

Slides: <https://github.com/pdp7/talks/blob/master/oshw-bof-lfclc-pdx-2018.pdf>

Open Source Hardware

“Birds of a Feather” (BoF) session at
Embedded Linux Conference 2018 in Portland



Drew Fustini

OSH Park

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[@oshpark](https://twitter.com/@oshpark) / [@pdp7](https://twitter.com/@pdp7)





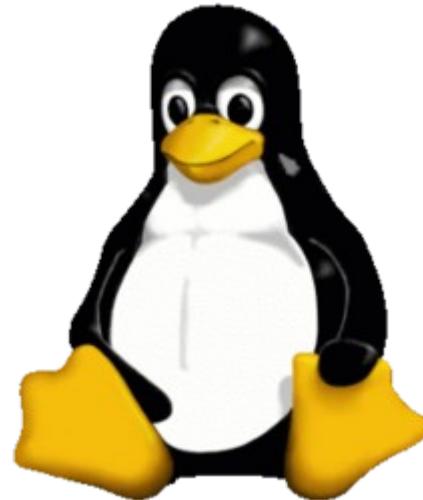
What is Open Source?



- Examples of popular Open Source projects



Apache



LibreOffice®



Firefox®



What is Open Source?

- The term "**open source**" refers to something people can **modify and share** because its design is **publicly accessible**
- **Open Source software** is software with source code that anyone can: **inspect, modify, and enhance**



What is Free Software?



A program is free software if the users have
four essential freedoms:

- 1) run the program as you wish, for any purpose
- 2) study how the program works, and change it
so it does your computing as you wish
- 3) redistribute copies so you can help your
neighbor
- 4) distribute copies of your modified versions



Open Source Hardware



- **FLOSS** is a term to describe software that is Free, Libre, or Open Source Software
- In the context of hardware projects, I consider these terms equivalent:
 - Free Hardware
 - Libre Hardware
 - Open Hardware
 - Open Source Hardware



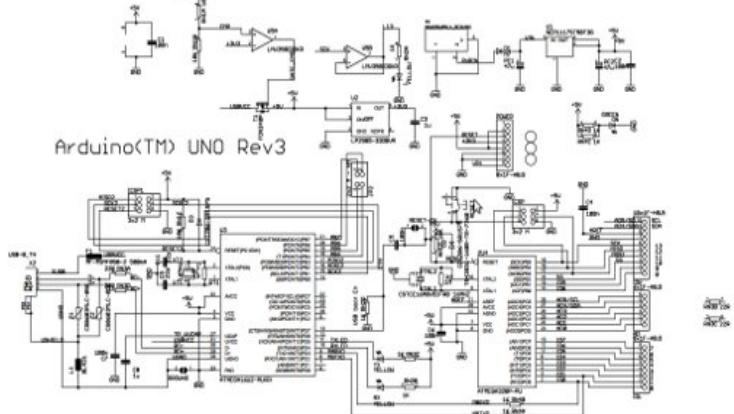
Statement of Principles:

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

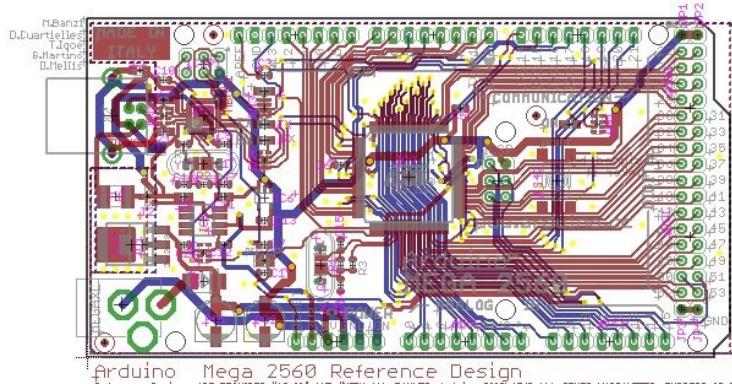
Open Source Hardware

Documentation required for electronics:

Schematics



Board Layout



Editable source files for CAD software such as KiCad or EAGLE

Bill of Materials (BoM)

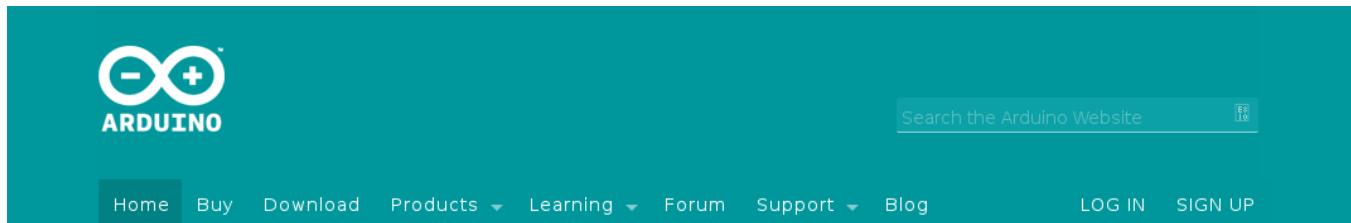
Best practice: all components available from distributors in **low quantity**



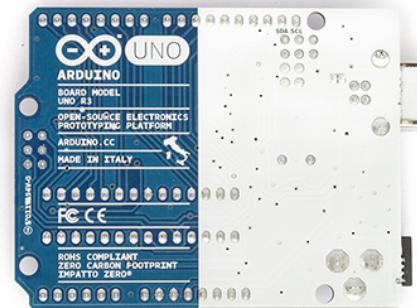
Open Source Hardware



Example: **Arduino** achieved critical mass by sharing their hardware designs and source code



Arduino Uno



Arduino: The Documentary describes the team's motivation



Open Source Hardware



- ✓ Example: [Arduino Uno](#) schematic and PCB layout design files for EAGLE CAD can be downloaded from [Arduino.cc](#)

The screenshot shows a web browser window with the Arduino website. The URL is https://www.arduino.cc/en/Main/ArduinoBoardUno. The page has a teal header with navigation links: Buy, Software, Products, Learning, Forum, Support, and Blog. On the left, there's a sidebar with links: Overview, Get Inspired, Related Items, Technical Specs, and Documentation (which is highlighted). The main content area is titled "Documentation" and includes a section for "OSH: Schematics, Reference Design, Board size". It says "Arduino / Genuino Uno is open-source hardware! You can build your own board using the following files:" followed by two download buttons: "EAGLE FILES IN .ZIP" and "SCHEMATICS IN .PDF".

Documentation

Overview

Get Inspired

Related Items

Technical Specs

Documentation



EAGLE FILES
IN .ZIP



SCHEMATICS
IN .PDF



Open Source Hardware



Publish documentation with an
Open Source license:

- Creative Commons Share-Alike: **CC-BY-SA**
 - Non-Commercial (NC) clause is NOT acceptable
- Copyleft: **GPLv2, GPLv3**
- Permissive: **Apache, BSD, MIT**
- OSHW inspired: **CERN OHL, TAPR, SolderPad**



CERN Open Hardware Licence

- Originally written for **CERN** designs hosted in the **Open Hardware Repository**
- Can be used by **any designer** wishing to **share design** information using a **license compliant** with the **OSHW definition criteria**.
- **CERN OHL version 1.2**
Contains the license itself and a guide to its usage



CERN Open Hardware Licence

Myriam Ayass, legal adviser at CERN and author of the CERN OHL:

- **OHL** is to hardware what **GPL** is to software
- Similar principles to Free or Open Source software
- Anyone should be able to:
see the source*, **study it**, **modify it** and **share it**

**the design documentation in case of hardware*



CERN Open Hardware Licence



- Video interview with [Javier Serrano](#)
- physicist and electronics engineer at CERN
- co-author of the **CERN Open Hardware License**
- creator of the **Open Hardware Repository**



Open Source Hardware



Licenses, Copyright and Patents
can get confusing!

Review of Popular OSHW Licenses

Video of Ari Douglas at OHS 2014

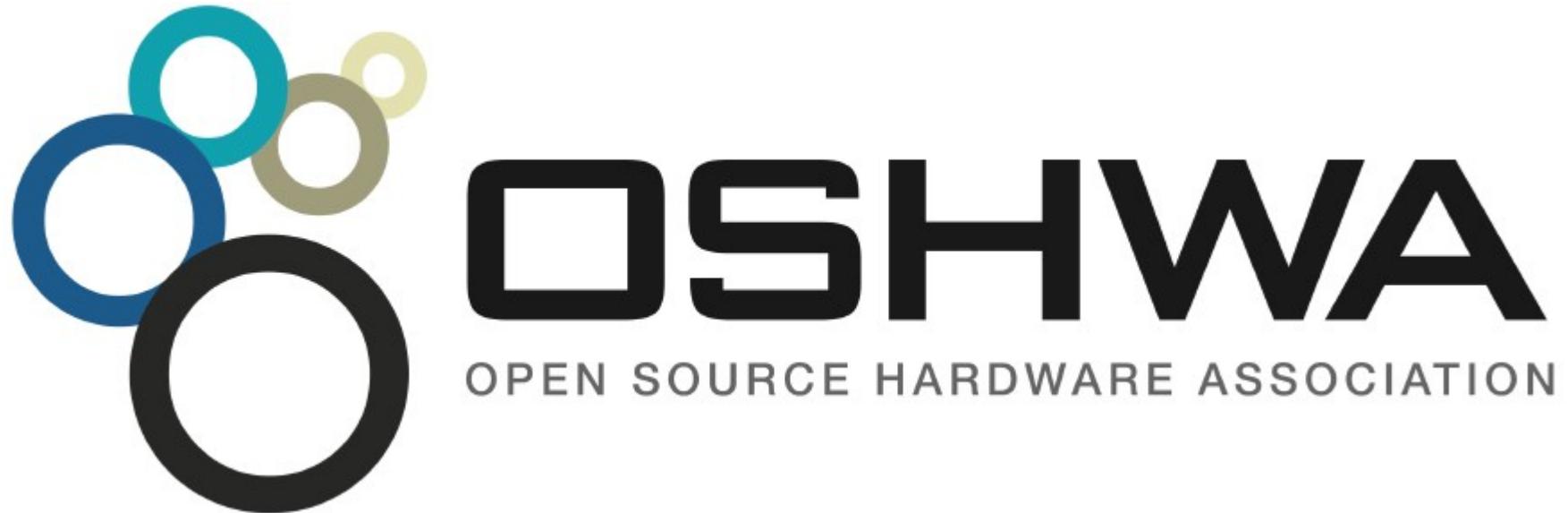


Open Source Hardware

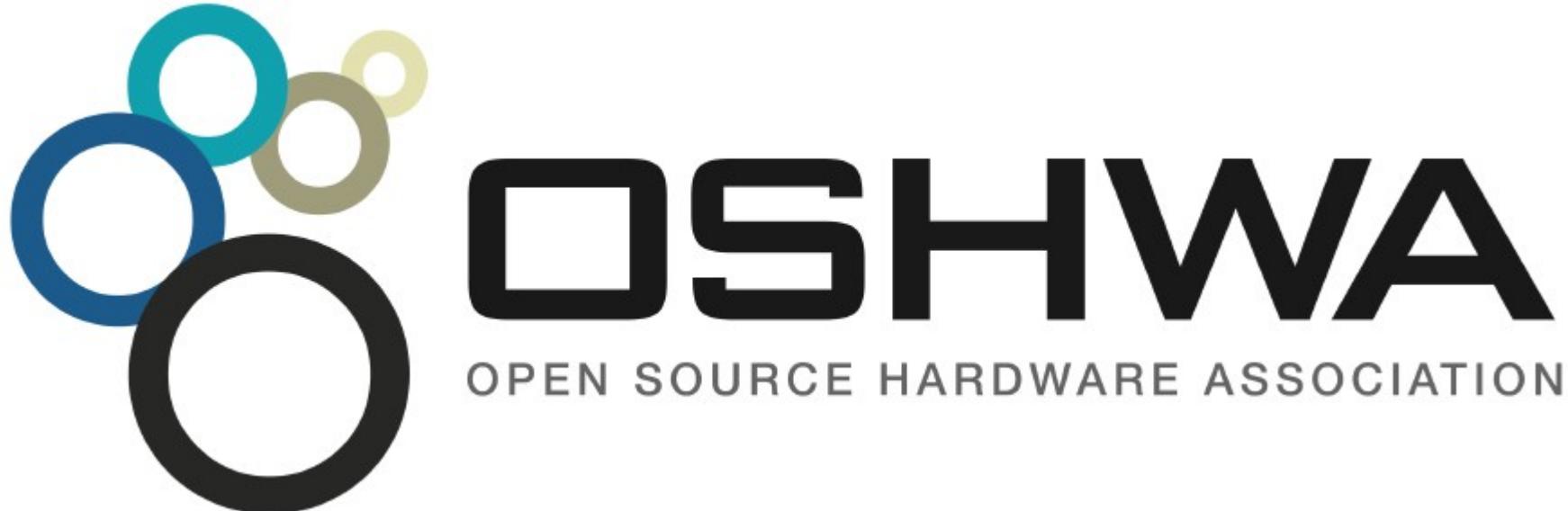


What is the spirit of Open Source?

