

# EPICS Training (Hands-on)

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Sakura Program  
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# Agenda

1. Visit PF Control Room
2. Training / Exercise / Hands-on

# Purpose of the training

## Main Purpose of Today

- Get familiar with EPICS
- Acquire a feeling of “Interaction between **Hardware** and **Program**”
- I hope you continue to enjoy after you go back to your institute.

## In order to achieve the goal:

- Use cheap hardware : Raspberry Pi (RPI) or BeagleBone Black (BBB)
  - Both are 5,000 JPY (~45 USD, ~ 300 RMB)
  - Easy-to-use Digital I/O pin available
  - Analog Input (BBB)
- Learn about
  - Usage of DIO
  - Distributed control system
  - GUI : Control System Studio (CSS) or MEDM
  - Analog monitor

# Procedure

## Introduction

- What is Control Framework? Why do we need?
- What is EPICS?

## Training Setup : Hardware

- BeagleBone Black (IOC) + Solderless Breadboard
- Device : LED, Switch, Temperature Sensor
- Network (Ethernet)
- Client PC (your laptop) + OPI (CSS or medm)

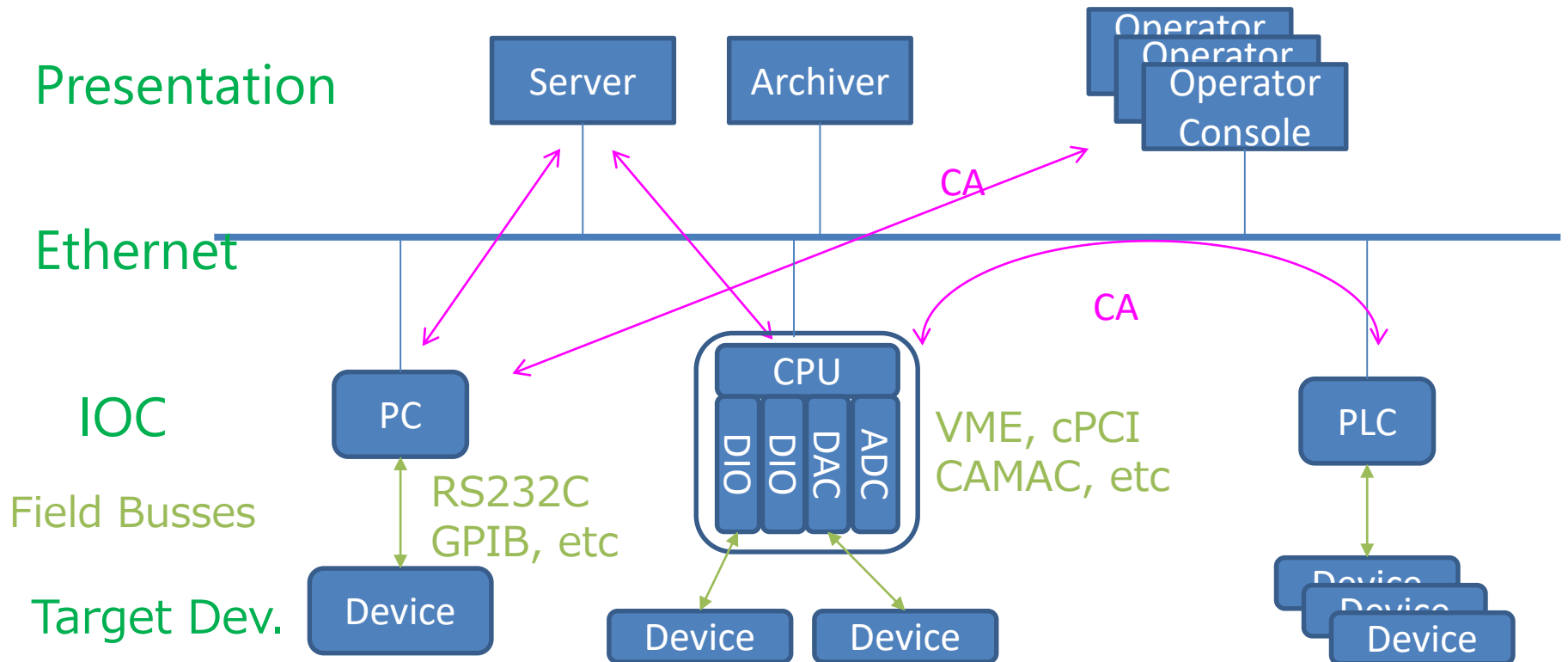
## Additional Topics (if time permits)

- Remote Device (Digital Multimeter via Ethernet)
- Different type sensors
  - Magnetic Sensor (analog)
  - i2c device, SPI device

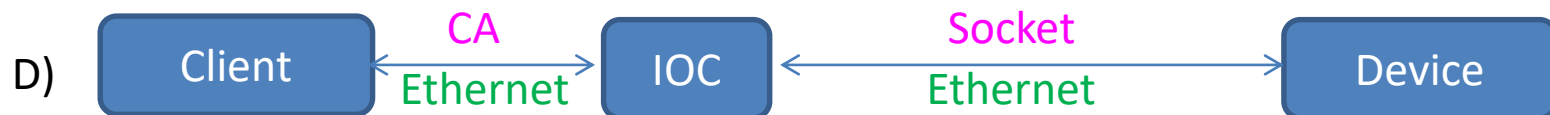
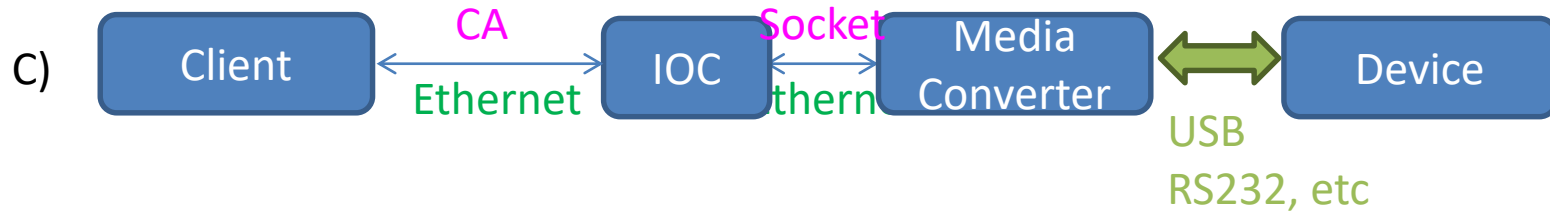
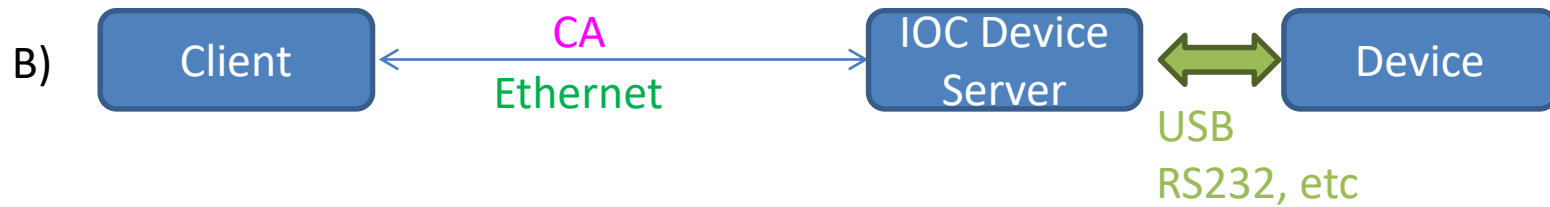
# EPICS : Communication Protocol

Communicate with Channel Access protocol

- PV (Process Variable) in IOC
- Network transparent. Distributed system.
- CA protocol is also used for communication between IOCs

