ALS Top-Off Mode Beam Interlock System

Kenneth Baptiste

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Contributors: EI Staff, EM Staff, C. Timossi, H. Mahic.

Lawrence Berkeley National Laboratory

Outline

- **Introduce Top-Off Beam Mode**
  - Why are Interlocks Needed?
  - System Requirements
  - System Specifications
  - Design Principles
- **System Overview**
  - Injection Mode Control & Beam Line Radiation Interlocks
  - Extraction Trigger Inhibit (ETI)
  - Energy Match Intrlk (EMI) & Lattice Match Intrlk (LMI)
  - Stored Beam Intrlk (SBI)
  - Programmable Logic Controller (PLC) roles
- **Commissioning & Testing**
  - Configuration Control
  - Testing
- **System Operation**
  - Timeline & Recent History
- **Conclusion**

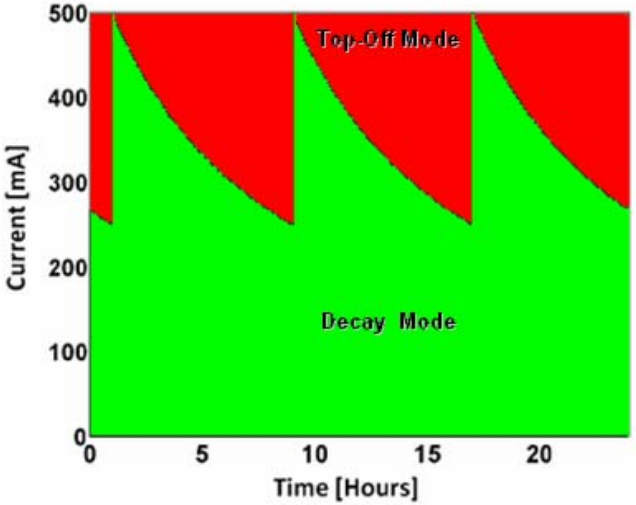
Top-Off Beam Mode

Decay Mode:

Refills every ~8 hrs with Safety Shutters closed, ID gaps open

Top-Off Mode:

Refills every ~30 sec with Safety Shutters open, ID gaps nominal



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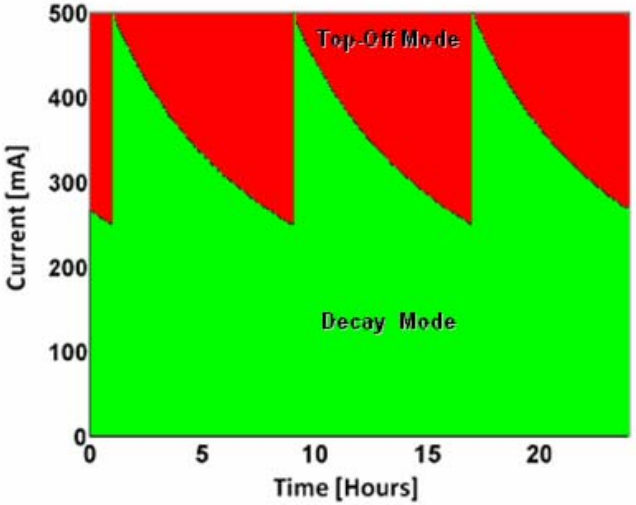

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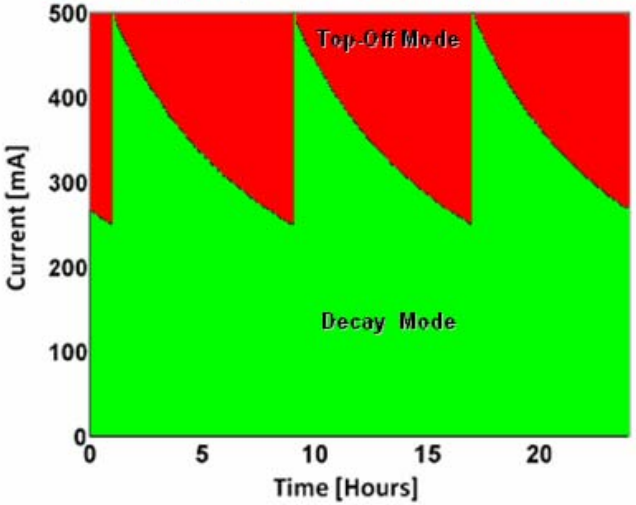

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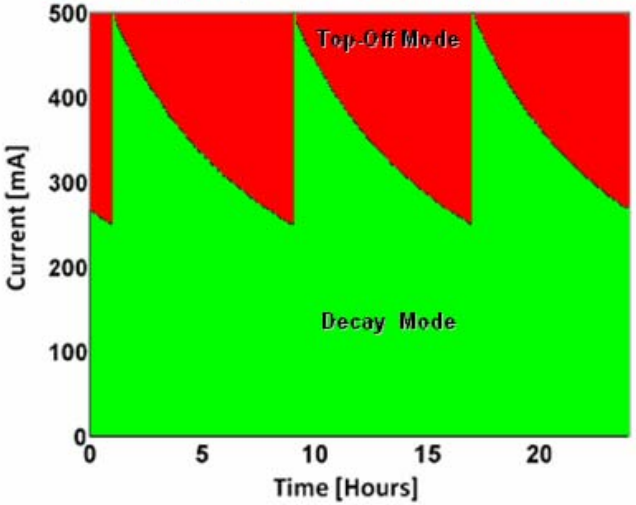

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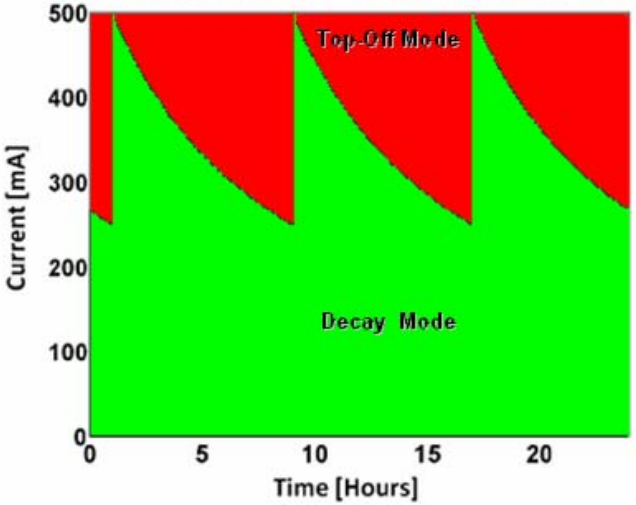

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Potentially Dangerous Condition

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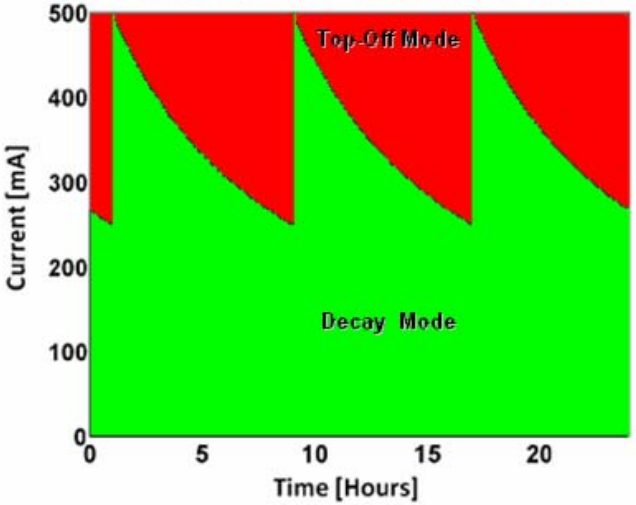

