

Open Source Hardware at CERN

Erik van der Bij

CERN, Geneva, Switzerland

Open Science: CERN perspectives
Geneva, 6 November 2019

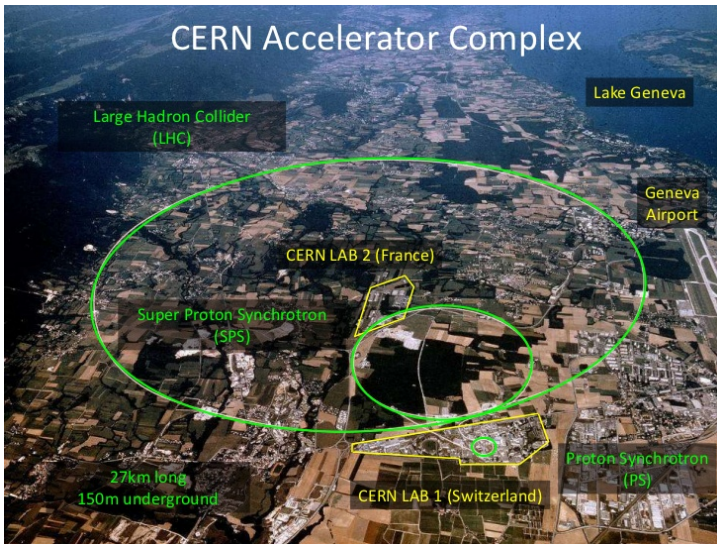
Outline

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

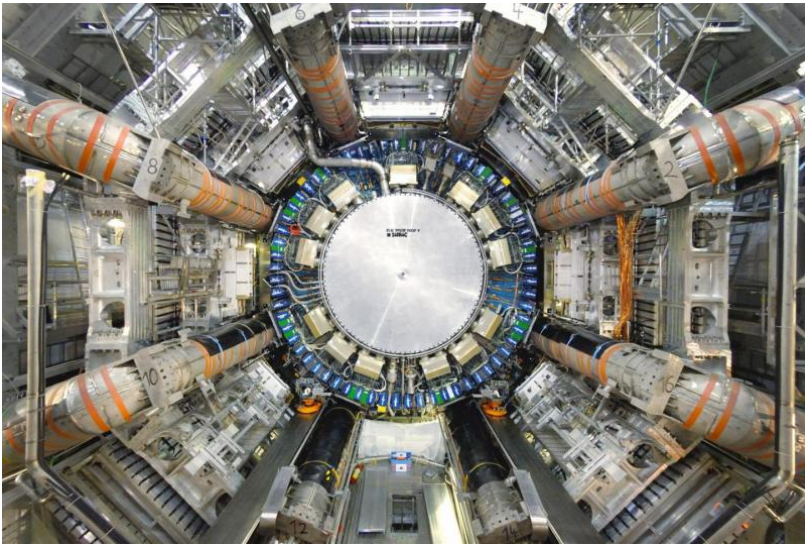
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Accelerators



Detectors



Dissemination



How to interpret one's dissemination mandate in the 21st century

Free and Open Source Software

Open Hardware

Open Data

Open Access

World Wide Web

open source

Open Hardware Repository

INSPIRE

An Updated Historical Profile of the Higgs Boson

Information Management: A Proposal

Tim Berners-Lee, CERN, DD

March 1989

Vague but exciting...

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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

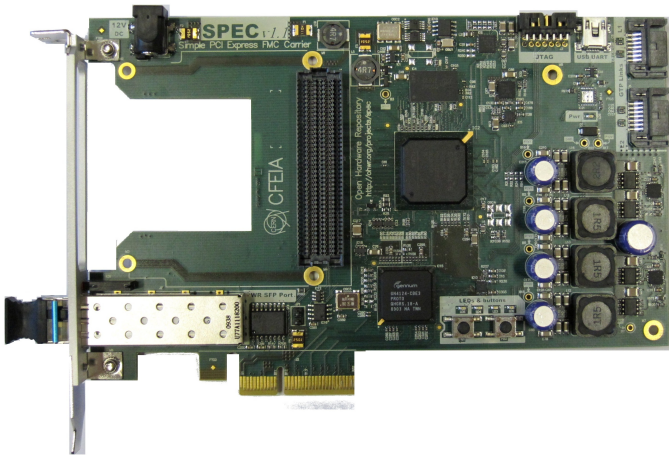
- When produce: licensee is invited to inform the licensor.

