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

Linux on Open Source Hardware and Libre Silicon

Embedded Recipes 2019

Drew Fustini

BeagleBoard.org Foundation

drew@beagleboard.org

Twitter: @pdp7

- Open Source Hardware designer at OSH Park
  - PCB manufacturing service in the USA known for purple soldermask!
  - drew@oshpark.com / Twitter: @oshpark

- Volunteer Member of Board of Directors of BeagleBoard.org Foundation
  - **drew@beagleboard.org**

- Volunteer Member of the Board of Directors of the Open Source Hardware Association (OSHWA)
  - serving as Vice President
  - **drew@pdp7.com**

What is Open Source?

- Examples of popular Open Source projects

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

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

Open Source Hardware

Statement of Principles:

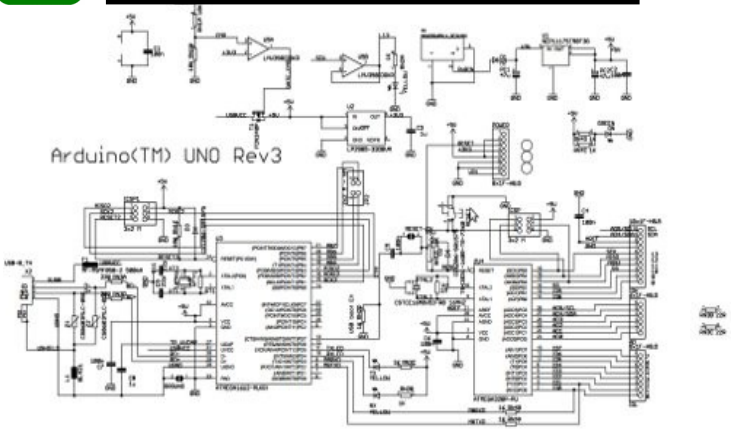
Hardware whose **design** is made **publicly available** so that anyone can **study**, **modify**, **distribute**, **make**, and **sell** the design or hardware based on that design

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

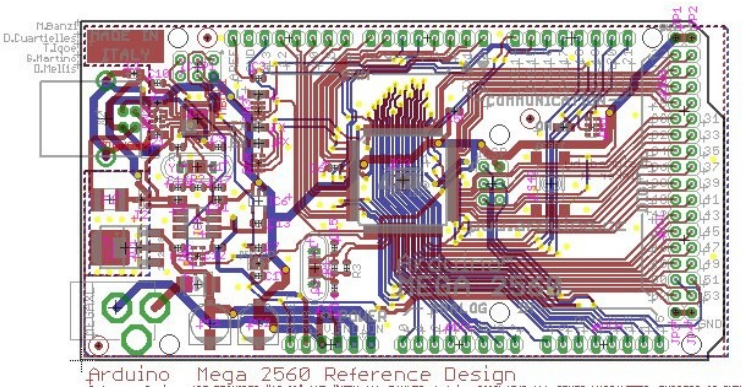
Open Source Hardware

Documentation required for electronics:

☑ Schematics



☑ Board Layout



Editable source files for CAD software such as KiCad or EAGLE

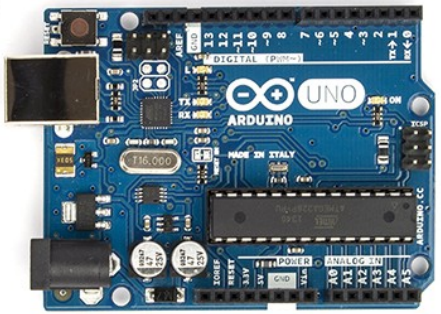
☑ Bill of Materials *(BoM)*

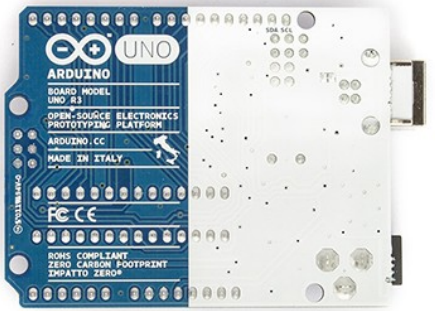
Best practice: all components available from distributors in **low quantity**

Open Source Hardware

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

Arduino Uno

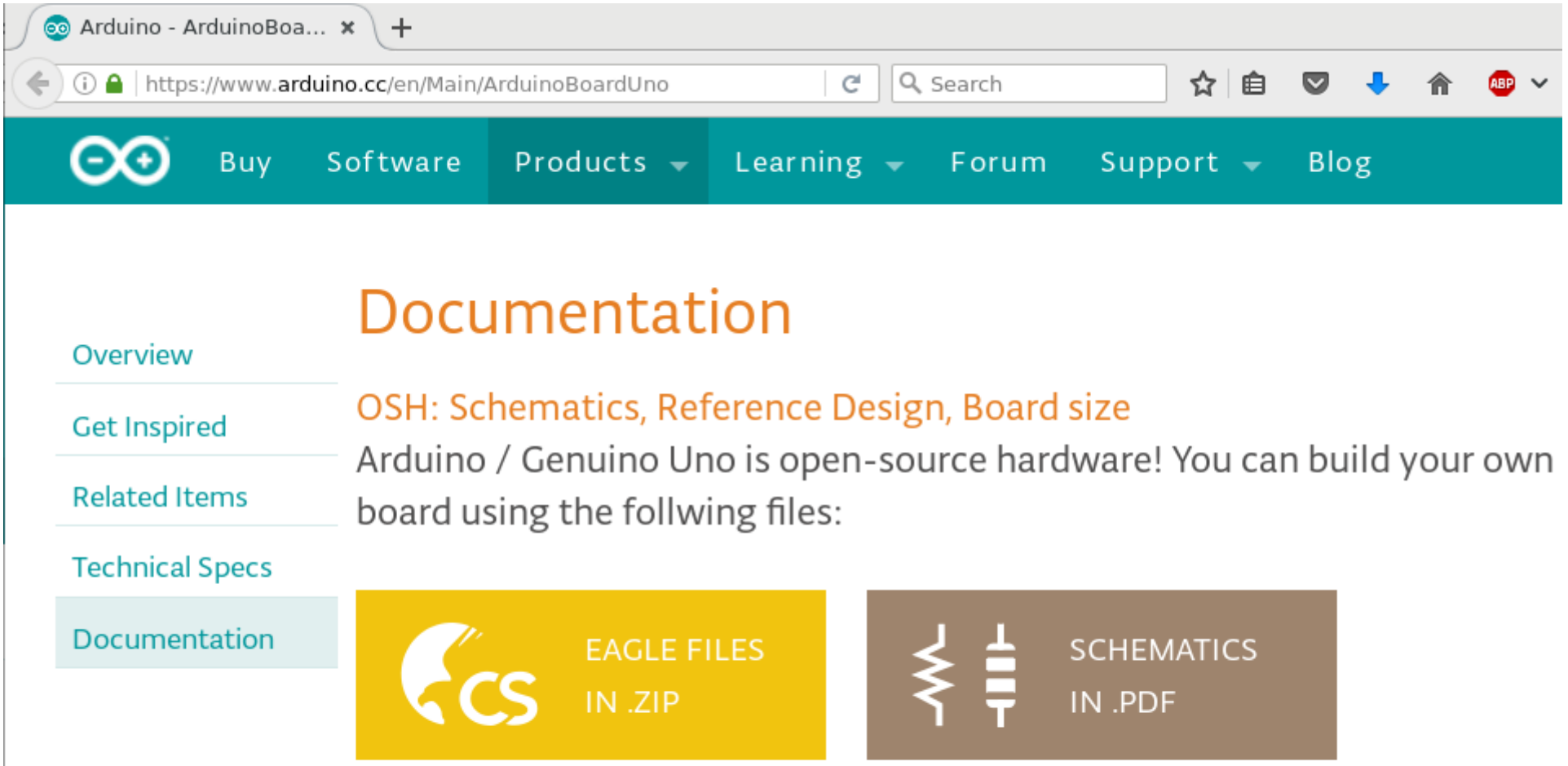




Arduino: The Documentary describes the team's motivation

Open Source Hardware

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



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

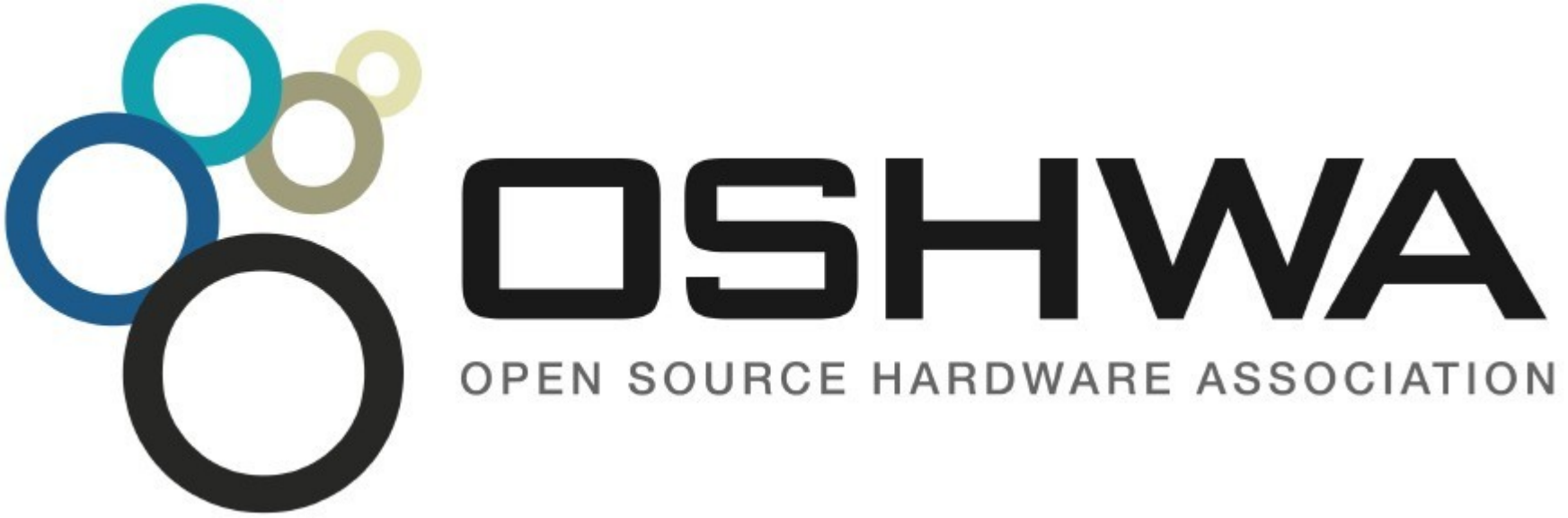
Open Source Hardware

What is the spirit of Open Source?

