The Fault Diagnosis of Event Timing System in SuperKEKB

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KEK
Outline

- Event Timing System in SuperKEKB
- Event Fault Diagnosis System
  - Data Acquisition
  - Data Processing
- Fault Diagnosis
  - Beam Mode Replacement
  - Redundant Beam Mode
- Conclusion and Outlook
Event Timing System in SKEKB
Event Timing System in SKEKB

Basic structure of Event Timing System

Event Generator
- RF clock reference
- Mains voltage reference

Event Receiver
- Kicker
- Septum
- Pulsed Magnet

Event code

Software Sequencer
- Trigger Source
  - 0: Event delay 0xAA
  - 1: Event delay 0xBB
  - 2: Event delay 0xCC
  - ... 
  - 2047: Event delay 0xEE

Hardware Sequencer

RAM address
- 32 bits timestamp
- 8 bits code

EPICS Channel Access
- OPI
- IOC EVG
- IOC EVR
- IOC EVR
- IOC EVR

MRF Event Link
Event Timing System in SKEKB

- Simultaneous injection to 4 rings!
- High precision: jitter less than 30 ps for MR, 300/700 ps for PF/PF-AR!
- Every pulse synchronized with 50 Hz AC power supply!

- MRF’s series Event Generator and Receivers
  - VME-EVG-230: 4
  - VME-EVR-230-RF: 50
  - PXI-EVR-300: 20
- 50 Hz beam mode repetition rate
- 114.24 MHz event rate
- **12** kinds of beam mode
- About 120 event codes are defined
- 11 or 12 events every pulse
- EPICS R3.14.12 with mrfioc2 (device support)
Event Timing System in SKEKB

- 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).
- Requiring two bucket selection timings (injection and extraction at DR, two EVGs are needed)
- The number of combination is $5120 \times 23$ (least common multiple of DR and MR)
- Can not coincide with AC50 every pulse

16/18 sequences injection, details are talked in

H. Kaji et al. “BUCKET SELECTION SYSTEM FOR SuperKEKB”, PASJ 2015 THP100

H. Kaji et al. “INSTALLATION AND COMMISSIONING OF NEW EVENT TIMING SYSTEM FOR SuperKEKB”, PASJ 2015 FROL15
Event Timing System in SKEKB

- *Pre event is necessary because of the kicker charging time*

![Diagram of Event Timing System]

- AC Power
  - 50 Hz generator
  - NIM
- EVG
- EVR
- TDC
- Software Sequencer
- Hardware Sequencer

**KEKB rev/49/23/2**
- Set EVG
- Current beam mode event
- Next beam mode event (pre event*)

**Upper-EVG 16/18 sequence**
- 20 ms
- AC50
- PF Trigger (PF-AR)
- BS delay
- Real beam trigger time

- Pre event is necessary because of the kicker charging time

- Software Sequencer
- Hardware Sequencer

- C, pre A
- A, pre B
- B, pre C
- C, pre A
- A, pre B
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Data Acquisition

- Requirements:
  - Event code and nanosecond-level timestamp is needed
  - Two EVRs in one VME to monitor two lower-EVGs.

- Obstacles using Channel Access
  - **Some data lost** due to high CPU usage
  - EPICS period Scan task delay in VxWorks IOC is very high

- New approach Implementation:
  - An EPICS thread with a large size ring buffer is created
  - Fetch data and timestamp from EVR FIFO memory
  - Transmit to NFS server using binary format

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<thead>
<tr>
<th>CA Client</th>
<th>CA Server</th>
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<tbody>
<tr>
<td>Modified Waveform Record</td>
<td></td>
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<tr>
<td>Mrfioc2 Device Support</td>
<td></td>
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<tr>
<td>EVR</td>
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<table>
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<tr>
<th>CA Client (Python, Java)</th>
<th>Hard Disk</th>
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Data Processing

- Using Python script check beam mode interval and event code
- Abnormal data is extracted
- Results are sent by email
- All actions automatically run every day

Optional, manually check detailed data
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Fault Diagnosis

Excerpt of the abnormal

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<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
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<th>N</th>
<th>O</th>
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<tbody>
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<td></td>
<td></td>
<td>pre pulse</td>
<td>pre kly timestamp</td>
<td>Interval (ms)</td>
<td>current pulse</td>
<td>current kly timestamp</td>
<td>Interval (ms)</td>
<td>next pulse</td>
<td>next kly timestamp</td>
<td>time</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>42</td>
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<td>30 930272424.558212675</td>
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<td>30 930272425.501544336</td>
<td></td>
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Beam mode repeat

Abnormal PF beam mode interval
Beam Mode Replacement

- AC50 comes very late
  - AC power fluctuation
  - Alternating during 16/18 sequences injection
- Bucket Selection delay increases
- ‘Set EVG’ signal comes late than pre event
- Current beam mode is replaced by the next beam mode
- Happened 15 times during 2-weeks operation in June
Redundant Beam Mode

- Abnormal value of the calculation of bucket selection of positron in DR and MR
- A positron beam mode comes about 5 ms earlier than normal
- Sequencer trigger source changed
- PF Trigger signal is later than ‘Set EVG’
- Happened 10 times during 2-weeks operation in June
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• Solution of beam mode replacement:
  • Upgrade the 50 Hz generator module
  • Decrease reference interval of AC50 (Already done)

• Solution of redundant beam mode:
  • Temporarily separate the positron beam mode and PF mode
  • Figure out the reason of abnormal bucket selection delay

• Much more data required to diagnose the bucket selection program

• Near future: On-line alarm system

• Furthermost, a fault prediction system based on time series forecasting models or deep learning
Thank You

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