HOWTO create a culture of hardware sharing in the sciences?

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/dev/joh

- **One** of **many** possible ways: create an academic journal!

  ```
  # makedev -v joh
  ```

- **What are the benefits? Or, why should we care?**
  - For community projects:
    Provide peer-review for HW documentation, long-term preservation in a public, indexed repository to generate “prior-art” (with persistent IDs)
  - For scientific instrumentation projects:
    Create strong incentive for academics to release their hardware as a peer-reviewed publication, guiding solid documentation practices for wider reproducibility
  - To create interfaces**:**
    Between academic and community-based OH projects

/dev/joh: Journal of Open Hardware

- **Created** at the “Gathering for Open Science Hardware” developers at CERN in 2016
- **Meant** primarily as a forum for Free and Open Source researchers, community members, and hardware designers
- **Dedicated** OA publication format for Open Hardware projects
- **Community** control over its governance, content, pricing, and platform development in fair partnership with:

]u[ubiquity press
open scholarship

/dev/joh: documentation guidelines

- **Draw from community-vetted OH definitions and documentation guidelines**
- **Four freedoms + four orientations for hardware documentation:**
  - Accessible: clearly documented + open licensed;
  - Sufficient: provide all the conditions for studying and replication;
  - Findable: privilege long-term, indexed repos;
  - Open in process, not only end-product!
- **We publish in 4 categories** of academic + community interest:

  0. HW metapapers
  1. Socioeconomic studies on OH development
  2. Educational OH projects
  3. Reviews (of books, events...)

/dev/joh: HW metapaper

- **What is in a "HW metapaper" ?**
  - *Overview*
    (introduction, description of design and implementation)
  - *Quality control*
    (safety, calibration, testing)
  - *Application*
    (use case(s), reuse potential and adaptability)
  - *Build details*
    (availability, difficulty of build, sources, links)
  - *Discussion*
    (conclusion, future work)

[… plus, **persistent IDs** linking to **HW and SW sources + build instructions]**

/dev/joh: open scientific instruments

Journal of
open hardware

Wayland, MT and Landgraf, M 2018 A Cartesian Coordinate Robot for Dispensing Fruit Fly Food. *Journal of Open Hardware*, 2(1): 3, pp.1–8, DOI: https://doi.org/10.5334/joh.9

HARDWARE METAPAPER

A Cartesian Coordinate Robot for Dispensing Fruit Fly Food

Matthew T. Wayland and Matthias Landgraf

The fruit fly, *Drosophila melanogaster*, continues to be one of the most widely used model organisms in biomedical research. Though chosen for its ease of husbandry, maintaining large numbers of stocks of fruit flies, as done by many laboratories, is labour-intensive. One task which lends itself to automation is the production of the vials of food in which the flies are reared. Fly facilities typically have to generate several thousand vials of fly food each week to sustain their fly stocks. The system presented here combines a cartesian coordinate robot with a peristaltic pump. The design of the robot is based on an open hardware CNC (computer numerical control) machine, and uses belt and pulley actuators for the X and Y axes, and a leadscrew actuator for the Z axis. CNC motion and operation of the peristaltic pump are controlled by grbl (gnea 2018), an open source, embedded, G-code parser. Grbl is written in optimized C and runs directly on an Arduino. A Raspberry Pi is used to generate and stream G-code instructions to Grbl. A touch screen on the Raspberry Pi provides a graphical user interface to the system. Whilst the robot was built for the express purpose of filling vials of fly food, it could potentially be used for other liquid handling tasks in the laboratory.

