TIMING SYSTEM UPGRADE FOR TOP-UP INJECTION AT KEK LINAC

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Abstract

KEK 8-GeV Linac provides electrons and positrons to Photon Factory (PF) and B-Factory (KEKB). Because of the nature of those factory machines, both quantity and quality of the beams are required. In order to improve the injections, quasi top-up injections of electrons to PF and KEKB rings have been planned and a new beam transport line was built. Fast beam switching mechanisms are being developed and installed. The timing and control system is also reinforced to realize fast (50 Hz) switching of rf timing pulses, low-level rf, beam instrumentation parameters, and beam feedback parameters. The present timing system provides precise (jitters down to 3 ps) timing pulses to 150 devices. Many of the signals will be upgraded to enable the fast switching scheme with an event system. At the same time a double-fold synchronization between asynchronous Linac and PF rf signals was developed to achieve precise injection timing mainly because both rings have independent circumference correction systems.

INTRODUCTION

The Linac routinely injects electron and positron beams into KEKB-LER, KEKB-HER, PF and PF-AR rings with four different characteristics. It takes 30 seconds to 2 minutes to switch between beam modes, depending on which magnets have to be standardized. The interruption of physics experiments at a ring by the injection to another ring is not small. The interruption is especially large when a beam development study is carried.

Thus, the fast switching of the injections between KEKB and PF rings have been planned in order to enable quasi-simultaneous injections, and the modified beam line is being constructed [1]. The timing and event system is also upgraded to fulfill the fast switching requirement. The new system should provide the fast parameter switching, while the timing precision should be kept to achieve the machine stabilities.

TIMING/EVENT DISTRIBUTION

Among 150 devices which require timing signals, some requires precise timing better than 5 pico seconds. At the same time devices have to know the beam mode or the event in order to operate with a corresponding parameters.

Present System

In the present system the timing and the event distributions are separated. A timing signal and rf signal are overlaid and distributed over a coaxial cable. 15 stations receive the overlaid signal and reproduce the timing and rf signals. The system provide us a good timing stability of 3 pico seconds (RMS) even with variable delay synchronized to the rf signal [2].

The event is sent with hard wires and with software messages over control networks. The fast event notifies information such as the pulse that has a beam or the beam with which instrumentations measure the quality. Only four gate signals are transferred for this purpose, which was enough for the normal operation. The event gate signals are sent over four twisted wire cables.

Slower event information is sent with the control system. Such information includes parameters of rf, optics, timing and instrumentations, which add up to a thousand. Presently the slow event or the beam mode switch typically occurs every four minutes.

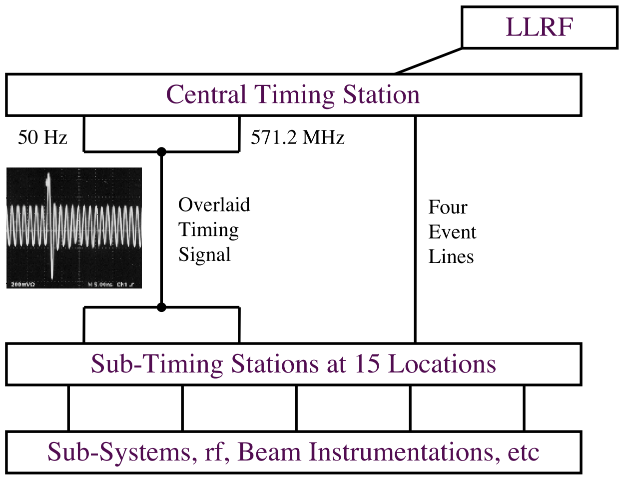

Figure 1: About 150 timing signals are provided through 15 timing stations.

New System

For the fast beam mode switch we have to change many parameters synchronizing to an event. Thus, we decided to employ the event timing system which was developed for the Diamond light source [3, 4]. In the event system an event generator send a stream of multiplexed signal and event receivers regenerate the signals locally. And it greatly simplifies the architecture as it distributes events, rf clock, time stamps and data buffer over a single optical fiber.

