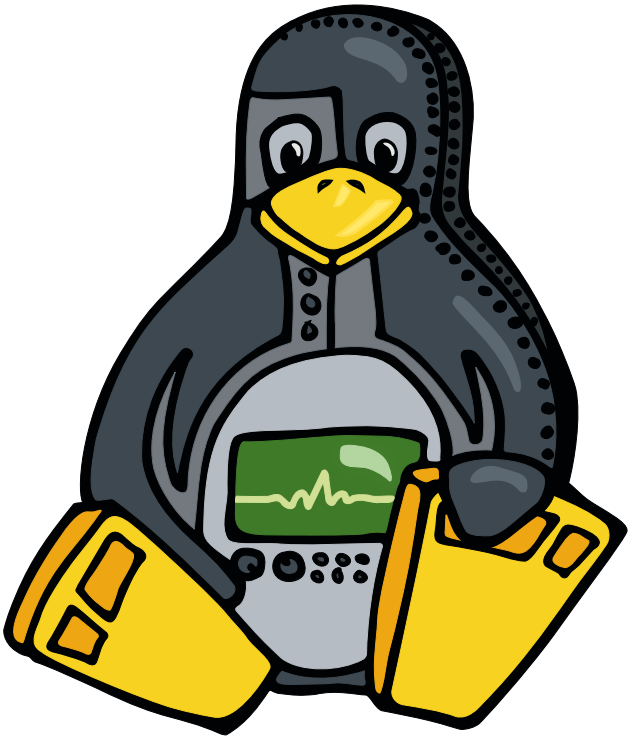
# OPEN HARDWARE AT CERN



CERN is actively making its knowledge and technology available for the benefit of society and does so through a variety of different mechanisms. Open hardware has in recent years established itself as a very effective way for CERN to make electronics designs and in particular printed circuit board layouts, accessible to anyone, while also facilitating collaboration and design re-use. It is creating an impact on many levels, from companies producing and selling products based on hardware designed at CERN, to new projects being released under the CERN Open Hardware Licence. Today the open hardware community includes large research institutes, universities, individual enthusiasts and companies. Many of the companies are actively involved in the entire process from design to production, delivering services and consultancy and even making their own products available under open licences.

*Open source hardware is hardware whose design is made publicly available so that anyone can study, modify, distribute, make, and sell the design or hardware based on that design.*

Open Source Hardware Association
oshwa.org/definition

CERN's main mission is fundamental research, probing the structure of the universe by using particle accelerators and detectors. Constantly pushing the frontiers of technology, the organization has a culture of innovation, often leading to tangible benefits for society. The World Wide Web is the most famous example. Initially created for scientists to share information, it has now grown to revolutionize communication worldwide.

Following on from the Web, CERN has continued to make many of its software developments open to the public. Recognizing the benefits that an open source philosophy could provide to hardware development and dissemination, a group of electronics designers working in the Beams Department at CERN created the Open Hardware Repository in 2009. Its manifesto states: "The Open Hardware Repository is a place on the web for electronics designers at experimental physics facilities to collaborate on open hardware designs, much in the philosophy of the free software movement".

Just as with open source software, open hardware needs a solid legal framework for distribution. CERN explored different options and it was clear that using an existing software or documentation licence was not sufficient to support the end result – creation of a tangible product. This led to the creation of the CERN Open Hardware Licence. The licence governs the use, copying, modification and distribution of hardware design documentation and the manufacturing and distribution of products based thereon. The licence essentially gives anyone these rights with the condition that new developments are published under the same terms. Therefore any improvements made by the open hardware community will be accessible to everyone.

## Benefits of an open hardware approach

Many of the advantages associated with open source software are applicable also to open hardware. A key component is a community of designers working together and sharing their knowledge to develop the best possible solutions. Engineers and researchers working on a project can receive feedback from a wider community on how to improve their design, effectively creating a 'peer review' process. In addition, as the design and documentation will be reviewed, many hardware designers strive to increase the quality on both designs and documentation.

Open hardware is a mechanism for making electronics designs accessible to a wider audience, allowing anyone to pick up and use them – be it for commercial or academic purposes, or simply just for curiosity's sake. Widely disseminating hardware designs also makes it more likely that they can be used for applications outside of the high-energy physics domain, thus widening CERN's impact on society.

Companies have found that 'going open' does not contradict being commercial. Of clear benefit to the companies is the use and re-use of existing designs or the customization of designs for a specific customer, thereby effectively reducing design costs. Additionally, if a company has appropriate production

*At CERN, open hardware is used for the timing system of the Antiproton Decelerator, among many other applications*

facilities, they can add any design licensed under an open hardware licence to their product portfolio. By releasing their own products under an open hardware licence, companies can also benefit from 'peer review', leading to improved products, more closely aligned to end-user requirements. If someone makes a redesign, modification or solves a bug for a particular piece of hardware, this new design will then be released under the same conditions.