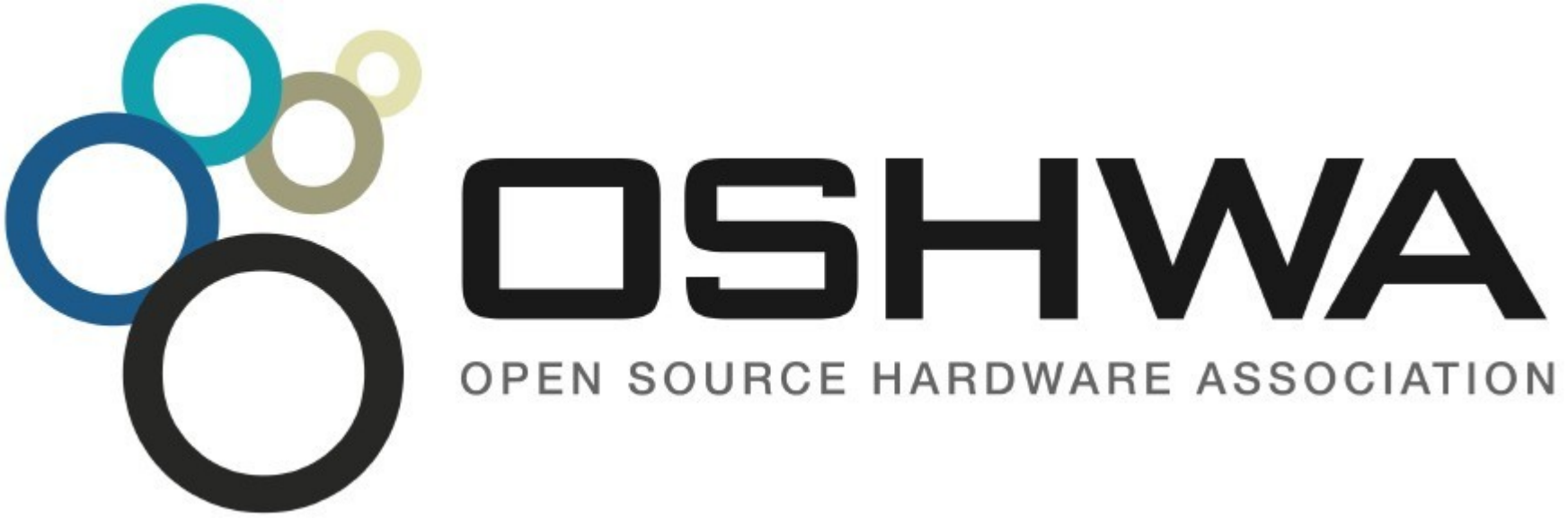
- Publish everything that will:

  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 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)

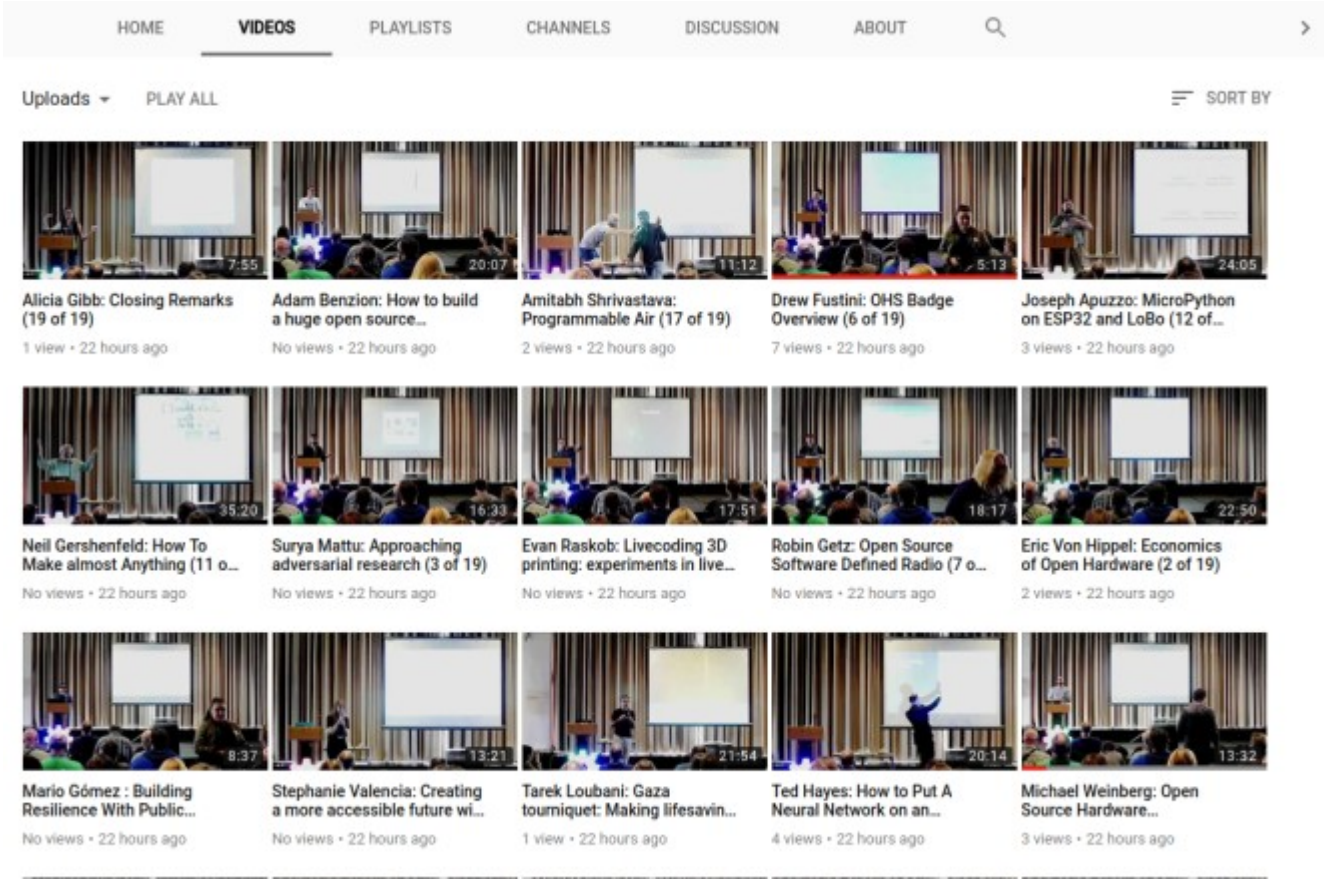
October is Open Hardware Month!

- OSHWA wants to encourage locally organized events around the world

- Sign up to host a meetup or workshop in your city! http://ohm.oshwa.org/

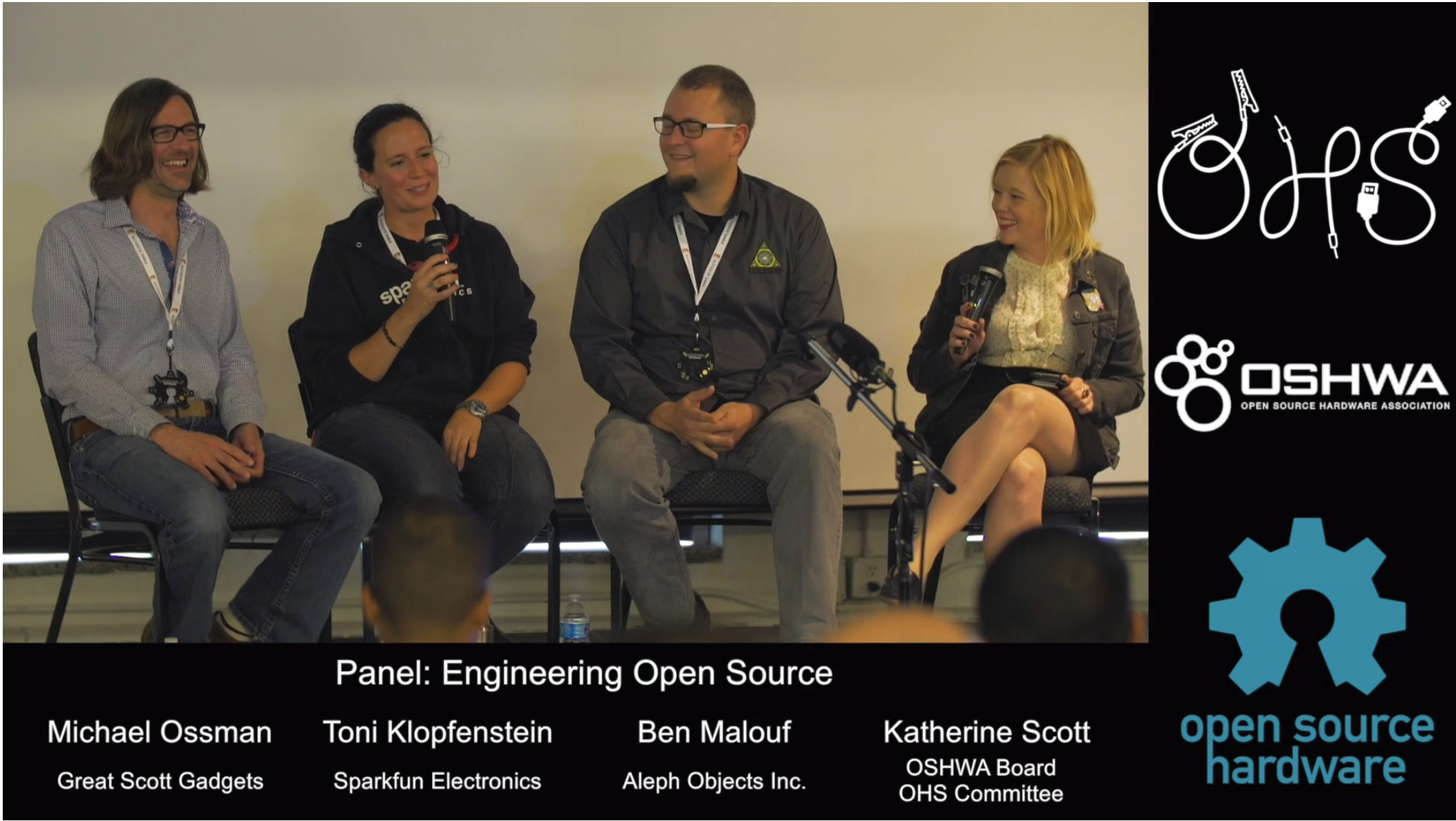
Open Hardware Summit *(OHS)*

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



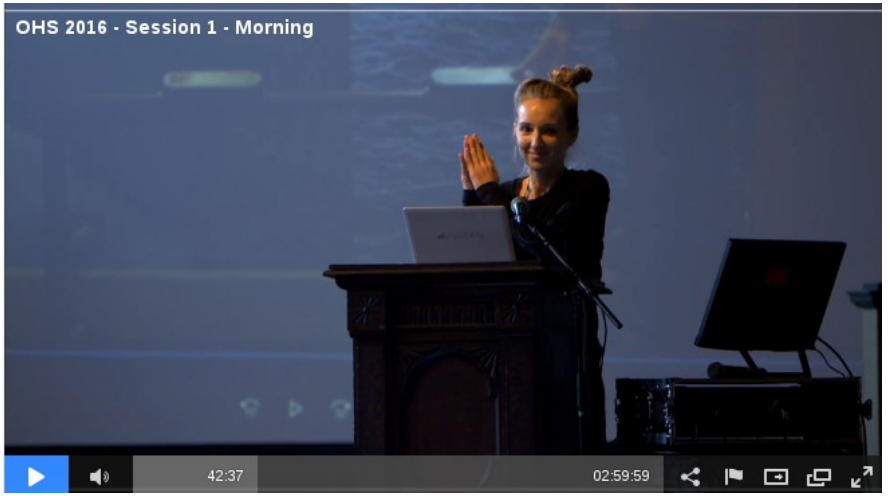
Open Hardware Summit *(OHS)*

- **OHS 2017: Engineering Open Source Hardware**

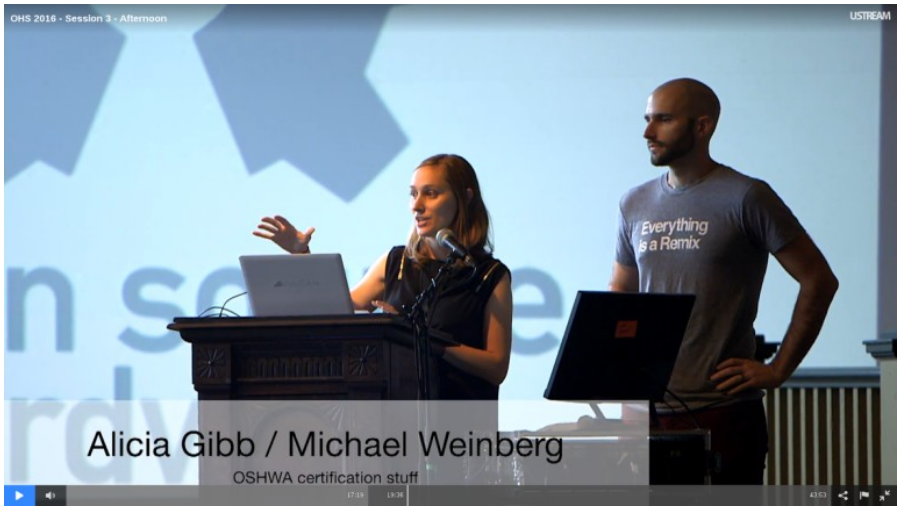


Open Hardware Summit *(OHS)*

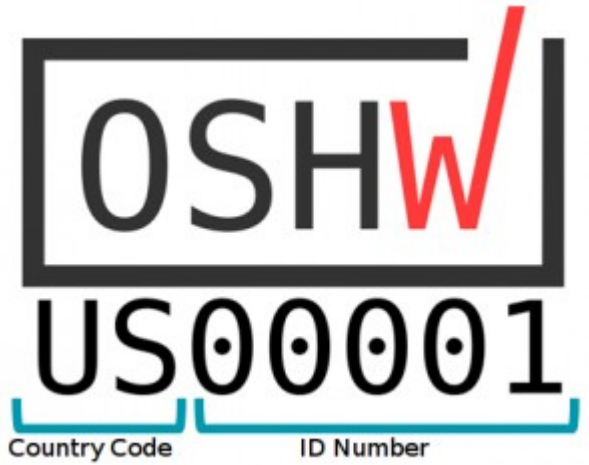
- **OHS 2016 morning sessions**



- **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

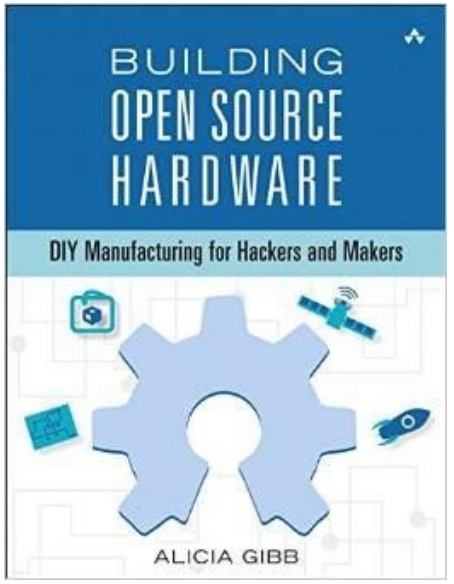
- **Video playlist on YouTube**
- Open Hardware Europe Summit
  - "The global open hardware community met in Vienna, Austria to give talks about new aspects, new methods and lessons learned for the open hardware movement."
  - ***Note: I talked to some people at CCCamp2019 interested in 2020. Email drew@pdp7.com to get connected***

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)*



Section:

LINUX on OSHW

(my two favorite things!)

