Open hardware and big science
A CERN perspective

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Outline

1. Introduction to CERN
2. Introduction to Open Source Hardware
3. Open Source Hardware in practice
4. How to get organised
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Accelerators

CERN Accelerator Complex

- Large Hadron Collider (LHC)
- Super Proton Synchrotron (SPS)
- 27km long, 150m underground
- CERN LAB 1 (Switzerland)
- CERN LAB 2 (France)
- Proton Synchrotron (PS)
- Geneva Airport
- Lake Geneva
... the results of its experimental and theoretical work shall be published or otherwise made generally available.

CERN Convention, Paris, 1st July, 1953
How to interpret one’s dissemination mandate in the 21st century
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Why we use Open Hardware

Design re-use
- When it’s Open, people are more likely to re-use it.
- When it’s Open, people are much more likely to contribute.

Peer review
- Get your design reviewed by experts all around the world.
- Therefore the designs will become better.

Dissemination of knowledge
- One of CERN’s key missions!
Why we use Open Hardware

Get a design just the way we want it
- We specify fully the design.

Healthier relationship with companies
- No vendor-locked situations. Companies selected solely on the basis of technical excellence, good support and price.

Spend money where you or your funding agencies want
- Makes life easier for public institutions.
- Opens the door to smaller companies with good local support.
There is an Open Source Hardware definition!

Check out http://www.oshwa.org/definition/

- Inspired by the Open Source definition for software.
- Focuses on ensuring freedom to *study, modify, distribute, make and sell* designs or hardware based on those designs.
- Now we know exactly what we mean when we say OSHW!
CERN Open Hardware License – ohwr.org/cernohl

Provides a solid legal basis

- Developed by Knowledge and Technology Transfer Group at CERN.
- Open Software licences not usable (GNU, GPL, ...).

Practical: makes it easier to work with others

- Upfront clear: anything you give is available to everyone.
- Everyone can use it for free.
- No strings attached. Really!
CERN Open Hardware License – ohwr.org/cernohl

Same principles as Open Software

- Anyone can see the source (design documentation).
- Anyone is free to study, modify and share.
- Any modification and distribution under same licence.
- Persistence makes everyone profit from improvements.

Hardware production

- When produce: licensee is invited to inform the licensor.
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Example: SPEC - Simple PCI Express FMC carrier
Made in Spain, The Netherlands, Greece & Poland
Example of a project in the Open Hardware Repository – ohwr.org

Overview

Project description

A simple 4-lane PCIe carrier for a low pin count FPGA Mezzanine Card (VITA 57). It supports the White Rabbit timing and control network. Commercially available. Linux and Labview drivers available for some mezzanine cards.
More info at the Wiki page

Project details

- Subprojects: Getting Started with the SPEC, Simple PCIe FMC carrier (SPEC) - Software, SPEC box 1 Node, SPEC Box 3 Nodes (Rack 19")

Members

Manager: Erik van der Bij; Javier Serrano; Matthieu Cattin; Tomasz Włostowski
Developer: Alessandro Rubini; Benoit Rat; Carlos Gil Soriano; Federico Vaga; Grzegorz Daniluk; Grzegorz Kasprowicz; Martin Brückner; Ralf Wischniewski; Samuel Iglesias Gonsálvez
Reporter: Cesar Prados; Dietrich Beck

Latest news

SPEC Fan design files released
Be Open

Use OHR to the fullest

- Document everything on OHR:
  - schematics, mechanics, status.
- Discuss over mailing list. Already from start of project.
- Document design review results.
- Track Issues and detected bugs.

Don’t be afraid to show mistakes!

- E.g. SPEC: 86 Issues documented, 40 still ’Open’.
- Issues may help others when adapting a design.
- OHR becomes a teaching tool.
White Rabbit – Innovation with Open approach

- Hardcore innovation.
- An enabling technology.
- Started at CERN and GSI high-energy physics labs.
- Everything Open: hardware, gateware, software.
- Made extensive use of small companies to develop.
- Companies develop and sell products based on it.
White Rabbit – is Ethernet

- Bandwidth: 1 Gbps
- Single fiber medium
- Up to 10 km links
- WR Switch: 18 ports
- Ethernet features (VLAN) & protocols (SNMP)
- Synchronization:
  - accuracy better than 1 ns
  - precision (tens of ps sdev skew max)
WR time transfer performance: lab tests
3 cascaded switches
WR time transfer performance: lab tests
3 cascaded switches

Histogram of offsets between master and each slave

- **Master (CH1)**
- **Slave 1 (CH2)**
  - mean = 161.86 ps
  - sdev = 5.45 ps
- **Slave 2 (CH3)**
  - mean = 24.67 ps
  - sdev = 5.30 ps
- **Slave 3 (CH4)**
  - mean = -135.25 ps
  - sdev = 6.14 ps
White Rabbit applications

