Embedded Linux Conference 2017:
Google Summer of Code and BeagleBoard.org

Google
Summer of Code

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What is Google Summer of Code?

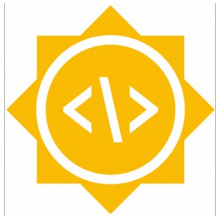
"**Google Summer of Code** is a global program that offers **students** stipends to write code for **open source projects**"

What is Google Summer of Code?

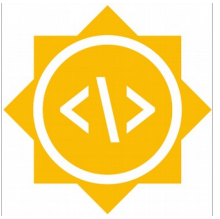
- 12 years
- 104 countries
- 568 open source projects
- 12,000+ students
- Over 30 million lines of code

Google Summer of Code 2016

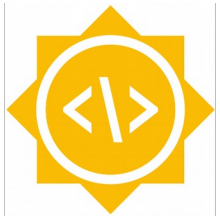
- 178 open source projects
- 1,206 university students
- 67 countries
- 1,032 students (85.6%) completed
- **$5,500** to each successful student



2017 GSoC Timeline



- **Jan. 19 – Feb. 9:** organizations apply
- **Feb. 27:** accepted organizations published
- **Feb. 27 – March 20:** potential student participants discuss application ideas with orgs
- **March 20 – April 3:** student applications
- **May 4:** accepted student proposals announced
- **May 30:** students begin coding
- **June:** mid-term evaluations
- **August:** final eval & project submissions
- **October:** Mentor Summit at Google



Student Requirements

- Must be at least 18 years of age
- Must currently be a full or part-time student (or have been accepted for fall term) at an accredited university
- Must be eligible to work in the country you will reside in during the program
- Not already been accepted as a Student in GSoC more than once
- Must reside in a country that is not currently embargoed by the United States

Student Stipends

- Stipends are paid after each successful evaluation.
  - First Evaluation (paid early July): 30%
  - Second Evaluation (paid early August): 30%
  - Final Evaluation (paid mid September): 40%
  - Stipend amounts are calculated based on your location.
- 2017: Purchasing Power Parity (PPP) based calculation to determine the stipend
  - Minimum 2400 USD & maximum 6600 USD

