



FAIR Principles for Open Hardware

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Open Science Practices

- Provide accessible publications, data, software, methods and physical samples to the general public.
- Enable research verification, reuse, transparency.
- Enable trustworthiness in science
- Reduce social inequality by enabling anyone to access scientific knowledge



Free Software and Open Hardware

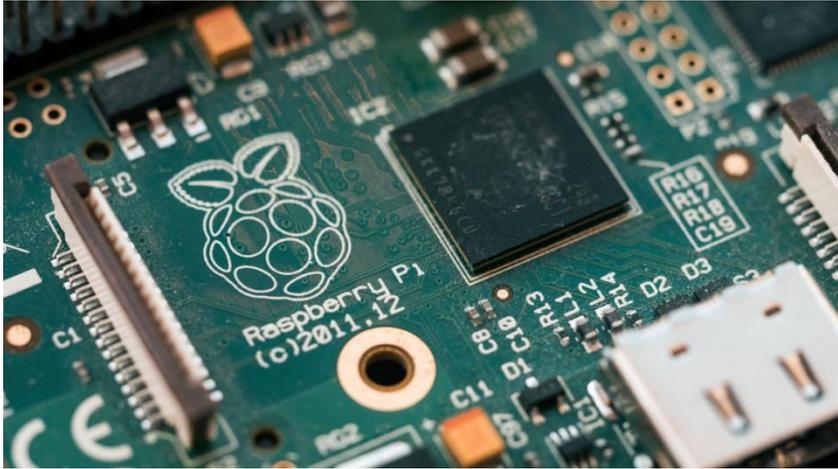
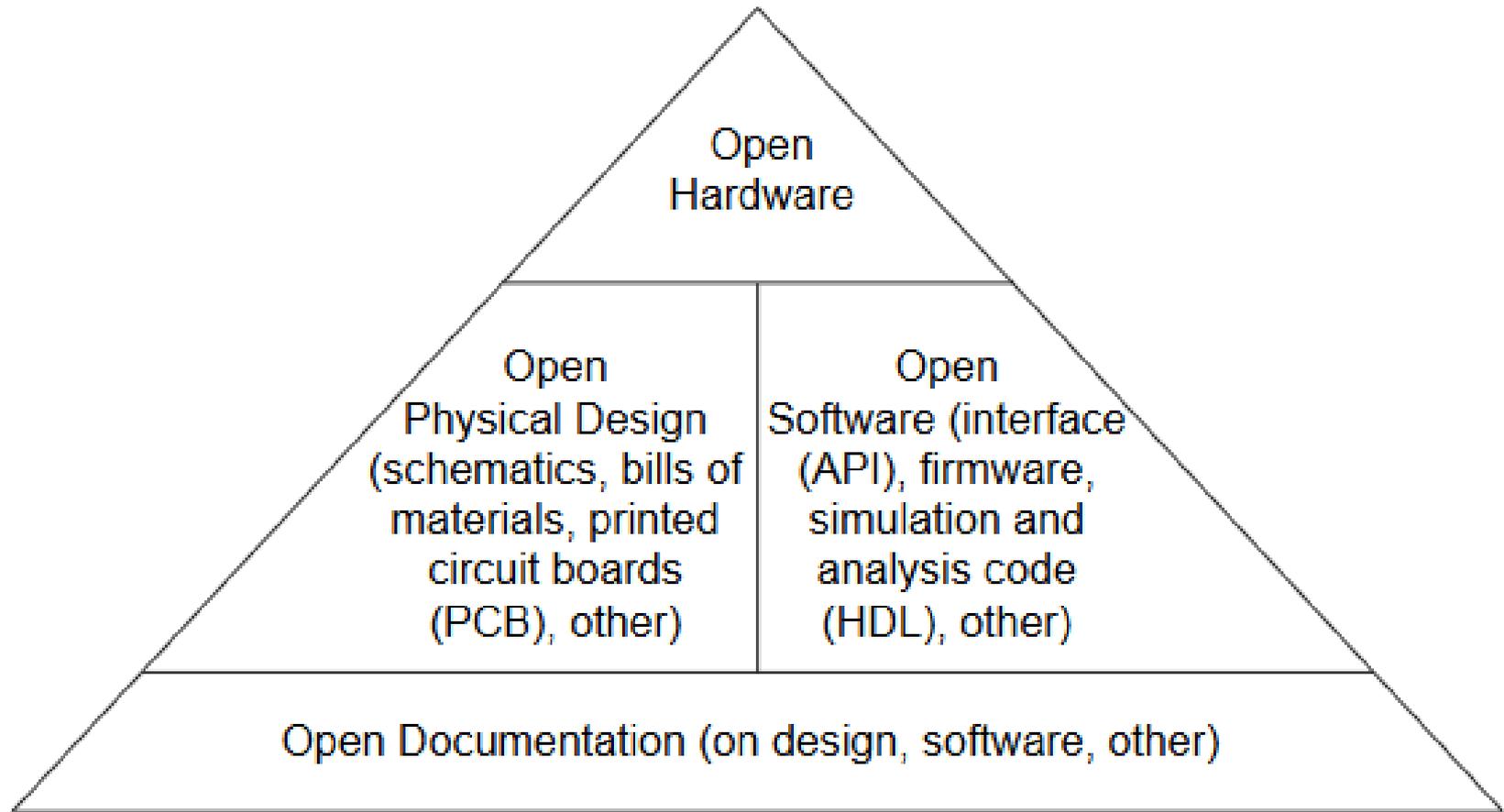