- Particle accelerators
  - CERN (Switzerland/France)
  - GSI (Germany)
White Rabbit applications

- Particle accelerators
  - CERN (Switzerland/France)
  - GSI (Germany)
- Cosmic ray & neutrinos detectors
  - LHAASO (China)
  - HiSCORE (Siberia)
  - KM3NET (Mediterranean)
- Metrology laboratories
  - MIKES (Finland)
  - VSL (Netherlands)

All users: [www.ohwr.org/projects/white-rabbit/wiki/WRUsers](http://www.ohwr.org/projects/white-rabbit/wiki/WRUsers)
How can this map to Quantum Engineering?

What could be your “killer app”?
## Business models

Dispelling the commercial vs open myth

<table>
<thead>
<tr>
<th>Open</th>
<th>Commercial</th>
<th>Non-commercial</th>
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<tbody>
<tr>
<td></td>
<td><strong>Winning combination. Best of both worlds.</strong></td>
<td>Whole support burden falls on developers. Not scalable.</td>
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<tr>
<td></td>
<td>Vendor lock-in.</td>
<td>Dedicated non-reusable projects.</td>
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Proprietary
Where the rubber meets the road
Seven years of experience at CERN
Free-as-in-freedom design tools
The last hurdle to efficient sharing - kicad-pcb.org
Free-as-in-freedom design tools

Similar case in the Quantum Engineering community?

Tools should be free and open to be able to share

- Simulation tools
- Control software
- Data processing tools
- Quantum Information Software
Hardware for quantum engineering projects
Duplication of effort: different labs build similar equipment

slide courtesy of G.Kasprowicz
Quantum engineering project: Sinara
Open source hardware for quantum applications

Sinara - github.com/m-labs/sinara/wiki
- Open-source hardware ecosystem designed for use in quantum physics experiments running ARTIQ control software.
- All design files, sources, mechanics, documentation published.
- Project shared under OHL, managed using github.

International collaboration
- Institutes: NIST Boulder, UMD, ARL, Warsaw WUT, Oxford University, Uni Hannover, PTB
- Industry: Mlabs, Quartiq, Creotech, Technosystem
Sinara hardware
Licenced under CERN OHL

- DDS (MTCA octal 2.4GS/s, Eurocard quad 1GS/s). Flexible analog front-ends
- ADC (MTCA octal 125MS/s, Eurocard octal 1MS/s)
- DAC (MTCA, Eurocard 32channel)
- Digital IO (BNC, SMA, LVDS)
- Deterministic real time controller (sub ns)
- Slow control VHDCI breakout
- Camera Link,
- Clock distribution
- 8 channel RF amplifier for AOM
- Many other modules in development (Piezo drivers, HV supplies, temperature controllers, magnetic field stabilisers)
- Control software (ARTIQ:https://m-labs.hk/artiq/) written mostly in Python including FPGA HDL, GPL
Quantum engineering project: Easy $\Phi$
Open source hardware for quantum applications

Easy $\Phi$ - easy-ph.ch

- Easy $\Phi$ is a platform aiming at physicists.
- Developed for the needs of quantum optics, usable for applications in physics or biology.
- Open standard platform.

Single institute, but Open

- University of Geneva
  - Group of Applied Physics in Optics
Easy Φ hardware
Licenced under CERN OHL

- Dual High-Speed Universal Input
- Dual High-Speed Universal Output
- Dual High-Speed Delay Line
- High speed coincidence
- Thermocouple temperature measurement
- Optical amplitude modulator
- ...

Rack 4U 63F with 12 modules
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Public institutions

They serve the interests of a whole society

- Try to maximise positive impact of decisions.
- Not always easy.
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Can be “tractor” institutions
- To help take projects to a mature state where they can be sustained commercially.
- Liaising with other public institutions to reach critical mass.
- Also with their procurement hat.
The funding agencies conundrum
Issues with “coopetition”

Research groups sometimes end up behaving as private companies (but with public money!) because of wrong incentives by funding agencies.
Look at Open Hardware, Open Access... even CERN itself! These things looked highly improbable before people got organised to make them happen.
Check out zenodo.org!

Why?

- Science cannot be open without open data ...
  - ... and software and hardware
- Avoid triple pay for tax payers
- Makes sharing research very easy!
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How?
- Open attitude from day 1
- Communities of interest in Zenodo
- Involving key commercial and non-commercial actors from the start
Quantum Engineering
How to get organised

- Open Hardware
- Open Software
- Site to collaborate
- Coordination
- Need for a “Tractor” institution?
So, how can the Quantum Engineering Community get organised?