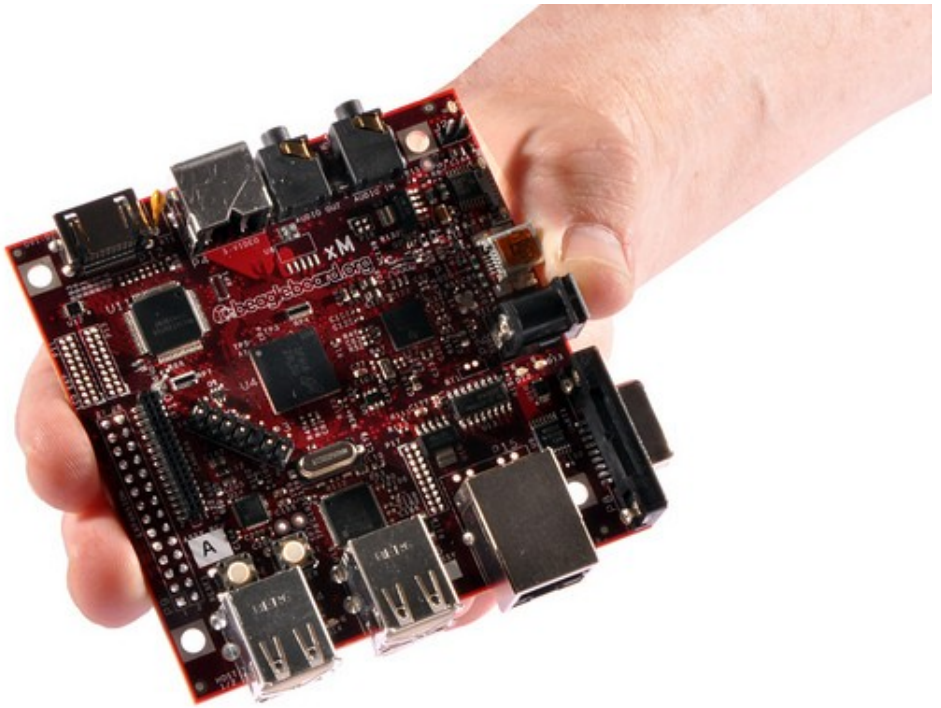
Novena laptop

- 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

beagleboard.org

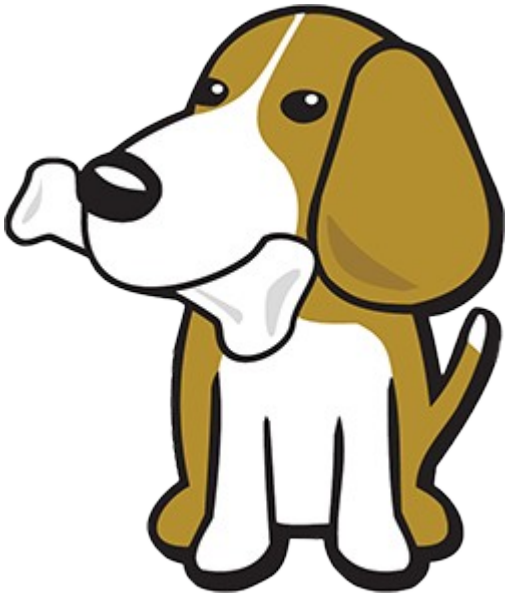
- Open Source Hardware computing for Makers, Educators & Professionals
- Developed by BeagleBoard.org Foundation and BeagleBoard.org Community
- Manufacturers: element14, GHI, Seeed

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



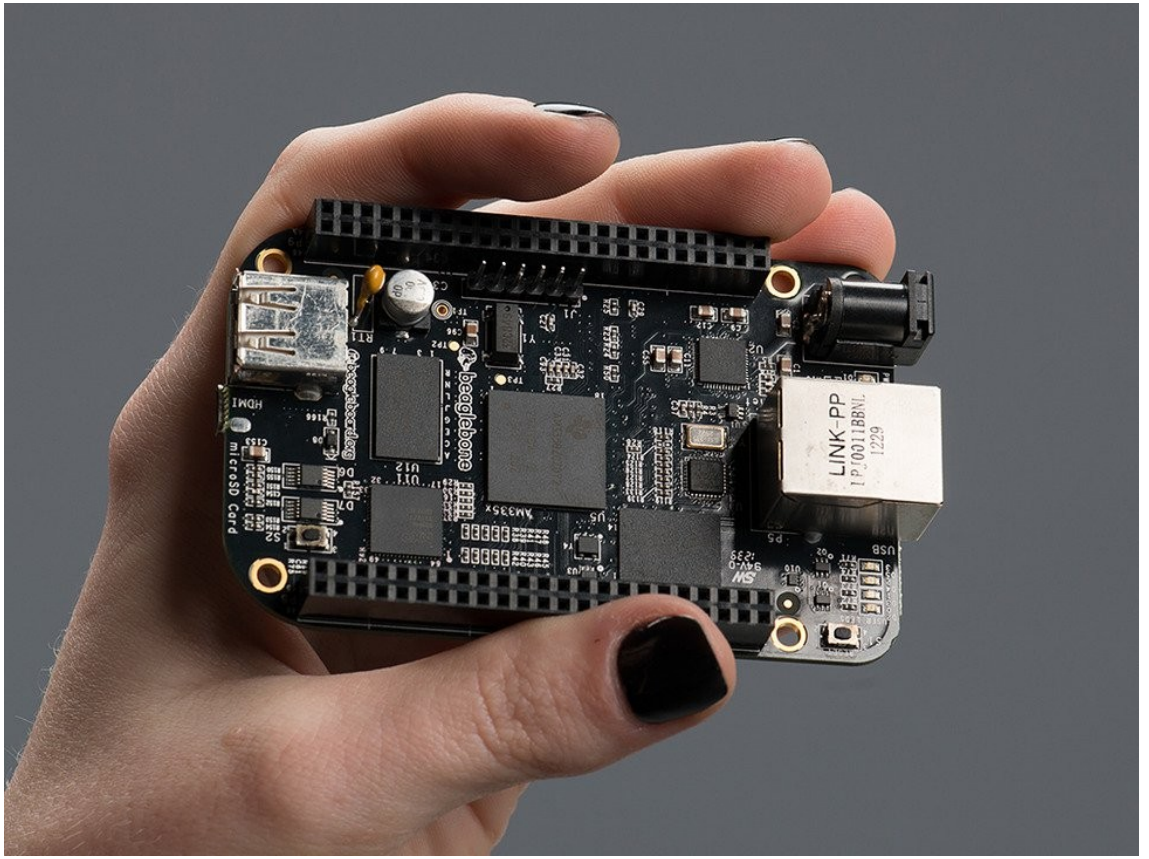
beagleboard.org

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



beagleboard.org

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

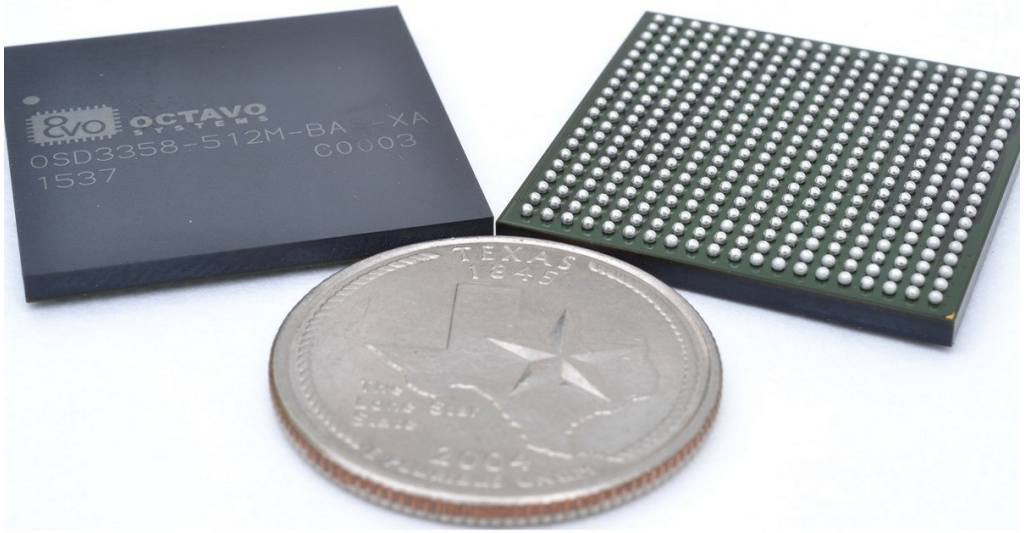


Open Source Hardware
BeagleBone derivatives

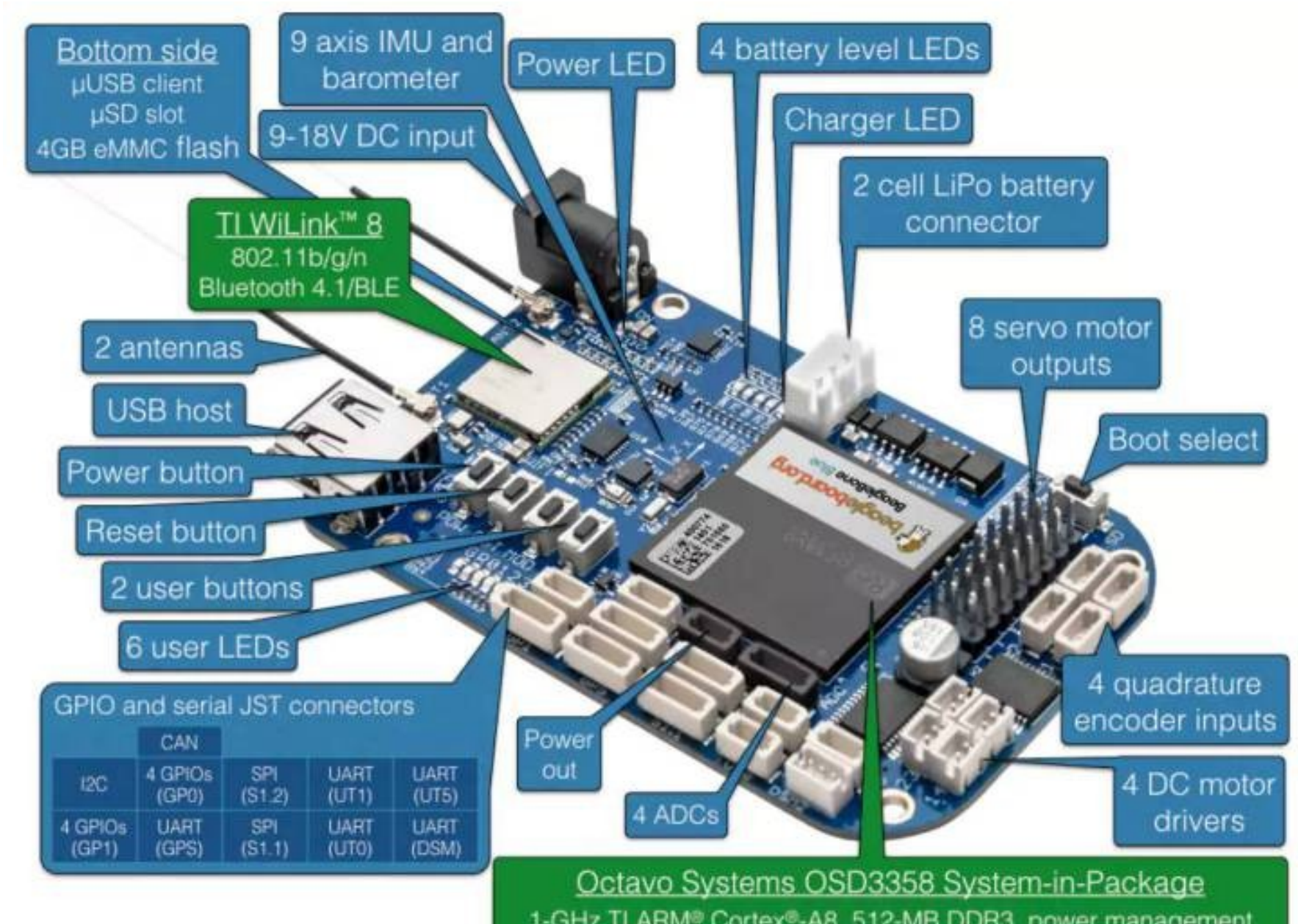
	Capes	HDMI	Flash	Special
BeagleBoard.org BeagleBone	Y	N	N	JTAG
BeagleBoard.org BeagleBone Black	Y	Y	Y	-
Arrow BeagleBone Black Industrial	Y	Y	Y	Industrial
Element14 BeagleBone Black Industrial	Y	Y	Y	Industrial
SeeedStudio BeagleBone Green	Y	N	Y	Grove
SanCloud BeagleBone Enhanced	Y	Y	Y	1GB, 1Gbit, wireless
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