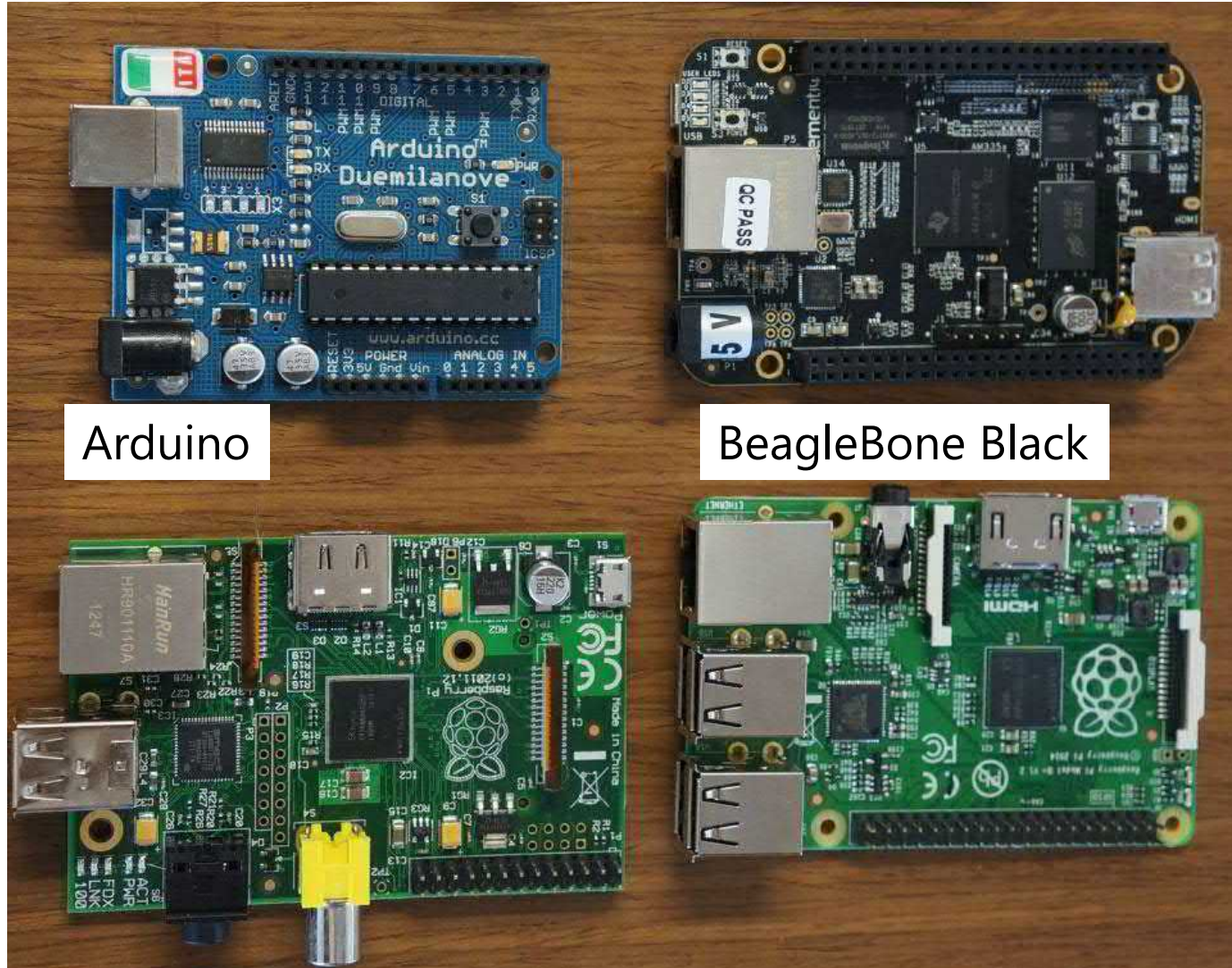


# Comparison of configuration



# Candidates

Credit-Card size board



Arduino

BeagleBone Black

Raspberry Pi (model B)

Raspberry Pi (model B+)

# Why BBB? Not Raspberry Pi?

- Advantage of Raspberry Pi
  - Most popular
  - Many information is available on the web. Many books on the market.
  - Variation : RasPi Zero, Zero-W, Compute Module
  - Good combination with Arduino
- Disadvantage of Raspberry Pi
  - No analog input (need Arduino)
  - Connector location is not good for embedding
  - High power consumption (Pi3)

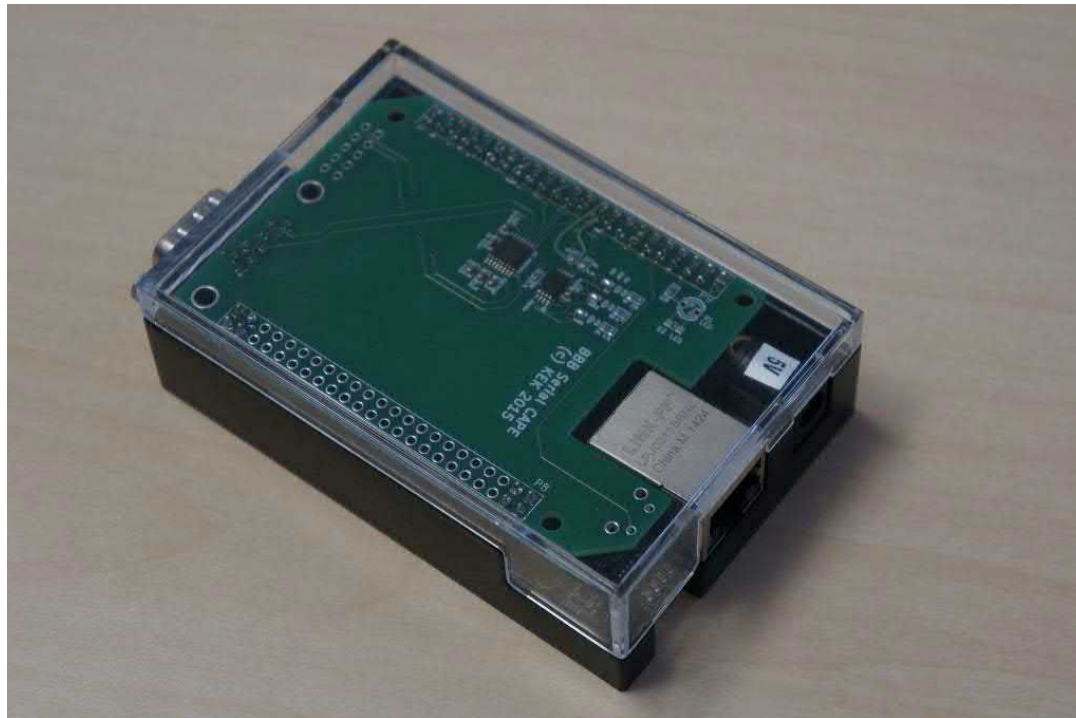




# RS-232 Device Server (KEK prototype)

Purpose : Replace Ethernet-RS232 converter with EPICS IOC box.

- BBB + Cape
- Board designed by ourselves (Michikawa-san)
- Cheap! Working stably for long time.