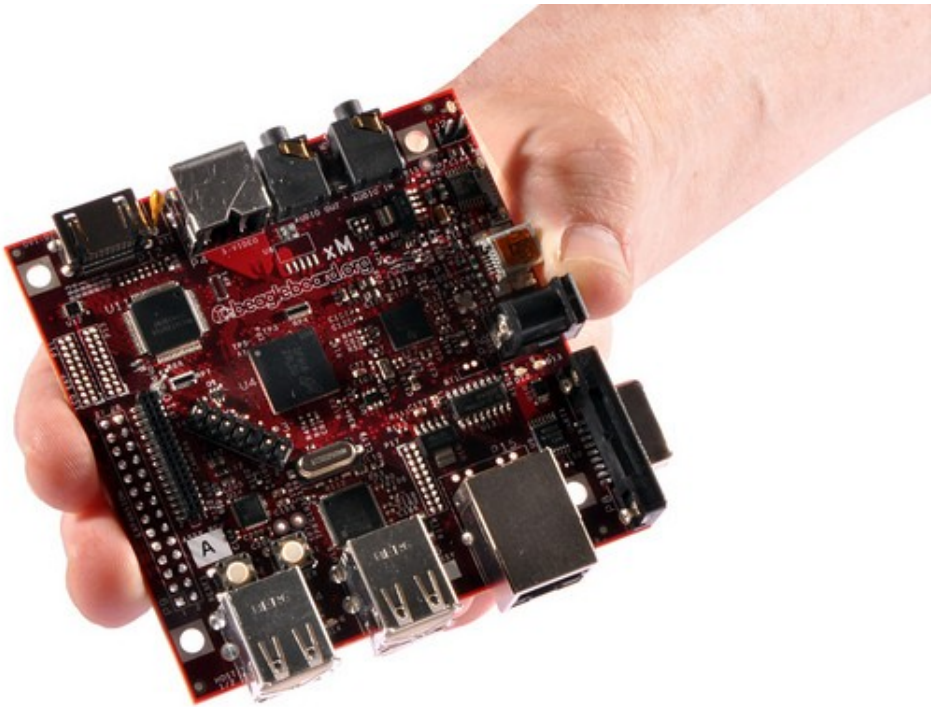
Open Source Hardware computing

for

Makers, Educators & Professionals

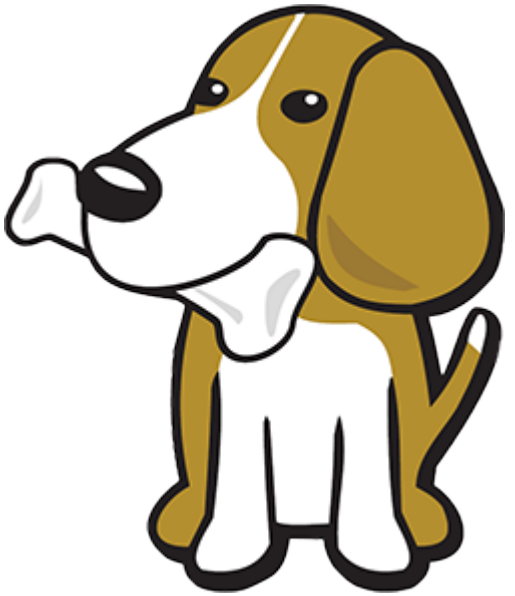
beagleboard.org

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



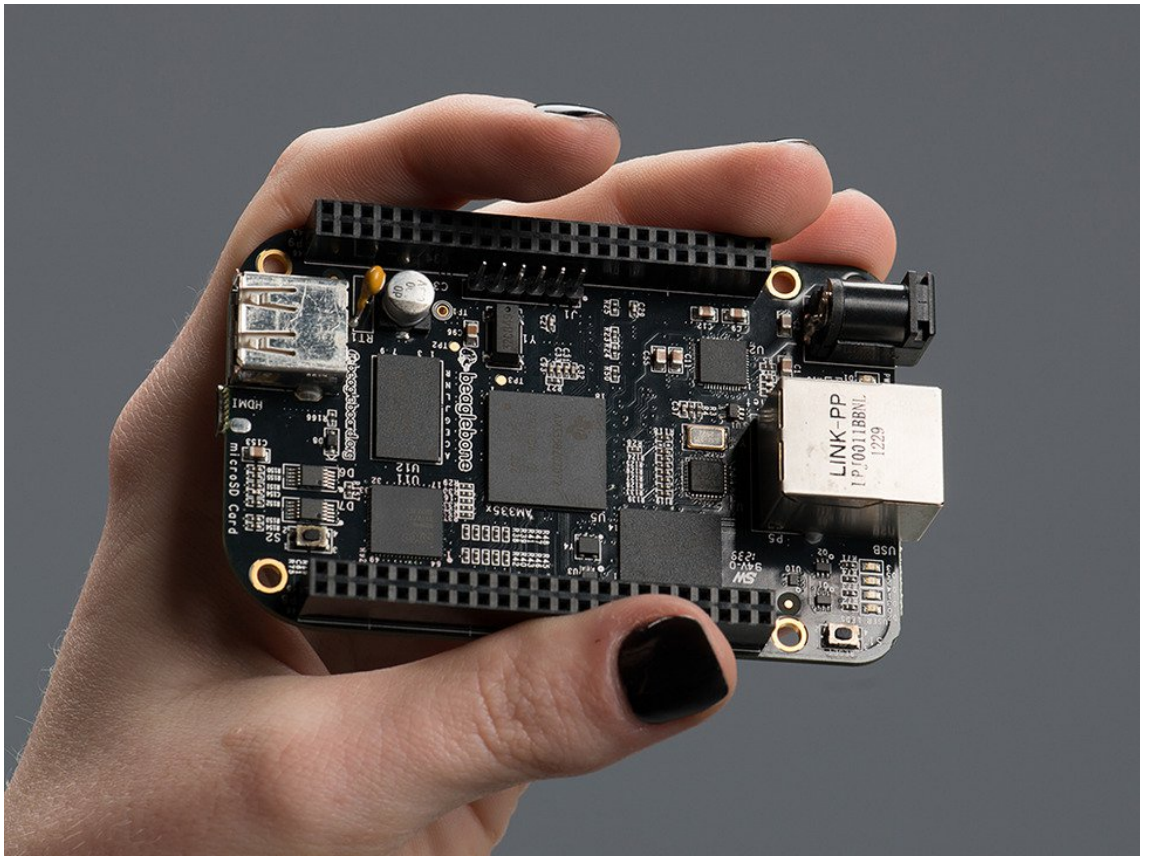
beagleboard.org

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



beagleboard.org

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

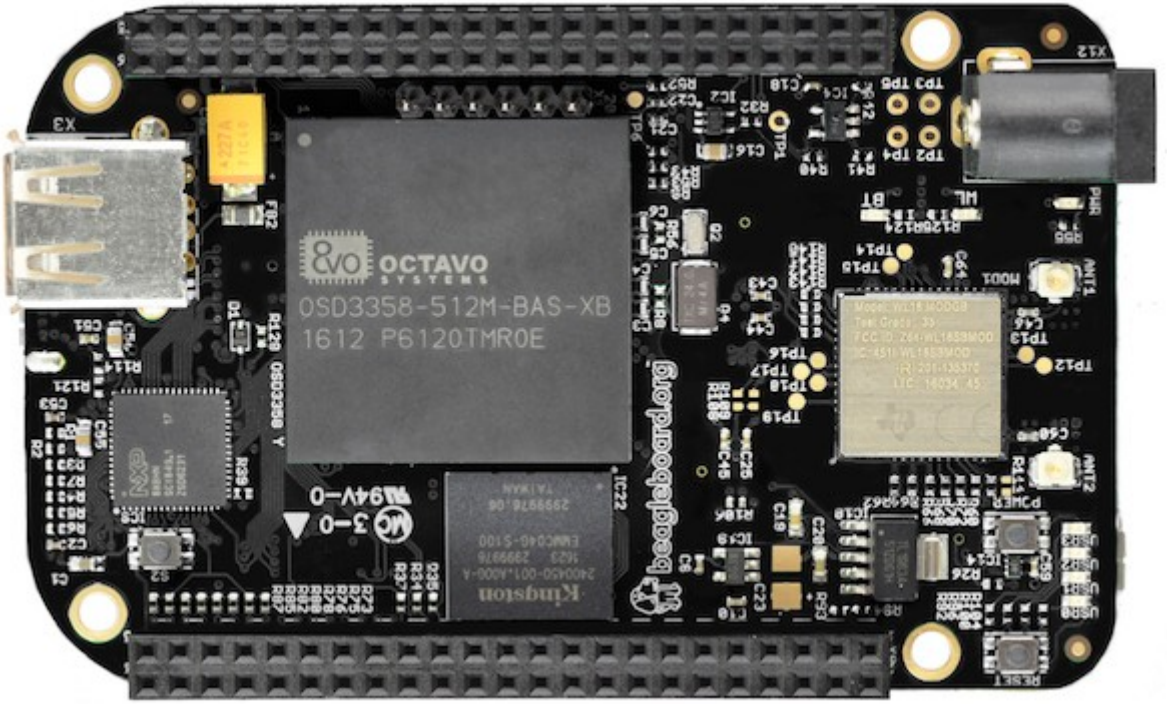


Open Source Hardware
BeagleBone derivatives

	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

beagleboard.org

BeagleBone Black Wireless



- **WiFi 802.11b/g/n and Bluetooth 4.1 with BLE**
- **1st Beagle with Octavo System-in-Package (SiP)**
- **Designed in EAGLE *(BBB was OrCad/Allegro)***

BeagleBoard.org BeagleBoard-X15

Jason Kridner

What is demonstrated

Open hardware computer
- ➡ Debian Linux system
- ➡ Open source 2D graphics acceleration
- ➡ Video acceleration
- ➡ OpenCL C66 DSP support
- ➡ Mainline kernel support
- ➡ GCC compiler support
  - ✓ ARM Cortex-A15
  - ✓ ARM Cortex-M4
  - ✓ TI C66x
  - ✓ TI PRU

What was improved

Fastest BeagleBoard available
More cores and more types of cores
Lots more I/O capability and bandwidth
More RAM (2GB)

Great open hardware ARM build platform

Hardware Information

https://bbb.io/x15

Dual-core ARM Cortex-A15, dual C66x DSPs, quad programmable real-time units, 3×USB 3.0, PCIe, 2×gigE, 2GB RAM, 4GB eMMC flash, ...

Source code or detail technical information availability

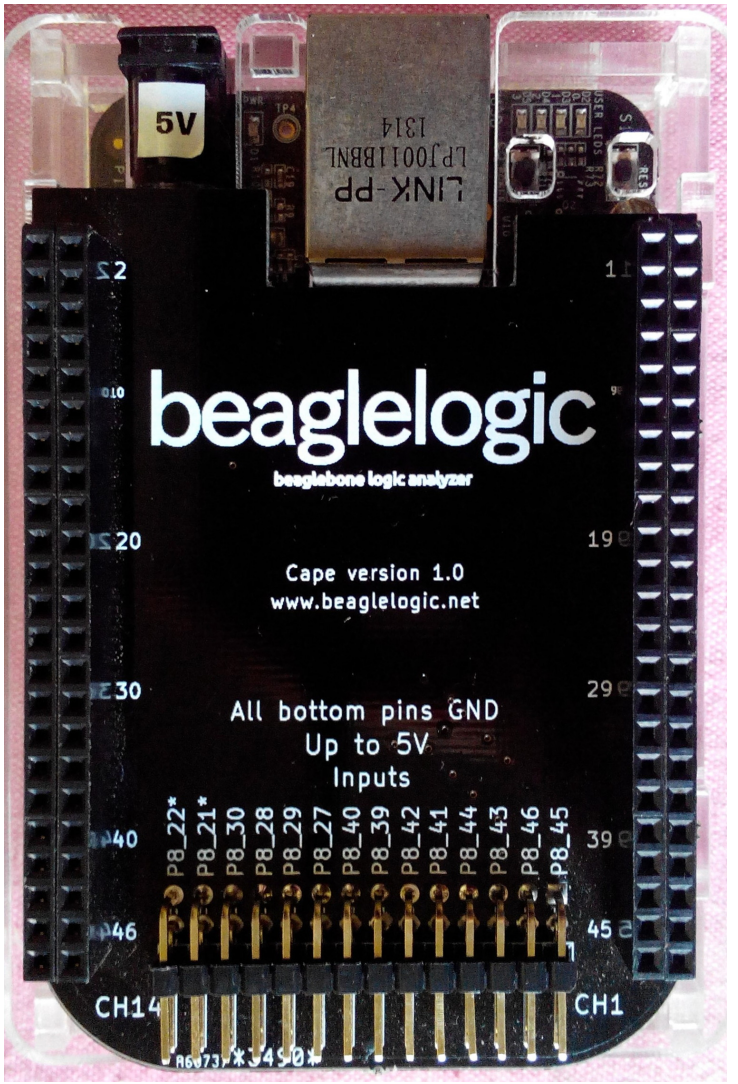
https://github.com/beagleboard/beagleboard-x15
https://github.com/beagleboard/linux
https://github.com/beagleboard/image-builder

- **BeagleBoard.org Foundation** is US-based non-profit corporation
- Provides education around the design and use of Open Source Software and Open Source Hardware
- Fosters communication between individuals interested in Open Source

beaglelogic

beaglebone logic analyzer

- **Kumar Abhishek** created BeagleLogic for GSoC 2014
- BeagleLogic turns BeagleBone into **Logic Analyzer**
- 14-channel, 100Msps
- Web browser user interface
- Video of final presentation



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Why BeagleLogic?

- Best In Class Sample Buffer Size – 320 MiB, 100 Msamples/sec

  (Excluding the cape + $55 / $39 for a BeagleBone Black / Green)

  3.3 secs of high-speed 8 channel data!
- Capture and Debug on the same hardware
  - Full-featured **sigrok** software stack preloaded
  - Decode over 30 digital protocols (I²C, I²S, SPI, UART, WS2812, 1 Wire, nRF24L01, DS1307, ARM SWO Trace ...)
- Networking Capabilities enabling remote debugging
- Web Interface
- Open Source Software & Open Hardware

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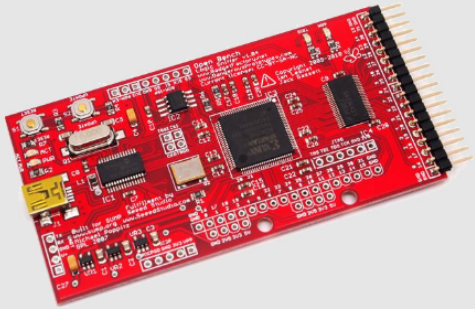

	OLS	Saleae Logic 8	BeagleLogic
Price	$50	$219	Cape + $39(BeagleBone Green)
Max Channels	32	8	14
Max Sample Rate	200 MS/s	100 MS/s	100 MS/s
Sample Depth (8 ch)	16KSamples (0.008sec)	Limited by PC	320 MSamples (3.2sec)
Triggering	Hardware	Software	Software
Interface	USB 2.0 12Mbps, UART	USB 2.0, 480Mbps	USB 2.0 480Mbps RNDIS, LAN
Remote Debug	No	No	Yes

BeagleLogic – Best feature/price balance in the sub-100$ category

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beaglebone logic analyzer

Quick Start

- Flash the BeagleLogic System Image (Debian distribution, 900 MB download) onto a SD card.
- Insert the SD Card into the BeagleBone Black / Green.
- Connect the BeagleBone to your PC via USB and install drivers (if on Windows)
- Navigate to http://192.168.7.2:4000 (USB) or http://<ip-of-beaglebone>:4000/ (LAN)