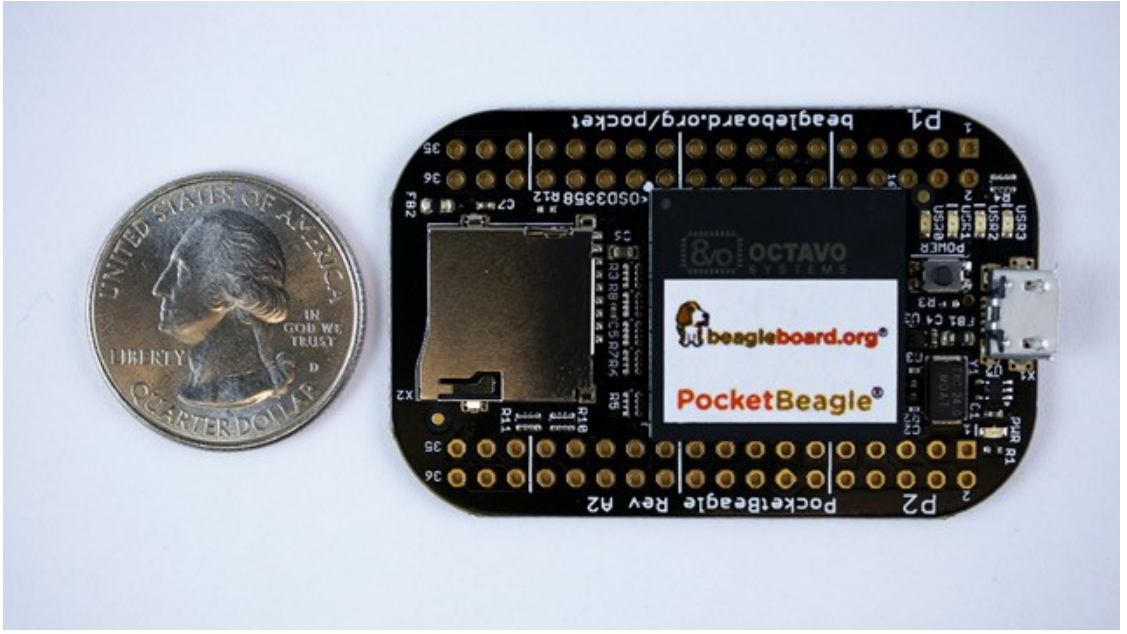
- CadSoft EAGLE design files hosted on GitHub
- Bill of Materials: every part available in qty 1
- Octavo System-in-Package (SiP) packages several ICs *(CPU, RAM, etc)* into one large-pitch BGA chip to simplify PCB layout and assembly



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



BeagleBoard.org PocketBeagle



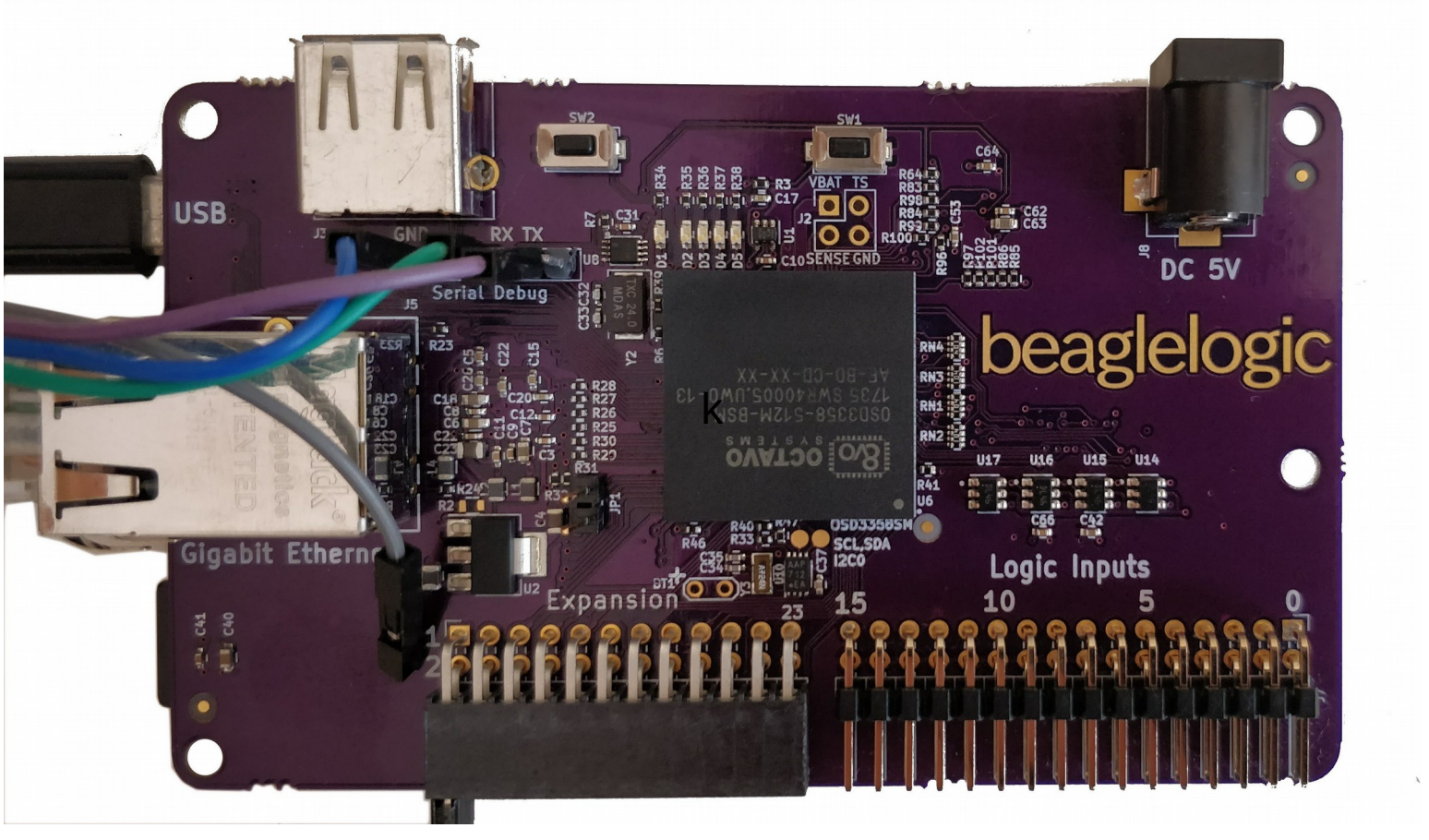
- Michael Welling designed the *"PocketBone"* using the Octavo SiP and shared on Hackaday.io
- In response to online demand, BeagleBoard.org worked with GHI in Michigan to design and manufacture a new product: the **PocketBeagle**

BeagleBoard.org PocketBeagle

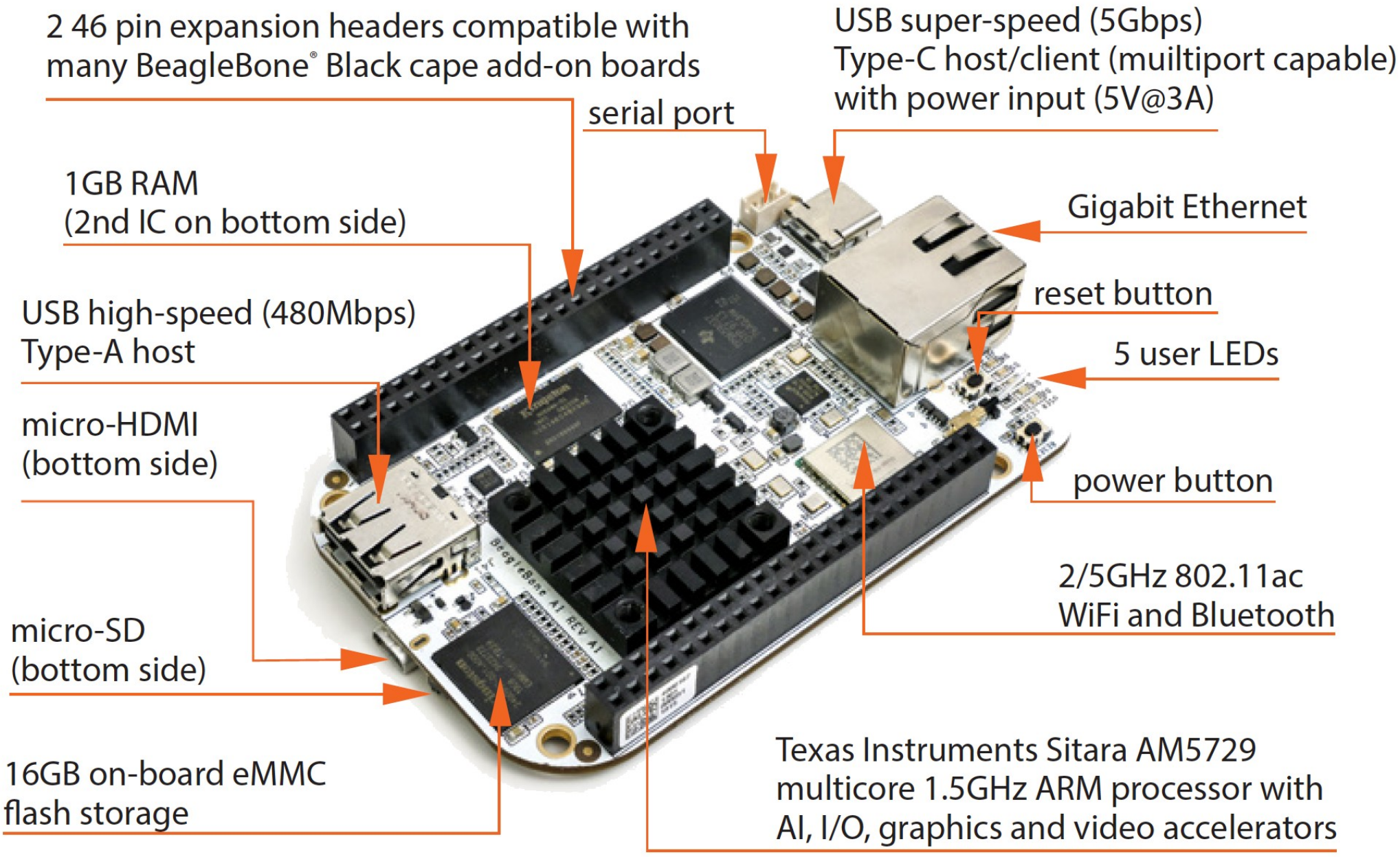
- PocketBeagle design makes it feasible for individuals to create their own derivatives
- 4 layer PCB published for EAGLE and KiCad
- Low cost assembly is possible with solder paste stencil and toaster oven

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
serial port
USB super-speed (5Gbps) Type-C host/client (muiltiport capable) with power input (5V@3A)
1GB RAM (2nd IC on bottom side)
Gigabit Ethernet
reset button
USB high-speed (480Mbps) Type-A host
5 user LEDs
micro-HDMI (bottom side)
power button
2/5GHz 802.11ac WiFi and Bluetooth
micro-SD (bottom side)
16GB on-board eMMC flash storage
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.”

