LCLS-I/LCLS-II Machine Protection System Overview

Matt Boyes - LCLS Machine Protection Team
SLAC National Accelerator Laboratory
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LCLS Overview and General MPS Requirements

Linac Coherent Light Source– (LCLS-I)

• Pulsed X-ray FEL
• Uses last 1/3rd of Linac + new injector, new e- transport line, Undulator and X-ray beam line
• 120Hz maximum rate

General Machine Protection System (MPS) Requirement

- Protect machine components from damage caused by beam within one pulse at 120Hz, by shutting off beam or reducing beam rate.
  • respond within 8.3ms LCLS MPS, actually responds within 2.78ms
LCLS-I MPS Schematic View

MPS Sensors:
- Vacuum Valve Position
- Waterflow Status
- Magnet Power Supply Status
- Temperatures
- In-beam Diagnostics Status
- Beam Position
- Beam Charge
- RF System Status
- Beam Containment Status
- Beam Loss Monitors

MPS Mitigation Devices:
- Laser Heater Mechanical Shutter
- Photocathode Laser Mechanical Shutter
- Gun Trigger Permit
- Pre-Uundulator Fast Kicker (ByKIK)

Injector | Linac | Beam Switchyard | Linac To Undulator (LTU) | Undulator

~1.5Km
System Description – Hardware

- A star network consisting of two entities: Link Processor and 33 Link-Nodes
- Interconnected over private MPS GigbE Network

MPS Link Processor

MPS Link Node
Link-Node Architecture

• 3u chassis with configurable board arrangement
  - Main motherboard with arrangement of other boards

• Contains:
  - MPS “Engine” in Virtex-4 FPGA
  - MPS Digital I/O, up to 96 inputs
  - Embedded Coldfire Arcturus uC5282 CPU for an EPICS IOC but has no safety function
  - Industry Pack (IP) bus interface
  - GigE Interface (FPGA core)
  - USB 1.0 Interface (dev & maintenance)

• Configured in different “flavors”:
  - Standard (MPS Digital I/O Only)
  - BLM (Undulator Beam Loss Monitor)
  - PIC (Beam Loss Ion Chamber)
  - ByKIK (Fast Kicker Magnet)
System Description – MPS Architecture

- **MPS Configuration Editor**
  - MPS Configuration RDB and files
- **MPS Logic Editor**
  - MPS Logic RDB and files
- **MPS Link Processor**
  - Timing data
  - Compile time & runtime files
  - Dedicated GbE over Cat5
- **GbE Switches**
  - Dedicated GbE over Fiber
  - GbE over Cat5
- **MPS Link Node**
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- **MPS Link Node**
  - Analog & digital I/O
  - Device
  - Mitigation Device (Gun Permit)
  - GTM
  - Mitigation Device (Lsr Htr Shutter)
  - Mitigation Device (Mech. Shutter)
- **MPS History GUI**
  - Java, on linux server
- **MPS History Server**
  - Java, on linux server
  - MPS History RDB
- **Interlocks & MPS (iMPS)**
  - 100BASE-TX
  - LCLS CA Network
- **LCLS CA Network**
  - Soft Input
  - Soft Input
  - Soft Input
System Description – Software

MPS Link Processor IOC
- Gathers device status from Link Nodes.
- Determines maximum allowed beam rate at each mitigation device.
- Broadcasts “Permit” message to Link Nodes.
- Handles fault bypassing, latching.
- Logs machine state changes with MPS history servers.
- Can load/unload MPS logic at run-time.

Interlocks MPS Processor IOC
- Supplement VME IOC
- Handles many MPS Soft EPICS Inputs

MPS Link Node IOCs
- Interfaces to on Board FPGAs
- Configuration, Control of MPS loss monitor devices
Link Processor Input and Logic Algorithm

- As Of Oct 2012 LCLS-I MPS handles
  - 2500+ Inputs
  - 670+ Logic Tables
    - 52,000 lines of source code just for the logic algorithm all of which is dynamically created
  - Logic and Input Configuration information stored in a system configuration relational databases
  - Expert Tools developed to interface with Input Configuration Database and Logic Database
Input Configuration

• **Configuration file exported to .db, .edl, .stt, .h, .tex, and .csv using Python module during make**

  - **.csv**
    – LN and LP boot time configuration
  - **.db**
    – LP EPICS records (five records per input)
  - **mpsEpicsFaultInputs.stt**
    – LP state notation used at compile time – monitors EPICS fault inputs
  - **MPSFaultNumbers.h**
    – LP and MPS Logic compile time configuration
  - **.edl**
    – EDM displays for users
  - **.tex, .pdf**
    – LaTeX documentation converted to PDF
  - **mpsdb.sqlite3**
    – Copy of configuration file for MPS GUI
  - **MPSDatabase.sql, pvlist.txt** – Dumped configuration file
    – List of records in .db files
Logic Configuration

