Slides: https://github.com/pdp7/talks/blob/master/penguicon17-oshw-fustini.pdf

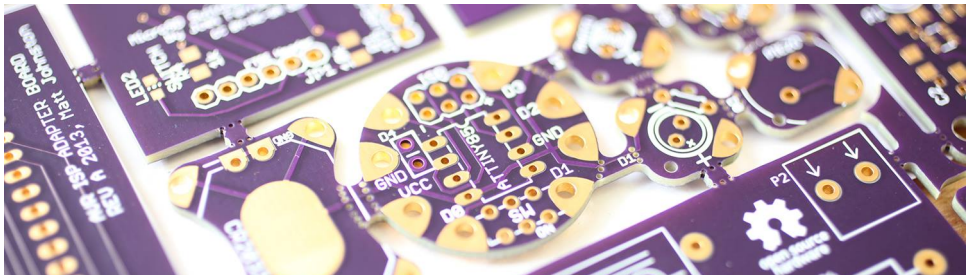
# Open Source Hardware and Libre Silicon


**Drew Fustini**

**OSH Park**

drew@oshpark.com

@oshpark / @pdp7

Slides: https://github.com/pdp7/talks/blob/master/penguicon17-oshw-fustini.pdf


Statement of Principles:

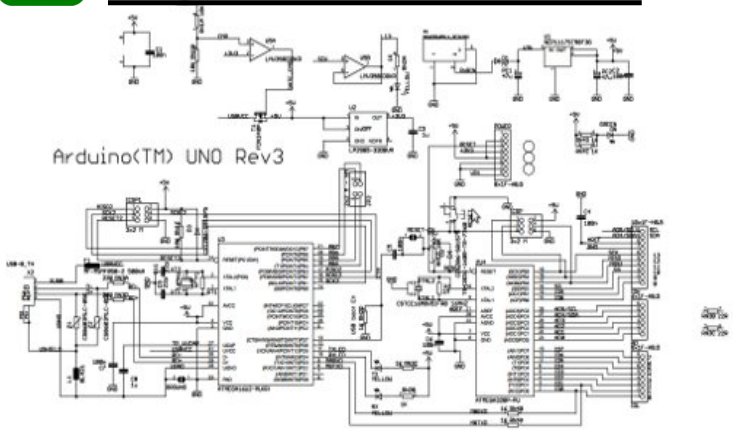
Hardware whose **design** is made **publicly available** so that anyone can **study**, **modify**, **distribute**, **make**, and **sell** the design or hardware based on that design

Slides: https://github.com/pdp7/talks/blob/master/penguicon17-oshw-fustini.pdf

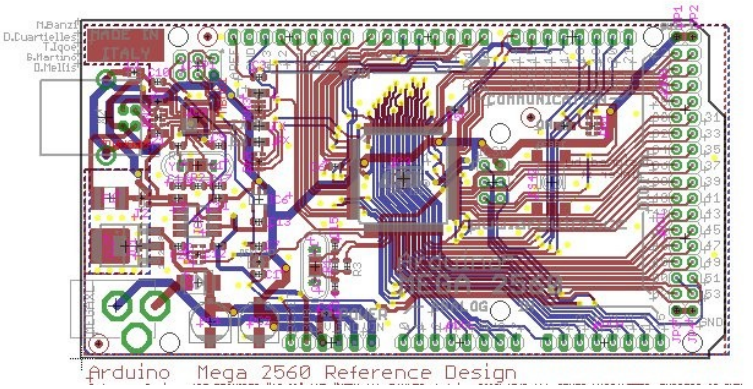
# Open Source Hardware

Documentation required for electronics:

## ☑ Schematics




## ☑ Board Layout



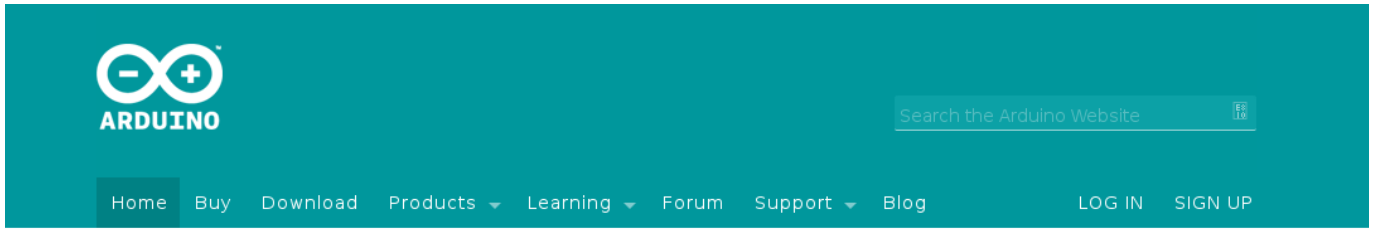

**Editable** source files for CAD software such as KiCad or EAGLE

## ☑ Bill of Materials *(BoM)*

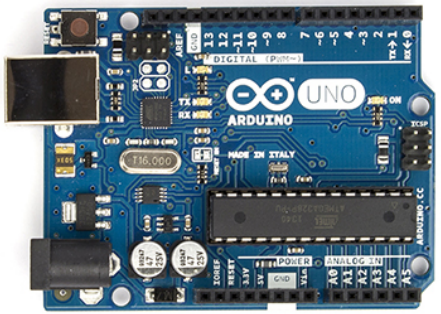
**Best practice:** all components available from distributors in **low quantity**

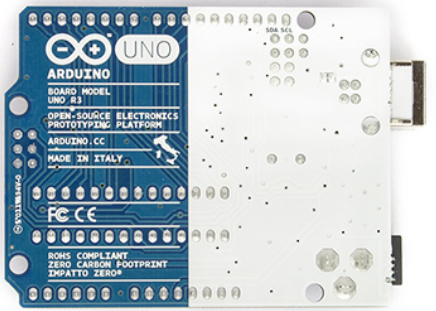
# Open Source Hardware

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




Arduino Uno

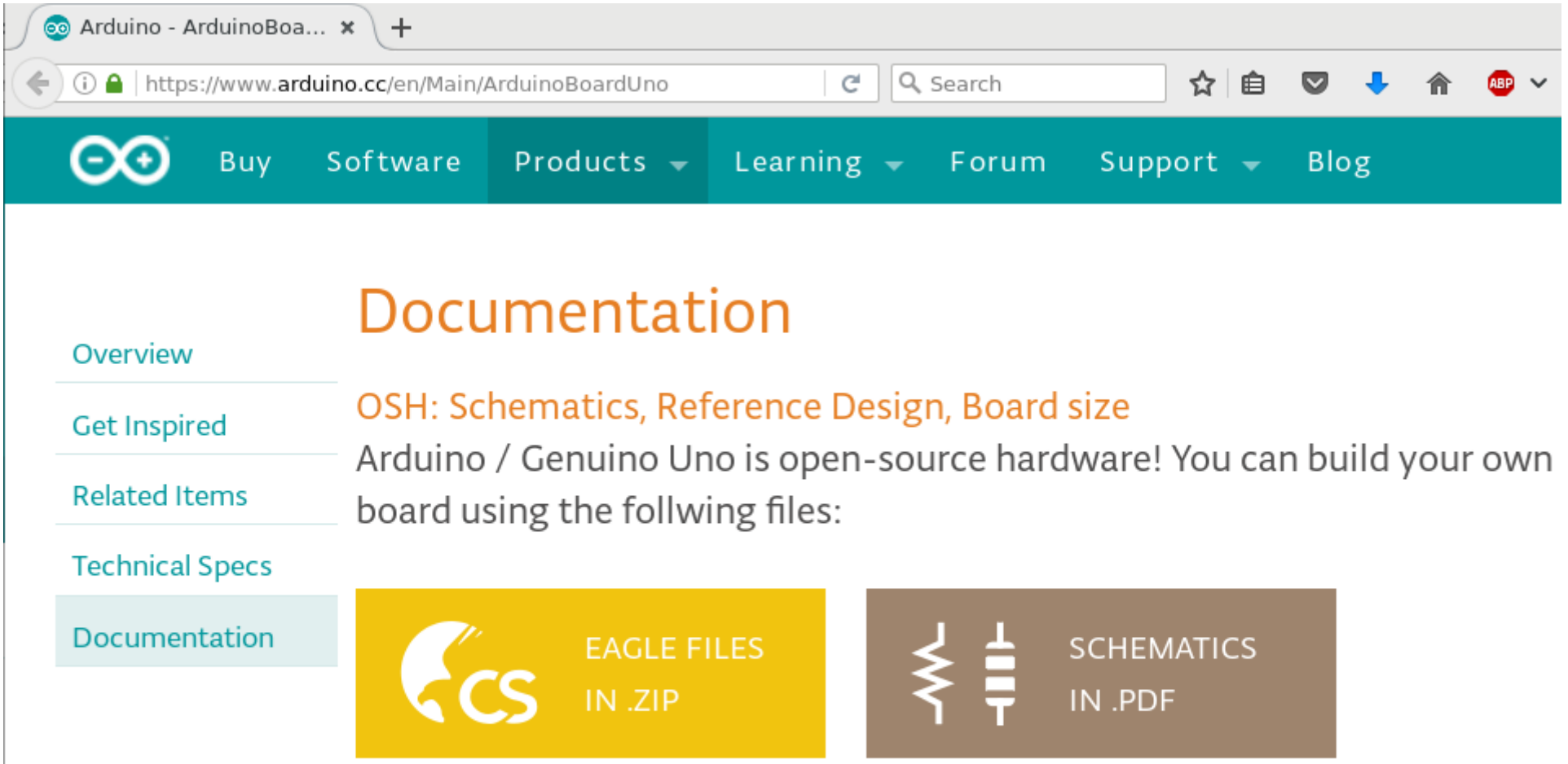



**Arduino: The Documentary** describes the team's motivation

# Open Source Hardware

☑ Example: **Arduino Uno** schematic and PCB layout design files for EAGLE CAD can be downloaded from Arduino.cc



# 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 Open Source?

- Open Source Initiative founded in 1998 and hosts the **Open Source Definition**:
  - “allow distribution in source code as well as compiled form”
  - “must not restrict anyone from making use of the program in a specific field of endeavor”
  - “may not restrict the program from being used in a business”
- compatible Open Source licenses include **Apache**, **BSD**, **GPL**, **MIT** and many more

# 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 **F**ree, **L**ibre, or **O**pen **S**ource **S**oftware
- I consider these hardware terms equivalent:
  - Free Hardware
  - Libre Hardware
  - Open Hardware
  - Open Source Hardware

# 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 Source Hardware

## MUST

Allow anyone to study, modify, distribute, make, and sell the hardware.

Provide publicly accessible design files and documentation (the source).

Clearly specify what portion of the design, if not all, is being released under the license.

Not imply that derivatives are manufactured, sold, warrantied, or otherwise sanctioned by the original designer.

Not use the trademarks of other companies without permission.

Not be released as non-commercial or no derivatives.

# Open Source Hardware

## MAY

Require attribution be given.

Use the open source hardware logo to signify their hardware follows the open source hardware definition.

Require derived works to carry a different name or version number from the original design.

Be copied directly or have derivitives created from it.

Require a viral license.