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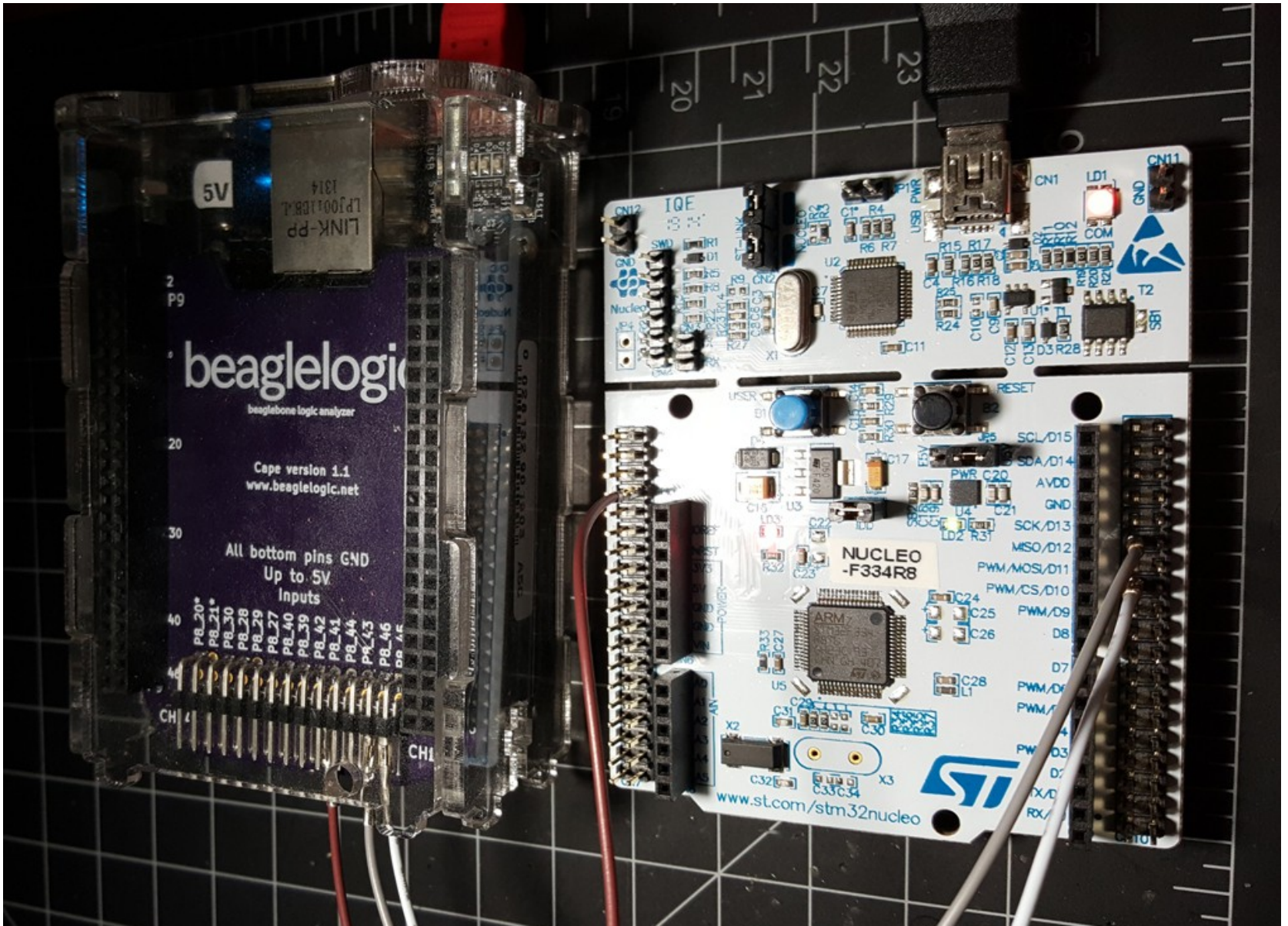

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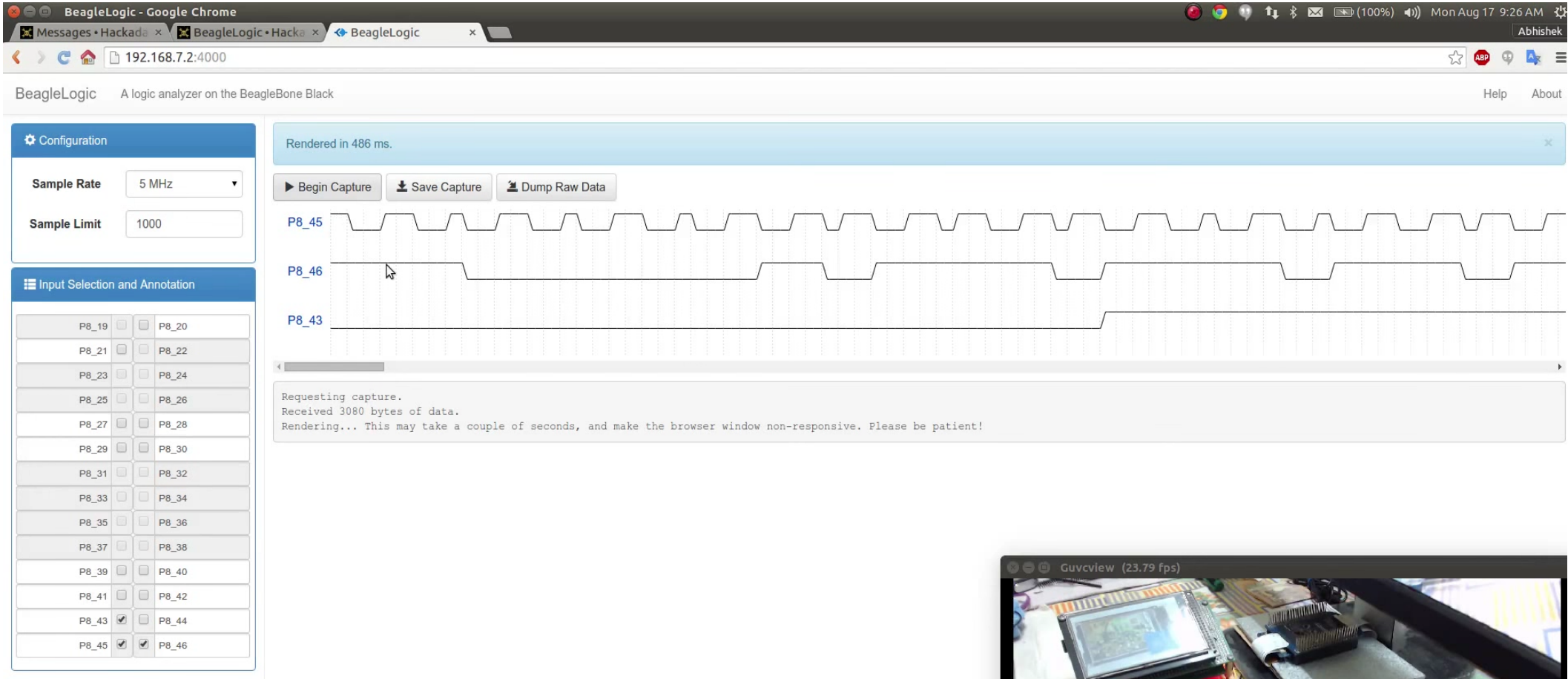

BeagleLogic - Logic Zero to One in 2 minutes

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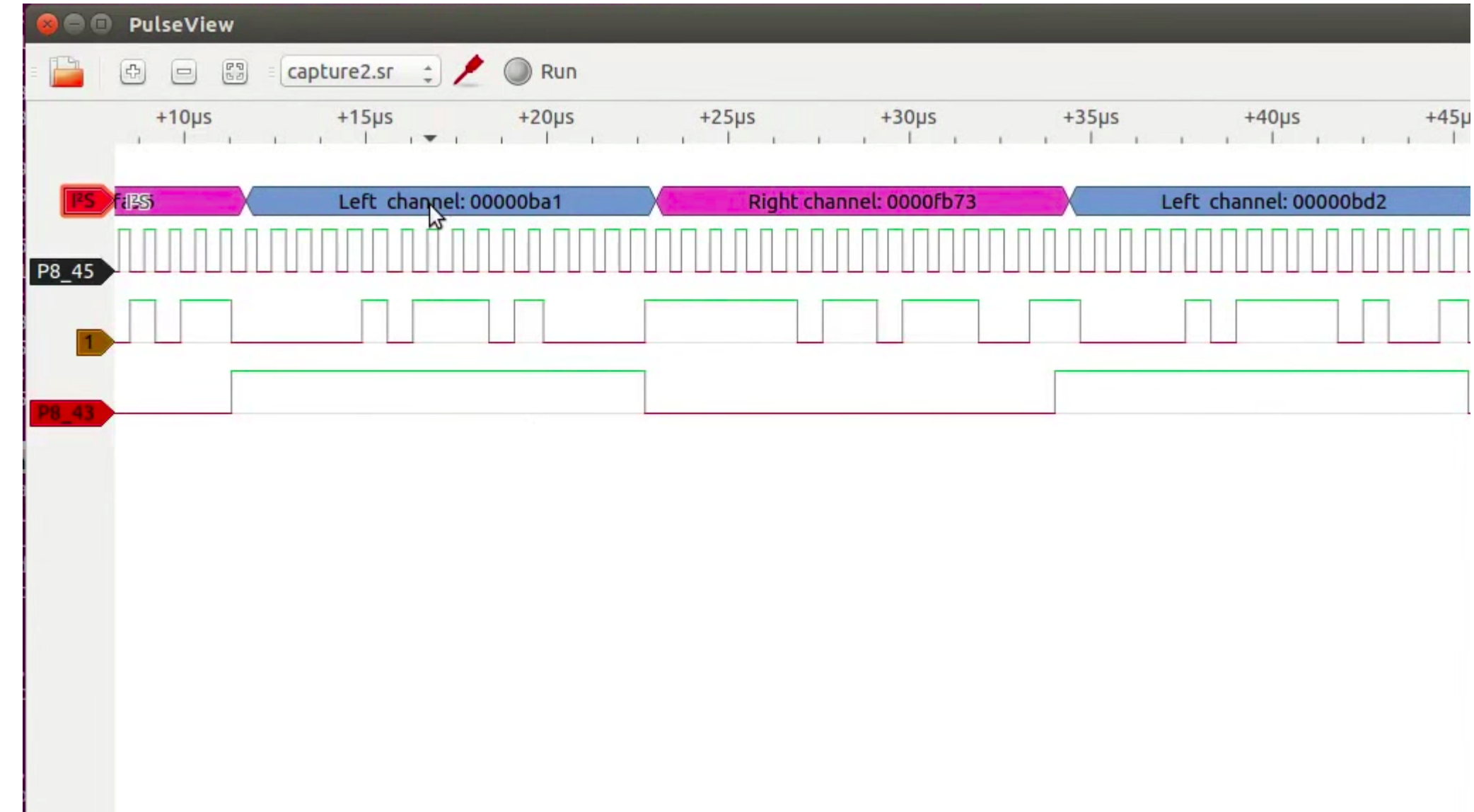
beaglebone logic analyzer