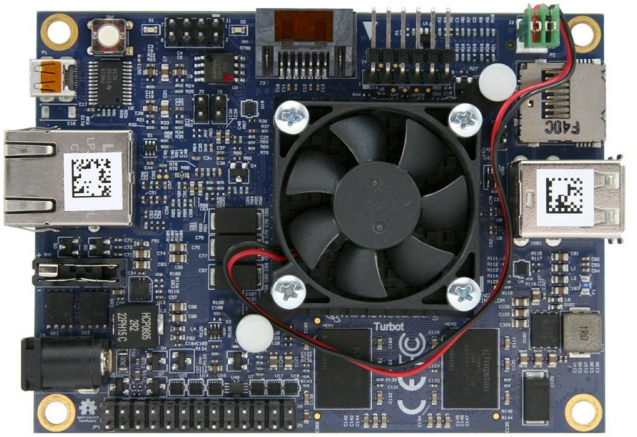
Feature highlights:

- 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

minnowboard.org

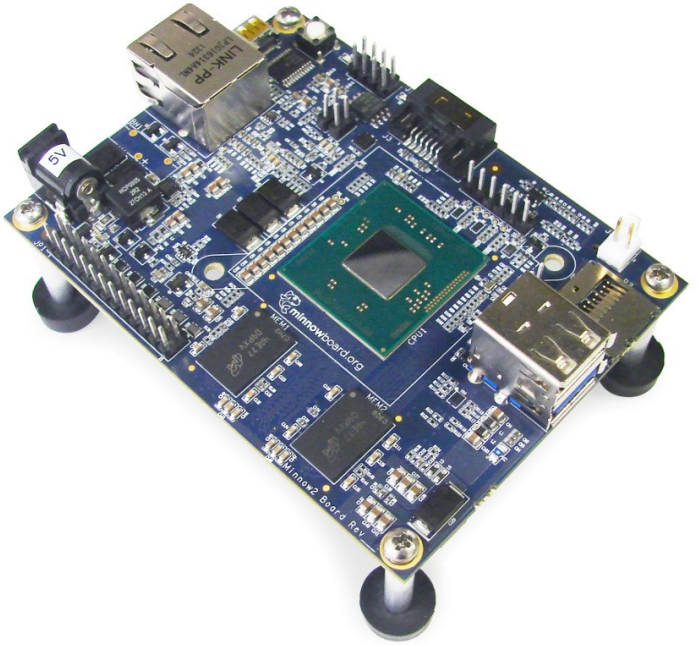
MinnowBoard



- 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

- Started by Intel, manufactured by ADI, still sold by Netgate… but I believe no future boards planned
- Released under Creative Commons **CC-BY-SA**
- Download design files:
  - ☑ **Schematic**
  - ☑ **Board Layout**
  - ☑ **Bill of Materials**

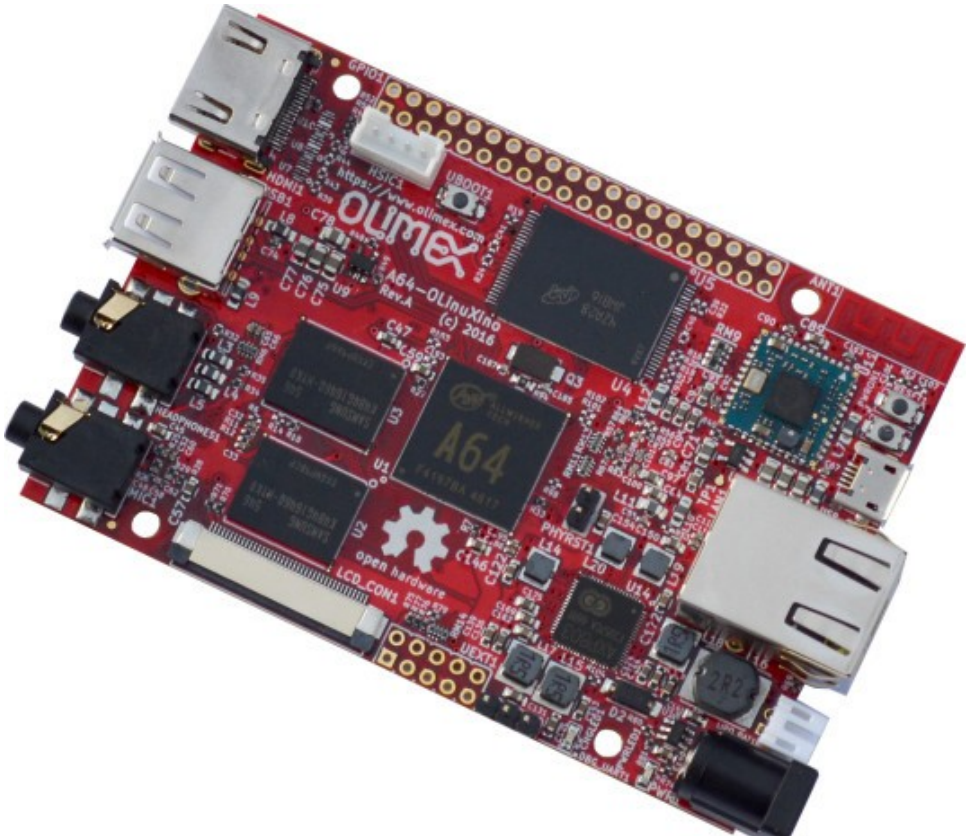


OLinuXino

- 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

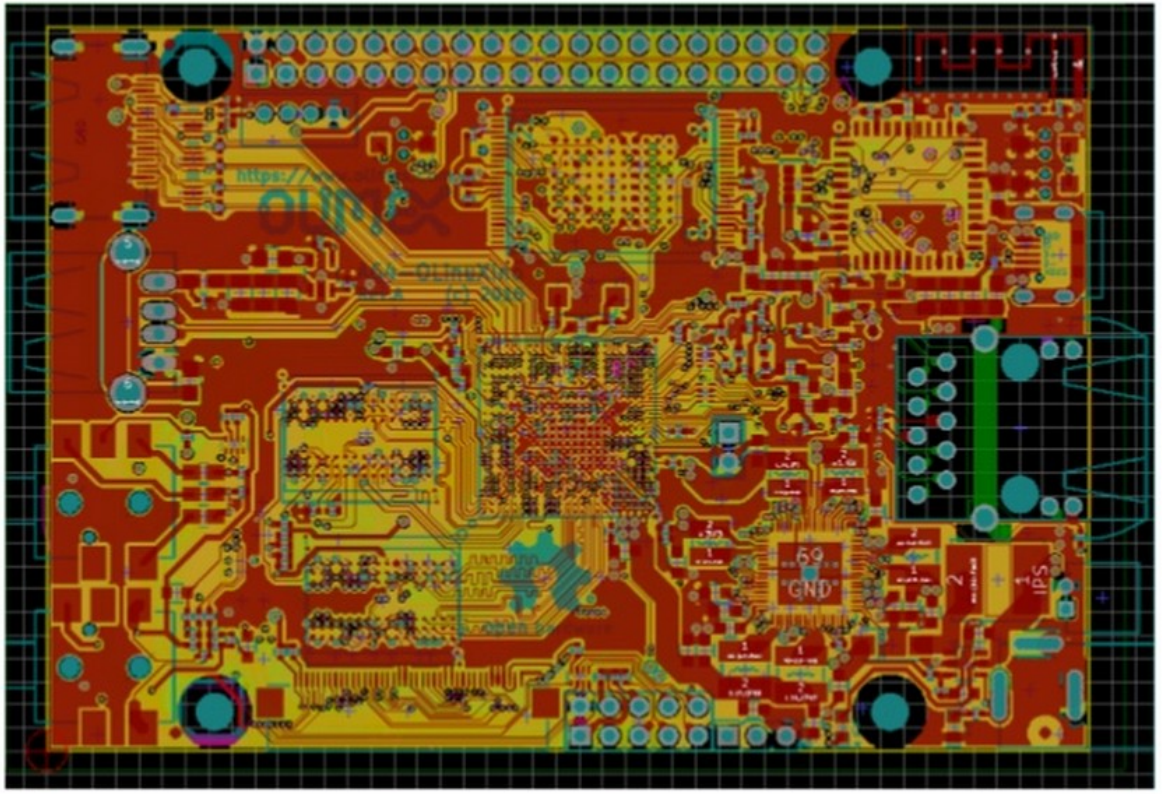
A64-OlinuXino

- 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

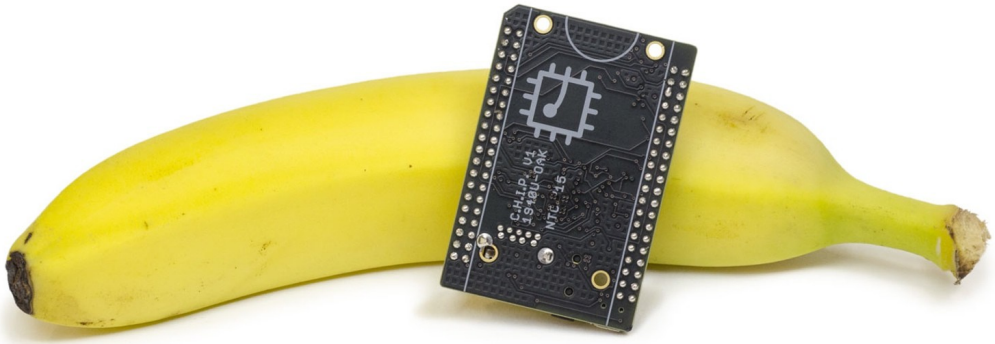
- **KiCad** is an Open Source EDA suite including Schematic Capture and PCB Layout
- Cross platform: **Windows**, **Mac OS** and **Linux**
- **CERN has contributed** professional CAD features for high-speed digital design
- Learn to design your own PCB in KiCad with: **Getting to Blinky**

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”

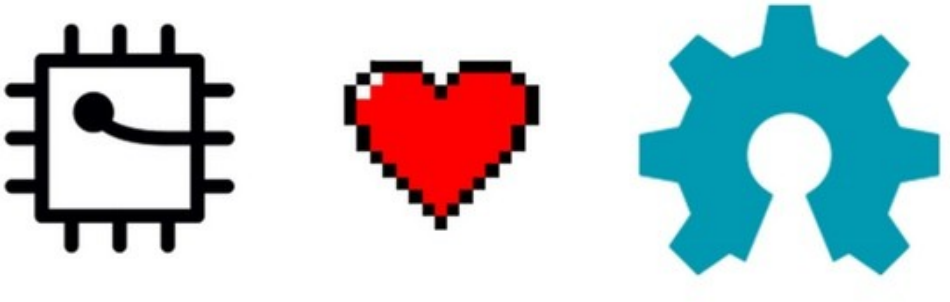
CHIP



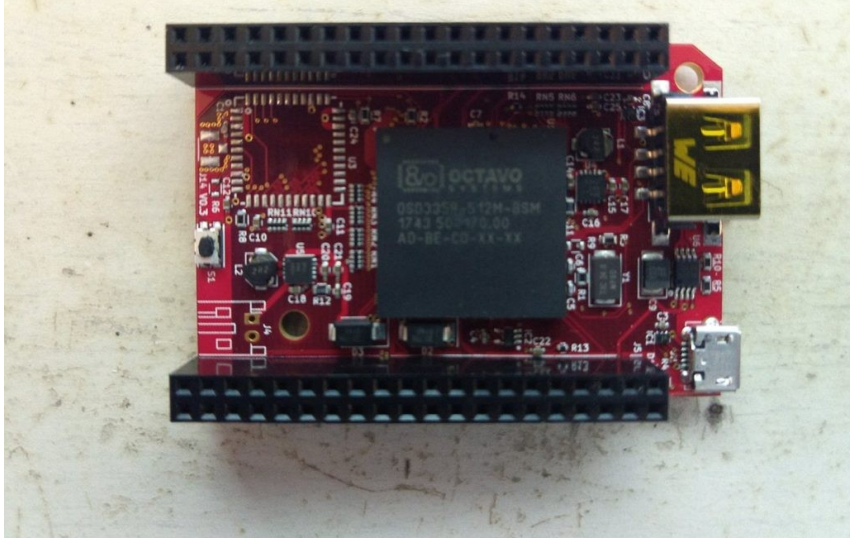
The World's First $9 Computer

- getchip.com
- Next Thing Co. in Oakland
- Kickstarter in 2015
- Company ended in 2018