# Open Hardware Summit *(OHS)*

- OHS 2017: Denver, Colorado, October 5th

OHS 2017

- ***7** prior summits:*
  - **2010, 2011:** New York Hall of Science
  - **2012:** Eyebeam *(NYC)*
  - **2013:** MIT *(Boston area)*
  - **2014:** Roma, Italia!
  - **2015:** Philadelphia
  - **2016:** Portland, Oregon

# Open Hardware Summit *(OHS)*

- OHS 2017: Denver, Colorado, October 5th

OHS 2017

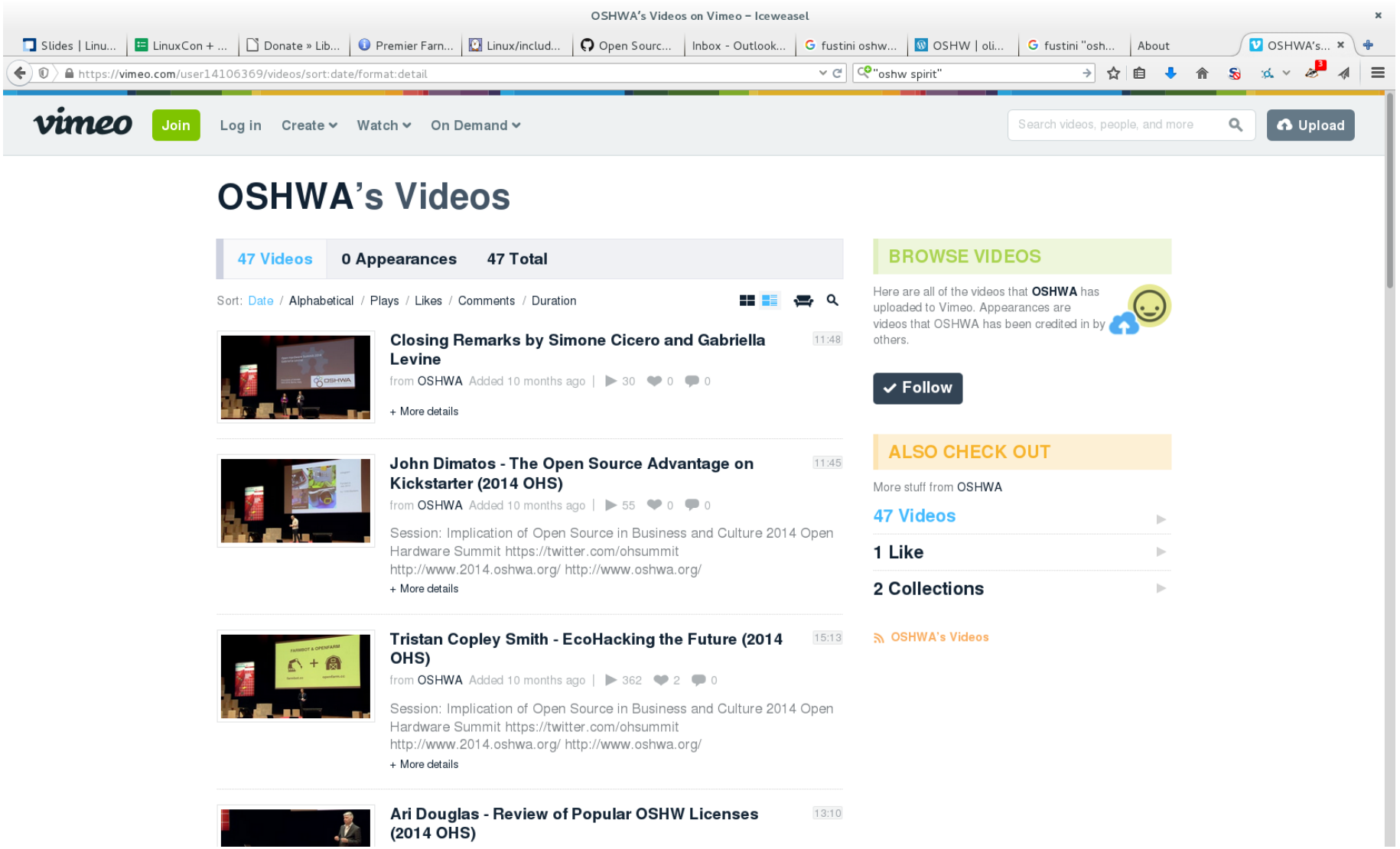
- Speaker Submissions are open

  **Deadline is Monday, May 1st!**

- Ada Lovelace Fellowship aims to increase diversity by offering a $500 travel stipend each for 10 people *(deadline was April 5th)*

# Open Hardware Summit *(OHS)*

## 2014 videos:



# Open Hardware Summit *(OHS)*

## 2015 videos:


2015 Summit Late Afternoon Sessions

4 months ago

2015 Summit Early Afternoon Sessions

4 months ago

OHS 2015

The Best Open Hardware Summit Ever.

2015 Summit Late Morning Sessions

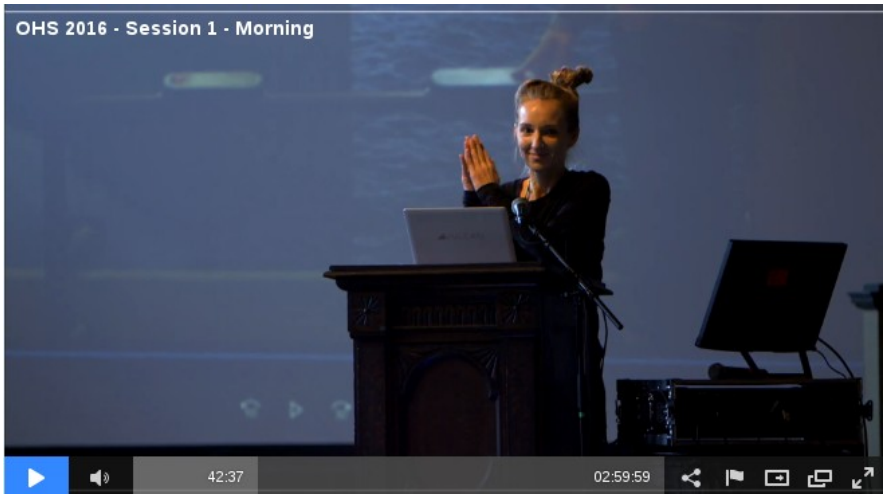
4 months ago

2015 Summit Early Morning Sessions

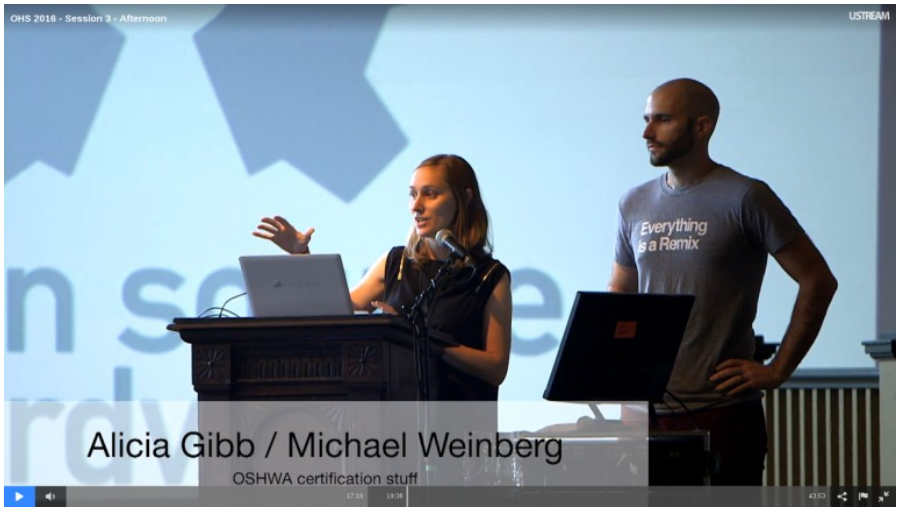
4 months ago

# Open Hardware Summit *(OHS)*

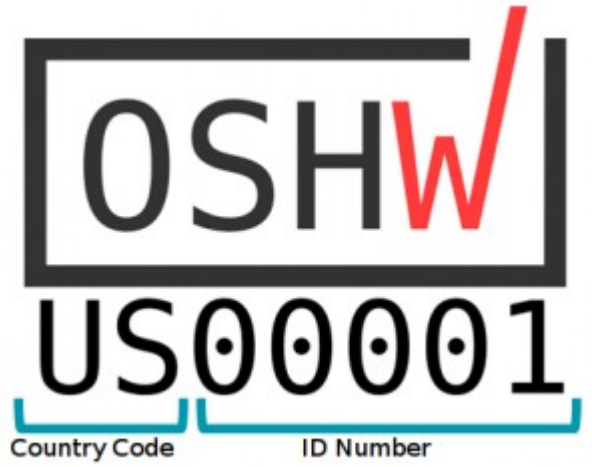
- **OHS 2016 morning sessions**




- **OHS 2016 afternoon sessions**

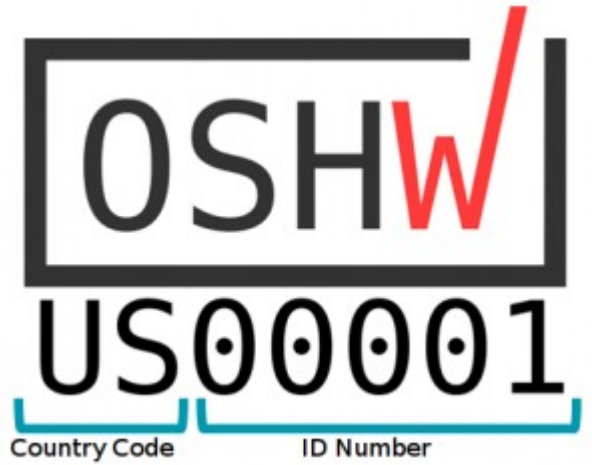


# Open Source Hardware Certification Program




- Announced by OSHWA at Open Hardware Summit in Portland back in October 2016
- Blog post: Announcing the OSHWA Open Source Hardware Certification Program

# 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

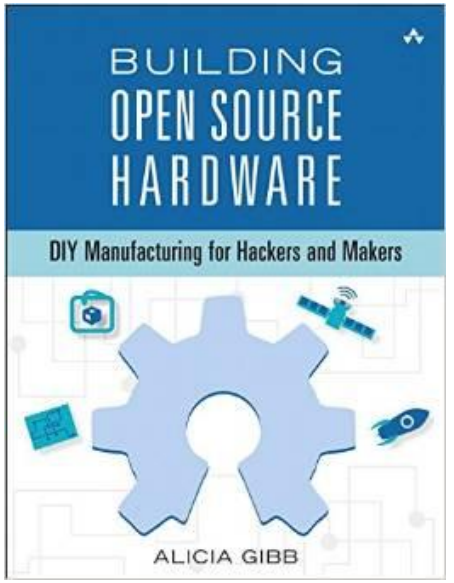

- **Video playlist on YouTube**
- Open Hardware Europe Summit & The DIY 2.0 revolution
  - “The global open hardware community met in Vienna, Austria to give talks about new aspects, new methods and lessons learned for the open hardware movement.”

# 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)*



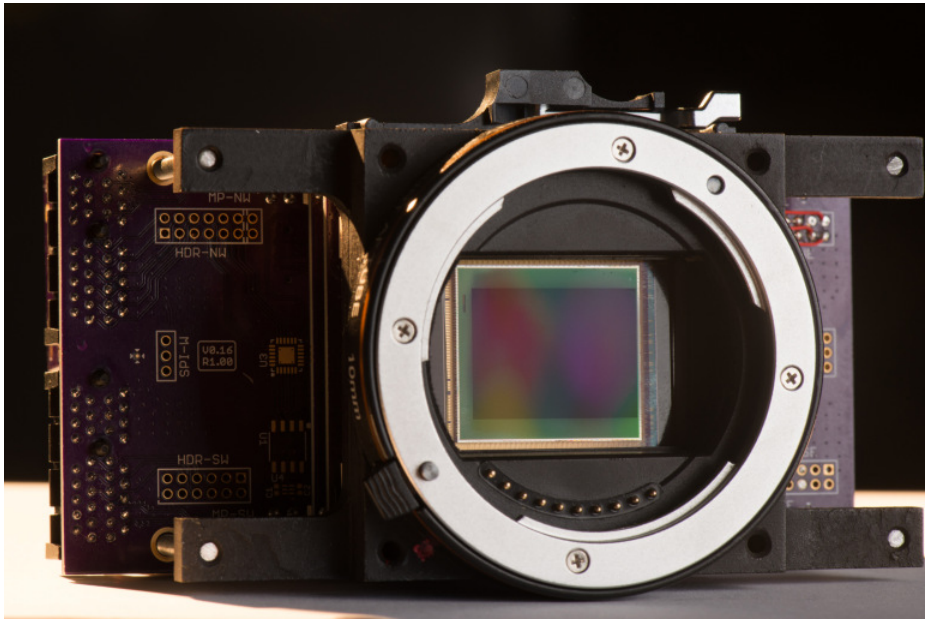
Slides:
https://github.com/pdp7/talks/blob/master/penguicon17-oshw-fustini.pdf


*Section:*

# OSHW PRODUCTS

apertus°
open source cinema

- “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**”