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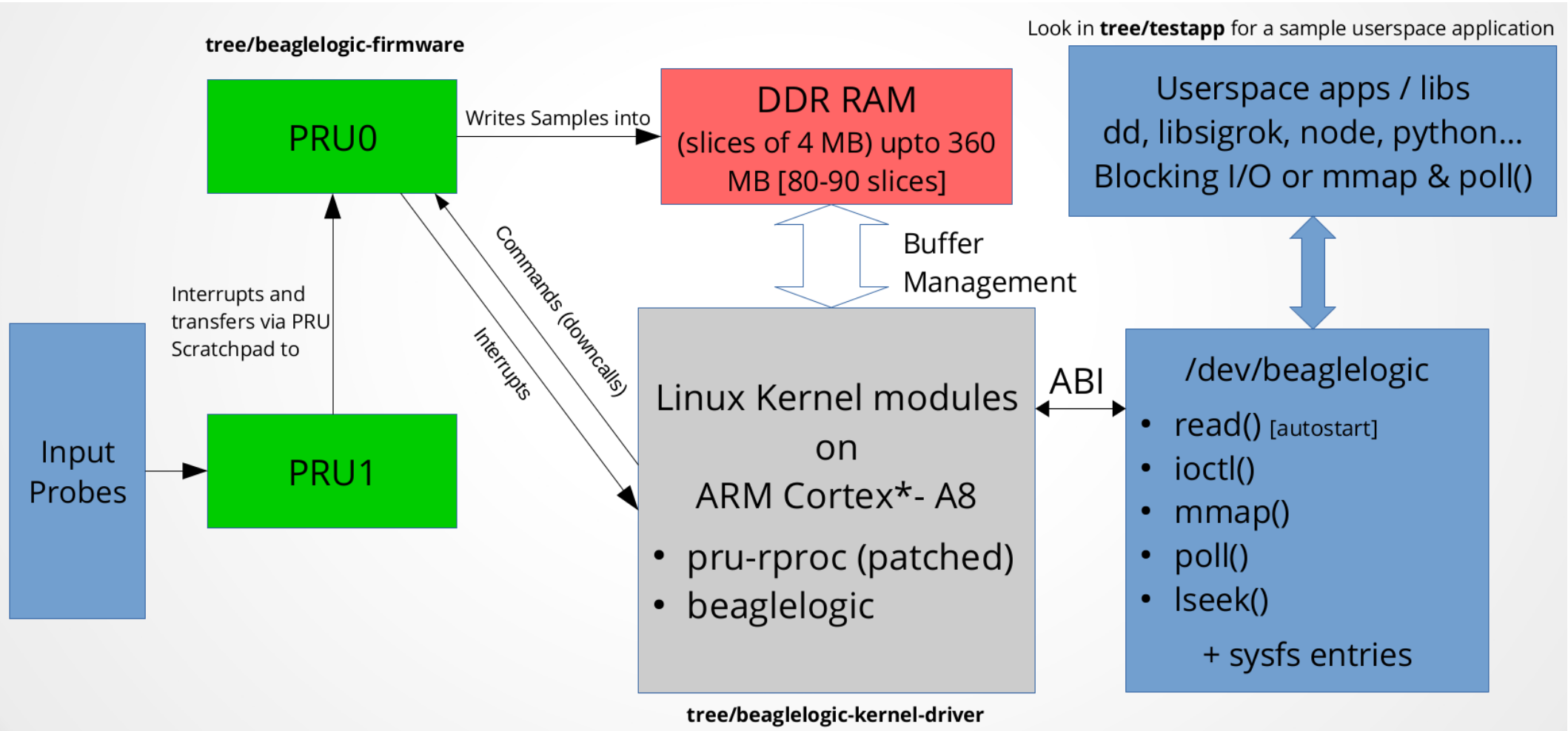

Source: https://hackaday.io/project/4395-beaglelogic

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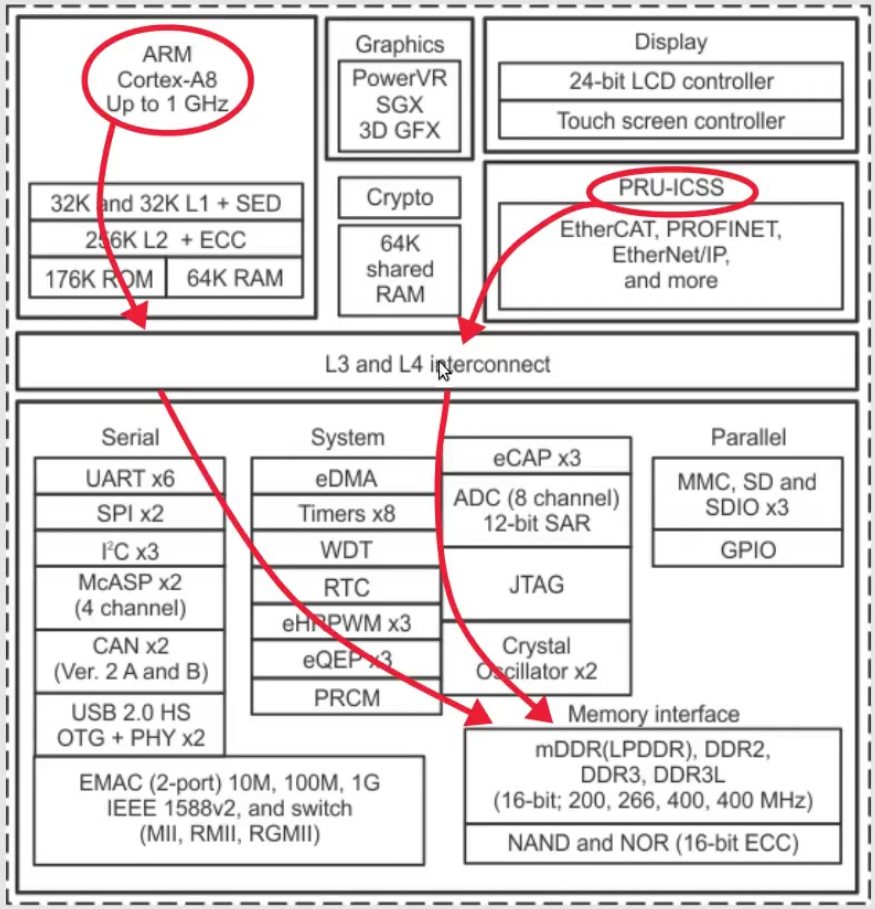
beaglebone logic analyzer

The AM3358 SoC



PRU
[Programmable Real-Time Unit]:

Two Programmable 200 MHz Microcontrollers on chip for real-time tasks.

Share the interconnect which connects the ARM core to system memory

Can access DDR3 RAM independent of ARM Core!

beaglelogic

beaglebone logic analyzer

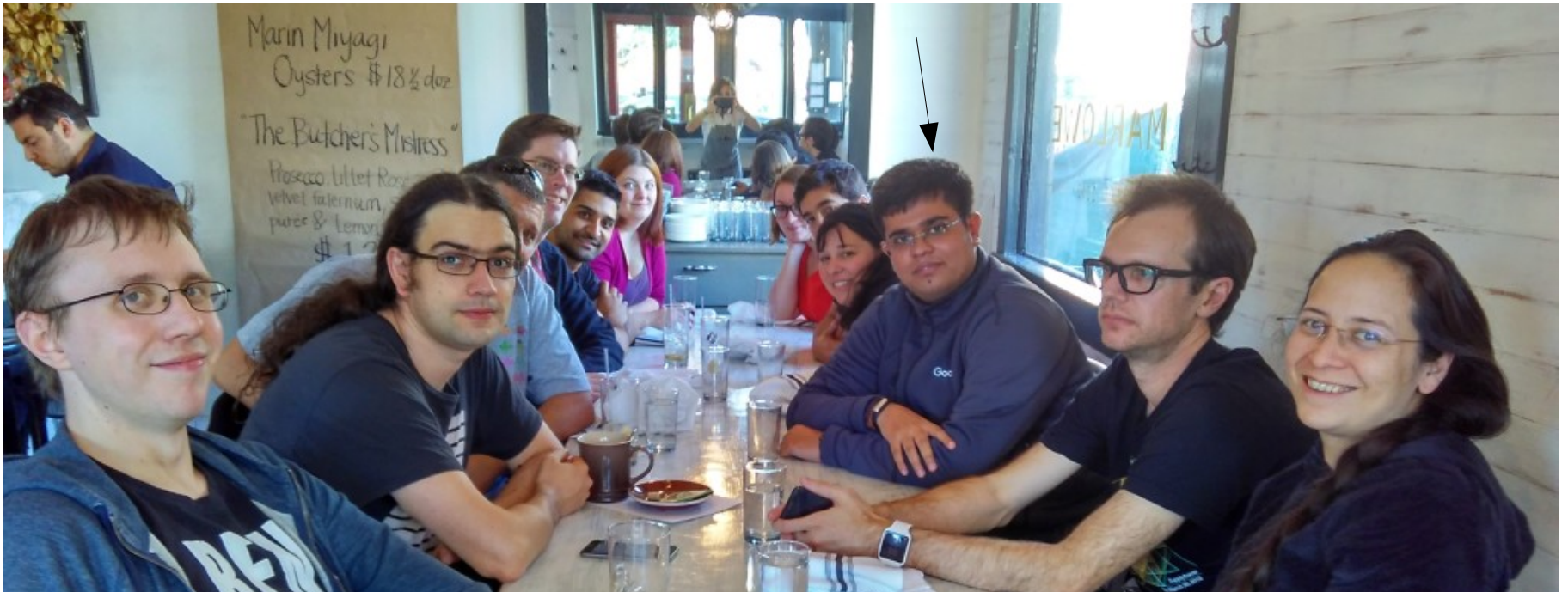
For Developers

- PRU Firmware
- Linux Kernel Driver [beaglelogic kernel module]
- Front-end /dev/beaglelogic **Character Device**
  - Appears as a standard file
  - open( ) to initialize
  - read( ) to sample, block-waits accordingly until data is available
  - ioctl( ) to configure sample rate and other settings
  - Non-blocking and Zero Copy I/O support via Memory Mapping [mmap ( )]
- NodeJS server, SocketIO link between Web interface & BeagleBone

beaglelogic

beaglebone logic analyzer

- **Best Product finalist** in **2015 Hackaday Prize**
- Traveled to Google Summer of Code Mentor Summit and Hackaday SuperCon in California
- Blog post about his journey: *A day with Hackaday*