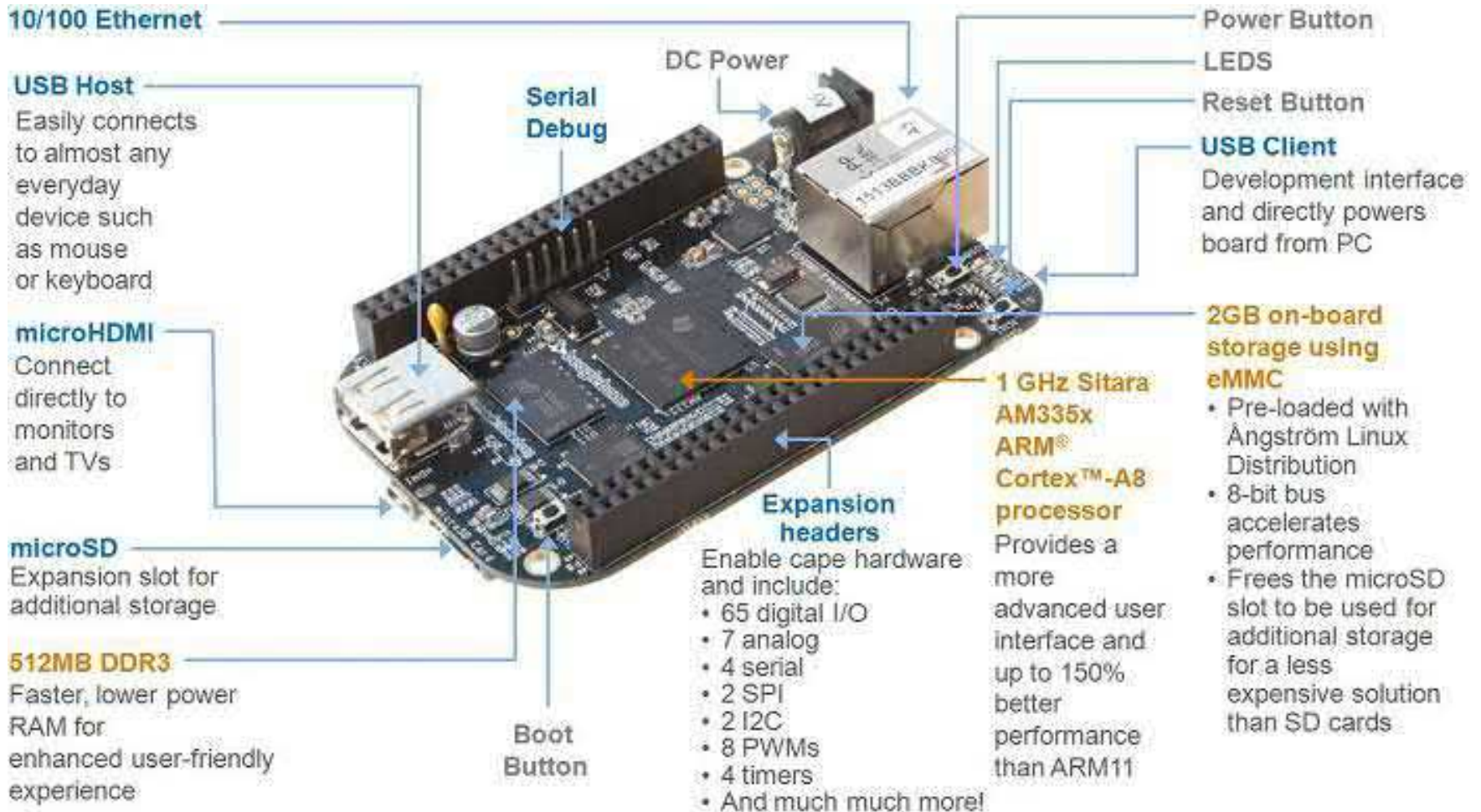


My personal opinion : BeagleBone Green is best for EPICS IOC because we don't use it as GUI terminal (in many cases). A laptop PC is much powerful than BBB or RasPi.

# Step 1: Hardware

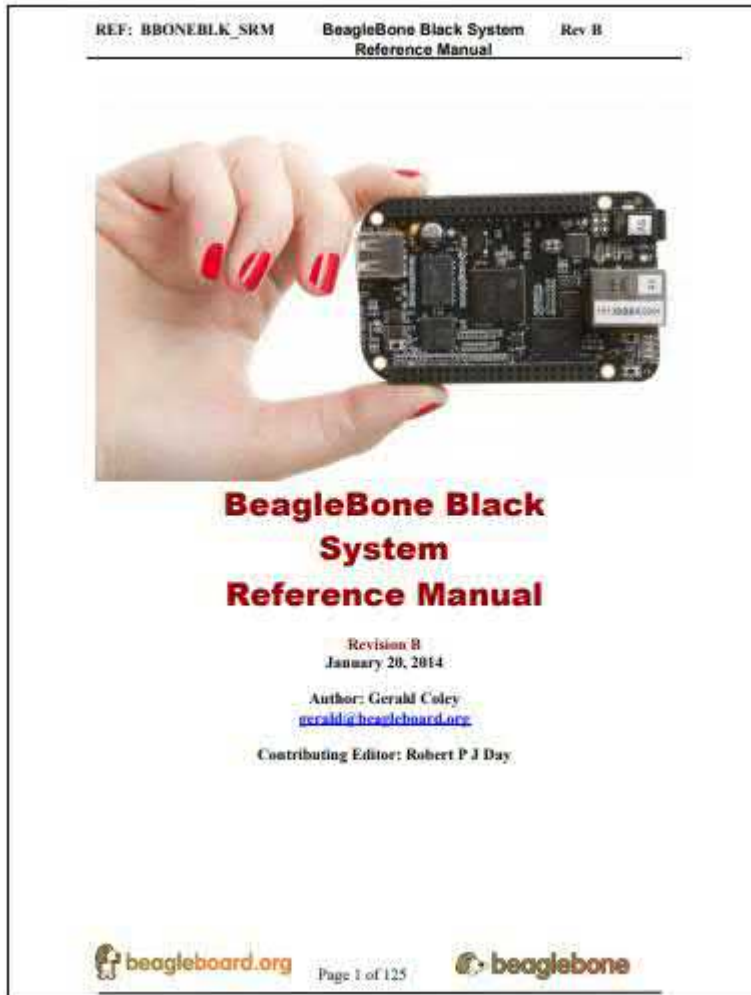
- Check Hardware
  - BeagleBone Black and/or BeagleBone Green

<http://www.tij.co.jp/tool/jp/beaglebk>

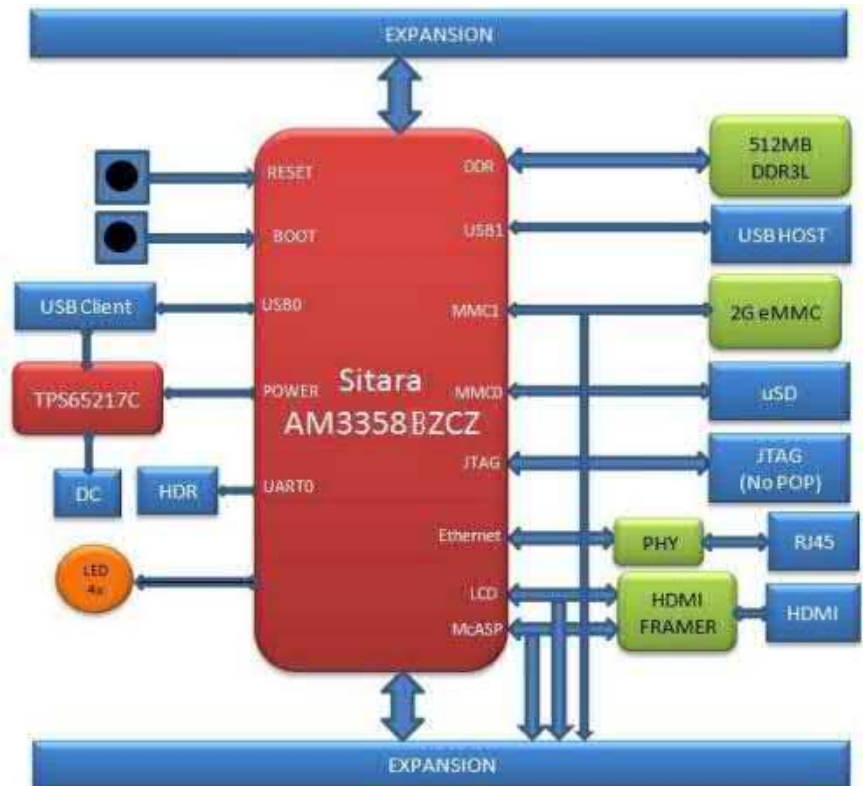


# System Reference Manual (SRM)

[https://github.com/CircuitCo/BeagleBone-Black/blob/rev\\_b/BBB\\_SRM.pdf](https://github.com/CircuitCo/BeagleBone-Black/blob/rev_b/BBB_SRM.pdf)

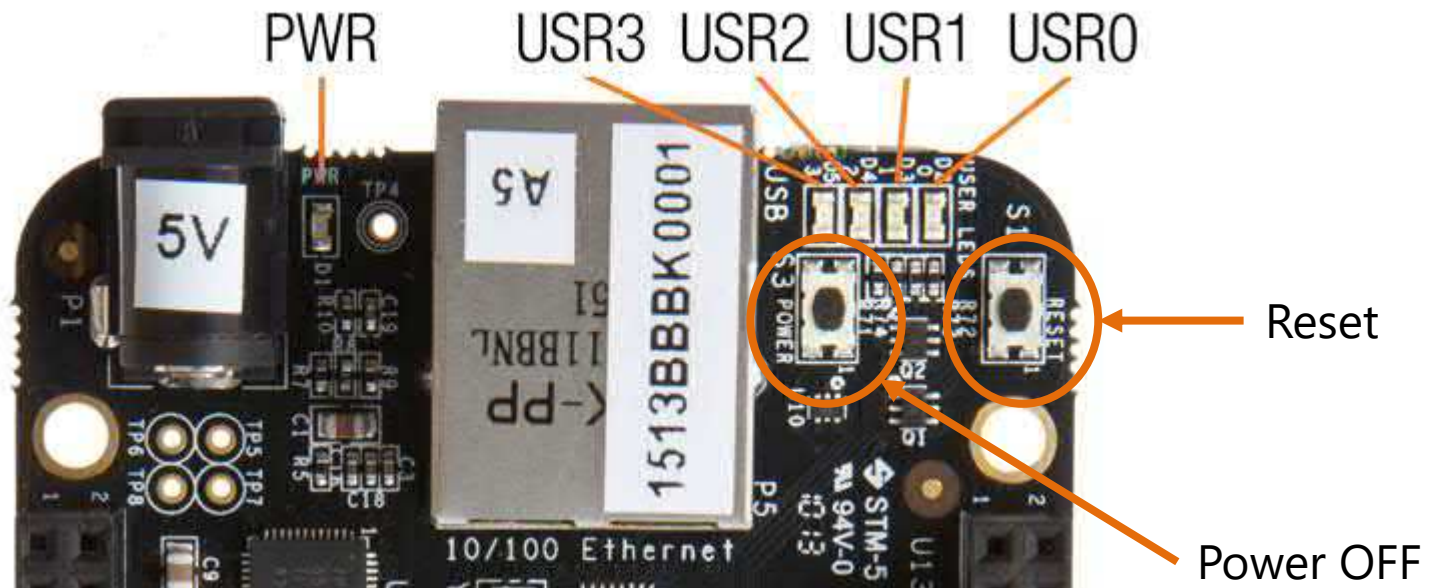


## Key Components



# on-board LED, Button

<http://beagleboard.org/getting-started>



USB0 is typically configured at boot to blink in a heartbeat pattern  
USB1 is typically configured at boot to light during SD (microSD) card accesses  
USB2 is typically configured at boot to light during CPU activity  
USB3 is typically configured at boot to light during eMMC accesses