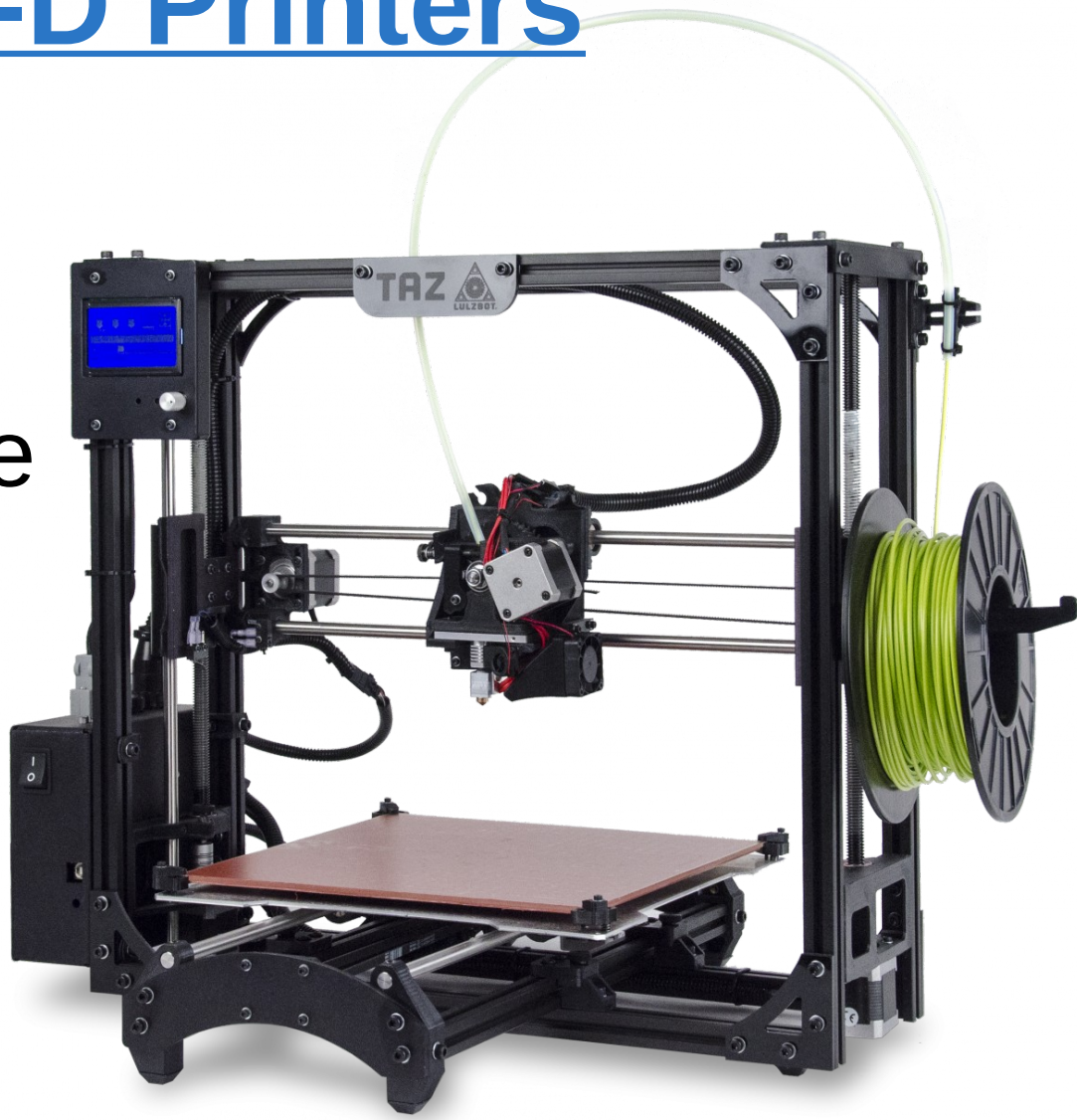
apertus
open source cinema

- “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/penguicon17-oshw-fustini.pdf


*Section:*

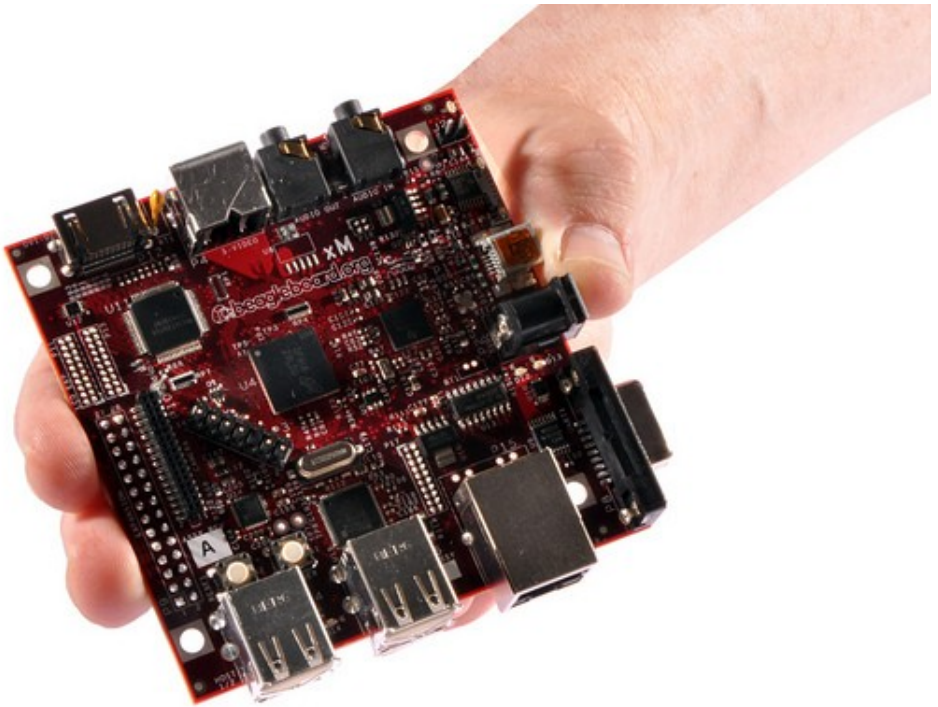
# LINUX on OSHW

# beagleboard.org

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

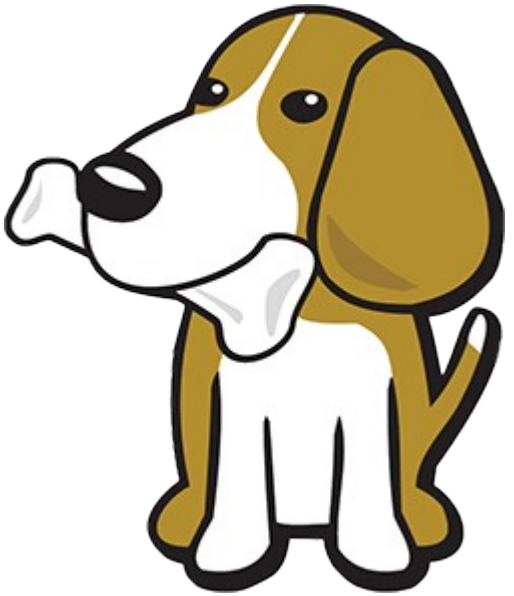
# beagleboard.org

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



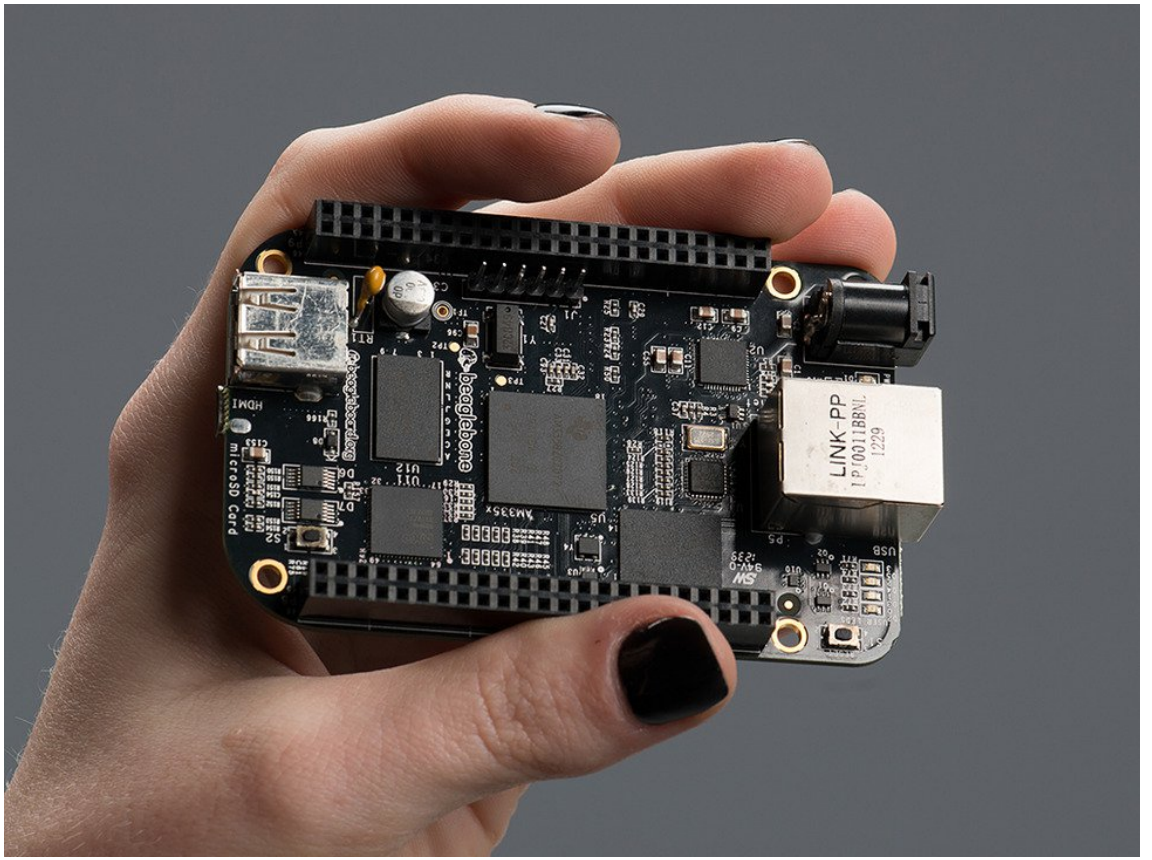
# beagleboard.org

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



# beagleboard.org

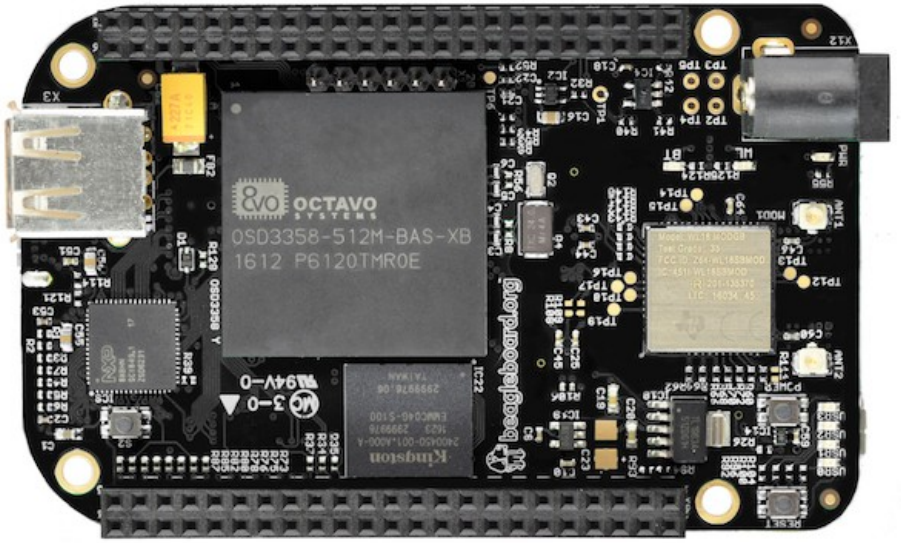
More affordable, more powerful
**BeagleBone Black** in **2013**