As the maintenance of the present signal transmitter and receivers requires careful tuning of the signal levels, the introduction of the event system is expected to be beneficial.

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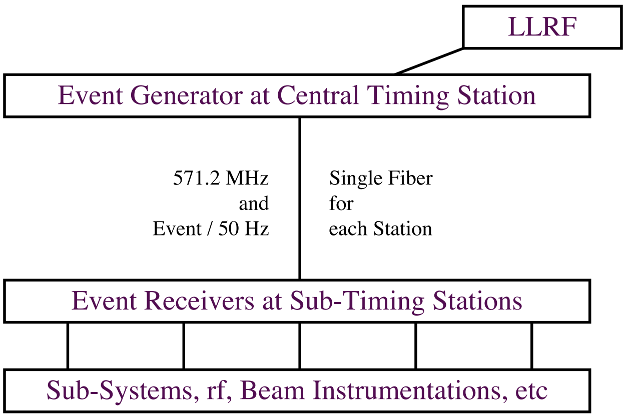

Figure 2: Event generator and receivers simplify the system, and they enable the fast switching of timing, digital and analog signals.

Although we need more experiences for the timing precision and jitter of the system, it will be sufficient for the most of the signals. Only a few signals require a jitter of 3 ps, where we'll keep the present system for a while.

At the beginning, 6 sub-timing stations are replaced with event receivers, since those locations require fast switching of analog and timing signals.

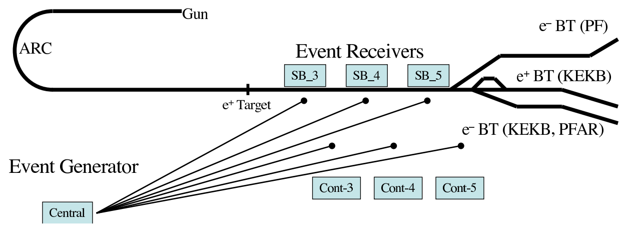

Figure 3: Six event receivers are installed at first, replacing old timing receivers.

PARAMETER SWITCHING

Digital, analog and timing values of equipment parameters are switched directly by an event or indirectly by software that is triggered by the event. Following parameters are included.

- Pulsed bending magnet
- High-power rf active / stand-by selections
- Low-level rf parameters
- Beam-position-monitor read-out modes
- rf measurement parameters
- Wire scanner modes

We need to operate on the machine that changes the property quickly. This means that several virtual machines need to be manipulated at the same time. Thus, following functionalities should be provided.

- Parameter manipulation / display for each mode
- Mode dependent archiving
- Beam energy / orbit feedback systems

The present system needs about 30 seconds to 2 minutes in order to switch between beam modes depending on the magnets to be standardized. Gradually it will be reduced down to 20 milliseconds increasing the responsibility of the event system.

TIMING RF SYNCHRONIZATION

The stable operation of the beam is achieved by the good synchronization between rf signals of Linac and rings.

Linac-KEKB Synchronization

The injection system of the KEKB allows only 30-ps jitter of the injection beam against the ring rf. Thus, the master rf system was designed with an integer relation between 4 rf signals [5]. Then a delay is added from common trigger timing in order to select a bucket in the ring [6].

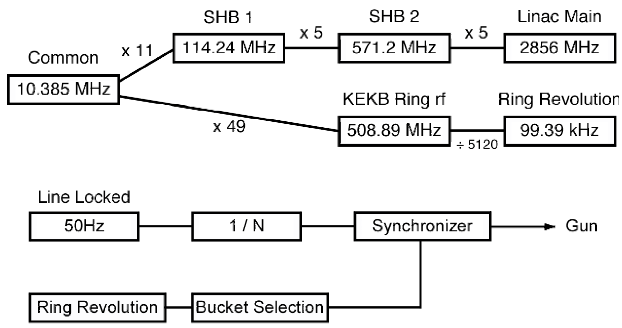

Figure 4: Four rf clocks are generated from a common master clock. The bucket selection system adds an appropriate delay for the injection.

