

Slides: <https://github.com/pdp7/talks/blob/master/oshw-garage.pdf>

# Open Source Hardware and Open Source Chip Design



Drew Fustini  
OSH Park  
[drew@oshpark.com](mailto:drew@oshpark.com)  
[@oshpark / @pdp7](https://twitter.com/oshpark)



- Open Source Hardware designer at OSH Park
  - PCB manufacturing service in the USA known for purple soldermask!
  - [drew@oshpark.com](mailto:drew@oshpark.com) / Twitter: [@oshpark](https://twitter.com/@oshpark)
- Volunteer Member of Board of Directors of BeagleBoard.org Foundation
  - [drew@beagleboard.org](mailto:drew@beagleboard.org)
- Volunteer Member of the Board of Directors of the Open Source Hardware Association (OSHWA)
  - serving as Vice President
  - [drew@pdp7.com](mailto:drew@pdp7.com)



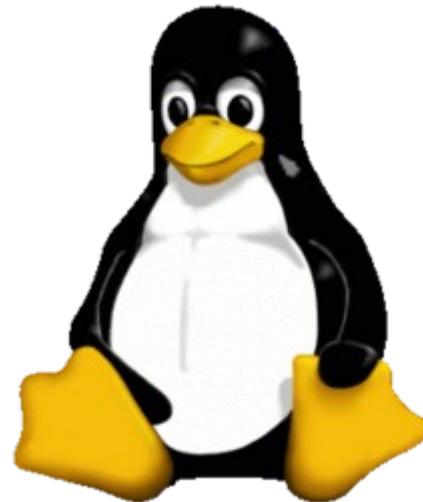
# What is Open Source?



- Examples of popular Open Source projects



**Apache**



**LibreOffice**<sup>®</sup>



**Firefox**<sup>®</sup>



# 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



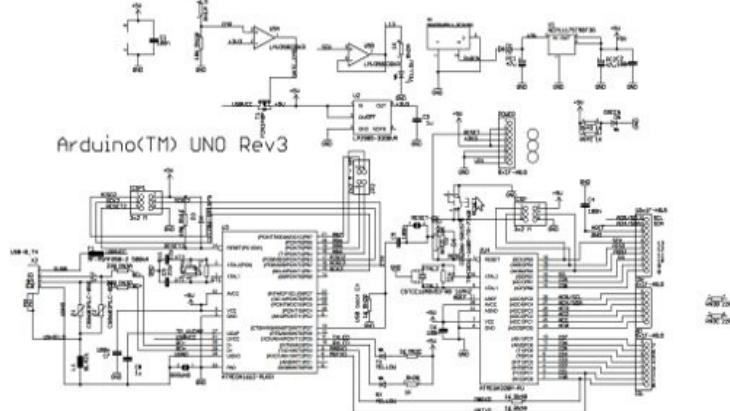
# Open Source Hardware



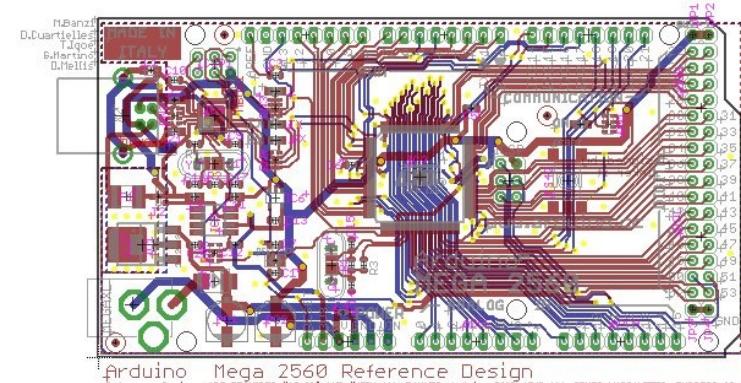
Documentation required for electronics:



## Schematics



## Board Layout



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



## Bill of Materials (BoM)

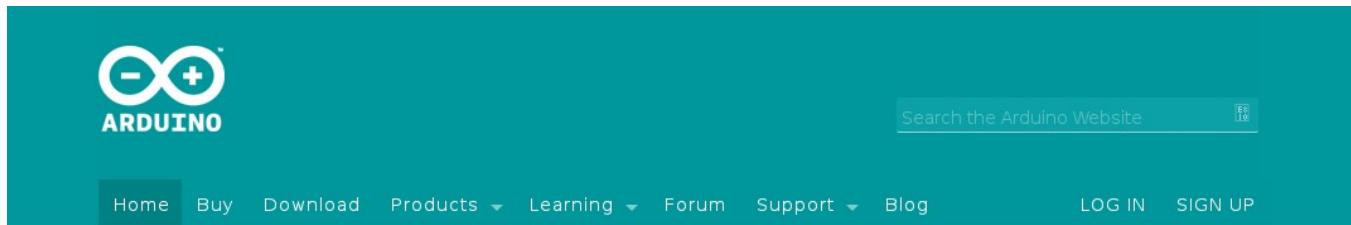
**Best practice:** all components available from distributors in **low quantity**



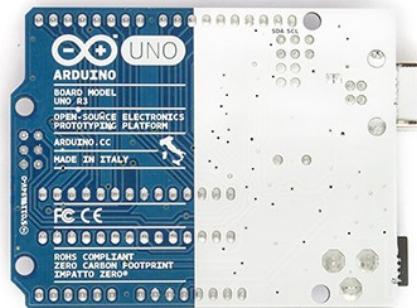
# Open Source Hardware



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 in the address bar is https://www.arduino.cc/en/Main/ArduinoBoardUno. The page title is "Arduino - ArduinoBoa...". The main content area is titled "Documentation" in orange. Below it, there's a section titled "OSH: Schematics, Reference Design, Board size" with the text: "Arduino / Genuino Uno is open-source hardware! You can build your own board using the following files:". On the left sidebar, there are links for "Overview", "Get Inspired", "Related Items", "Technical Specs", and "Documentation", with "Documentation" being the active tab. At the bottom, there are two download buttons: one for "EAGLE FILES IN .ZIP" and another for "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



- 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

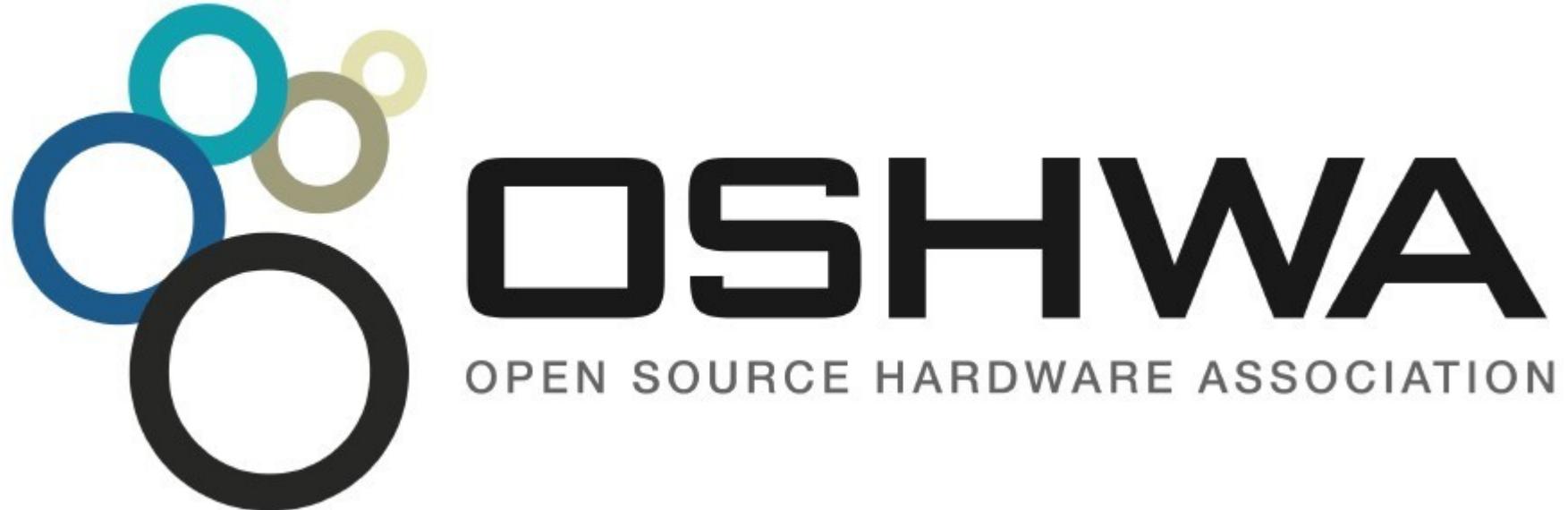


# Open Source Hardware

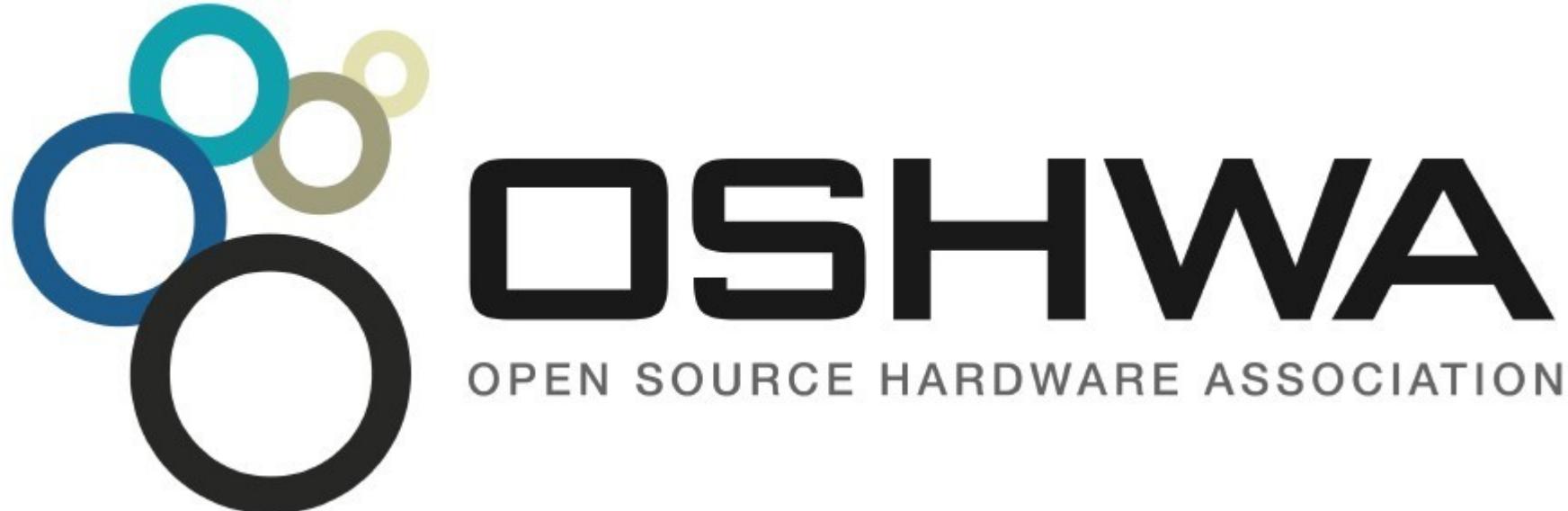


## What is the spirit of Open Source?

- 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 2020: March 13 in NYC (USA)
  - <http://2020.oshwa.org/>
- *8 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
  - **2018:** MIT (Cambridge, MA, USA)