Photo by [Harrison Broadbent](#) on [Unsplash](#)

- Software and hardware are an integral part of the modern scientific process.
- Free and open/source software (FOSS) and open hardware (OH) follow open science practices.
- However, disseminating OH remains a challenge
- OH is modeled on FOSS, but the two are fairly different.

Open Hardware Components

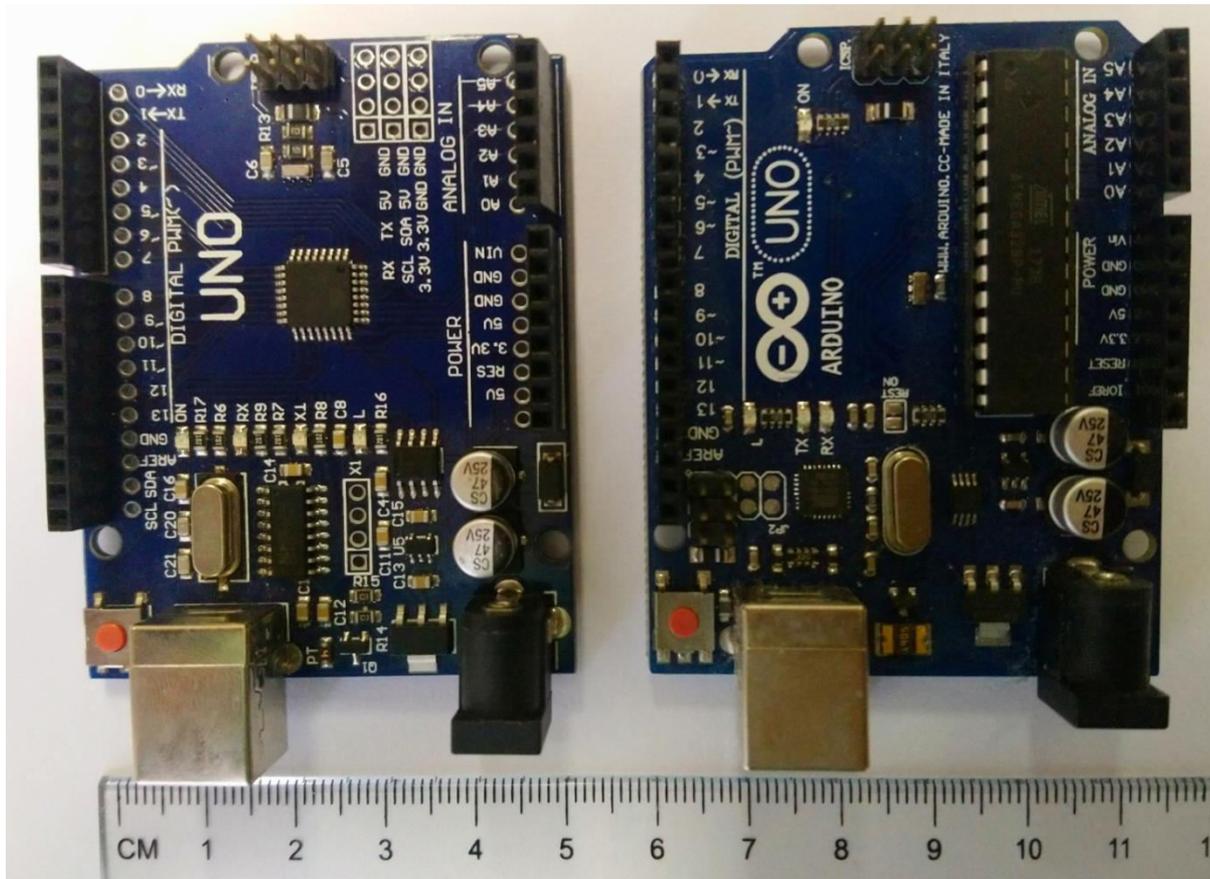


Components of OH, inspired by OSHWA (Open Source Hardware Association)