New Linac-PF Synchronization

The rf clocks of Linac and PF-ring are independently designed and an asynchronously generated multi-bunch beam is injected into an rf bucket of the ring. For the top-up injection to PF-ring, however, requires higher stability of the beam quality and lower energy spread. The compatible beam optics between KEKB and PF injections also requires a further stability. To this end a single-bunch beam should be accelerated even for PF-ring injection, and the jitter between the beam and the rf bucket is required to be less than 700 ps.

A new synchronization module was designed to satisfy the jitter tolerance. While the design employs the same idea as the system which was used in the previous project [7], the advance of the fast circuit enables the simpler design as in Fig. 5. This scheme provides the jitter down to 300 ps and it is adjustable.

The injection tests have been carried several times. The beam quality, the resultant injection efficiency and the beam-loss radiation in the beam-transport line were all satisfactory.

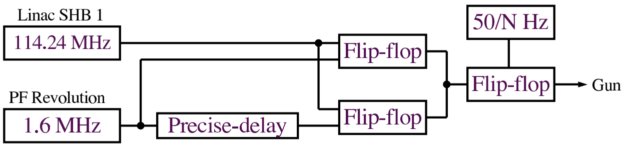

Figure 5: Double synchronization of rf clocks between Linac and PF-ring.

The above synchronization technique depends on the accidental coincidence of the clocks. If two rf clocks have an integer relation, no synchronous signal is achieved. Since the both KEKB-ring and the PF-ring have circumference correction systems by rf-frequency adjustment, such accidental synchronization has a risk. Actually, far integer relationship exists about 20-ppm away from the nominal frequencies.

Practically, the rate of the synchronous signal is determined by the jitters of related signals, and the both frequencies vary to the same direction under normal circumstances. The synchronous signal is used to generate the 50-Hz pulse for Linac, and the pulse timing homogeneity have to be better than 3 milliseconds in order to keep the stability of the high-power rf modulators. Thus, the frequencies are monitored so that they keep away from the integer relation.

BEAM PULSE SELECTION

After the fast beam mode switching is accomplished, the event system will be programmed to provide a beam pulse to one of PF and KEKB rings. Because power supplies of septums and kickers require that the pulse interval should be constant at the moment, the beam pulse selection is restricted. Currently following three schemes are planned, depending on how the rings request the beam. After the power supplies are tuned, unrestricted beam pulse selection will be enabled.

Mostly KEKB

KEKB	PF-Ring
50 Hz	0 Hz
50-1 Hz	1 Hz
50-2 Hz	2 Hz
50-4 Hz	4 Hz
50-5 Hz	5 Hz
...	...

25Hz Allocated

KEKB	PF-Ring
50/2 Hz	50/2 Hz
50/4 Hz	50/4 Hz
50/6 Hz	50/6 Hz
50/8 Hz	50/8 Hz
50/10 Hz	50/10 Hz
...	...

10Hz Allocated

KEKB	PF-Ring
50/5 Hz	50/5 Hz
50/10 Hz	50/10 Hz
50/20 Hz	50/20 Hz
50/25 Hz	50/25 Hz
50/50 Hz	50/50 Hz
...	...

Figure 6: Three basic beam-pulse delivery schemes. This is interim until the kicker/septum power supplies would be improved.

SUMMARY

The new timing synchronization between Linac and PF-ring satisfies the injection timing criteria. This is important to make a stable injection into PF-ring. The fast beam switching system is being installed employing a new timing/event system, which will cover many of timing and other parameters directly and indirectly. The event system is expected to simplify the timing and control system much. The overall system will be tested in the next spring, and is hoped to provide faster switching step by step.

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