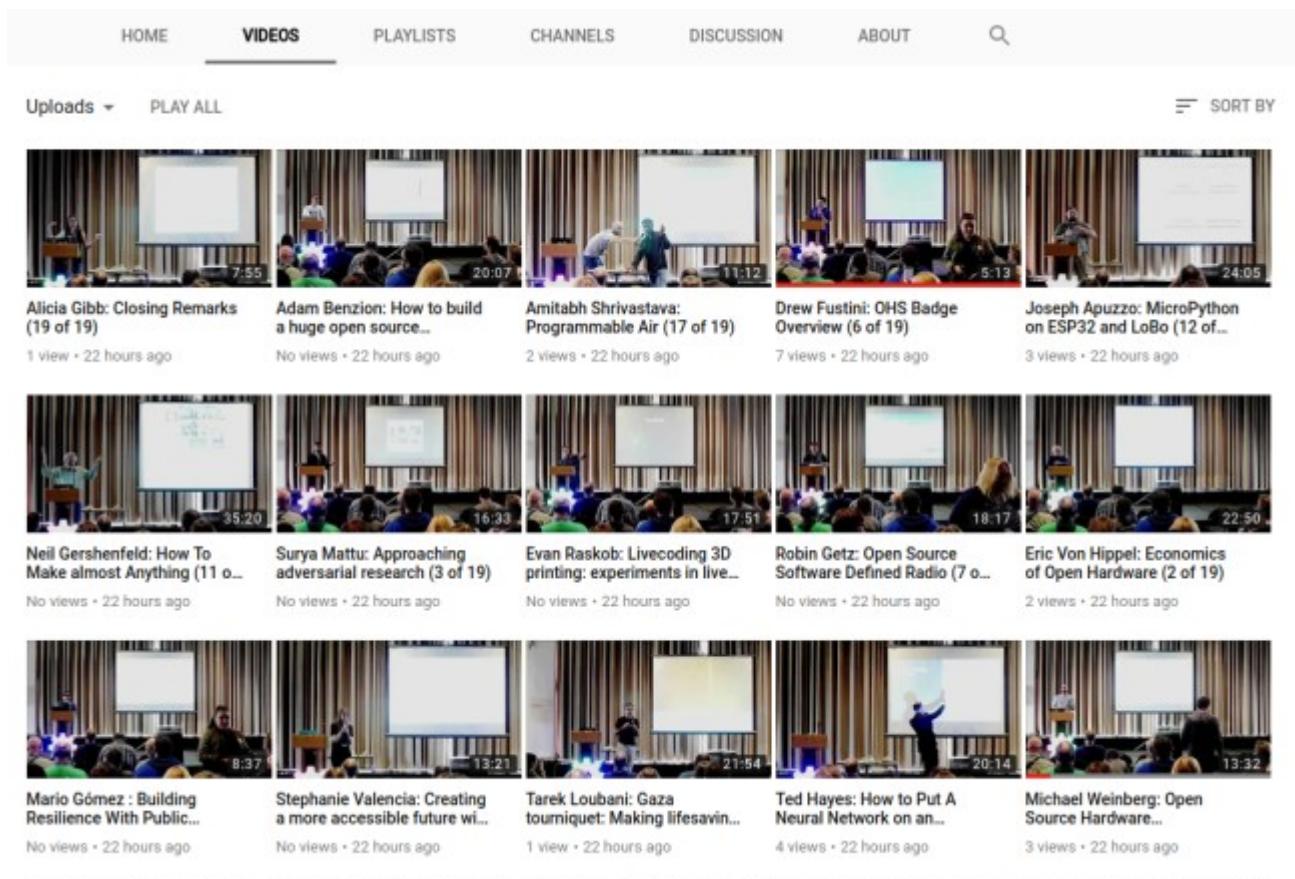
# October is Open Hardware Month!



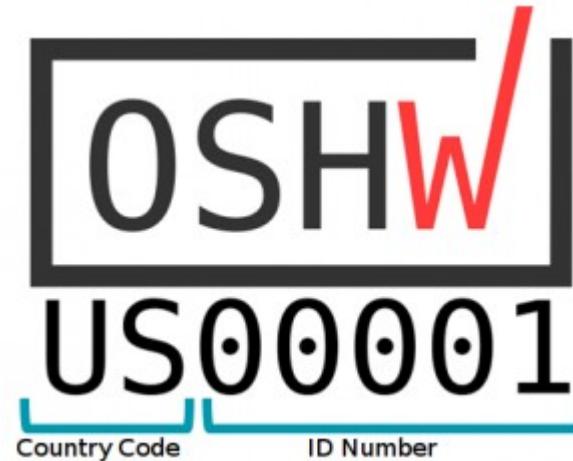
- People all over the world celebrated with meet-ups, talks and workshops
- Kicked off with events at RAIT in Vienna (Austria) and SparkFun in Colorado (USA), followed by gatherings in Poland, Panama, Thailand, Japan, Ghana and more!
- 40 events in 14 different countries across 5 continents

# Open Hardware Summit (OHS)

- The Open Hardware Summit 2018 talks are available as individual videos on YouTube



# 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](#)



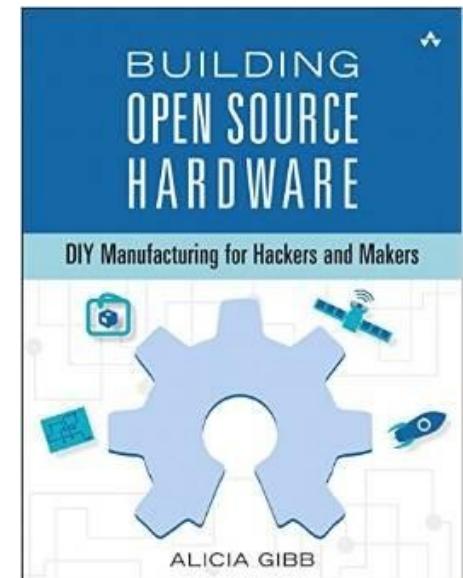
# Open Source Hardware



## 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/oshw-garage.pdf>



*Section:*  
LINUX on OSHW  
(my two favorite things!)

# 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



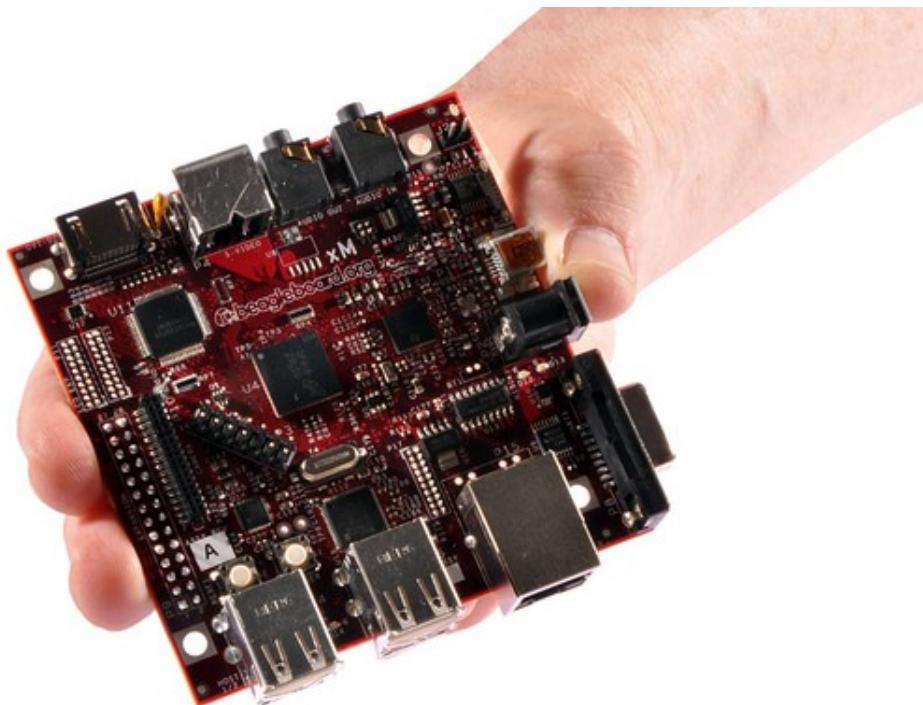


- Open Source Hardware computing for Makers, Educators & Professionals
- Developed by [BeagleBoard.org Foundation](#) and [BeagleBoard.org Community](#)
- Manufacturers: [element14](#), [GHI](#), [Seeed](#)





