

PocketBeagle TechLab Workshop

PocketBeagle walk-through

Friendly to novices and experts alike, the Beagle experience tracks mainline u-boot, Linux and Debian development, while augmenting it to enable development to start as quickly as possible. Attendees will get started interacting with the hardware via the command-line, shell scripts, Python and JavaScript. Attendees will be walked through the configuration details for the boot configuration, pin multiplexing, USB networking and other helper scripts they should get to know. Support and development processes within the BeagleBoard.org community will be covered. Exercises will pave the way for the other workshops to dive into their topic without needing to backtrack excessively on PocketBeagle-specific details.

Author and license

- Author
 - Jason Kridner
Co-founder BeagleBoard.org, Texas Instruments Sitara apps
<https://beagleboard.org/about>
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Outline

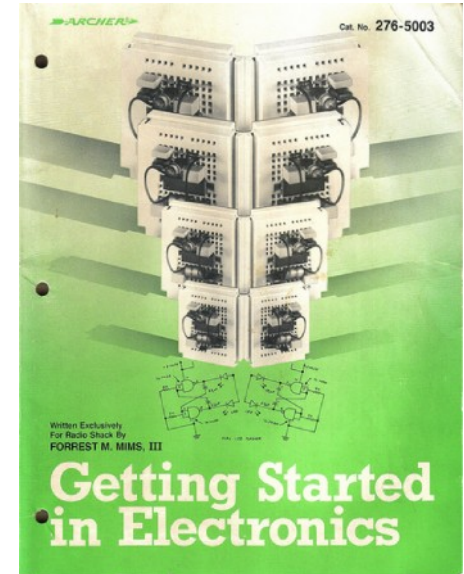
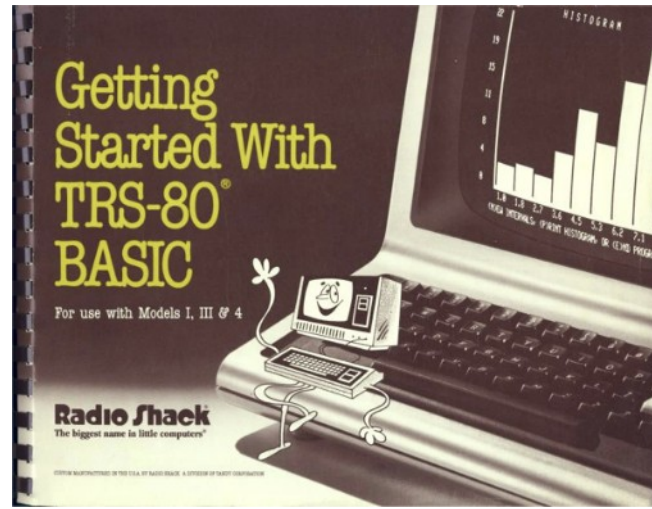
- BeagleBoard.org, PocketBeagle and BaconBits
- Developer experience
 - Command-line and shell script
 - JavaScript and Python
 - C/C++
 - C on PRUs
- Project examples
- Labs

BeagleBoard.org's objectives

- Education
 - Design and use of open source SW/HW
 - Embedded computing
- Collaboration
 - Physical computing
 - Robotics
 - Industrial/machine controls

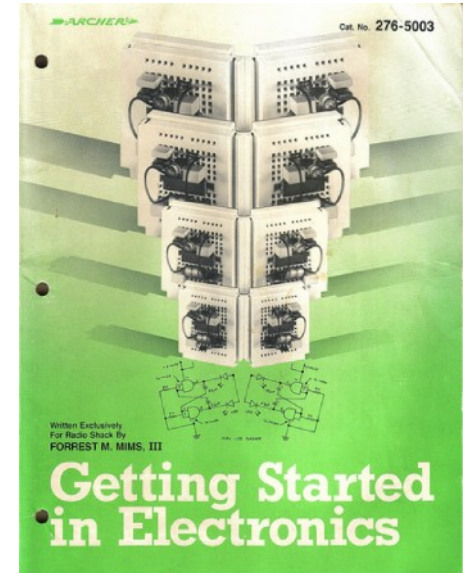
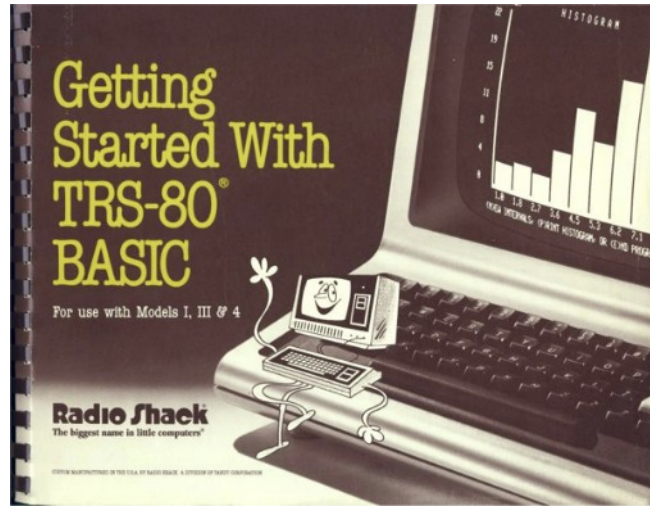


Inspiration from early PCs



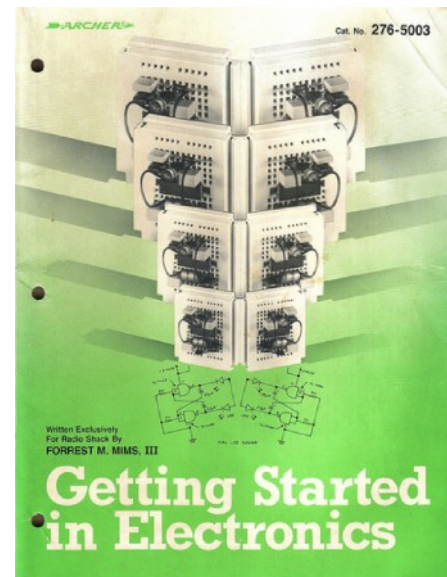
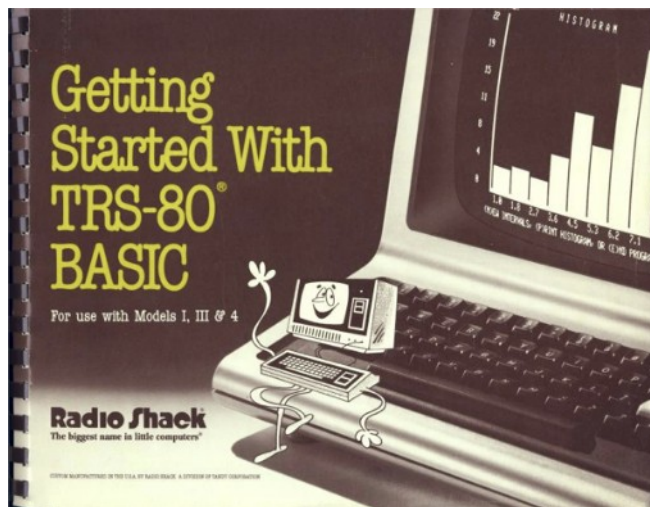
Inspiration from early PCs

- How do people learn about embedded computers with so much ground to cover?



Inspiration from early PCs

- How do people learn about embedded computers with so much ground to cover?
- Linux keeps history
- Affordable -> hackable
- Open from boot
- High-level languages
- Motivate with hardware



Vision

- Creating with electronics should be as easy as creating a web page



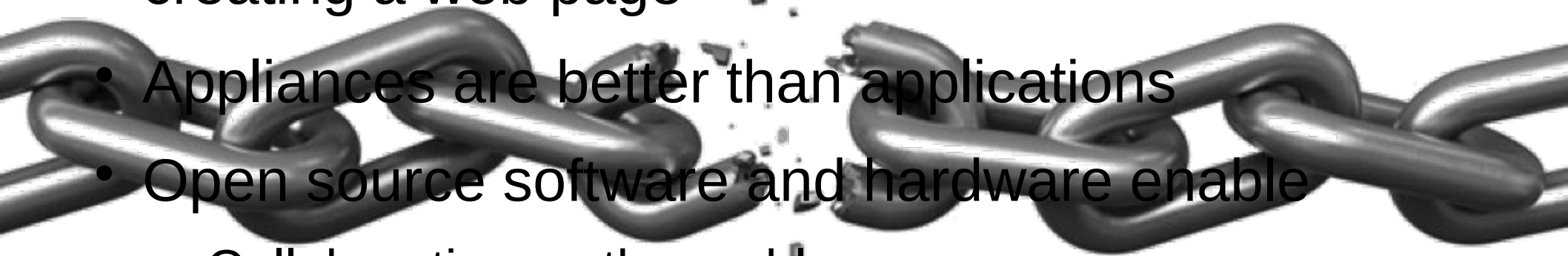
Vision

- Creating with electronics should be as easy as creating a web page
- Appliances are better than applications



Vision

- Creating with electronics should be as easy as creating a web page
- Appliances are better than applications
- Open source software and hardware enable
 - Collaboration on the problem
 - Ability to understand and improve the fundamentals



Reality

- Boot-to-browser feels too limiting → booting to Debian distro
- Collaborative programming still complex → collaborate at the kernel
- Many possible development environments
 - command-line/ssh, Cloud9 IDE, node-red, pureData, SuperCollider, LabView, Matlab, Eclipse, Visual Studio, Scratch, Blockly
- Domain specific approaches
 - Machinekit/LinuxCNC, PLC, many IoT toolkits
 - Many rapid sensor approaches: capes, mikroBus, Grove/Grove Zero, PMOD
 - Many rapid build approaches: LEGO, printing/milling, Makeblock, Vex, various other aluminum kits

