Protecting the future of particle physics

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HL-LHC UPGRADE

High Luminosity Large Hadron Collider (HL-LHC)

- ***Objective:*** More luminosity → More particles colliding → More data → More discoveries
- ***Challenge:*** More luminosity → More radiation
- ***Challenge:*** More data → Needs more bandwidth
- ***Solution:*** Build new systems!

All-silicon inner tracking detector with strip system

- Silicon sensors are very radiation tolerant and have higher granulation
- Strip barrel modules need powerboards for DC-DC conversion, HV switching, monitoring
- Powerboards must be reliable

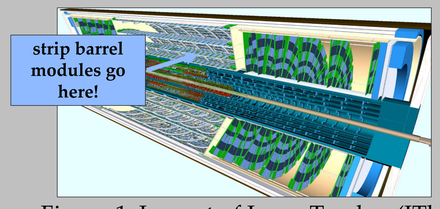


Figure 1: Layout of Inner Tracker (ITk)
Credit: CERN-LHCC-2017-005, pg. 19

QUALITY CONTROL

- ***Objective:*** Quality control (QC) testing → Reliable powerboards
- ***Challenge:*** QC testing → Many tests to run on 14000 boards
- ***Solution:*** Build test crate!

Thermal Cycle Crate

- Massive test crate simultaneously tests 200 powerboards (passive side)
- Daisy-chained active boards (reusable PCBs) host testing circuits, receive/store output signals from powerboards (active side)
- Electrical tests run at warm and cold temperatures after different exposures
- Graphical user interface used to execute many tests automatically during electrical testing
- ***Challenge:*** Ensuring the safety of the powerboards during QC