- Publish everything that will:
enable collaborative development
- Goal is NOT to check a box on a marketing brochure or add keywords to a crowdfunding campaign



- US-based 501(c)3 non-profit organization
- Hosts the **Open Source Hardware definition**
- “aims to be the **voice of the open hardware community**, ensuring that technological knowledge is accessible to everyone, and encouraging the collaborative development of technology”



- OSHW Best Practices
- Quick Reference Guide
- OSHW "May and Must" (PDF)
- OSHW Checklist (PDF)

Open Hardware Summit (OHS)

- OHS 2018: MIT, Thursday, September 27th
(Cambridge, MA, USA)
- 7 *prior summits*:
 - 2010, 2011: New York Hall of Science
 - 2012: Eyebeam (NYC)
 - 2013: MIT (*Boston area*)
 - 2014: Roma, Italia!
 - 2015: Philadelphia, USA
 - 2016: Portland, Oregon, USA
 - 2017: Denver, USA

Open Hardware Summit (OHS)

- OHS 2017: Engineering Open Source Hardware



Panel: Engineering Open Source

Michael Ossman
Great Scott Gadgets

Toni Klopfenstein
Sparkfun Electronics

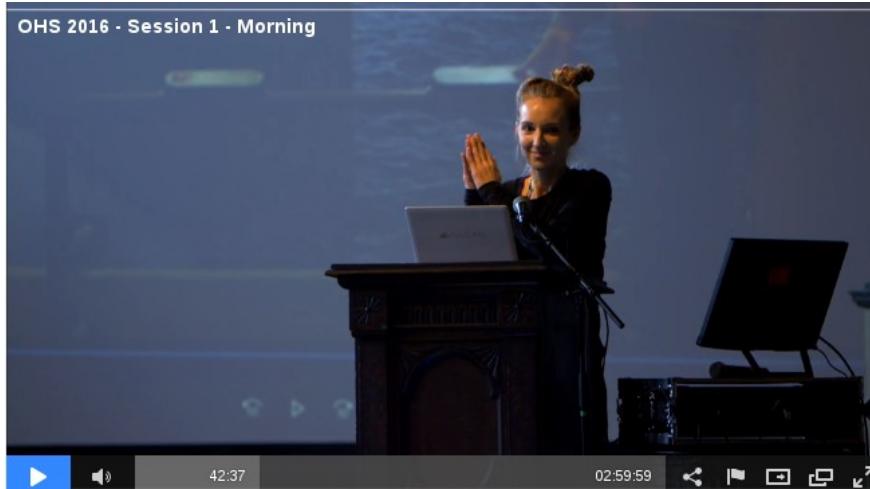
Ben Malouf
Aleph Objects Inc.

Katherine Scott
OSHWA Board
OHS Committee



Open Hardware Summit (OHS)

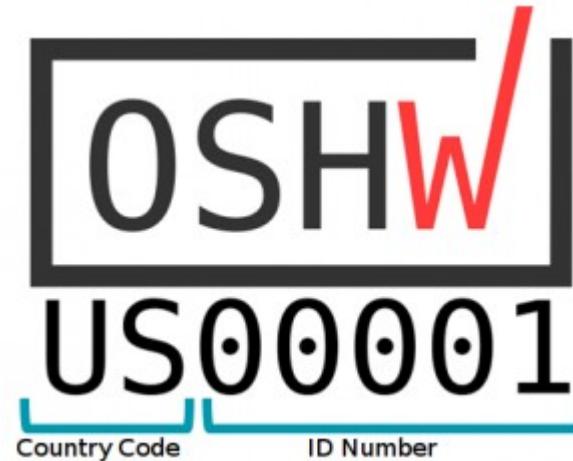
- OHS 2016 morning sessions



- OHS 2016 afternoon sessions



Open Source Hardware Certification Program



- Allows hardware that complies with the community definition of Open Source Hardware to display a certified OSHW logo
- Make it easier for users of OSHW to track down documentation and information
- *More information:* certificate.oshwa.org

Open Hardware Europe Summit 2016



- [Video playlist on YouTube](#)
- [Open Hardware Europe Summit](#)
 - “The global open hardware community met in Vienna, Austria to give talks about new aspects, new methods and lessons learned for the open hardware movement.”



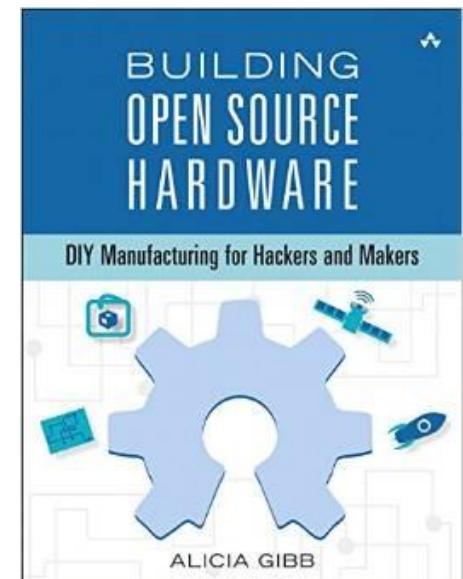
Open Source Hardware



Resources

- Join OSHWA
- Subscribe to the mailing list
- Post in the OSHWA Forum
- Follow on Twitter:
 - @OHSummit
 - @oshwassociation
- [Building Open Source Hardware](#)

by Alicia Gibb (*executive director of OSHWA*)



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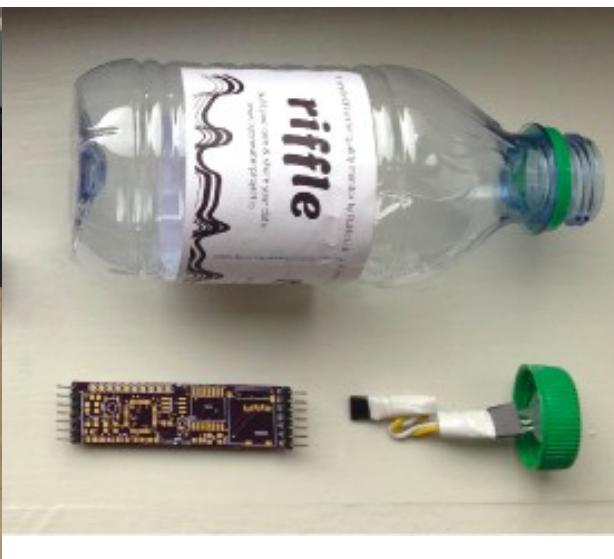


Section:
OSHW in Science

Suggestions from the OSHWA mailing list

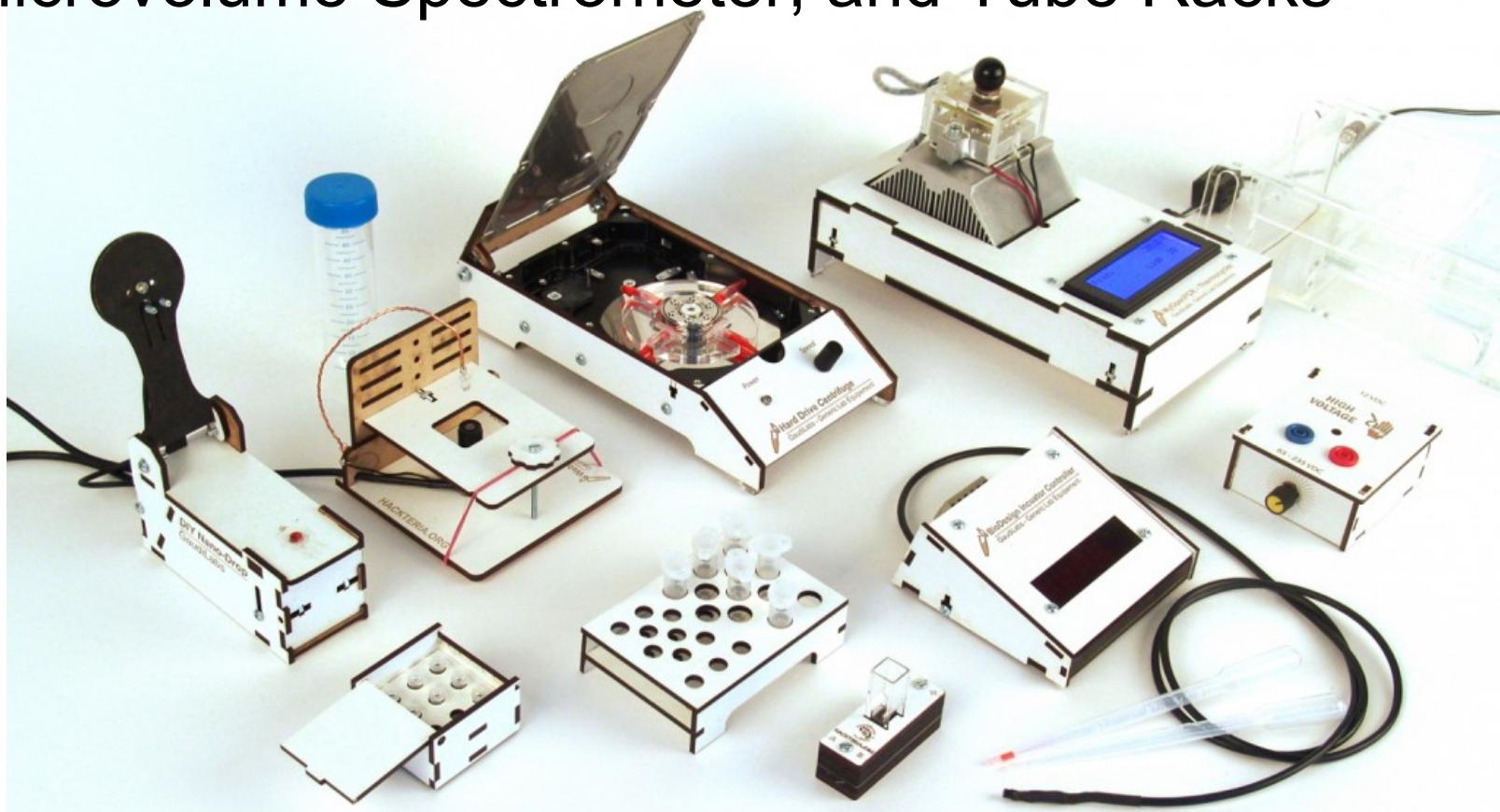
Public Lab

- “Using inexpensive DIY techniques, we seek to change how people see the world in environmental, social, and political terms.”
- Riffle: Open Source Water Monitoring
- Desktop Spectrometry
- Balloon Mapping Kit



Generic Lab Equipment

- GaudiLabs in Switzerland has designed: WebCam Microscope, Hard Drive Centrifuge, Incubator Controller, Gel Box and HV Supply, Turbidity Meter, Microvolume Spectrometer, and Tube Racks