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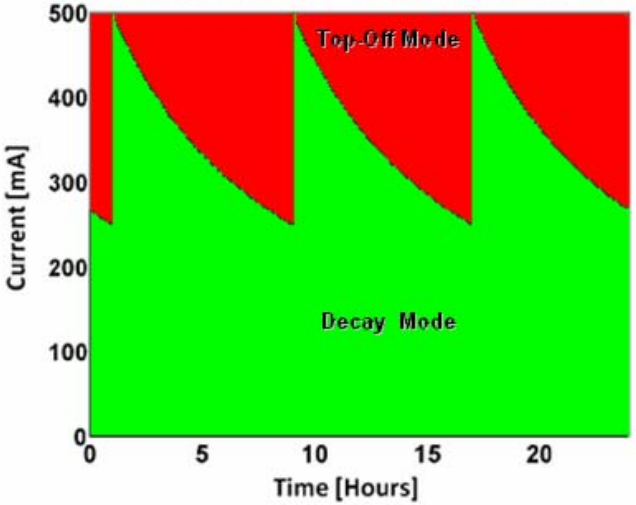

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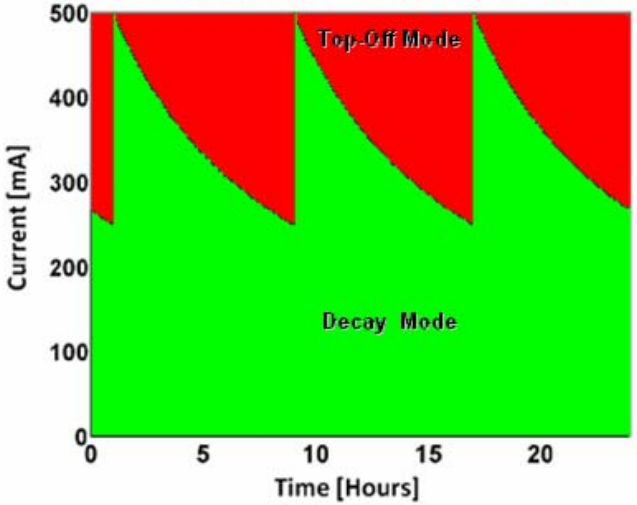

Typical Beam Operation

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Top-Off Injection

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- **Non-Injected Beam Losses:** RF Trips, Beam Scrappers, Vacuum

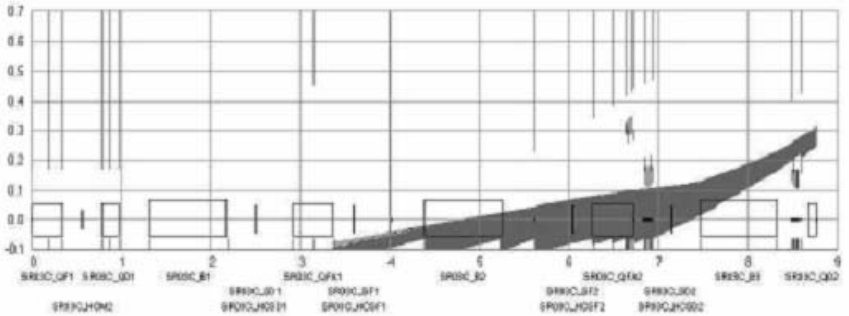
Requirements Determined by Physics Simulations

Simulations were conducted using:

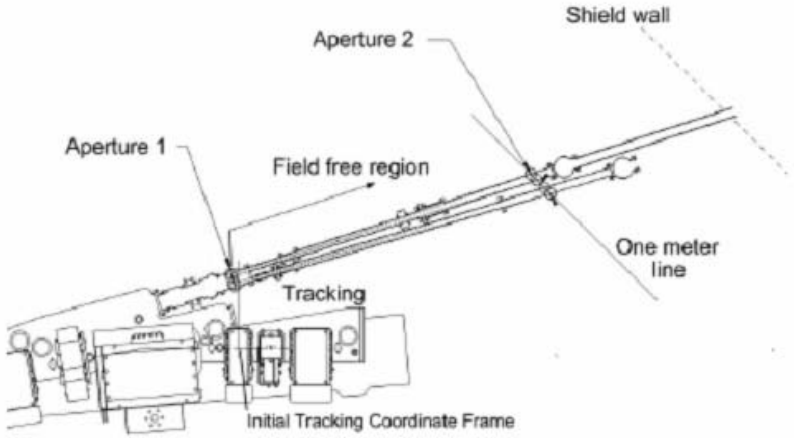
- Reverse Tracking Method
- Abnormal and Failure Scenarios
  - Human Missettings
  - Feedback Systems
  - Power Supply Trips
  - Shorts in Magnet
  - etc.,
- Energy Scanning
- Magnet Current/Field Scanning
- Apertures
- Alignment Tolerances
- etc.,

Analysis was done to determine:

- The shortest time to reach a potentially dangerous condition.
  Included effects: vacuum chamber, power supply & magnet



Graphic of Reverse Tracking for One Beam Line



Partial Plan View of Storage Ring & One Beam Line

2., 3., 4. H. Nishimura, *et al.*, "Advanced Light Source's Approach to Ensure Conditions for Safe Top-off, Operation" NIM (submitted 2009).

System Specifications

Injected Beam Losses - 3 Systems of Intrlks:

- Energy Match Intrlk (EMI)
- Lattice Match Intrlk (LMI)
- Stored Beam Intrlk (SBI)
- Apertures

} Injection Intrlks & Mode Control
Extraction Trigger Inhibit (ETI)

Requirements include both Value & Time Response

Provided by Physics Group

Power Supply	Intrlk System	F. S. Output (A)	Nominal Current (A)	Intrlk Accuracy ±% of Nominal	Max Response Time (ms)	Intrlk Value (A)	Intrlk +/- Limits % of Nominal
BR Bend	EMI	1050	982	0.1%	1	981.55	+0.268, -0.201
SR Bend	EMI	1000	897	0.1%	1	896.82	+0.374, -0.348
SR4, 8, 12 Super- Bends	EMI	350	298	0.1%	1	298.5 298.6 298.46	+0.297, -0.284
SR QFA	LMI	550	492	0.1%	1	492.349	+0.519, -0.433
SR4, 8, 12 QFAs (Super-Bend)	LMI	550	521	0.1%	1	521.387	+0.64, -0.45
SR SF	LMI	400	373	10%	1	372.87	+2.77, -46.6
SR SD	LMI	400	250	10%	1	250.02	+24.5, -35.5
SR Beam (BPM)	SBI	1000 mA	500 mA	1%	1	500 mA	+120.0, >2.5

System Specifications & Design Principles

Non-Injected Beam Losses:

- Radiation Monitors

Requirements include both Value & Time Response

Radiation Monitor	Intrlk System	Slow Integration Time (hr)	Intrlk Value (mRem)	Fast Integration Time (s)	Intrlk Value (mRem)	Loss of Counts Timeout (s)
HPI 6031 w/6012 controller	BL	1	5.0	4.0 w/60s delay	10.0	30