Identified challenges

- Choosing adequate licenses for OH design, software, data, and documentation
 - Separate licenses as proposed by OSHWA
- Identifying a dissemination channel (e.g., OSHWA, HardwareX, GitHub, or other)
 - Journals have more structure, but git-based platforms have more functionality
- Organizing, separating and interlinking resources (e.g., if software and hardware are used for the same purpose researchers tend to choose the same license)
 - Digital identifiers?
- Providing detailed metadata and documentation on OH to be reusable, modifiable, and reproducible.
 - Good practices and templates

OH example



UNO and Arduino UNO OH boards are released under CC license introduced in 2005 before establishment of dedicated OH licenses. Arduino has estimated revenue of \$56.8 M per year (<https://growjo.com/company/Arduino>). Photo credit N.M.



But, good practices are important

- They can ensure appropriate reusability and reproducibility
- This can lead to a wider adoption of OH
- Better science
- And to success!

FAIR as a solution

- FAIR stands for Findable, Accessible, Interoperable, and Reusable
- FAIR is meant to be applied to all digital assets
- FAIR is “enhancing the ability of machines to automatically find and use the data, in addition to supporting its reuse by individuals.”
- Widely adopted for scientific data
- Currently extensively defined for research software
- To the best of our knowledge, this is first attempt to define FAIR for OH

scientific **data**

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The FAIR Guiding Principles for scientific data management and stewardship

Mark D. Wilkinson, Michel Dumontier, [...] Barend Mons 

Scientific Data **3**, Article number: 160018 (2016) | [Cite this article](#)

340k Accesses | **2935** Citations | **1912** Altmetric | [Metrics](#)

Wilkinson, M., Dumontier, M., Aalbersberg, I. *et al.* The FAIR Guiding Principles for scientific data management and stewardship. *Sci Data* **3**, 160018 (2016).

<https://doi.org/10.1038/sdata.2016.18>

F in FAIR for OH

Data (www.go-fair.org)	Research software [49]	Open Hardware (proposed)
<i>Findable</i>		
F1. (Meta)data are assigned a globally unique and persistent identifier	F1. <u>Software</u> is assigned a globally unique and persistent identifier	F1. <u>Hardware</u> is assigned a globally unique and persistent identifier through OSHWA or a trusted repository, such that each hardware design and software versions have <u>unique identifier</u>
F2. Data are described with rich metadata (defined by R1 below)	F2. <u>Software</u> is described with rich metadata	F2. <u>Hardware</u> is described with rich metadata (defined by R1 below)
F3. Metadata clearly and explicitly include the identifier of the data they describe	F3. Metadata clearly and explicitly include the identifier of the <u>software</u> they describe	F3. Metadata clearly and explicitly include the identifier (<u>DOI or OSHWA</u>) of the <u>hardware</u> they describe
F4. (Meta)data are registered or indexed in a searchable resource	F4. <u>Software</u> is registered or indexed in a searchable resource	F4. <u>Hardware</u> is registered or indexed in a searchable resource through <u>OSHWA</u> or a registry

A in FAIR for OH

Data (www.go-fair.org)	Research software [49]	Open Hardware (proposed)
<i>Accessible</i>		
A1. (Meta)data are retrievable by their identifier using a standardized communications protocol (the protocol is open, free, and universally implementable, and to allow for an authentication and authorization procedure, where necessary)	A1. <u>Software</u> is retrievable by its identifier using a standardized communications protocol	A1. <u>Hardware</u> is open and retrievable by its identifier using a standardized communications protocol (the protocol is open, free, and universally implementable, and to allow for an authentication and authorization procedure, where necessary). <u>OH files should be stored cohesively on a repository infrastructure (rather than in multiple disjointed locations), which support long-term hardware stewardship.</u>
A2. Metadata are accessible, even when the data are no longer available.	A2. Metadata are accessible, even when the <u>software</u> is no longer available	A2. Metadata is accessible, even when the <u>hardware</u> is no longer available.