Approach

- Don't try to boil the ocean
 - We seek to engage the open source community
- Help where we can
 - Blue supports Grove cables
 - PocketBeagle supports mikroBus click pinout
 - Many “BeagleBoard Compatible” devices targeting specific application areas

Board history

Fanless open computer
(BeagleBoard)



\$249

Mint tin sized with industrial
peripherals (BeagleBone)



\$69

Application focused BeagleBones

Smalls mint tin sized with super-
flexible design - PocketBeagle



\$79



\$25

PocketBeagle objectives

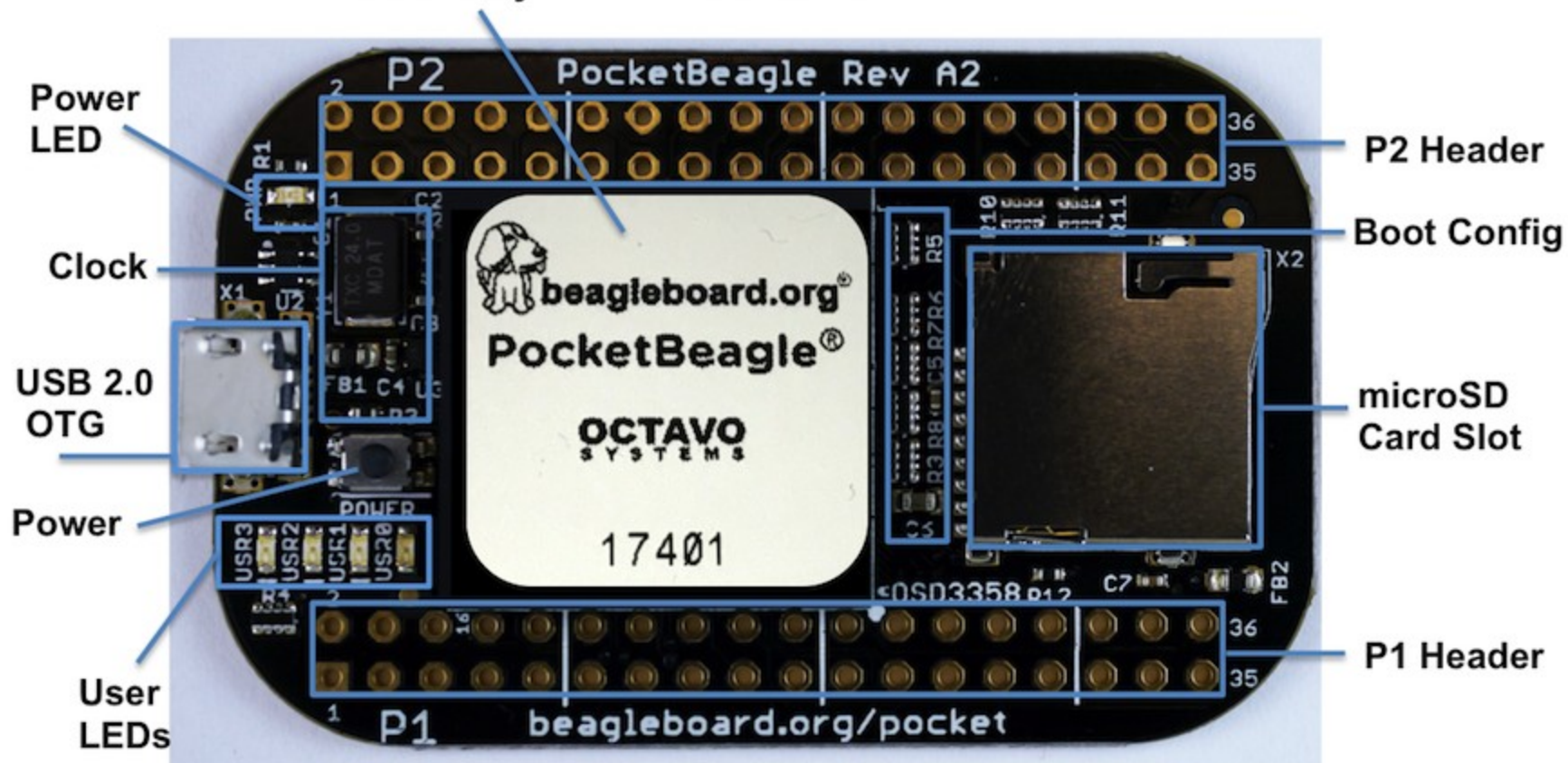
- Get simple
 - 4-layer PCB done in both Kicad and EAGLE
 - Every expansion header pin has a useful predefined mode
- Get flexible
 - USB to holes, no on-board pin consumption, no header soldered
 - Support for 2 mikroBus Click boards (over 300 already exist)
- Get small
 - Stick with mint-tin survival-kit theme, but go to “smalls” (35mm x 55mm)
- Get low cost
 - System-in-package approach has can lower build costs
 - Launched/sustainable at \$25

PocketBeagle key features

- Processing
 - 1-GHz ARM Cortex-A8 processor
 - 2x200-MHz programmable real-time units (PRUs)
 - ARM Cortex-M3 microcontroller for power and security
 - SGX530 graphics processor (OpenGL ES)
- Memory
 - 512-MB DDR3
 - 4-KB I2C EEPROM
- Interfaces
 - USB 2.0 OTG
 - microSD
- 72 expansion header pins
 - 8 analog inputs (6@1.8V, 2@3.3V)
 - 44 digital I/Os (18 enabled)
 - 3 UARTs (2 enabled)
 - 2 I2C ports
 - 2 SPI ports
 - 2 quadrature encoders accessible
 - 2 CAN bus controllers accessible
 - USB, power/reset buttons, battery/DC