# 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 |

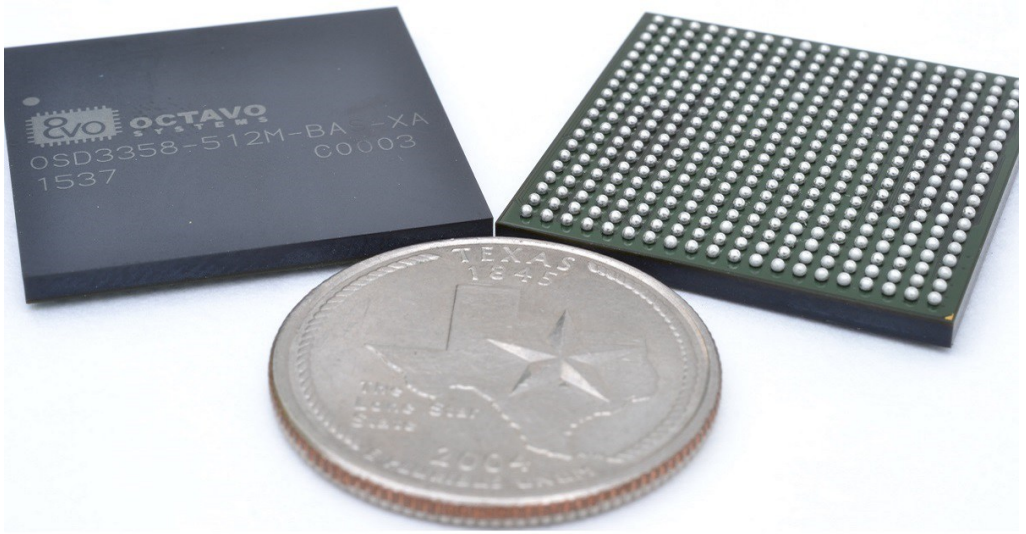
# BeagleBone Black Wireless



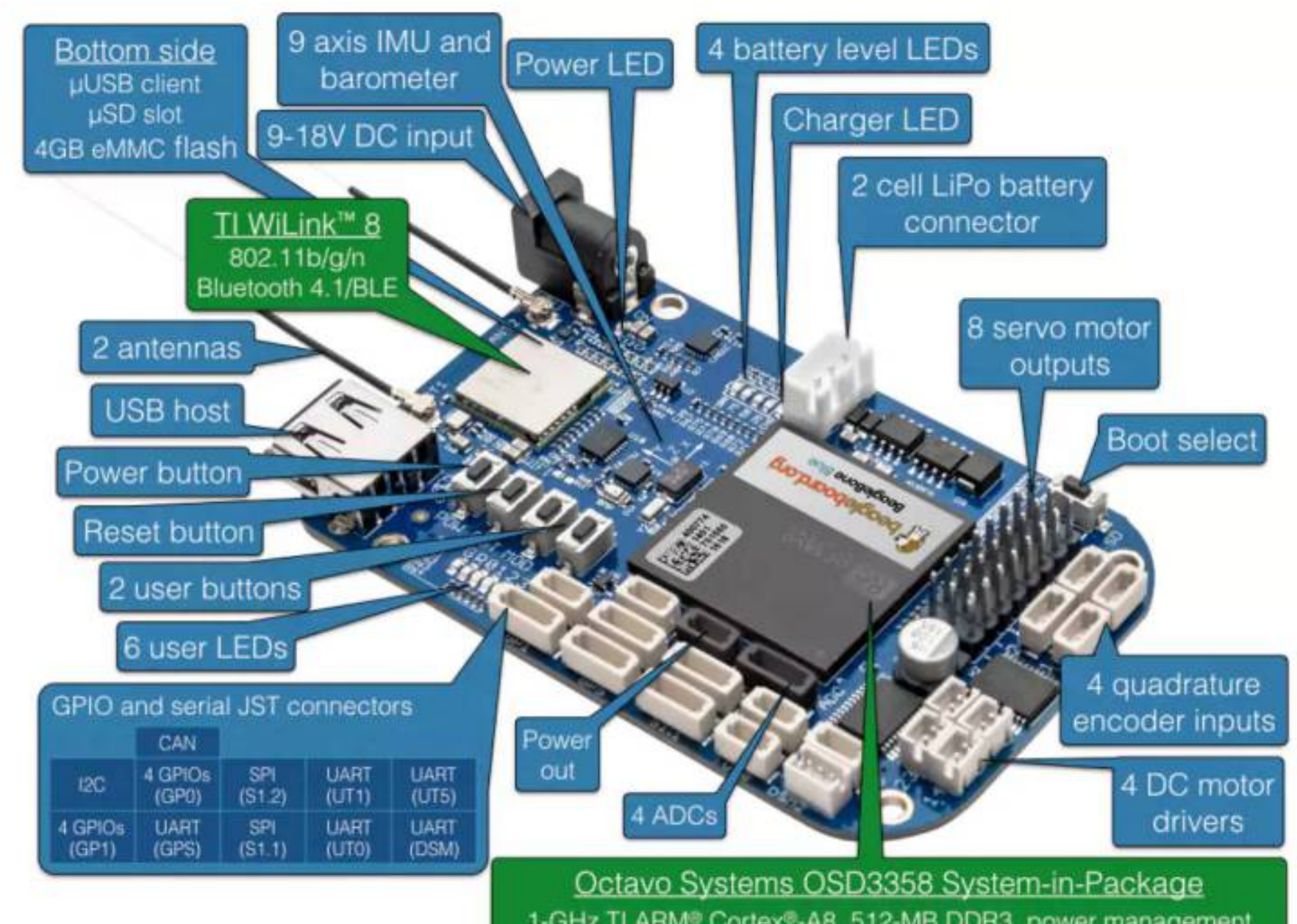

- 1 GHz ARM processor, 512 MB RAM
- 2x 32-bit PRU microcontroller for hard real-time
- 4GB eMMC with Debian GNU/Linux installed
- WiFi, Bluetooth+BLE, HDMI, USB 2.0, 65 GPIO, 8 PWM, 7 analog inputs, 4 UART, 2 $I^2C$, 2 SPI

# 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

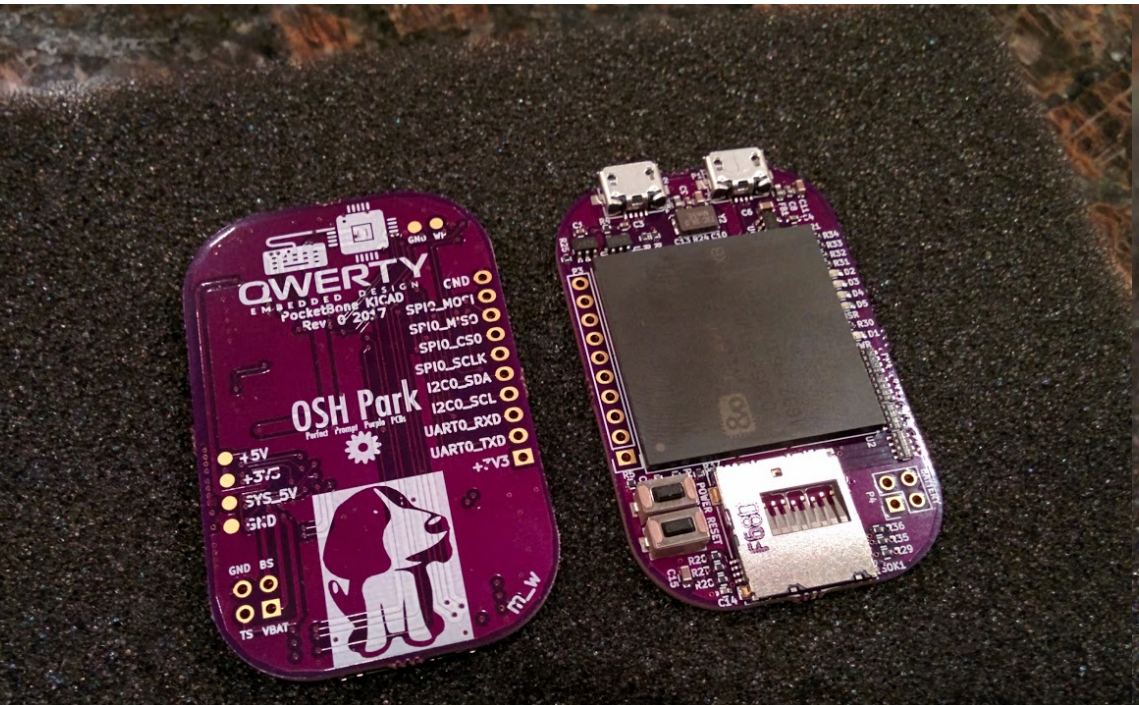


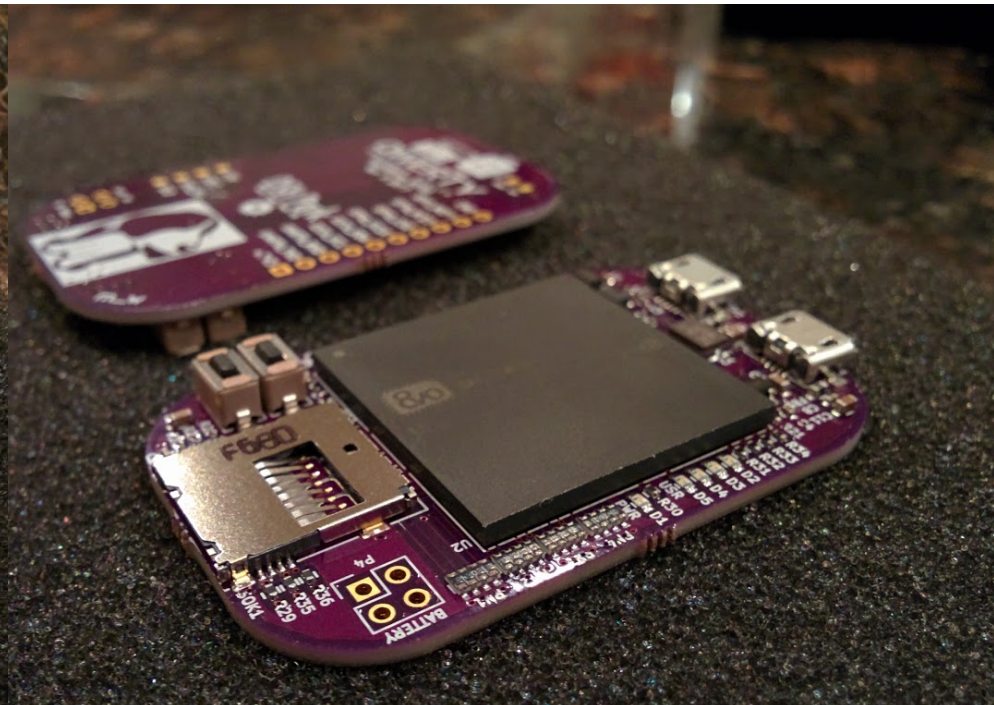
# BeagleBone Blue: complete Linux robotics controller. 4 layer PCB designed in EAGLE.



# PocketBone

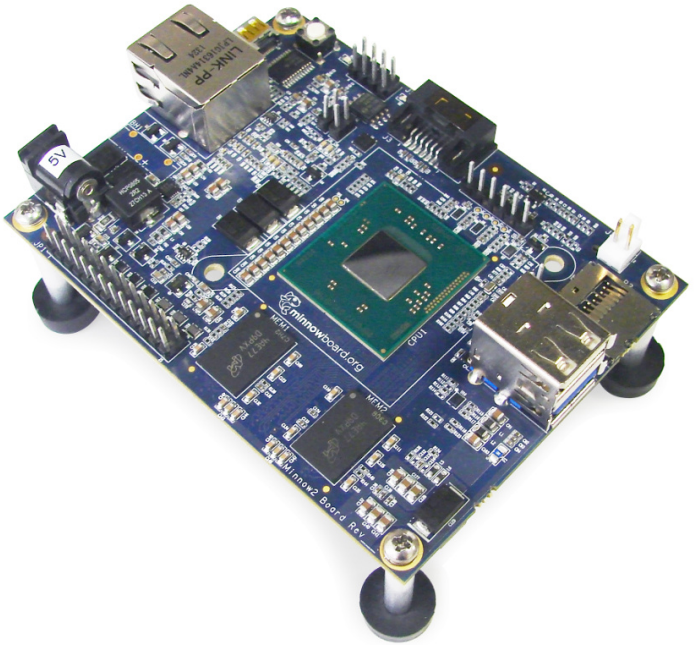
- **Michael Welling** designed this BeagleBone derivative with Octavo SiP that fits in the mini Altoids tin!
- 4 layer PCB design in **KiCad** can be manually assembled

minnowboard.org

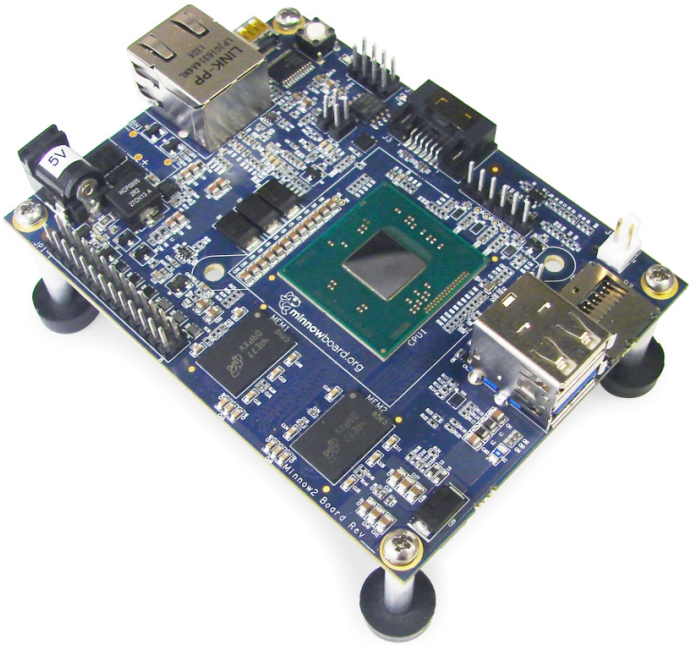
# MinnowBoard



- 64-bit Intel Atom *“Bay Trail”*
- MinnowBoard Turbot
  - $135: E3826 (dual-core, 1.46 GHz)
- USB 3.0, SATA, PCIe, Gigabit Ethernet, HDMI
- Integrated Intel HD Graphics
  - Open Source Mainline Linux drivers!