OpenTrons

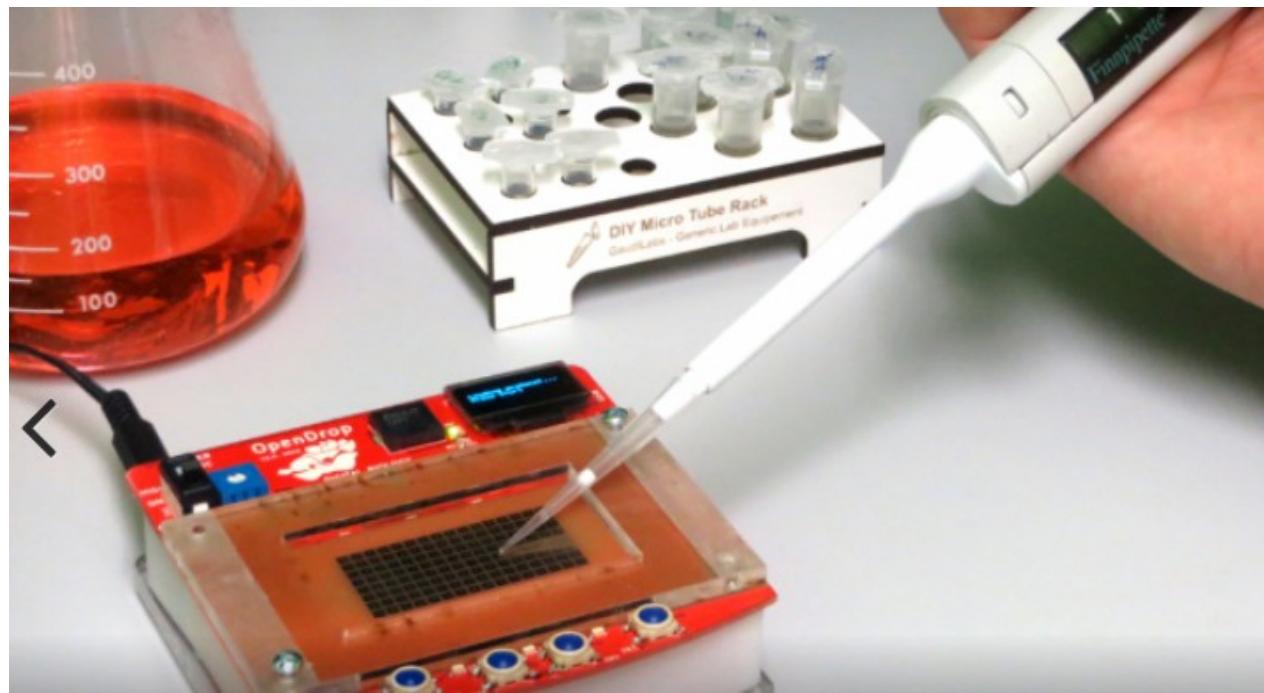
- **Robots for Biologists**
- “We think biologists should have robots to do **pipetting** for them.”
- “They should be able to spend their time designing experiments and analyzing data.”



OpenDrop



- “Desktop Digital Biology Laboratory”
- digital **microfluidics** platform for research
- aim of making personal lab-automation accessible to more people



OpenPCR

- PCR is a method of **copying** DNA molecules.
- OpenPCR is a project to develop open source hardware, software, and protocols to perform **PCR** and **Real-Time PCR reactions**



Open Source Imaging Initiative

- “development of **medical imaging devices**, aiming to make health-care benefits of modern instruments **accessible to many more**”
- “**pool the knowledge and experience** of many experts in open-source designs for **MRI**”
- **Opencore NMR** is an open-source toolkit for implementing an NMR spectrometer



Open-Source Lab

- “open-source 3D printing and microcontrollers running on free software enables scientists, engineers, and lab personnel in every discipline to **develop powerful research tools at unprecedented low costs**”
- Author **Joshua Pearce** runs the **MOST research group** which is exploring the way solar photovoltaic technology can sustainably power our society



Gathering for Open Science Hardware

- “**GOSH** is a diverse, global community working to enhance the sharing of open, scientific technologies”
- [Video of GOSH 2016 at CERN](#)
- [GOSH 2016 in the Journal of Open Hardware](#)
- [GOSH 2018: Shenzhen, China](#)



Libre Space
Foundation

- Non-profit for Open Source HW & SW in Space
- **SatNOGS**: global network of satellite ground stations designed as an open source participatory project
- **UPSat**: 1st open source hardware & software satellite
 - Launched in 2017
 - "Flying The First Open Source Satellite"





conservify

- building and deploying hardware to help monitor ecological problems in the wildest places on Earth
 - sensors to monitor ocean fishing practices
 - watch the movements of glaciers
 - gather real time data about Okavango Delta in Botswana.
- Shah Selbe of Conservify at Hackaday Supercon:

[Wild Hardware: Adventures with Ecological IoT and National Geographic](#)



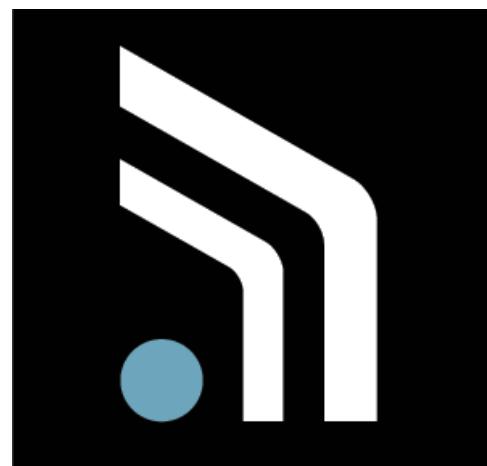
fieldkit

- “brought thousands of people along with us into the Okavango Delta on a ‘live data’ expedition”
- “tools to collect and share field-based research data and to tell stories through interactive visualizations for conservation, science, exploration and education”

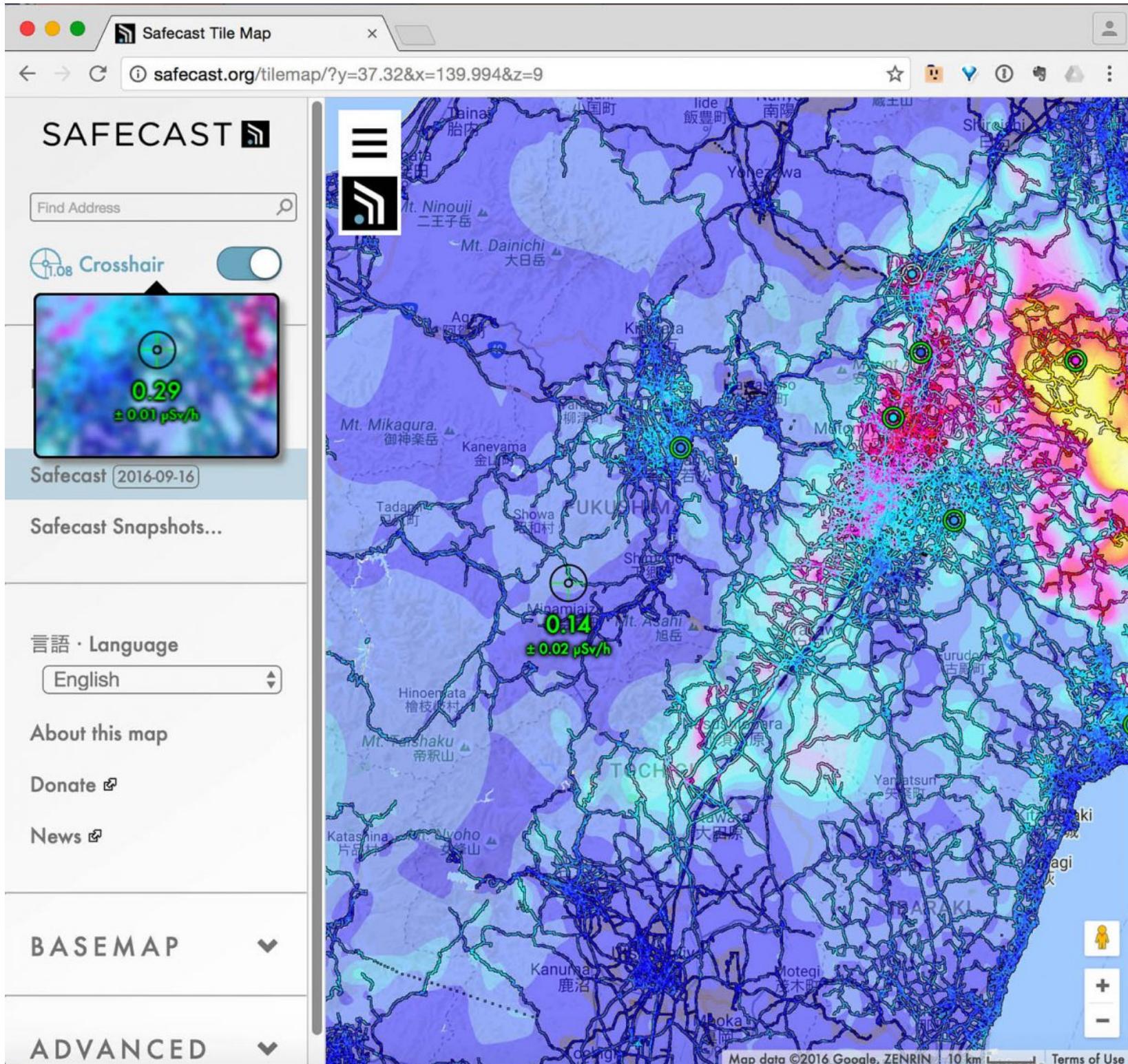


Safecast

- international organization devoted to open citizen science for the environment
- created after the Fukushima Daiichi nuclear disaster in Japan, because accurate and trustworthy radiation information was not available to the public



SAFECAST



Safecast bGeigie Nano

- mobile, GPS enabled, logging, radiation sensor
- designed for mounting on the outside of a car window but can be used on bicycles, trains, planes, and other modes of transportation



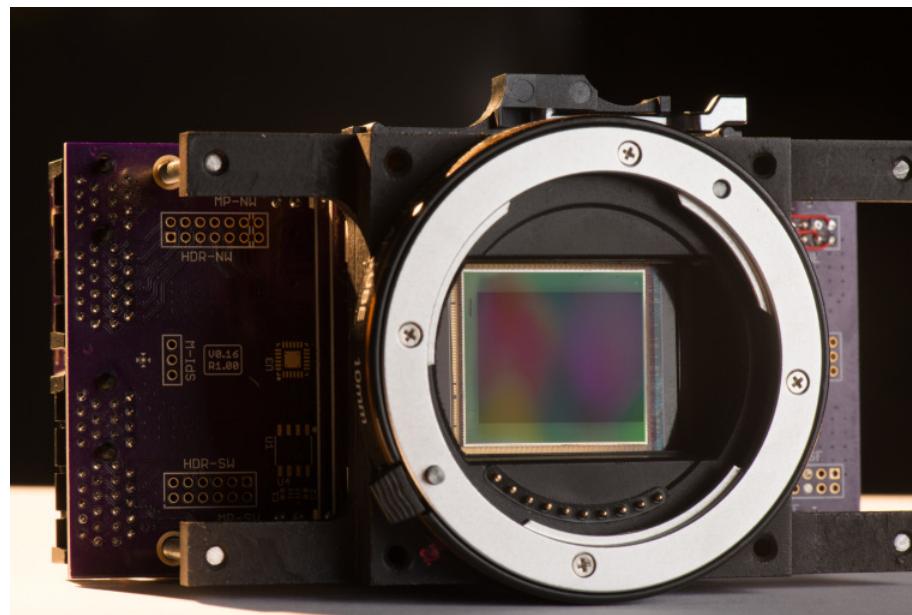
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Section:
OSHW PRODUCTS



- “The goal of the global community-driven **apertus° project** is to create a variety of powerful, affordable, free (in terms of liberty), **sustainable and open digital cinema tools** that we as **filmmakers love to use**”





- “AXIOM product line is the result of this ongoing endeavor and after **successful crowd funding** and receiving an **EU Innovation grant** is well on track to redefine the industry well beyond the DIY garages and hobbyist labs”



Lulzbot 3-D Printers

- 100% Open Source Hardware & Software



FSF Respects Your Freedom certified!