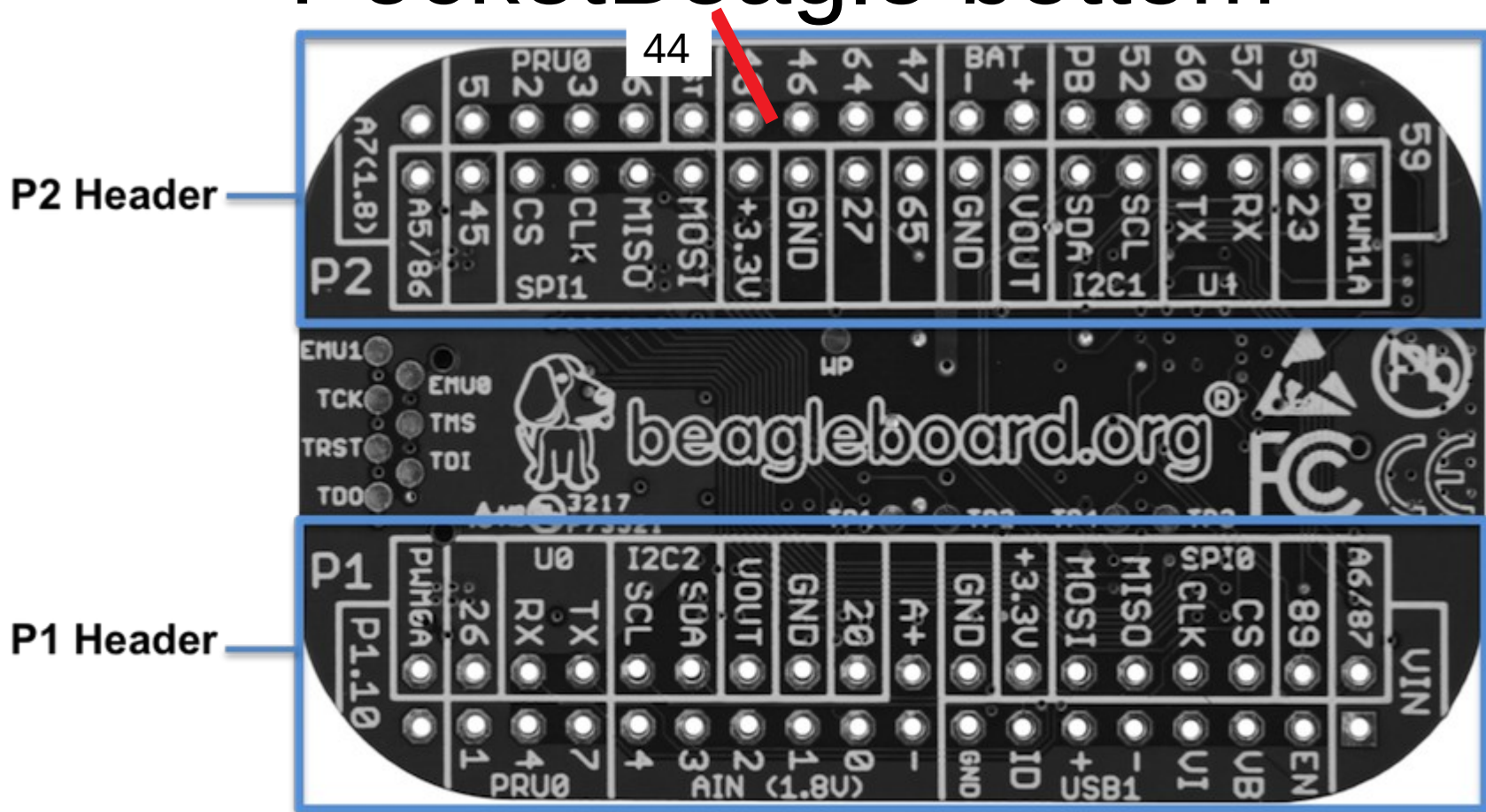
PocketBeagle top

Octavo Systems OSD3358-SM





PocketBeagle bottom





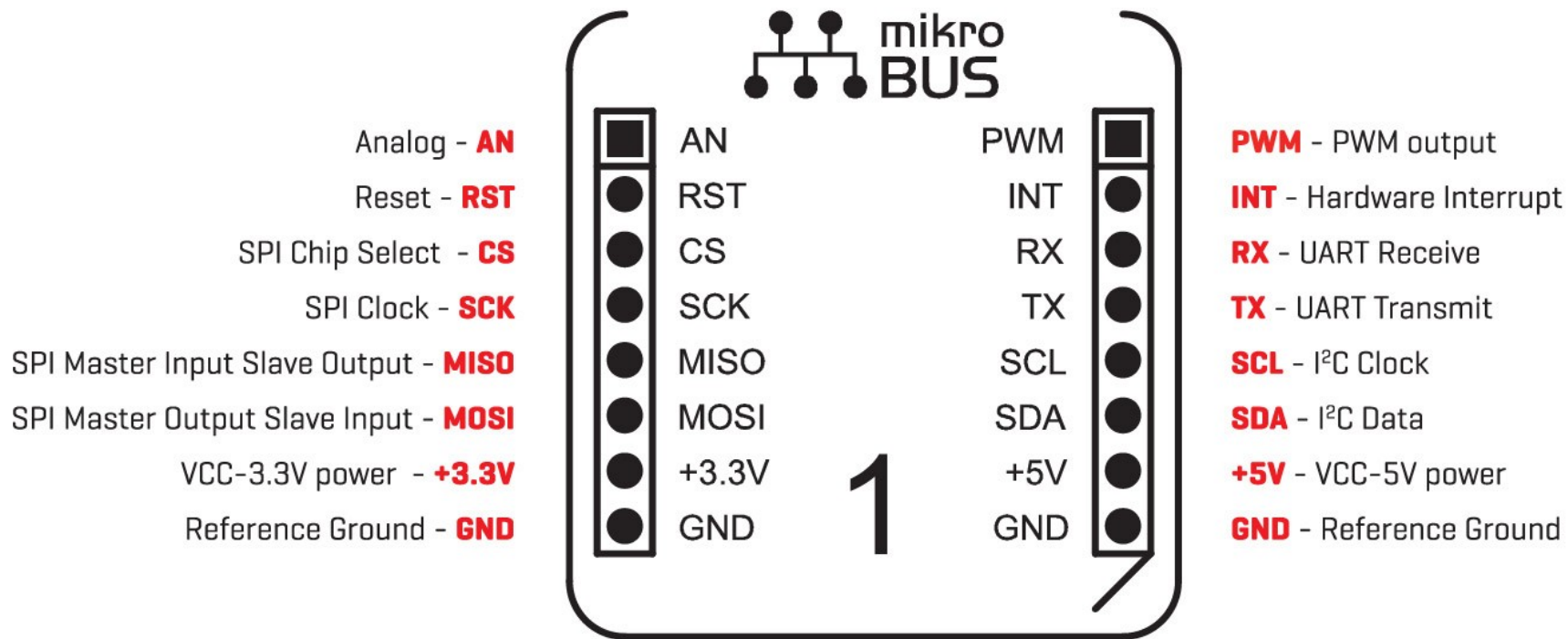
PocketBeagle expansion

PocketBeagle Expansion Headers (Rev A2a)

P1													
SYS			VIN	1	2	87		6	AIN 3.3V	9	PRU1		
USB1		V_EN	GPIO	109	3	4	89			11	PRU1		
USB1			VBUS	5	6	5	GPIO	CS	SPIO	TX	PRU		
			VIN	7	8	2		CLK		RX	UART2		
			DN	9	10	3		MISO		TX	UART2		
			DP	11	12	4		MOSI		RX	PRU		
			ID	13	14	3.3V	SYS						
			GND	15	16	GND	SYS						
AIN 1.8V			REF-	17	18	REF+	AIN 1.8V						
			0	19	20	20	GPIO		16(in)	PRU0			
			1	21	22	GND	SYS						
			2	23	24	VOUT	SYS						
			3	25	26	12	GPIO	SDA	I2C2	TX	CAN0		
			4	27	28	13		SCL		RX	CAN0		
PRU0	7	QEP0	STRB	GPIO	117	29	30	43	GPIO	TX	UART0	15	PRU1
	4		A		114	31	32	42		RX	UART0	14	
	1	PWM0	B		111	33	34	26					
PRU1	10				88	35	36	110		A	PWM0	0	PRU0

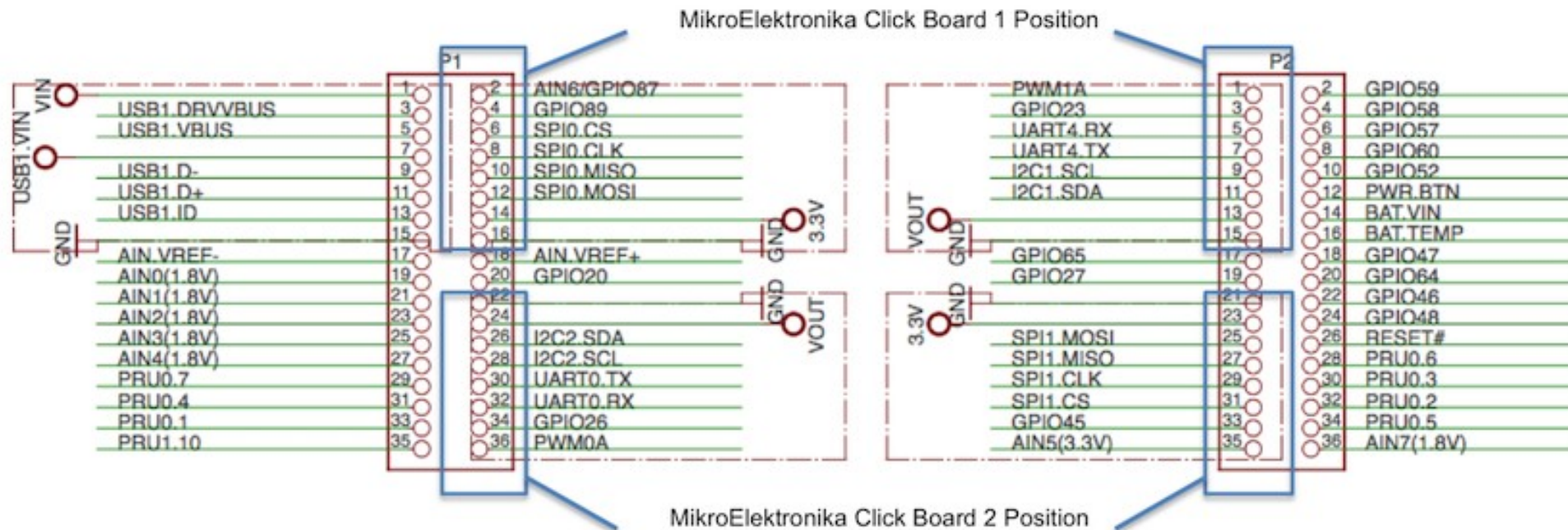
P2											
PWM1			A		50	1	2	59			
PWM2			B		23	3	4	58			
UART4			RX	GPIO	30	5	6	57	GPIO		
			TX		31	7	8	60			
CAN1	RX		I2C1	SCL	15	9	10	52			
	TX		SDA		14	11	12	PWR BTN	SYS		
SYS			VOUT	13	14	VIN	BAT				
			GND	15	16	TEMP					
				GPIO	65	17	18	47		STRB	QEP2
					27	19	20	64	GPIO		15i
SYS			GND	21	22	46			IDX	QEP2	14(in)
			3.3V	23	24	44			A		14(out)
CAN1	RX				41	25	26	NRST	SYS		
	TX				40	27	28	116		IDX	QEP0
PRU	eCAP		SPI1	MOSI	7	29	30	113	GPIO		6
PRU1	16(in)			MISO	19	31	32	112			3
PRU0	15(out)	QEP2	B		45	33	34	115		B	QEP0
PRU1	8	AIN 3.3V			86	35	36	7	AIN 1.8V		5

mikroBus Click





Connecting mikroBus Clicks

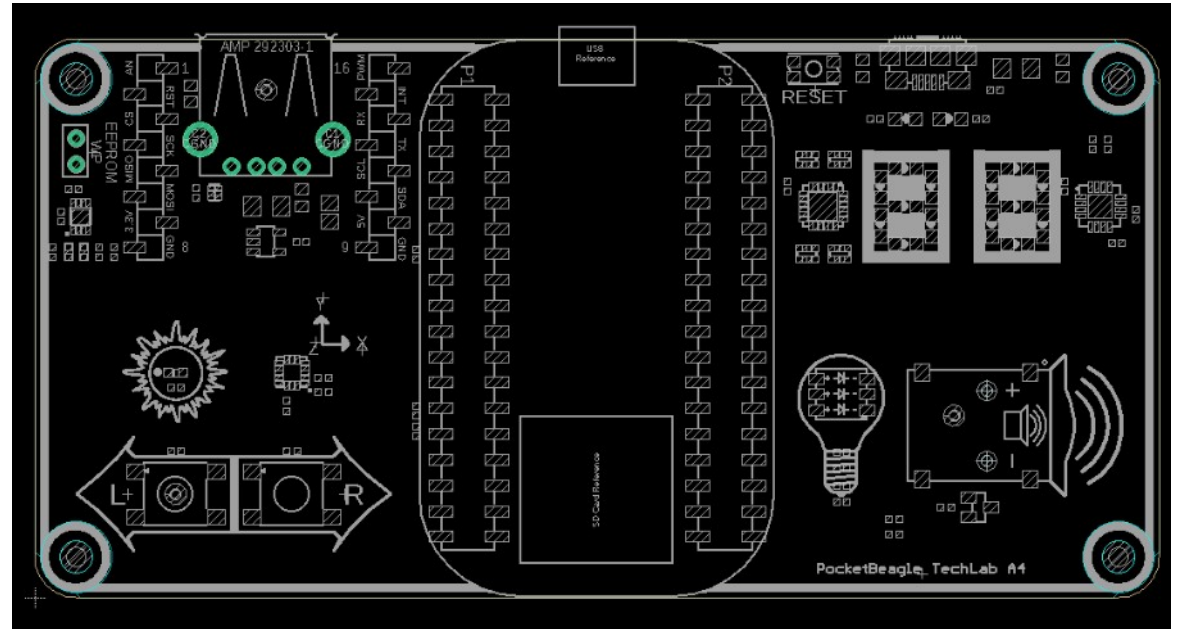


TechLab objectives

- Designed specifically for e-ale training
- Inspired by “Bacon Cape” by Dave Anders
 - Designed for similar purpose on BeagleBone
- Migrated to PocketBeagle as “BaconBits” by Michael Welling
- Updated to have mikroBus header and made “pretty”
 - Extra button (with PRU option), light sensor rather than potentiometer
- Provides target for common embedded interfaces
 - SPI, I2C, GPIO, PWM, ADC, USB, serial
- Avoid users needing to buy several modules