Keywords: open source; Drosophila; CNC; liquid handling; Cartesian coordinate robot; Arduino; Raspberry Pi; G-code

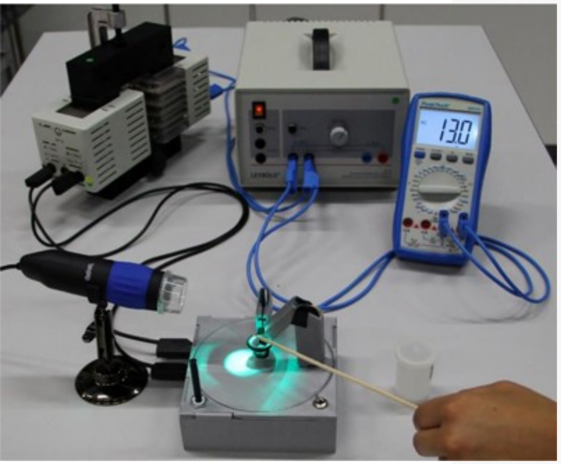
Metadata Overview

- Hardware design files: https://doi.org/10.5334/joh.9.s1.
- Software source code: https://doi.org/10.5281/zenodo.846812.
- User manual: https://waylandm.github.io/fly-food-robot/ (archived with software source code in: https://doi.org/10.5281/zenodo.846812).
- Target group: scientists and technicians working in the biological sciences.
- Skills required: laser cutting acrylic – easy; soldering through-hole components onto printed circuit boards – easy; cutting aluminium profile using a mitre saw – easy.

the model system for pioneering work that revealed the fundamental principles of genetic inheritance, specification of body plans, innate immunity and circadian rhythms. These groundbreaking discoveries led to six Nobel prizes in physiology and medicine, for a total of ten scientists (Manchester Fly Facility 2018).

One reason for Drosophila's success as an experimental model system is its straight forward maintenance in the laboratory environment. This enables scientists to breed large numbers of flies, and to generate and keep large numbers of genetically distinct stocks with relative ease and at comparatively low cost. Fruit flies are commonly reared in vials (glass, polystyrene or polypropylene) containing a small quantity of food (**Figure 1**). Fly food is pre-

/dev/joh: educational hardware



EDUCATIONAL HARDWARE

3D-Printable Model of a Particle Trap: Development and Use in the Physics Classroom

Lachlan McGinness[*,†], Susanne Dührkoop[*], Alexandra Jansky[*,‡], Oliver Keller[*], Ankatrin Lorenz[§], Sascha Schmeling[*], Klaus Wendt[‖] and Julia Woithe[*]

Quadrupole ion traps are modern and versatile research tools used in mass spectrometers, in atomic frequency and time standards, in trapped ion quantum computing research, and for trapping anti-hydrogen ions at CERN. Despite their educational potential, quadrupole ion traps are seldom introduced into the physics classroom not least because commercial quadrupole ion traps appropriate for classroom use are expensive and difficult to set up. We present an open hardware 3D-printable quadrupole ion trap suitable for the classroom, which is capable of trapping lycopodium spores. We also provide student worksheets developed in an iterative design process, which can guide students while discovering particle traps.

The quadrupole ion trap operates using a 3 kV 50 Hz alternating current power supply and uses an astable multivibrator circuit including high luminosity LEDs to illuminate the spores, using the stroboscopic effect to exhibit their movement.

The trap can be used in teaching laboratories to enhance high school and university students' understanding of electric fields and their applications.

Keywords: Physics Education; Quadrupole Ion Trap; Paul Trap; Particle Trap; 3D Printable

Metadata Overview

- Design files & accompanying documents: DOI: https://doi.org/10.5281/zenodo.1473292.
- Link: https://zenodo.org/record/1473292#.W9a-zaNUzaUk.
- Target group: secondary school students, undergraduate students, and their teachers.
- Skills required: Desktop 3D printing – easy; Point to

(1) Overview

Introduction

3D printing and 'making' in an educational context has become more prevalent and 3D printers are becoming more widespread in schools and universities throughout Europe, America and Australia [12, 19, 22]. There is also increasing focus on modern physics and particle physics in high school curricula [2, 4, 10]. However, particle physics

/dev/joh: empirical research

ISSUES IN OPEN HARDWARE

What is the "Source" of Open Source Hardware?