RepRap 3-D Printers



- RepRap started as an academic initiative to develop a **low-cost 3D printer** that can **print most of its own components**
- Giving Manufacturing a New Life
by Adrian Bowyer
- Prusa i3 M2 RepRap named
Make:'s Best 3D Printer for 2017



Novena laptop

- Created by Bunnie Huang & Sean Cross (xobs)
 - Chumby, “Hacking the Xbox”, [amazing reverse engineers](#)
- 100% Open Source Hardware laptop
- Quad-core 1.2GHz ARM, 4GB RAM, SSD, WiFi
- Xilinx FPGA for custom hardware design
- Software Defined Radio (SDR) module



Slides: <https://github.com/pdp7/talks/blob/master/oshw-bof-lfclc-pdx-2018.pdf>



Section:
LINUX on OSHW

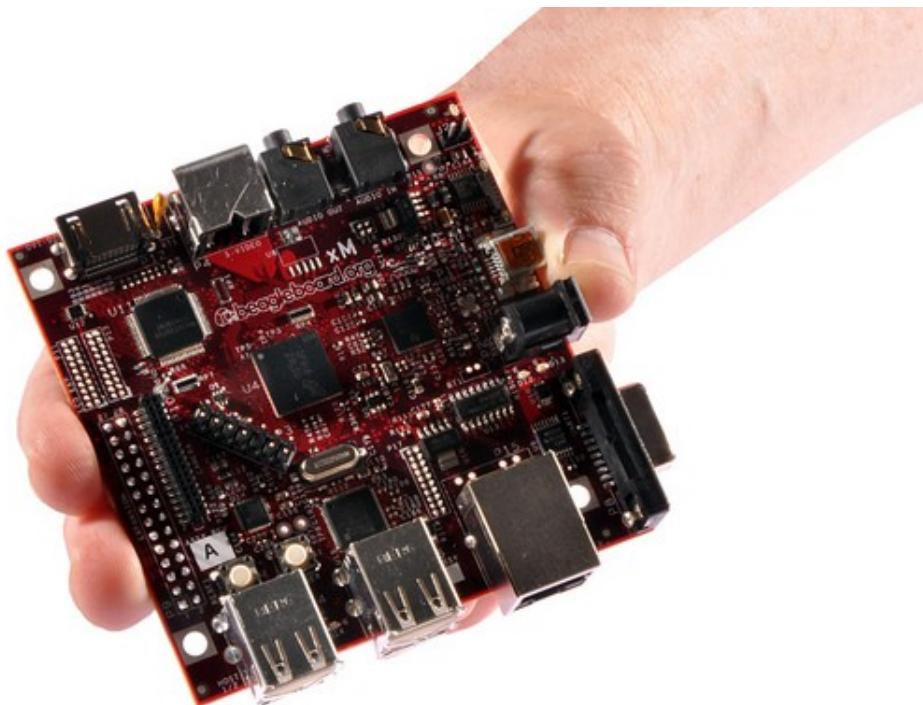


- Open Source Hardware computing for Makers, Educators & Professionals
- Developed by BeagleBoard.org Foundation and BeagleBoard.org Community
- Manufacturers: element14, GHI, Seeed



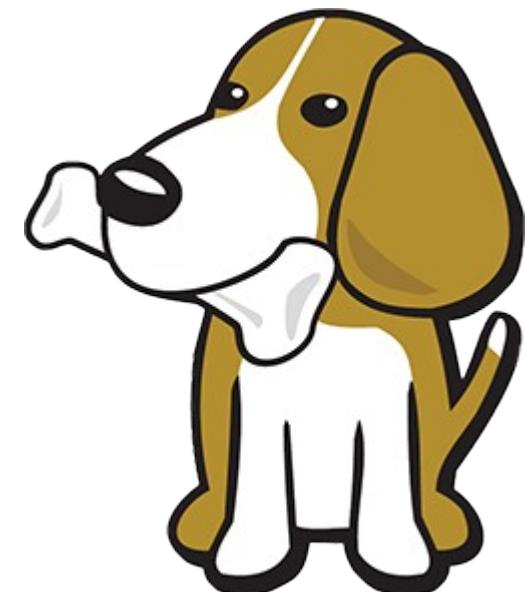


BeagleBoard.org released the first
BeagleBoard, an affordable, open
hardware ARM computer in **2008**





Maker focused, Altoids tin sized
BeagleBone introduced in **2011**





More affordable, more powerful
BeagleBone Black in 2013





Open Source Hardware BeagleBone derivatives

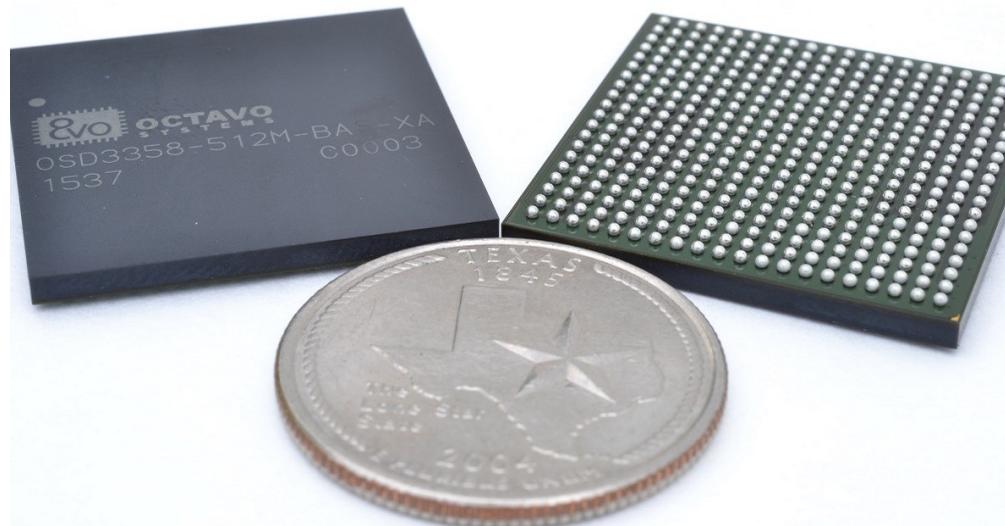
	Capes	HDMI	Flash	Special
BeagleBoard.org BeagleBone	Y	N	N	JTAG
BeagleBoard.org BeagleBone Black	Y	Y	Y	-
Arrow BeagleBone Black Industrial	Y	Y	Y	Industrial
Element14 BeagleBone Black Industrial	Y	Y	Y	Industrial
SeeedStudio BeagleBone Green	Y	N	Y	Grove
SanCloud BeagleBone Enhanced	Y	Y	Y	1GB, 1Gbit, wireless
BeagleBoard.org BeagleBone Blue	N	N	Y	Robotics
BeagleBoard.org BeagleBoard-X15	N	Y	N	Big jump in CPUs and I/O



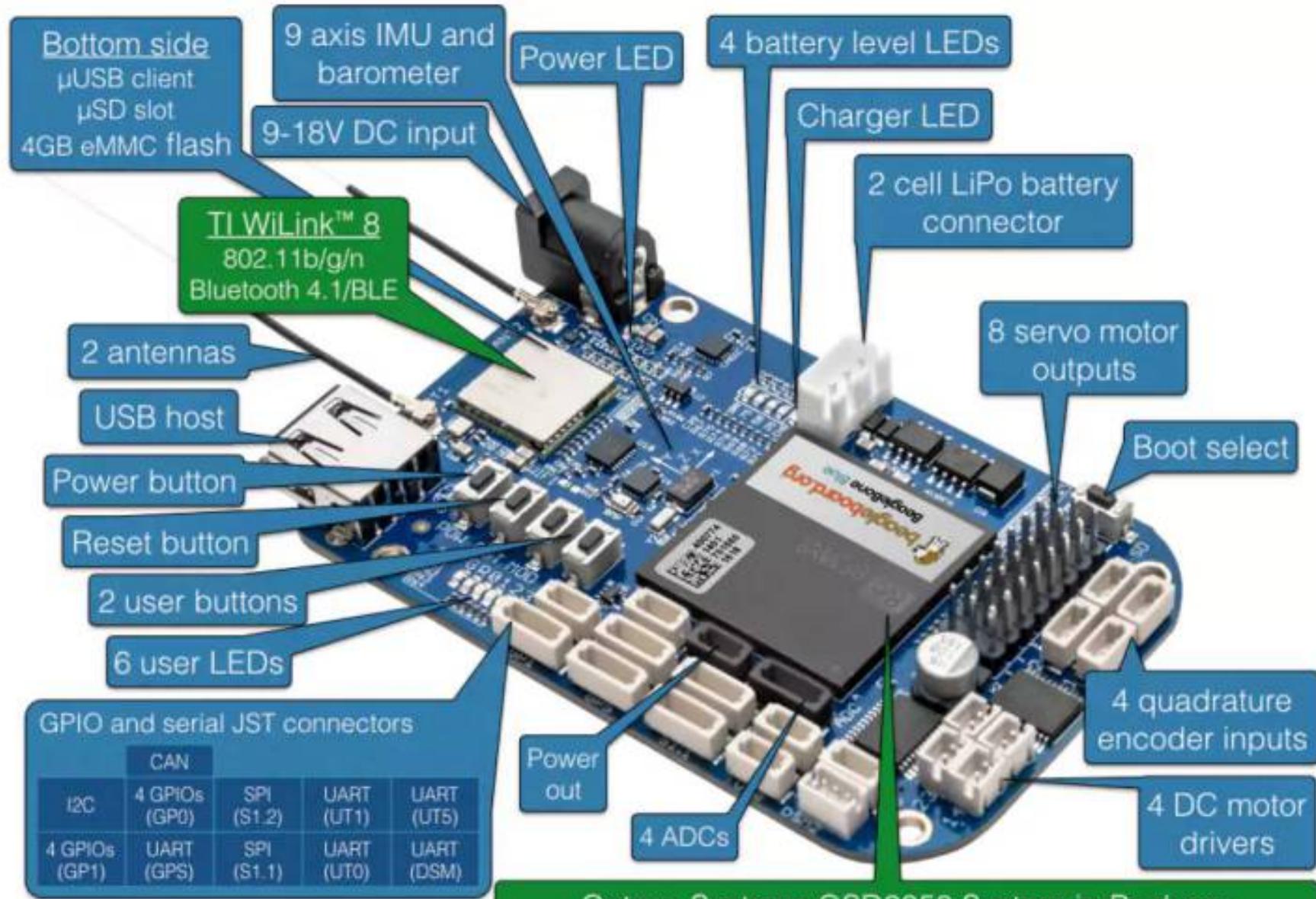
BeagleBone Black Wireless



- CadSoft EAGLE design files hosted on GitHub
- Bill of Materials: every part available in qty 1
- Octavo System-in-Package (SiP) packages several ICs (*CPU, RAM, etc*) into one large-pitch BGA chip to simplify PCB layout and assembly

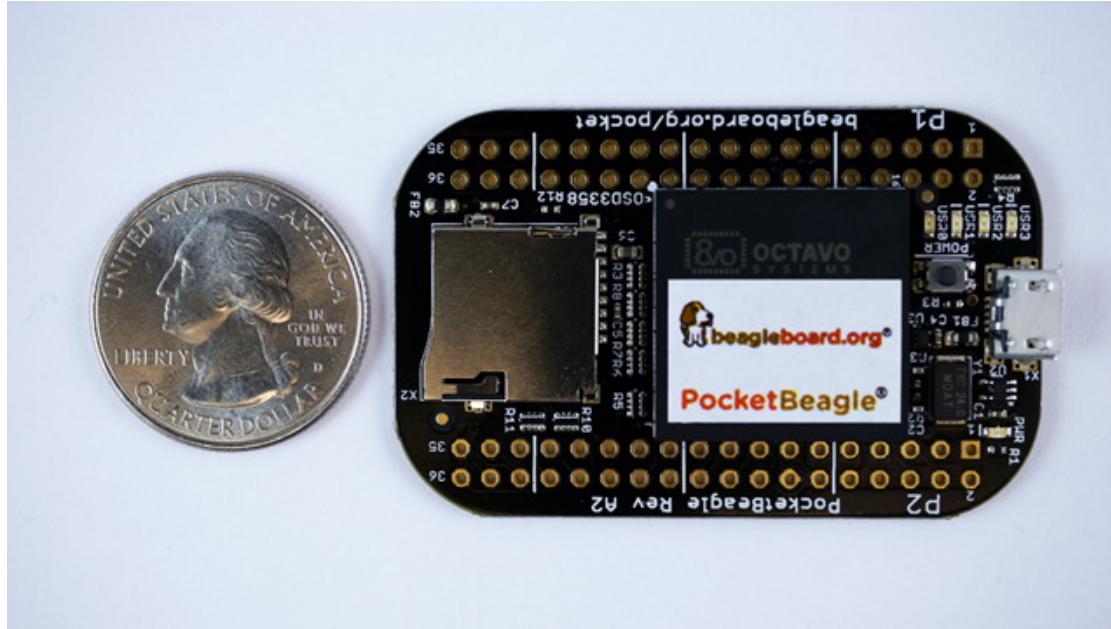


BeagleBone Blue: complete Linux robotics controller. 4 layer PCB designed in EAGLE.