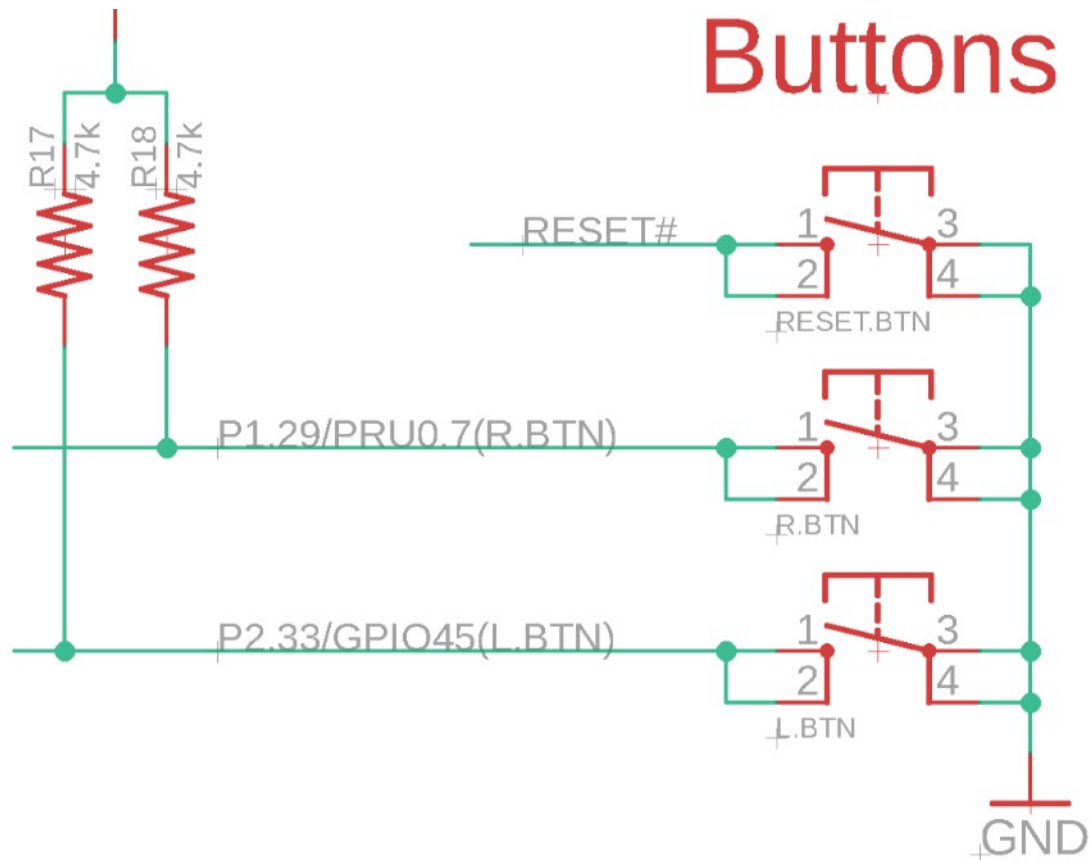
TechLab features

- USB-to-Serial micro B
- USB Host A with power
- Reset button
- 2 GPIO push buttons (L and R)
- ADC light sensor
- PWM tri-color LED
- SPI 2-digit 7-segment display
- I2C accelerometer
- mikroBus header



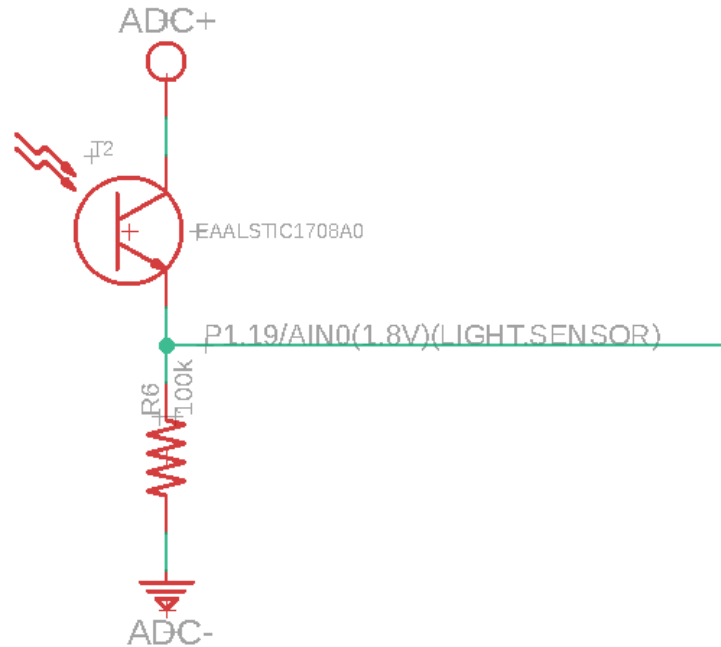
TechLab GPIO inputs

Buttons



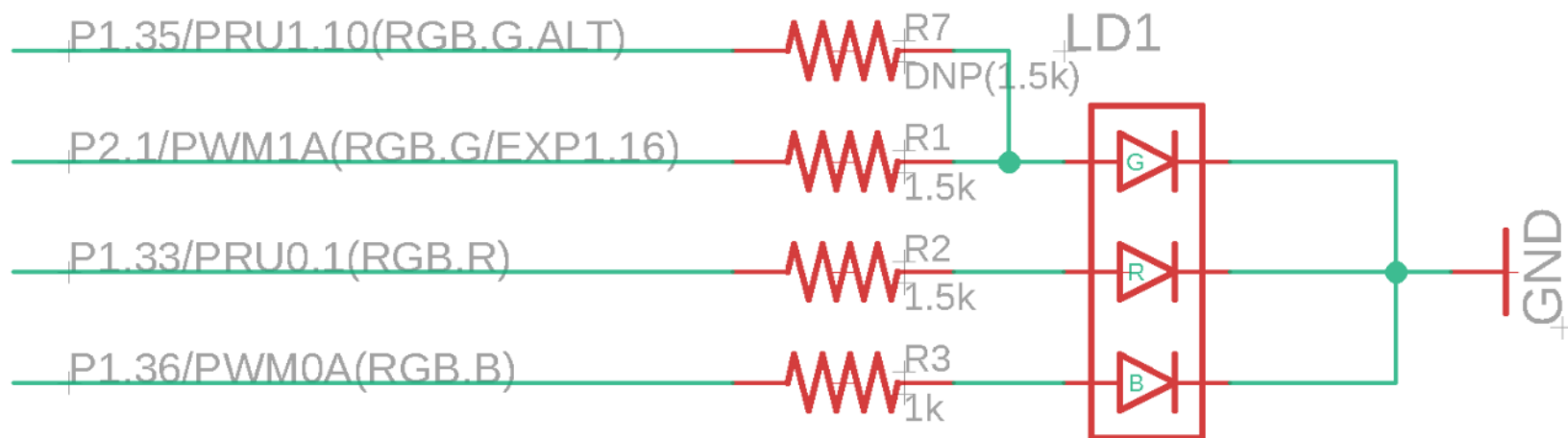
TechLab ADC input

Light Sensor



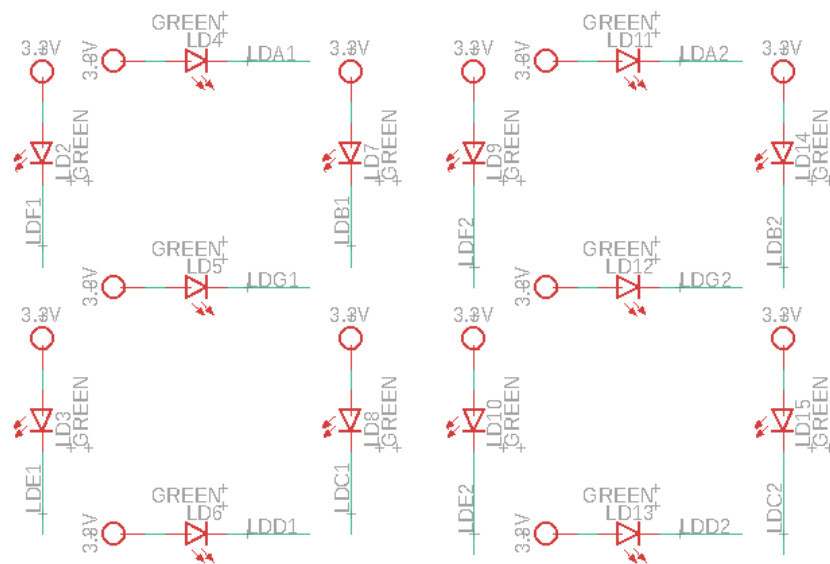
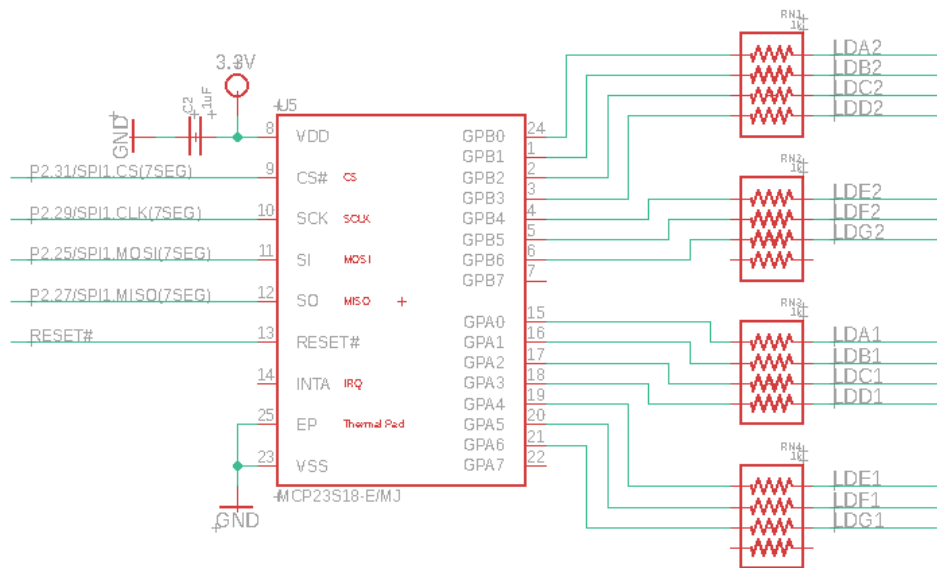
TechLab PWM output