I in FAIR for OH

Data (www.go-fair.org)	Research software [49]	Open Hardware (proposed)
<i>Interoperable</i>		
I1. (Meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation.	I1. Software should read, write or <u>exchange data in a way that meets domain-relevant community standards</u>	I1. Hardware uses a formal, accessible, shared, and broadly applicable language for knowledge representation used in both academia and industry (and <u>enabling their collaboration</u>).
I2. (Meta)data use vocabularies that follow FAIR principles	I2. <u>Software</u> includes qualified references to other <u>objects</u> .	I2. <u>Hardware</u> uses vocabularies that follow FAIR principles
I3. (Meta)data include qualified references to other (meta)data		I3. <u>Hardware</u> includes <u>cross-references</u> (to own software, data, documentation) and qualified references to other <u>objects</u> (e.g., software, data, documentation).

R in FAIR for OH

Data (www.go-fair.org)	Research software [49]	Open Hardware (proposed)
<i>Reusable</i>		
<p>R1. (Meta)data are richly described with a plurality of accurate and relevant attributes (with a clear and accessible data usage license, detailed provenance, whilst meeting domain-relevant community standards).</p>	<p>R1. Software is richly described with a plurality of accurate and relevant attributes</p> <p>R2. Software includes <u>qualified references to other software</u></p>	<p>R1. Hardware is richly described with a plurality of accurate and relevant attributes <u>that reflects its complex structure compliant with the OSHWA definition (with clear and accessible usage licenses, to be applied on each of the components and compatible with the dependencies, detailed provenance on all components (bill of materials, assembly instructions and other), whilst meeting domain-relevant community standards).</u></p> <p>R2. Hardware includes <u>qualified references to other hardware and available components (that would enable reuse).</u></p>

Beyond-FAIR challenges

- For FOSS and OH
 - Maintainability of the software
 - Version & Quality control
 - Computational efficacy
 - See for example output of CURE-FAIR RD WG, . Peer, F. Arguillas, T. Honeyman, N. Miljković, K. P.V. Gehlen, and C.F. W. S. 3, “Challenges of Curating for Reproducible and FAIR Research Output,” 2021, publisher: Research Data Alliance Version Number: 2.1. [Online]. Available: <https://zenodo.org/record/5094155#.YO0a8OgzaUk>
 - ...
- FOR OH
 - Schematics can be seen as both design file and software, and can even produce data
 - Industrial standards should be included in guidelines (currently DIN SPEC 3105)
 - ...

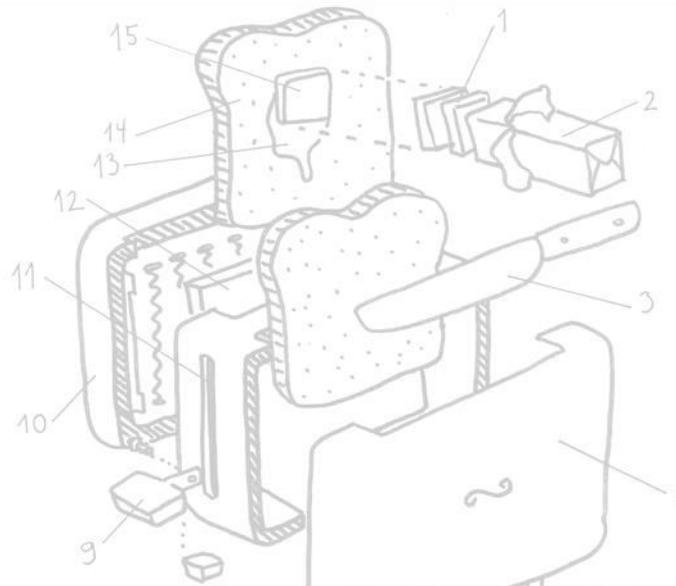
Advice for Open Hardware Practitioners

- Not all OH practitioners are scientists, but they can also use FAIR principles to share OH adequately
- They can also benefit from sharing "smartly"
- FAIR principles outline good practice in science and beyond



OSHWA Certification provides an easy and straightforward way for producers to indicate that their products meet a uniform and well-defined standard for open-source compliance.

[SHOULD I CERTIFY MY PROJECT?](#)





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