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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

Simple PCIe FMC carrier (SPEC) OPEN HARDWARE REPOSITORY

«

- Overview
- Activity
- Mailing List
- Roadmap
- Work packages
- News
- Repository
- Wiki
- Members
- Documents
- Project settings

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](#)

Edit

Members

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

Member View all members

Project details

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

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!

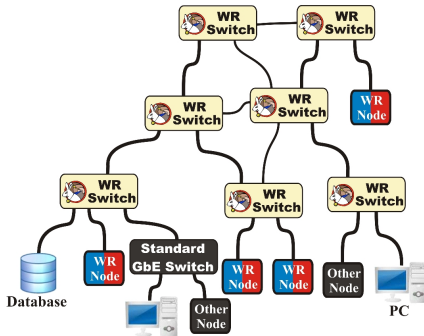
- E.g. SPEC: 86 Issues documented, 40 still 'Open'.
- Issues may help others when adapting a design.
- OHR becomes a teaching tool.

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)



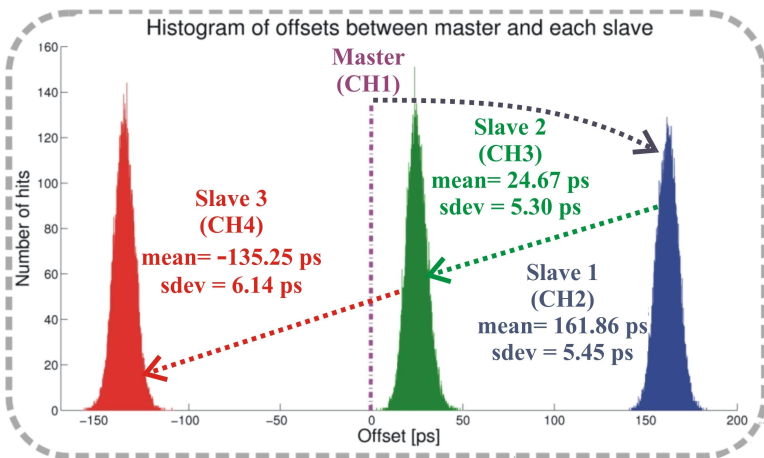
WR time transfer performance: lab tests

3 cascaded switches



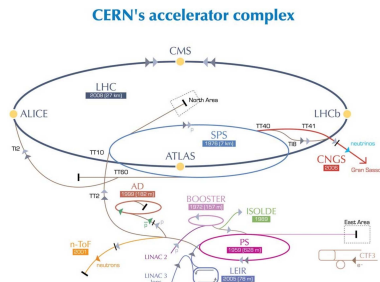
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White Rabbit applications

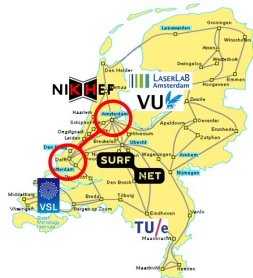
- Particle accelerators
 - **CERN (Switzerland/France)**
 - **GSI (Germany)**



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)**

Dutch Metrology Institute



All users: www.ohwr.org/projects/white-rabbit/wiki/WRUsers

How can this map to your project?

What could be your “killer app”?

Business models

Dispelling the commercial vs open myth

	Commercial	Non-commercial
Open	Winning combination. Best of both worlds.	Whole support burden falls on developers. Not scalable.
Proprietary	Vendor lock-in.	Dedicated non-reusable projects.

Where the rubber meets the road

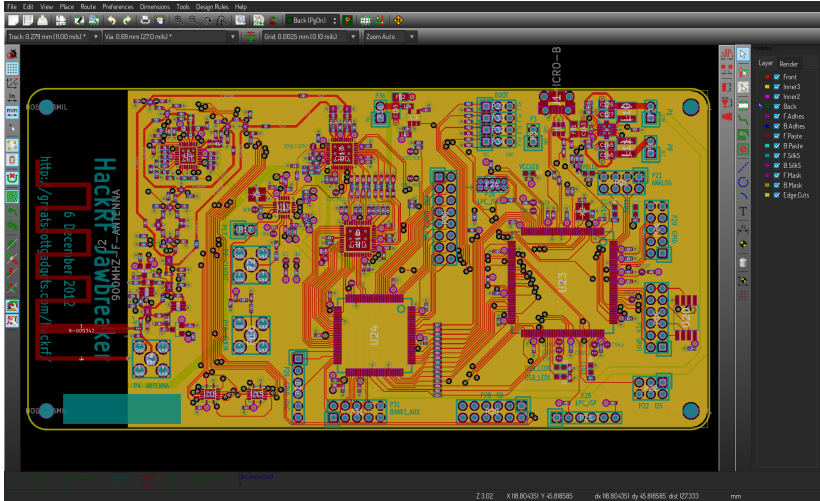
Eight years of experience at CERN

The collage consists of four overlapping screenshots of hardware-related websites:

- Top Left:** Screenshot of the SEVEN Solutions website. The main heading is "WR Switch (18/8 SFPs)". It describes the White Rabbit Switch (WRS) as a key component for precision timing and high synchronization over Ethernet. It lists two standalone SFP versions and highlights main features such as Virtex-6 FPGA, ARM (Atmel AT91SAM9G45) @ 400MHz, 18/8 x SFP cages, 32H x 16 DDR2, Two 512Kx36 QDRII SRAM, Ethernet 10/100 PHY, 256 MB NAND Flash, 8 MB SPI Boot Flash, 5 SMC coaxial Clocks (PPS I/O, 125MHz I/O, 10MHz), and 1.6 GHz VCO (AD9516-4).
- Top Right:** Screenshot of the INGAA website. The main heading is "4ch 105 Mps 30 MHz 14 bit ADC". It lists features for a 4 channel FMC ADC module, including a max sample rate of 105 Mps, analog bandwidth of 30 MHz, DC-coupled bits, ENOB of 11, 11.5, 11.7 bits, 4 channels, and connections for signals and triggers.
- Bottom Left:** Screenshot of the janztec website. The main heading is "Simple VME FMC Carrier". A physical carrier board is overlaid on the page, showing a label with "QC Pass 11/13/105", "JC", "Simple VME FMC Carrier", "VME FMC", "40-PIN-SFP", "1000000000", and "HCCV01".
- Bottom Right:** Screenshot of the CERN TECH website. The main heading is "Simple PCIe FMC carrier (SPEC)". It includes a list of supported FMCs and a description of the carrier's capabilities, such as holding an FMC card and an SFP connector, and being optimized for cost and ease of use.

Free-as-in-freedom design tools

The last hurdle to efficient sharing - kicad-pcb.org



Free-as-in-freedom design tools

Example: similar case in the Quantum Engineering community?

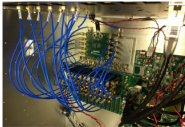
Tools should be free and open to be able to share

- Simulation tools
- Control software
- Data processing tools
- Quantum Information Software

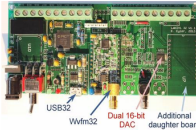
Hardware for quantum engineering projects

Duplication of effort: different labs build similar equipment

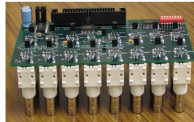
DDS



DAC



Digital IO



AOM driver



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

Licensed 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 Φ

Open source hardware for quantum applications

Easy Φ - easy-ph.ch

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

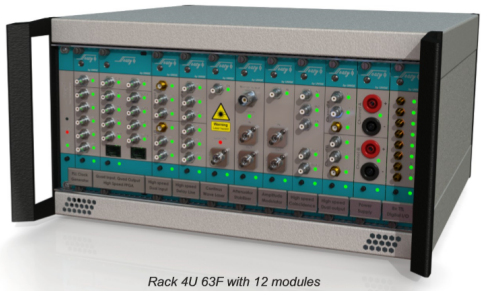
Single institute, but Open

- University of Geneva
 - Group of Applied Physics in Optics

Easy Φ hardware

Licensed 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.

The power of getting organised

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 double pay for tax payers
- Makes sharing research very easy!

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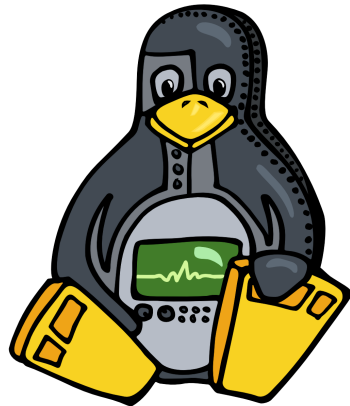
How?

- Open attitude from day 1
- Communities of interest in Zenodo
- Involving key commercial and non-commercial actors from the start

OpenX

How to get organised

- Open Hardware
- Open Software
- Site to collaborate
- Coordination
- Need for a “Tractor” institution?



So, how can the OpenX Community get organised?