The open hardware repository has a very collaborative community with significant knowledge-sharing. For companies this can assist them in accessing expertise they do not have in-house. Companies specializing in hardware design, for instance, can add a new project to the repository and subsequently benefit from community-wide reporting of bugs, in addition to helping solve them. They can also benefit from related developments, such as specialized software made for the device and released as open source software. On the other side, a software company can benefit from the feedback of the hardware company. This can be particularly valuable for SMEs, which often do not have the necessary resources to do all of the developments themselves.

Visibility is another important factor for companies participating in open hardware projects. It helps the company to attract new business, not only on the basis of their product portfolio, but also on the competences they demonstrate while taking part in open projects. Companies participating in the open hardware community are therefore also selling their expertise, installing systems and providing consultancy. This benefits the community as it allows hardware designers to focus on designing rather than on providing support, while also creating economic incentives for participating in the development of new open projects to gain this experience.

## Impact

*More than 1200 units have been produced for more than 100 different end-users*

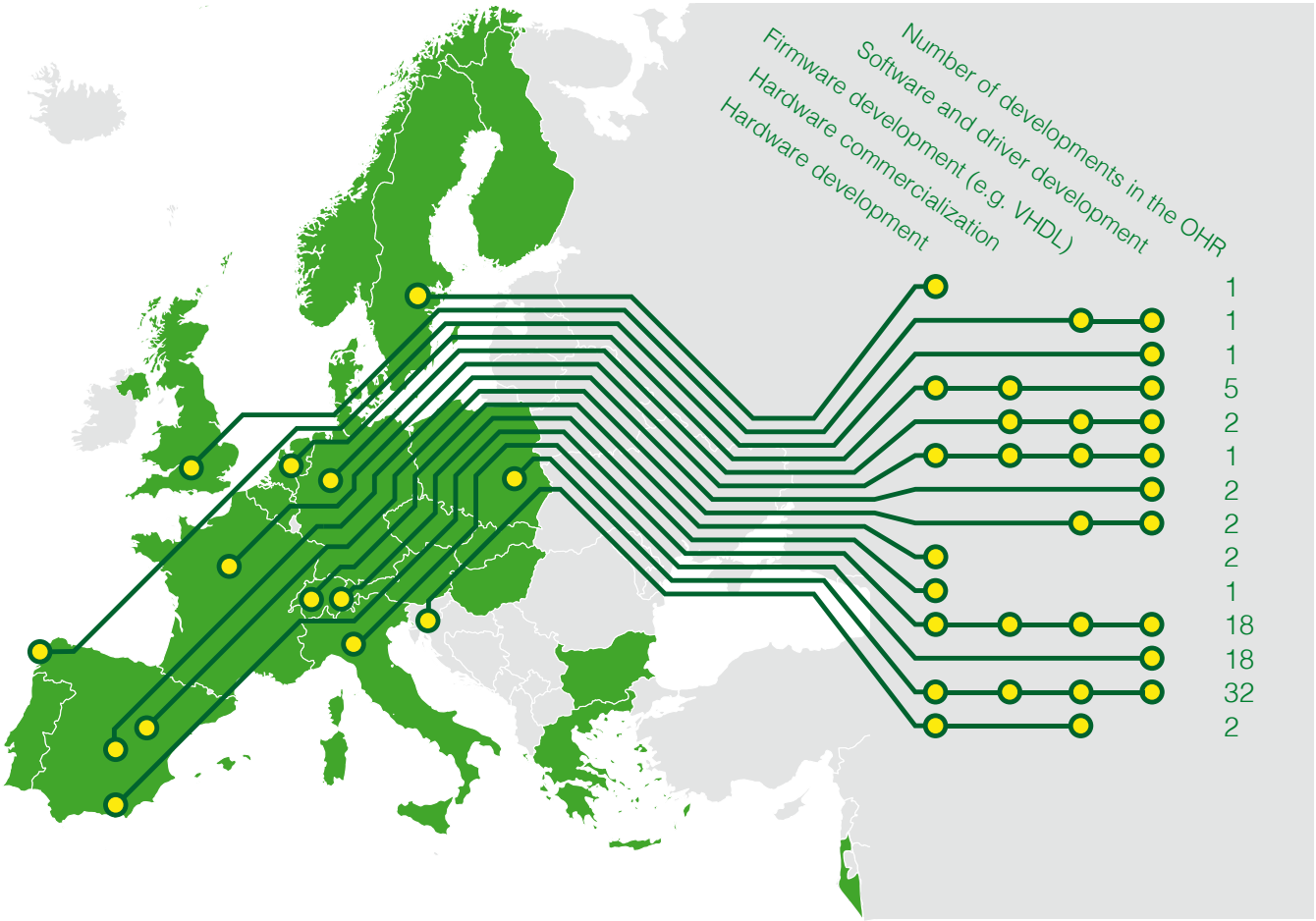
Open hardware allows anyone to study, modify, use and produce the design. Measuring the impact of such open models is therefore intrinsically difficult. Even so, there are several examples where the impact of CERN's efforts is clear.