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**

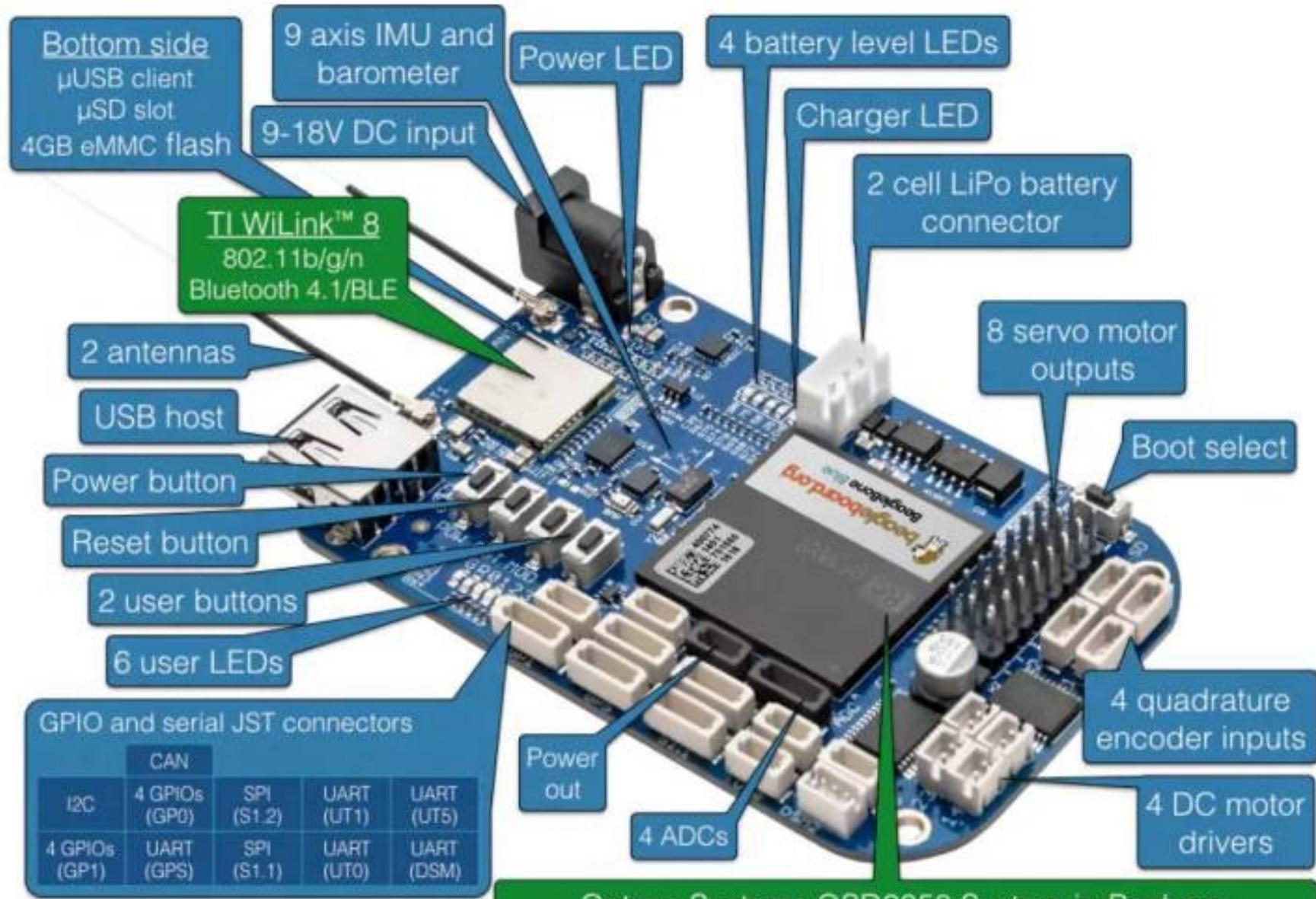




# Open Source Hardware BeagleBone derivatives

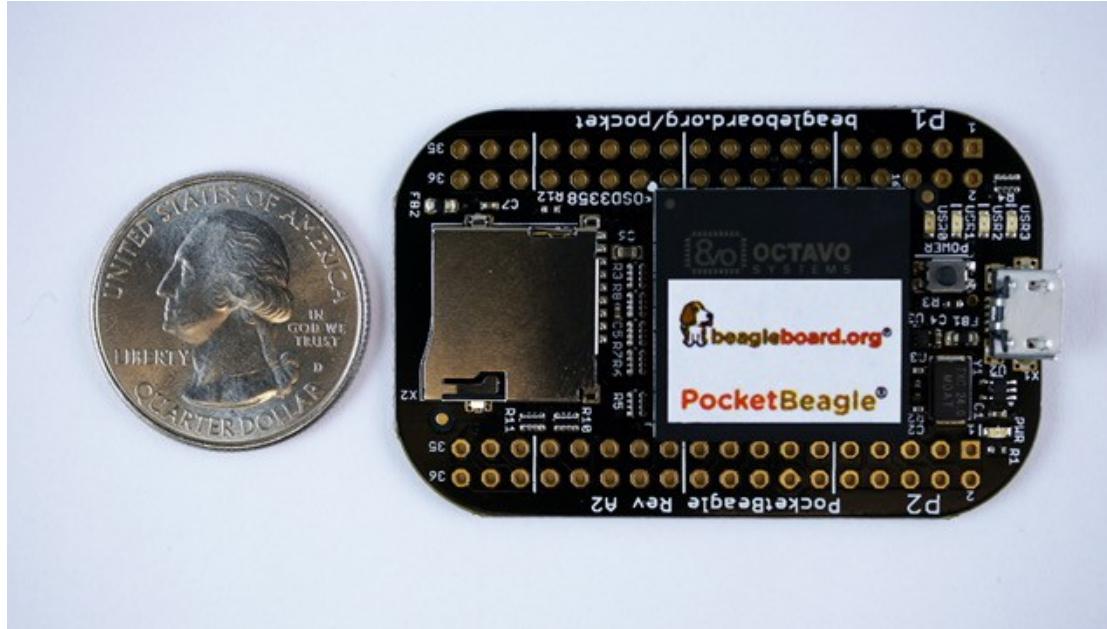
	Capes	HDMI	Flash	Special
BeagleBoard.org BeagleBone	Y	N	N	JTAG
BeagleBoard.org BeagleBone Black	Y	Y	Y	-
Arrow BeagleBone Black Industrial	Y	Y	Y	Industrial
Element14 BeagleBone Black Industrial	Y	Y	Y	Industrial
SeeedStudio BeagleBone Green	Y	N	Y	Grove
SanCloud BeagleBone Enhanced	Y	Y	Y	1GB, 1Gbit, wireless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

# BeagleBone 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

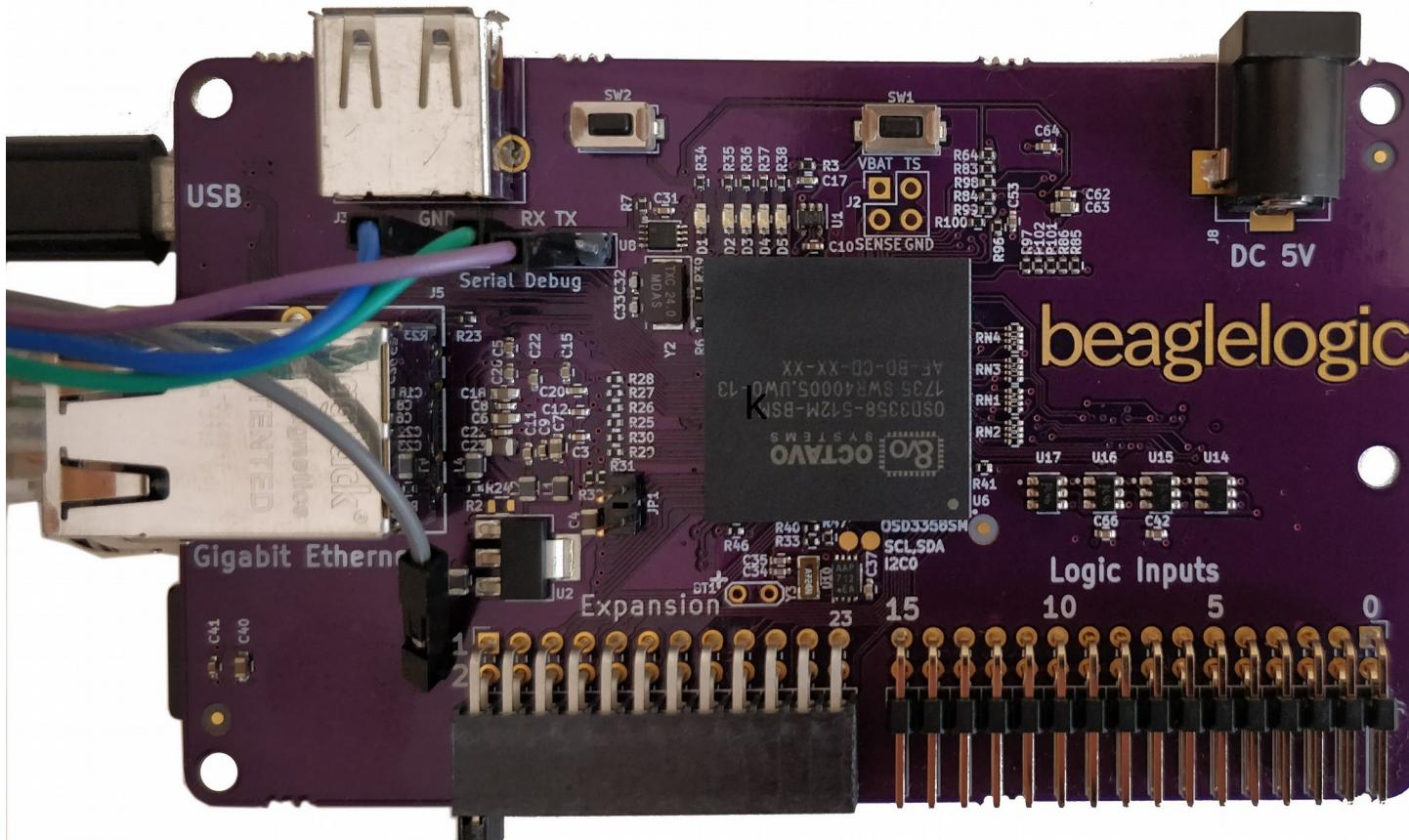
# BeagleBoard.org PocketBeagle

- 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



# BeagleBone AI: The Fast Track for Embedded Machine Learning



2 46 pin expansion headers compatible with many BeagleBone® Black cape add-on boards

USB super-speed (5Gbps) Type-C host/client (multiport capable) with power input (5V@3A)

1GB RAM  
(2nd IC on bottom side)

USB high-speed (480Mbps)  
Type-A host

micro-HDMI  
(bottom side)

micro-SD  
(bottom side)