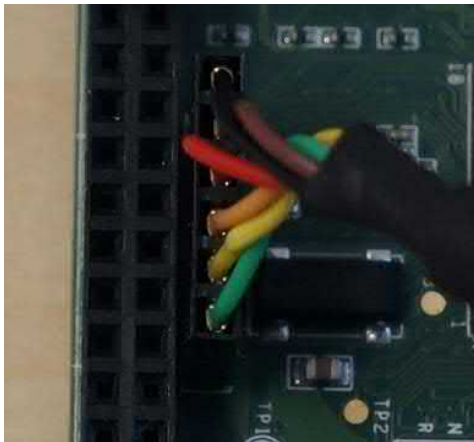
You can configure the LED behavior (check it later).

# Power ON, Check Boot Sequence

Power feed : DC 5V Jack or USB

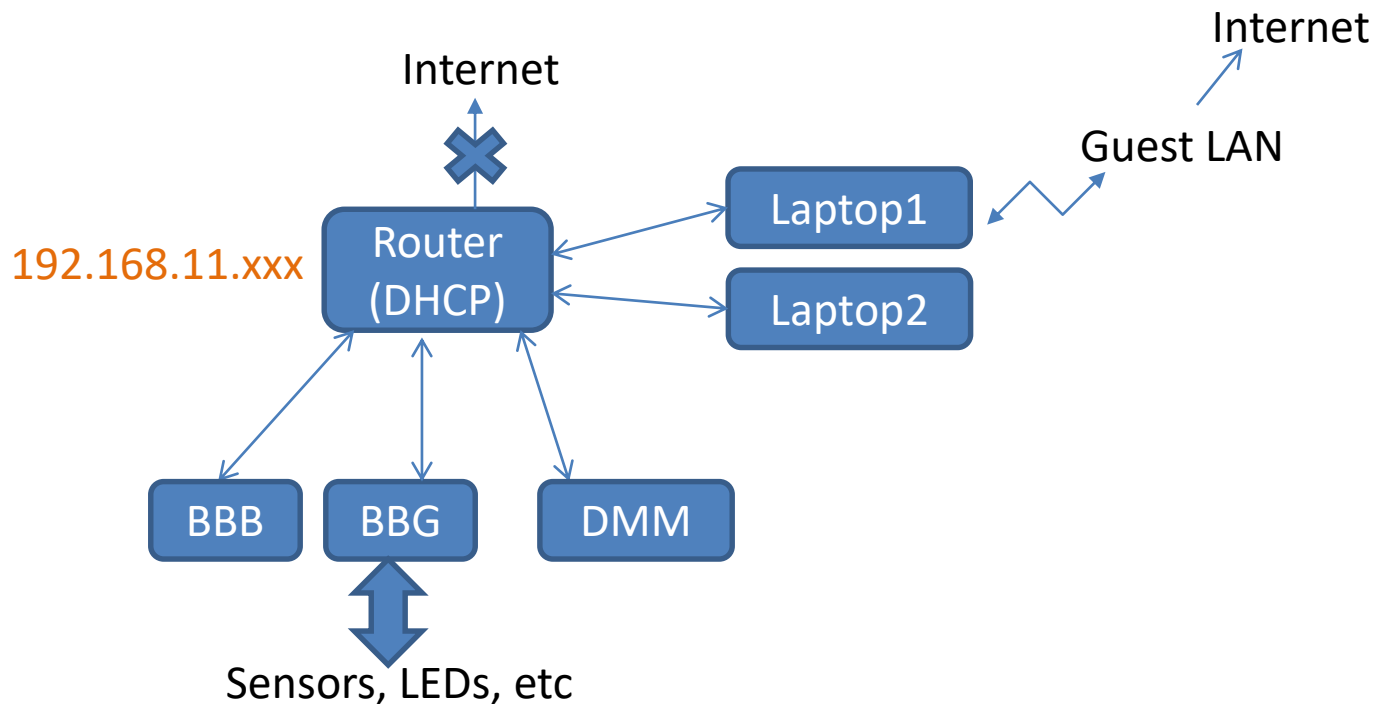
Connect Serial Console (demo)

- 3.3 V USB to Serial cable (FTDI chip); PIN1 → GND(Black)
- Terminal Software (Tera Term, Putty, etc), 11520bps, 8bit, Parity None
- Download windows device driver from FTDI web site (skip today)



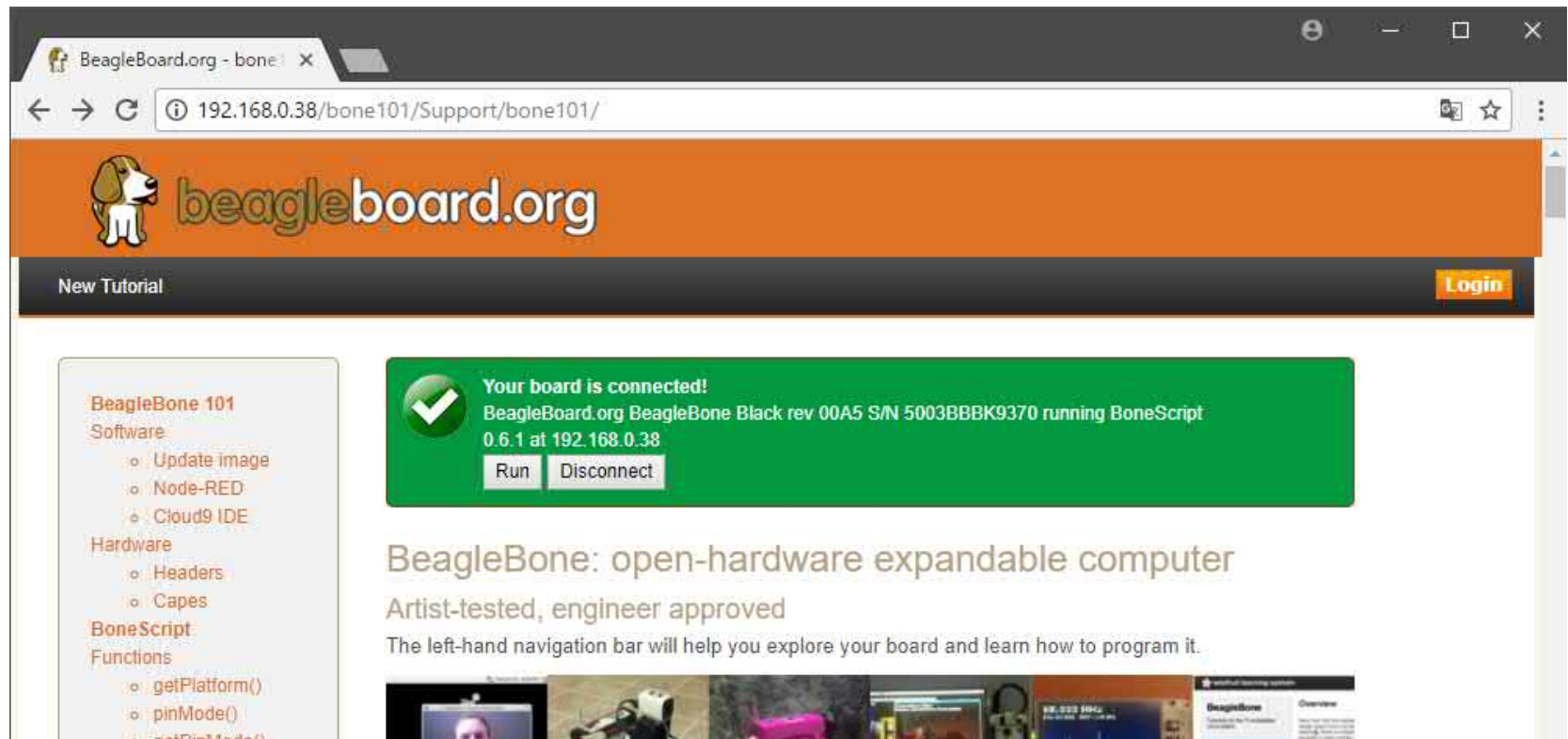
## Step 2 : Network

- Network configuration
- Check IP address of your PC and BBB/BBG
- ping to BBB
- ssh to BBB
- http connection (web browser) to BBB (next page)
  - check routing table



# connect via http

- check for connection
- It is possible to use “Bonescript” to control BBB
  - we don’t use them
- This page is useful to check “Pinout” configuration



The screenshot shows a web browser window with the address bar displaying `192.168.0.38/bone101/Support/bone101/`. The page header features the BeagleBoard.org logo and a "Login" button. A prominent green notification box in the center reads: "Your board is connected! BeagleBoard.org BeagleBone Black rev 00A5 S/N 5003BBBK9370 running BoneScript 0.6.1 at 192.168.0.38". Below this notification, the main heading is "BeagleBone: open-hardware expandable computer" with the subtext "Artist-tested, engineer approved". A left-hand navigation menu lists categories like "BeagleBone 101", "Software", "Hardware", and "BoneScript".