Multi-colored LED (Bulb)



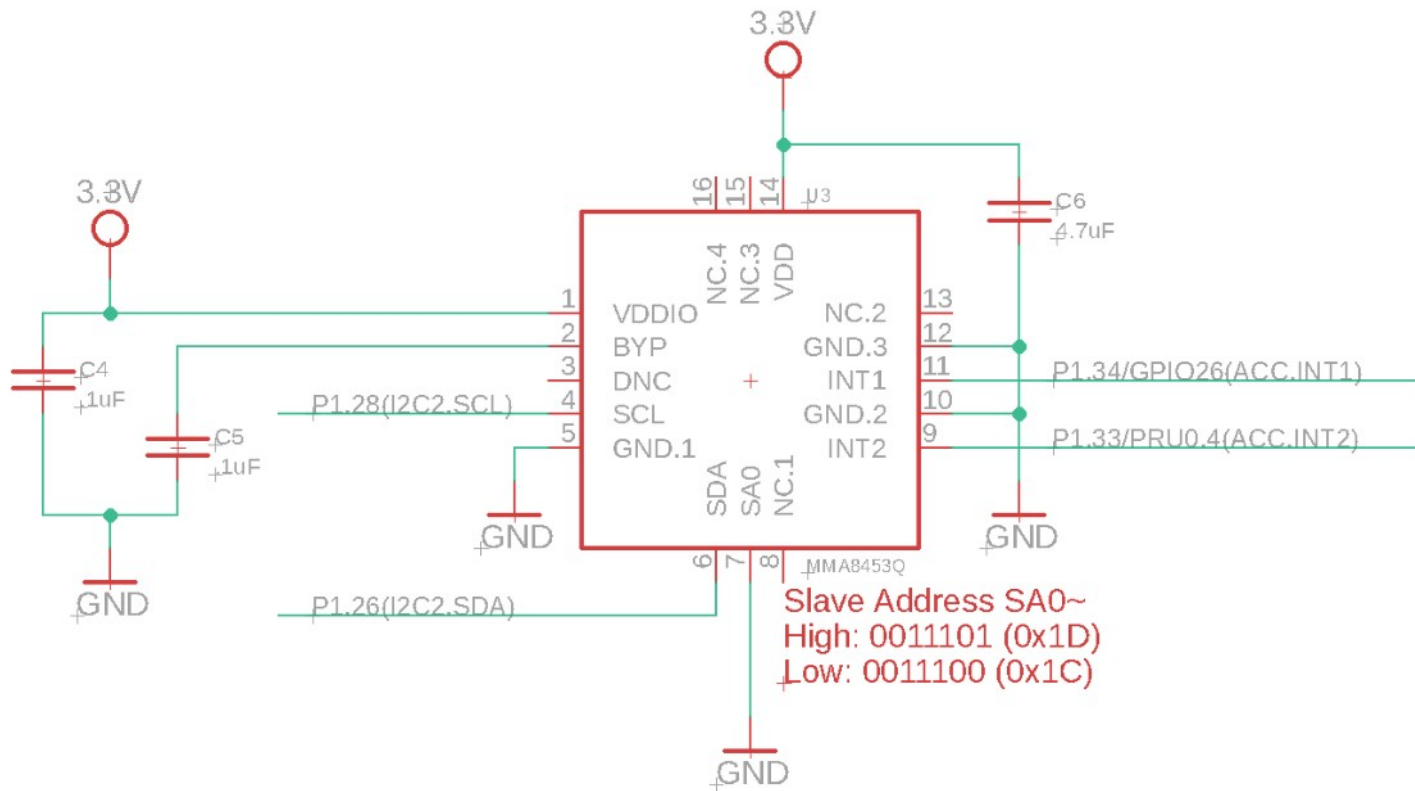


TechLab SPI 7-segment display



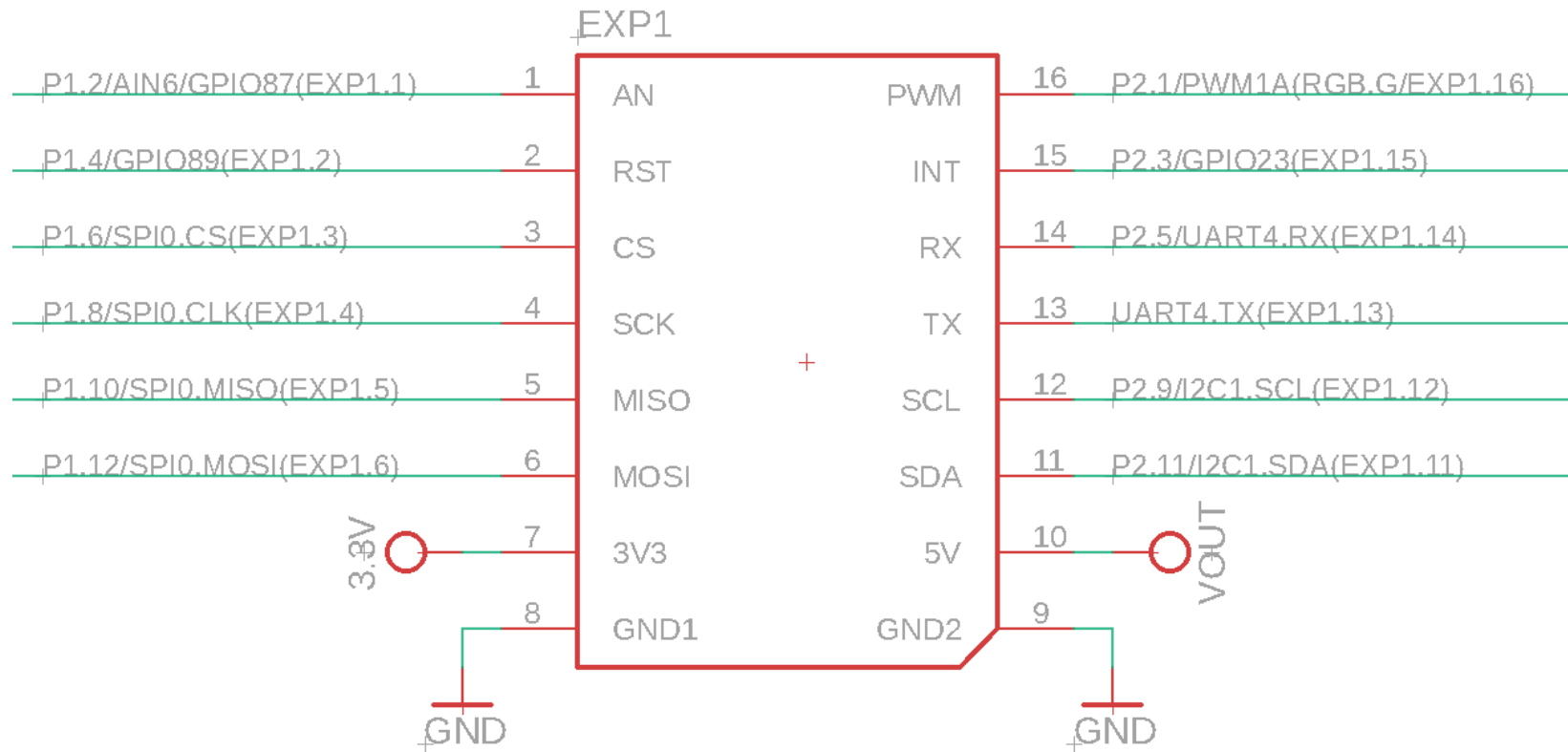
TechLab I2C sensor

Accelerometer

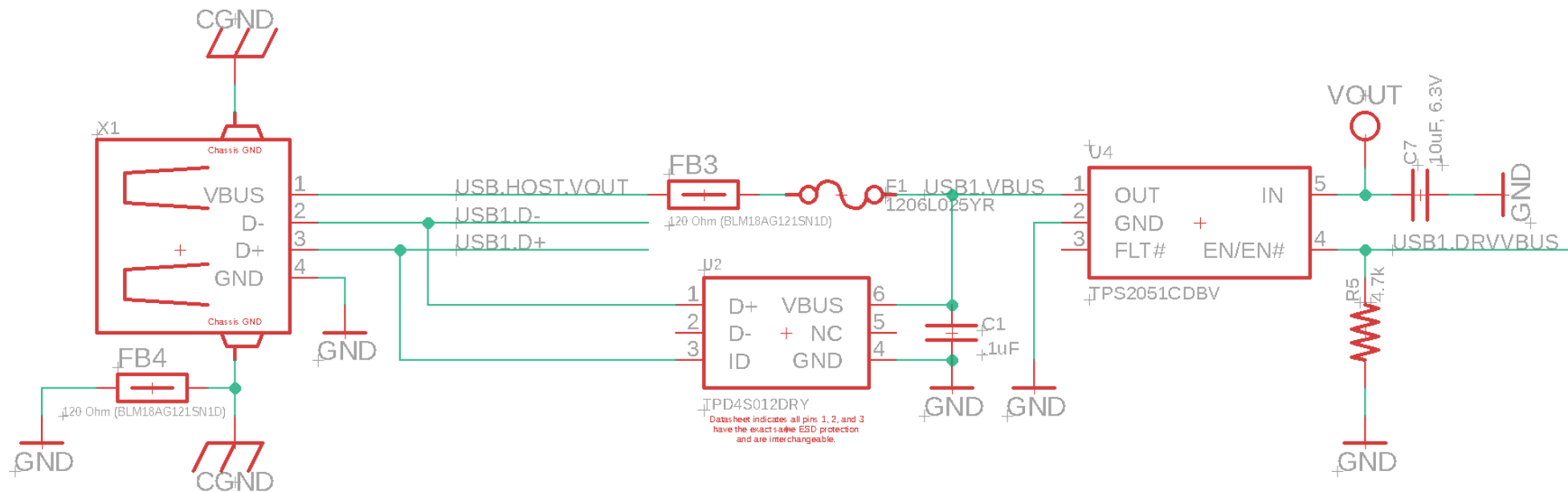




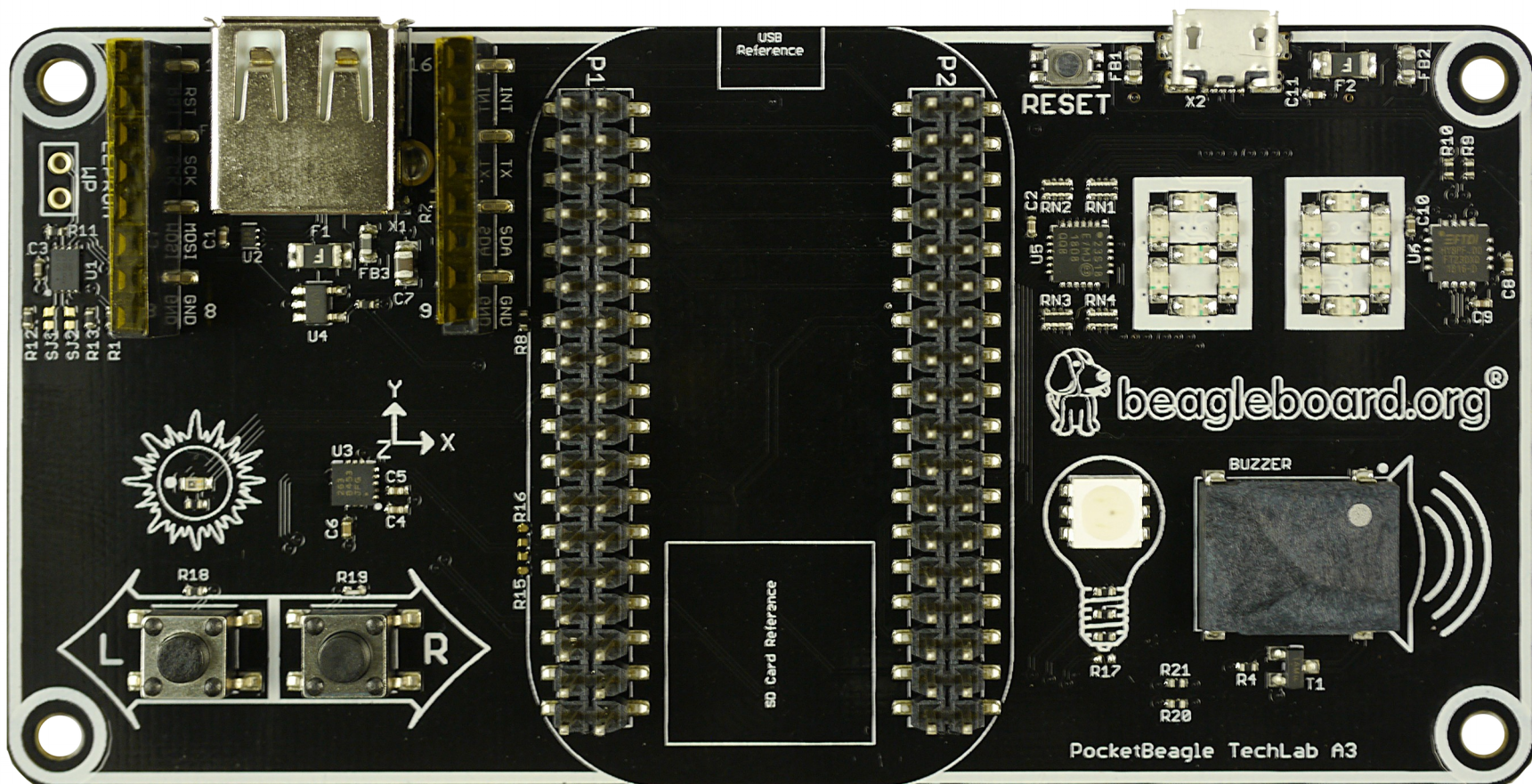
TechLab mikroBus header



TechLab USB host



TechLab board image



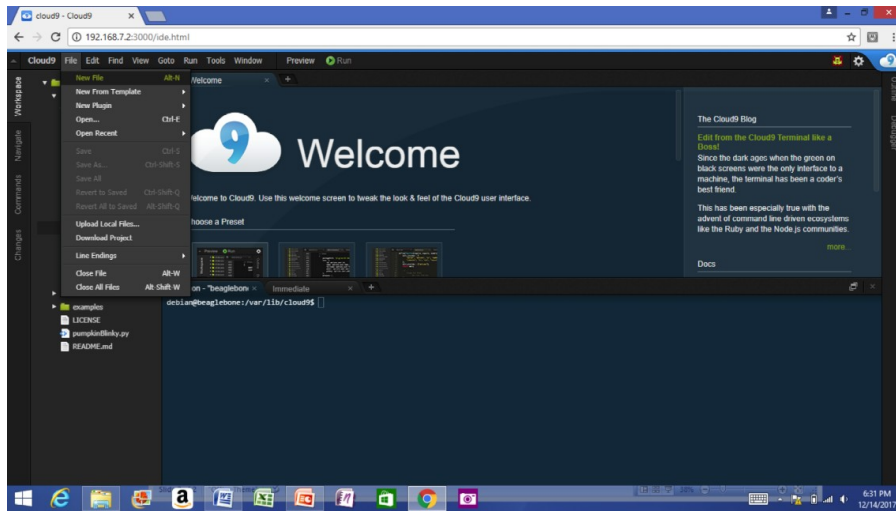
Developer experience

- Customized Debian images – bbb.io/latest
- Self-hosted tools for ARMs and PRU
- Libraries for various high-level languages
- Scripts for common tasks
- Sources for bootloader, device tree, etc.
- Servers for network-based development



Single cable development

- Power, network, develop
- You can add a network and power many other ways



Some work in progress

- Add proxy for various services (in Buster IoT images today)
- Integrate common web-based WiFi provisioning
 - SeeedStudio BeagleBone Green Wireless ships with 'wifidog' → we will unify approach
- Cross-platform distro installer app
 - See USB NETCONSOLE presentation
- Support for Grove modules and mikroBus clicks
 - Focus on device-tree overlays and kernel patches
- Integration alignment with complete domain solutions
 - Intelligent Agent Replicape/Revolve, Bela Mini, BeagleLogic, etc.
- Improved and integrated PRU examples
- Move to distro friendly approaches for customizations

Download image



×

https://beagleboard.org/latest-images

beagleboard.org®

f t in YouTube 8+

Start ↓ Discover Boards ↓ Learn ↓ Explore ↓ Collaborate ↓

BeagleBoard.org > latest-images

BeagleBoard.org Latest Firmware Images

Download the latest firmware for your BeagleBoard, BeagleBoard-xM, BeagleBoard-X15, BeagleBone, BeagleBone Black, BeagleBone Black Wireless, BeagleBone Blue, SeeedStudio BeagleBone Green, SeeedStudio BeagleBone Green Wireless, SanCloud BeagleBone Enhanced, element14 BeagleBone Black Industrial, Arrow BeagleBone Black Industrial, Mentorl BeagleBone uSOMIQ, Neuromeka BeagleBone Air, or PocketBeagle

See the [Getting Started guide](#) and the [community wiki page](#) for hints on loading these images.