1-GHz TI ARM® Cortex®-A8, 512-MB DDR3, power management

BeagleBoard.org PocketBeagle



- Michael Welling designed the “*PocketBone*” using the Octavo SiP and shared on Hackaday.io
- In response to online demand, BeagleBoard.org worked with GHI in Michigan to design and manufacture a new product: the PocketBeagle

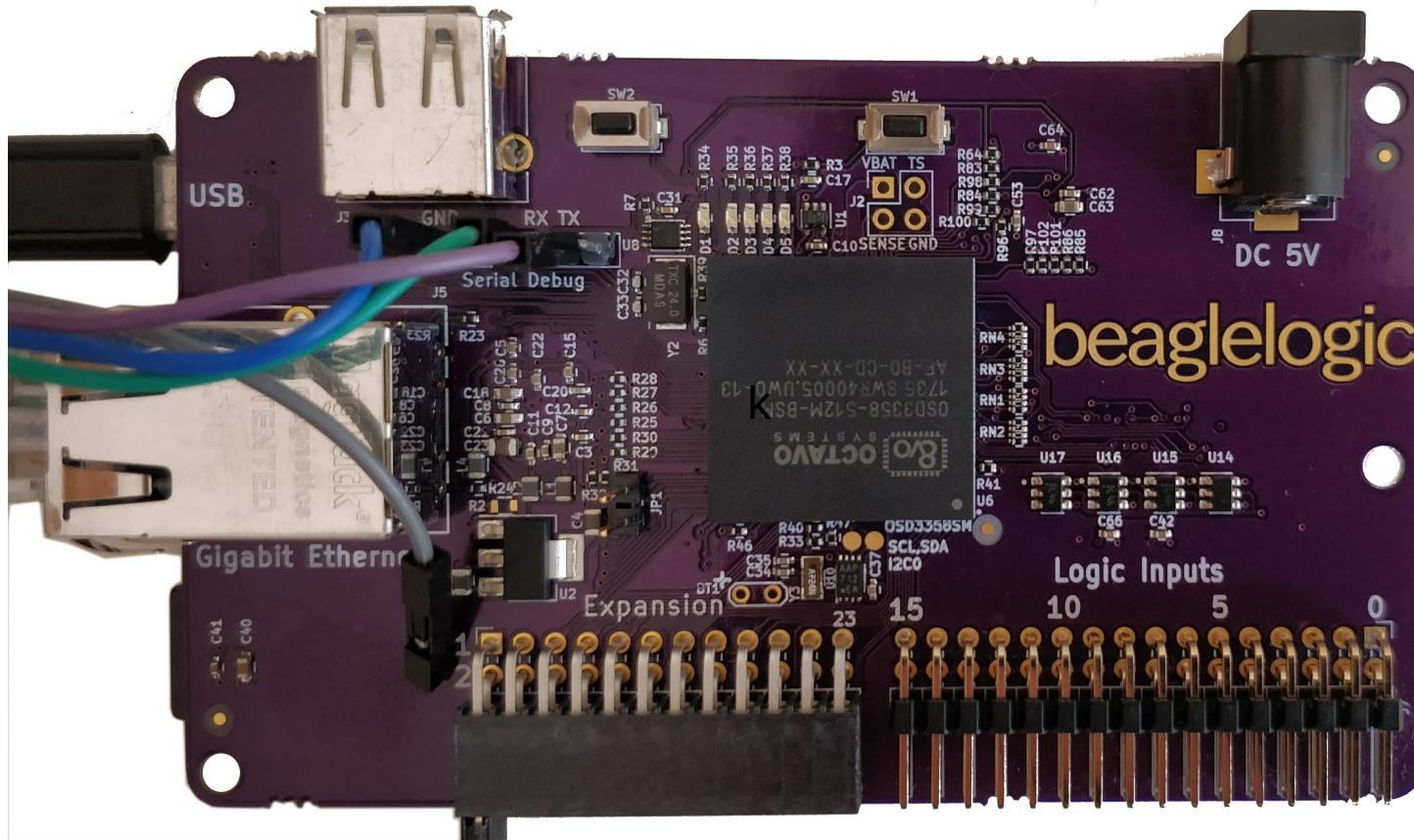
BeagleBoard.org PocketBeagle

- PocketBeagle design makes it feasible for individuals to create their own derivatives
- 4 layer PCB published for EAGLE and KiCad
- Low cost assembly is possible with solder paste stencil and toaster oven



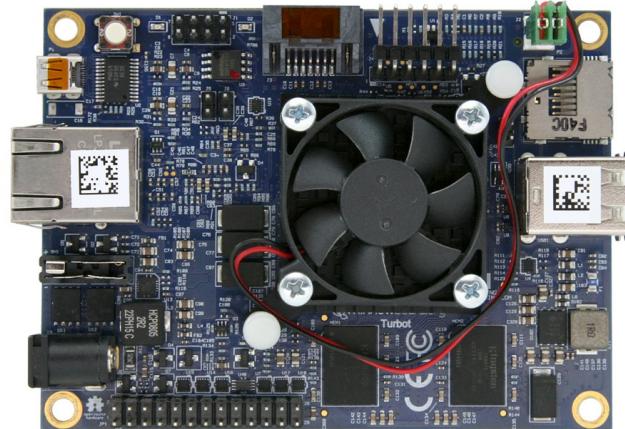
BeagleLogic

- Kumar Abhishek created a derivative board intended to be used a logic analyzer
- Finalist in the Best Product round of the Hackaday Prize





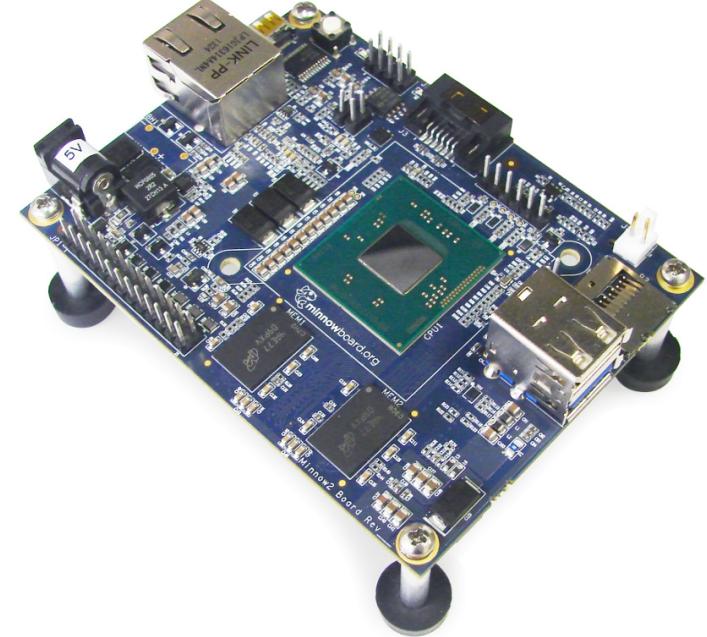
MinnowBoard



- 64-bit Intel Atom (dual or quad core)
- MinnowBoard Turbot
- USB 3.0, SATA, PCIe, Gigabit Ethernet, HDMI
- Integrated Intel HD Graphics
 - Open Source Mainline Linux drivers!



MinnowBoard



- Manufactured by [ADI](#)
- Released under Creative Commons **CC-BY-SA**
- [Download design files:](#)
 - Schematic**
 - Board Layout**
 - Bill of Materials**

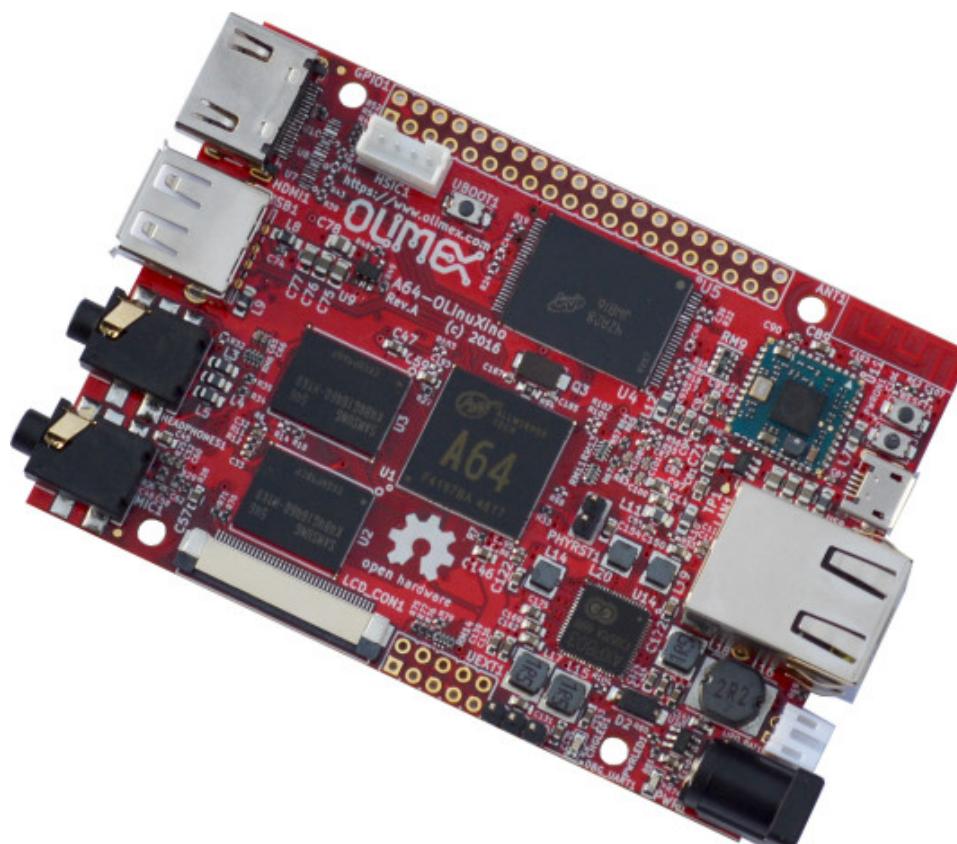


OLinuXino



- Low cost OSHW Linux computers
- Designed and manufactured by **Olimex** in **Bulgaria**
- Great blog post:
[Open Source Hardware, why it matters and what is pseudo OSHW](#)