Jérémy Bonvoisin*, Robert Mies†, Jean-François Boujut‡ and Rainer Stark*

What "open source" means once applied to tangible products has been so far mostly addressed through the light of licensing. While this approach is suitable for software, it appears to be over-simplistic for complex hardware products. Whether such a product can be labelled as open source is not only a question of licence but a question of documentation, i.e. what is the information that sufficiently describes it? Or in other words, what is the "source" of open source hardware? To date there is no simple answer to this question, leaving large room for interpretation in the usage of the term. Based on analysis of public documentation of 132 products, this paper provides an overview of how practitioners tend to interpret the concept of open source hardware. It specifically focuses on the recent evolution of the open source movement outside the domain of electronics and DIY to that of non-electronic and complex open source hardware products. The empirical results strongly indicate the existence of two main usages of open source principles in the context of tangible products: publication of product-related documentation as a means to support community-based product development and to disseminate privately developed innovations. It also underlines the high variety of interpretations and even misuses of the concept of open source hardware. This reveals in turn that this concept may not even be clear to practitioners and calls for more narrowed down definitions of what has to be shared for a product to be called open source. This article contributes towards this effort through the definition of an open source hardware lifecycle summarizing the observed approaches to open source hardware.

Keywords: open source hardware; open design; open innovation; open source innovation; open source product development

1 Introduction

In present times, we are witnessing increasing numbers of initiatives transferring product development and production from the private sector to the public. Enabled by the growing accessibility of affordable manufacturing social and environmental potential. One of the challenges they face is that sharing knowledge about atoms is not as frictionless as sharing bits.

Both practitioners and the scientific community generally acknowledge that online sharing of a piece of

/dev/joh: economic studies

ISSUES IN OPEN HARDWARE

Emerging Business Models for Open Source Hardware

Joshua M. Pearce[*,†]

The rise of Free and Open Source models for software development has catalyzed the growth of Free and Open Source hardware (also known as "Libre Hardware"). Libre Hardware is gaining significant traction in the scientific hardware community, where there is evidence that open development creates both technically superior and far less expensive scientific equipment than proprietary models. In this article, the evidence is reviewed and a collection of examples of business models is developed to service scientists who have the option to manufacture their own equipment using Open Source designs. Profitable Libre Hardware business models are reviewed, which includes kit, specialty component, and calibration suppliers for makers. The results indicate that Libre Hardware businesses should target technically sophisticated customers first and, as usability matures, target expanded markets of conventional consumers.

Keywords: Open Source; Open Source Hardware; Libre Hardware; Business Models; Innovation

1. Can You Make a Business of Open Source Hardware?

Conventional business models for hardware sales normally involve creating artificial scarcity for a product by obtaining a monopoly over it (Demsetz, 1973; McGaughey, 2002; Smith, 2007; May, 2013). This is accomplished by either protecting the intellectual property (IP) (Teece, 2000) related to the product as a trade secret or with a patent, the latter of which provides an exclusive right to make and sell the product for 20 years in the U.S. and other members of the World Intellectual Property Organization (WIPO). This provides the firm with a monopoly over the product (Boldrin, 2005; Boldrin and Levine, 2008; 2009). Conventional business wisdom states that "failure to

and Open Source Software (FOSS) (Lerner and Triole, 2000; Lakhani and Von Hippel, 2003; Bonaccorsi and Rossi, 2003; Vetter, 2009). There is a large body of literature on the benefits of FOSS over established development models (Deek and McHugh, 2008; DiBona et al. 1999) which describes why firms would choose to liberate software-related IP and join collaborative and distributed development. The FOSS community has demonstrated through many successful software projects that, by facilitating participation in projects with little to no startup costs, meaningful contributions from the community can be made (Raymond, 1999; Lakhani and Von Hippel, 2003; Weber, 2004). Large-scale collaborations result in superior design with lower associated costs due to the continuous improvement, which leads

