Synchronized Timing and Control System Construction of SuperKEKB Positron Damping Ring

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KEK

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SuperKEKB Project

- $e^+ - e^-$ collider, B-Factory
- Aim at 40-times higher Luminosity than previous KEKB project
  - $2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1} (\text{KEKB}) \rightarrow 8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1} (\text{SuperKEKB})$
- Twice larger storage beam $\rightarrow$ Higher beam current at Linac
- 20-times higher collision rate with nano-beam scheme
Damping Ring (DR)

- Emittance become down to 1/500 during damping time.
- 40 ms damping while linac operate at 50 Hz
- Accomodate 2-bunches × 2-pulses
- 2-bunches in a pulse are separated by 96.3 ns (10.385 MHz)
- Injection/extraction kickers rise/fall times are ~ 100 ns

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy</td>
<td>1.1 GeV</td>
</tr>
<tr>
<td>Repetition frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Length</td>
<td>135.5 m</td>
</tr>
<tr>
<td>RF frequency</td>
<td>508.9 MHz</td>
</tr>
<tr>
<td>Harmonic Number</td>
<td>230</td>
</tr>
<tr>
<td>Number of bunches</td>
<td>2</td>
</tr>
<tr>
<td>Bunch spacing</td>
<td>96 ns</td>
</tr>
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Event Timing System for Simultaneous Top-up Injection

- Fast, global and synchronous controls
  - synchronized with 114 MHz RF clock and 16 bit/clock event/data transfer
- MRF’s series Event Generator and Receivers
  - VME-EVG-230 / VME-EVR-230-RF / PXI-EVR-300
- System communicate VME64x and PCIe (VxWorks v6.8 and Windows)
- EPICS R3.14.12 with mrfioc2 (device support)
Two timings (injection and extraction at DR) are needed.

- Common frequency between 2856 MHz and 508.9 MHz is 10.38 MHz (96 ns, 49 buckets duration)
  - Chance of injection timing turns up once per 96 ns (49 buckets).
- Need to consider bucket select combination each DR and MR buckets.
- The number of combination is $5120 \times 23$ (least common multiple of DR and MR).
Master Timing System

Master Timing System consists of 1-upper EVG, 1-upper EVR and 2-lower EVGs in 1-IOC. It delivers dozens kinds of timing (BPM, Kicker, Septum ...).

Upper EVG calculates which bucket is injected/extracted (bucket selection). Lower each EVGs delay timing according to bucket-ID.

LINAC 2856 MHz
DR(230Bkt) 508.9 MHz
LINAC 2856 MHz
MR(5120Bkt) 508.9 MHz
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Kicker Timing

- Injection/extraction (especially extraction) kicker timing is most important to have effect of beam jitter.
- Injection/extraction kicker need charging trigger \(\sim 15 \text{ ms} \) before firing. We call “pre-trigger”.

Pulse trains should be provided for BPM

- at revolution frequency (508.9 MHz/230)
- synchronized to one of the beam bunches in DR

Dispersion measurement

- 508.9 MHz ± 50 kHz
- should be disconnected from other clocks
Injection and extraction timing event is sent to each EVRs. EVR for injection and extraction timing distribute main timing and pre-trigger timing. The pre-trigger timing is originally generated EVR itself. For dispersion measurement, valuable delay logic is added.
Pre-trigger Timing

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Event stream from EVG to EVR

Event is sent from EVG to EVR every 20 ms. Suppose to think about DR injection timing at Shot\#n.

![Diagram showing Event stream from EVG to EVR]

- Event stream from EVG to EVR every 20 ms.
- Suppose to think about DR injection timing at Shot\#n.

**Diagram Notes:**
- EVG to EVR every 20 ms.
- Timing considerations for Shot\#n.
MR timing is sent after bucket selection delay \( D_{\text{main}} \). \( D_{\text{main}} \) would change shot by shot due to bucket selection.

\[
\begin{array}{c}
\text{EVG} \\
\bullet \\
\text{EVR} \\
\bullet \\
\bullet \\
\end{array} \\
\begin{array}{c}
D_{\text{main}}[n-2] \\
\text{Shot}\#n-2 \\
20\text{ms} \\
\text{Shot}\#n-1 \\
\text{Shot}\#n \\
D_{\text{main}}[n-1] \\
D_{\text{main}}[n] \\
20\text{ms} \\
\end{array}
\]

MR Timing
Delay time for pre-trigger ($D_{pre}$) is received by using “Data Buffer” before Shot #n-1. Then, set $D_{pre}$.

Event stream from EVG to EVR
Pre-trigger timing is generated from MR timing. Main trigger timing is generated from Linac timing with no delay.

The delay time ($D_{pre}$) from MR timing is calculated as eq(1).

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

In this system, timing jitter is measured with 30 ps jitter.
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Summary

- SuperKEKB project aims at 40 times higher luminosity than previous KEKB project
- Operation of damping ring will be started in this FY
- Injector linac, damping ring, EPICS control system, event-based synchronous system are being constructed
- Pre-trigger system was constructed with 30 ps timing jitter
- Long stability test will be started soon.