# Further Learning

network command : basics

- ping
- netstat
- traceroute
- arp

Learn IP address, subnet, MAC address

Ping to subnet hosts, and check arp table

- write a python script to do that



## Step 3 : using GPIO

GPIO : General-Purpose Input/Output port

- Check Pinout of BBB (P8, P9 header)
- Learn usage of solderless breadboard

Procedure of the lesson

- A) Digital Output : Turn LED on/off with GPIO
- B) Digital Input : Button switch to process EPICS record (I/O Intr)

# Pinout Header

P9

DGND	1	2	DGND
VDD_3V3	3	4	VDD_3V3
VDD_5V	5	6	VDD_5V
SYS_5V	7	8	SYS_5V
PWR_BTN	9	10	SYS_RESETN
UART4_RXD	11	12	GPIO_60
UART4_TXD	13	14	EHRPWM1A
GPIO_48	15	16	EHRPWM1B
SPIO_CS0	17	18	SPIO_D1
I2C2_SCL	19	20	I2C2_SDA
SPIO_D0	21	22	SPIO_SCLK
GPIO_49	23	24	UART1_TXD
GPIO_117	25	26	UART1_RXD
GPIO_115	27	28	SPI1_CS0
SPI1_D0	29	30	GPIO_112
SPI1_SCLK	31	32	VDD_ADC
AIN4	33	34	GND_ADC
AIN6	35	36	AIN5
AIN2	37	38	AIN3
AIN0	39	40	AIN1
GPIO_20	41	42	ECAPPWM0
DGND	43	44	DGND
DGND	45	46	DGND



P8

DGND	1	2	DGND
MMC1_DAT6	3	4	MMC1_DAT7
MMC1_DAT2	5	6	MMC1_DAT3
GPIO_66	7	8	GPIO_67
GPIO_69	9	10	GPIO_68
GPIO_45	11	12	GPIO_44
EHRPWM2B	13	14	GPIO_26
GPIO_47	15	16	GPIO_46
GPIO_27	17	18	GPIO_65
EHRPWM2A	19	20	MMC1_CMD
MMC1_CLK	21	22	MMC1_DAT5
MMC1_DAT4	23	24	MMC1_DAT1
MMC1_DAT0	25	26	GPIO_61
LCD_VSYNC	27	28	LCD_PCLK
LCD_HSYNC	29	30	LCD_AC_BIAS
LCD_DATA14	31	32	LCD_DATA15
LCD_DATA13	33	34	LCD_DATA11
LCD_DATA12	35	36	LCD_DATA10
LCD_DATA8	37	38	LCD_DATA9
LCD_DATA6	39	40	LCD_DATA7
LCD_DATA4	41	42	LCD_DATA5
LCD_DATA2	43	44	LCD_DATA3
LCD_DATA0	45	46	LCD_DATA1

## LEGEND

POWER/GROUND/RESET

AVAILABLE DIGITAL

AVAILABLE PWM

SHARED I2C BUS

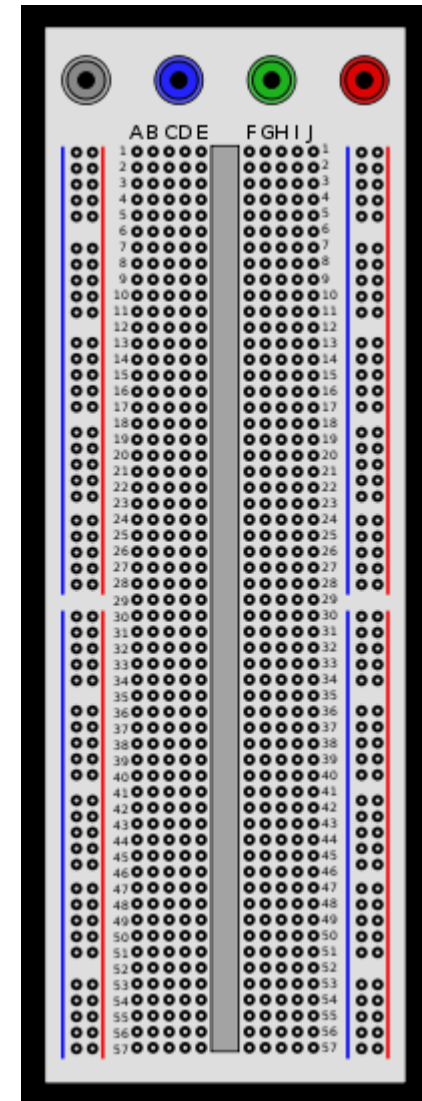
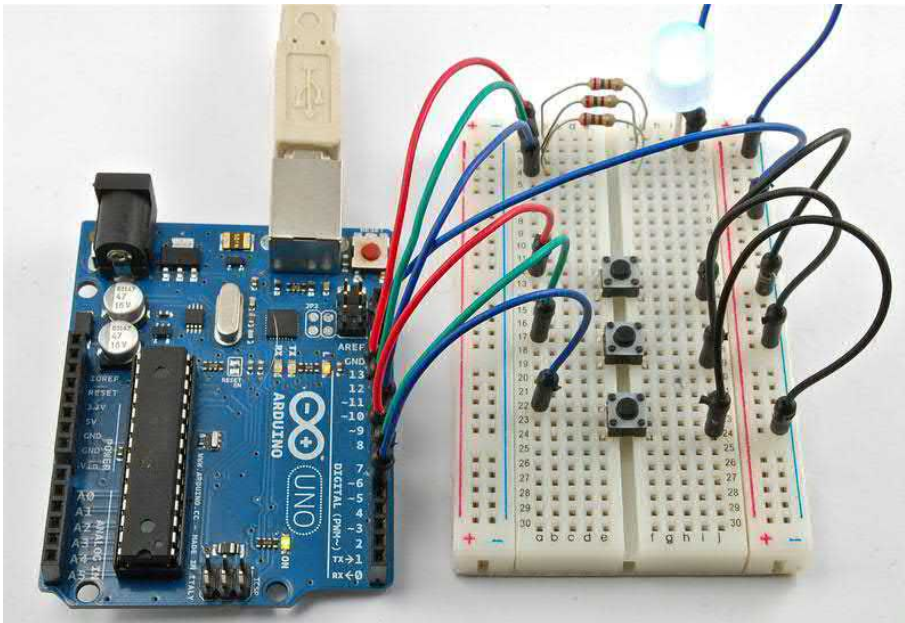
RECONFIGURABLE DIGITAL

ANALOG INPUTS (1.8V)

# Solderless Breadboard

Very convenient tool for prototyping.

- Use Jumper-wire to connect
- horizontal line(A-E, F-J) is connected internally
- place ICs in the center (Between E-F in right fig.)