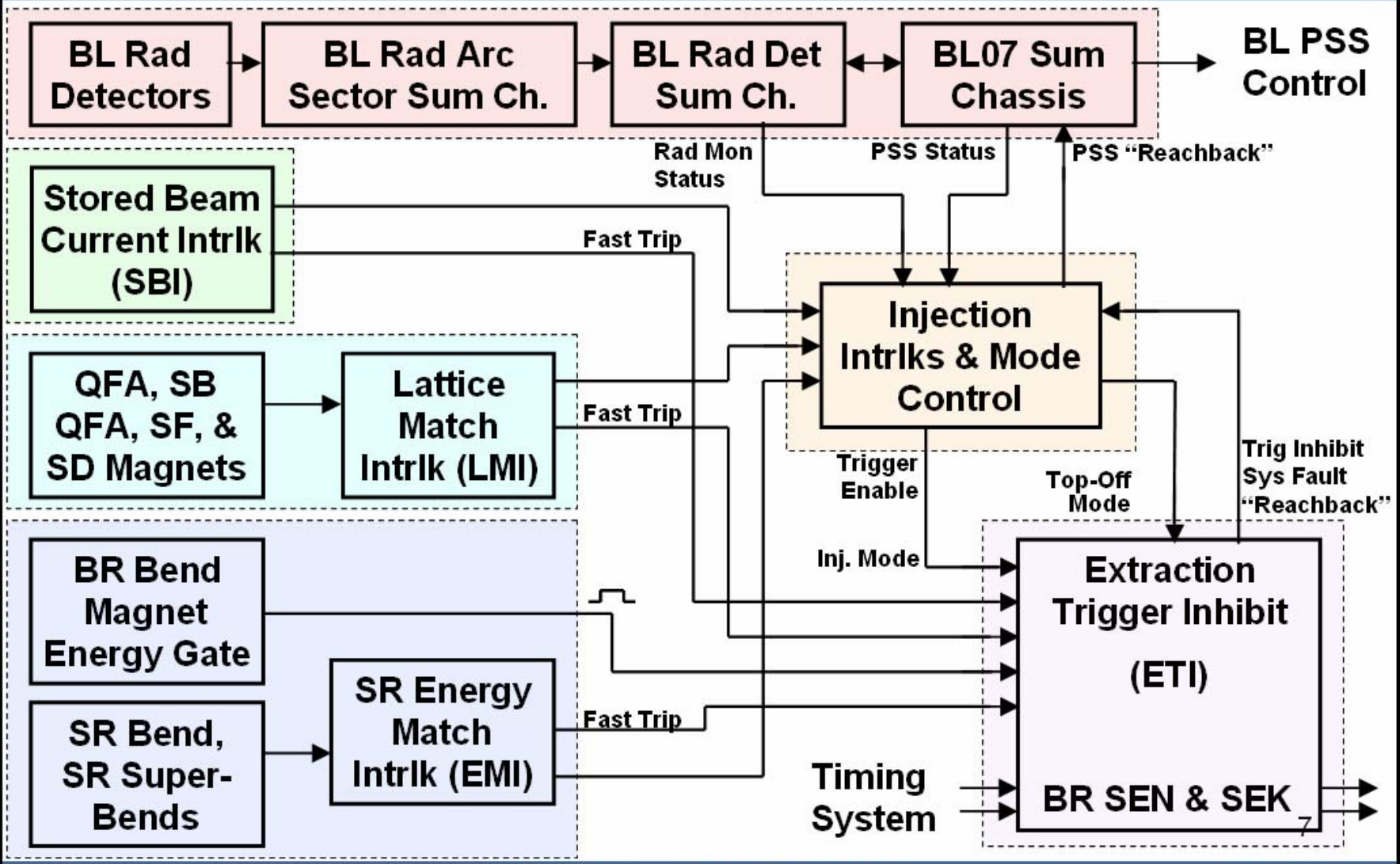
System Design Principles:

- Fail-safe
- Redundant (parallel)
- Testable
- Visible
- Self-checking – increase reliability

Technologies:

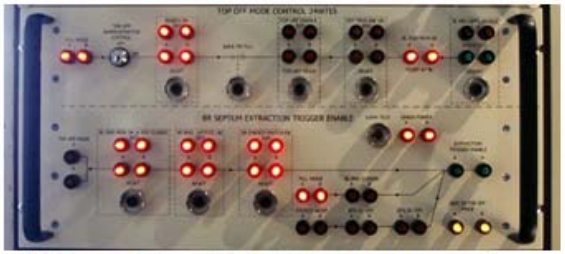
- Solid-state devices – hardware intrlk to meet Time Response
- Solid-state Radiation Monitors
- Commercial PLC's
- Electro-mechanical relays – existing Radiation Safety System

Top-Off Interlock System



Injection Mode Intrlk & Control & Beamline Radiation Monitors

Injection Mode Intrlk & Control:



- Electromechanical, redundant, failsafe
- Fill Mode (Transfer Line Magnets Enabled, PSS closed)
- Stored Beam Mode (Transfer Line Magnets Disabled, PSS open)
- Top-Off Mode (start in Fill Mode, Stored Beam, Admin Key turned)
  - If NO Radiation Monitor Trips or ETI Faults
    - Permit PSS open
  - Extraction Triggers are Enabled if, LMI, EMI, & Rad Mon OK or PSS closed

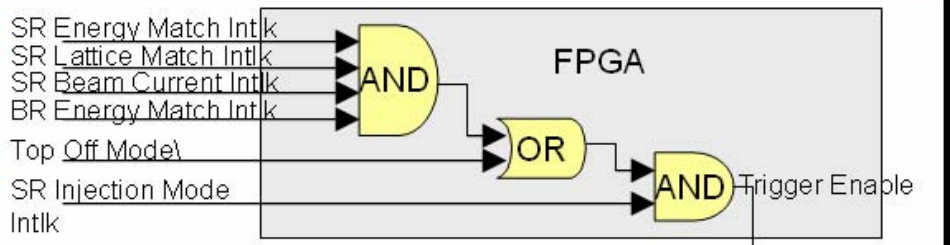
Radiation Beam Line Monitors:

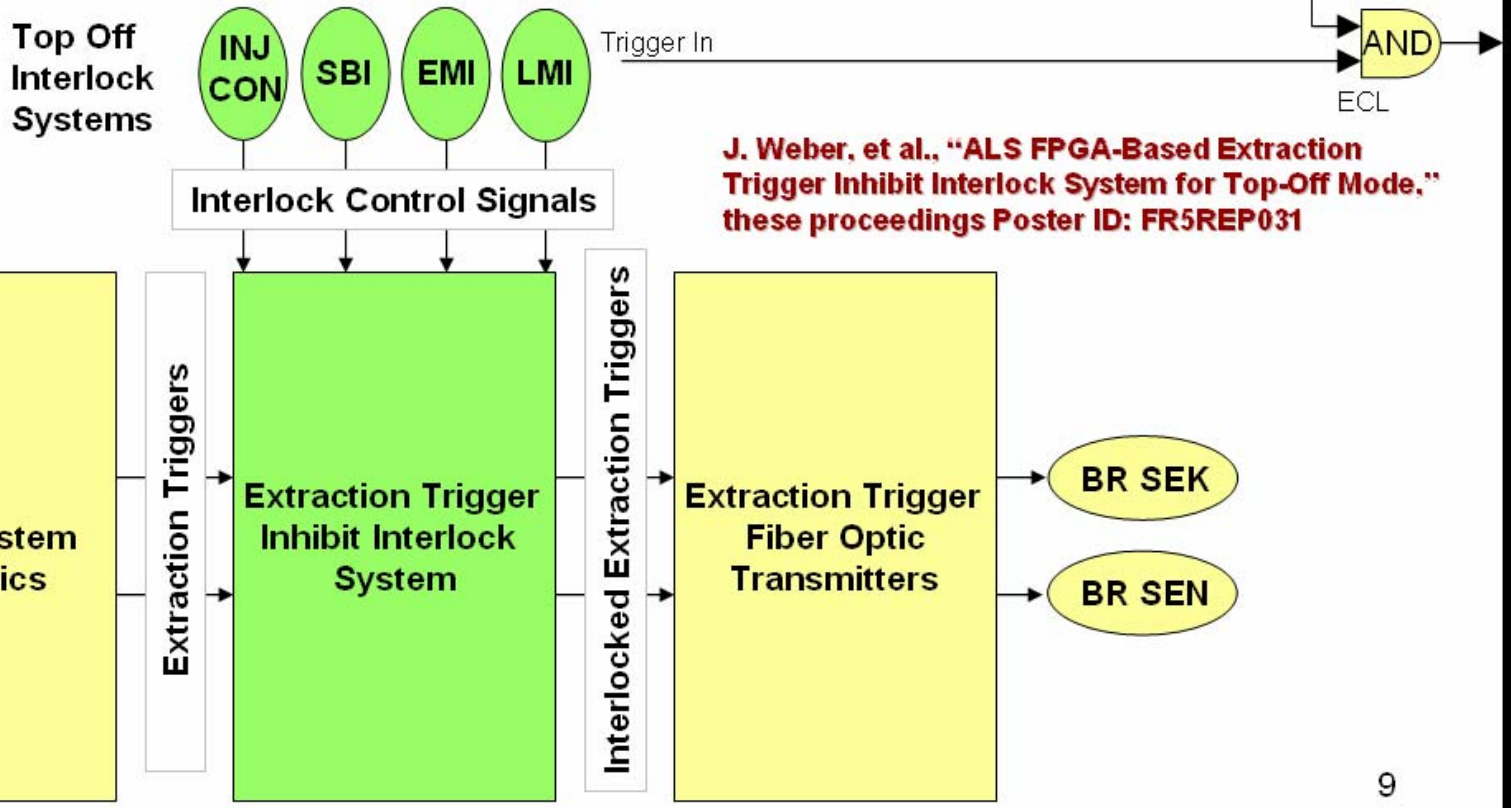
- Solid-state & Electromechanical, Failsafe (low-level source)
- Radiation Monitor Trip compared with PSS position status
- Radiation Monitors are Reset Locally
- Annual Test & Calibration