Recommended Debian Images

Stretch IoT (non-GUI) for BeagleBone and PocketBeagle via microSD card

- ▶ **Debian 9.2 2017-10-10 4GB SD IoT image** for PocketBeagle, BeagleBone, BeagleBone Black, BeagleBone Black Wireless, BeagleBone Blue, SeeedStudio BeagleBone Green, SeeedStudio BeagleBone Green Wireless, SanCloud BeagleBone Enhanced, element14 BeagleBone Black Industrial, Arrow BeagleBone Black Industrial and Mentorl BeagleBone uSOMIQ - more info - bmap - sha256sum: be1eac7a5e526930155520215329a6c39071b82199c0745c300e68b7e6c7180b

Stretch for BeagleBone via microSD card

- ▶ **Debian 9.1 2017-08-31 4GB SD LXQT image** for BeagleBone, BeagleBone Black, BeagleBone Black Wireless, BeagleBone Blue, SeeedStudio BeagleBone Green, SeeedStudio BeagleBone Green Wireless, SanCloud BeagleBone Enhanced, element14 BeagleBone Black Industrial, Arrow BeagleBone Black Industrial and Mentorl BeagleBone uSOMIQ - more info - bmap - sha256sum: bc8292d97458987481d45da025ef9868b8ccf8477a72f11b541bf97d329a6d7e

Jessie for SeeedStudio BeagleBone Green Wireless via microSD card

- ▶ **Debian 8.6 2016-11-06 4GB SD SeeedStudio IoT image** for SeeedStudio BeagleBone Green Wireless - more info - bmap - sha256sum: 48582b8a1a134679ff324eacc1e0b4af612cdabfb56dafb6b932fe11129b404f

Stretch for BeagleBoard-X15 via microSD card

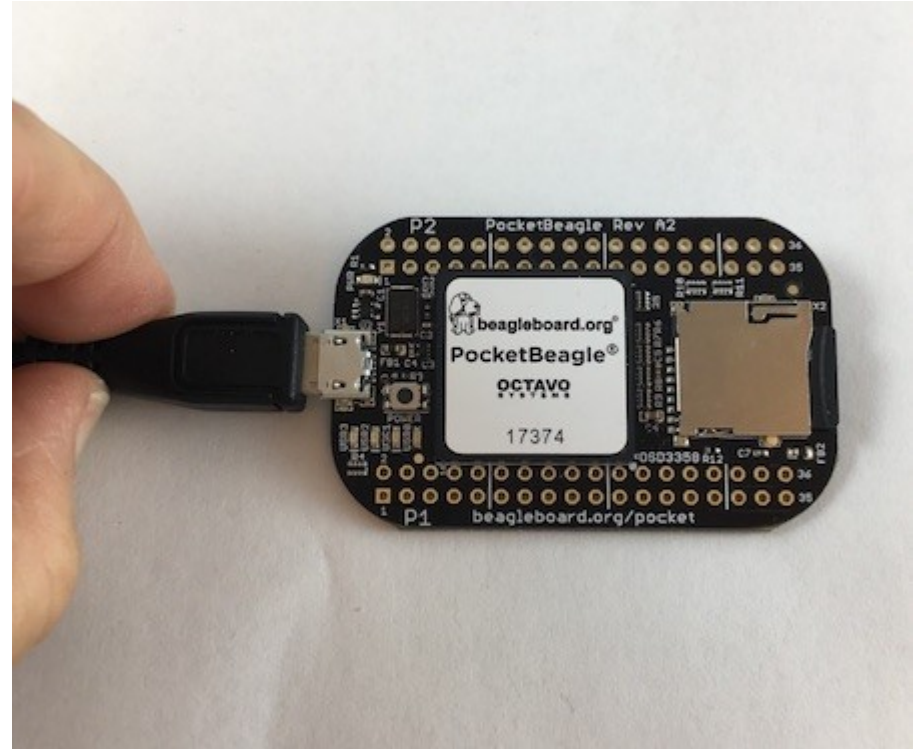


Write image to microSD with Etcher





Insert microSD and boot





Connect to the USB network

Getting started with Beagle x

file:///Volumes/BEAGLEBONE/START.htm

beagleboard.org®

Start ↓ Discover Boards ↓ Learn ↓ Explore ↓ Collaborate ↓ Google Custom Search Search

Start your Beagle

Beagles are tiny computers with the capability of modern systems, without the bulk, expense, or noise. Read the step-by-step getting started tutorial below to begin developing with your Beagle in minutes.

For user supplied tips on getting started, visit the eLinux (or other) community wiki pages:

- BeagleBoard g/
- BeagleBoard-xM g/
- BeagleBoard-X15 g/
- BeagleBone g/
- BeagleBone Black g/
- BeagleBone Black Wireless g/
- BeagleBone Blue g/
- SeeedStudio BeagleBone Green g/
- SeeedStudio BeagleBone Green Wireless g/
- SanCloud BeagleBone Enhanced g/
- NeuroNeka BeagleBone Air g/

If any step fails, it is recommended to update to the latest software image to use the instructions below.

Step 1 ▶ Power and boot

Most Beagles include a USB cable, providing a convenient way to provide both power to your Beagle and connectivity to your computer. If you provide your own, ensure it is of good quality. You'll connect the "type-B" plug g/ of the USB cable to your Beagle and the "type-A" plug g/ to your computer. Note that BeagleBoard-X15 must always be powered instead by a 12V adapter with a barrel jack.

Alternatively, for Beagles other than BeagleBoard-X15 and BeagleBone Blue that require 12V, you can utilize a 5V adapter connected to the barrel jack.

Getting started with Beagle x

192.168.6.2:3000

Step 2 ▶ Enable a network connection

If connected via USB, a network adapter should show up on your computer. Your Beagle should be running a DHCP server that will provide your computer with an IP address of either 192.168.7.1 or 192.168.8.1, depending on the type of USB network adapter supported by your computer's operating system. Your Beagle will reserve 192.168.7.2 or 192.168.8.2 for itself.

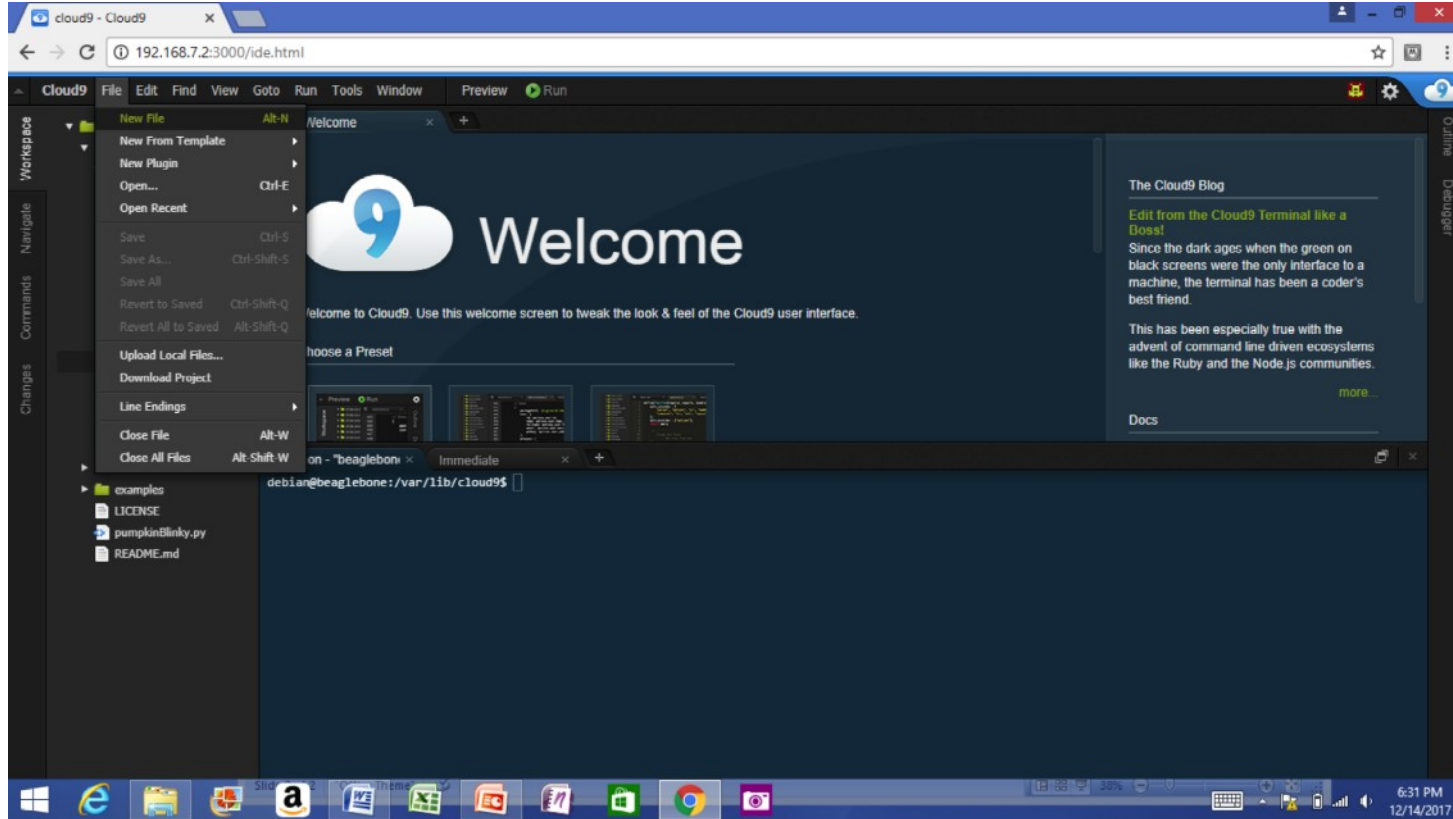
If your Beagle includes WiFi, an access point called "BeagleBone-XXXX" where "XXXX" varies between boards. The access point password defaults to "BeagleBone". Your Beagle should be running a DHCP server that will provide your computer with an IP address in the 192.168.x range and reserve 192.168.8.1 for itself.

If your Beagle is connected to your local area network (LAN) via either Ethernet or WiFi, it will utilize mDNS g/ to broadcast itself to your computer. If your computer supports mDNS, you should see your Beagle as beaglebone.local. Non-BeagleBone boards will utilize alternate names. Multiple BeagleBone boards on the same network will add a suffix such as beaglebone-2.local.

The below table summarizes the typical addresses and should dynamically update to indicate an active connection. Note that you must load this page without HTTPS security for the automatic detection to work.