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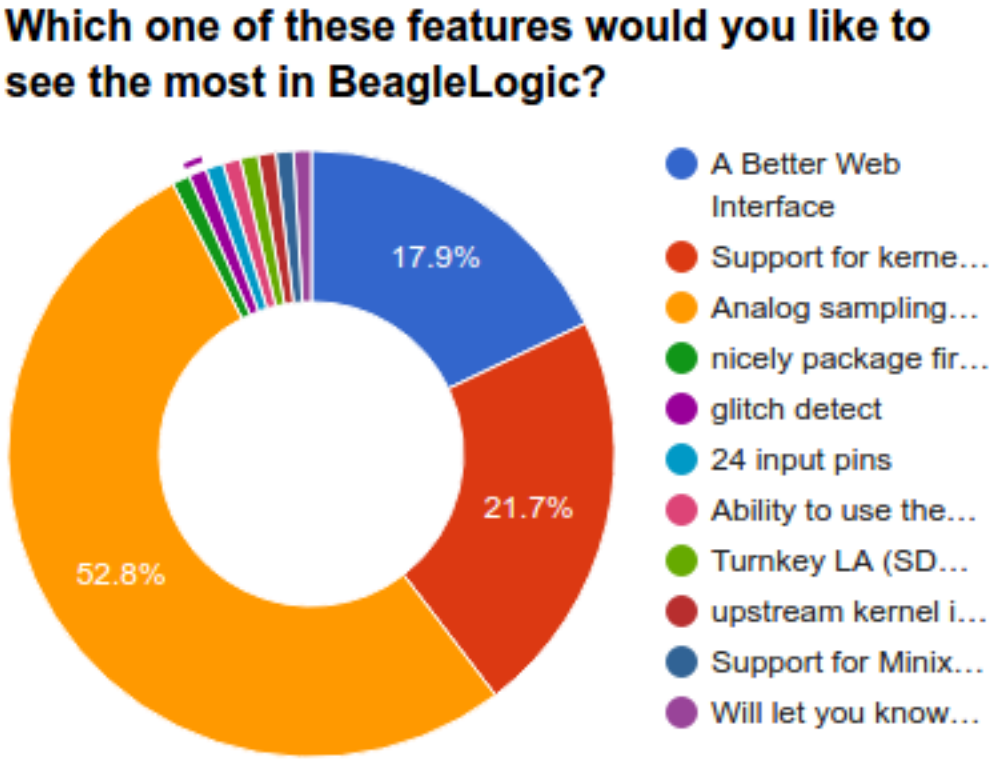
- Summer 2016: Kumar was intern at Google HQ
- July 2016: **BeagleLogic: now also analog**

"Majority of prospective users wanted to be able to do analog sampling with BeagleLogic"



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- July 2016 - **Google Research** blog announced **PRUDAQ**, an ADC cape for BeagleBone:

[Announcing an Open Source ADC board for BeagleBone]

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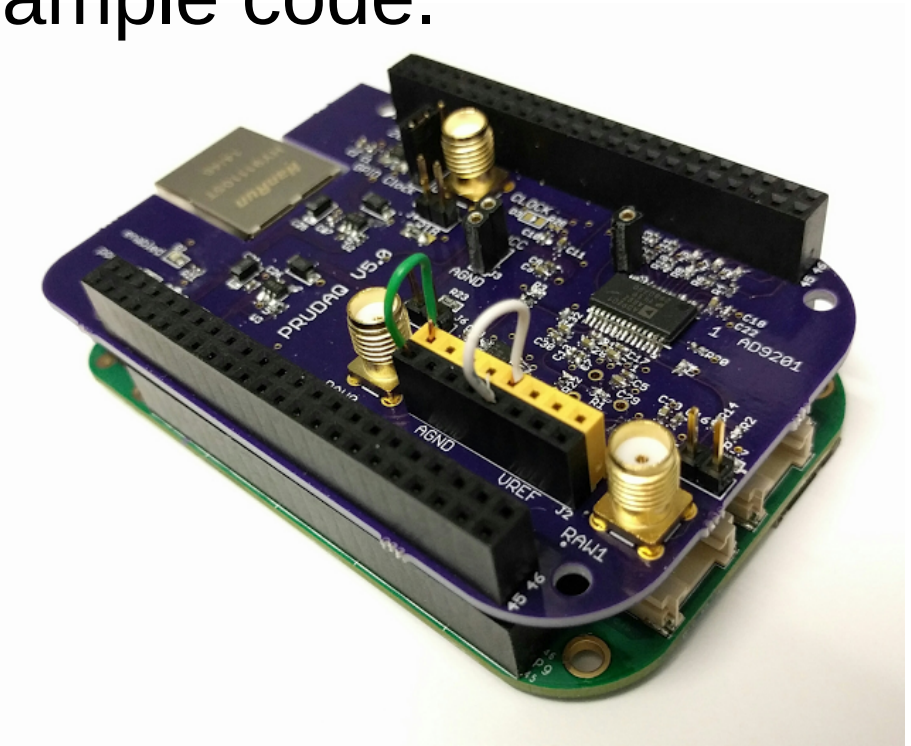
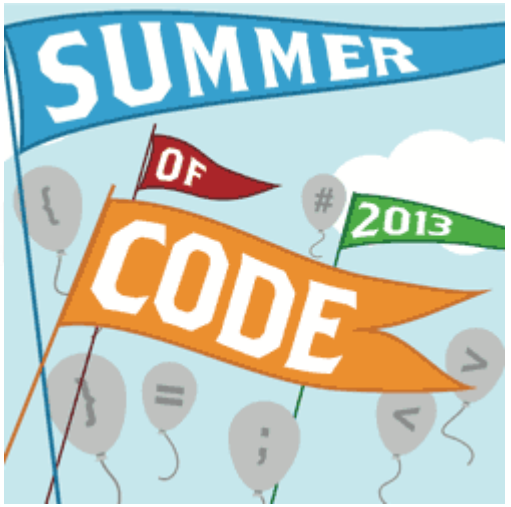
beaglebone logic analyzer

- Google Research Blog: “We also were fortunate to have help from Google intern Kumar Abhishek. He added support for PRUDAQ to his Google Summer of Code project BeagleLogic that performs much better than our sample code.”



Beagle-ROS



ROS

Víctor Mayoral Vilches

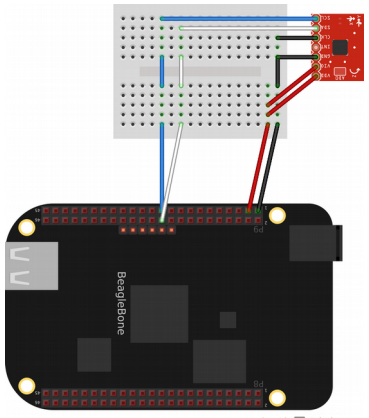
Mentor: Koen Kooi

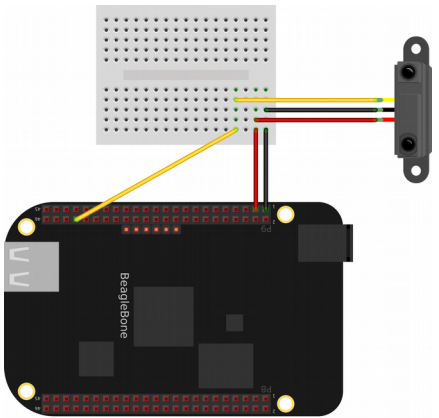
Beagle-ROS

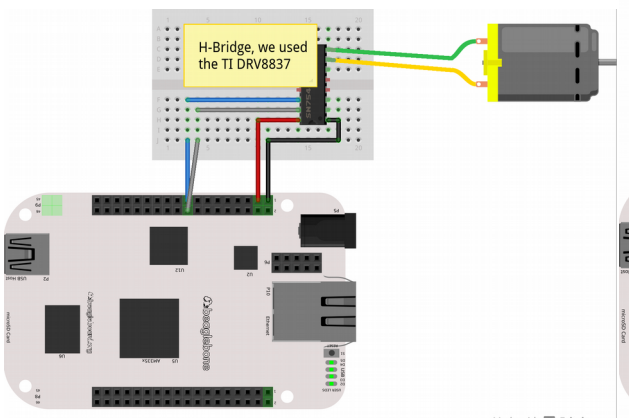
- Víctor Mayoral Vilches for GSoC 2013
- Integration of Robot Operative System (ROS) and BeagleBone through the meta-ros project, a layer for OpenEmbedded Linux
- GitHub: vmayoral/beagle-ros
- Blog: Beagle-ROS
- Video: Beagle-ROS Final

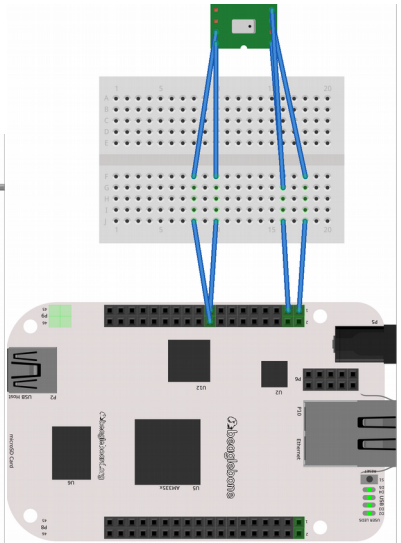
Beagle-ROS

- BeagleBone ROS Packages
  - bb_altimeter: publishes the altimeter MPL3115A2 values to a Topic
  - bb_dc_motors: launches a node to control a DC motor connected to the BeagleBone
  - bb_mpu9150: publishes the Invensense MPU-9150 data into a Topic
  - bb_sharp_ir: Sharp IR sensors









BeaglePilot

- **Víctor Mayoral Vilches** for GSoC 2014
- Linux-based autopilot for flying robots based on BeagleBone
- Ported ArduPilot to Linux
- ROS integration
- Videos: Introduction & Final report
- GitHub: BeaglePilot

BeaglePilot

- **Towards an Open Source Linux autopilot for drones**
  - Publication accepted at LibreCon 2014
  - “Linux can perfectly be used to meet the real-time requirements needed by an autopilot requiring only about 25% of the processor in BeagleBone Black.”