minnowboard.org

# MinnowBoard



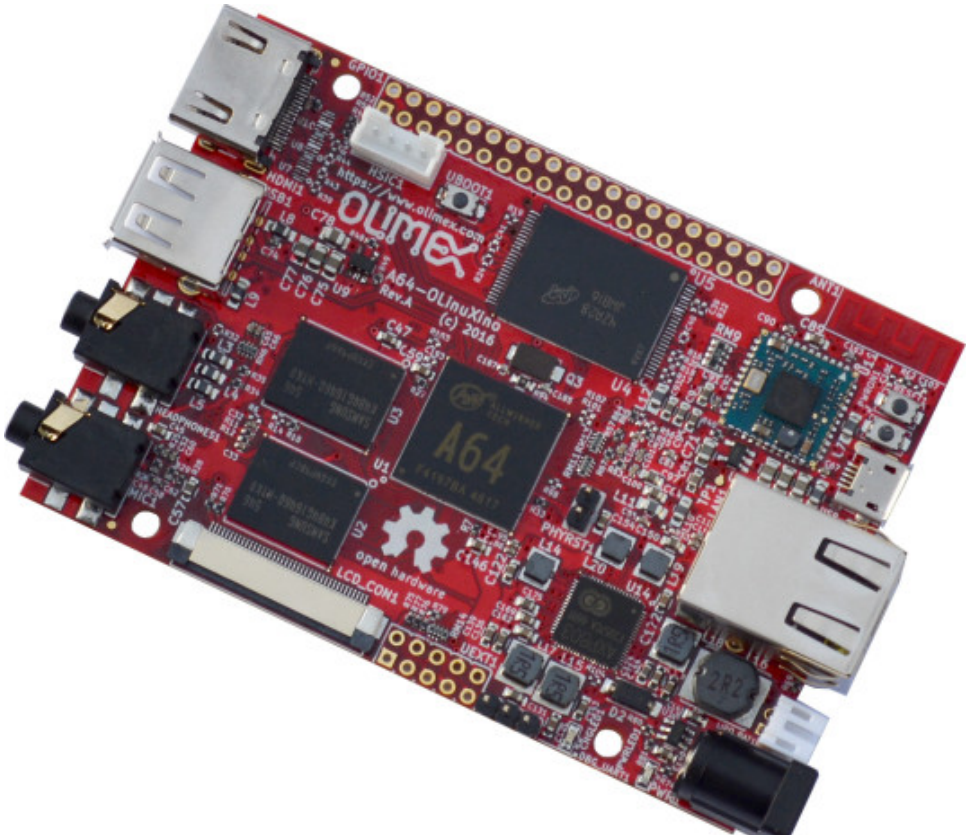
- Manufactured by ADI
- Released under Creative Commons **CC-BY-SA**
- Download design files:
  - ☑ **Schematic** (Orcad DSN & PDF)
  - ☑ **Board Layout** (Allegro BRD & Gerbers)
  - ☑ **Bill of Materials**

# 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

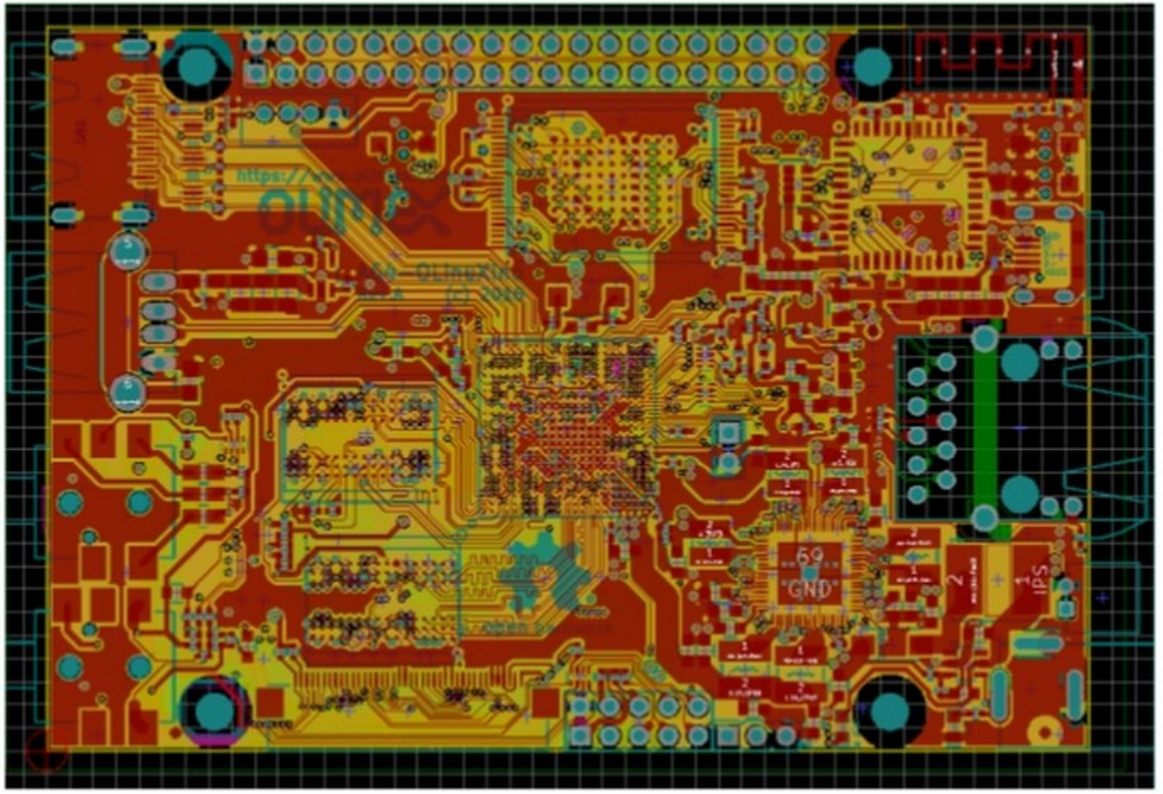
# A64-OlinuXino

- 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**

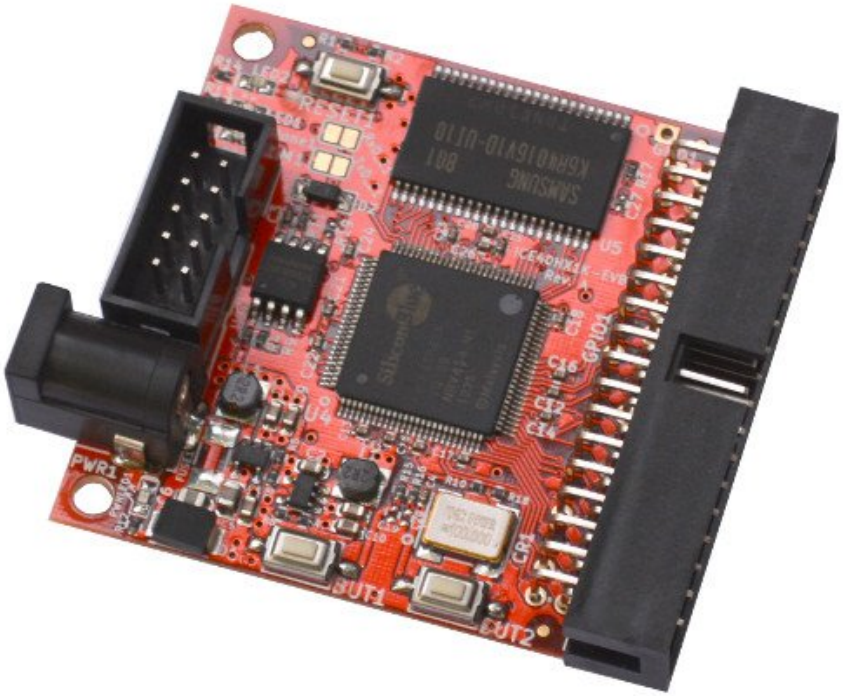
# TERES I Laptop

- “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”

# iCE40 FPGA Board

- Low cost development board for iCE40 FPGA family from Lattice Semiconductor.
- “Interesting part about this family of FPGAs is that there is a completely free & open source development tool available”



# Project IceStorm

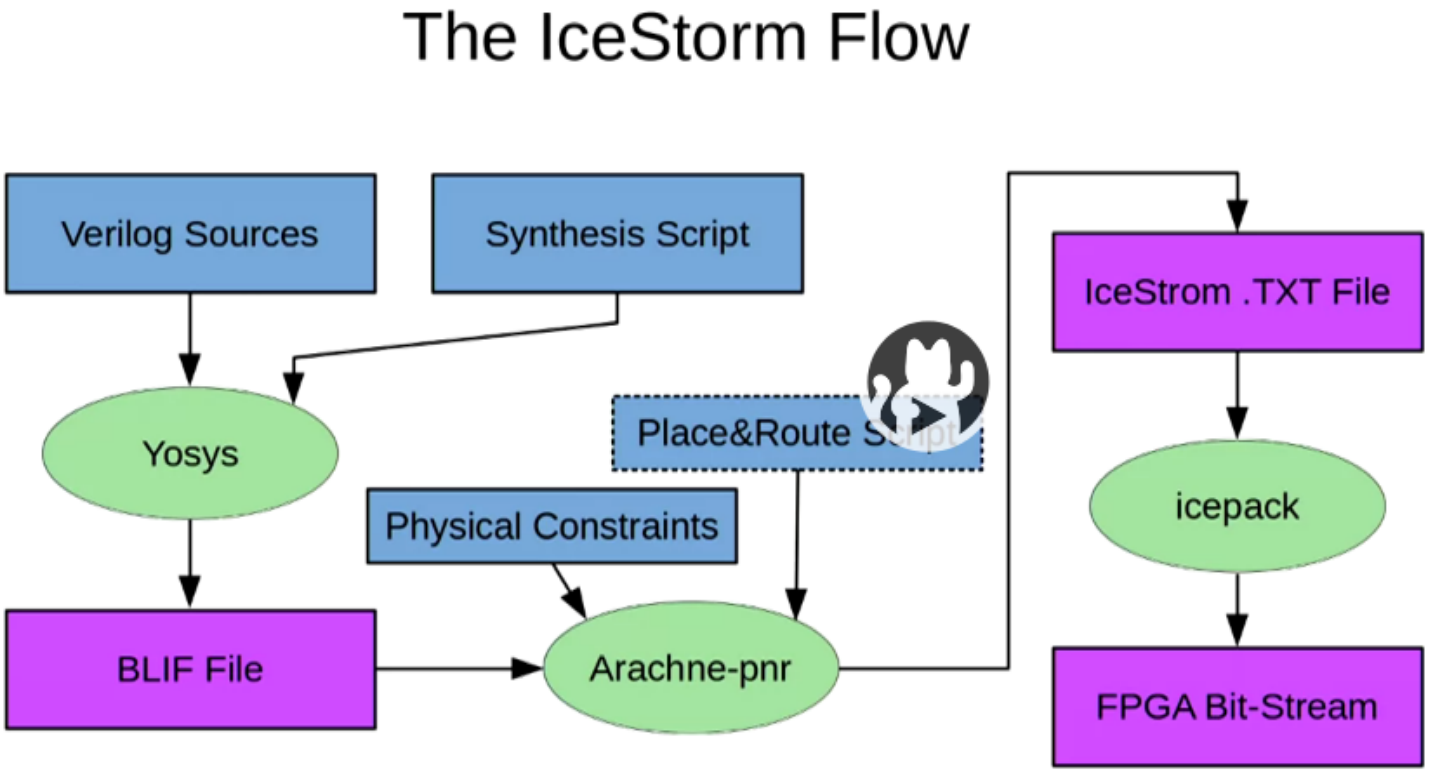
- **Clifford Wolf** has been "**reverse engineering** and documenting the bitstream format of **Lattice iCE40 FPGAs** and providing simple tools for analyzing & **creating bitstream files**"

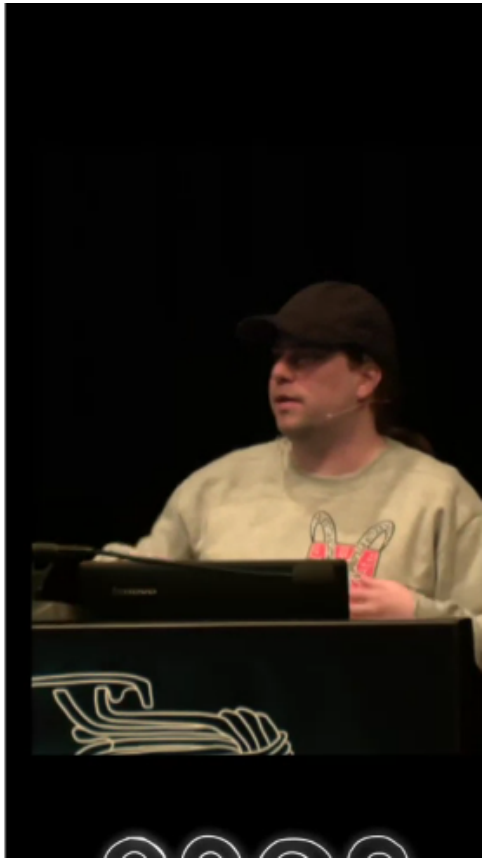
- **Yosys** (Yosys Open Synthesis Suite) by Clifford Wolf is an **Open Source Verilog synthesis** and verification tool