Figure 2: Massive test crate (active side)
Credit: Zhicai Zhang

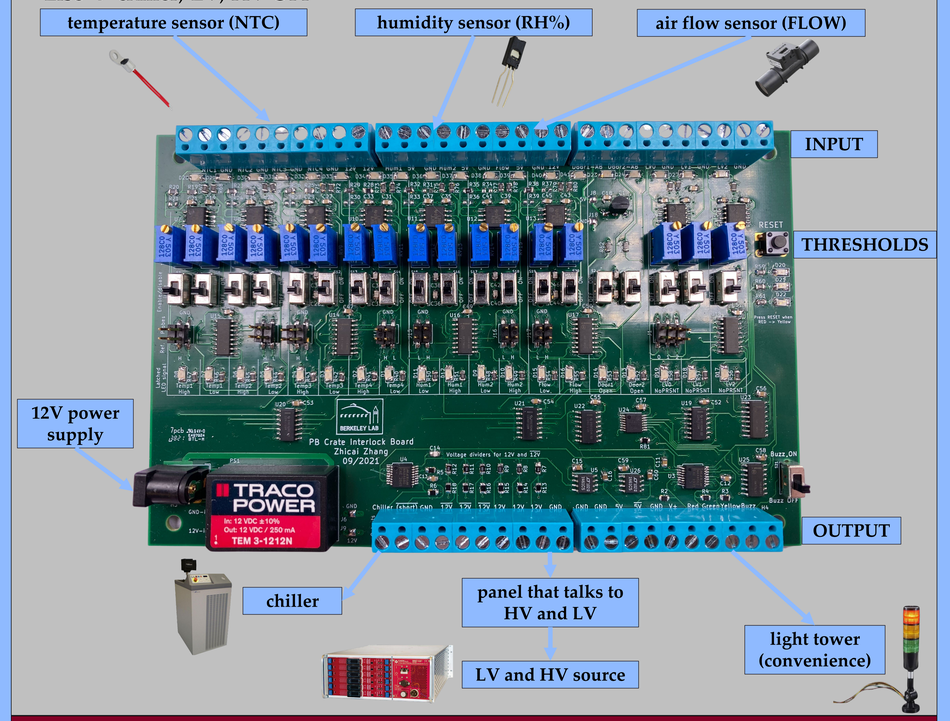
INTERLOCK SYSTEM

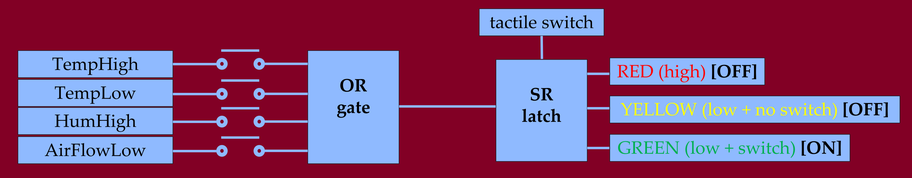
Motivation

- ***Challenge:*** Temperature gets too hot/cold → Damages board
- ***Challenge:*** Humidity gets too high → Water condensates → Damages board
- ***Solution:*** Find a way to shut down crate if humidity or temperature can hurt powerboards

System Design

- Crate temperature and humidity monitored via climate sensors
- Interlock printed circuit board reads analog temperature/humidity sensor input signals, sends interlock output signals to LV/HV source and chiller
- Interlock is hardware-based with analog signals as input
- Uses comparators/logic gates to take simple OR of monitored signals as interlock signals
- All input signals within thresholds (low) + tactile switch pressed → chiller, LV, HV ON
- Else → chiller, LV, HV OFF





INTERLOCK THRESHOLDS

- ***Objective:*** Want to set interlock to fire when unsafe
- ***Method:*** Collect data for each sensor type and fit to model
- ***Solution:*** Tune potentiometers on board to roughly 47.25 °C for TempHigh on both passive and active sides, -3 °C for TempLow on active side, 25% relative humidity for HumHigh on both sides, and 1.15 CFM for AirFlowLow on both sides

INTERLOCK THRESHOLDS

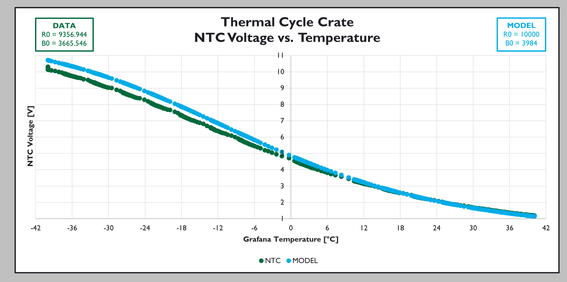


Figure 3: NTC Voltage vs. Temperature fit

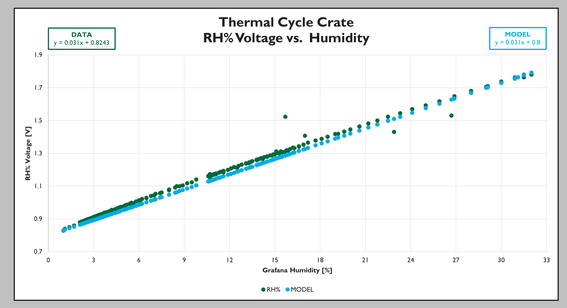


Figure 4: RH% Voltage vs. Humidity fit

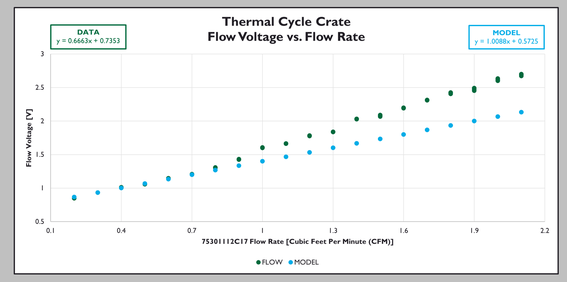


Figure 5: FLOW Voltage vs. Flow Rate fit

IMPLEMENTATION

QC Impact

- 500 powerboards tested during Pre-Production B Batch 4 and Batch 5
- 9 boards failed, 97.4% yield
- Exceeds target yield
- Interlock system will be implemented with additional testing crates during Production

ACKNOWLEDGEMENTS

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