Extraction Trigger Inhibit (ETI)

Functions Implemented in FPGA :

- Intrlk'd Trigger Control
- Self-Checking & Monitoring
- Test



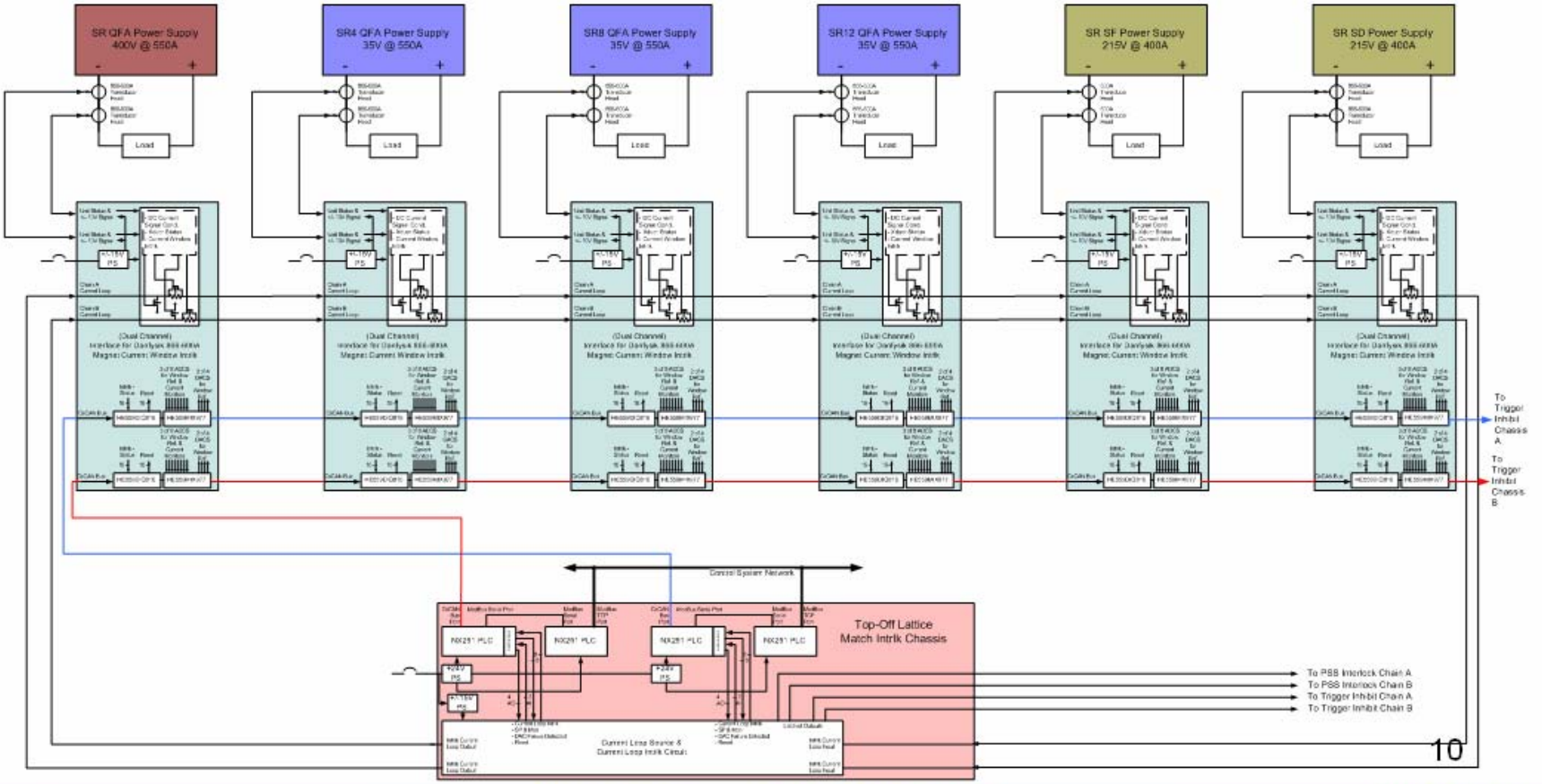


J. Weber, et al., "ALS FPGA-Based Extraction Trigger Inhibit Interlock System for Top-Off Mode," these proceedings Poster ID: FR5REP031

Lattice Match Interlock (LMI)
Energy Match Interlock (EMI)

Components :

- DC Current Transducers
- Comparator Based Intrlk
- Optically Isolated Current Loop Intrlk
- Networked PLC I/O (Digital & Analog)



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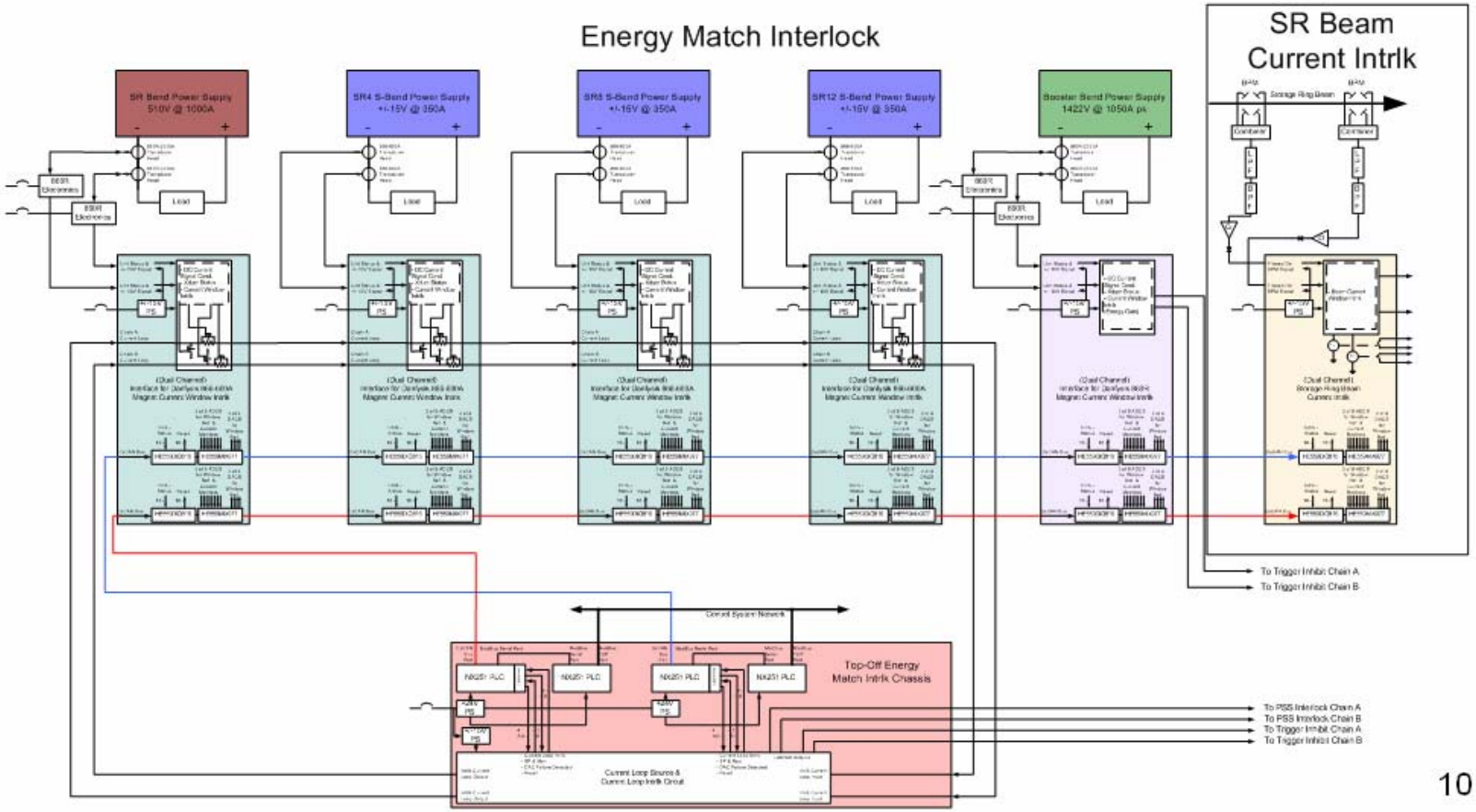