16GB on-board eMMC  
flash storage

serial port

Gigabit Ethernet

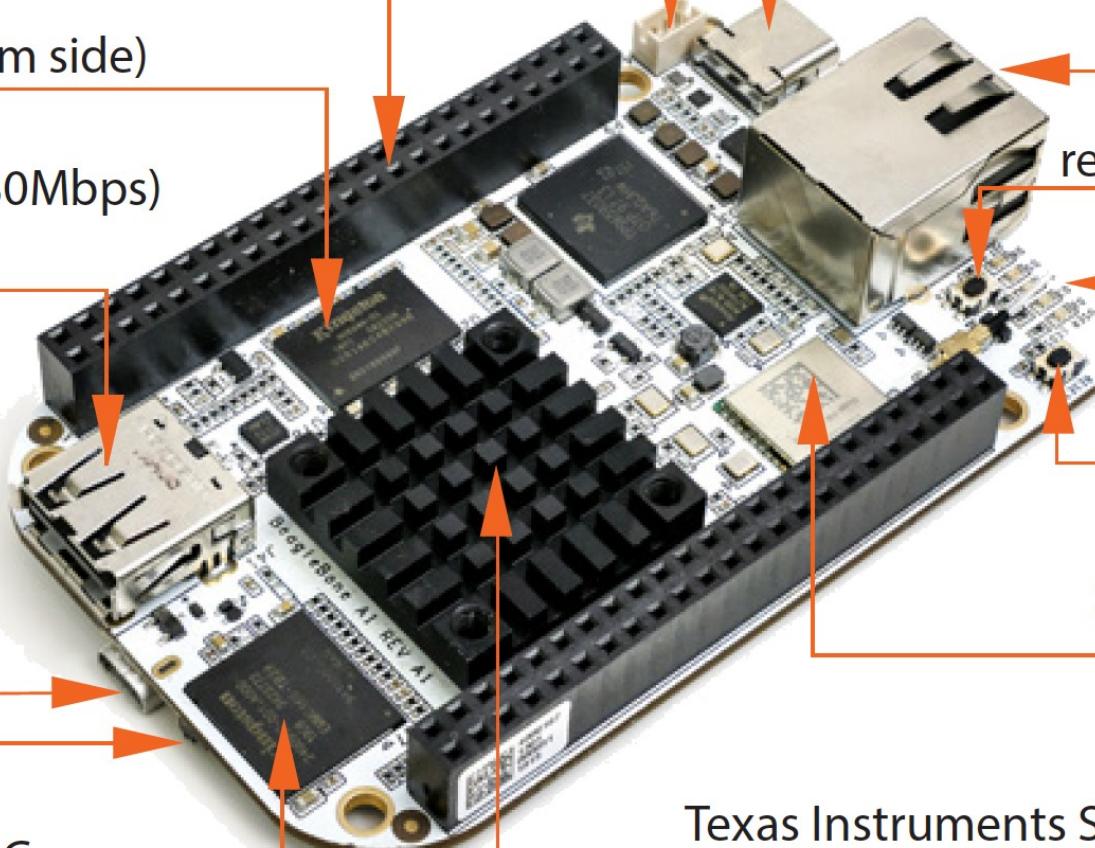
reset button

5 user LEDs

power button

2/5GHz 802.11ac WiFi and Bluetooth

Texas Instruments Sitara AM5729 multicore 1.5GHz ARM processor with AI, I/O, graphics and video accelerators



# BeagleBone AI

“TI C66x digital-signal-processor (DSP) cores and embedded-vision-engine (EVE) cores supported through an optimized TIDL machine learning OpenCL API with pre-installed tools. Focused on everyday automation in industrial, commercial and home applications.”

## Feature highlights:

- BeagleBone Black mechanical and header compatibility
- TI AM5729 SoC: 2x A15 CPU, 2x C66 DSP, 4x M4 MCU, 4x PRU and 4x EVE
- 1GB RAM and 16GB on-board eMMC flash with high-speed interface
- USB type-C for power and superspeed dual-role controller; and USB type-A host
- Gigabit Ethernet, 2.4/5GHz WiFi, and Bluetooth
- microHDMI
- Zero-download out-of-box software experience

# BeagleBone AI design files

README.md

## BeagleBoard.org BeagleBone AI

Fast track to Embedded Artificial Intelligence

BeagleBone AI is built on the proven BeagleBoard.org® open source Linux platform for small SBCs and more powerful industrial computers. Based on the Texas Instruments® Sitara™ processor, it provides the power of the Sitara™ processor and the performance of the BeagleBoard.org® SoC in a compact package. It features the powerful SoC with the ease of BeagleBone® Black header and the BeagleBoard.org® Dev Board. It is designed to explore how artificial intelligence (AI) can be used in everyday applications. The BeagleBone AI includes a neural network engine (NNE) and embedded-vision-engine (EVE) cores supported through the BeagleBoard.org® Dev Board. It also includes a wide range of installed tools. Focused on everyday automation in industrial environments.

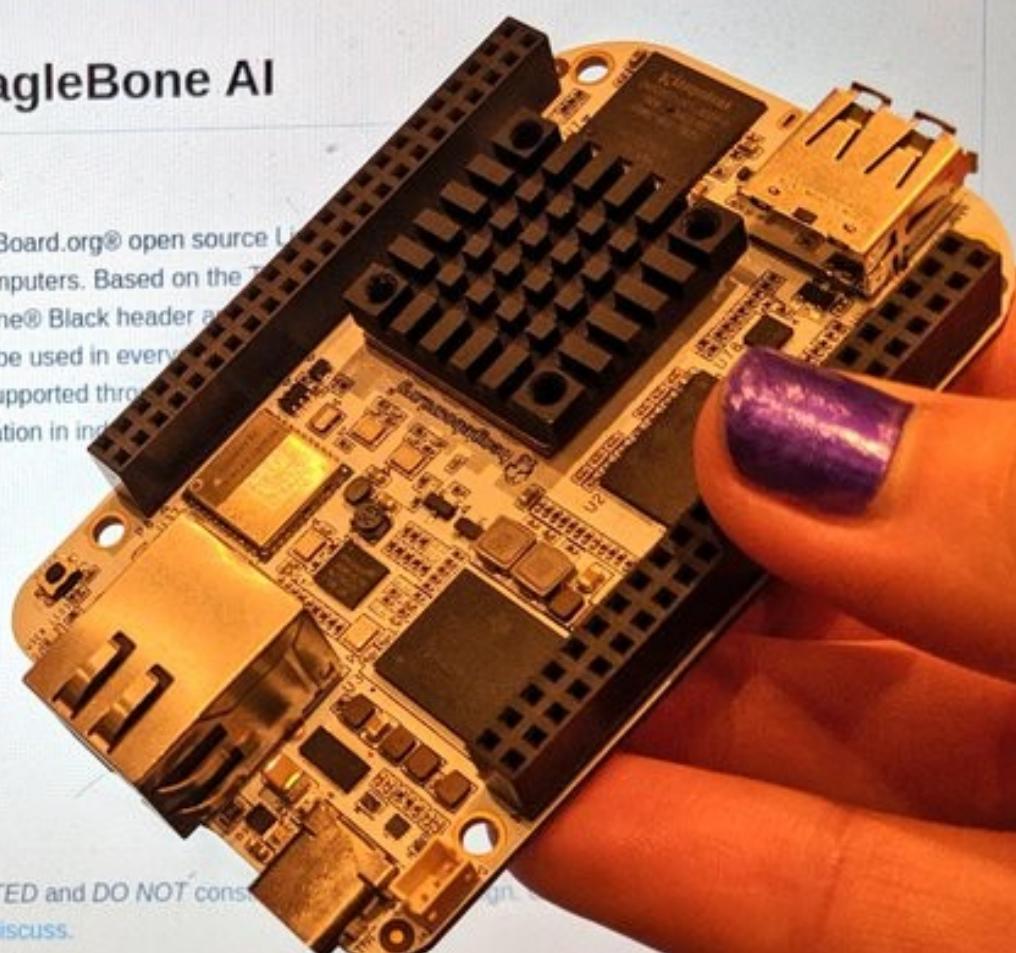
**OSHW**  
US000169

### Terms

These design materials are NOT SUPPORTED and DO NOT constitute a legally binding contract. Support is allowed via resources at [BeagleBoard.org/discuss](#).

THERE IS NO WARRANTY FOR THE DESIGN MATERIALS, TO THE EXTENT PERMITTED BY APPLICABLE LAW. EXCEPT WHEN OTHERWISE STATED IN WRITING THE COPYRIGHT HOLDERS AND/OR OTHER PARTIES PROVIDE THE DESIGN MATERIALS "AS IS" WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESSED OR IMPLIED.