- **Logic file exported to** `.h`, `.tex`, `.txt`, `.pdf` and `.csv` using Python module during `make`

  - **Algorithm.h**
    - Loadable and unloaded from LP at run time – Built against a specific MPS Input configuration
    - Logic Table Definitions
    - Can contain C specific logic for more complex logic

  - ***.pdf, *.txt**
    - Logic documentation

28.4 HXRSS State

The following code assigns the truth table’s state number to the variable `state`.

```c
state = 0 : (128 Hz) burn allowed, HXRSS on
state = 1 : full rate (128 Hz) burn allowed, HXRSS off
state = 2 : full rate (128 Hz) burn allowed, HXRSS SAFE (aka phase shiftless mode)
state = 3 : no burn allowed, undefined state
```

- Initialize to a good value
- `state = (assigned state) - 1`

```c
if (state == 0)
    // HXRSS on, the raft is in...
else if (state == 1)
    // HXRSS off, the raft is...
else if (state == 2)
    // HXRSS SAFE mode, the raft is...
else
    // Otherwise, do not allow burn.
```

- Ignored when A-line B1/3 is Not On AND A-line Kicker Is Not Enabled, A-line SL10 is Closed, B31/B32 is Off, B15 Is On, TD1 is In, or VG B2/4 Is In.
LCLS-I MPS GUI

Main MPS Fault User Interface

Some logic is being masked because A-Line B1/B2 is Not On AND A-Line Kicker is Not Enabled, A-Line SL10 is Closed, BX01/BX02 is On, BXG is Off, M3H Mirror is Out of Beam, Stopper HFF-MPA-02 is 

Summary State History

Currently showing states 1 of 1
12/17 21:00:37

Bypassed Faults

Exp Date  Truth Table  Current State
12/09 11:38:00  Flowswitch BSV RAD LCW Slit 10/30  Off

Summary / Faults / Logic / Ignore Logic / History /
MPS Gui Summary of Input Status and Logic Table

States

Filter

Area  | LTU1
Card  | 30
Channel | 26
Link Node ID | 39
Description | PIV::LTU1:712:PDL,H

Auto recoverable: No  Desirable: No

OK State Name | E_OK
Faulted State Name | E_SYS_BUSY

Position X | 0
Position Y | 0
Position Z | 0

Current State: ●

View Logic

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Summary/ Faults / Logic / Ignore Logic / History/

---

Where:

Current PV

Latched PV

Bypass Act PV

Bypass Vol PV

---

Summary/ Faults / Logic / Ignore Logic / History/

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MPS History

- Independent MPS Logging System
- Logs MPS events such as Faults and Rate Changes
- MPS Messages are also forward to the our standard EPICS Message Logging System
- No Message Throttling
- Messages stored in Oracle
LCLS-I MPS Improvements and Challenges

• Improvements
  - Automated Rate Recovery
  - Enhancing Expert User Tools and MPS GUI
  - Undulator Beam Loss Monitor beam synchronous acquisition

• Challenges
  - System is large and complex
  - requires a team to support and maintain
  - Link Node Embedded Coldfire Arcturus CPU is under powered and is easily overwhelmed
LCLS-II Injector construction has just started
LCLS-II System MPS Overview

Link Nodes

<table>
<thead>
<tr>
<th>Injector</th>
<th>Sector 10</th>
<th>Sector 20</th>
<th>Sector 25</th>
<th>Sector 30</th>
<th>Bldg 136</th>
<th>Bldg 911</th>
<th>Bldg 912</th>
<th>Bldg 921</th>
<th>EH2</th>
</tr>
</thead>
</table>

Link Nodes

- M – Mitigation
- P – PIC
- B – BLM
- BY - BYKIK

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LCLS II Specific MPS Enchantments

- The LCLS MPS Architecture will be duplicated for LCLS-II and will incorporate some additional improvements
  - LCLS-I and LCLS-II should not interfere with each other
    - Determine which machine was the source of beam losses
  - 2 Undulator beam lines each sharing the Linac rate
    - Separate Undulator Rate Control
    - Exploring alternatives to Protection Ion Chambers and Beam Loss Monitors such as Beam Loss Fibers
  - Exploring Link Node inputs enhancement to support temperature monitoring and General Purpose Analog Inputs
Thank You