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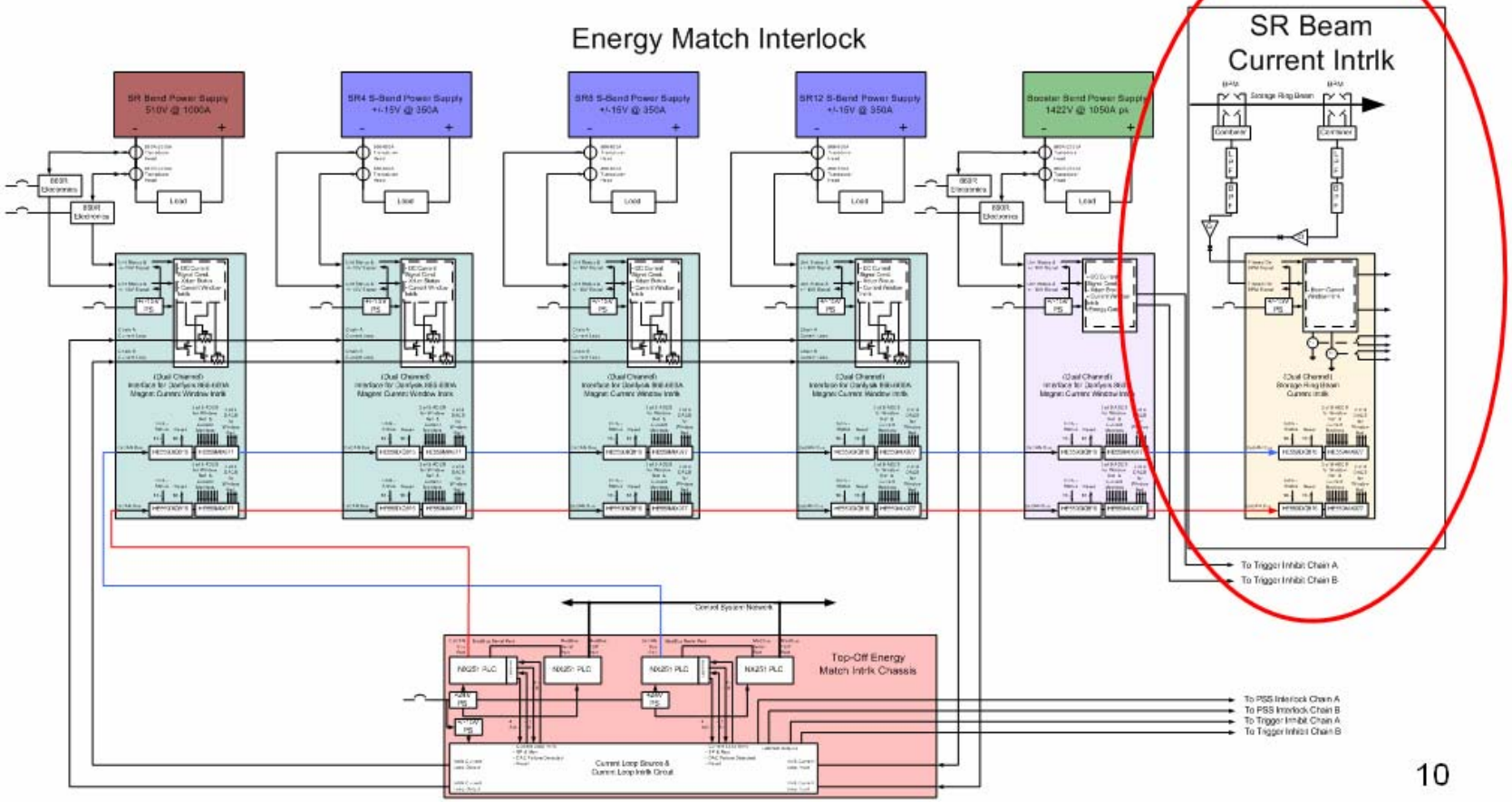
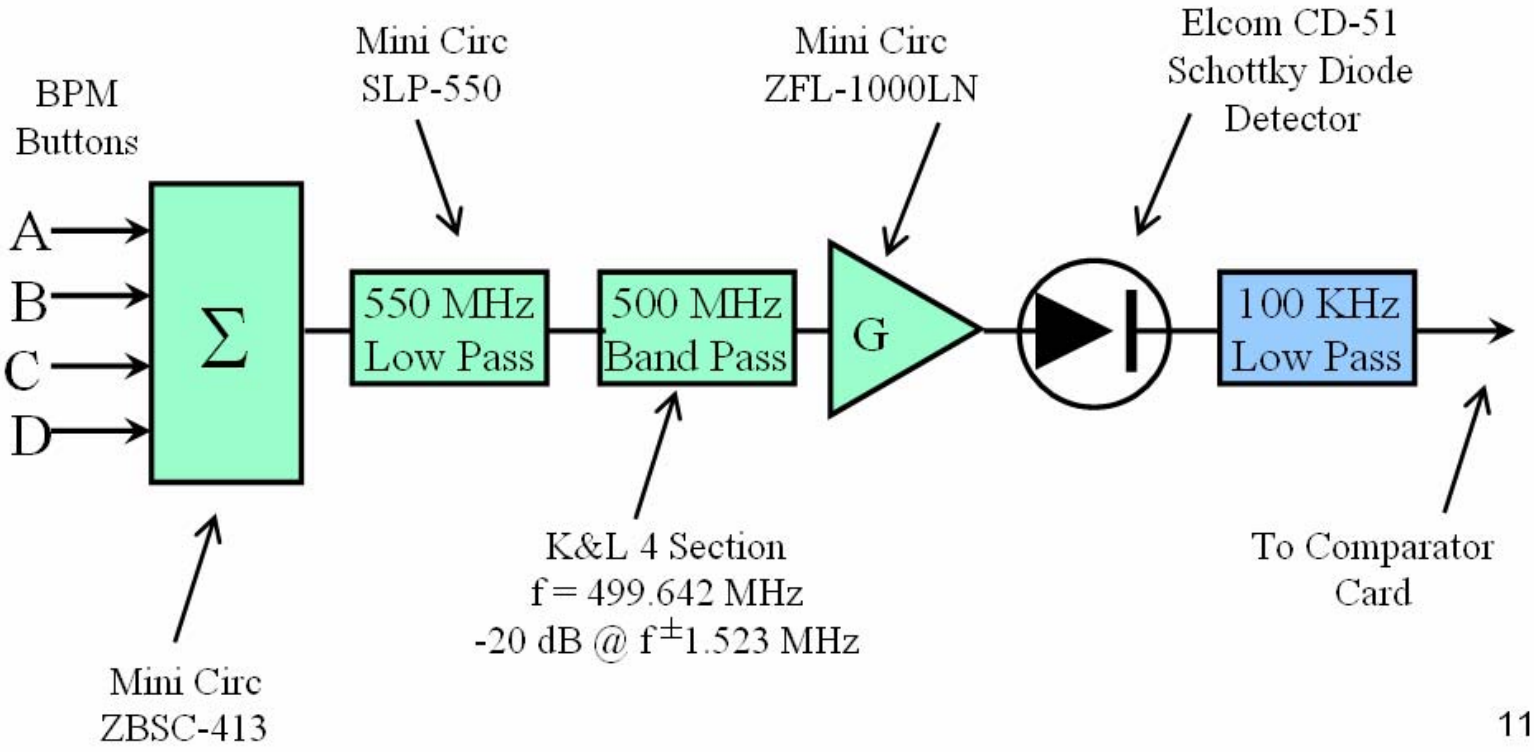


