessary additional cable connection, the hardware component became simple structure. Furthermore, beam gate control is able to operate more quickly than EPICS process.

The second is we constructed pre-trigger generation algorithm in the EVRs by using data buffer function of event timing system. The kicker magnet is need 12 ms to charge condenser with precise timing. So, pre-trigger is additionally generated at EVRs. The pre-trigger setting value is sent from EVG, and set delay in previous shot. The system could be kept fixed charging time for Kicker magnet.

The last is we developed manual extraction system. Extraction would be done in the bucket selection calculation in the normal. However, after some optics measurements or occurred irregular abort in Main Ring, manual extraction system manages trigger signal to deliver to each device by setting stored beam bucket number.

The DR operation was successfully finished with no serious event timing problems. Phase-3 project is scheduled to start in spring 2019 to attempt to update the world highest luminosity record and obtain new particle physics events by Belle2 experiment [9]. We will prepare to ensure more stable operation than phase-2 operation.

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