Thermal study of a 300W ATCA card with Optics

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Remain nervous about cooling

Xilinx Power Estimator
• Very nice tool, but have had nasty surprises in the past

Current cards dissipate 40W with dT about 40 °C

New era of cards up to 130W

Cooling governed by physical dimensions
• Worse than MicroTCA in some ways.
• Hard to change late in the design cycle
Serenity

7Tb/s: 288 fibres @ 25Gb/s via 12x MTP24s
Thermal Studies

Thermal **measurements** with an ATCA mock up board

- Two shelves tested
- Shelf A: Standard industry shelf with front-back cooling
- Shelf B: ATCA Shelf used for LHC Phase-1 Upgrades
  - Modified for CERN so that cooling is Top-to-Bottom

Thermal **simulations** with Ansys Icepak

- Shelf B (LHC Phase-1 Upgrade)
- Mock up board simulation
- Heat sinks optimization
Test Setup

- PC blade
- ATCA shelf 14 slots
- 3 PSU 2 channels 60V-7A connected to the PC via Ethernet
- Front and rear fillers with plastic baffles
- 1 mockup board
- 2 heater boards
- S7 system for temperature probe (pt1000) reading
- LAN connecting the shelf manager, PSUs, and the PC
- Temperature measurements accessible using Simatic GUI and via Python-snap7 interface
Kapton heaters made at CERN
**Temperature Sensor Location**

**Optical** block mock up
- Ought to stay below **50°C** for good part longevity
- Heatsink 25 x 80 mm
- Power for tests = **10W** or **20W**

**FPGA** mock up
- Must stay below **100°C**
- Heatsink 90 x 90 mm
- Power for tests = **90W**
Shelf A & External Effects

Rated for 300W per slot
- 4x RiCool3 on top of the shelf
- Air flow: front-inlet back-outlet
- For each fan:
  - Airflow: 320 m3/h (188 CFM)
  - Static Pressure: 897 Pa
  - At 70% full speed: Noise = 59 dB(A), MTBF = 60 Th (40°C)
  - At 100% full speed: Noise = 64dB(A), MTBF = 35 Th (70°C)

Neighbour board impact
- Tested the cross board heating by sandwiching the board with another two with same power injection:
  - Negligible effect: ~1 Celsius difference

Filler effects
- Removed the baffles at the end of the fillers:
  - Negligible effect: Temperature increase of 1-3 Celsius at the bottom sensors, marginal for the others.

Measurement, Max Fan Speed

<table>
<thead>
<tr>
<th>Temperature [°C]</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>39°C</td>
<td>91°C</td>
</tr>
<tr>
<td>36°C</td>
<td>85°C</td>
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<tr>
<td>52°C</td>
<td></td>
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<tr>
<td>42°C</td>
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</tbody>
</table>
**Shelf B**

**Rated:** 450W per slot
- 2 fan trays, each fan tray contains 6 fans
- Air flow: bottom->top
- For each fan:
  - Airflow: 336 CFM
  - Power: 120 W
  - RPMs: 11000
  - Noise: 78 dbA
- Better cooling possible, but requires more power and generates more noise.

All subsequent results use shelf B because it has become it was chosen for the LHC Phase-1 upgrades.

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**Measurement**, Fan Speed = 10/15

Results similar to Shelf A

- 39°C, 47°C
- 34°C, 39°C
- 78°C

**Measurement**, Fan Speed = 15/15

- 35°C, 42°C
- 33°C, 37°C
- 73°C

90W / FPGA, 10W / Optics
**Measurement v Simulation**

**Measurement, Fan Speed 15**

- 35°C
- 33°C
- 42°C
- 37°C
- 73°C

**Simulation, Fan Speed 15**

- 40°C
- 36°C
- 78°C
- 67°C
- 38°C
- 42°C

**FPGAs @ 90W each**
- Max temperature 100 °C

**Optics @ 10W each**
- Max temperature 50 °C
- May increase to 20W so need margin

Standard LHC ATCA crate, Vertical Airflow
Crate noise and power (2 fan trays)

Setup: heater-boards off. Top and bottom fan trays activated

Noise reaches 90 dBA at maximum fan speed (single shelf)
power consumption at maximum fan speed = 2kW

Fan power (level 15) sufficient to raise air temp by 4 deg C
**Noise & Cooling v Power**

- Measurements taken at fan speed settings from 10 to 15 (maximum)
- Higher fan settings produces only a limited reduction in temperature but does result in significant additional noise and power consumption.
**Fins or Pins**

**Measurement, Pins**
Cu, 26 pins per row, 1.7mm diameter
Total height **12.7mm**, base 4.4mm

**Measurement, Fins**
Cu, 28 fins, 0.45mm wide
Total height **10.1mm**, base 2.9mm

**Simulation, Fins**
As left

Fan Speed 10 out of 15
90W / FPGA, 10W / Optics
Optimisation

90 W/FPGA - 20 W/Optics

10/15 equivalent fan speed

Procedure:
- Optimization of fins
- Fixed 25 fins, optimization of the thickness of the fins
- Fixed 0.5 thickness, optimization of the base height
Heat Sink Type

Default
- FPGA HS: Pins
- Optics HS: Pins

FPGA heatsink with fins
- FPGA HS: 37 fins 0.35 mm width
- 90/37 mm pitch

Optic heatsink larger & denser
- Width increased: 25 to 40 mm
- Pin density same as FPGA

All Simulation
Fan Speed 10 out of 15
90W / FPGA, 10W / Optics
FPGA HS: Copper

44°C  47°C

38°C  39°C

FPGA HS: Extruded Aluminium

44°C  47°C

38°C  39°C

All Simulation, Same Geometry
Fan Speed 10 out of 15
90W / FPGA, 10W / Optics
Possible real heat sink
• Aluminum (cheaper and lighter)
• 25 fins/90 mm
• 4 mm base (to increase rigidity)
• 14.2 mm total height
• 1 mm fin thickness (extrudable)

- Fan speed: 10/15
- 90 W per FPGA, 20W per Optic Bank
- Copper, 25 fins/90 mm
- 3 mm base
- 14.2 mm total height
- 0.4 mm fin thickness
**Thermal Conclusions**

Good agreement between simulation & measurement
- Rapid simulation of new heatsink designs

The cooling performance, power consumption and fan noise as a function of fan speed have been measured.
- Will limit fan speed to 10 out of 15 as a consequence

Optimisation of heatsink design yielded significant improvement in cooling
- Despite thermal margin will retain large heatsinks to accommodate larger, pin compatible FPGAs and 28Gb/s optical modules

In simulation aluminium has shown comparable performance to copper
- Switch to lower cost, lighter weight heatsinks seems feasible

Caveats
- Junction to package thermal resistance has been ignored. It is typically less than 5°C for FPGAs
  - e.g. KU115 has 0.1 °C/W, VU9P has 0.06 °C/W
- Thermal interface pad on optical modules will add up to 5°C to optical measurements
APPENDIX
A single slide in this talk, but it requires significant effort to properly document system

http://cern.ch/serenity

Already have large sections on
• Hardware
• Firmware – EMP
• Low level software – SMASH
• IPMC functionality

Some sections have extended walkthroughs to guide those new to the system
• Much done but will take several more months before complete.

Alex Howard, Imperial College
Front Panel