CSV





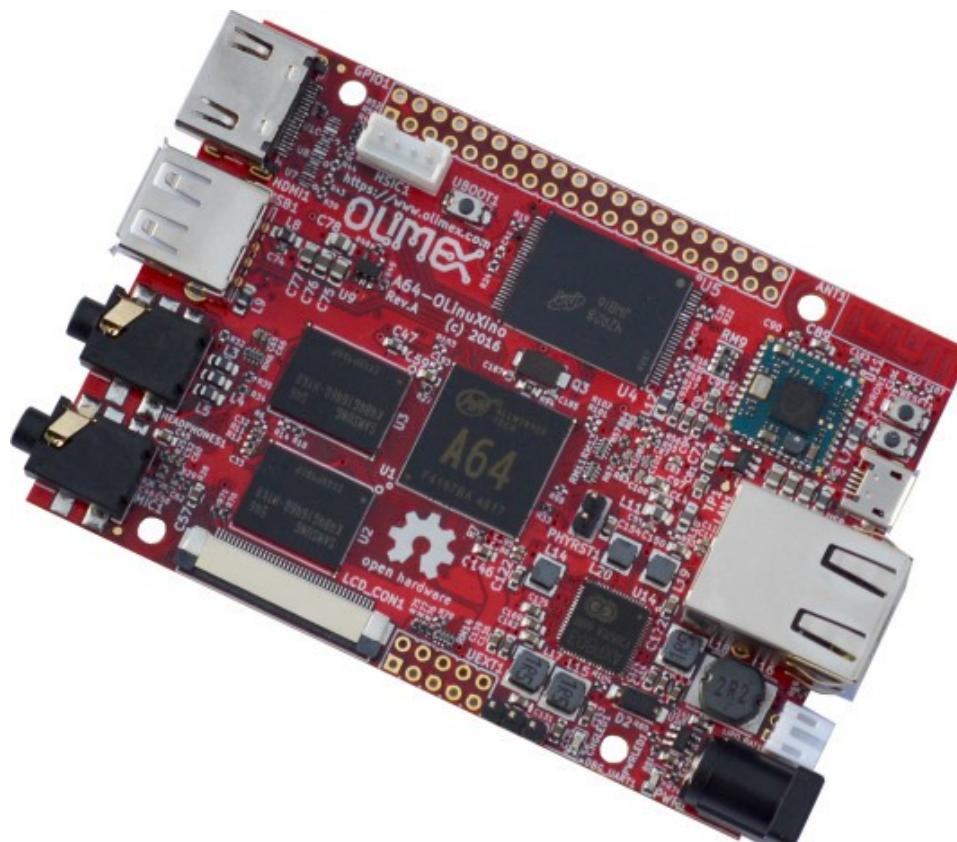
## OLinuXino



- 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

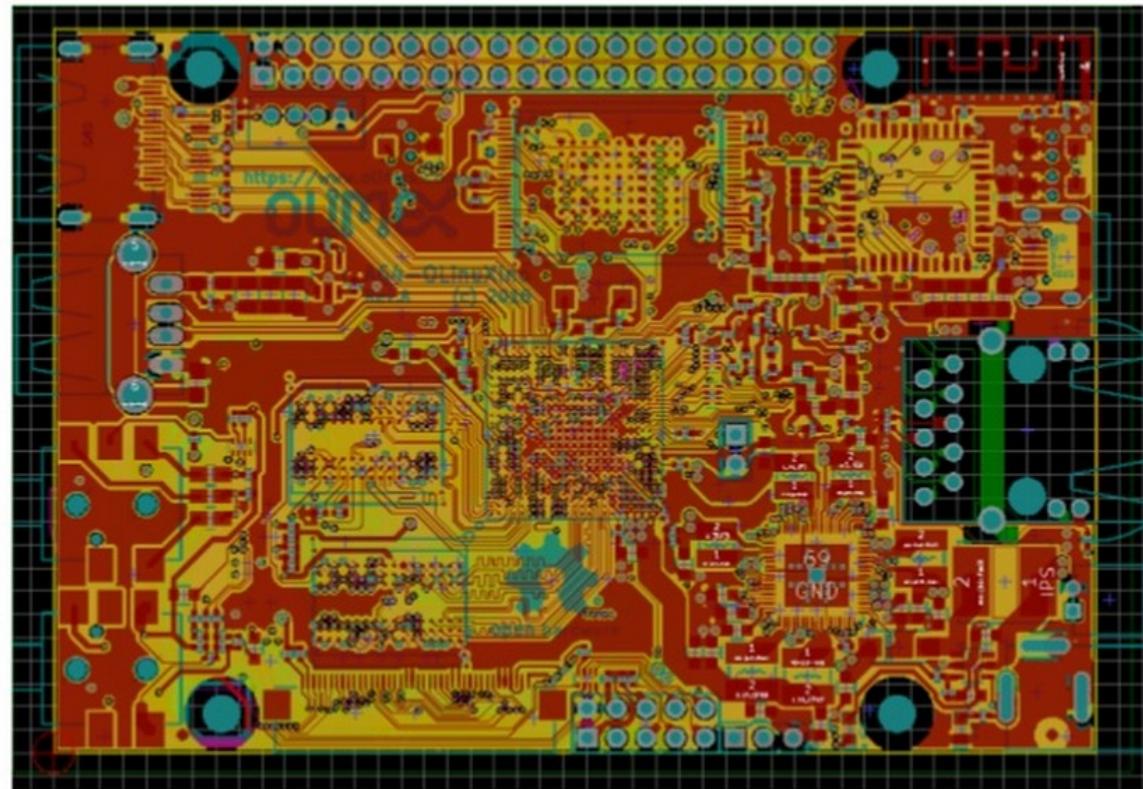
- Allwinner A64: Quad Core **64-bit ARM**
- Designed with Open Source **KiCad**
- 1GB RAM, 4GB eMMC, WiFi+BLE4.0





Using FOSS tools for OSHW project

# Designing with KiCAD of 64-bit ARM board



Tsvetan Usunov, OLIMEX Ltd

FOSDEM 2016

[Slides](#) / [Video](#)

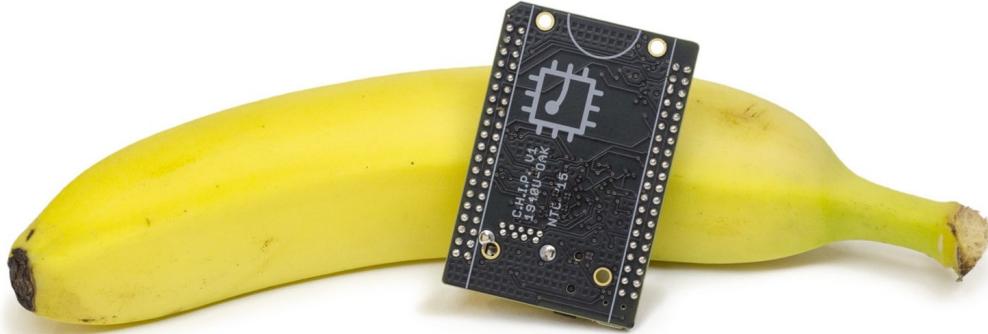


- **KiCad** is an Open Source EDA suite including Schematic Capture and PCB Layout
- Cross platform: **Windows**, **Mac OS** and **Linux**
- **CERN has contributed** professional CAD features for high-speed digital design
- Learn to design your own PCB in KiCad with: **Getting to Blinky**

- “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

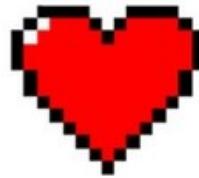
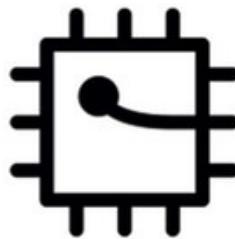


*The World's First \$9 Computer*

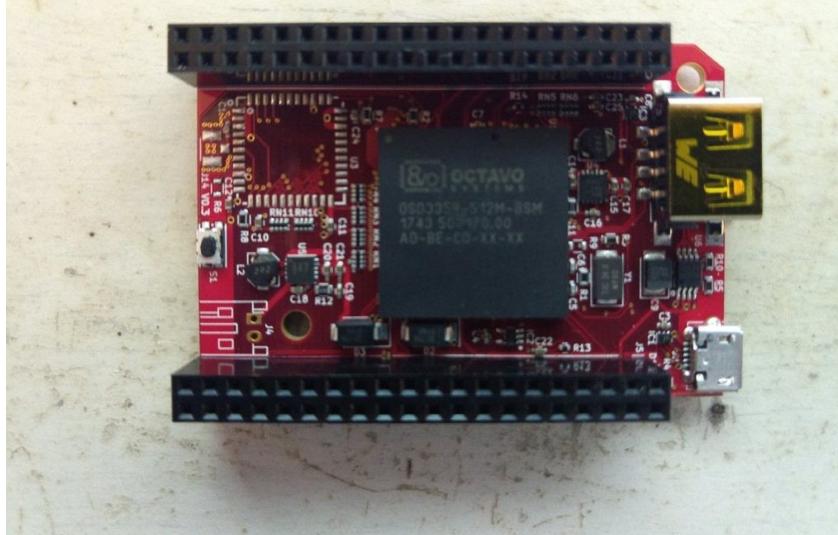
- [getchip.com](http://getchip.com)
- Next Thing Co. in Oakland
- Kickstarter in 2015
- Company ended in 2018



# 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)



- Nebula One created by Groguard to be compat
- PocketChip with Nebula One running DOOM!

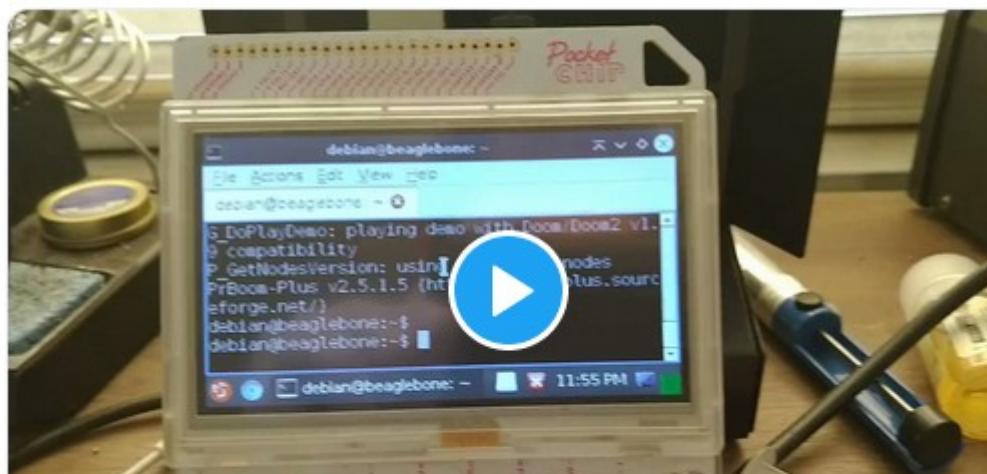


Groguard  
@groguard

Follow ▾

Doom running on the NebulaOne board in the  
PocketCHIP. Wifi and LCD are working! Just  
need get the keyboard sorted next! @pdp7

@Jadon @dcschelt



# Giant Board by groguard

- A single-board computer in the Adafruit Feather form factor
- Funded on Crowd Supply

CROWD SUPPLY

BROWSE

LAUNCH

ABOUT US

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## Giant Board

by Groboards

Open Hardware  
Computers & Networking  
Development Kits

A single-board computer in the Adafruit Feather form factor

Part of  
Microchip Get Launched  
2019



\$13,670 raised  
of \$12,250 goal

111% Funded!