# Project IceStorm

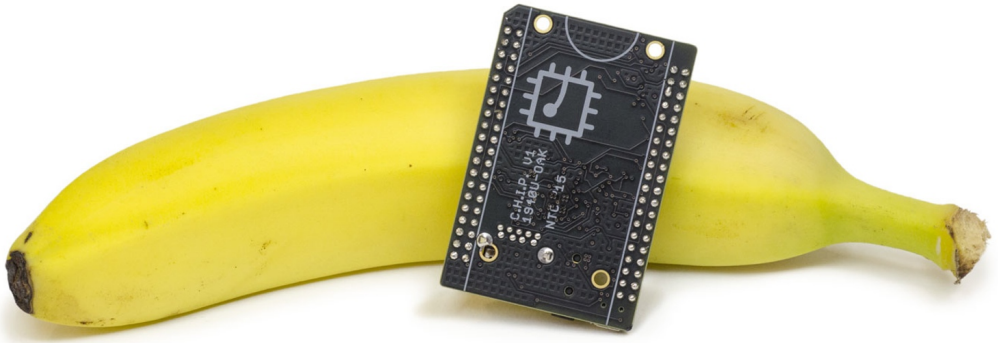
## Video of talk at 32C3:

**“A Free and Open Source Verilog-to-Bitstream Flow for iCE40 FPGAs”**



# CHIP

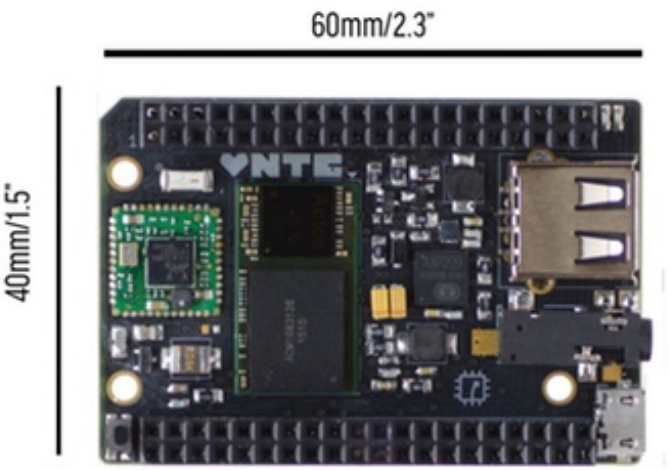


*The World's First $9 Computer*

- [getchip.com](getchip.com)
- Next Thing Co. in Oakland
- Kickstarter in 2015:
  - 39,560 backers
  - $2,071,927 pledged

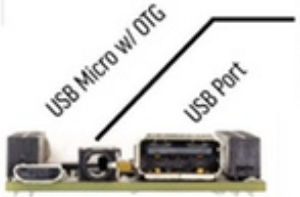
# 1GHz + 512MB + 4GB

processor ram storage




R8

1GHZ Allwinner A13 Compatible SoC
Mali400 GPU w/ OpenGLES 2.0 & OpenVG 1.1
512MB DDR3 Ram
4GB NAND Flash Storage




Composite Video
HDMI & VGA Out via adapter
Headphone Audio Out
Mic In

open source hardware

## C.H.I.P. is built with Making in Mind

Realtek 2-in-1 Bluetooth 4.0 + WIFI B/G/N
I2C + SPI + UART + 8 x GPIO
Camera Sensor Support (MIPI-CSI)
Native LCD Support 4.3-8"
Battery Power & Charging

Fast Boot Debian Based Linux OS
Over The Air Updates
OpenGLES 2.0
OpenVG 1.1

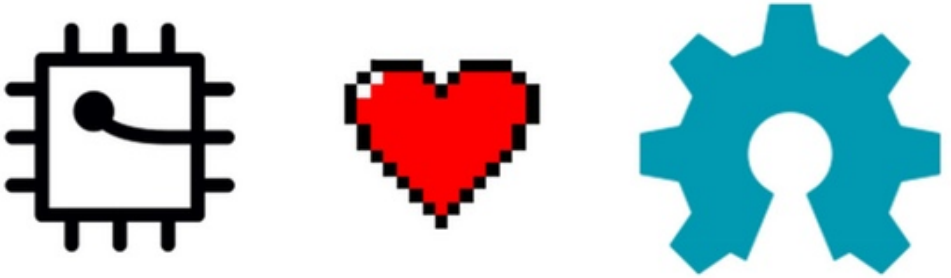
## WIFI & Bluetooth

802.11B/G/N 4.0

*Battery Power & Charging Built In!*

*Run CHIP for Hours with a Single Cell Lipo.*

# 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)*

Slides:
https://github.com/pdp7/talks/blob/master/penguicon17-oshw-fustini.pdf

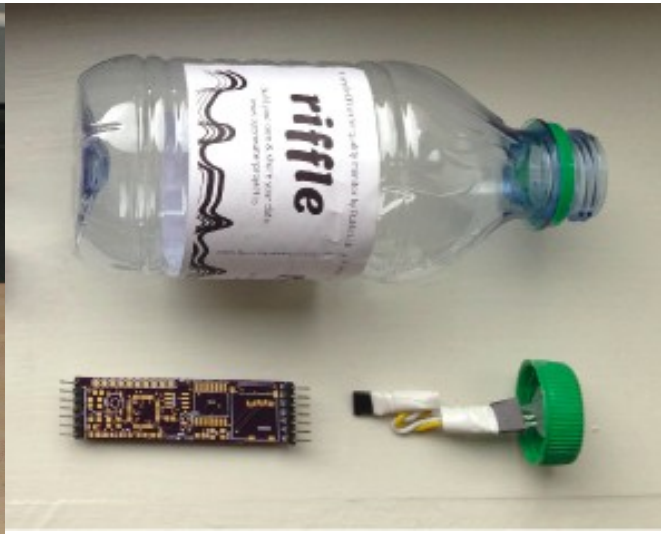

# *Section:*
# OSHW in Science

*Suggestions from the OSHWA mailing list*

# Public Lab

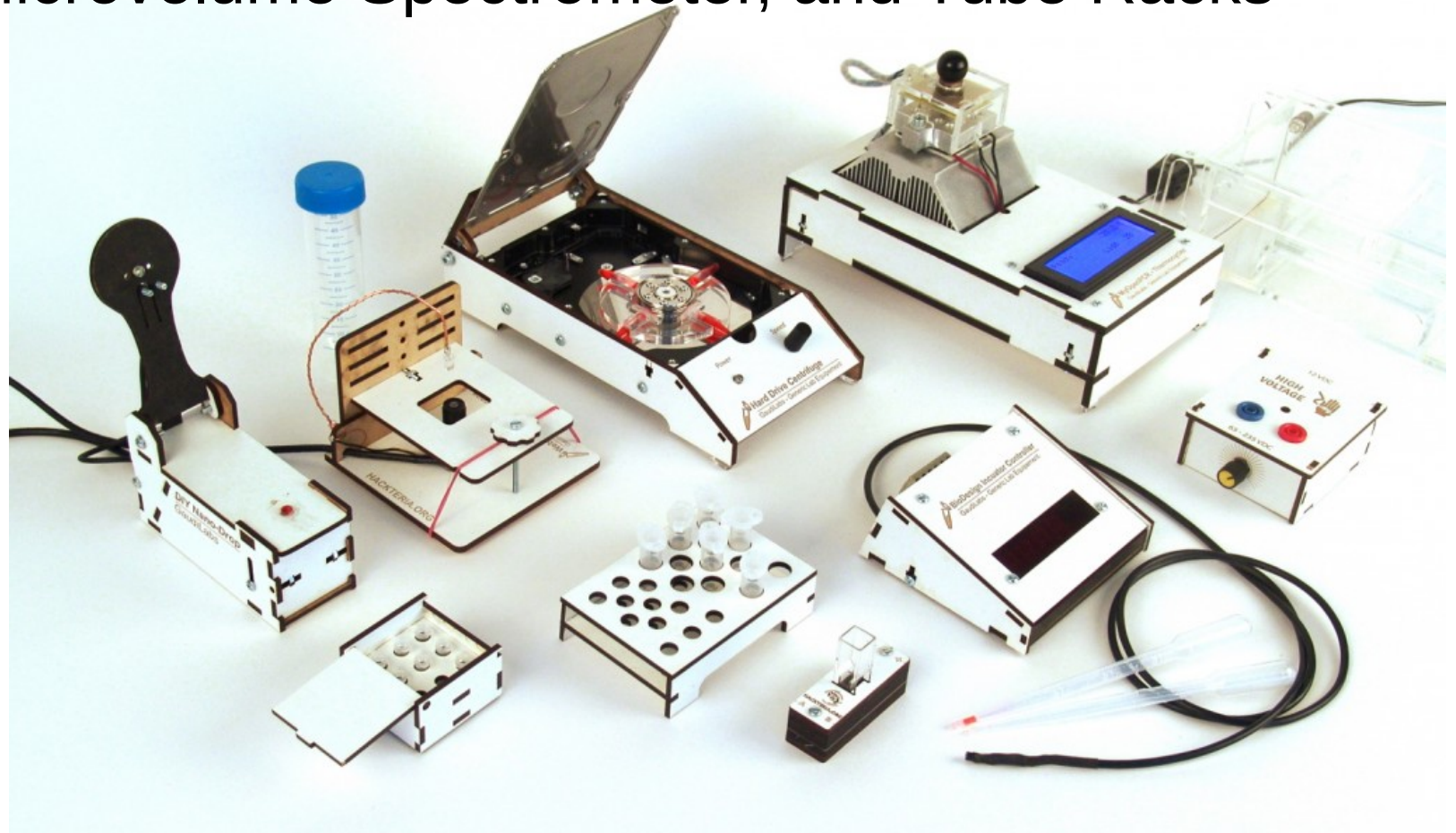
- “Using inexpensive DIY techniques, we seek to change how people see the world in environmental, social, and political terms.”
- **Riffle: Open Source Water Monitoring**
- **Desktop Spectrometry**
- **Balloon Mapping Kit**