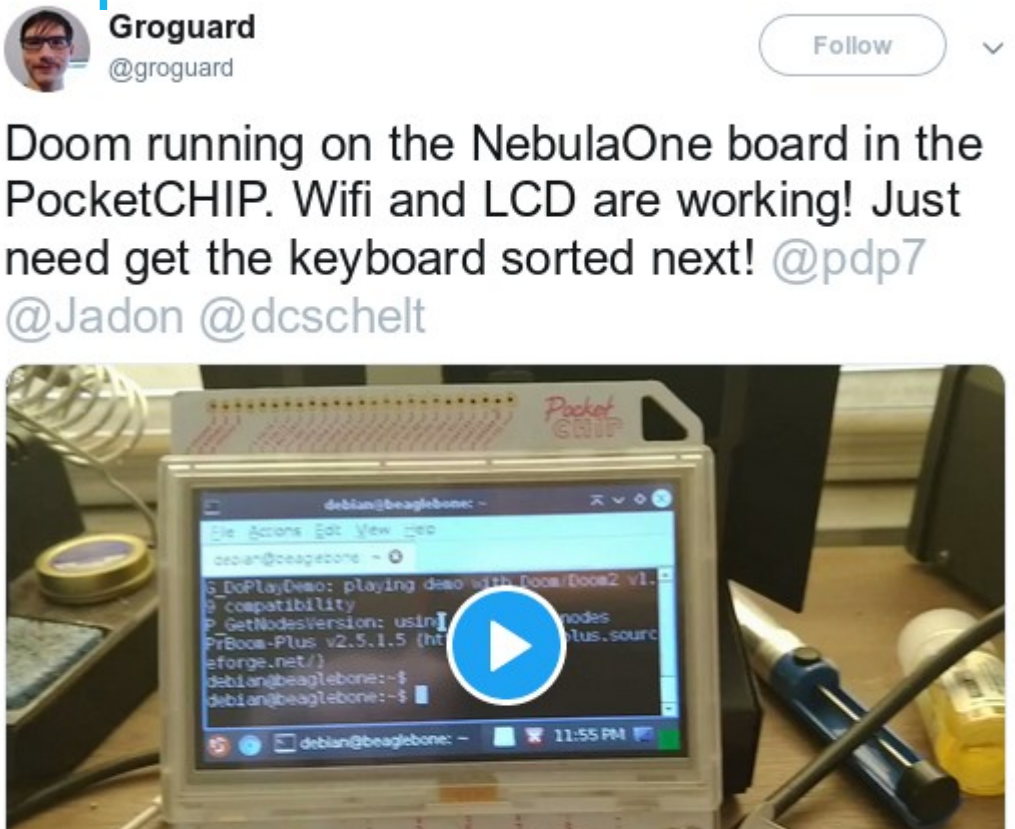
C.H.I.P. is OSHW



- **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!



Giant Board by groguard

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

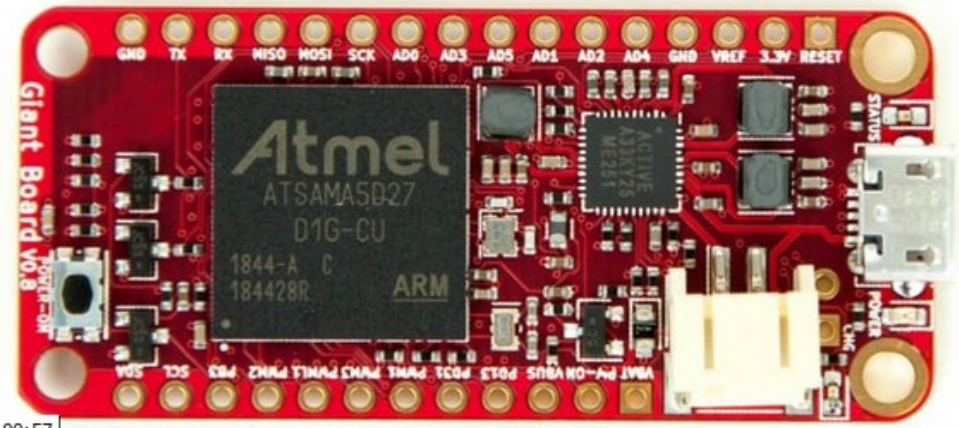
CROWD SUPPLY BROWSE LAUNCH ABOUT US Search

Giant Board by Groboards

A single-board computer in the Adafruit Feather form factor

Open Hardware
Computers & Networking
Development Kits

Part of Microchip Get Launched 2019



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$13,670 raised of $12,250 goal

111% Funded! Order Below

8	Aug 08	162
updates	funded on	backers

Last update posted Aug 07, 2019

me@example.com Subscribe to Updates

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”

Are there other OSHW boards that run Linux?

Please let me know!

drew@pdp7.com Twitter: @pdp7

Create a list on eLinux wiki?

Are there other OSHW boards that run Linux?

Thanks Twitter!

- HiFive Freedom Unleashed with 64-bit RISC-V
  - PCB design files are available
  - (thanks to Palmer Dabblet for the link)
- VoCore2: “The Coin-sized Linux Computer”
- OSHW FPGA boards ECP5 FPGA running RISC-V!
  - Orange Crab by Greg Davill
  - Radiona.org ULX3S
  - David Shah's Trellis board (Ultimate ECP5 Board)
    - Fork Sand has built this board
  - MyStorm with ECP5 by Alan (who is here!)
  - *More?*

Are there other OSHW boards that run Linux?

Any OSHW on 96boards.org?

96Boards

About Products Projects Documentation Blog Forums

Consumer Edition (CE)

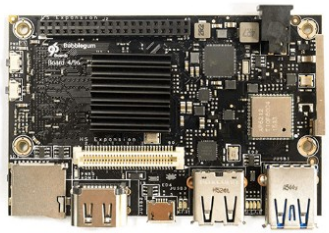
96Boards » Products » Consumer Edition (CE)

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

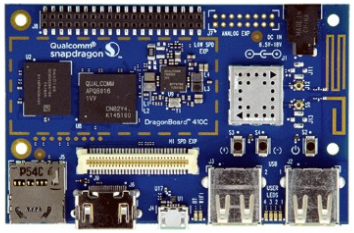
96Boards Consumer

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...

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Any OSHW on 96boards.org?

96Boards and Open Source Hardware

“Linaro is a software company, and the goal of 96Boards is to provide an option for standardization of SoC boards for software developers, the maker community and embedded product manufacturers.”

“There is a considerable investment in tools and specialist engineering effort required in designing with a modern high speed SoC which can have over 600 pins in a 0.4mm pitch BGA package - board design and layout costs can easily exceed $25K even before an initial prototype can be built. Furthermore, designs for new SoCs often require the direct involvement of the SoC vendor’s engineers to ensure that design rules for the SoC and PMIC have been fully met.”

Any OSHW on 96boards.org?

Mezzanine Community:

The 96Boards Mezzanine Community was formed by a group of individuals who shared the passion of Open-Source hardware & software.

This community aims to create an ecosystem of Open-Hardware platforms based around the 96Boards CE Mezzanine Specification and also provide a unified platform to host mezzanine designs.

Udoo: no PCB design files?

START DISCOVER COMMUNITY RESOURCES PROJECTS DISTRIBUTORS SHOP

DOCUMENTATION

DOCUMENTS

USER MANUAL

MECHANICAL SPECS

3D MODEL

SCHEMATICS

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SCHEMATICS TOP BOT

OTHER FILES

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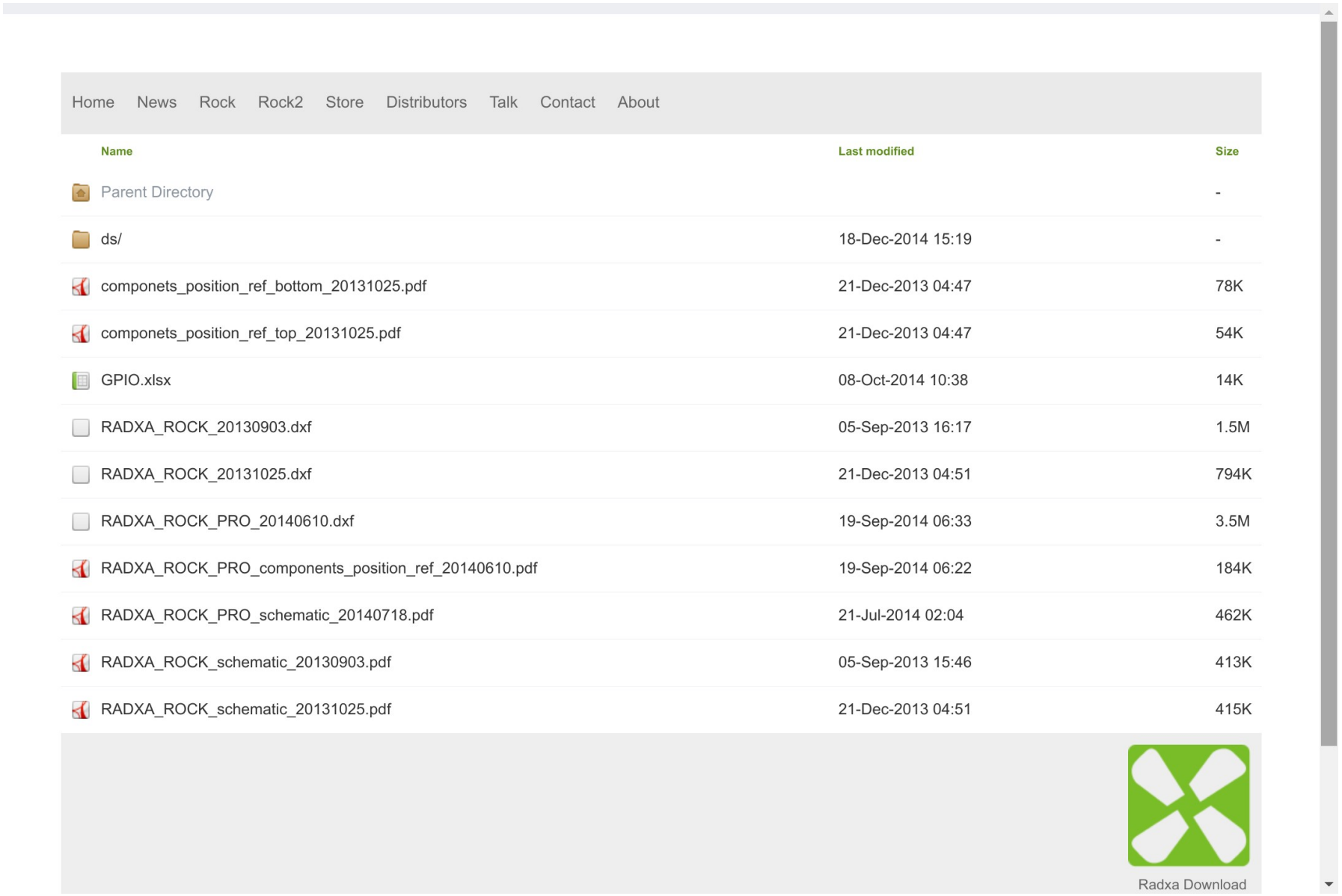
Radxa: no PCB design files?



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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?

LET'S GET START TO KNOW WITH THE Cubieboard NOW!