Table 2: Kernel benchmarking results

Kernel type	Min (us)	Avg (us)	Max (us)
vanilla	14	19	193
PREEMPT	16	21	68
RT_PREEMPT	20	27	91
Xenomai	15	23	630

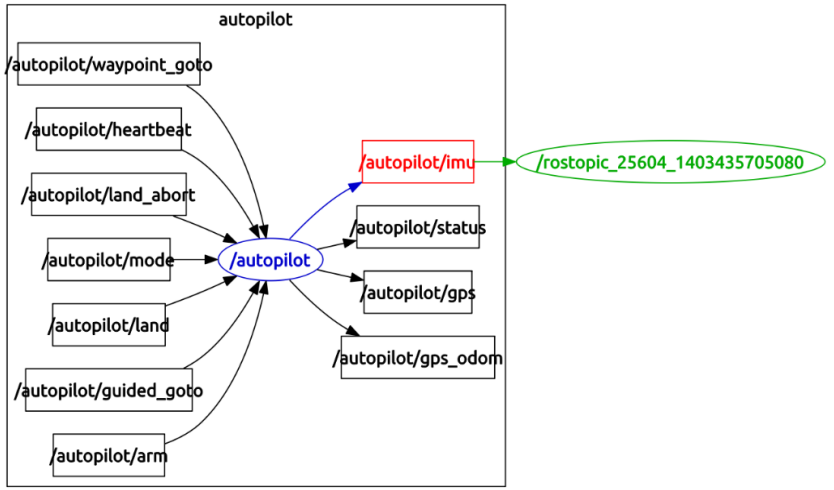


Figure 6: `autopilot_bridge` **topics and nodes pictured with** `rosgraph`

BeaglePilot

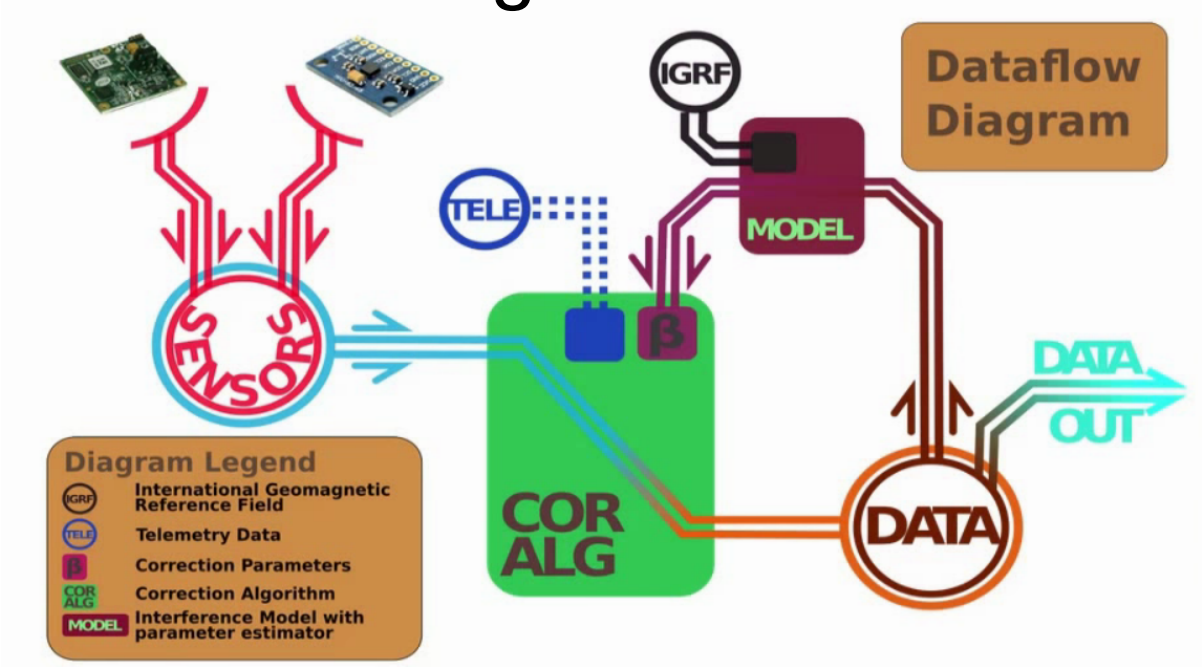
- **Victor** co-founded **Erle Robotics** to develop commercial products based on BeaglePilot
- **Erle-Brain**: “An artificial brain for making robots and drones”

BeagleSat

- **Niko Visnjic** for GSoC 2015
- Nano satellite platform based on BeagleBone
- Github repo: nvisnjic/BeagleSat
- Project video

BeagleSat

- Run data fitting algorithms in real-time on the BeagleBone Black
- Interface with the MPU9250 sensor using the PyBBIO library in Python
- Data visualizer during data collection and correction

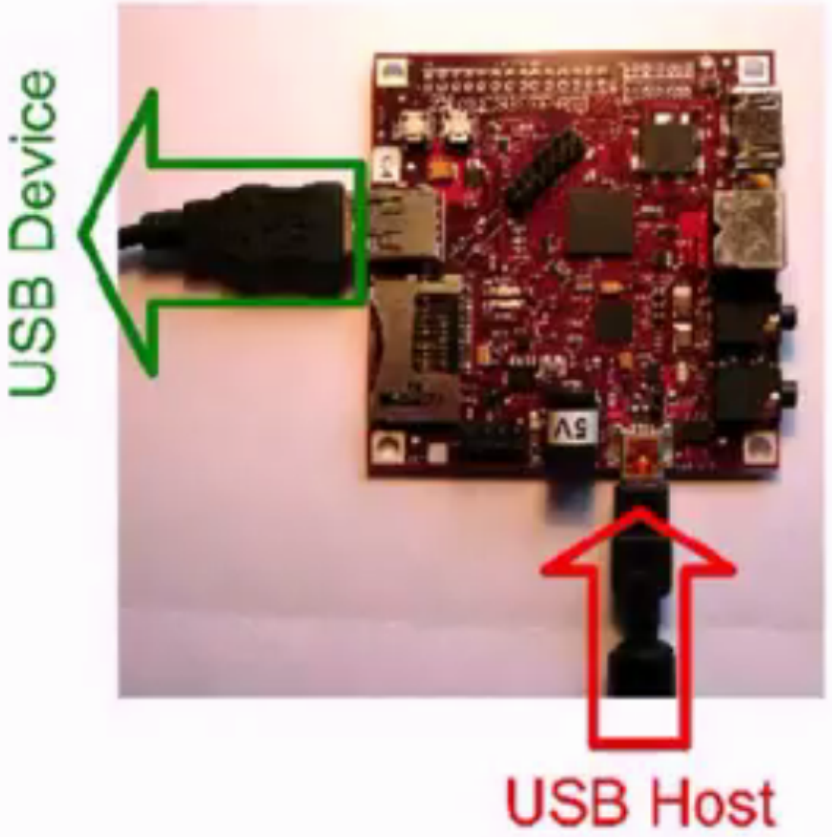


USB Sniffer

- GSoC 2010 project by **Nicolas Boichat**
- Use the BeagleBoard as an USB sniffer
- Code:
  - Gitorious repo: beagleboard-usbsniffer-kernel
  - GitHub mirror: beagleboard-usbsniffer-kernel
- Blog: beagleboard-usbsniffer.blogspot.com
- Video: USB sniffer on Beagle Board

USB Sniffer

Project goal



- Connect an **USB host** to the slave port,
- and an **USB Device** to the master port.
- **Forward** USB traffic, and **log** it.
- **Transparent** for both the host and the device.

USB Sniffer

Implementation

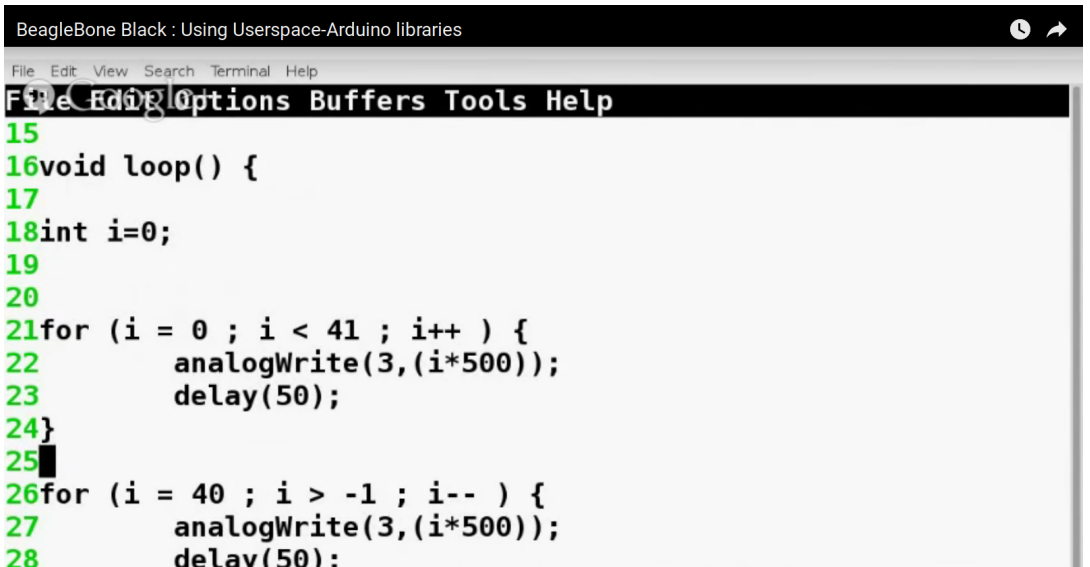
- Linux "**proxy**" driver:
  - **Gadget** driver (slave side)
  - **Device** driver (host side)
- **Pretend** to be the device, on the gadget side
  - Forward **control** requests
  - According to the USB **descriptors**:
    connect USB **endpoints**, and forward **data.**

