SYNCHRONIZED TIMING AND CONTROL SYSTEM CONSTRUCTION OF SUPERKEKB POSITRON DAMPING RING

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Abstract

A KEK electron/positron injector linac delivers beams for particle physics and photon science experiments. A damping ring has been constructed at the middle of the linac to generate a positron beam with sufficiently low emittance and to support 40 times higher luminosity in the SuperKEKB asymmetric collider than the previous project of KEKB. A timing and control system at the damping ring has been constructed to enable the timing synchronization and beam bucket selection among the linac, the positron damping ring and the SuperKEKB main ring. It should manage precise timing down to several picoseconds for the beam energy and bunch compression systems. Besides precise timing controls to inject and extract positron beams, it has to meet local analysis requirements owing to measure beam properties with changing RF frequency. The timing control system is constructed with MRF modules.

INTRODUCTION

SuperKEKB, electron/positron assynmetric collider, is being constructed for flavour physics experiment of elementary particles. It aims at a luminosity of 8×10^{35} cm^{-2}s^{-1}, 40 times higher than that of previous KEKB project by squeezing the beams at the collision point. To achive this luminosity, a Damping Ring(DR) was constructed for making lower emmitance positron beams. It is located at the middle of the injector Linac as shown in Fig.1. The main beam parameters are listed in Table1.

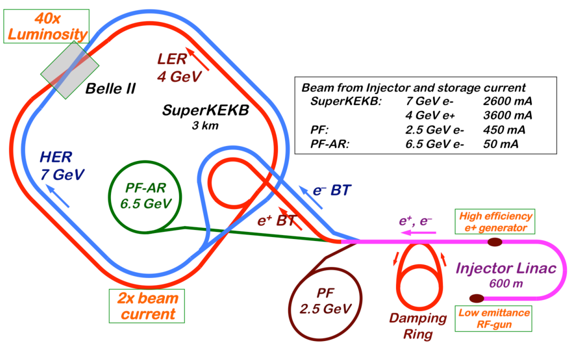

Figure 1: SuperKEKB Accelerator

The emmittance of positron beam is gone down to 92 μm at DR in the case of strage time of 40 ms. The DR can accumlate 2-pulses × 2-bunches, and need to keep more than 100 ns between pulses because of rising and falling time of Kicker magnets. Ideal bunch position is shown in Fig.2.

Table 1: Parameters of the Damping Ring

Parameters	Value	Unit
Energy	1.1	GeV
Repetition frequency	50	Hz
Length	135.5	m
RF frequency	508.9	MHz
Harmonic Number	230	
Number of bunches	2	
Bunch spacing	96	ns

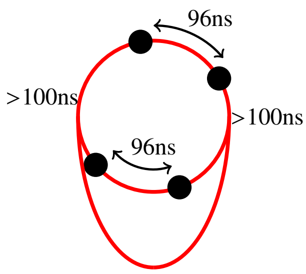

Figure 2: The storage configuration of 2-bunch, 2-pulse at Damping Ring

EVENT TIMING CONTROL SYSTEM

Overview

The control system of injector linac is required very complex system to operate such a several rings (SuperKEKB electron/positron ring and two light source rings) with several parameters. One of the important technologies is Pulse-to-Pulse Modulation (PPM). The PPM enables to inject simultaneously the top-up filling operation to four rings. To identify which ring will be injected, Event Timing Control system is introduced. This system delivers not only timing signal but also PPM information as an "Event" to beam line devices. We introduced event timing system produced by MRF [1] company to satisfy our requirement. MRF's event timing system consists of an "Event Generator (VME-EVG-230)" and an "Event Receiver (VME-EVR-230RF)". The protocol is based on 8B10B encoded characters. 2 byte of characters are transmitted to EVR on event clock cycle. The event clock cycle is used with 114.24 MHz RF frequency. The first encoded byte is an event code and the second encoded byte is shared by the distributed bus and synchronous

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data buffer. The system is worked on EPICS [2] IOC in the version of 3.14.12, and operated with the device/driver version of mrfioc2.

The event distribution system was constructed at Main Timing Station, Linac. It is a master brain of event and timing generation, and manages injection pattern and bucket selection system. A schematic diagram at Main Timing Station is shown in Fig.3.

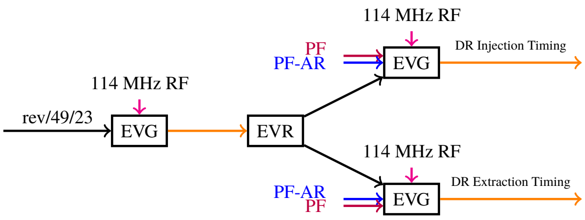


Figure 3: Event Timing System at Main Timing Station

Event timing system at Main Timing Station is configured with two-layer delivery. Upper EVG-EVR couples are functioned with the division of MR revolution which indicates original starting point of bucket number of DR and MR. Lower EVGs generate timings with bucket selection delay by using base timing information received from upper EVR. The EVGs generate it for injection or extraction timing for DR, respectively. In addition to DR timing, the EVGs manage the timing for two light sources, PF and PF-AR by putting into extra input. These timings are selected in an IOC according to injection pattern and send to each rings.

Bucket selection system

The bucket selection makes it possible to put the beam in which the RF buckets in the ring, that is different RF frequency between Linac (2856 MHz) and DR (508.9 MHz). The chance of injection or extraction timing turns up in 10.38 MHz (96 ns, 49 buckets duration) which value is calculated by common frequency between 2856 MHz and 508.9 MHz. The number of injection timing is 230 which is harmonic number of the Damping Ring. Furthermore, it becomes 5120×23 pattern timing including the harmonic number of the Main Ring. The bucket selection delay is calculated on IOC at Main Timing Station and is set on lower EVGs each 96 ns steps [3].