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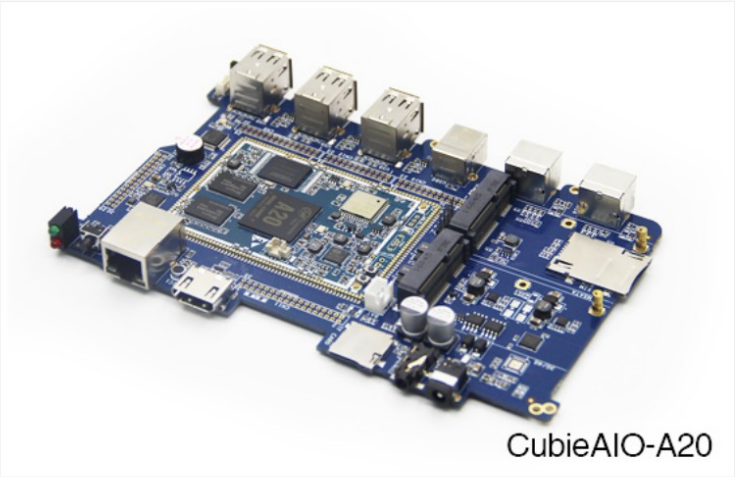
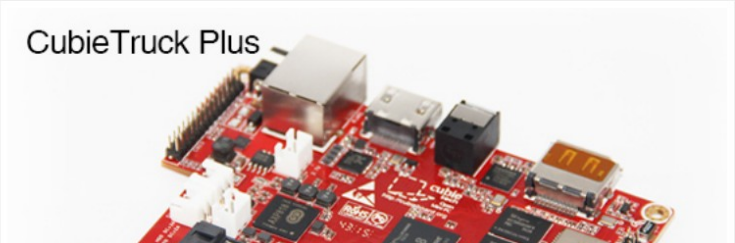
Model



CubieAIO-A20



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

Section:

Open Source and Libre Silicon

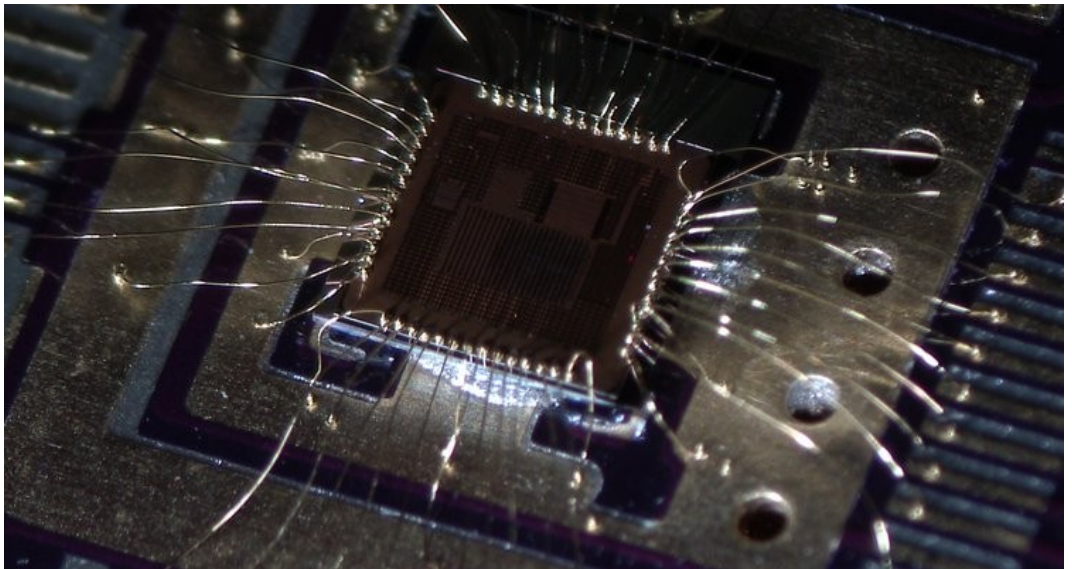
What about silicon?

- **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?

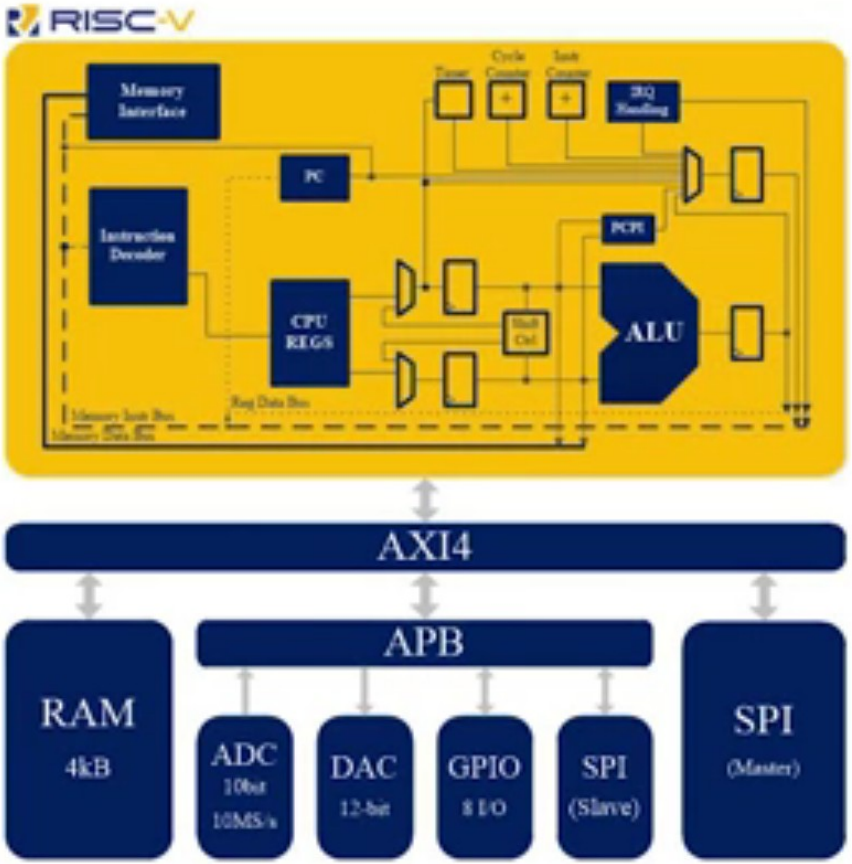
- **OnChip Open-V**

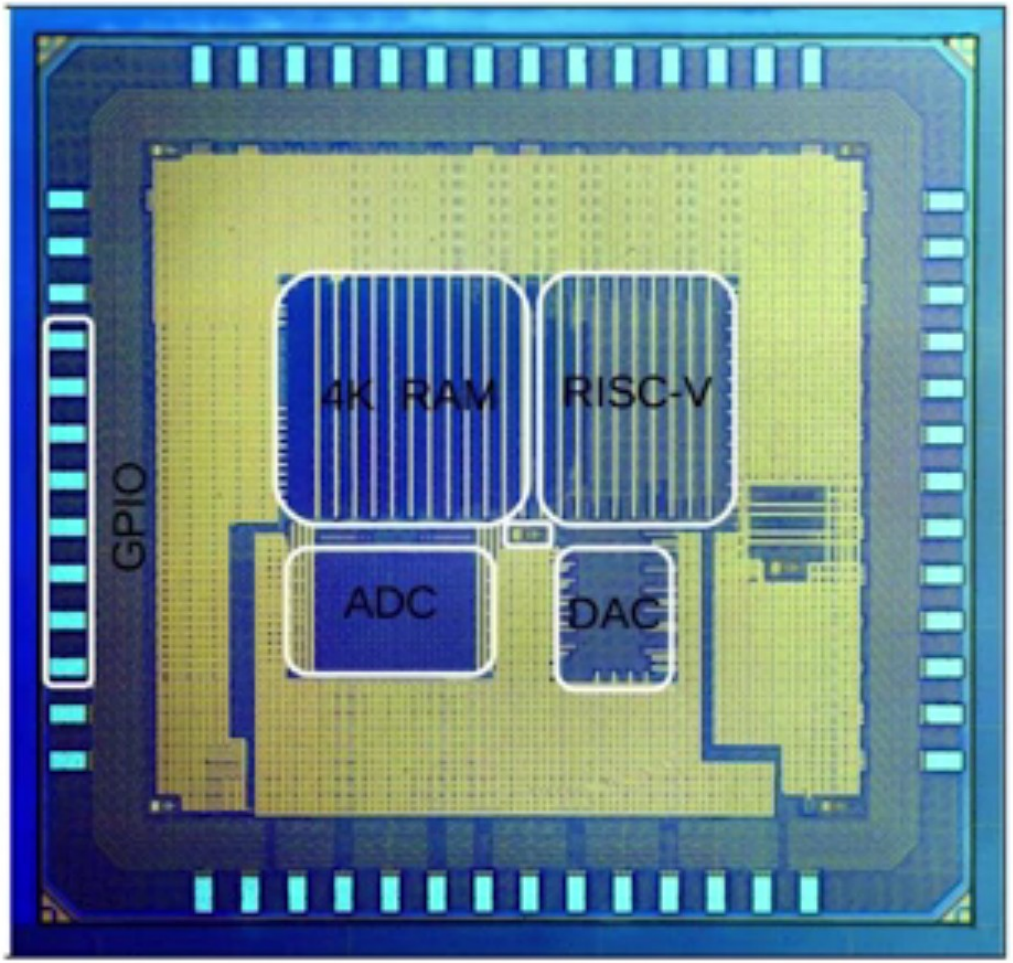
  “completely free (as in freedom) and open source 32-bit microcontroller based on the RISC-V architecture”



What about silicon?

A 32-bit RISC-V based Microcontroller



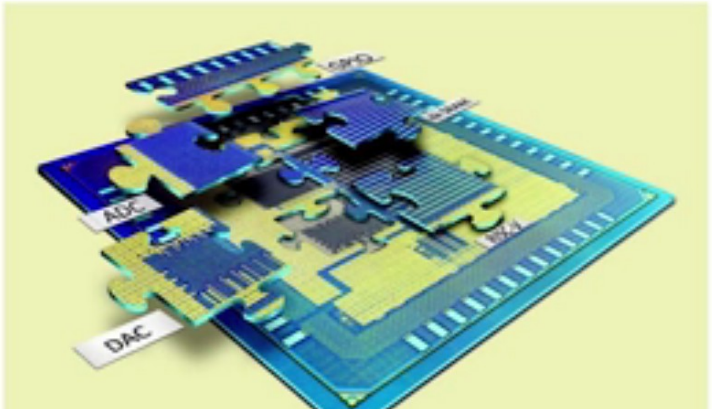


What about silicon?

- 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)

- Laura James from lowRISC is here!

What about silicon?

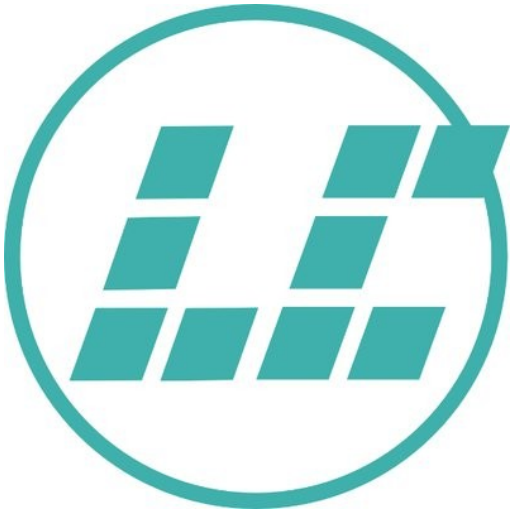
- **FOSSi Foundation**
  - The **F**ree and **O**pen **S**ource **S**ilicon **F**oundation
  - “non-profit foundation with the mission to promote and assist free and open digital hardware designs”
  - “FOSSi Foundation operates as an open, inclusive, vendor-independent group.”

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”

Latch-Up Conf 2019 videos

Week of Open Source Hardware

CERN Open Hardware Licence 2.0

80 views

3 0 SHARE SAVE ...

FOSSi Foundation
Published on Jun 20, 2019

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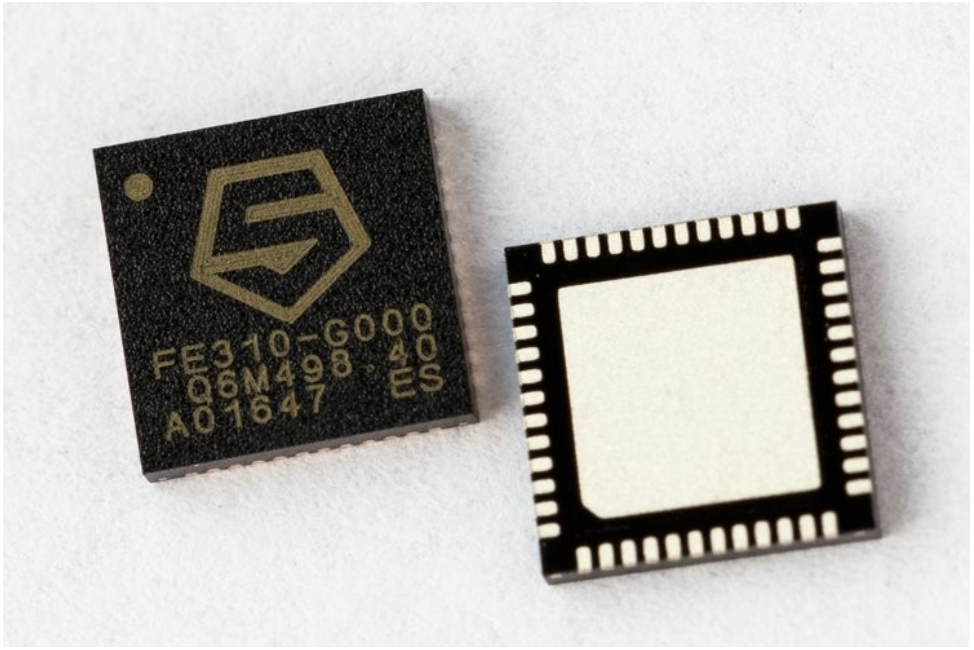
What about silicon?