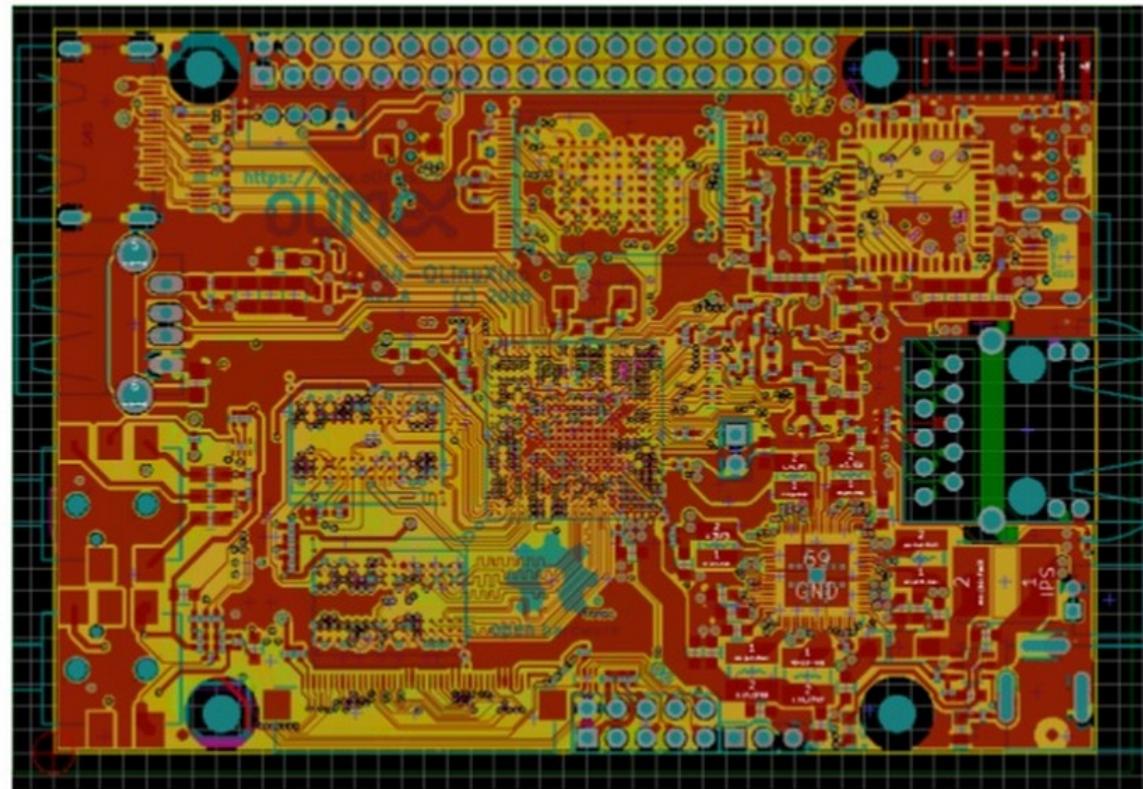
- Allwinner A64: Quad Core 64-bit ARM
 - Designed with Open Source **KiCad**
 - 1GB RAM, 4GB eMMC, WiFi+BLE4.0





Using FOSS tools for OSHW project

Designing with KiCAD of 64-bit ARM board



Tsvetan Usunov, OLIMEX Ltd

FOSDEM 2016

Slides / Video

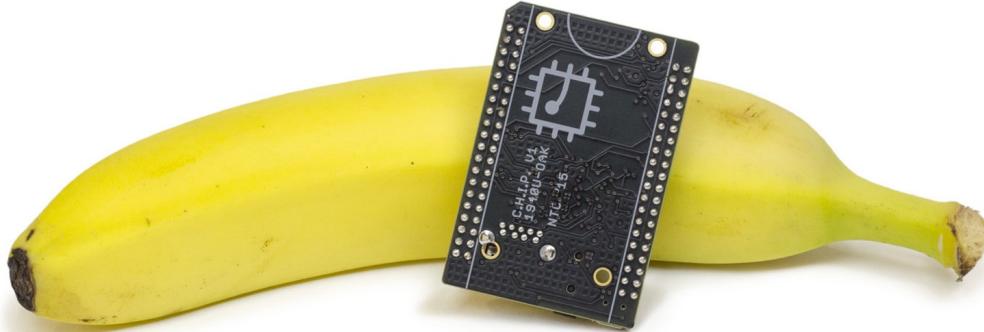


- **KiCad** is an Open Source EDA suite including Schematic Capture and PCB Layout
- Cross platform: **Windows**, **Mac OS** and **Linux**
- **CERN has contributed** professional CAD features for high-speed digital design
- Learn to design your own PCB in KiCad with:
Getting to Blinky

- “DIY Open Source Hardware Software Hacker's friendly Modular Laptop”
- Developing an Open Source Laptop talk by Olimex founder Tsvetan Usunov at Hackaday Belgrade
- Design files on GitHub:
“everyone can download & learn, study, edit, modify”



C.H.I.P



The World's First \$9 Computer

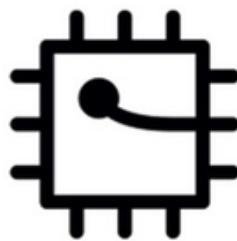
- getchip.com
- Next Thing Co. in Oakland
- Kickstarter in 2015
- March 2018: not in stock?



"C.H.I.P, PocketCHIP & Voder's Maker Next Thing Co. Is Still Up and Running (Correction)"



C.H.I.P. is OSHW



- **GitHub:** [NextThingCo/CHIP-Hardware](#)
 - Schematics
 - PCB Layout
 - Bill of Materials (*BoM*)
- **License:**
 - Creative Commons Attribution-ShareAlike (CC-BY-SA)

EOMA68 Computing Devices

- Embedded Open Modular Architecture
- “responsible about both the ecological and the financial resources required to design, manufacture, acquire and maintain our personal computing devices.”
- “**This campaign** therefore introduces the world’s first devices built around the EOMA68 standard, a freely-accessible royalty-free, unencumbered hardware standard”
- Estimated to ship in 2018



Are there other **OSHW** boards that run Linux?

Please let me know!

drew@pdp7.com

Twitter: @pdp7

Create a list on **eLinux wiki**?

Any OSHW on 96boards.org?



About ▾ Products ▾ Projects ▾ Documentation ▾ Blog Forums ▾



Consumer Edition (CE)

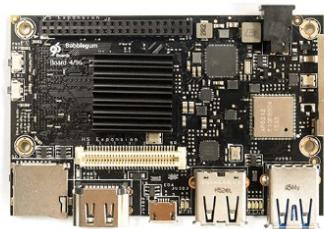
96Boards » Products » Consumer Edition (CE)

Latest Boards Consumer Edition Enterprise Edition IoT Edition Mezzanine Products Accessories

The 96Boards Consumer Edition (CE) specification targets the mobile, embedded and digital home segments. The boards below are all certified conformig to this specification, which defines a fixed set and location



Specification



bubblegum-96

Board based on Actions Semi S900 Processor...



DragonBoard™ 410c (Arrow)

Board based on Qualcomm® Snapdragon™ 410 processor...



Hikey (LeMaker)

Board based on HiSilicon Kirin 6220 processor...



HiKey 960

Board based on Huawei Kirin 960 octa-core ARM® big...

Read More

Buy

Read More

Buy

Read More

Buy

Read More

Buy

Udoo: no PCB design files?

[START](#)[DISCOVER](#)[COMMUNITY](#)[RESOURCES](#)[PROJECTS](#)[DISTRIBUTORS](#)[SHOP](#)

DOCUMENTATION

DOCUMENTS

[USER MANUAL](#)

MECHANICAL SPECS

[3D MODEL](#)

SCHEMATICS

These files are released under the Creative Commons CC BY-SA 3.0 license.

[SCHEMATICS](#)[TOP](#)[BOT](#)

OTHER FILES

[DATASHEET](#)[BOM](#)

Radxa: no PCB design files?

Name	Last modified	Size
Parent Directory		-
ds/	18-Dec-2014 15:19	-
components_position_ref_bottom_20131025.pdf	21-Dec-2013 04:47	78K
components_position_ref_top_20131025.pdf	21-Dec-2013 04:47	54K
GPIO.xlsx	08-Oct-2014 10:38	14K
RADXA_ROCK_20130903.dxf	05-Sep-2013 16:17	1.5M
RADXA_ROCK_20131025.dxf	21-Dec-2013 04:51	794K
RADXA_ROCK_PRO_20140610.dxf	19-Sep-2014 06:33	3.5M
RADXA_ROCK_PRO_components_position_ref_20140610.pdf	19-Sep-2014 06:22	184K
RADXA_ROCK_PRO_schematic_20140718.pdf	21-Jul-2014 02:04	462K
RADXA_ROCK_schematic_20130903.pdf	05-Sep-2013 15:46	413K
RADXA_ROCK_schematic_20131025.pdf	21-Dec-2013 04:51	415K



Radxa Download

CubieBoard: no PCB design files?

The screenshot shows the Cubieboard website's Model page. At the top is a banner with a cartoon monkey icon, the text "LET'S GET START TO KNOW WITH THE", the word "Cubieboard" in large letters, and "NOW!" at the bottom right. Below the banner is a navigation bar with links: Home (selected), Model (current page), News, Stories, Download, Resources, Docs, Flickr, Mail List, and a search bar. Underneath the navigation bar are links for Forum ML, Forum Japan, Forum Cn, Support, Buy, and CubieTech. The main content area displays the text "You are here: Home > Model" followed by a large heading "Model". Below the heading is a photograph of the CubieAIO-A20, a blue printed circuit board with various components and connectors. The text "CubieAIO-A20" is centered below the image.



Slides: <https://github.com/pdp7/talks/blob/master/oshw-bof-lfclc-pdx-2018.pdf>



Section:
Open Source and Libre Silicon

What about silicon?



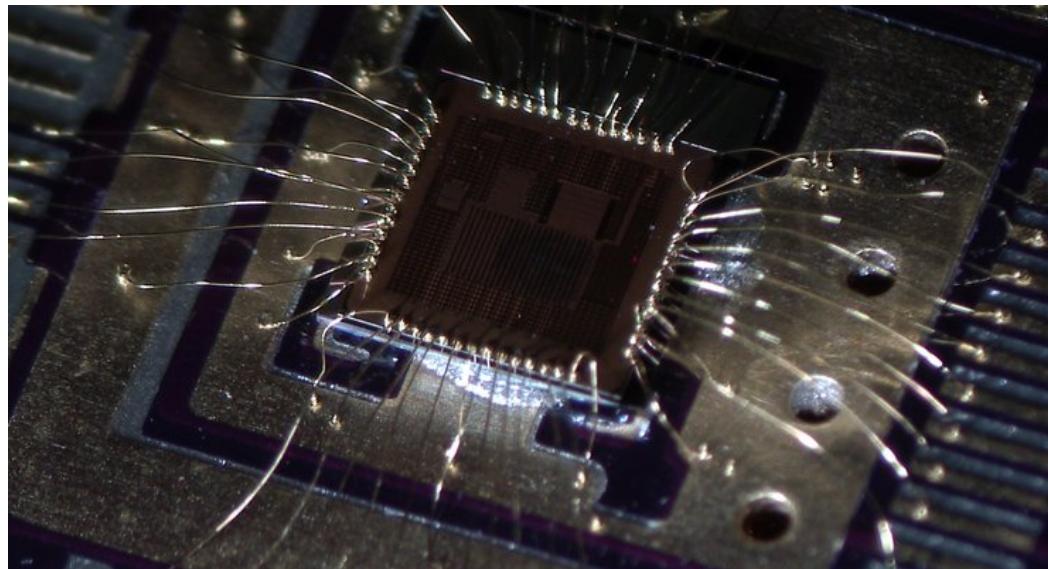
- **RISC-V: Free and Open RISC Instruction Set Arch**
 - “new instruction set architecture (ISA) that was originally designed to support computer architecture research and education and is now set to become a standard open architecture for industry”
 - Video: [Instruction Sets Want To Be Free: A Case for RISC-V](#)
 - Video: [Krste Asanovic presents](#) at RISC-V and Open Source Silicon Event in Munich on March 23, 2017

What about silicon?