/dev/joh: conference reviews

REVIEW

Gathering for Open Science Hardware 2016

Shannon Dosemagen*, Max Liboiron† and Jenny Molloy‡

Without hardware, there is no science. Instruments, reagents, computers, and other equipment are essential for producing systematic knowledge. Yet, current supply chains limit access and impede creativity and customization through high mark-ups and proprietary designs, compounded by proprietary hardware licenses and patents. Open Science Hardware (OSH) addresses part of this problem by sharing designs, instructions for building, and protocols. Expanding the reach of OSH within academic research, NGO initiatives, citizen science, and education has potential to increase access to experimental tools and facilitate their customization and reuse. We organized with others the "Gathering for Open Science Hardware" (GOSH) in 2016 to address what we see as the primary barrier to OSH: early adopters are disparate and separated by geographical and disciplinary borders which limit interaction, exchange and community building. This inaugural gathering brought together 50 of the most active developers, users, and thinkers in the OSH movement, complemented by expertise from diverse backgrounds, to seed a global community. This article provides a review of the activities and debates we conducted at GOSH 2016.

Keywords: open science hardware

Introduction

What is the Gathering for Open Science Hardware (GOSH)?

Without hardware, there is no science. Instruments, reagents, computers, and other equipment are essential for producing systematic knowledge. Yet, current supply chains limit access and impede creativity and customization through high mark-ups and proprietary designs, compounded by proprietary hardware licenses and patents. Open Science Hardware (OSH) addresses part of this problem by sharing designs, instructions building. This inaugural gathering brought together 50 of the most active developers, users, and thinkers in the OSH movement, complemented by expertise from diverse backgrounds, to seed a global community. Now in its second year with a gathering in Santiago, Chile in 2017, GOSH fosters a community to overcome these difficulties, based on commonalities in approach and a need for similar standards, best practices and enabling technologies. Many developers of open hardware for science are highly active Internet citizens and already share designs and information online, often under

/dev/joh: book reviews

REVIEW

Sustainable Innovation for Open Hardware and Open Science – Lessons from The Hardware Hacker

Pen-Yuan Hsing

Sometimes, businesses restrict their hardware products with intellectual property legal instruments to maintain near-monopolies in market niches. This proprietary approach to technology risks creating anti-competitive rent-seeking behaviour and comes with its own set of economic and social costs. In *The Hardware Hacker*, Andrew 'Bunnie' Huang builds on his entrepreneurial experience in manufacturing hardware to provide a viable alternative. In addition to extensive tips on the practicalities of hardware mass production, Huang's book documents the thriving technology counterculture in Shenzhen, China's 'Silicon Valley'. Called the 'shanzhai', these entrepreneurs ignore patent and copyright restrictions and openly copy features from other products to remix them into new ones. While some call them thieves, shanzhai innovations pre-empted now-common device categories such as the smartwatch, and may address market niches unreachable by intellectual property-encumbered business models. Huang personally experimented with this approach (while operating within existing intellectual property laws) through his open hardware business ventures – notably the Novena open laptop – and in this book discusses the lessons learned. They include reflections on access to hardware as a form of civic action, implications of advances in biotechnology, and an optimistic view on the growth of open hardware in light of the deceleration of Moore's Law. Refreshingly accessible and entertaining, *The Hardware Hacker* shows us the importance of the right to tinker in an age where technology permeates all aspects of life.

Keywords: open hardware; open science; business models; intellectual property; innovation; entrepreneurship

Introduction

One method of introducing hardware innovations is spinning-off academic discoveries into marketable products. From my experience as a scientist, university technology transfer offices typically promote (or require) commercialising hardware through the aggressive enforce-

that touches on three broad themes: Practical advice for manufacturing hardware, the 'gongkai' approach to hardware innovation, and the future of open hardware. In this review, I will discuss examples from the book around these themes and their lessons for the open hardware community or anyone with an interest in the intersection

/dev/joh: conclusion ← CfP

Support FOSS and OH-focused research journals: one of the ways we can help create a culture of hardware sharing in academia!

If you know researchers working on scientific instruments or studying OH development, consider asking them to send us papers for peer-review:

- *Hardware Metapapers*
- *Educational Hardware*
- *Socioeconomic and legal issues in Open Hardware*
- *Book and event reviews*

Join us now and help liberate scientific hardware!
For more info, visit: journalofopenhardware.org