<https://learn.sparkfun.com/tutorials/how-to-use-a-breadboard>

<https://learn.adafruit.com/breadboards-for-beginners>

wikipedia

# Lesson A) Digital OUTPUT

## Lesson Procedure

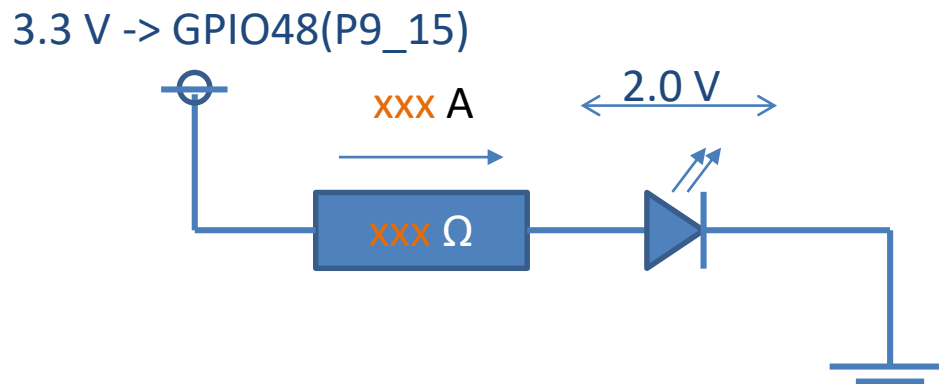
1. Connect a LED and a resistor as shown in the next page
  - Don't forget to add current limiting resistor to protect BBB !!
2. Test with SYS\_3.3V (P9\_ 3 or 4) to check polarity and health of LED.
3. connect GPIO pin
4. Turn ON/OFF with python script
5. Turn On/OFF with EPICS

copy sample program from `/opt/epics/sample` to your home directory, and edit

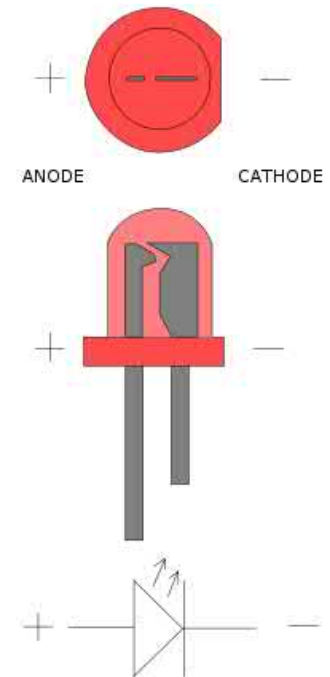
# Current limiting resistor

To turn on a LED, you need to calculate “current” and “voltage”

- Typical Red LED need at least 2 V (check datasheet for detail)
- Recent high brightness LED need at least 2 – 3 mA (check max current)



LED (Wikipedia)



Note on BBB Hardware Specification

- GPIO pin is 3.3 V
- Max 4 – 5 mA on each port
- Total (about) 10 mA for all GPIO pins
- SYS\_5V and SYS\_3.3V can source more current (~250 mA)

## Lesson A) Control Digital Input from a program

1. Use python + Adafruit\_BBIO module
  - Good tool for check
2. Execute an "Example" Soft IOC
  - detail in next page
3. Use EPICS (devgpiio)
  - create database
  - execute st.cmd as root privilege (sudo)
  - use dbpf to control
  - use caput to control
  - create CSS or medm GUI to control ON/OFF (Optional)

# EPICS Example Application

## EPICS software IOC

- Build an “example application” on BBB
  - `makeBaseApp.pl -l` ← list template
  - `makeBaseApp.pl -t example example`
  - `makeBaseApp.pl -i -t example example`
  - `make` ← check errors
  - `edit exampleApp/Db/user.substitutions` ← replace “debian” to your name
  - `make`
  - `cd iocBoot/iocexample/`
  - `edit st.cmd` ← replace “debian” to your name
  - `chmod +x st.cmd`
  - `sudo ./st.cmd`
- execute `st.cmd`, and use `camonitor` to check value
- Create a MEDM or CSS panel, and monitor `aiExample1`
- monitor PVs on the other BBB or BBG

Need to install VcXsrc or Xming to use MEDM or Gnuplot

# EPICS Example Application

## Optional topics

- Use “excas” to execute simple soft ioc (jane, fred, freddy, etc)
- camonitor the value, and redirect to some file
- Use gnuplot to visualize the data

Need to install VcXsrc or Xming to use MEDM or Gnuplot



## timestamp of BBB

Ubuntu on BBB automatically adjust timestamp via NTP

- `systemctl -l status systemd-timesyncd`

BBB (and RasPi) do not have RTC (real-time clock) and separate battery

- Today's network is isolated from internet
- Just adjust the time manually. i.e. `sudo date -s '2018/01/30 15:00:00'`
- otherwise time difference between your laptop and BBB will cause problem

# EPICS devgpio

<https://github.com/ffeldbauer/epics-devgpio>

The screenshot shows the GitHub repository page for `ffeldbauer/epics-devgpio`. The browser address bar displays the URL `https://github.com/ffeldbauer/epics-devgpio`. The repository name is `ffeldbauer / epics-devgpio`. The page features a navigation bar with links for `Features`, `Business`, `Explore`, `Marketplace`, and `Pricing`. Below the navigation bar, there are tabs for `Code`, `Issues 0`, `Pull requests 0`, `Projects 0`, and `Insights`. A prominent banner encourages users to `Join GitHub today`, stating that GitHub is home to over 20 million developers. Below the banner, the repository description reads: `EPICS device support to control GPIOs on the BeagleBone Black / Raspberry Pi via the /sys/class/gpio interface`. At the bottom of the page, repository statistics are shown: `5 commits`, `1 branch`, `0 releases`, and `1 contributor`.

## Lesson B) Digital Input with EPICS

### Digital Input

- edit "gpio1.db" -> add your name on the head
- use EPICS devgpio
- add a switch (SPST) on breadboard. Press button for high level
- No resistor is required on the input pin ✂
- use I/O interrupt to process EPICS record

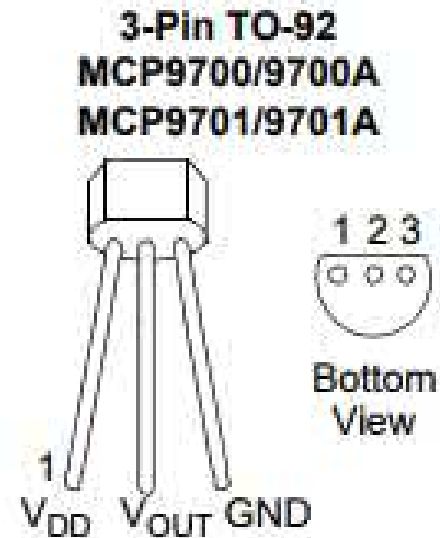
### ✂ Note

- Internal pull-down resistor exists. (Configurable!!)
- Open Pin → low level
- Consider the difference of "Source/Sink"
- How to measure the resistance of internal resistor? Pull-up or Pull-down?

## Step 4 : Analog Input

### Temperature Sensor

- MCP9701
- 3 wire, analog output sensor
- Cheap : ¥40 - ¥50
  
- 400 mV at 0 °C
- Tcoef = 19.5 mV/°C
- $V_{out} = Tcoef * Temp + V_{0deg}$



## Further (Advanced) Topics

### Advanced topics : Hardware

- Serial interface (UART, i2c, SPI, 1-wire, HID device, etc)
  - Many sensors can be attached
- Analog Input
  - Attach voltage limiting circuit (Op-Amp) or Voltage divider to extend input voltage range from 0-1.8V to 0-5 V, +/-10V, for example.
  - Test other equipment : Magnetic sensor (Hall effect sensor), Joystick, etc
- PWM (can be used instead of analog output)
  - Drive servo motors or LEDs
- Drive Stepping Motor
- Use Arduino for analog and sensor input
- RPU (Real-time Processing Unit) of BBB
- Other ARM-Linux based board : Tinker board, RPi3, Armadillo, etc
- Boot from eMMC

### Advanced topics : Software related

- Realtime OS, Create custom micro-SD boot image, etc

## Further (Advanced) Topics : EPICS

### Improvement of the hands-on/training procedure

- document, hardware, procedure, etc

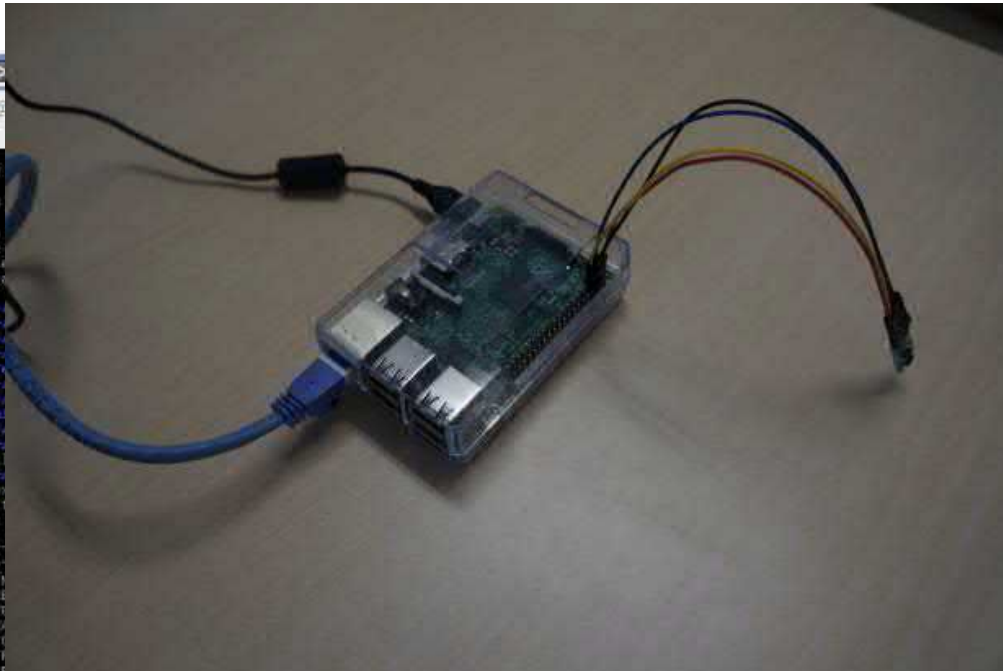
### EPICS related topics

- Asyn + Stream device (for example, DMM via Ethernet)
- Build EPICS Base/Extensions/Modules, Device support, etc
- Python/CA interface (pyepics or PythonCA)
- Development of device support
- I/O interrupt : How fast?
- Cross-compile environment
  