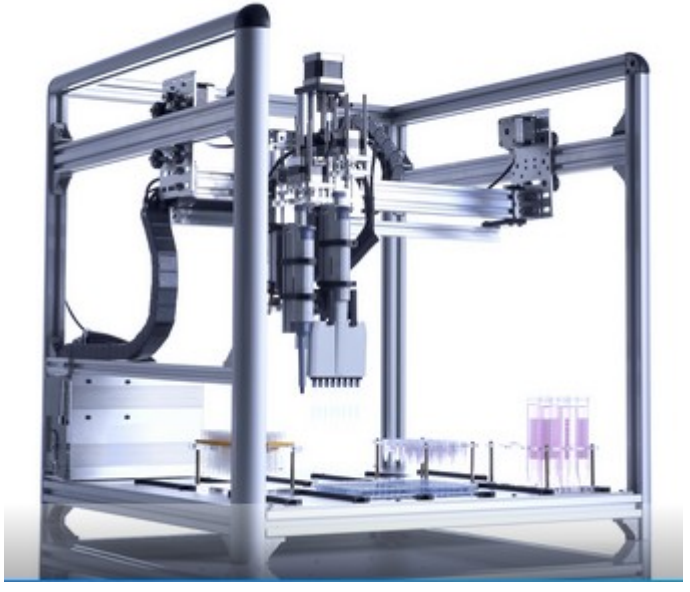
# Generic Lab Equipement

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



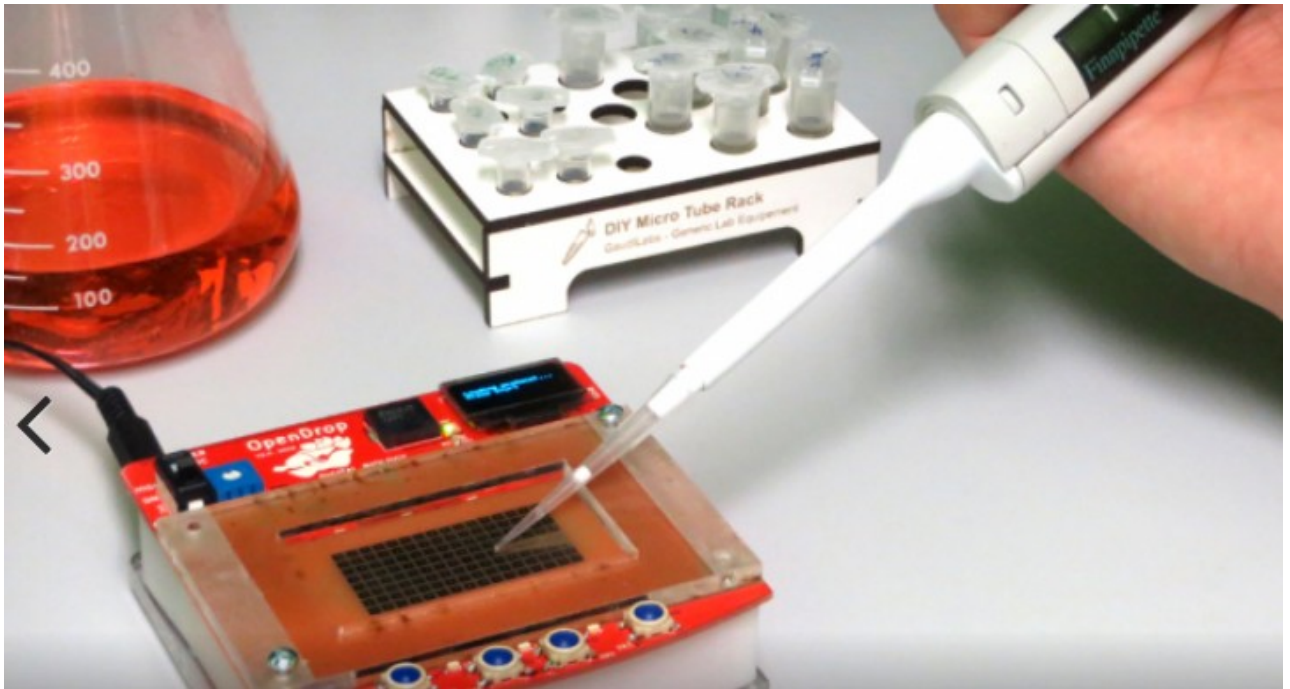
# OpenTrons

- **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

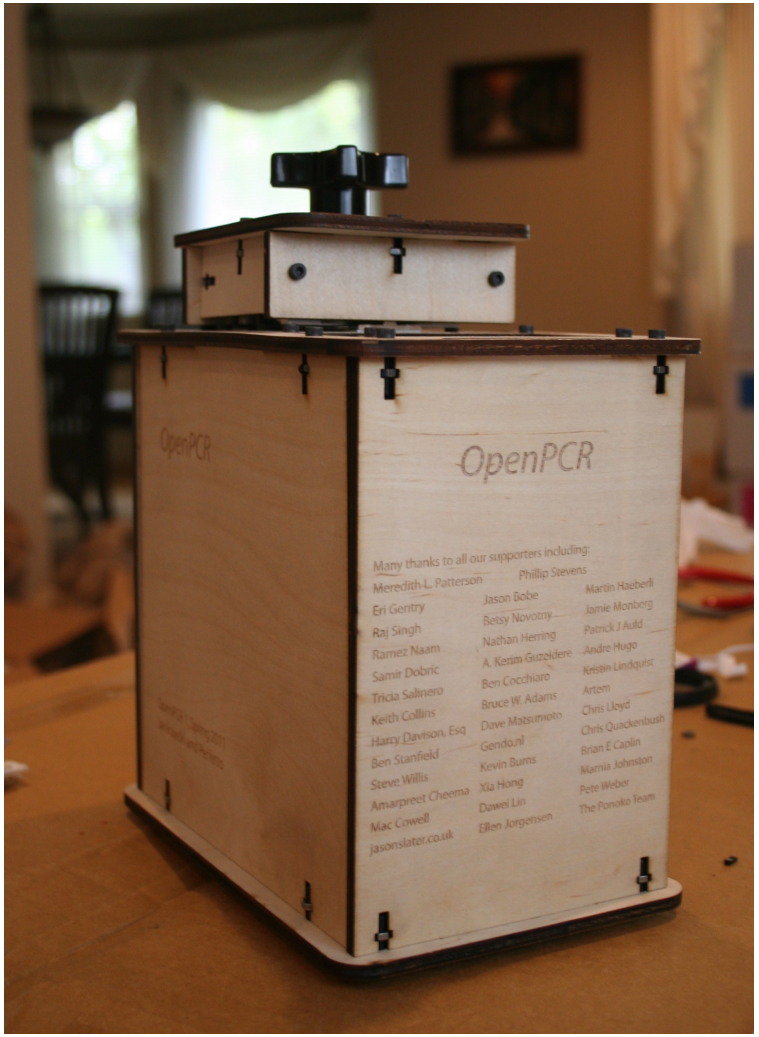
- “Desktop Digital Biology Laboratory”
- digital **microfludics** platform for research
- aim of making personal lab-automation accessible to more people



# 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**

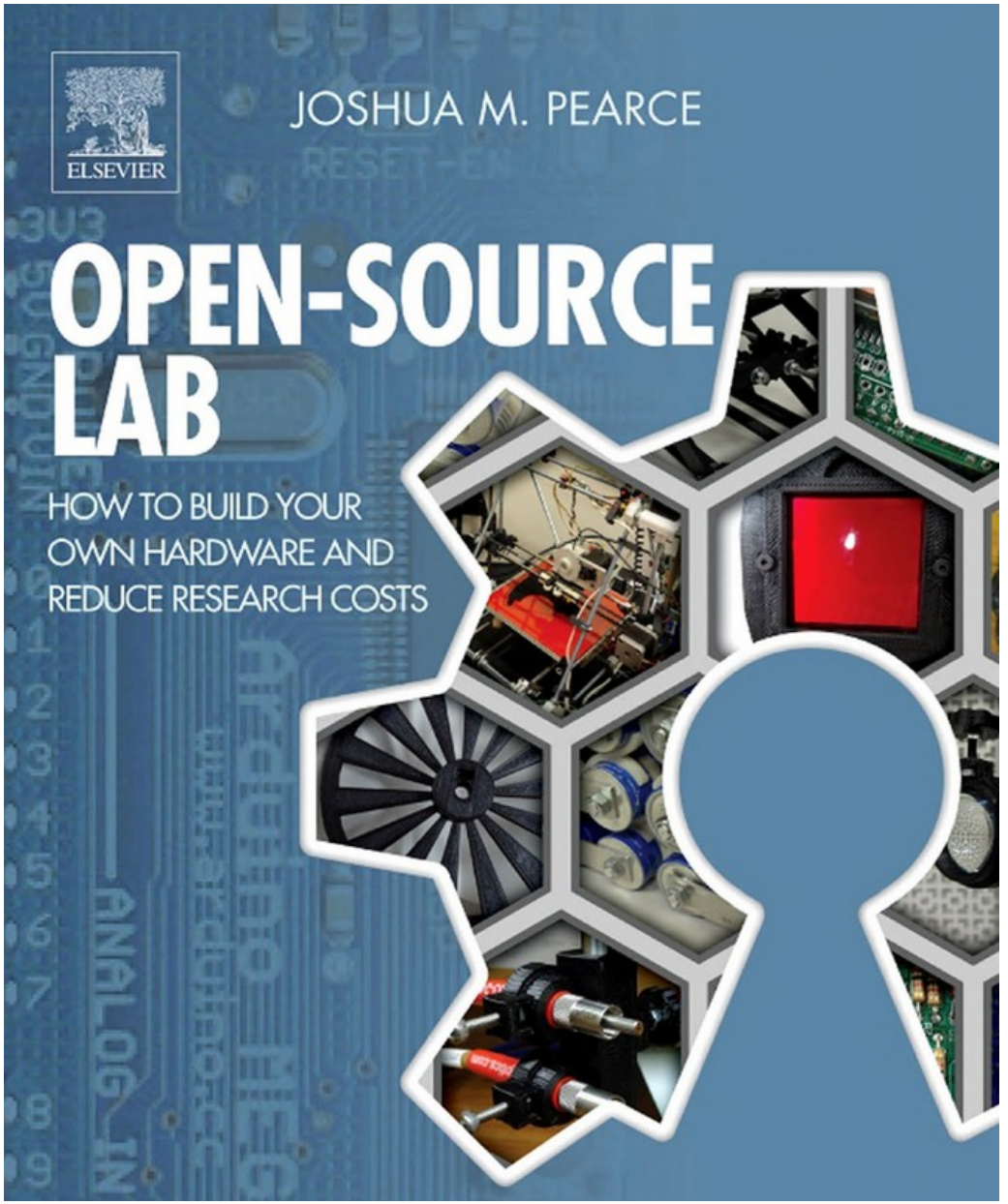


# Open Source Imaging Initiative

- “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 2017: Santigo, Chile *(March 22-25)*

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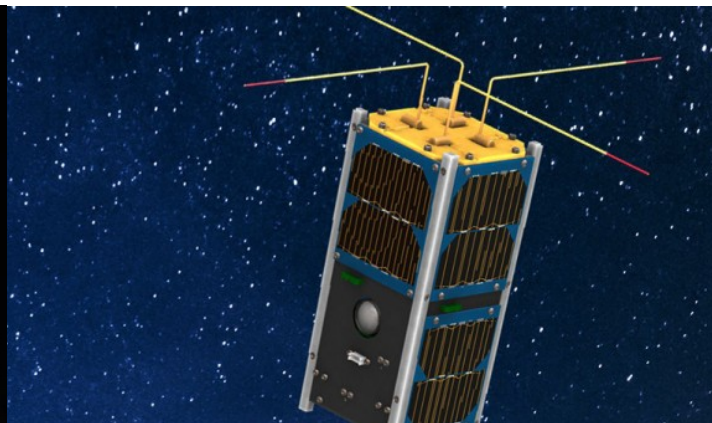
- **Opencore NMR** is an open-source toolkit for implementing an NMR spectrometer

# 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 on April 18th! Waiting for deployment from ISS
  - "Flying The First Open Source Satellite"