Order Below

8 updates Aug 08 funded on 162 backers

Last update posted Aug 07, 2019

me@example.com

Subscribe to Updates



# Open Source and FPGAs

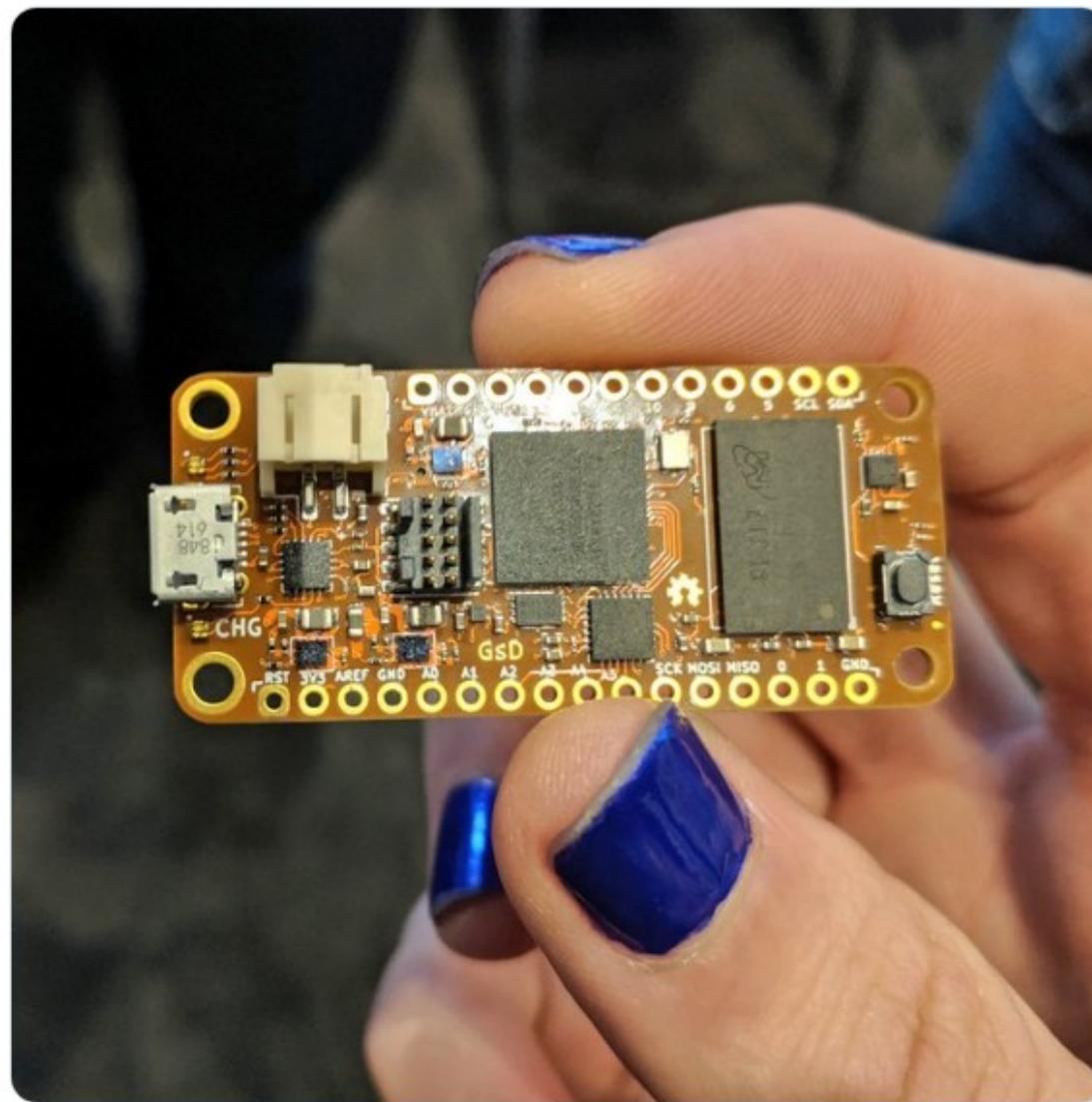
- Open Source toolchains for FPGAs!
  - Project IceStorm for Lattice iCE40
  - Project Trellis for Lattice ECP5
- Open Source Hardware boards with Lattice ECP5 FPGA with open RISC-V “soft” CPU:
  - [Orange Crab by Greg Davill](#)
  - [Radiona.org ULX3S](#)
  - [David Shah's Trellis board \(Ultimate ECP5 Board\)](#)
  - [MyStorm with ECP5 by Alan](#)

← Tweet



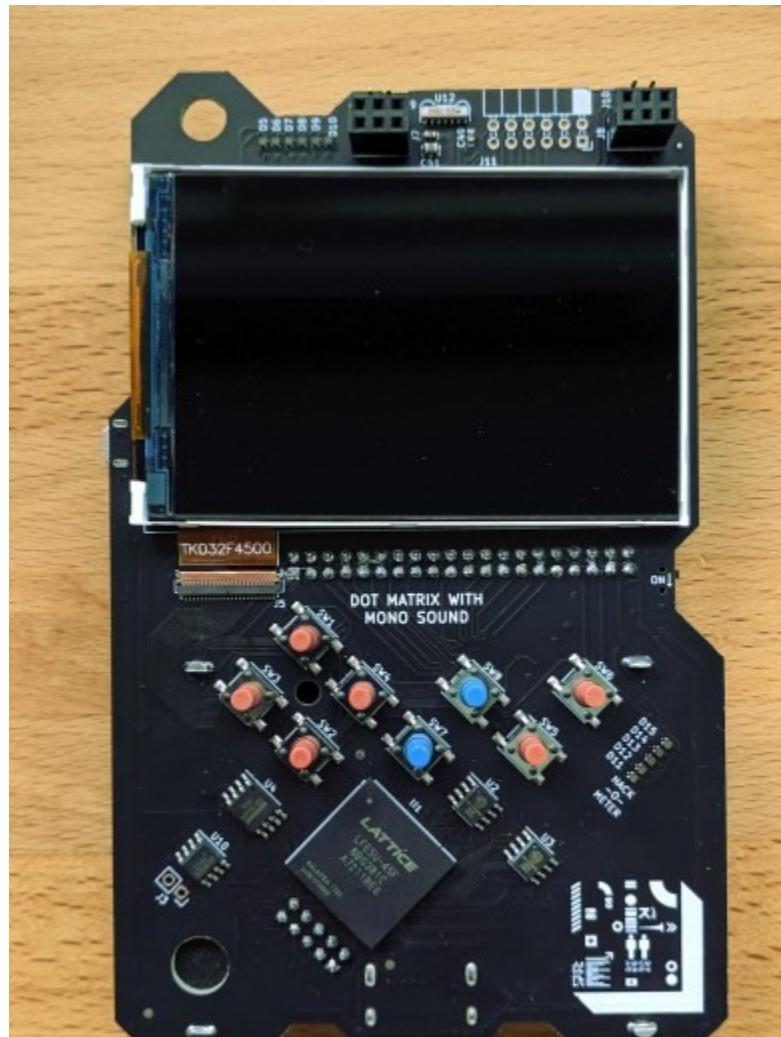
Drew Fustini  
@pdp7

Awesome to see the Orange Crab ECP5 FPGA board by  
@GregDavill in Lyon thanks to @antonblanchard! 🍔



# Hackaday 2019 Supercon badge

- RISC-V “soft” core on ECP5 FPGA
- Gigantic FPGA In A Game Boy Form Factor



Slides: <https://github.com/pdp7/talks/blob/master/er2019.pdf>



*Section:*  
Open Source and Chip Design

# *What about open source chips?*



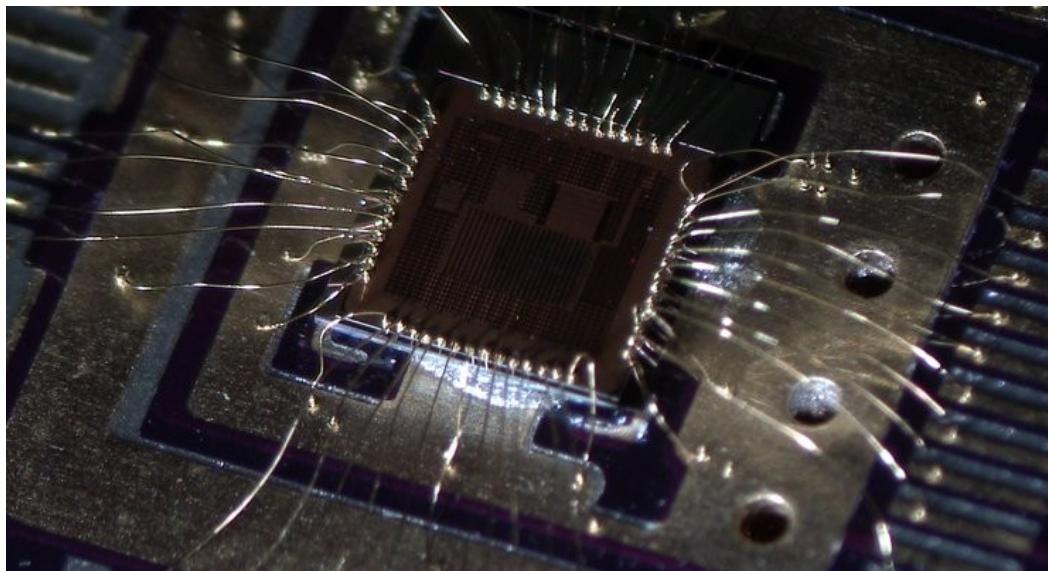
- **RISC-V: Free and Open RISC Instruction Set Arch**
  - “new instruction set architecture (ISA) that was originally designed to support computer architecture research and education and is now set to become a standard open architecture for industry”
  - Video: [Instruction Sets Want To Be Free: A Case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

