Experience powering Virtex-7 FPGAs

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1.5Tb/s optical signal processor

Xilinx Virtex-7 FPGA:
- XC7VX485T or XC7VX690T

Advanced boot-loader & diagnostics (full system test at start-up)

On-board firmware repository

2 × 144Mbit 550MHz QDR RAM (optional)

Been in hand for over a year
- Continuous testing over that period
- Exceptionally well understood

Imperial MP7 processor board

See also TWEPP 2012: https://indico.cern.ch/contributionDisplay.py?contribId=86&confId=170595&sessionId=51
  https://indico.cern.ch/contributionDisplay.py?contribId=97&confId=170595&sessionId=53

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FPGA architecture

- MP7 uses XC7VX485T or XC7VX690T
- Pin-compatible FFG1927 package
- This is how the XC7VX690T looks in the documentation:
FPGA architecture

- MP7 uses XC7VX485T or XC7VX690T
- Pin-compatible FFG1927 package
- And if we colour in the power pins:
- Half of the pins on the chip are dedicated to powering the thing
MP7 board – Top half

- Receivers
- Transmitters
- FPGA
- 2V5
- 3V3
- 1V0
- 1V5
- 1V8
- Header
MP7 board – Bottom half
MP7 Ro power architecture

Bulk regulators

3v3
LTM4628
3v3@8A
2v5@8A

LTM4628
1v0@8A
1v0@8A
LTM4628
1v0@8A
1v0@8A
LTM4628
1v0@8A
1v0@8A
LTM4628
1v0@8A
1v0@8A

12v
LTM4606
1v0@6A
LTM4606
1v0@6A
LTM4606
1v2@6A

MIC5319
2.5V
MIC5319
1.8V

μTCA-crate operation

Speciality and secondary regulators

Bench-top operation

μC
CPLD
Optics
USB
FPGA Core
Upper GTX/GTH
Lower GTX/GTH
SRAM
FPGA I/O
RT9040
0.9V
RT9040
0.9V
MGTs

- MP7 is an optical stream processor
- 72 links @ >10Gb/s, fully bidirectional
- 7-series MGTs require:
  - 1v0
  - 1v2
  - 1v8
- but there are very tight constraints!
MGTs

• The noise limits and tolerances on the MGT power supplies are tight!
• There are also constraints on voltage drop across the chip
  • Ohmic losses in the planes required that the regulators are as close as possible to the MGTs
  • There are two banks of MGTs
  • Each needed powering independently
• Space constraints also mean that the 10Gb/s signals run underneath the regulators
• Noise was a concern...
MGTs: Revision 0

- Favoured LTM4606 6A ultralow-EMI switch-mode regulators by Linear, since:
  - These are designed for transceiver applications
  - Are sufficiently low that the fitted on the bottom of the board
  - We had used these successfully on the Mini-T5 card

- Included a regulator on a test board to test for interference

- Also, taped a Samtec kapton cable to top of regulator and tested 10Gb/s signal integrity that way

- Good news – regulator had no effect on a 10G signal passing under it
MGTs: Revision 0

- Card was designed before 7-series engineering silicon was available
- LTM4606 should have had ~35% headroom based on Xilinx’s power estimator
- When card assembled and tested, power consumption 30% to 220% higher than Xilinx had predicted
- A lot of discussion with Xilinx engineers – found a lot of “features” that Xilinx weren’t aware of. The price you pay for living at the cutting edge.
MGTs: Revision 0

- Very impressed with LTM4606
  - Rated 6A nominal
  - 8A peak
- But performed excellently even when run flat-out at 25% above its nominal rating
MGTs: Revision 1

• We were very concerned about the possibility of power supply changes introducing noise.

• Several test cards were made to test alternative power supply designs on an Ro card.

• Noise was measured both electrically and by its effect on the error-rate of the 10Gb/s optical links.

• LTM4601 switch-mode regulator by Linear won the day:
  • Same size as the LTM4606 (although different footprint)
  • Similar external components
  • Simple replacement.
MGTs: Revision 1

- 485, RPBS7, 10G, QPLL, 24 links (one side),
- Plots show bathtub from 6 different links: 1 from each quad.
Core power

- Large BGAs puncture the board with vast forest of vias
  - Increase the effective resistivity of the power planes
- Core power pins are at centre of BGA
- Use fills in three layers to get power into core to ensure sufficient current
  - Prefer layers with 1oz copper over ½oz copper layers
- Use remote sense, even though the distance is only a few cm
Power supply monitoring

- MP7 makes extensive use of LTC2990 four channel voltage/current/power and temperature monitor
  - Sub-millivolt resolution
  - 1% current resolution
  - 1% temperature resolution
  - 10-Lead MSOP Package – size is important in the space-constrained µTCA environment

- MP7 measures:
  - Both incoming supplies
  - ALL bulk supplies on the board
  - Subset of secondary/speciality supplies

- Sensors are distributed around the board allowing an approximate temperature profile of the board
Power consumption sensitivity

• Power consumed by the Virtex-7 can be extraordinarily sensitive to configuration flags

• Unused and non-optimally configured resources can contribute massively to power consumption. Not always immediately obvious.

• Need to consider the entire design (all configuration flags) before making statements about power consumption

• No substitute for hands-on experience
With early revision of board, 48-link design hit thermal cut-out when on the bench (no fans). Reached 60°C in a crate.

- Designed a heatsink ourselves (old-school educated guesswork, no simulations) and prototyped in-house. Dissipated 40% more power than the off-the-shelf part. Temperature didn’t exceed 45°C in 48-link design.

- Production heatsinks manufactured externally and anodized (increase radiative transfer by further 25%)
Conclusions

• The compact nature and excellent performance of Linear’s switch-mode modules make them an excellent match for 7-series FPGAs and the μTCA environment, where space is constrained.

• Xilinx power estimator should be considered exactly that… AN ESTIMATOR
  • Don’t rely on it being correct
  • It is no substitute for hands-on experience

• 7-series FPGAs have a large number of configuration flags and it is not always immediately obvious how these will affect power consumption.