Next generation of radiation tolerant field-bus clients for QPS

J. Spasic, TE-MPE-EP
Field-bus clients in QPS

- There are 2532 QPS field-bus clients
- Processing data from quench detectors, crate and heater discharge monitors
- Connecting Quench Protection Systems (QPS) via WorldFIP to the controls system and providing data for:
  - Operator screens and expert consoles
  - Software interlock
  - LHC logging database
  - Post mortem servers, viewers and automatic analysis
  - Warning generation (email) for pre-defined faults states (e.g. loss of a quench heater power supply)

Next generation of radiation tolerant field-bus clients for QPS

03/02/2021
One of the QPS clients – DQAMC

- DQAMC = Acquisition and Monitoring Controller
- 1624 DQAMC in MB&MQ (asymmetric) quench detection systems in LHC

[Image of DQAMC]

Next generation of radiation tolerant field-bus clients for QPS

03/02/2021
Another one of the QPS clients – DQAMGS

- DQAMGS = Acquisition and Monitoring Controller
- 436 DQAMGS for MB&MQ (symmetric) quench detection systems in LHC

DQLPU-S
MB&MQ
QPS field-bus clients – closer look

- ADuC831 8-bit μC
- Interface circuits for local (in-the-crate) communication
- Analogue stage for heater discharge supply monitoring

WorldFIP

- MicroFIP component
- Field-drive line driver
- Line transformer

03/02/2021
Development motivation

- DQAMC/GS in half-cell 8 and 9 around P1, P2, P5 were affected by radiation in Run2
- Vulnerable component (moreover obsolete): MicroFIP – 13 faults in 2018
  - Timing data corruption → prevents data transmission to (NX)CALS
  - MicroFIP data corruption → could trigger beam dump
  - Command transmission corrupted → could delay LHC refill
  - Hardware failures → could trigger beam dump
Solution strategy

• Make one design implementing both DQAMC and DQAMGS
• Remove circuits not in use anymore after recent upgrades (e.g., monitoring of heater discharge supplies)
• Implement WorldFIP client functionality in a radiation tolerant FPGA
  • Use BE-CO nanoFIP IP core
  • Implement interface between the core and the μC
• Keep QPS controller implementation in μC
• Exchange DQAMC/DQAMGS in radiation-critical positions
Solution strategy

- According to estimated radiation levels in DS areas of 10 Gy/year and 100 Gy/year\(^1\)
  - Exchange planned in 8 to 12 half-cells of P1, P5, (P7), P2 and P8
  - 140 DQAMC and 60 DQAMGS boards to be changed
- Board exchange planned to be done in multiple exchange campaigns
- The earliest board exchange could be during the annual closure 2021/2022
- If this is not possible, exchange will be during the YETS 2022/2023
  - Should not be an issue as 2022 radiation levels are expected to be moderate

\(^1\)https://edms.cern.ch/ui/file/2302154/1.0/HLLHC_Specification_Document_v1.0.pdf
Development status

- First prototype based on ProASIC FPGA produced and functional
- Second prototype based on IGLOO2 FPGA will be sent for production in the coming days
- Both prototypes replace both DQAMC and DQAMGS
Development status

- nanoFIP IP core (BE-CO) adapted to local communication in QPS
- FPGA firmware uses different SEU mitigation techniques
  - TMR and fail-safe state machines → currently under test
- μC firmware under development & test
- Remote fault mitigation techniques implemented (μC and gateway level)
- Software stack for QPS supervision yet to be modified!
- Design expected to be ready for production in Q3 2021
Component-level R2E considerations

- P82B96TD to be tested in PSI
- SSSB231, ADUC831BSZ could be tested within system-level CHARM test
- M2GL010 not tested, but family tested
- Diodes could be tested with Co60

<table>
<thead>
<tr>
<th>Component</th>
<th>Component class</th>
<th>Status</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>P82B96TD</td>
<td>Bus buffer</td>
<td>Used in QPS in the tunnel</td>
<td>Works fine up to 500 Gy</td>
</tr>
<tr>
<td>SN74LVTH16245ADGGR</td>
<td>Bus Transceiver</td>
<td>Tested by R2E</td>
<td></td>
</tr>
<tr>
<td>SSSB231</td>
<td>FIELDRIVE line driver</td>
<td>Used in QPS in the tunnel</td>
<td>Works fine up to 500 Gy</td>
</tr>
<tr>
<td>AT25DN512C-SSHF-B</td>
<td>Flash Memory</td>
<td>Tested by R2E</td>
<td>Works fine up to 1000 Gy</td>
</tr>
<tr>
<td>LT3083EQ#PBF</td>
<td>Linear Regulator</td>
<td>Tested by R2E</td>
<td></td>
</tr>
<tr>
<td>ADUC831BSZ</td>
<td>MCU</td>
<td>Used in QPS in the tunnel</td>
<td></td>
</tr>
<tr>
<td>LFSPX50018042</td>
<td>Oscillator</td>
<td>24&amp;25MHz of the same series tested</td>
<td></td>
</tr>
<tr>
<td>M2GL010-TQ144</td>
<td>IGLOO2 FPGA</td>
<td>Family tested by R2E</td>
<td>Works fine up to 450 Gy</td>
</tr>
<tr>
<td>A3P400-1PQG208I</td>
<td>ProASIC3 FPGA</td>
<td>Used in QPS in the tunnel</td>
<td>Survived 130 Gy</td>
</tr>
<tr>
<td>PM54002EJ</td>
<td>Shottky diode</td>
<td>CHARM test by TE-MPE-EP</td>
<td></td>
</tr>
<tr>
<td>BAV99LT1G</td>
<td>Diode</td>
<td>Used in QPS in the tunnel</td>
<td>Works fine up to 1000 Gy</td>
</tr>
<tr>
<td>BZX5C3V9</td>
<td>Zener Diode</td>
<td>Tested by R2E Co60</td>
<td></td>
</tr>
<tr>
<td>BZX5C6V2</td>
<td>Zener Diode</td>
<td>Tested by R2E Co60</td>
<td></td>
</tr>
</tbody>
</table>
System-level R2E considerations

- If schedule allows, system-level test should be done in CHARM up to 500 Gy for a modified DQLPU-S crate that hosts new DQQBS boards, DQQDS boards (symmetric quench detection for MB&MQ) and new nanoFIP field-bus clients
Summary

- Two prototypes of the FPGA (nanoFIP IP) based field-bus QPS clients have been designed to replace vulnerable QPS field-bus clients in the LHC.
- Few (non-critical) components left to be qualified in radiation.
- Testing the DQLPU-S crate hosting new field-bus client and new bus-bar detection board would be beneficial.
- Prototype evaluation expected to be finished in coming months.
  - Expected production in Q3 2021.
- Deployment campaign might start in 2021.
Thank you for your attention!

Questions?