# *What about open source chips?*



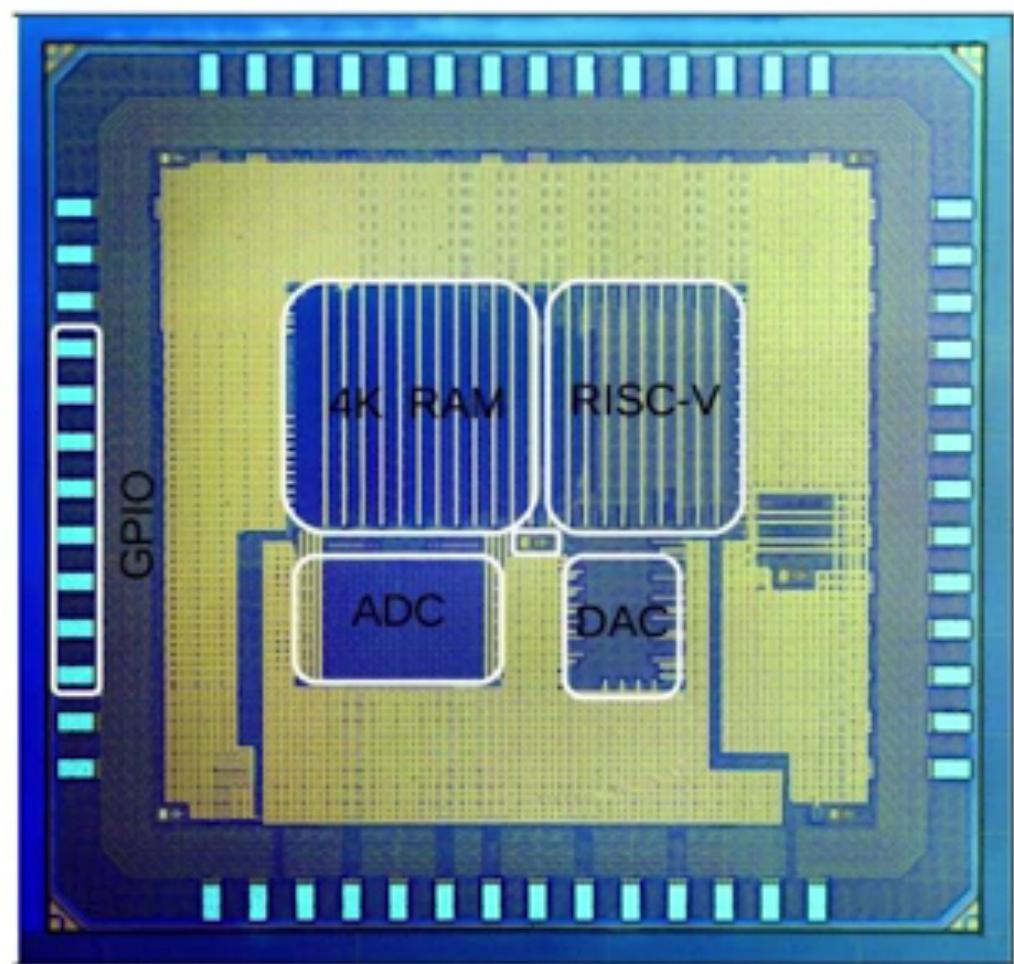
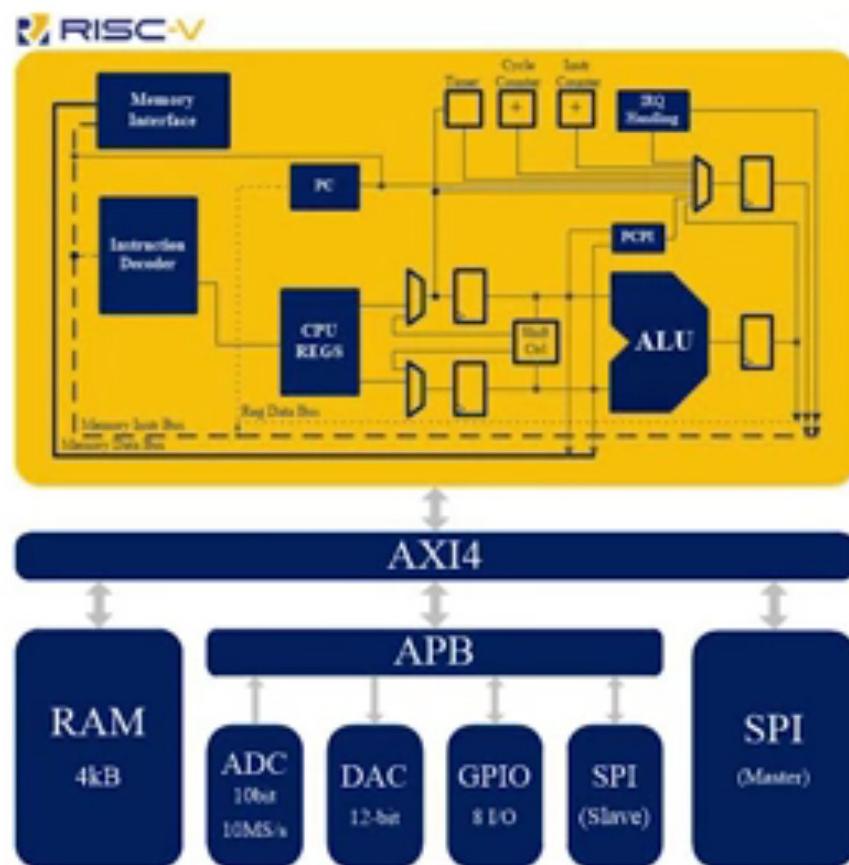
- [OnChip Open-V](#)

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



# OnChip Open-V

A 32-bit RISC-V based Microcontroller



# OnChip Open-V

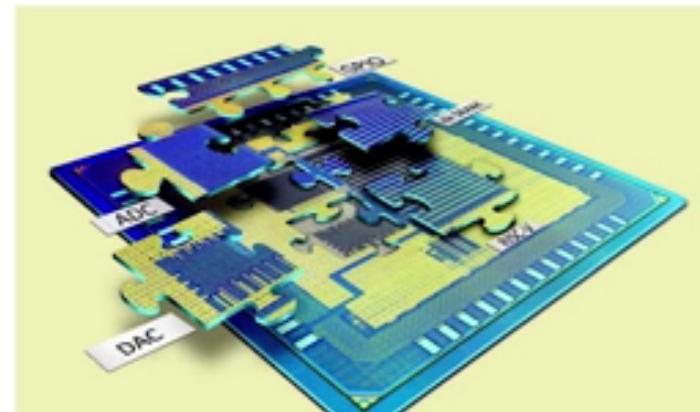


- Crowd Supply update: [A Taste of Chip Design](#)
- Video: [YoPuzzle: mRISC V development platform](#)
- Video: [RISC-V Community needs Peripheral Cores](#)

**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.

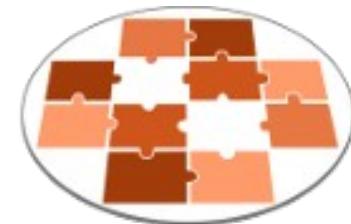


# Open Source chip design



- 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)
- [Laura James](#) from lowRISC is here!

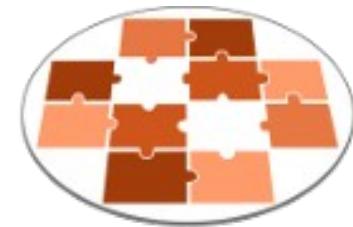
# Open Source chip design



**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.”

# Open Source chip design

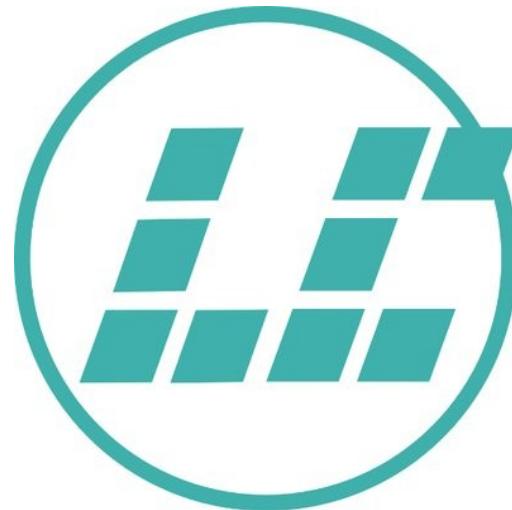


**FOSSi**  
Foundation

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



# Open Source chip design



- **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”

# Latch-Up Conf 2019 videos

Portland Oregon



May 4-5 2019

# Week of Open Source Hardware

The video player displays a slide with the following content:

**History**

- March 2011: CERN OHL 1.0
- July 2011: CERN OHL 1.1
- September 2013: CERN OHL 1.2
- 2017: CERN OHL 2, beta 1
- 2019 : CERN OHL 2, beta 2

Below the slide, the video player interface shows:

CERN Open Hardware Licence 2.0  
80 views

Like 3 | Dislike 0 | Share | Save | ...