- Archiver on BBB
  - CSS Archiver, Archiver Appliance, Channel Archiver, Portable Archiver

# Example : i2c temperature sensor

[http://cerldev.kek.jp/trac/EpicsUsersJP/wiki/epics/raspberrypi/setup\\_epics\\_i2c](http://cerldev.kek.jp/trac/EpicsUsersJP/wiki/epics/raspberrypi/setup_epics_i2c)

– ADT7410 Temperature Sensor (Analog Devices)



```
epics> xl1
epics> aiExample2
epics> ai2
epics> aiExample3
epics> ai3
epics> subExample
epics> xxxExample
epics> iSubExample
epics> compressExample
epics> cdc
p&#62; raspberrypi:
p&#62; raspberrypi:
p&#62; raspberrypi:
p&#62; raspberrypi:
cd /home/pi/epics/app/i2cTest/
p&#62; raspberrypi:
p&#62; raspberrypi:
ad7998TestApp
p&#62; raspberrypi:
p&#62; raspberrypi:
envPaths Makefile
p&#62; raspberrypi:
#! /bin/limp
## You may have
## everywhere it
< envPaths
epicsEnvSet("I2C")
epicsEnvSet("TOP")
epicsEnvSet("ASYN")
epicsEnvSet("STRT")
epicsEnvSet("BEW")
epicsEnvSet("DBW")
epicsEnvSet("EPI")
epicsEnvSet("STRT")
epicsEnvSet("STRT")
## Register all support components
dbLoadDatabase "/home/pi/epics/app/i2cTest/db/ad7998Test.dbd"
ad7998Test_registerRecordDeviceDriver pdbbase
## Load gpio and I2C drivers
#pinConstConfigure("BEAGLEBONE_BLACK")
drvAsynI2CConfigure("I2C", "/dev/i2c-1", 1)
## Load record instances
#dbLoadRecords("${TOP}/db/ad7998.db", "IO=33,CORVST=PP_22,BUSY=PP_21")
dbLoadRecords("/home/pi/epics/app/i2cTest/db/test.db")
cd "/home/pi/epics/app/i2cTest/incRoot/incad7998Test"
locInit
Starting locInit
=====
## EPICS R3.15.5
## EPICS Base built Jun 1 2017
=====
locRun: all initialization complete
env streamDebug 1
#asynSetTraceMask("I2C", 0, 10)
#asynSetTraceIDMask("I2C", 0, 10)
epics> db1
ADT7410.SET
epics> |
```

A screenshot of the EPICS graphical user interface. It features a data table with columns for 'ADT7410:GE7', 'User Specified', and 'Low Limit'. The table contains 10 rows of data, all with '0.00' in the 'User Specified' and 'Low Limit' columns. Below the table, there are input fields for 'Period: 50' and 'Units: second'. To the right, a 'Strip Chart Data' window displays a plot of the sensor's output over time, showing a curve that rises and then levels off. The plot has a y-axis ranging from 4176 to 4296 and an x-axis labeled 'TIME'. A large digital display in the foreground shows the current value '4176'.

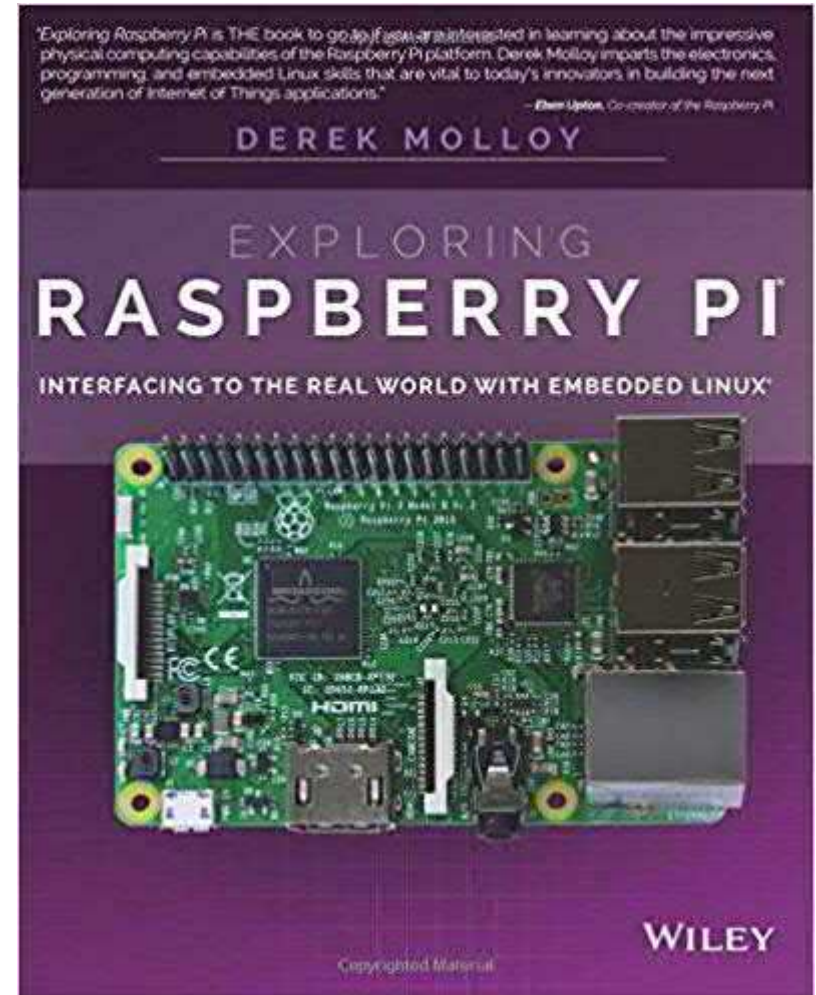
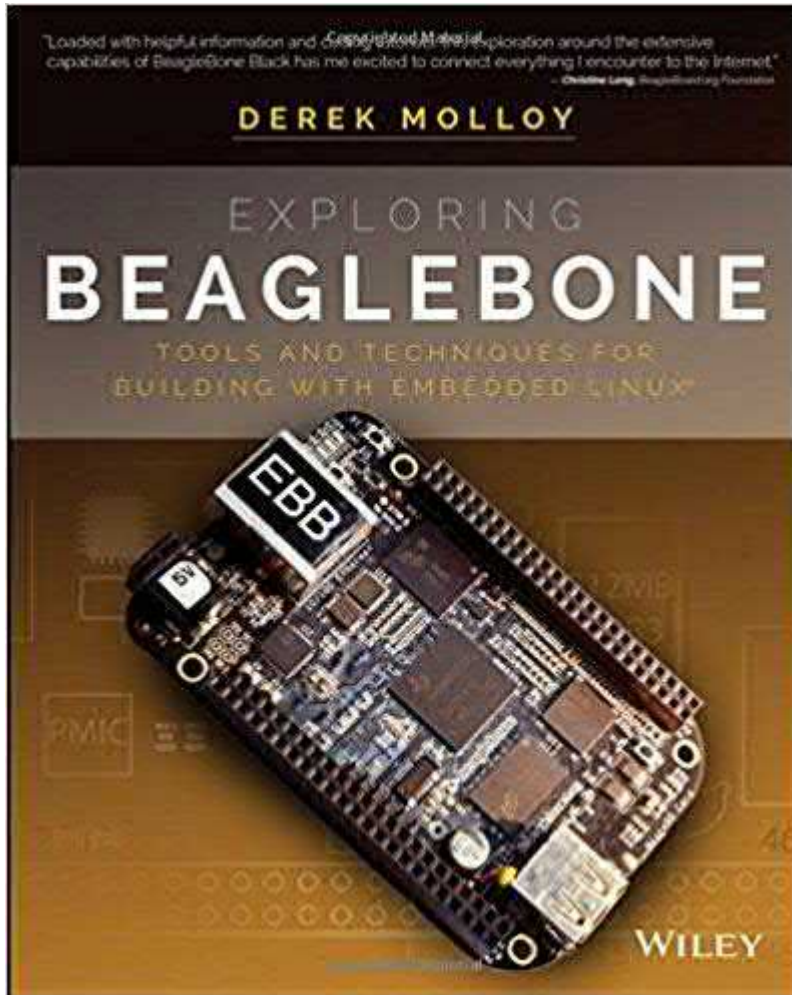
ADT7410:GE7	User Specified	Low Limit
	0.00	4500.00
Channel	0.00	1.00
Channel	0.00	1.00
Channel	0.00	1.00
Channel	0.00	1.00
Channel	0.00	1.00
Channel	0.00	1.00
Channel	0.00	1.00
Channel	0.00	1.00
Channel	0.00	1.00