Userspace Arduino

- GSoC 2013 project by students Anuj Deshpande and Parav Nagarsheth
- Provide a Linux Userspace environment for compiling Arduino style wiring/process sketches to run under Linux

Userspace Arduino

- eLinux wiki: Userspace_Arduino
- GitHub repo: Userspace-Arduino
- Example: Userspace Arduino:BlinkUserspace
- Video: Using Userspace-Arduino libraries
- Screencast: Running Arduino Sketches on BBB



GSoC 2016 projects

- **BeagleScope**
- Student: **Zubeen Tolani**
- Mentors: SJLC, Abhishek Kumar, Michael Welling, Hunyue Yau

Google Summer of Code

BEAGLESCOPE

Developer : Zubeen Tolani
<zeekhuge@gmail.com>

Empower your beaglebone

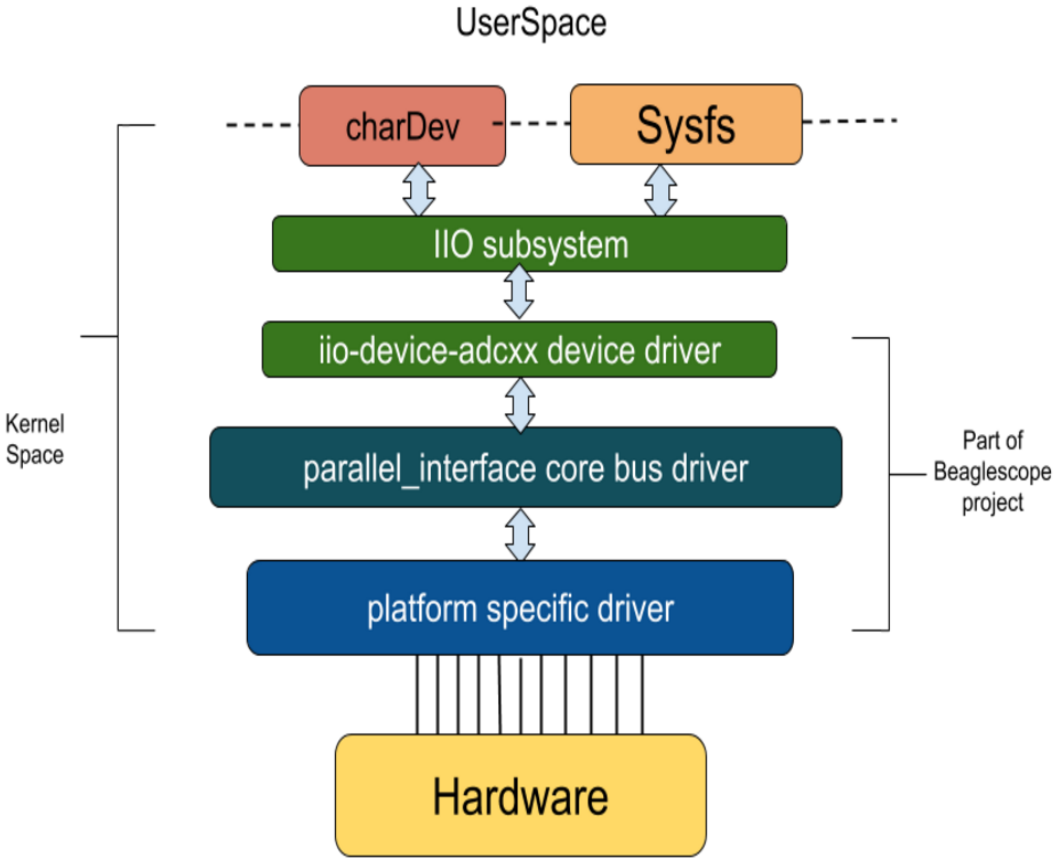
Summary

- Bootstrapped as a GSoC-2016 project under **BeagleBoard.org**.
- Uses the 2 SoC Programmable realtime units (PRUs) to interface a IIO device using parallel data interface.
- The software adds a sort of 13 bit wide parallel data bus to the board with a few limitations.
- Uses well known IIO subsystem to provide user interface.
- Modular and generic software stack so as to provide highest level of customization and further development specially to kernel hackers.
- The software stack developed can be used for applications like: Oscilloscope, Ultrasound scanners, Software defined radios etc.

Overall working

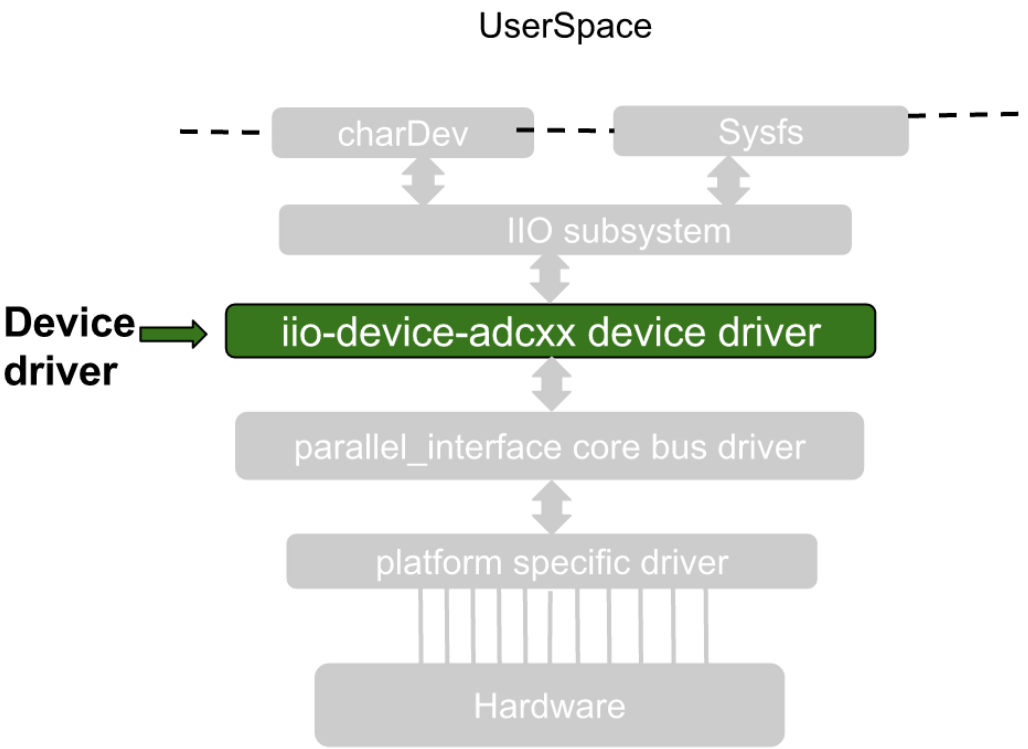
The overall working is divided into 3 parts:

1. The iio-device driver
2. The parallel_interface bus driver
3. The platform specific driver.



For users:

- The users need to worry about just one thing : **“If there is a device driver for the device they want to use ?”**
- The beagle-scope project also aims to develop device driver for the DC782A-P adc board.



How to use

- Just as you would use an IIO device. Some example and docs can be found:
  - https://kernelnewbies.org/IIO_tasks
  - http://www.at91.com/linux4sam/bin/view/Linux4SAM/IioAdcDriver
  - https://wiki.analog.com/software/linux/docs/iio/iio

It supports :

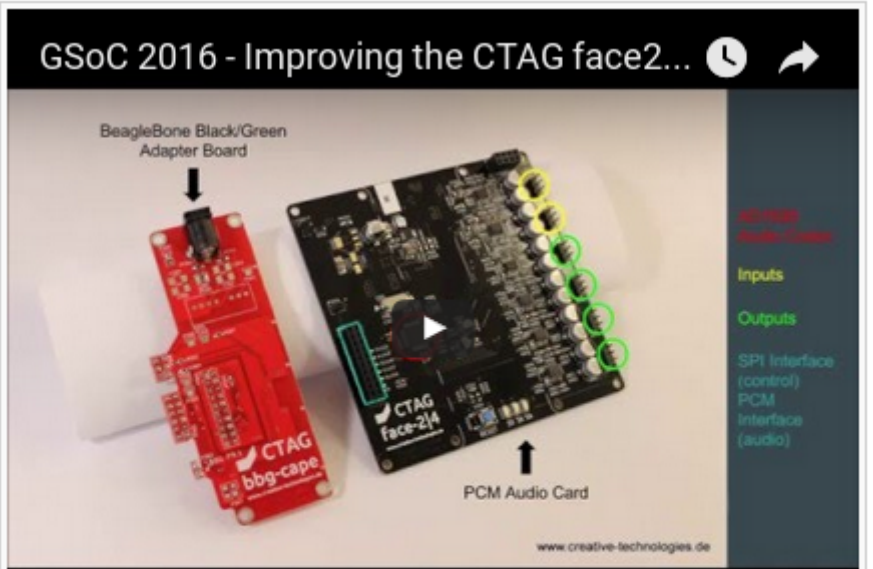
- Supports reading raw data.
- Supports buffered capture using IIO buffers.