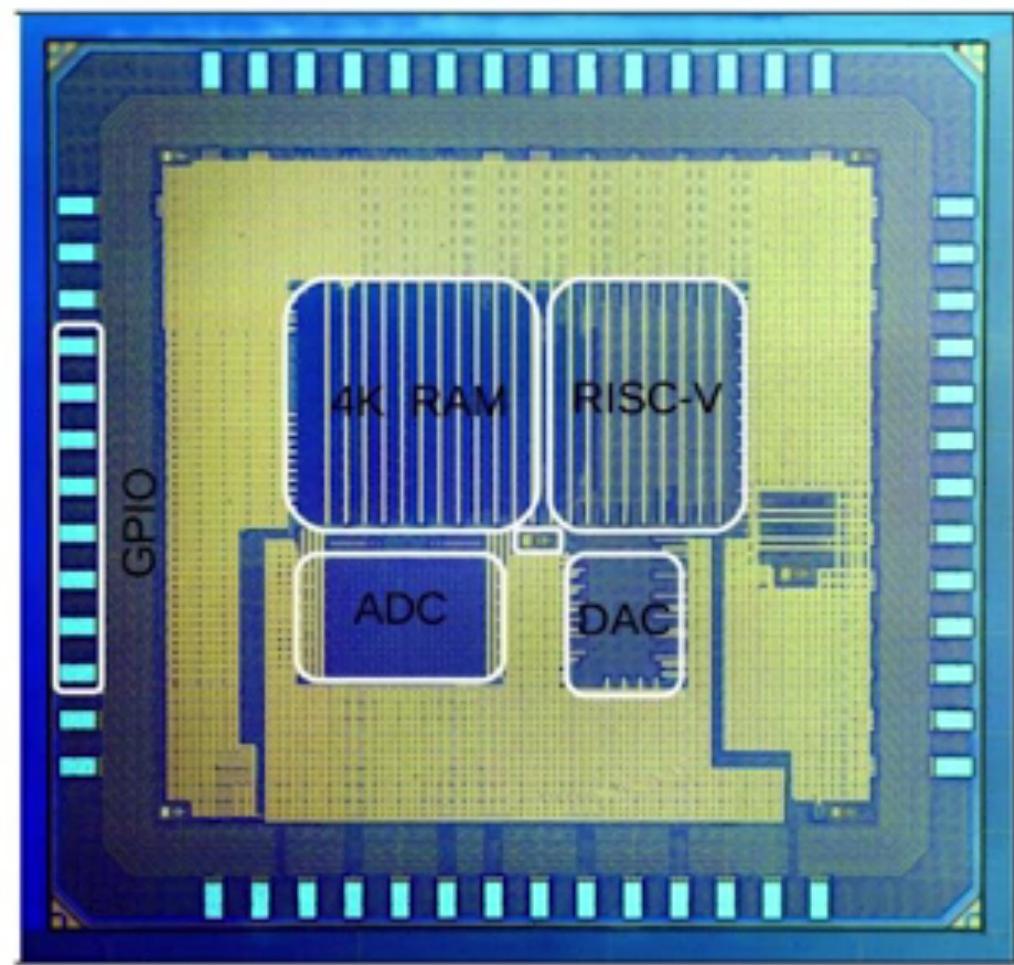
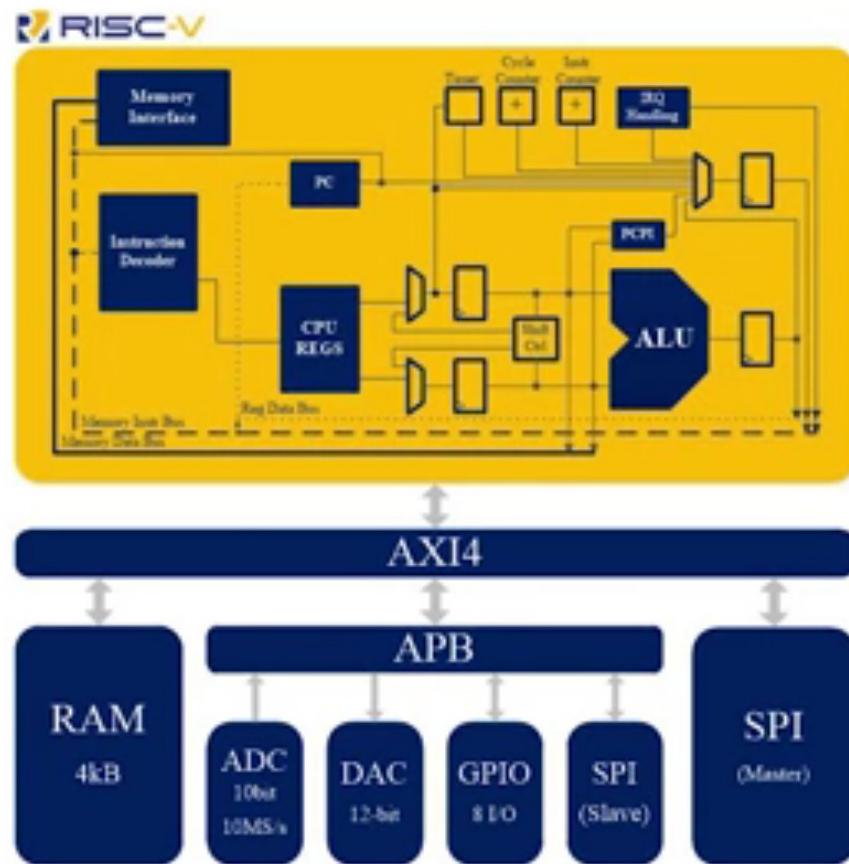
- OnChip Open-V

“completely free (as in freedom) and open source 32-bit microcontroller based on the RISC-V architecture”



What about silicon?

A 32-bit RISC-V based Microcontroller



What about silicon?

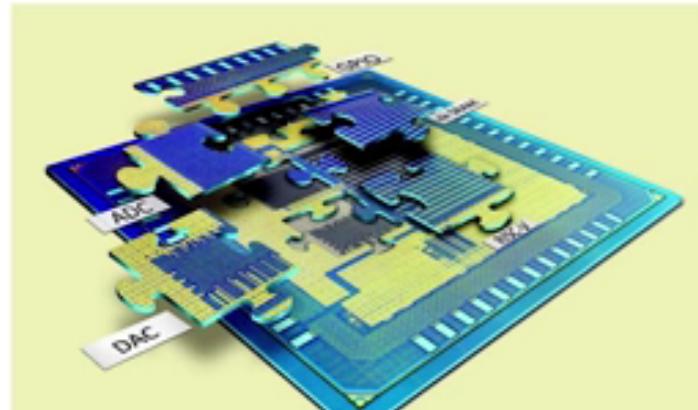


- Crowd Supply update: [A Taste of Chip Design](#)
- Video: [YoPuzzle: mRISC V development platform](#)
- Video: [RISC-V Community needs Peripheral Cores](#)

Good to have an Open ISA. What about Peripheral?



- IP vendors have IP based on previous customer. **Hard to get** a glue-and-play that works for your SoC. → \$\$\$
- There are some std, such as PHYs: USB, LPDDR, PCIe, AMBA
BUT
no for clocking circuitry, biasing, GPIO
For instance a simple Power-on-Reset can hit your pocket, just because!
- Buses IP are out there but expensive.

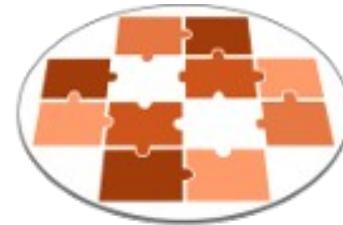


What about silicon?



- [lowRISC](#):
“creating a fully open-sourced, Linux-capable, RISC-V-based SoC, that can be used either directly or as the basis for a custom design”
- Video: [Rob Mullins talking about lowRISC](#)
(RISC-V & Open Source Silicon Event in Munich on March 23, 2017)

What about silicon?



FOSSi
Foundation

- FOSSi Foundation
 - The Free and Open Source Silicon Foundation
 - “non-profit foundation with the mission to promote and assist free and open digital hardware designs”
 - “FOSSi Foundation operates as an open, inclusive, vendor-independent group.”

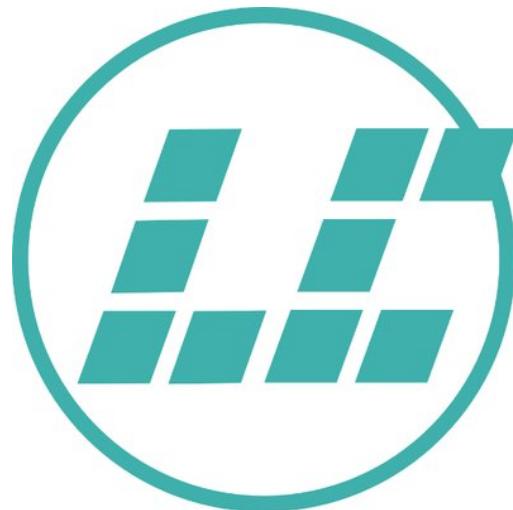
What about silicon?



- Open Source Silicon Design Ecosystem
 - Talk by FOSSi co-founder Julius Baxter

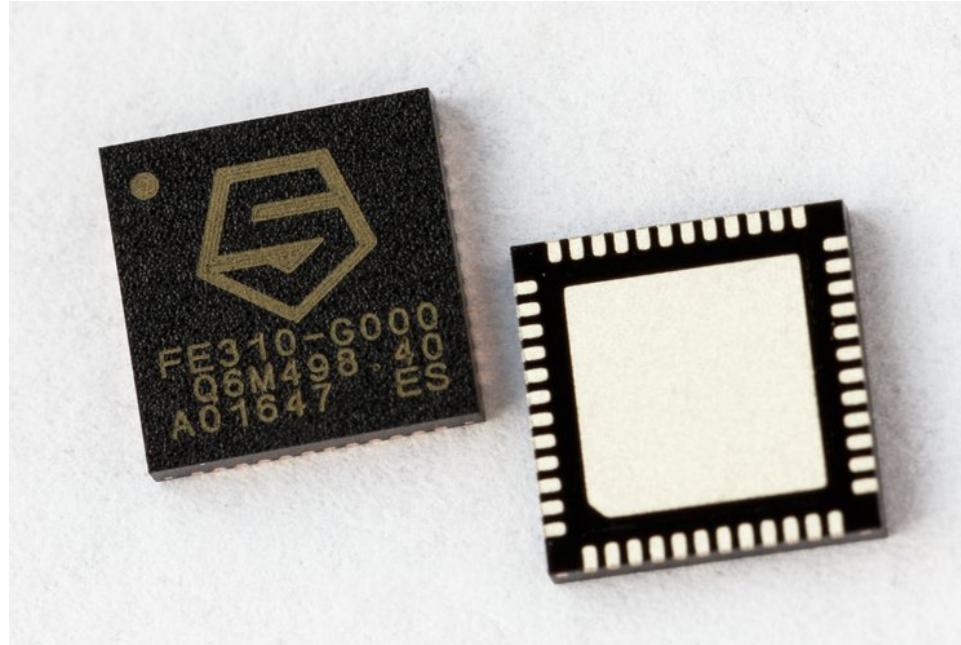


What about silicon?



- **LibreCores**
 - Project of the FOSSi Foundation
 - “**gateway to free and open source digital designs** and other components that you can use and **re-use in your digital designs**”
 - “advances the idea of OpenCores.org”

What about silicon?



- SiFive

“founded by the creators of the free and open RISC-V architecture as a reaction to the end of conventional transistor scaling and escalating chip design costs”