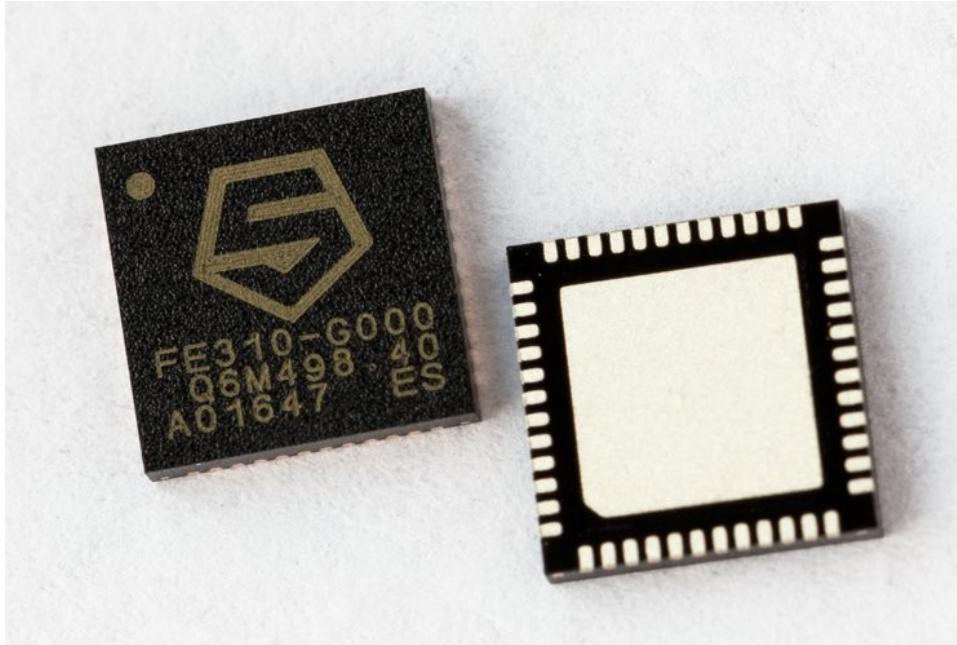


FOSSI Foundation

Published on Jun 20, 2019

SUBSCRIBE 654

# *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”

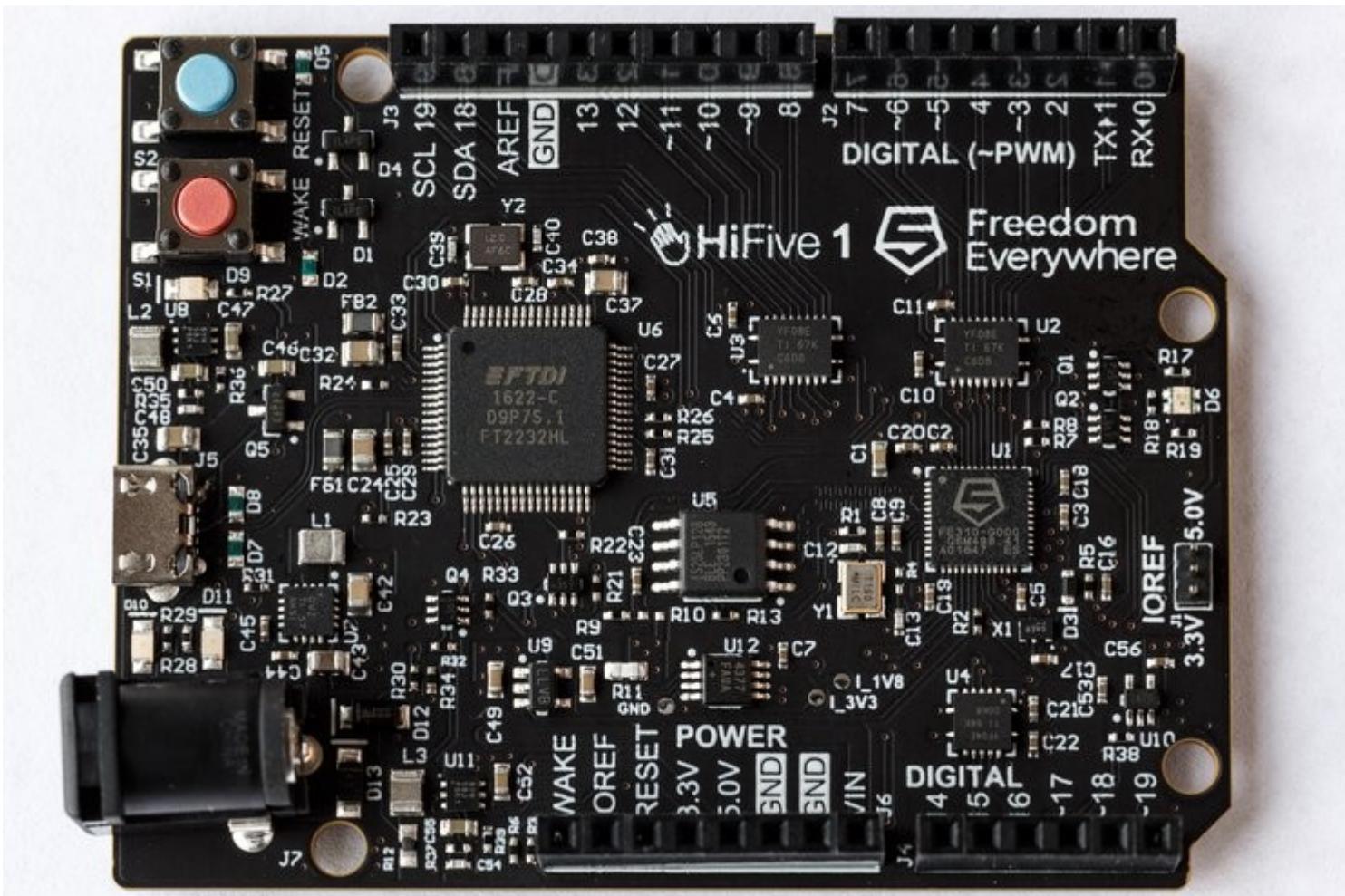
# RISC-V ecosystem

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



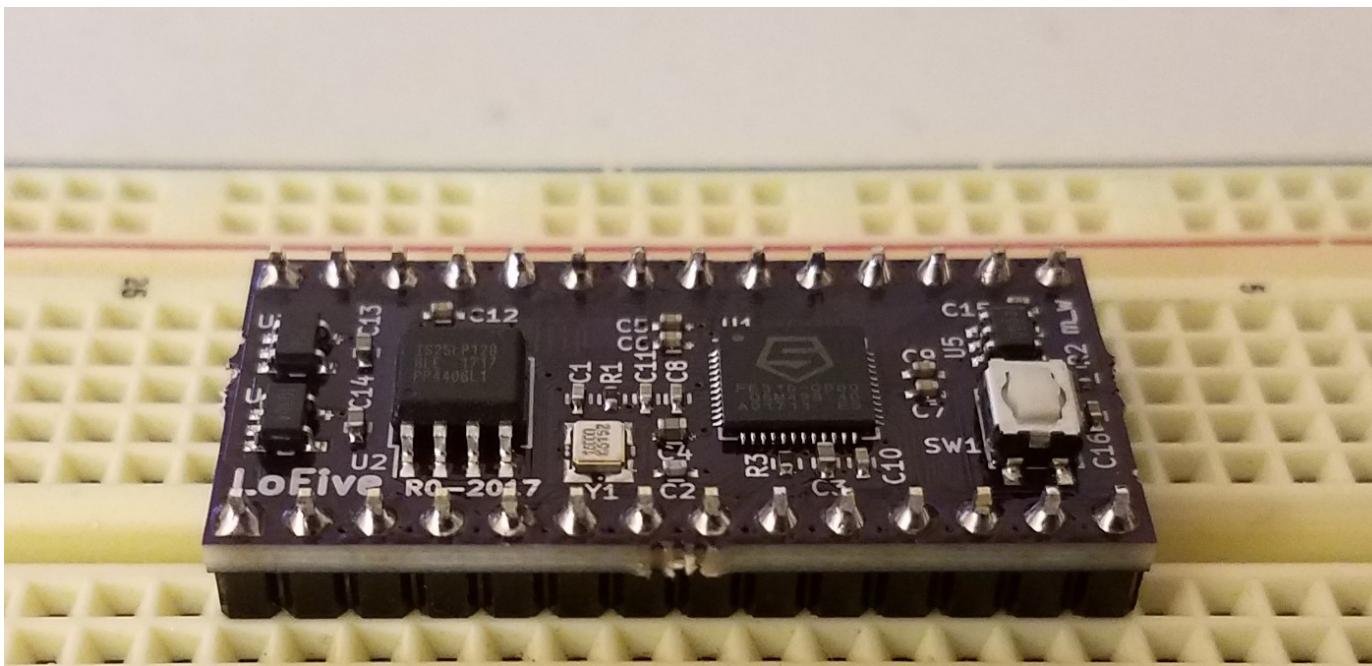
# SiFive FE310 microcontroller

- HiFive1: Arduino-Compatible RISC-V Dev Kit



# SiFive FE310 microcontroller

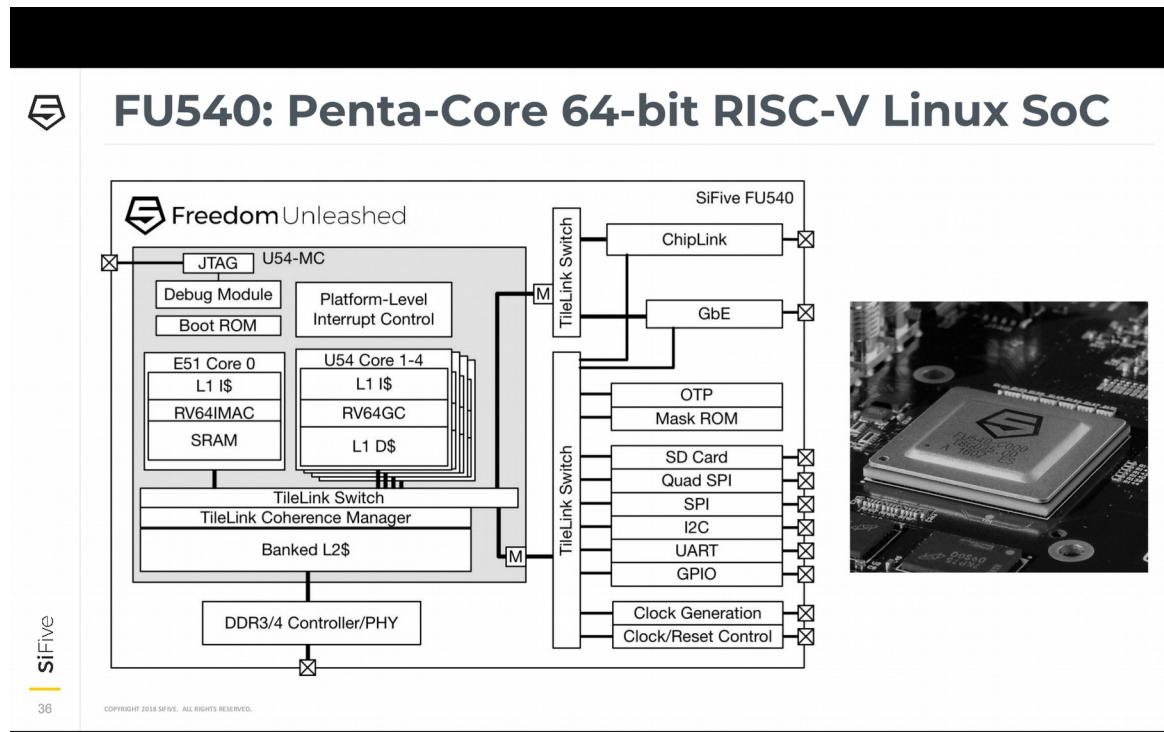
- [LoFive](#) designed by [Michael Welling](#)  
*(QWERTY Embedded Design)*
- Lower cost eval board for SiFive FE310.
- [Open Source Hardware design files](#)
- Sold as group buy on [GroupGets](#)



# SiFive: Linux on RISC-V

- FOSDEM 2018 talk

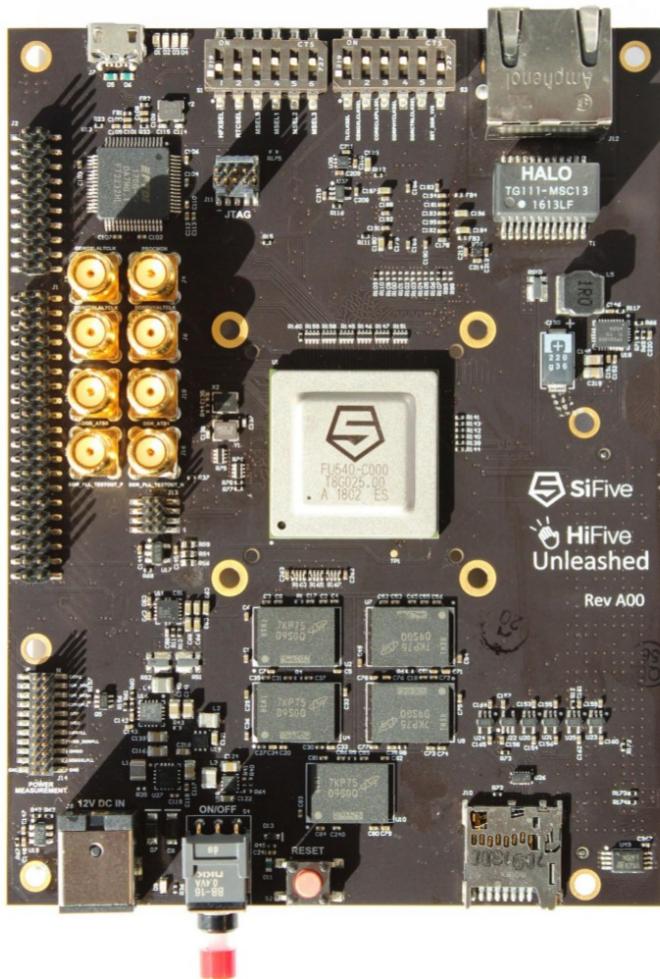
- YouTube: “Igniting the Open Hardware Ecosystem with RISC-V: SiFive's Freedom U500 is the World's First Linux-capable Open Source SoC Platform”
- Interview with Palmer Dabbelt of SiFive



# 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 OHS 2020?
- Interested in working together?
  - [drew@oshpark.com](mailto:drew@oshpark.com) / Twitter: [@pdp7](https://twitter.com/pdp7)
  - create a mailing list?

Slides:  
<https://github.com/pdp7/talks/blob/master/oshw-garage-2019.pdf>

**Drew Fustini**  
**drew@oshpark.com**  
**@pdp7 / @oshpark**



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