Companies, research institutions and individuals are adopting the CERN Open Hardware Licence as a way for them to share their designs. The licence is used for most of the hardware projects hosted in the Open Hardware Repository. However, the use of the licence is not limited to projects in the open hardware repository and companies operating in markets far from high-energy physics have adopted the licence. Companies and individuals are using the licence on products ranging from electronic modules for do-it-yourself projects

and music controllers to platforms for scientific instrumentation developed for quantum optics. Many projects for STEM education have embraced the licence, often providing the possibility for people to buy the parts and do the assembly themselves, while at the same time they are available as complete packages sold by small companies.

The Open Hardware Repository currently hosts more than 100 projects, ranging from small projects with a few collaborators to bigger projects with multiple contributors from both industry and academia. A dozen companies are actively involved in projects in the Open Hardware Repository and some of them are producing the physical hardware for CERN and other customers. CERN plays an important part also as a pilot customer for the hardware, legitimizing

*Map of CERN's Member States (green) showing where European companies are using the Open Hardware Repository, the areas they are involved in and the number of developments they take part in*



the quality, thus making it easier for companies to sell it to other customers at a later stage. The Open Hardware Repository has led to an unprecedented re-use of existing design among scientific collaborators and internally at CERN.

An overview made at the end of 2014 showed that of the eight CERN designs commercially available, more than 1200 units were produced for almost 100 different users. This shows that open hardware developed at CERN can lead to the creation of commercially-successful products sold by European industry.

## *White Rabbit*

*"White Rabbit offers a tremendous opportunity to get into the nanosecond range and we are working intensely to bring this capability to distributed systems"*

Jim Truchard, CEO National Instruments

Fittingly named both as an excellent 'timekeeper' and as the starting point of CERN's journey into the open hardware space, the White Rabbit (WR) project is particularly important. WR is a timing system initially developed for experimental physics facilities able to synchronize up to 1000 nodes with sub-nanosecond accuracy over fibre lengths of up to 10 km. The project, initiated by CERN and GSI in Germany, involves multiple companies, research institutions, universities and individuals in the further development of the original design and over 20 sub-projects for specific components. This shows that open hardware allows for efficient collaboration between many different public and private entities.

Several European companies are already producing and selling WR modules and offering services and installation of systems to both industry and academia. Astronomy is a field where WR seems to have significant potential and it is already used for the timing system in the gamma- and cosmic-ray experiment HiSCORE-EA at the Tunka site in Siberia. The Cherenkov Telescope Array and the LHAASO Telescope are planning to use WR for their timing systems. Comparison and synchronization of geographically-distant atomic clocks is another application being tested in Finland and the Netherlands. Most of these projects are collaborating with European companies for development, support and future procurement. Some other foreseen uses are in finance, telecommunication and energy, all of which are in need of accurate time measurements.

*Commercially available SPEC card*

## *SPEC*

The Simple PCIe FMC carrier (SPEC) is a data-acquisition card that can be plugged in to a PC, allowing the use of different FPGA Mezzanine Cards (FMCs), such as a digital input/output module, a time-to-digital converter and a fine delay module. The SPEC is the most widely-sold card offering WR support for synchronization. Several companies sell the card and are involved in its development. The SPEC cards have found their way to many scientific applications, such as fusion energy, tracking of space debris and control systems for accelerator complexes. Some of these companies have also produced

FMC modules for specific scientific projects or purposes, which they have added as projects in the open hardware repository and included as part of their product portfolio.

## Opening open hardware to everyone

To make electronics designs truly open, it must be possible to create and access them in formats not tied to proprietary software. Thus there is a need for tools for complex hardware designs that are free and open source. This is why CERN, as part of its broader efforts in open hardware, actively supports the development of two existing free and open source projects, KiCad and Icarus Verilog. KiCad is a tool for the design of schematics for electronic circuits and their conversion into printed circuit boards. Icarus Verilog is a simulation tool using the Verilog hardware descriptive language, which will also be extended to work with the VHDL language.

*Do what GCC did for free software in the hardware domain*

The aim of supporting these projects is to encourage and facilitate the exchange of designs and knowledge in a form that can be freely shared by all. This will greatly expand the number of possible users and projects that may benefit from these designs and increase the participation in the surrounding community. In addition, free and open source alternatives will provide great educational value, as students and academics will have a tool for learning about electronics through the design of actual circuits. The aspiration is to do for open hardware, what the GNU Compiler Collection (GCC) did for free software.

## Further information

For more information on the CERN Open Hardware Licence and the projects CERN is involved in, visit the Open Hardware Repository. The webpage includes many examples of open hardware developments at CERN and elsewhere.

*www.ohwr.org*

In addition to open hardware, CERN disseminates its intellectual property and technical competences through many different channels. For more information on possible ways of tapping into CERN's knowledge and technology, contact CERN's Knowledge Transfer Group:

*www.cern.ch/knowledgetransfer*

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