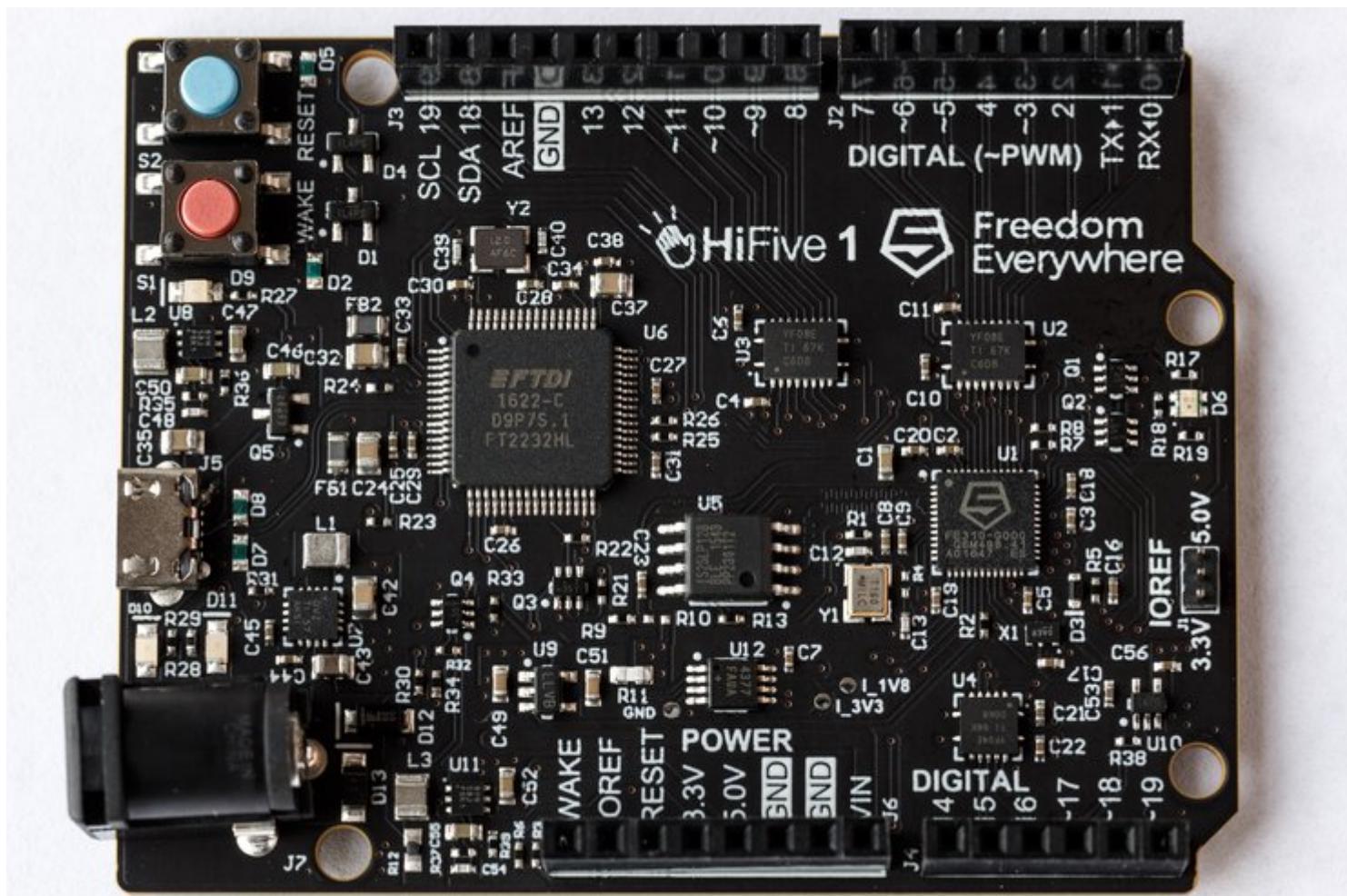
RISC-V ecosystem

- RISC-V Keynote at Embedded Linux Conf
 - March 12th, 2018
 - Yunsup Lee, Co-Founder and CTO, SiFive
 - Designing the Next Billion Chips: How RISC-V is Revolutionizing Hardware



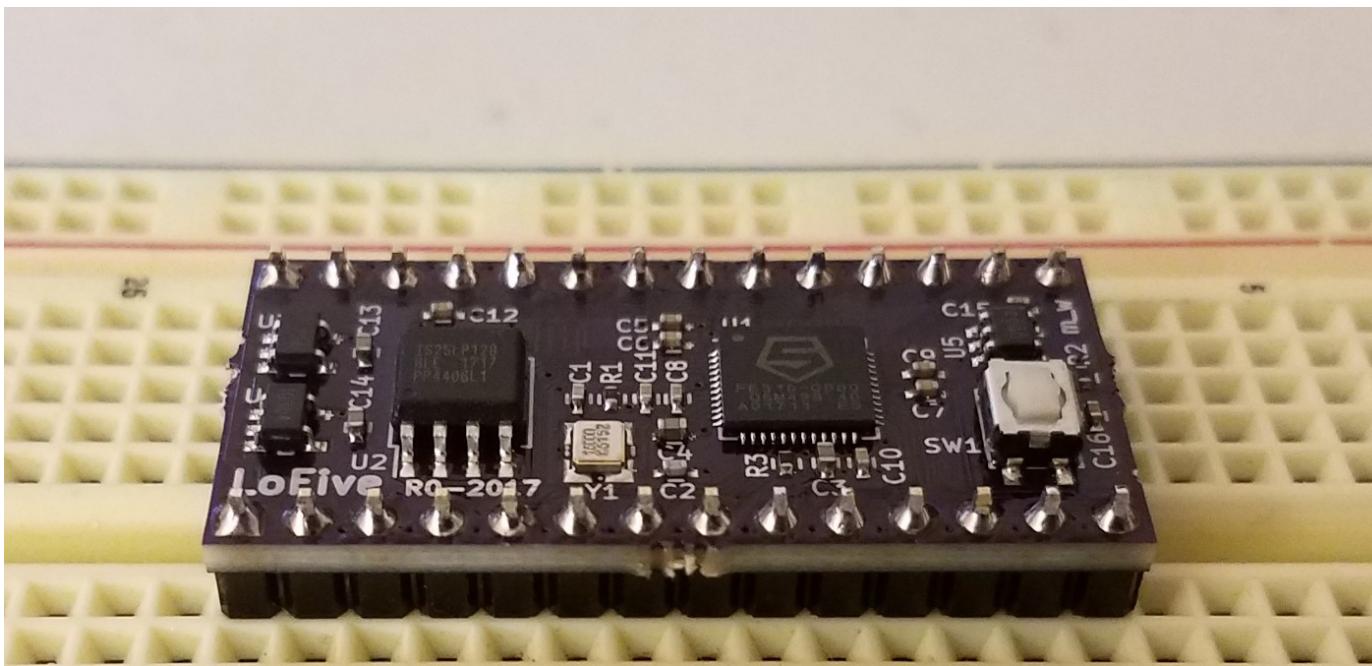
SiFive FE310 microcontroller

- **HiFive1**: Arduino-Compatible RISC-V Dev Kit



SiFive FE310 microcontroller

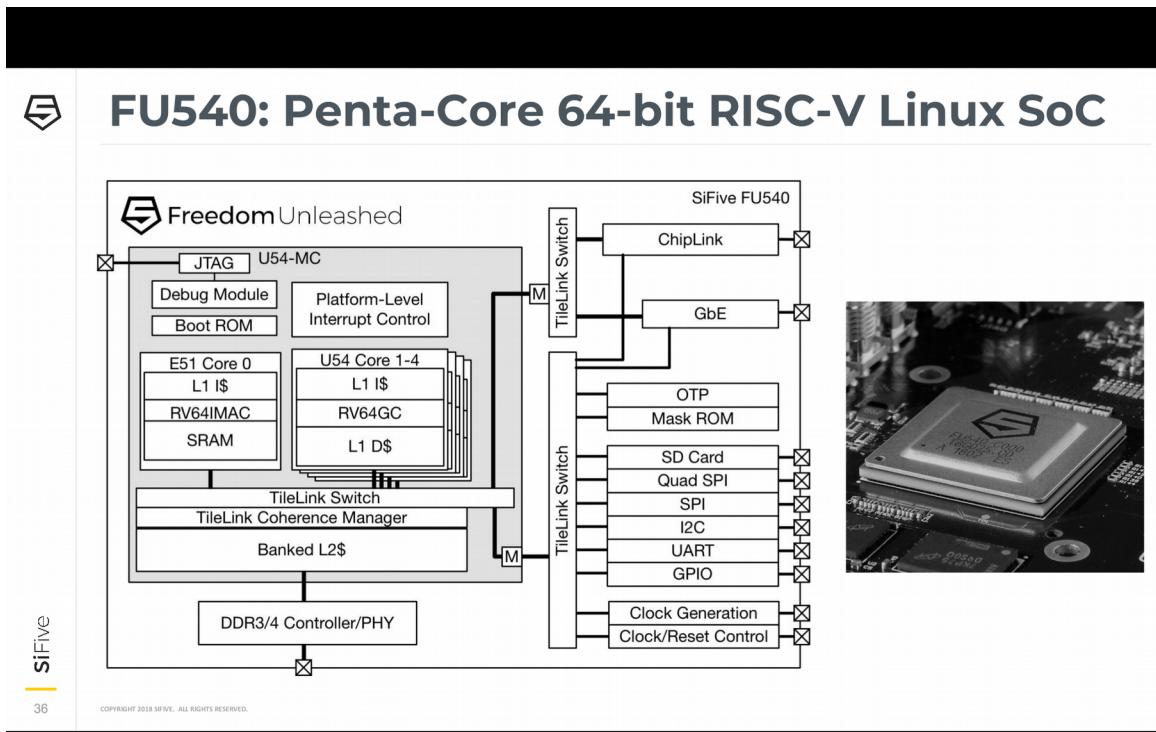
- LoFive designed by Michael Welling
(QWERTY Embedded Design)
- Lower cost eval board for SiFive FE310.
- Open Source Hardware design files
- Sold as group buy on GroupGets



SiFive: Linux on RISC-V

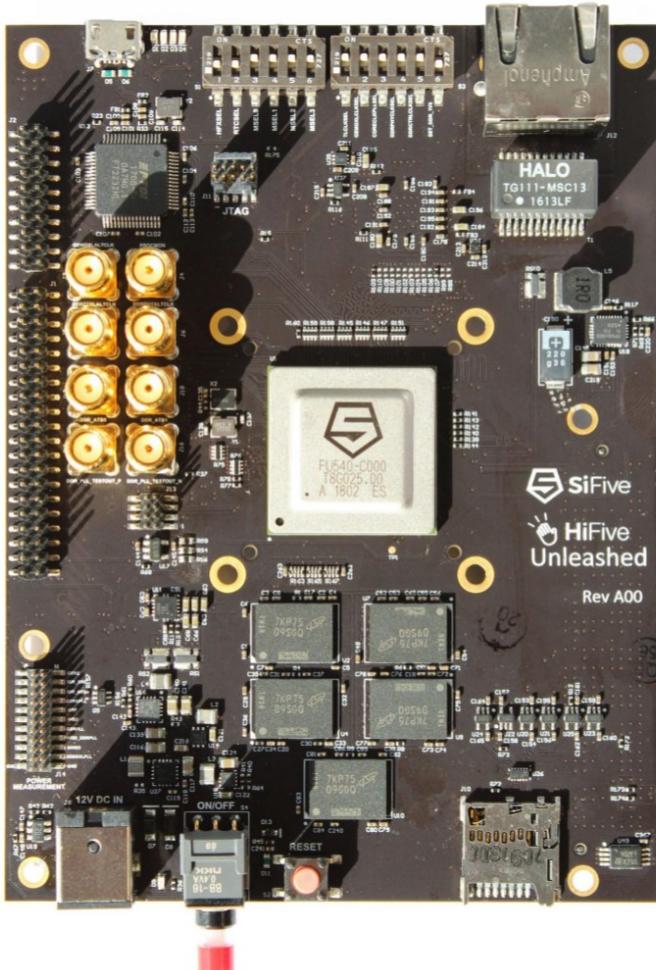
- FOSDEM 2018 talk

- YouTube: “Igniting the Open Hardware Ecosystem with RISC-V: SiFive's Freedom U500 is the World's First Linux-capable Open Source SoC Platform”
- Interview with Palmer Dabbelt of SiFive



SiFive: Linux on RISC-V

HiFive Unleashed



- World's First Multi-Core RISC-V Linux Development Board
 - SiFive FU540-C000 (built in 28nm)
 - 4+1 Multi-Core Coherent Configuration, up to 1.5 GHz
 - 4x U54 RV64GC Application Cores with Sv39 Virtual Memory Support
 - 1x E51 RV64IMAC Management Core
 - Coherent 2MB L2 Cache
 - 64-bit DDR4 with ECC
 - 1x Gigabit Ethernet
 - 8 GB 64-bit DDR4 with ECC
 - Gigabit Ethernet Port
 - 32 MB Quad SPI Flash
 - MicroSD card for removable storage
 - FMC connector for future expansion with add-in cards

OSHW RISC-V Linux board for less than \$100?

- Goal: Sub-\$100 Open Source Hardware board that can run Linux on RISC-V
- Possible by ELC 2019?
- Interested in working together?
 - drew@oshpark.com / Twitter: [@pdp7](#)
 - create a mailing list?

Thanks

- Suggestions from the OSHWA mailing list:
 - Abram Connelly
 - Andrew Plumb
 - Andrew Quitmeyer
 - Eleftherios Kosmas
 - Marcin Jakubowski

OSHW boards that run Linux?

Please let me know!

drew@pdp7.com

Twitter: @pdp7

Create a list on eLinux wiki?

These slides are available at:
github.com/pdp7/talks/blob/master/irl-summit-oshw-2018.pdf

Drew Fustini

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OSH Park Blog



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