## References



# Reference : Books

- <http://exploringbeaglebone.com/>



# Adafruit

- <https://www.adafruit.com/>



## BREAKOUT BOARDS

Breakout your Raspberry Pis and Arduinos with this broad selection of versatile breakout boards! Engineered to help you realize your robotics, GPS and altitude sensing projects as well as servo and touch screen interfacing, you'll find many uses for these high-quality boards, most of which are manufactured in house at Adafruit!

CELLULAR (9)  
PWM DRIVERS (6)  
MOTOR CONTROL (11)  
LEVEL SHIFTERS & EXPANDERS (6)

STORAGE (6)  
WIFI (30)  
OTHER (8)  
RADIO (4)  
CLOCKS (7)

ACCEL, GYRO, AND  
MAGNETOMETERS (18)  
AMPLIFIERS/SOUND (22)  
BATTERIES/POWER (19)  
LCDS, LEDS, & DISPLAYS (17)

SMT BREAKOUT PCB (10)  
TOUCH (12)



### Adafruit 16-Channel 12-bit PWM/Servo Driver - I2C interface - PCA9685

PRODUCT ID: 815

You want to make a cool robot, maybe a hexapod walker, or maybe just a piece of art with a lot of moving parts. Or maybe you want to drive a lot of LEDs with precise PWM output. Then you realize that your microcontroller has a limited number of PWM outputs! What now? You could give up OR you could just get this handy PWM and Servo driver breakout. When we saw this chip, we quickly realized what an excellent

ADD TO CART

<sup>tw</sup> \$14.95  
IN STOCK



### ADXL335 - 5V ready triple-axis accelerometer (+-3g analog out)

PRODUCT ID: 163

We've updated our favorite triple-axis accelerometer to now have an on-board 3.3V regulator - making it a perfect choice for interfacing with a 5V microcontroller such as the Arduino. This breakout comes with 3 analog outputs for X, Y and Z axis measurements on a 0.75"x0.75" breakout board. The ADXL335 is the latest and greatest from Analog Devices, known for their exceptional quality MEMS devices. The VCC

ADD TO CART

\$14.95

- <https://www.sparkfun.com>

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EDUCATION AVC FOR

HOME / PRODUCT CATEGORIES / SENSORS / ENVIRONMENT (46 PRODUCTS)

## Environment

JUMP TO SUBCATEGORY:

Magneto Sound Temperature Weather

**Weather Meters**  
SEN-08942  
\$76.95  
★★★★☆ 21

**Temperature Sensor - Waterproof (DS18B20)**  
SEN-11050  
\$9.95  
★★★★☆ 20

**SparkFun Environmental Combo Breakout - CCS811/BME280 (Qwiic)**  
SEN-14348  
\$34.95  
★★★★☆ 2

**SparkFun Air Quality Breakout - CCS811**  
SEN-14193  
\$19.95  
★★★★☆ 4

**SORT BY:**

- Most Popular
- Highest Price
- Lowest Price
- Alphabetical
- Highest Reviewed
- Newest
- Oldest

**SUBCATEGORY:**

- Magneto
- Sound
- Temperature
- Weather

**REFINE BY:**

- SparkFun Original

- <http://akizukidenshi.com>

The screenshot shows the Akizuki Electronics website interface. At the top, there is a navigation bar with icons for 'マイページ' (My Page), '注文書' (Order Sheet), 'お問い合わせ' (Contact Us), 'かごの中身' (Cart), 'トラ技広告' (Tech Tips), and '回路図集' (Circuit Diagrams). Below this is a search bar and a list of navigation links including '商品カタログ' (Product Catalog), '新商品' (New Products), 'お知らせ' (Notice), '注文方法' (Ordering Method), '振込先' (Bank Transfer), 'よくある質問' (FAQ), 'ダウンロード' (Download), '広告PDF' (Ad PDF), '配送状況確認' (Delivery Status Check), and 'ログイン' (Login).

The main content area shows a search for '温度センサー' (Temperature Sensor). The search results are displayed in a grid format. The first row of results includes:

- 高精度 I C 温度センサー LM35DZ**: [LM35DZ] [I-00116] 1個 ￥110 (税込)
- デジタル温度センサー (1wire) DS18B20+**: [DS18B20+] [I-05276] 1個 ￥250 (税込)
- サーミスタ 10 kΩ (ラジアルリードタイプ)**: [103AT-2] [P-07258] 1個 ￥50 (税込)
- BME280 使用 温湿度・気圧センサーモジュールキット**: [AE-BME280] [K-09421] 1個 ￥1,080 (税込)
- サーミスタ 10 kΩ (平行線タイプ)**: [103AT-11] [P-07257] 1本 ￥200 (税込)

On the left side, there is a sidebar with a search bar and a list of categories under '全カテゴリー一覧' (All Categories List), including 'ハズレパーツ' (Miscellaneous Parts), '組立キット' (Assembly Kits), '新品' (New Products), 'ディスプレイ・表示器' (Display/Indicator), '基板' (PCB), 'カメラ' (Camera), '電子工作便利商品' (Convenient Electronics Components), '電池一般' (General Batteries), 'パーツ一般' (General Parts), '雑貨' (Miscellaneous Goods), 'カー用品' (Car Accessories), and 'センサー一般' (General Sensors). Under 'センサー一般', there are sub-links for 'ジャイロセンサー', 'GPS(全地球測位システム)', 'GPS受信機', and '加速度センサー'.

- <https://www.sengoku.co.jp/>

千石電商オンラインショップ

営業時間 10:30~17:00/月

せんごくネット通販

商品検索

ホーム ご案内

商品カテゴリー
電子工作部品
基板・フレッドボード
コイル・コンデンサ・抵抗
マイコン・半導体・LED
無線・ワイヤレス機器
フィジカルコンピューティング
センサー
GPS
コネクタ・端子
電線・ケーブル
チューブ・配線材
ヒューズ
スイッチ
リレー
スピーカー・ブザー・サウンダ・マイク
高周波発振子・発振器
ノイズ対策部品
放熱関連 ベルチェ 放熱器 FAN
その他類

**送料値上げとネコポス利用開始のお知らせ**

1月4日より送料が変更になりました。また、2月1日よりネコポスによる配送を開始します。

▶▶▶ 詳細はこちら ◀◀◀

最新の商品 次の15件 >>>

 カモン アンテナケーブル S4C-FB(片側直角タイプ) 10m FQ-100 A	 スイッチサイエンス Raspberry Pi 3対応PoE基板 SSCI-032865	 サンワサプライ バキュームクリーナー&エアダスター CD-108	 カモン φ3.5ステレオ分配ケーブル(メス-オス×2) 0.2m 35SF-35 SM2	 自己融着性絶縁テープ H-520-JP
				

# shop, etc

## Online Shop

- RS Components <https://jp.rs-online.com/web/>
- Digi-key <https://www.digikey.jp/>
- Mouser Electronics <https://www.mouser.jp/>

## Parts/Kit shop

- Adafruit <https://www.adafruit.com/>
- Sparkfun <https://www.sparkfun.com>
  
- Akizuki(秋月) <http://akizukidenshi.com>
- Sengoku(千石) <https://www.sengoku.co.jp/>
  
- Switch Science <https://www.switch-science.com/>
- marutsu parts shop <https://www.marutsu.co.jp/>
- Strawberry Linux <https://strawberry-linux.com/>

# Link

## Web site

- BeagleBone Black <https://beagleboard.org/black>
- Raspberry Pi <https://www.raspberrypi.org/>