IP Address	Connection Type	Operating System(s)	Status
192.168.7.2	USB	Windows	Inactive
192.168.8.2	USB	Mac OS X, Linux	Active g/
192.168.8.1	WiFi	all	Inactive
beaglebone.local	all	mDNS enabled	Active g/
beaglebone-2.local	all	mDNS enabled	Inactive

Open the IDE



See labs in the Handouts

- No need to program the microSD card
 - The link is for your reference. This is already done for you.
- Do the first 4 labs
 - “Blink PocketBeagle on-board USRx LED”
 - “Read a button”
 - “Read an analog sensor”
 - “Fade an LED”
- I will interrupt with hints and discussion at intervals

USB gadgets

- Linux name for device/slave drivers
 - ie., when not host
- USB devices have “classes”
 - Mass storage
 - Camera
 - Audio
 - Printer
 - “HID” or human-interface device like mouse and keyboard
 - Communications

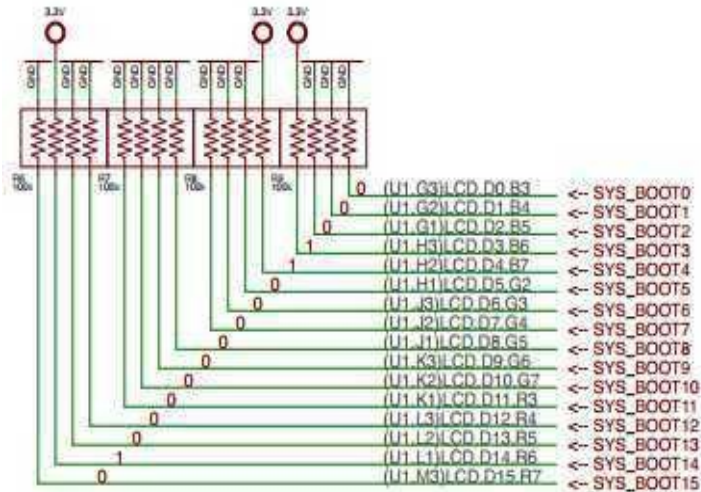
USB gadgets

- Default image USB gadgets
 - Virtual mass storage
 - Serves you up README.htm
 - Virtual serial
 - Provides access to console after kernel boot
 - Virtual network
 - Enables access to ssh and web servers

TI AM335x: bootrom

From: ([AM335x and AMIC110 Sitara™ Processors Technical Reference Manual \(Rev. P\)](#))

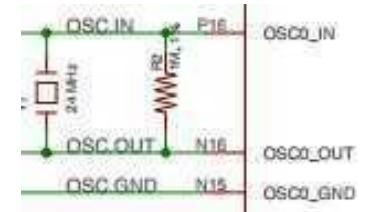
- <http://www.ti.com/lit/ug/spruh73p/spruh73p.pdf> (page 5032)



SYSBOOT[15:14] = 01 = 24Mhz

SYSBOOT[4:0] = 11000

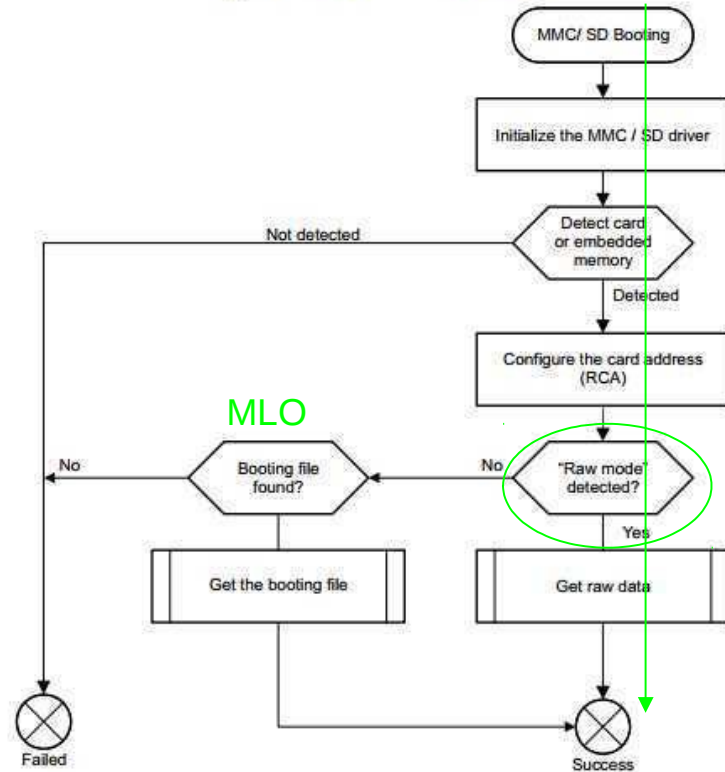
1. SPI0
2. MMC0 - going to use today
3. USB0 - (node-beagle-boot)
4. UART0



26.1.8.5.3 Booting Procedure

The high level flowchart of the eMMC / eSD and MMC/SD booting procedure is depicted in Figure 26-22.

Figure 26-22. MMC/SD Booting



TI AM335x: bootrom

<http://www.ti.com/lit/ug/spruh73p/spruh73p.pdf>

Page: 5053



TI AM335x: bootrom: raw mode:

<http://www.ti.com/lit/ug/spruh73p/spruh73p.pdf> (Page: 5054)

1. 0x0 <- (FAT Boot Sector, let's leave it blank...)
2. 0x20000 (128KB) <- We are going to use this location
3. 0x40000 (256KB) <- (2nd “backup” location)
4. 0x60000 (384KB) <- (3rd “backup” location)

Only 128KB in size... (hint, only 128KB of SRAM)



Das U-Boot (the Universal Boot Loader) U-Boot

Original Author: Wolfgang Denk, now maintained by Tom Rini

- <https://www.denx.de/wiki/U-Boot>
- <http://git.denx.de/?p=u-boot.git;a=summary>
- https://en.wikipedia.org/wiki/Das_U-Boot



U-Boot: AM335x

Outputs two files for TI am335x targets:

- MLO = SPL (or Secondary Program Loader)
- u-boot.img (or u-boot-dtb.img) (U-Boot)





U-Boot: SPL

1. Initializes main memory (DDRx for am335x)
2. Loads full (U-Boot) into DDR memory

Or:

3. Initializes main memory (DDRx for am335x)
4. Loads Linux Kernel into DDR memory (aka: Falcon mode, faster boot mode/etc)



U-Boot:

- Network
- USB
- MMC
- File System (fat/extX)
- Shell

Sometimes you don't need a full OS, have U-Boot init and then have U-Boot load/run your application.



U-Boot:

CPU : AM335X-GP rev 2.1

I2C: ready

DRAM: 512 MiB

Some drivers were not found

Reset Source: Power-on reset has occurred.

MMC: OMAP SD/MMC: 0, OMAP SD/MMC: 1

Using default environment

Board: BeagleBone Black

<ethaddr> not set. Validating first E-fuse MAC

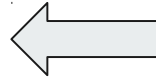
BeagleBone Black:

Model: SeeedStudio BeagleBone Green:

U-Boot: microSD

Insert USB-microSD adapter, and type "lsblk"

```
voodoo@hestia:~/Supercon-2017-PocketBeagle$ lsblk
NAME        MAJ:MIN RM  SIZE RO TYPE MOUNTPOINT
sda          8:0    0 465.8G  0 disk
└─sda1       8:1    0 465.8G  0 part /
sde          8:64   1   7.4G  0 disk
└─sde1       8:65   1   7.4G  0 part
```



That's our 8GB USB Flash Drive

Open: system.sh change: MMC=/dev/sde



U-Boot: Format microSD

```
sudo dd if=/dev/zero of=${MMC} bs=1M count=10
```

```
sudo sfdisk ${MMC} <<- __EOF__  
4M,,L,*  
__EOF__
```

```
sudo mkfs.ext4 -L rootfs ${MMC}1
```

```
voodoo@hestia:~/Supercon-2017-PocketBeagle$ ./scripts/format_drive.sh
```



U-Boot: (refresh for your memory)

<http://www.ti.com/lit/ug/spruh73p/spruh73p.pdf> (Page: 5054)

1. 0x0
2. 0x20000 (128KB) <- We are going to use this location
3. 0x40000 (256KB)
4. 0x60000 (384KB)

```
sudo dd if=./deploy/MLO of=${MMC} count=1 seek=1 bs=128k  
sudo dd if=./deploy/u-boot.img of=${MMC} count=2 seek=1 bs=384k
```



Base Rootfs: Debian 9.x (Stretch)

Maintainer: ~~Robert~~ Nelson (with lots of help from all the Debian Developers and 1000's of other users)

- [https://elinux.org/Beagleboard:BeagleBoneBlack_Debian#2017-11-05 - Debian 9 .28Stretch.29 - Weekly](https://elinux.org/Beagleboard:BeagleBoneBlack_Debian#2017-11-05_-_Debian_9_.28Stretch.29_-_Weekly)
- <https://www.debian.org/>
- <https://github.com/beagleboard/image-builder>

Device Tree

- See kernel documentation for bindings
 - [devicetree/bindings/eeprom/eeprom.txt](#)
- Local copies enable you to extend on the fly
 - [/opt/source/dtb-4.14-ti](#)
 - [/opt/source/bb.org-overlays](#)
- Overlays loaded in u-boot, but also possible via kernel configs

config-pin

- `config-pin -i p1.36`
- `config-pin -q p1.36`
- `config-pin p1.36 pruout`

show-pins.pl

- `perl /opt/scripts/device/bone/show-pins.pl -v`

mikroBus Click usage

- See bbb.io/pbmb
- Supported with device-tree overlays loaded in u-boot

Enabling PRU

- 2 possible drivers: remoteproc or uio
- Enabled via device tree at boot
 - Different systems might have different defaults

Some current projects

- [Bela Mini](#)
- [PocketPilot](#)

Contributions and issues

- Cape/add-on support
 - <https://github.com/beagleboard/bb.org-overlays>
- Image deltas
 - <https://github.com/beagleboard/image-builder>
- In-system examples
 - <https://github.com/beagleboard/bone101>



Questions?

Thank you!