Stored Beam Interlock (SBI)

Components :

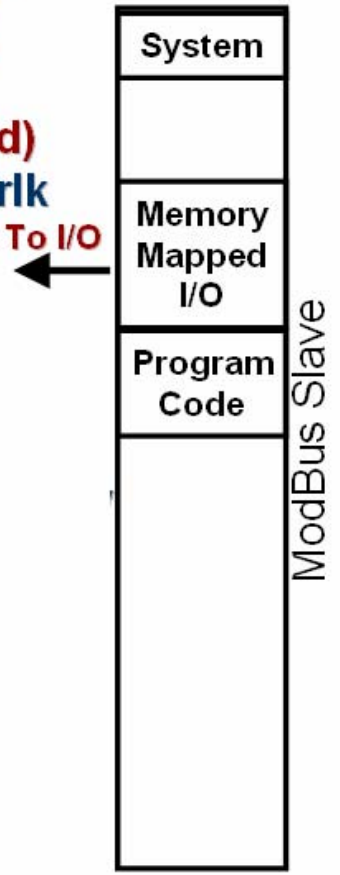
- Beam Position Monitor Buttons in Sum Mode
- Narrow Band 500MHz Detection
- Bunch Pattern Independent
- Simple, Mostly Passive – High Reliability



The Programmable Logic Controller's (PLC) Roles

Embedded PLC (Intrlk System Management)

- CsCAN to I/O, ModBus Slave (serial)
- Configuration Authorization (key & password)
- For each Magnet System & Current Loop Intrlk



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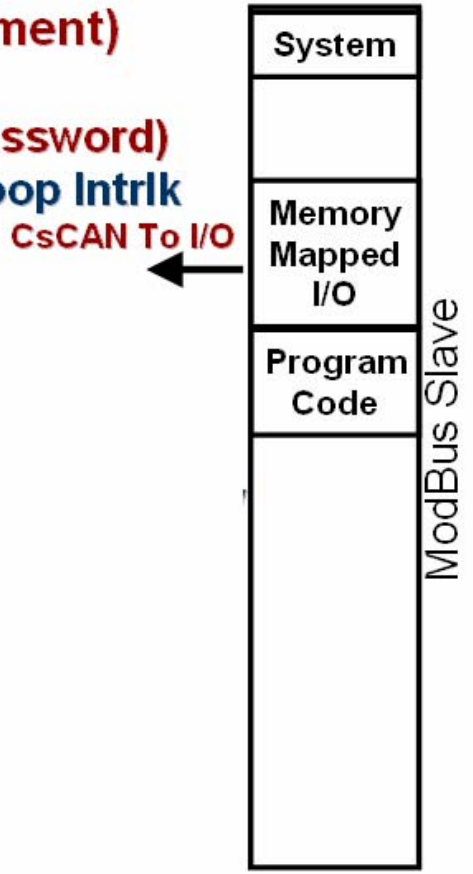

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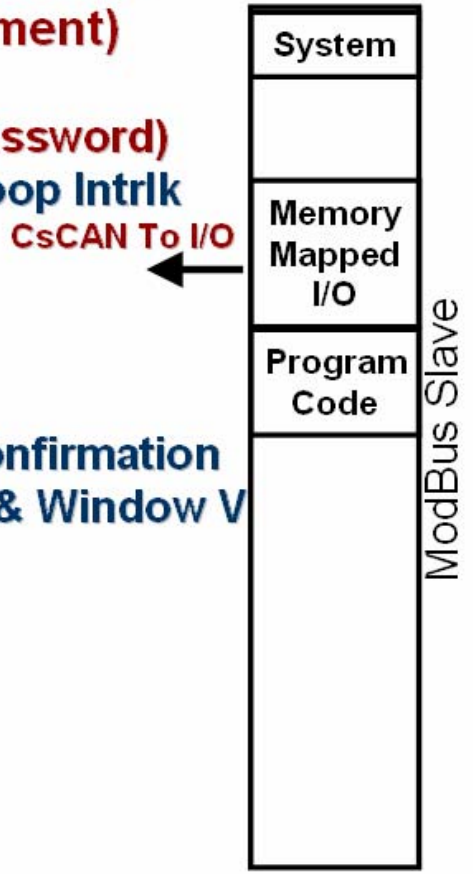
    - Configuration Intrlk Set Point & Window V



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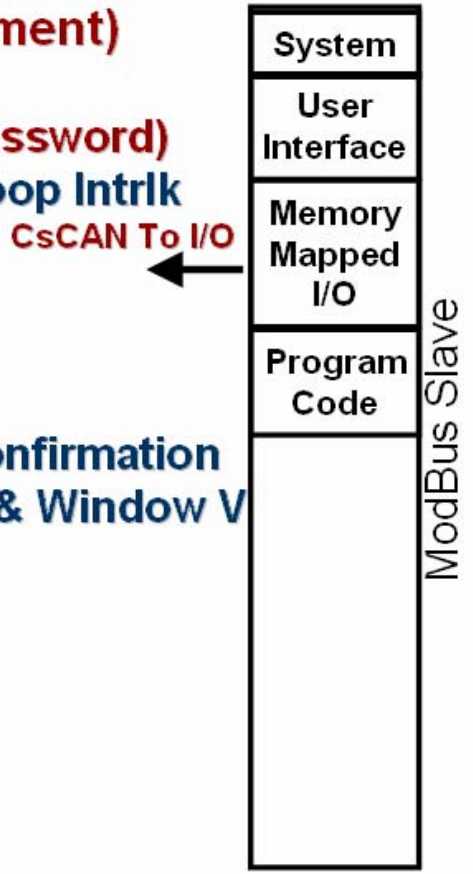

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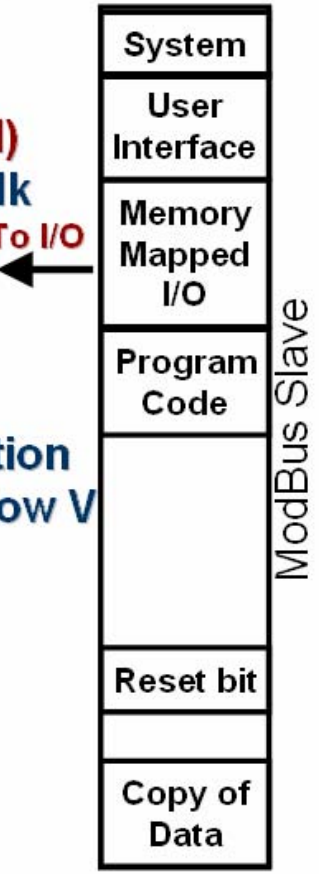

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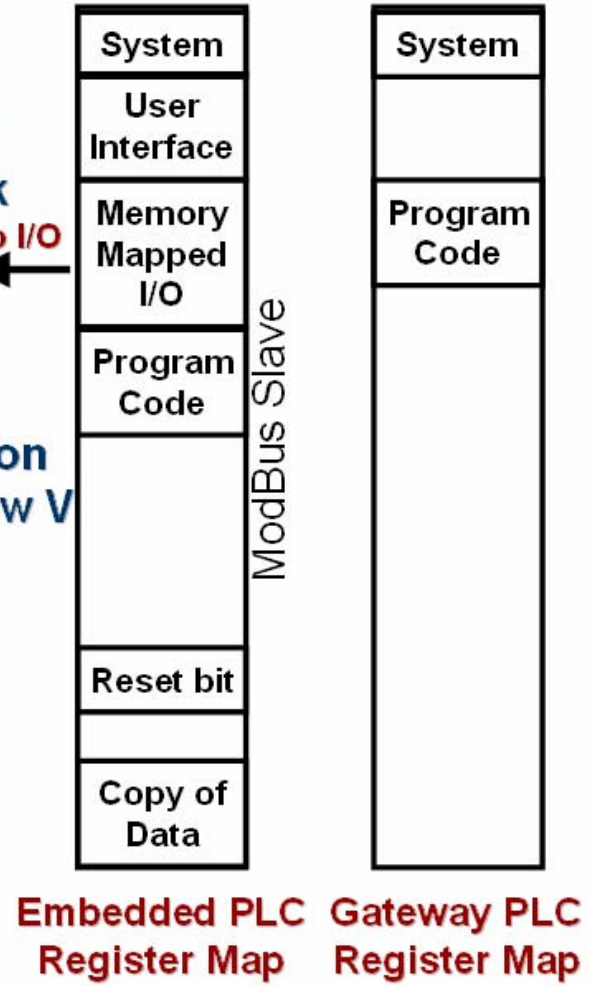
Gateway PLC (Control System Interface)