Relevant Hyperlinks

- Project Source : https://github.com/ZeekHuge/BeagleScope
- Project Wiki : https://github.com/ZeekHuge/BeagleScope/wiki
- Blog : https://www.zeekhuge.me
- GSoC project : https://summerofcode.withgoogle.com/projects/#5391975498907648
- Organization : https://beagleboard.org
- Developer's Contact : email at zeekhuge@gmail.com

GSoC 2016 projects

- **BeagleBoard X15 multichannel sound driver**
- Student: **Henrik Langer**
- Mentors: Robert Manzke, Vladimir Pantelic
- Wiki for libdsp-x15
- Slides from project presentation



Google Summer of Code BeagleBoard.org

Henrik Langer
Kiel University of Applied Sciences

Overview

- CTAG face2|4 is a multichannel I2S sound card with 4 stereo inputs and 8 stereo outputs based on AD1938 audio codec and designed for embedded music applications
- Music applications (e.g. audio effects, synthesizers) typically require low latencies and complex signal operations (like Fast-Fourier-Transform)
- Before GSoC 2016 the sound card could only be used with a BeagleBone Black/Green, which doesn't offer these requirements whereas the new BeagleBoard-X15 is based on AM5728 SoC with two cores and two integrated C66x DSPs.

Project Part 1: Porting Audio Card Drivers to BB-X15

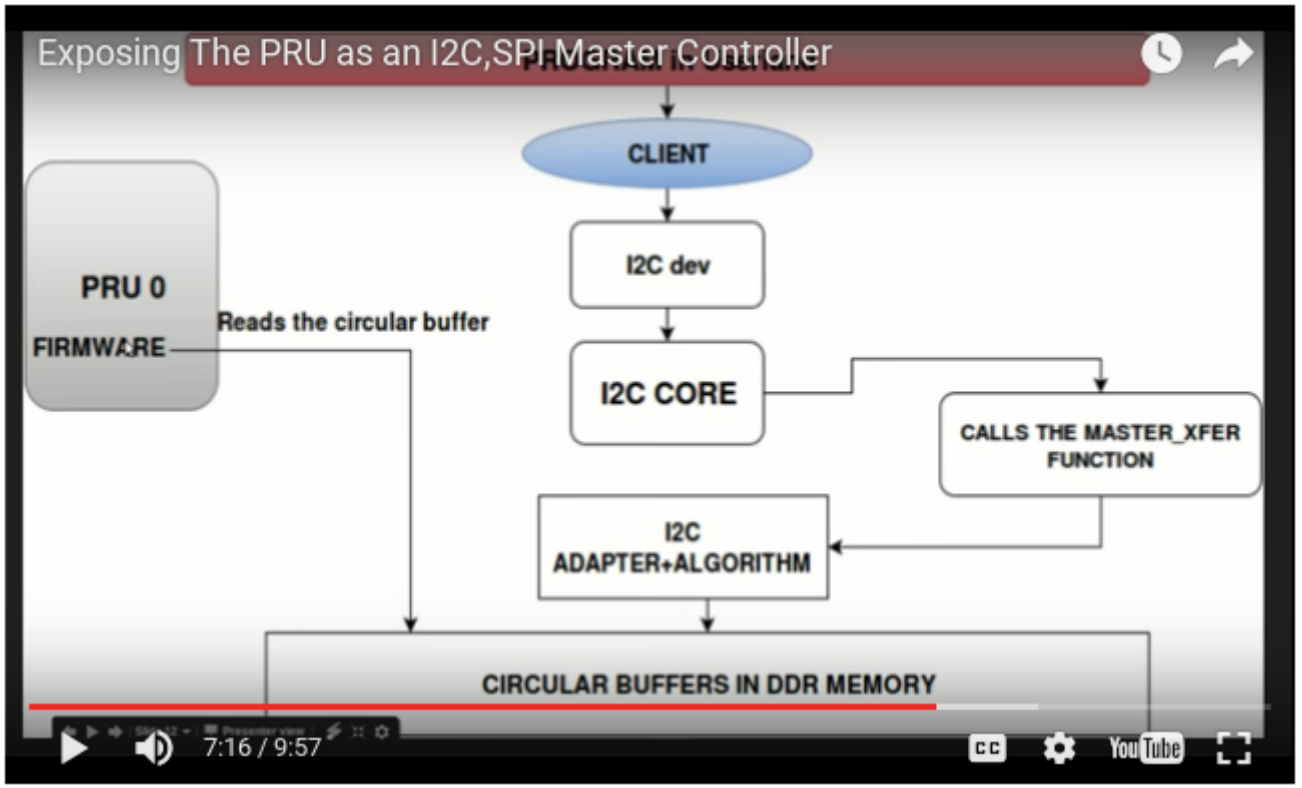
- To use the CTAG face2|4 audio card with the BeagleBoard-X15 the drivers had to be ported:
  - Modifications in ASoC-Machine Driver (glues together digital audio interface of CPU and audio codec)
    - Modifications of clock configurations (new device tree property “bb-device” has been introduced to distinguish between BBB/BBG and BB-X15)
  - New device tree for configuration of required peripherals (e.g. SPI, McASP)
- Problems with remoteproc framework
  - Crash of DSP firmware occurred when sound card is triggered (i.e. audio is played / captured)
    => Kernel crash
  - Turned out that kernel crash is caused by remoteproc recovery of DSP firmware
    => Crash could be avoided by disabling recovery of DSP firmware (DSPs still work)

Project Part 2: Create library for C66x DSPs

- To simplify usage of C66x DSPs for audio applications a user-space library “libdsp-x15” has been created
- libdsp-x15 offers the following signal operations:
  - Fast Fourer Transformation (FFT)
  - Inverse Fast Fourier Transformation (IFFT)
  - Biquad Filter (often used in audio applications)
- libdsp-x15 uses OpenCL to offload signal operations to DSPs via remoteproc
  - Currently OpenCL is only available in 4.1 kernel, therefore sound card drivers has been ported on 4.1 as well (port to 4.4 is available soon as well)
- Demo
  - For demonstration purposes of signal operations a real time spectrum plot application based on JACK and SDL using FFT has been created

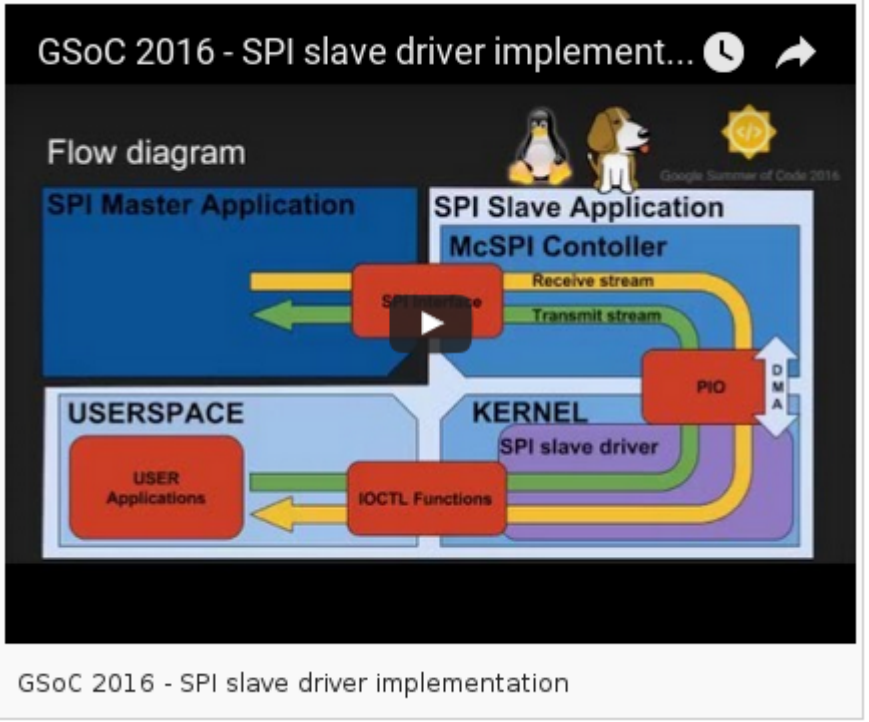
GSoC 2016 projects

- **Exposing the PRU as I2C & SPI master**
- Student: **Vaibhav Choudhary**
- Mentors: Andrew Bradford, Matt Porter



GSoC 2016 projects

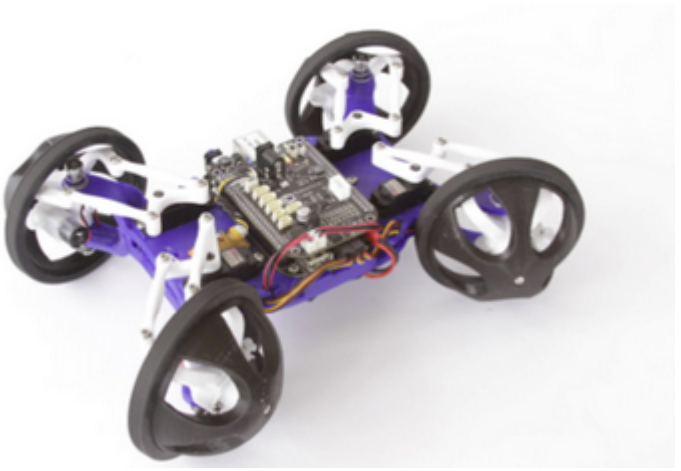
- **SPI slave driver implementation**
- Student: **Patryk Mężydło**
- Mentors: Michael Welling, Andrew Bradford, Matt Porter



GSoC 2016 - SPI slave driver implementation

GSoC 2016 projects

- **API support for Beaglebone Blue**
- Student: **Kiran Kumar Lekkala**
- Mentors: Alex Hiam, Micheal Welling, Kumar Abhishek, Deepak Karki
- Website / Source Code / Wiki / Documentation



Students: Apply March 30th!

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