New Event Timing System for Damping Ring at SuperKEKB

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SuperKEKB and KEK

SuperKEKB
Accelerators, the electron-positron collider
One of the most important projects at KEK
Operation will start in the early 2016
Target luminosity is $8 \times 10^{35} \text{ cm}^{-2}\text{s}^{-1}$. ← world record

Today, we focus on the timing system for newly constructed Damping Ring.
**Event Timing System** is utilized for delivering triggers to injector. Also works for **Pulse-to-Pulse Modulation** of operation parameters at LINAC to provide beam-pulses with different particle/energy/charge.
Sub-timing Station at Damping Ring

Damping Ring (DR) needs two kinds of triggers:
- Injection/extraction Triggers ⇒ Events from Main Timing Station
- Triggers for beam monitors ⇒ New Modules triggered by DR revolution

**LINAC**

Main Timing Station
- Lower-layer
  - EVG for 1st half of LINAC
  - EVG for 2nd half of LINAC

Sub-timing Station
- EVR
  - Injection Devices
  - Extraction Devices
- EVO
  - DR rev.

**Damping Ring**

**Local IOCs**
- EVE TTB
- EVE TTB
- EVE TTB
- EVE TTB
- BPMs
VME-EVO works as EVG, EVR, or fanout modules — *It depends on the setting.*

Based on
FPGA Xilinx vertex-6

Input:
TTL or Up-link Event

Output:
8 Ports for Event output

Event clock:
60-135 MHz

Originally developed for proton therapy machine at SINAP. We customized it for SuperKEKB.

We do not need fanout module.
VME-EVO(EVG) can choose different Event clock from that of up-link module. even though it operates with the triggers from up-link.
It can be connected with VME-EVG-230 (up-link) and VME-EVR-230RF (8outputs).
VME-EVE and VME-TTB

They work as EVR and its expansion modules.
We customized also them for SuperKEKB.

**VME-EVE:**
- 8 TTL outputs
- Two kinds of delays
  1. Event clock delay
  2. 20 time fine delay (based on GTX)

**VME-TTB:**
- Expansion board for VME-EVE
- 16 TTL outputs
- Two kinds of delays
  1. Event clock delay
  2. 20 time fine delay (based on GTX)

Totally 24 outputs, they can be enable/disable and delayed independently. Note, we are developing also module with NIM outputs. Its up-link can be connected with VME-EVG-230.
Trigger Requirements for 84 BPMs at DR

There are 84 BPMs at DR.

⇒ We prepare 4 IOCs of “VME-EVE and VME-TTB” and individual IOCs manage triggers for 21 BPMs.

Triggers should be coincided with the storage bunches.

⇒ Put RF clock of 508.89MHz for RF cavity into RF-IN
⇒ Put DR revolution into AC-IN

Delay values for triggers are determined from two kinds of timing adjustments.
- Adjustment for compensating the difference in BPM positions
- Adjustment to the timing to storage bunches
Delay Setting for BPM Triggers

### Module Settings

<table>
<thead>
<tr>
<th>Module</th>
<th>Type</th>
<th>Precision</th>
<th>For beam-pulse timing, changed in 50Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>VME-EVO</td>
<td>Scheduled on sequence RAM</td>
<td>127.2225 MHz, 7.8ns step</td>
<td></td>
</tr>
<tr>
<td>VME-EVE (or VME-TTB)</td>
<td>Event clock delay</td>
<td>127.2225 MHz, 7.8ns step</td>
<td>For BPM position, static</td>
</tr>
<tr>
<td>VME-EVE (or VME-TTB)</td>
<td>Fine delay based on the GTX technology</td>
<td>2544 MHz (127.2225 x20)</td>
<td>For beam-pulse timing, changed in 50Hz</td>
</tr>
</tbody>
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### Timing Adjustment for BPM Positions

- Different for the individual BPMs
- Set them on the Event clock delay of individual output channels on VME-EVE and VME-TTB

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### Adjustment to fit the timing to storage bunches

- Common for all BPMs
- Scheduled on the sequence RAM of VME-EVO, however 4 times precise setting is mandatory
- Use find delay functions of VME-EVE outputs to satisfy required precision

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### Diagram

- DR revolution → EVO
- Event Clock: 127.2225 MHz
- Event → EVE
- TTB
- BPMs

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### Notes

508.9 MHz

Event Clock: 127.2225 MHz
Timing Accuracy of New Modules

VME-EVE: CH1
(all other channels show same size of jitter.)

14.16ps

VME-TTB: CH0
(all other channels show same size of jitter.)

11.79ps

Note, same study performed at SINAP shows jitters of ~6ps and ~8ps for VME-EVE and VME-TTB, respectively.
Summary

We utilize the Event Timing System for operating our injector.
- not only for delivery of triggers but frequent switching of parameters.

We develop Sub-timing Station at DR with three Event modules.
- injection/extraction timing for septum magnets
  synchronized with injector
- triggers for beam monitors which are synchronized with DR revolution

New Event modules are developed (work done by SINAP and KEK).
- The triggers for 84 BPMs can be managed with only 5 Event modules.
- Complicated timing adjustment can be realized with VME-EVO and VME-EVE
- They are compatible with MRF modules.

Timing accuracy of triggers from VME-EVE and VME-TTB are
determined to be ~15ps and ~12ps, respectively.
⇒ They are well satisfies requirements from our BPMs
Damping Ring

Sub-timing Station

EVR

EVR

EVO

Injection Devices

Extraction Devices

Local IOCs

EVE

TTB

EVE

TTB

EVE

TTB

BPMs

BPMs

BPMs

BPMs