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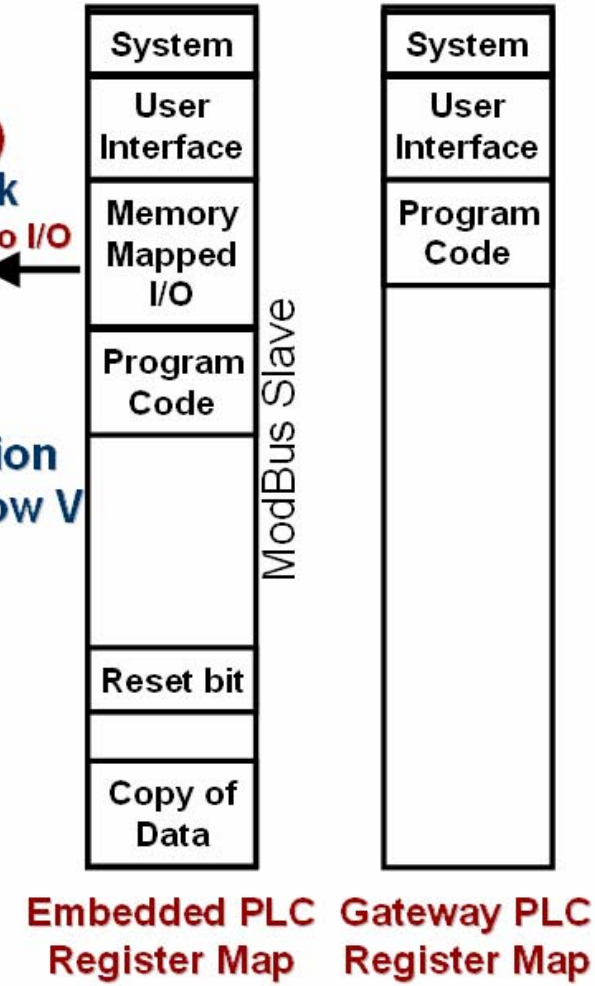

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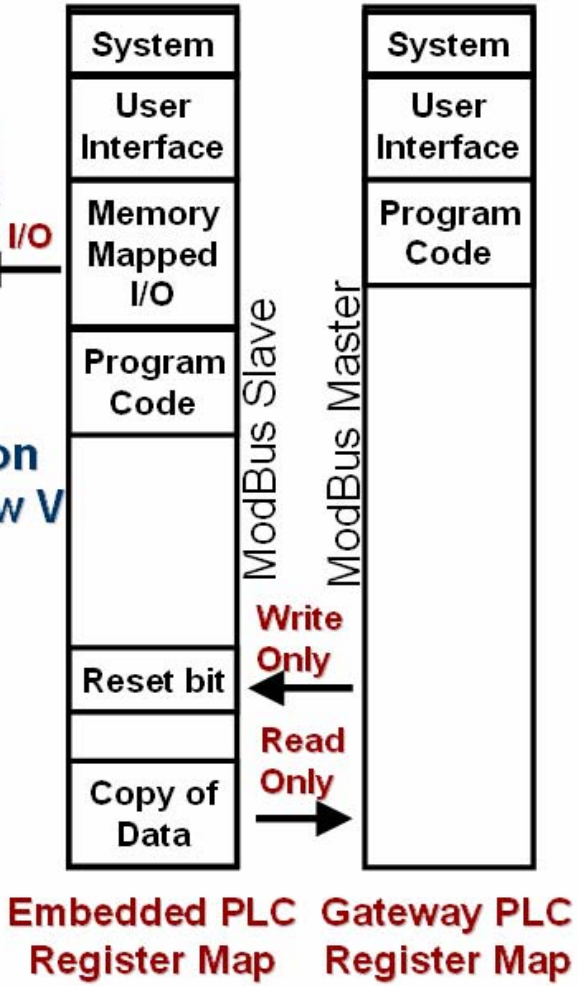

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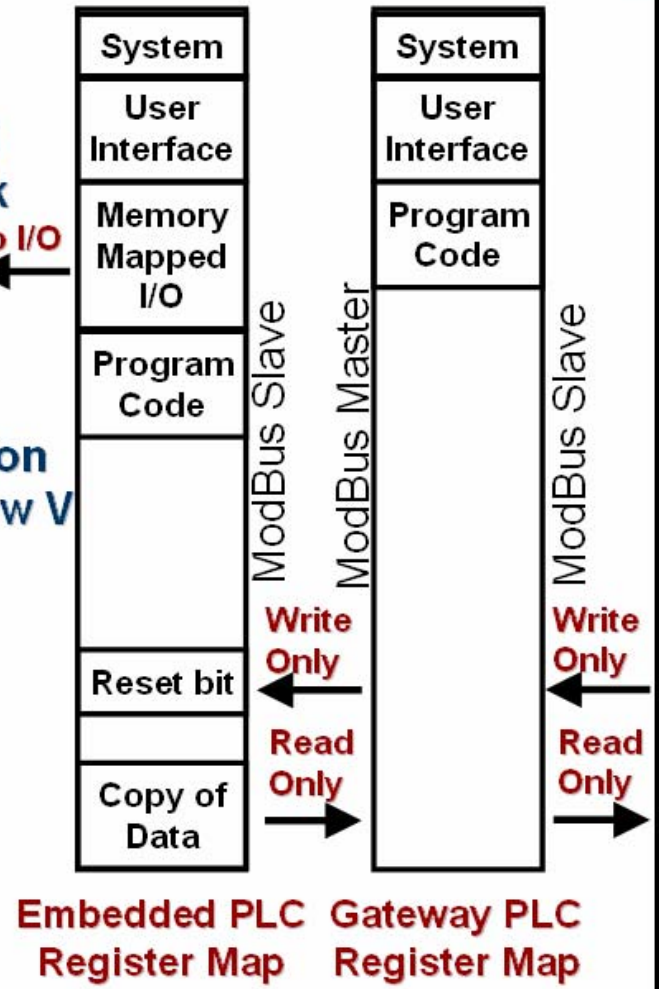
- ModBus Slave to EPICS (TCP/IP)



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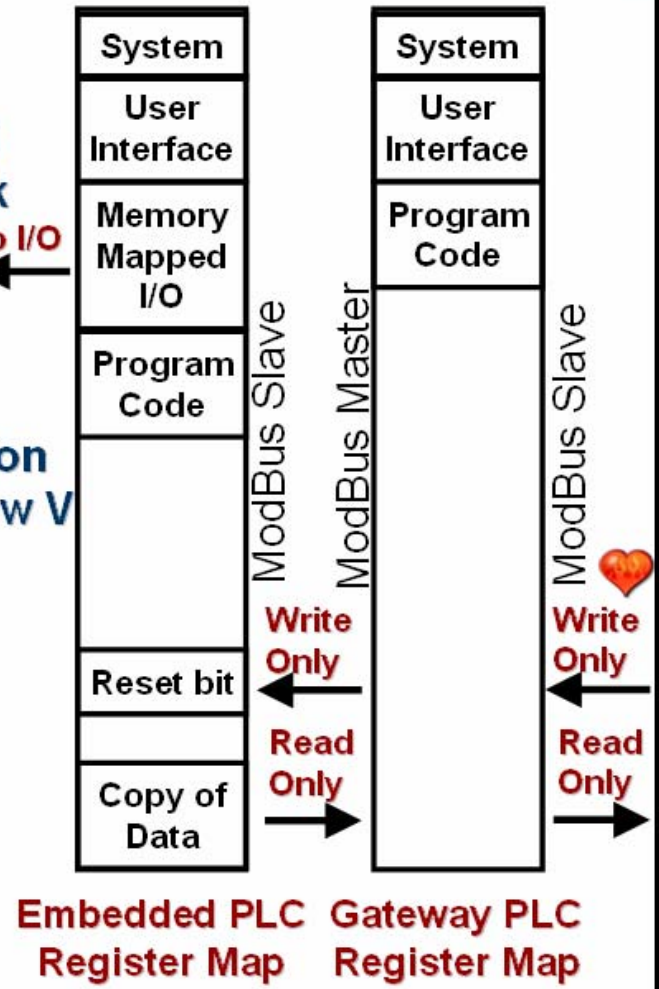
- Heartbeat for EPICS