Sub Timing Station at DR

The event signal which is generated at Main Timing Station is delivered to Linac devices and sub Timing Station at DR and MR. The event timing system at sub Timing Station at MR is already reported [4] The sub Timing Station at DR is newly constructed to distribute timing signal to some devices in DR. The two event timings for injection and extraction are received at sub timing station at DR. One of the important timing is discharged trigger for extraction kicker magnets. It is sensitive to increase beam jitter. Therefore, it is required to jitter less than nanosecond. Besides precise timing, it has to meet local analysis requiments due to measure beam properties with changing RF frequency. The schematic diagram is shown in Fig.4.

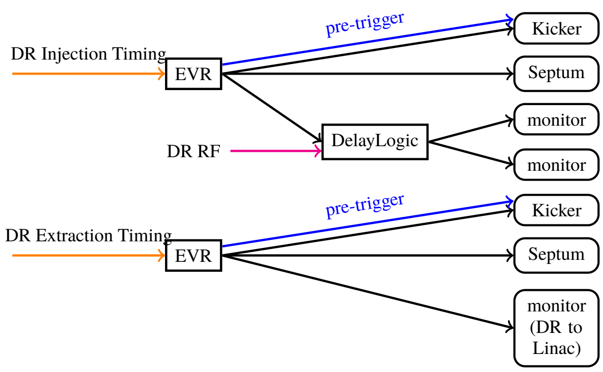
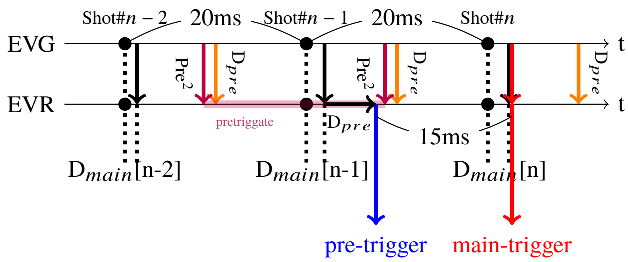


Figure 4: Event Timing System at DR

Pre-Trigger Algorithm

The kicker magnet is the most important devices to inject and extract positron beam among linac and rings. it is required to generate "charging start timing" 15 ms before injection or extraction timing (main trigger). We are calling "pre-trigger" as chaging start timing. Since it is difficult to generate pre-trigger timing from EVG due to out of generation sequence of 50 Hz repetition, the pre-trigger is originally made by EVRs at DR. The detailed pre-trigger generation logic is shown in Fig.5.

Figure 5: Pre-trigger generation logic



At first, the EVG generates "pre" and "pre-pre" timing to inform which event code will be send in the next and next-next sequence, respectively. The EVR makes pre-trigger generation gate with this "pre-pre" timing. When the EVR receives "pre-pre" timing for positron beam, it opens software gate for pre-trigger generation. Then, the gate closes at "pre-pre" timing for non-positron beam. This algorithm is able to avoid blank firing in the Kicker magnets. Next, the EVG sends data buffer including shotID, bucket selection delay, RF phase and so on. The EVR makes pre-trigger timing with data buffer information. If shot#n will be generate positron main timing, EVR has to receive the information of pre-trigger generation timing at shot#n-2. If we would like to make pre-trigger 15 ms before at shot#n, the generation timing (D_{pre}) could calculate in following formula:

$$D_{pre} = D_{main[n]} - D_{main[n-1]} + 5\ ms \qquad (1)$$

where $D_{main[n]}$ is the bucket selection delay value scheduled on the EVG. The value of D_{pre} is calculated on the EVG and send with data buffer. The EVR receive the delay and set it at shot#n-2 sequence. The pre-trigger generates at shot#n-1 sequence with the delay of D_{pre}. In this algorithm, we succeeded to make precise pre-trigger timing in EVR.

We also checked trigger jitter in timing system. According to MRF's original specification [1], timing jitter is 15 ps. However, the real operation includes RF jitter, cable jitter and so on. Therefore, we tested jitter including these devices. Figure 6 shows timing jitter of output trigger.

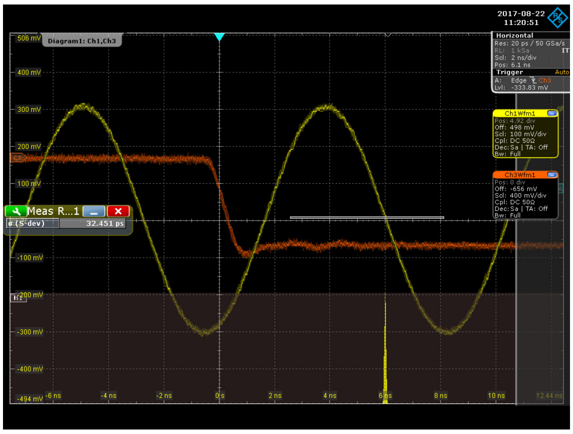


Figure 6: Timing precision of output trigger from EVR

The output trigger is synchronized with RF clock at DR. The jitter value was measured to be about 30 ps. The result was sufficiently small value and doesn't influence on beam jitter at Kicker magnet.

REFERENCES

[1] MRF website:
`http://www.mrf.fi/index.php/vme-products`

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http://www.aps.anl.gov/epics

[3] H. Kaji *et al.*, Bucket selection system for SuperKEKB, Proceedings of 12th Annual Meeting of PASJ, THP100.

[4] H. Kaji *et al.*, Injection control system for the SuperKEKB Phase-I operation, Proceedings of 13th Annual Meeting of PASJ, TUP092.