*Source:* https://github.com/pdp7/talks/blob/master/penguicon17-oshw-fustini.pdf


*Section:*

# Open Source and Libre Silicon

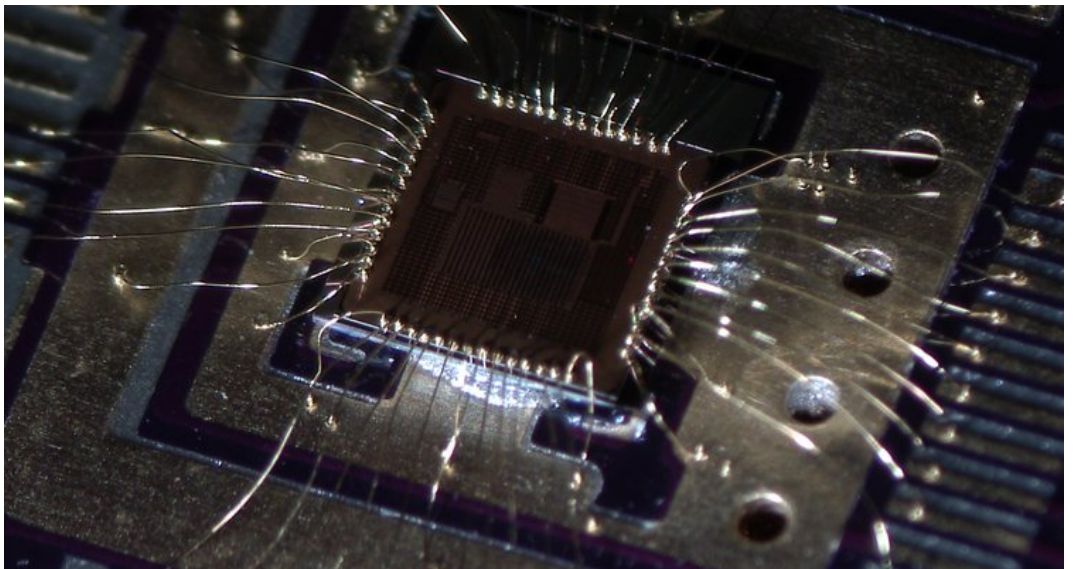
# *What about silicon?*


- **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?*

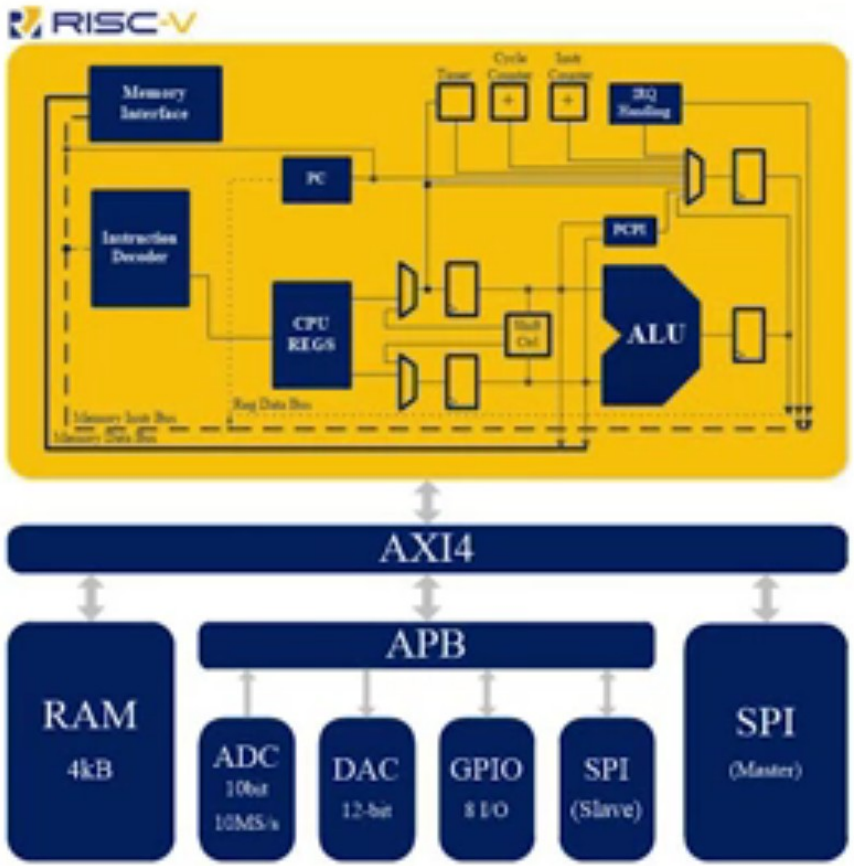
- **OnChip Open-V**

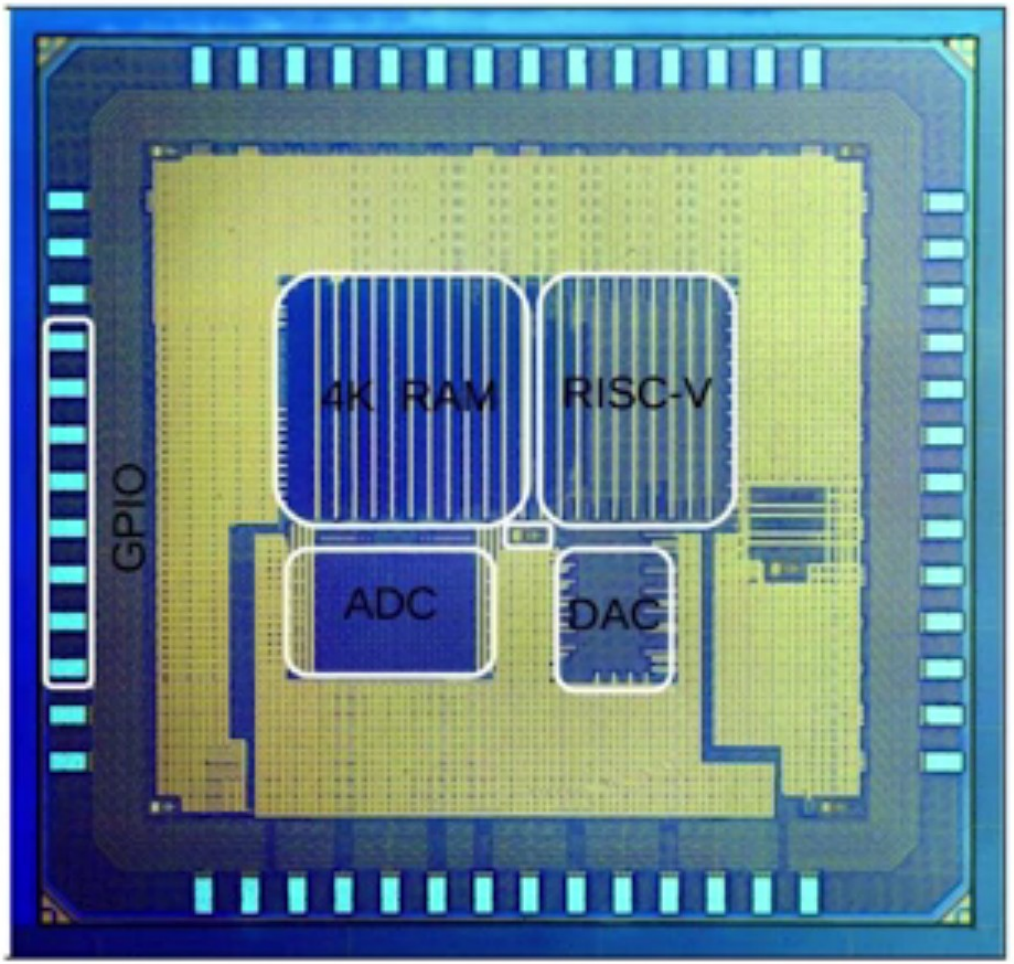
  “completely free (as in freedom) and open source 32-bit microcontroller based on the RISC-V architecture”



# *What about silicon?*

## A 32-bit RISC-V based Microcontroller



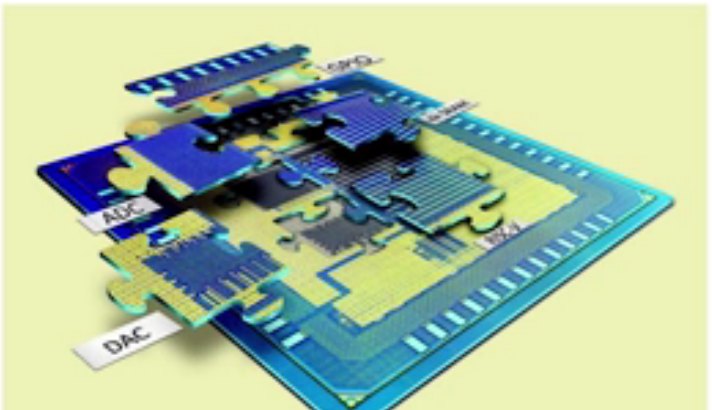



# *What about silicon?*

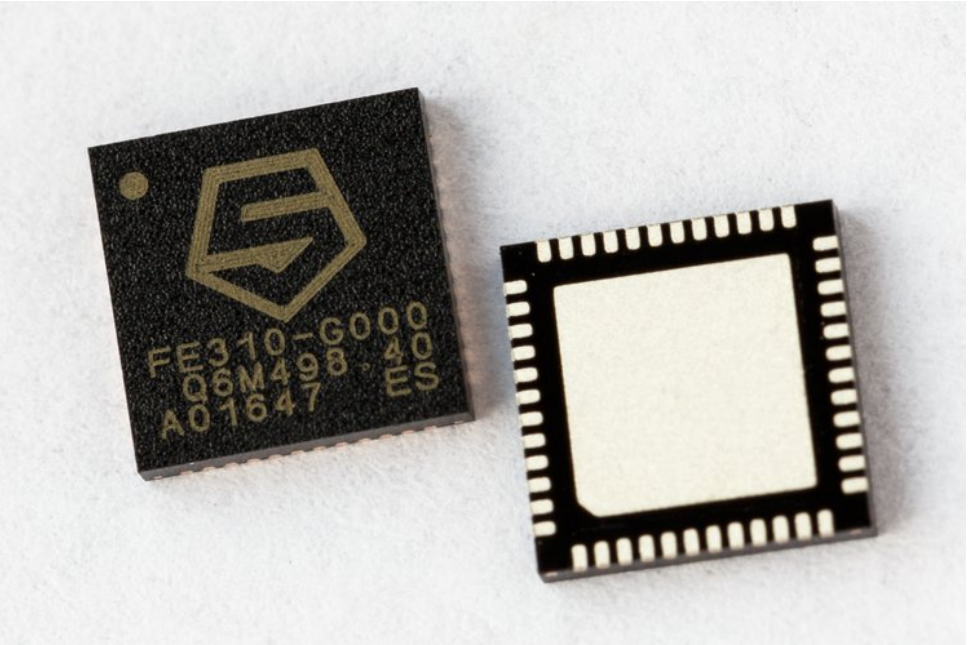

- Crowd Supply update: **A Taste of Chip Design**
- Video: **YoPuzzle: mRISC V development platform**
- Video: **RISC-V Community needs Peripheral Cores**

## 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?*

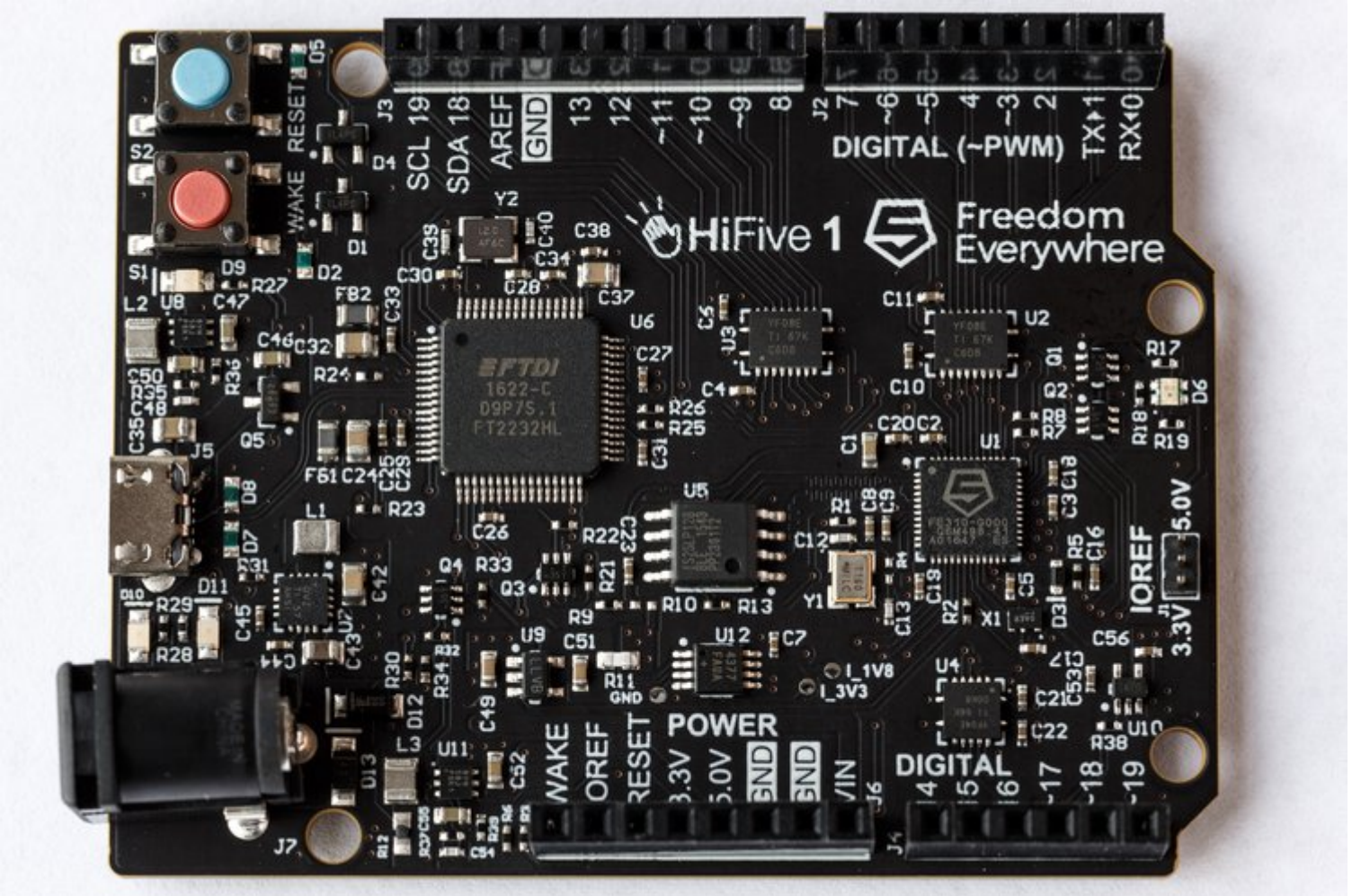



- **SiFive**

  “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”

# *What about silicon?*

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



# *What about silicon?*

- **SiFive FE300 & low cost HiFive Dev Board**
  - Video of talk by Jack Kang of SiFive (Dec 22, 2016)

# *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?*

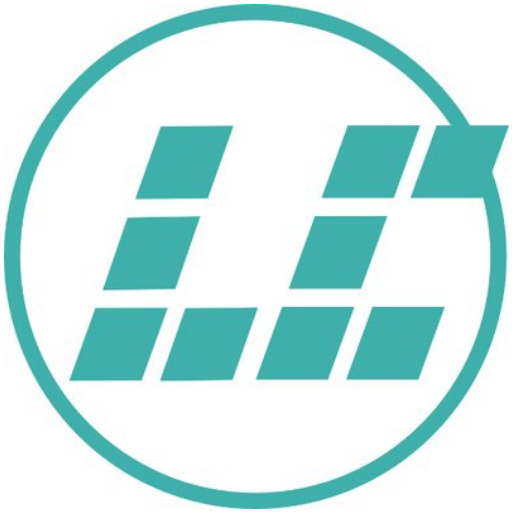

- **FOSSi Foundation**
  - The **F**ree and **O**pen **S**ource **S**ilicon **F**oundation
  - “non-profit foundation with the mission to promote and assist free and open digital hardware designs”
  - “FOSSi Foundation operates as an open, inclusive, vendor-independent group.”

# *What about silicon?*

FOSSi Foundation

- **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”

# Thanks

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

These slides are available at:
https://github.com/pdp7/talks/blob/master/penguicon17-oshw-fustini.pdf

**Drew Fustini**

**drew@oshpark.com**

**@OSHPark / @pdp7**

**OSH Park Blog**