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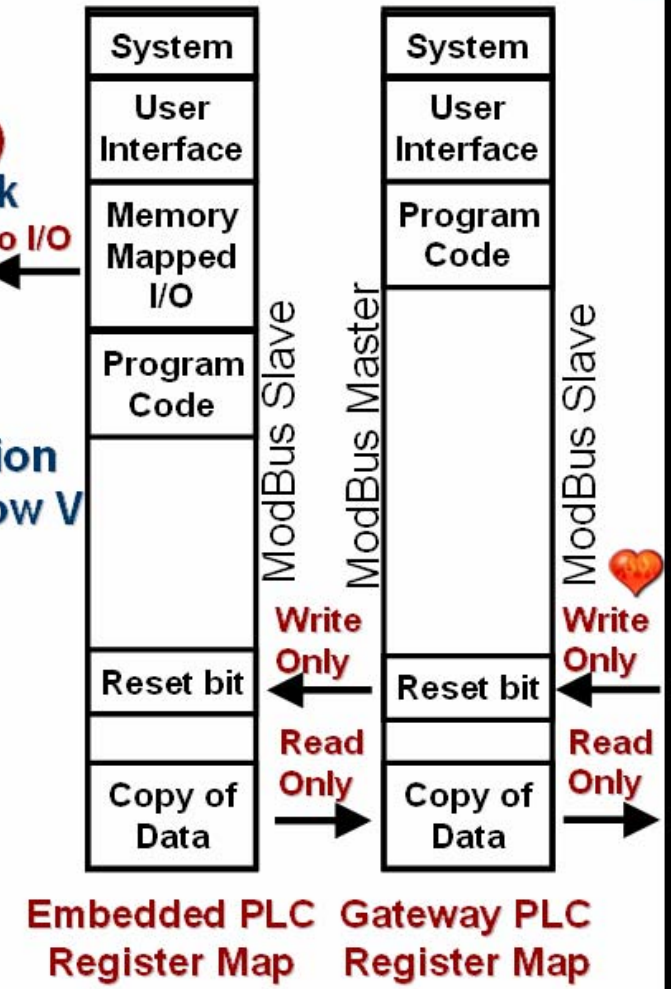


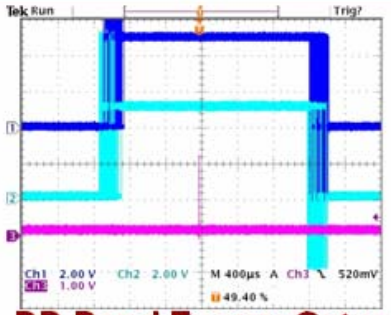
Commissioning & Testing

Commissioning

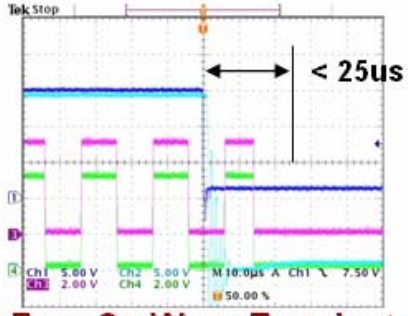
- Board-Level Bench Testing Prior to Installation
- PLC Programming – Many Problems with CAN Network
- Configuration & Control (procedure based)
  - ➢ Hardware, Software & Firmware
  - ➢ Intrlk SP, UL & LL Intrlk Thresholds
  - ➢ PCB Jumper Setting

System Testing (procedure based)

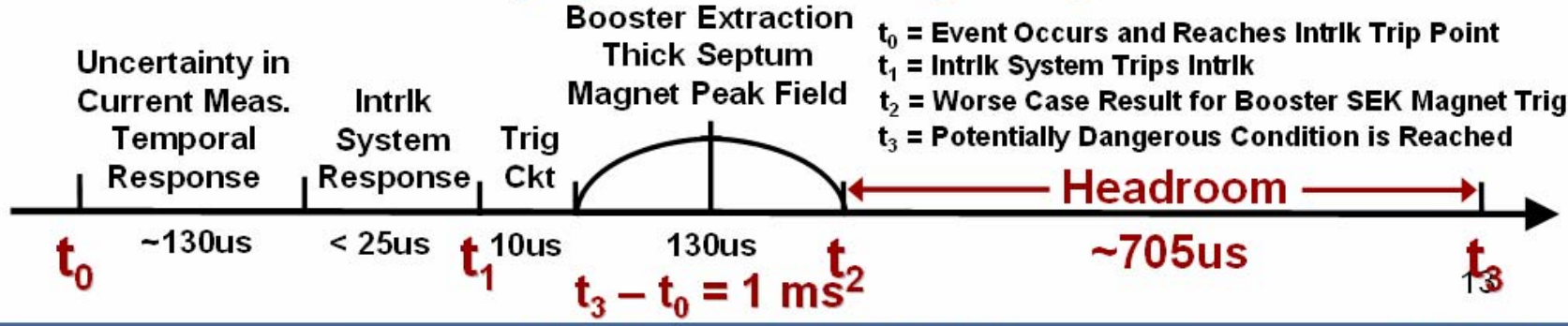
- ➢ Intrlk Window (static & ramped magnets, beam)
  - ➔ Small incremental ± changes in Magnet I
- ➢ Intrlk Time Response
  - ➔ Large neg step change in Magnet I (>=10%) to minimize uncertainty in Time Measurement
  - ➔ Substituted Hi-Freq square-wave for magnet trig.



BR Bend Energy Gates



Hi-Freq Sq-Wave Terminated



System Operation

Project Timeline

- Design – Reviewed – Installed: (10/07 – 08/08)
- Debugging – Commissioning: (09/08 – 11/08)
- ALS Top-Off Mode Testing: (11/08 – 02/09)

User Beam Top-Off Operation (02/09 – present)

Top-Off Beam Interlock Statistics

- Failures: ETI – relay, EMI – PLC I/O modules, fuse
- System Faults: Failures, Op Error, DAC-ADC Match, Self-Check Timing, RSS Test Procedure
- Interlock Trips: System Faults, Mag PS trips, Mis-settings, Temperature

Concluding Remarks

System Design

- Extensive Physics Simulations
- Conservative Margins on Intrlk Settings - Increased Radiation Safety

Commissioning & Testing

- Problematic CAN Networking – Fixed
- Reset (Trips & Faults) – Fixed
- Self-Checking Timeout Sys Fault when using 50kHz sq-wave test signal for Time Response Test – Fixed
- Periodic Re-Test – Labor Intensive

System Operation

- Complicated – Need more Training & Automation
- ALS Beam Reliability – Remained Constant
- Exceeding our Expectations – Users Very Happy!

Improvements

- Automate the Intrlk System's Resets – Eliminate Op Introduced Faults
- Automate Periodic Re-Test

References

1. D. Robin, et al, "PLAN TO UPGRADE THE ADVANCED LIGHT SOURCE TO TOP-OFF INJECTION OPERATION" EPAC04, pg. 2442.

2. H. Nishimura, *et al.*, "BEAM LOSS SIMULATION STUDIES FOR ALS TOP-OFF OPERATION" PAC05, pg. 3532

3. H. Nishimura, *et al.*, "ALS TOP-OFF SIMULATION STUDIES FOR RADIATION SAFETY" PAC07, pg. 1173

4. H. Nishimura, *et al.*, "Advanced Light Source's Approach to Ensure Conditions for Safe Top-off, Operation" NIM (submitted 2009).

5. J. Weber, et al., "ALS FPGA-Based Extraction Trigger Inhibit Interlock System for Top-Off Mode," these proceedings Poster ID: FR5REP031

Thank You