- **SiFive**

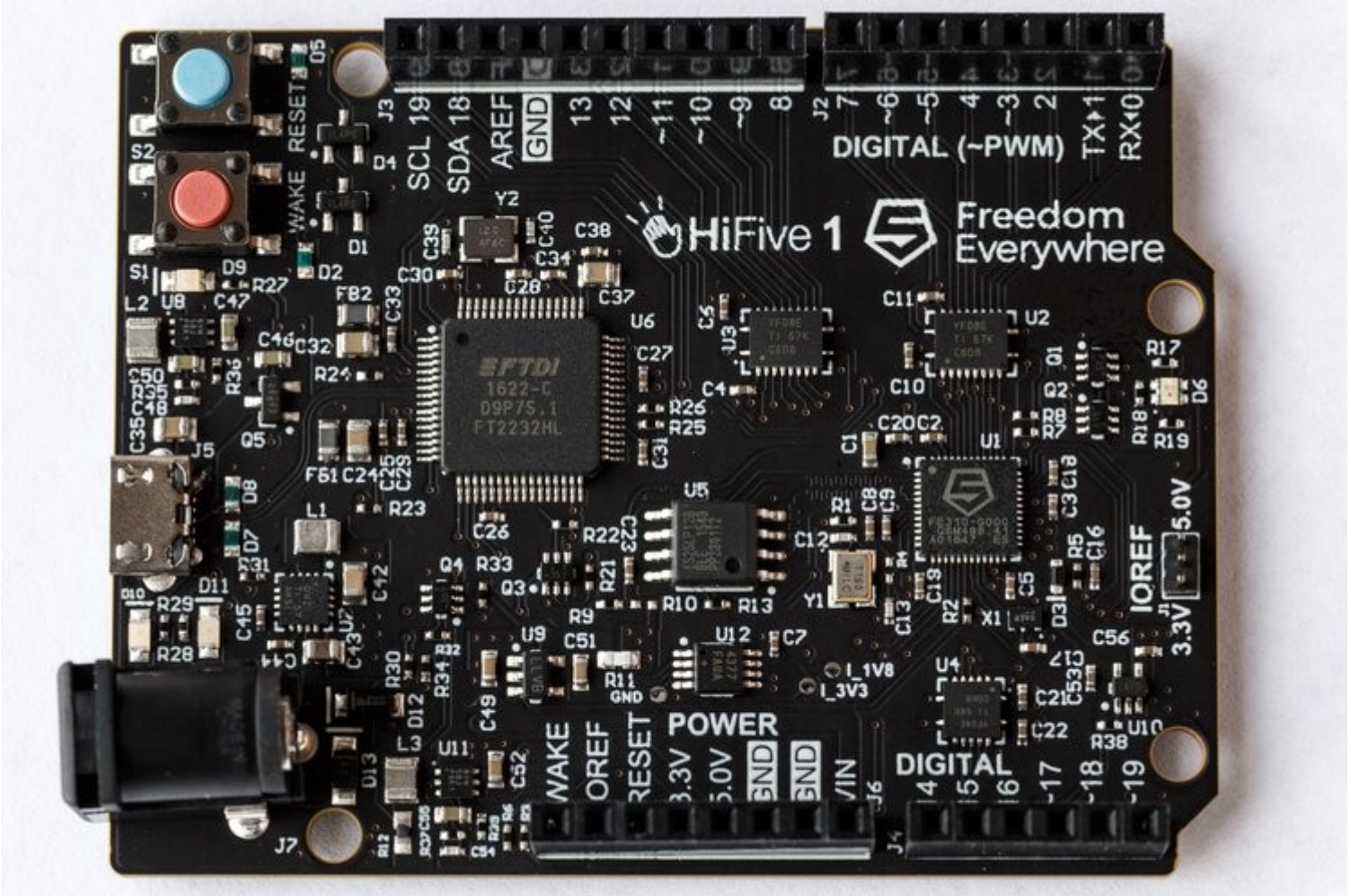
  “founded by the creators of the free and open RISC-V architecture as a reaction to the end of conventional transistor scaling and escalating chip design costs”

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

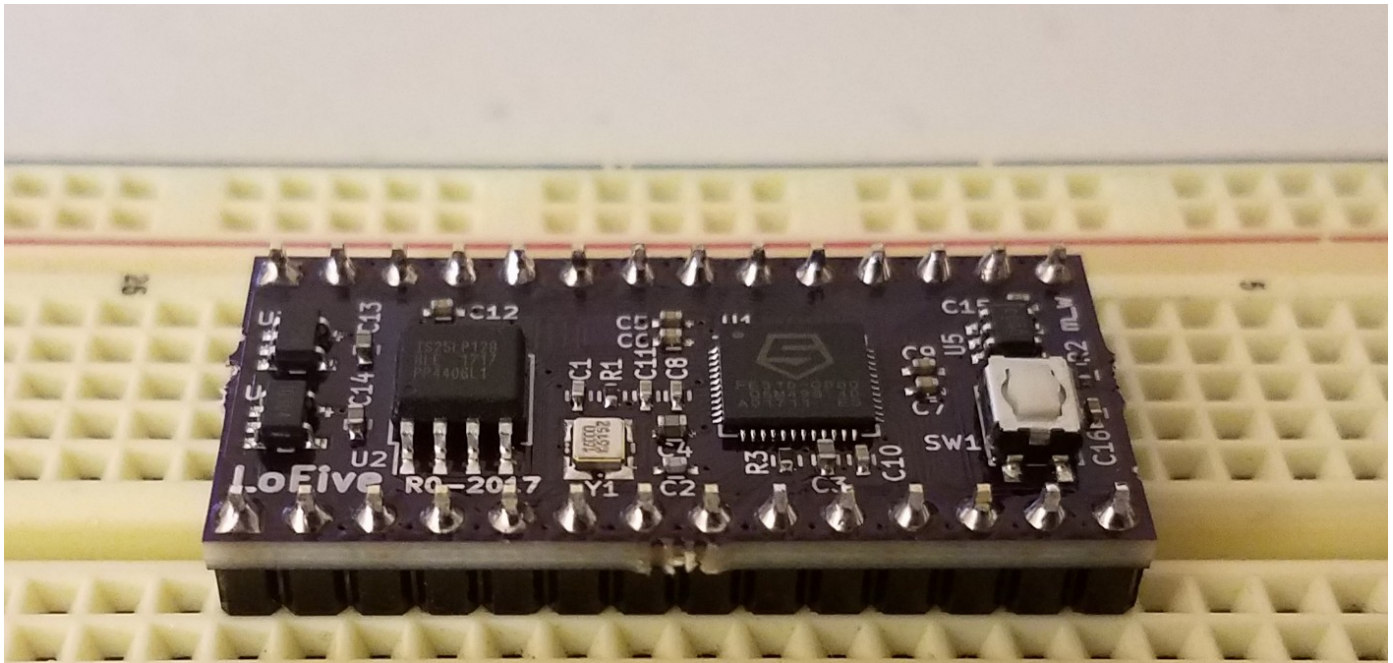
SiFive FE310 microcontroller

- HiFive1: Arduino-Compatible RISC-V Dev Kit



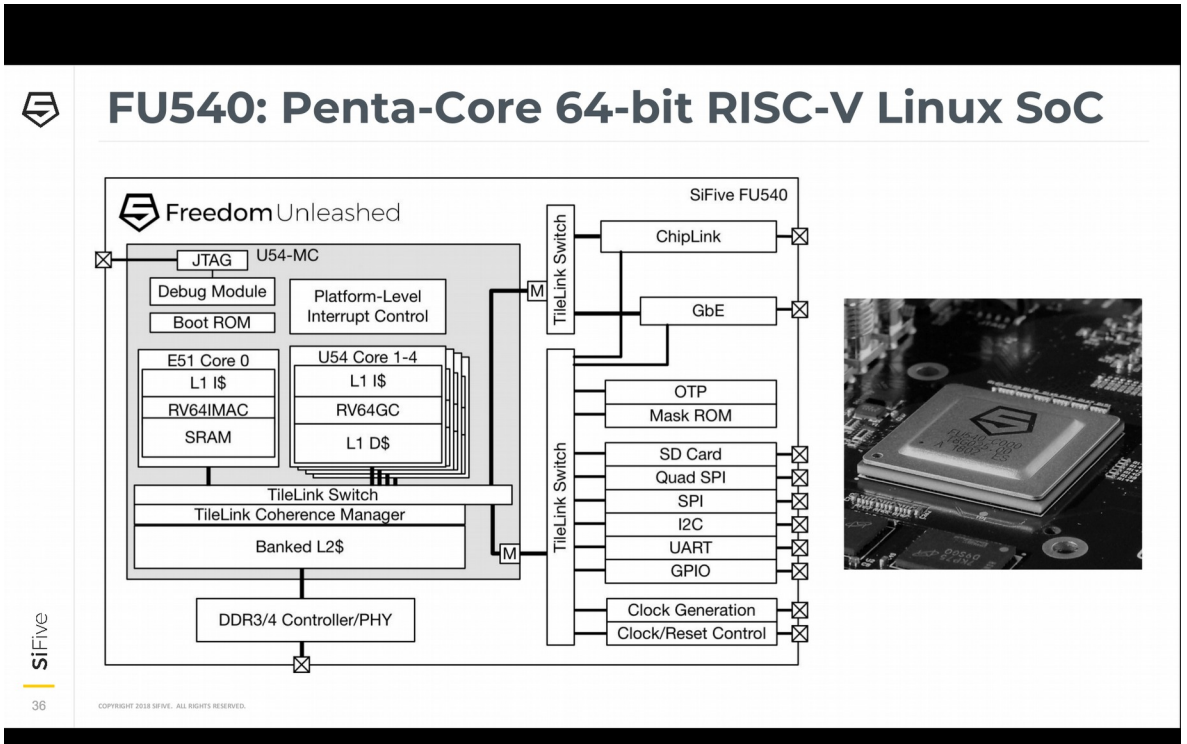
SiFive FE310 microcontroller

- **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



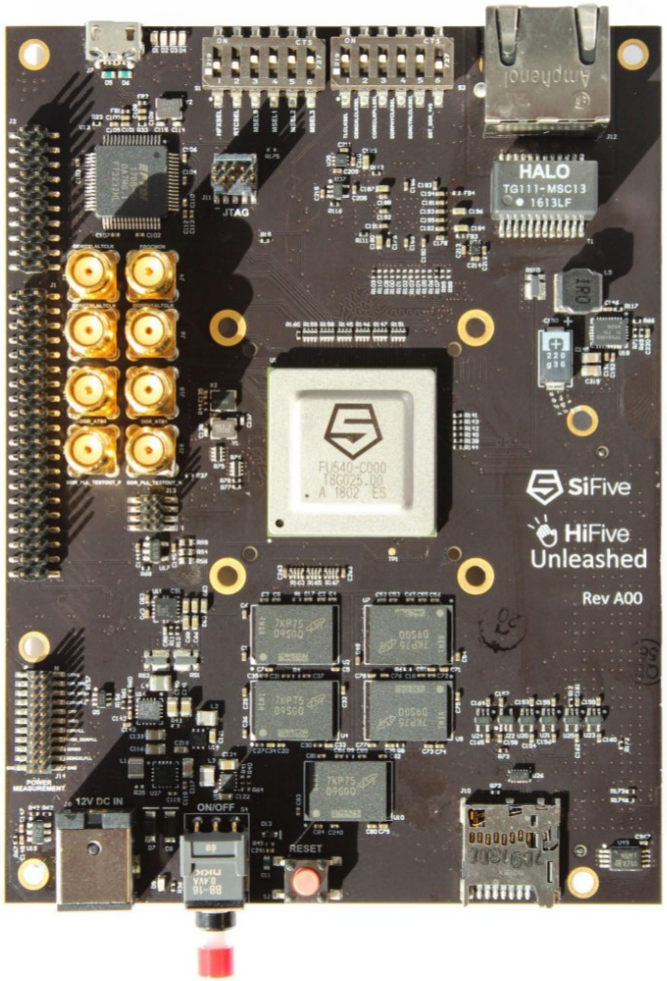
SiFive: Linux on RISC-V

- 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:
https://github.com/pdp7/talks/blob/master/er2019.pdf

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@BeagleBoardOrg / @pdp7
https://beagleboard.org/blog/